-FINAL-

DELAWARE RIVER
LOWER REACH B
MAIN CHANNEL DEEPENING PROJECT

PEDRICKTOWN SOUTH CONFINED DISPOSAL FACILITY MONITORING AND WATER QUALITY MONITORING AT THE POINT OF DREDGING

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EXECUTIVE SUMMARY

Dredging for the second portion of the Delaware River Main Channel Deepening Project was conducted from November 9 to December 29, 2011. Deepening occurred in Lower Reach B of the channel. The area deepened included 3.2 miles of channel bottom falling from approximately Deepwater Point to just north of Edgemoor (see Figure 1-1). Approximately 769,916 cubic yards of material was dredged and placed in the Federally-owned Pedricktown South confined disposal facility (CDF). In conjunction with the dredging, monitoring for potential water quality impacts was conducted at the point of active dredging and at the CDF. The monitoring program was coordinated with the Delaware Department of Natural Resources and Environmental Control (DNREC) because the area dredged falls entirely within Delaware waters and subaqueous lands.

One hydraulic cutterhead suction dredge was used to deepen the lower portion of Reach B. Hydraulic cutterhead suction dredges work by pumping a mixture of dredged material and water (called a slurry) from the channel bottom through a pipeline to the CDF. The cutterhead, located on the suction end of the pipe, has rotating blades or teeth to break up and loosen the bottom material so that it can be pumped through the pipeline. The cutterhead is buried in the bottom sediment during operation. Contaminants associated with the sediment can be released to the water column if sediment is suspended in the water column rather than being drawn into the intake pipe. The point of dredging is one location where water quality impacts can occur.

Water quality was monitored near the point of active dredging. Water samples were also collected at background locations in the Delaware River for comparison to dredge plume data. In addition to the water samples, over 9,000 turbidity measurements were collected at 0.5, 6 and 11-m depth increments during active dredging 200 feet down current from the cutterhead. Total Suspended Solids (TSS) concentrations at the point of dredging were similar to background levels. Samples were also analyzed for inorganics, pesticides, polychlorinated biphenyls (PCBs) and semi-volatile organics. Sample data indicated that for the point of dredging, contaminants were either non-detect, or at similar concentrations detected in the background samples.

The dredged material for lower Reach B was pumped into the Pedricktown South CDF (see Figure 1-1). At the CDF, dredged material is pumped into a diked cell, which contains the mixture of dredged material and water for a sufficient time to allow the sediment to dewater, and the effluent water to return to the river. As the water moves through the cell, it slows, allowing sediment particles to settle out. Finally, water reaches the weir and is discharged from the site back to the Delaware River. Some suspended sediment is released back to the river at this discharge point. Contaminants dissolved in the water and contaminants associated with suspended sediment will also be released. The CDF discharge point is the second location where water quality impacts can occur.

Water quality was monitored at the Pedricktown South CDF discharge point over the 51 day period of dredging. The environmental monitoring program included material flowing

into the containment cell (influent), and water and associated suspended solids discharging from the cell back to the Delaware River (weir). Influent and effluent samples were analyzed in the laboratory for inorganics, pesticides, PCBs, and semi-volatile organics including PAHs.

CDF weir effluent results were compared to DNREC water quality criteria, after proper consideration of near field and far field dilution as well as background concentrations. Comparisons indicated that almost all of the parameter concentrations met water quality criteria, and when background concentrations were considered there were no significant increases in contaminant concentrations in the Delaware River as a result of the placement of deepening sediments into the Pedricktown South CDF.

A mass balance evaluation of the contaminant load entering and leaving the Pedricktown South facility indicated that for most contaminants including PCBs, pesticides, PAHs, and mercury, close to 99 percent of the contaminant load was retained by the CDF and not released back to the Delaware River.

The following conclusions are made based on monitoring data collected over the entire dredging project:

- Suspended solids and contaminant levels down-current of the cutterhead were consistent with or less than background levels, indicating that water quality was not impacted at the point of dredging;

- Weir discharges from the Pedricktown South CDF did not adversely impact water quality in the Delaware River; and

- A mass balance evaluation of the contaminant loads entering and leaving the Pedricktown South facility indicates a large net removal of contaminants from the Delaware River during main channel deepening of lower Reach B.

In summary, the deepening of the Delaware River navigation channel in lower Reach B to 45 feet resulted in no adverse water quality impacts with respect to toxics, and in fact removes far more contaminants from the river than it liberates, thus providing for an overall net benefit to the water quality in the river. These results are consistent with the earlier monitoring program conducted during the 2010 deepening of Reach C.

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1.0 INTRODUCTION

Delaware River water quality was monitored in conjunction with the deepening of lower Reach B, the second construction contract for the Delaware River Main Channel Deepening Project. The project calls for deepening the existing Delaware River Federal Navigation Channel from 40 to 45 feet from Philadelphia Harbor, Pa., and Beckett Street Terminal, Camden, N.J., to the mouth of the Delaware Bay, appropriate bend widening, and partial deepening of the Marcus Hook anchorage and relocation of and addition of aids to navigation. Dredged material is to be placed by hydraulic and hopper dredges in confined upland containment areas in the Delaware River portion of the project and for beneficial uses in Delaware Bay.

On November 9, 2011 the dredge Charleston, owned and operated by Norfolk Dredging Company, began dredging in Reach B of the Delaware River Federal navigation channel (Figure 1-1). Dredging for deepening in lower Reach B extended from channel station 155+000 (at the lower end of the Bellevue Navigational Range) to channel station 172+385 (downriver from the Christina River mouth). The Charleston is a 24-inch hydraulic cutterhead suction dredge. The Charleston began dredging in the navigation channel at station 155+000. Dredged material was pumped via pipeline from the Charleston to the Federally-owned Pedricktown South CDF (Figure 1-1). The Charleston completed dredging on December 29, 2011. Approximately 769,916 cubic yards of material was dredged from the channel during this phase of the project. Periodic water quality monitoring was conducted on the dredge boat at a distance of 200 feet directly down-current to capture plume-generated turbidity and contaminant resuspension caused by the dredge boat’s cutterhead. Monitoring included the collection of detailed data on TSS and turbidity in the dredge plume. A TSS performance standard of 250 mg/L at a distance of 200 feet down-current of the cutterhead has been established through modeling calculations as a TSS level at which acute water quality criteria are expected to be met. Water samples for contaminant testing were collected within the dredge plume and at upriver and downriver background locations in the Delaware River. This program represents the second intensive Delaware Deepening environmental monitoring project; the first project was conducted during March to September 2010 for the Reach C deepening (Burton and Pasquale 2011).

In addition to monitoring near the dredge, water quality was also monitored at the Pedricktown South CDF. Sampling included material flowing into the containment cell (influent), and water and associated suspended solids that were discharged from the cell back to the Delaware River (effluent).

Figure 1-1. Main channel Reach B and the location of Pedricktown South. Reach B extends from the upstream limit of the Tinicum Range, located opposite of the Philadelphia International Airport to the downstream limit of the Cherry Island Range, located opposite of Wilmington, DE.

1.1 THE DREDGING PROCESS

Dredging is the underwater excavation of sediment from the bottom of the channel. A dredge is a machine that scoops or suctions sediment from the bottom of waterways or is used to mine materials underwater. Modern dredgers use satellite information and computers to help dig channels. Dredge captains use global positioning systems (GPS), which use satellite information to calculate the location of the dredge in the channel. On the dredge, information about the channel, the location of the shoal, and even the position of the dredge in the channel is displayed on a computer screen while they are working. Using computers to process and display information about the job and the dredge allows the dredging to be done with great efficiency. It saves time and money, and results in safer navigation channels.

One hydraulic cutterhead suction dredge was used for this contract. Figure 1-2 depicts a typical hydraulic cutterhead suction dredge. Hydraulic dredges work by pumping a mixture of dredged material and water from the channel bottom. The amount of water taken up with the material is controlled to make the best mixture. Too little water and the dredge will bog down; too much water and the dredge will not be efficient in moving sediment. A typical dredging operation in the Delaware River navigation channel hydraulically pumps dredged material through a pipeline to an upland CDF with a sediment to water ratio of about 25% to 75%.

For this contract, dredged material was pumped into the federally owned Pedricktown South CDF. In CDFs, dredged material is placed behind dikes, which contain and isolate it from the surrounding environment. A mixture of dredged material and water is pumped into the CDF and the flow of water is controlled by placement of training dikes to lengthen the path water must take to reach a weir discharge location, where water is discharged back to the river (Figure 1-3). Water pumped with the dredged material is contained in the disposal site until the solids settle out. It is then discharged back into the waterway. Heavier, coarser-grained sands and gravels drop out of the water column close to where material enters the cell. As the water moves through the CDF, it slows, allowing finer-grained sediment particles to settle out. Finally, water reaches the weir and is discharged from the site. The purpose of the weir structure is to regulate the release of ponded water from the CDF. Proper weir design and operation can control resuspension and release of settled solids. As the height of the weir is increased, the depth of the pond increases and only the cleaner surface waters of the pond are released.

A pipeline dredge pumps dredged material through one end, the intake pipe, and then pushes it out the discharge pipeline directly into the CDF. Because pipeline dredges pump directly to CDFs, they operate continuously and can be very cost efficient. Most pipeline dredges have a cutterhead on the suction end. A cutterhead is a mechanical device that has rotating blades or teeth to break up or loosen the bottom material so that it can be pumped through the dredge. The cutterhead is buried in the bottom sediment during operation. Pipeline dredges are mounted (fastened) to barges and are not usually self-powered, but are towed to the dredging site and secured in place by special anchor piling, called spuds. During operation, the cutterhead dredge swings from side to side alternately using the port and starboard spuds as a pivot. Cables attached to anchors on each side of the dredge control lateral movement. Figure 1-4 is an overhead view of the operation of a cutterhead dredge.

Figure 1-2. Configuration of a typical cutterhead dredge

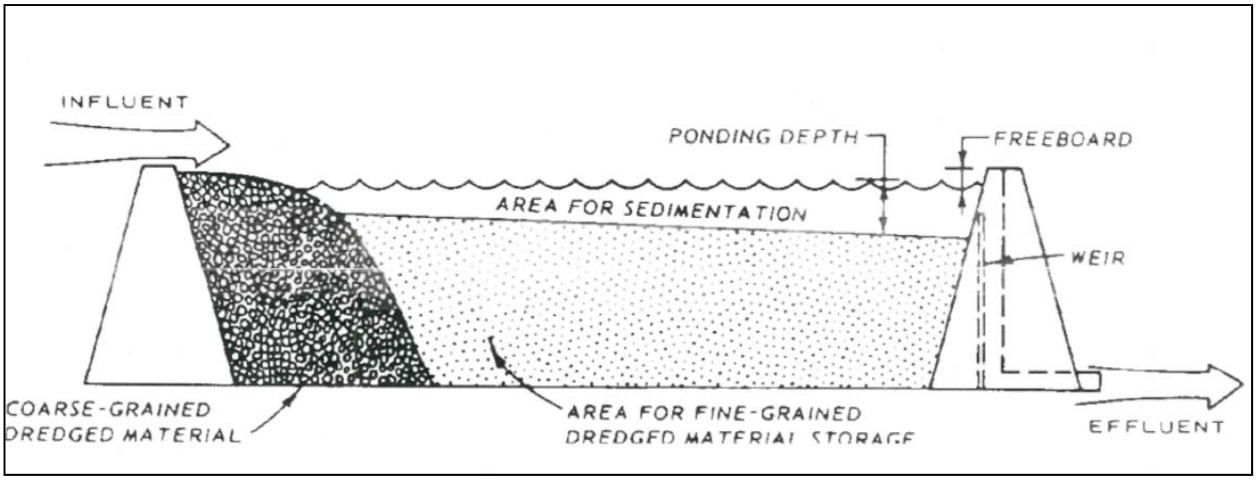


Figure 1-3. Generic CDF design

1.2 CONTAMINANTS IN THE AQUATIC ENVIRONMENT

Contaminants move within the aquatic environment in a variety of ways. Contaminants generally enter the aquatic environment in dissolved or suspended form in runoff, in dissolved form in groundwater, and in wet and dry deposition from the atmosphere. Once in the aquatic environment, dissolved contaminants are usually rapidly taken up through adsorption to suspended sediment particles or organic matter. Contaminants bound to particles are most likely to settle to the bottom. Dissolved contaminants will stay within the water column. The largest reservoir of contaminants in the aquatic environment is in the bottom sediment. Bottom sediments in the aquatic environment are not static but continuously in flux. Bottom sediments can become resuspended in the water column by natural processes such as winds, waves, currents, tidal action and episodic events such as storms. In the Delaware River, bottom sediments are also resuspended through human activities such as ship traffic and dredging. Contaminants associated with suspended sediment are affected by a variety of chemical factors within the water column which control the rate of adsorption or desorption of dissolved contaminants to either sediment particles or organic matter. Once contaminants are resuspended in the water column with sediment they may resettle to the bottom, be swept away by currents or become dissolved in the water column. A complex set of processes continuously in flux define the concentrations of contaminants in the water column of the aquatic environment.

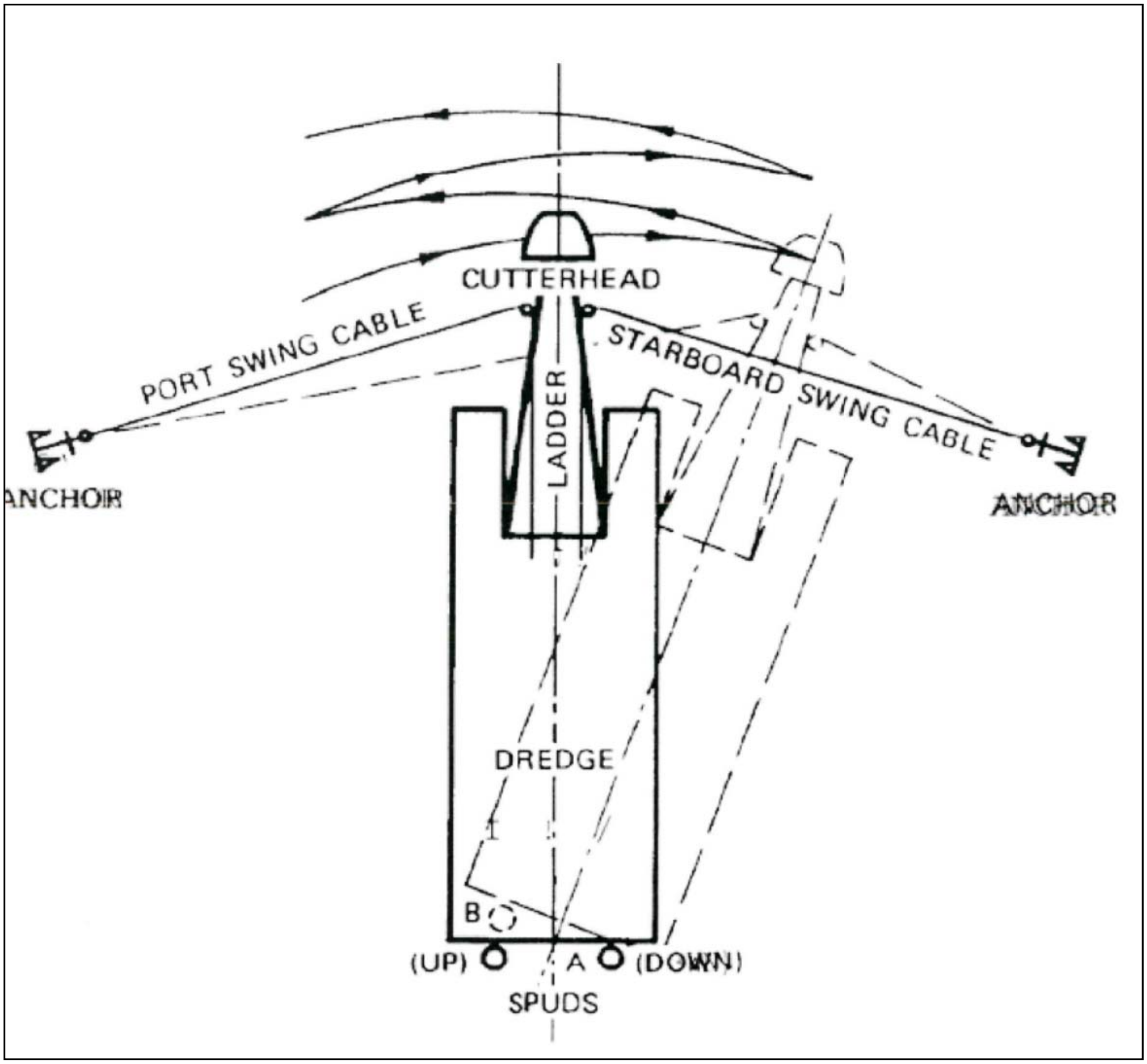


Figure 1-4. Anchoring and cabling system used to swing dredge back and forth during active dredging

Because of contaminant concerns in the waters of the Delaware Estuary, the states of Delaware, New Jersey, and Pennsylvania have issued fish consumption advisories that indicate by species the safe number of meals an individual can eat over a period of time. Fish can absorb contaminants from the water and the food they eat, and chemicals may build up over time in fish tissues even with extremely small amounts of chemicals in the water. The amount of contaminants in fish depends on the species, size, age, sex and feeding area of the fish. Chemicals, such as polychlorinated biphenyls (PCBs), mercury, and dioxin in fish are a health risk for people who regularly consume their catch.

1.3 ENVIRONMENTAL MONITORING APPROACH

There are two potential pathways resulting from the dredging process that can increase exposure of contaminants associated with the bottom sediments to aquatic life. The first route of possible exposure occurs when the cutterhead disturbs the sediment in the area being dredged. Sediment resuspended into the water column may result in the release of sediment contaminants, which can then be available for uptake by aquatic organisms. A second possible exposure pathway is the release of contaminants associated with water and suspended sediment discharged from the CDF. In addition to resuspension of sediment and contaminants associated with the dredging process, it is also important to consider the overall contaminant load within the aquatic system. The dredging process removes contaminants associated with dredged sediments from the aquatic environment by permanently sequestering them in the CDF. From a mass balance perspective it is important to consider how sediment and contaminant mass are added to the water column (mobilization at the cutterhead and discharges from the CDF) versus how sediment and contaminant mass are removed from the water column (resettling of suspended sediments mobilized at the cutterhead but not drawn into the pipeline and retention within the CDF). Water quality was monitored at two locations during Reach B construction for the deepening project (see Figure 1-5). Longitudes and latitudes for sampling locations are provided in Appendix B. Scopes of work to guide sample collection and analysis were prepared and coordinated with the Delaware Department of Natural Resources and Environmental Control (DNREC) for their comment and approval prior to the start of construction.

Water quality was also monitored at the Pedricktown South CDF. The scope of work for this effort is titled: *FY-2011 Delaware River Deepening Project Pedricktown South CDF Water Quality Monitoring* (see Appendix A). Sampling included material flowing into the containment cell (influent) and water and associated suspended solids and contaminants discharging from the cell back to the Delaware River (effluent).

As part of the point of dredge monitoring, periodic water quality monitoring took place at the working dredge at a distance of 200 feet directly down-current of the cutterhead to capture any plume generated by the dredge. The scope of work for this effort is titled: *Delaware River Main Channel Deepening Project Reach B Water Quality Monitoring at the Point of Dredging* (see Appendix A). Monitoring included the collection of detailed data on total suspended solids and turbidity in the dredge plume. A TSS performance standard of 250 mg/L at a distance of 200 feet down-current of the cutterhead has been established through modeling calculations as a TSS level at which acute water quality criteria for the protection of aquatic life are expected to be met. Water samples were also collected within the dredge plume and at background locations in the Delaware River for contaminant testing. Background sampling locations are shown on Figure 1-5 and associated longitudes and latitudes are provided in Appendix B.

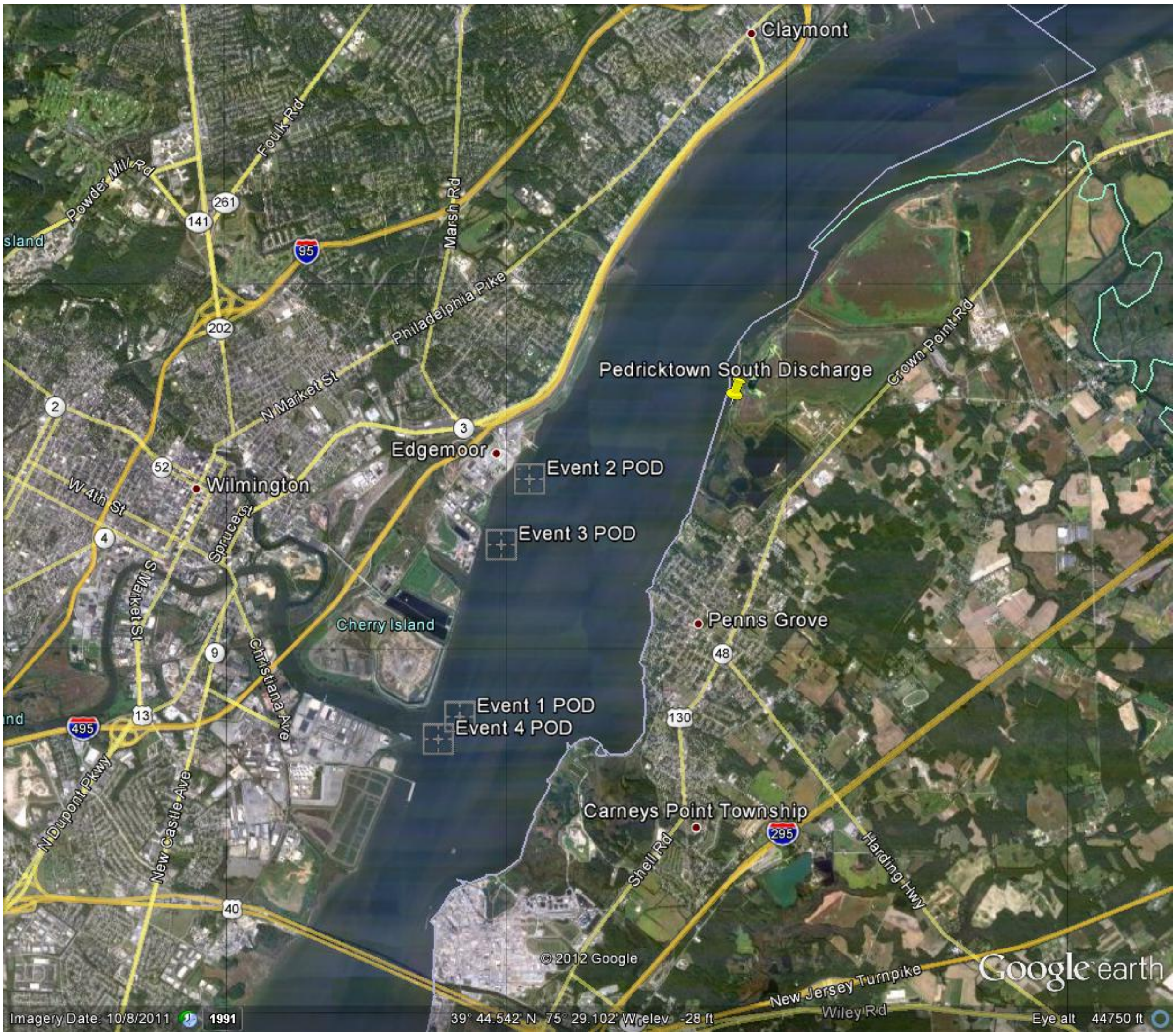


Figure 1-5. Location of the Point of Dredge sampling events relative to the Pedricktown South Discharge. Up and Down river background sampling stations were approximately one mile above or below the dredge boat.

2.0 POINT OF DREDGE MONITORING

2.1 FIELD METHODS

TSS/turbidity data and water samples for contaminant testing were collected off the dredge Charleston during five specific events. Events 1 through 5 included simultaneous TSS and turbidity measurements while events 1, 3, and 5 also included water sampling for contaminants (Table 2-1).

Table 2-1. Point of Dredge sampling dates and parameters sampled in 5 monitoring events for Reach B deepening

Date	Event Number	Number of Sampling Rounds	Tide Stage	TSS	NTU	Water Column Contaminants
11/30/2011	1	2	Flood	X	X	X
12/6/2011	2	2	Flood	X	X	
12/13/2011	3	2	Flood	X	X	X
12/27/2011	4	2	Flood	X	X	
12/29/2011	5	1	Flood			X (Background only)

The sampling was conducted from Versar's research vessel moored onto the port side of the Charleston dredge approximately 200 feet downstream of where the cutterhead contacted the river bottom (Figure 2-1). For all the dredging in lower Reach B the Charleston's cutterhead was pointing downriver. Because the dredge boat swings from side to side during active dredging and the presence of pipelines, anchor chain, high currents, and workboats, sampling could only be safely conducted while moored to the dredge boat. Therefore in any given sampling event only one tidal cycle (6 hour duration) could be taken in a given work day. Turbidity and TSS samples were taken at 0.5, 6, and 11-meter depths while water samples for contaminant testing were only taken at the 11-meter depth increment. Using a data logging YSI 6600 water quality meter, turbidity, temperature, salinity, dissolved oxygen, and pH were recorded every 2 seconds at each of three depths for a total of 15 minutes per depth during active dredging. Since the dredge boat swings in a 400 foot swath while dredging, the swing position was recorded on field sheets every minute during the data logging. Dredge boat swing position and swing rate varied according to bottom hardness, depth of cut, ambient depth, and other conditions deemed necessary by the captain who operated independently of the environmental sampling team.

Figure 2-1. Versar sampling vessel, RV Polgar, moored along the starboard side of the Charleston dredge approximately 200 feet from where the cutterhead contacted the river bottom

The YSI meter was attached horizontally to a Wildco® opening and closing sample bottle (Figure 2-2). After 15 minutes of data logging at depth three water samples for TSS measurements were taken by sending a weighted tripping mechanism down the cable to close the bottle. The field NTU on the YSI hand held display was recorded when the bottle tripped shut. TSS samples were taken at port, center, and starboard swing positions whenever possible. Water samples for contaminant testing were taken during Events 1 and 3 (Table 2-1) using a peristaltic pump and a Teflon® hose attached to the closing sample bottle. Contaminant sampling was scheduled for Event 5 but the dredger finished the deepening ahead of schedule so only background samples were taken. Upriver and downriver background samples were taken approximately 1/2 mile away from the dredge boat for each sampling event. A data logging water quality cast from surface to 11-meters was taken along with TSS sampling at 0.5, 6 and 11-meter depths similar to the collection taken while moored to the Charleston. Only one round of background samples was taken per event and contaminant samples were taken at the 11-m depth increment. To characterize the grain size and chemical composition of the dredged material, sediment samples were taken in front of the cutterhead with a ponar grab for each contaminant sampling event. The ponar grab was decontaminated with an alconox wash, an acetone rinse, and a final deionized water rinse before obtaining sediment samples for bulk sediment testing.

Figure 2-2. YSI water quality meter attached to open sample bottle for the Point of Dredge TSS and turbidity testing for the Delaware River Deepening project

All water and sediment samples were labeled and shipped on ice to TestAmerica laboratories in Pittsburgh, PA for analysis. TSS samples were processed the next day in Versar's sediment laboratory in Columbia, MD. Contaminant testing included pesticides, PCBs (as Aroclors and congener-specific), dioxins and furans, semi-volatile organics, inorganics, and dissolved and particulate organic carbon. All the 11-meter depth water samples were tested for high resolution congener specific PCBs and dioxins and furans. Laboratory methods for the various parameters tested are presented in Section 5.2 and Table 5-2.

The field measurements of turbidity (NTUs) fluctuated in real time due to the flow-by of particles making the exact turbidity at the time the Wildco® bottle closed subject to some uncertainty. Therefore turbidity was re-measured in the laboratory using the same YSI meter just before filtering the water for the TSS analysis. Regression analysis was run on both field and laboratory NTUs against the sample specific gravimetric measurement of TSS.

2.2 POINT OF DREDGE MONITORING DATA ASSESSMENT METHODS

Water quality monitoring was conducted during dredging operations in lower Reach B to evaluate the magnitude of the turbidity plume and the level of contaminant releases at the cutterhead of the working dredge deepening Reach B. Data and analyses for this assessment are provided in Appendix B. The frequency of turbidity observations in various data bins were calculated for the 11-m, 6-m, and 0.5-m measurements taken 200 feet down-current from the working cutterhead with a data logging water quality meter. It was anticipated that if a significant turbidity plume was generated by the cutterhead a higher percentage of the observations at the 11-m depths would be above 250 mg/L TSS and that the turbidity pattern would be dramatically dissimilar to background turbidity casts. Previous turbidity plume studies by USACE and subsequent reviews by DNREC suggested that if TSS levels are kept below 250 mg/L 200 feet from the point of dredging then Delaware River water quality criteria for the protection of aquatic life will likely be maintained. To identify the level of NTU that represents 250 mg/L TSS a regression analysis was first required to correlate turbidity (measured in Nephelometer Units - NTUs) to Total Suspended Solids. Real time measurements for turbidity can only be accomplished with a turbidity meter that records NTUs. Turbidity is an optical measurement of light attenuation caused by particles in the water column. To convert NTUs into TSS site specific water sampling and simultaneous NTU measurements were needed to develop a regression equation to accurately convert turbidity into TSS.

Contaminant mobilization and potential toxic effects at the cutterhead were assessed by comparing the Point of Dredge samples taken at the 11-m depth to DNREC acute and chronic freshwater protection of aquatic life criteria (Appendix C). Note that concentrations at the 11-m depth are likely to be worst case within the water column because solids concentrations are highest closest to the bottom. Freshwater criteria are appropriate when salinity is below 5.0 Parts per Thousand (PPT). Salinity measurements made during the monitoring program were consistently below 5.0 PPT. For this assessment the average hardness observed in the background samples (63.9 mg/L) was used for calculating hardness based criteria. Mean contaminant concentrations were also computed for the 11-m dredge plume samples and compared to background concentrations by computing a ratio of mean plume to mean background concentrations. Ratios over 1.0 would suggest an increase in contaminant concentration was caused by the cutterhead.

3.0 POINT OF DREDGE MONITORING RESULTS

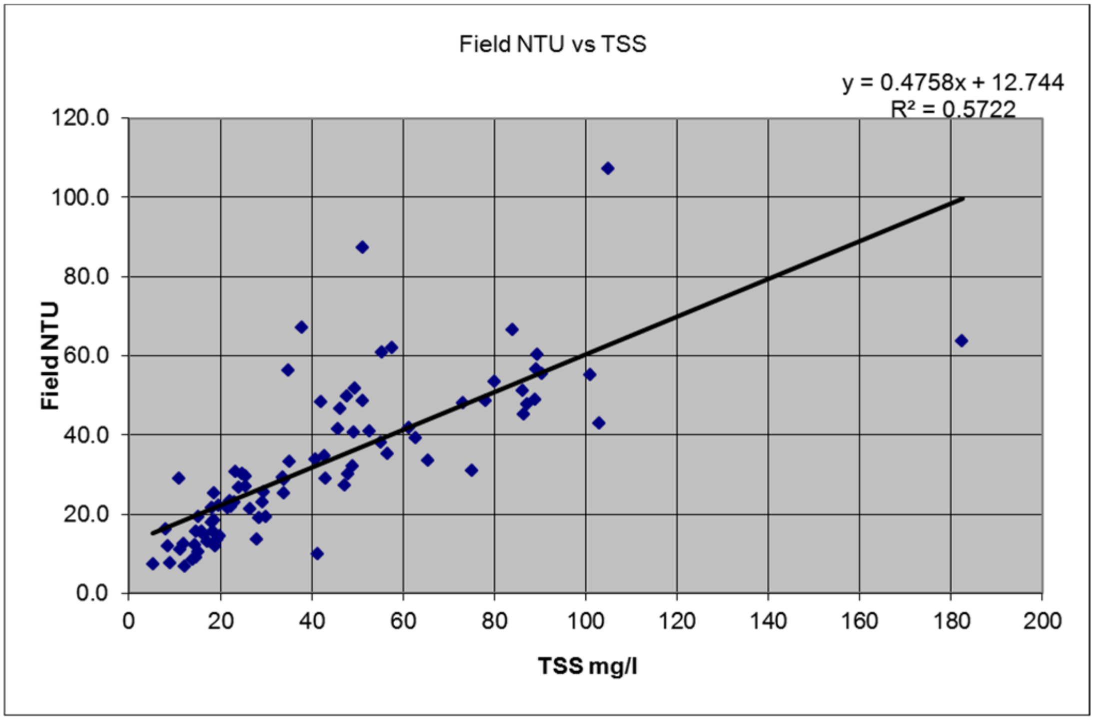
3.1 TURBIDITY

Among five sampling events for TSS and turbidity a total of 87 paired samples were collected. The highest TSS concentration measured was 182.4 mg/L with a corresponding lab NTU of 114.3 while the lowest values in the data series was a TSS of 5.2 mg/L and a lab NTU of 22.0. Figure 3-1 presents the regression analysis of the field and lab turbidity, respectively. In the controlled laboratory environment the lab NTU regression had a better R^2 of 0.843 relative to the field turbidity regression with an R^2 of 0.572. Table 3-1 presents the expected turbidity values that correspond to various TSS concentrations using the laboratory based regression. Based on the regression, turbidity readings of 160 or less met the 250 mg/L TSS water quality goal 200 feet from the hydraulic cutterhead.

Table 3-1. Expected NTUs at various mg/L TSS using lab based regression equation; ($y = 0.5538x + 21.726$)

y (NTU)	**x (TSS)**
160.2	250
132.5	200
104.8	150
77.1	100
49.4	50

During the Point of Dredge monitoring over 9,000 measurements of turbidity were logged at 0.5, 6 and 11-m depth increments during active dredging. These data were binned into 5 NTU categories from 0 to 300 NTUs (for a total of 60 bins) and the frequency of occurrence in each category was calculated for each depth increment (Figure 3-2). At the point of dredging no values over 160 NTUs were observed at the surface, 6-m, or 11-m depth increments during active dredging. Slightly higher turbidity was observed at the 11-m depth relative to 6-m and surface measurements. Background measurements logged during a slowly descending surface to 11-m cast had a similar turbidity pattern to that observed at the 6-m and surface depth increment 200 feet behind the working cutterhead.



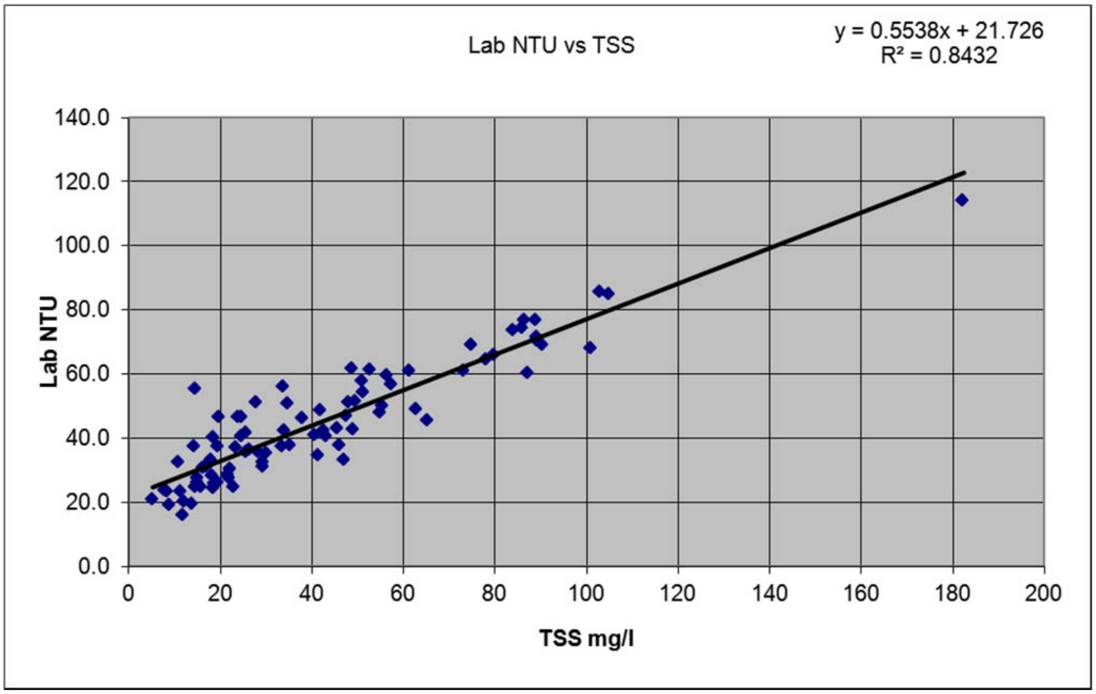


Figure 3-1. Results of regression analysis of field and laboratory turbidity measurements relative to TSS concentrations for samples collected while moored to the Charleston dredge boat during the 2011 monitoring

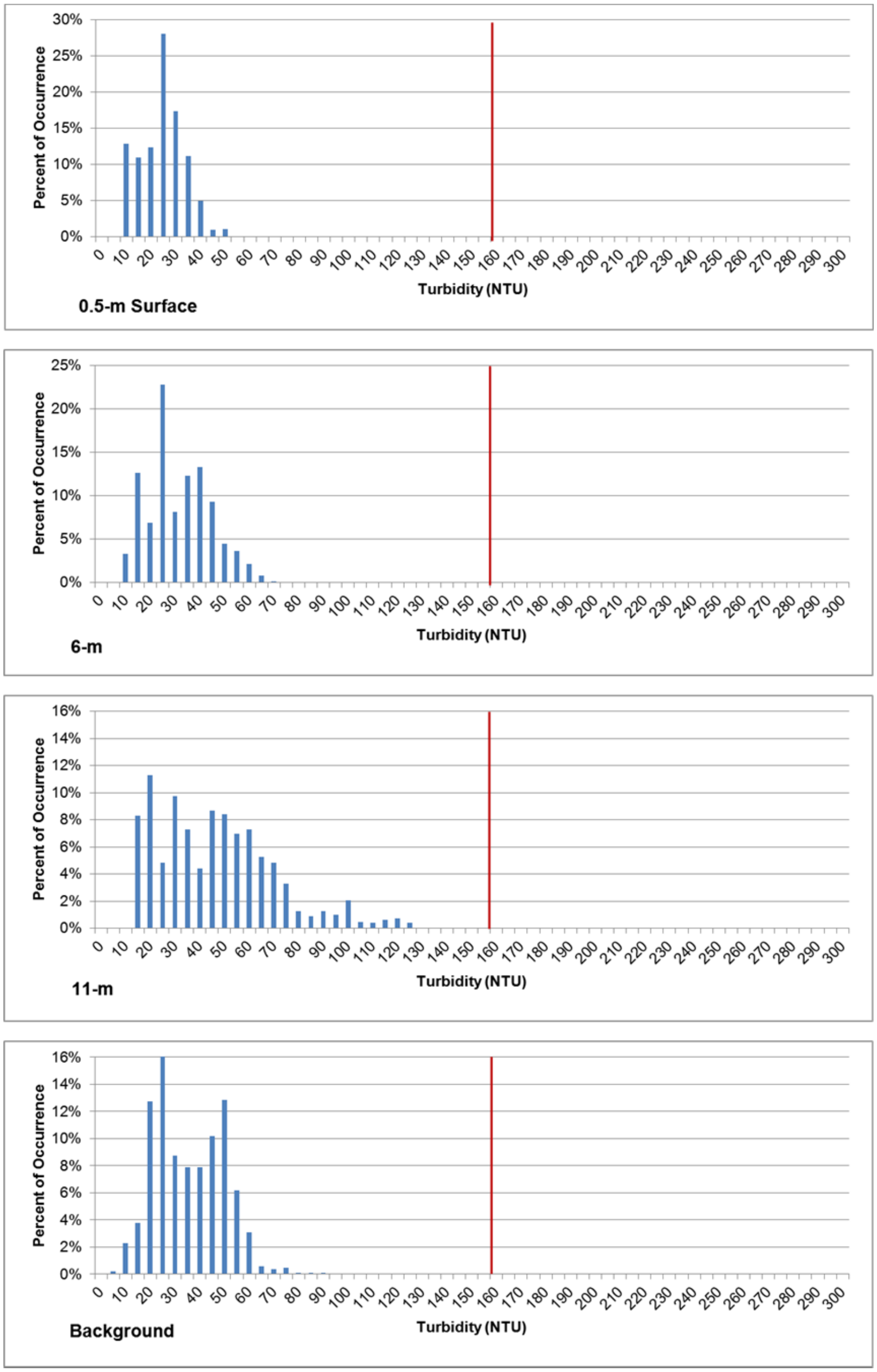


Figure 3-2. Frequency distribution of turbidity measurements in 5 NTU increments observed at 0.5, 6, and 11-m depths 200 feet down current of the working cutterhead and at upriver and downriver background stations monitored in Reach B during 2011

3.2 CONTAMINANTS

Samples collected for chemical analysis at the 11-m depth increment suggest that water quality behind the working dredge was not significantly altered compared to background. Tables 3-2 through 3-9 present the Pesticides/Aroclor PCBs, semi-volatile organics, total inorganics, and dissolved inorganics for the 11-m Point of Dredge samples and background samples. At the 11-m depth, with the exception of total aluminum, all of the parameters were measured in concentrations below DNREC's published freshwater acute criteria for the protection of aquatic life (Appendix C). Although total aluminum concentrations were over the acute criterion (Table 3-4), the observed concentrations were within the range reported for the upriver and downriver background samples (Table 3-8). Dissolved copper concentrations were over the chronic criterion of 6.11 µg/L during sampling in event 1 (Table 3-5). All pesticides, PCB aroclors, and semi-volatile organics (including PAHs) were either not detected or below applicable chronic aquatic life water quality criteria (Tables 3-2 and 3-6). Although DNREC does not have aquatic life criteria for PAHs, criteria are available in the peer reviewed literature (DiToro et al. 2000). None of the detected concentrations exceed those criteria.

Congener specific high resolution PCB analyses were conducted on the 11- m Point of Dredge and the 11-m upriver and downriver background samples (Tables 3-10 and 3-11). At the Point of Dredge, the sum of congeners were all below DNREC's chronic aquatic life water quality criterion (14 ng/L) for total PCBs. Background total PCB concentrations were all below the chronic aquatic life criterion as well. All Point of Dredge and background samples were above DNREC's human health carcinogen water quality criterion (0.064 ng/L) for PCBs. While there are no direct water quality criteria for the protection of aquatic life established for dioxin and furans for the Delaware River, the sum of homologs suggests Point of Dredge concentrations were in a similar range to those observed in the background samples (Tables 3-12 and 3-13). DNREC does have a human health criterion for Dioxin and Furan expressed as 2,3,7,8-TCDD TEQ (0.0051 pg/L). The toxic equivalence for a sample is the sum of the concentration for specific congeners multiplied by its associated Toxicity Equivalence Factor (TEF). A listing of these TEFs is presented on page 31 of DNREC's surface water quality standards as amended on July 11, 2004 (Appendix C). The resulting Dioxin and Furan TEQ's ranged from 0.00028 to 1.039 pg/L for all 11-m plume and 11-m background samples. Both 11-m Point of Dredge and background samples were typically over the 0.0051 pg/L human health TEQ for Dioxins and Furans.

The exceedance of the human health water quality criteria for PCBs and Dioxin and Furan TEQs was expected based on the fact that these two contaminants contribute to fish advisories in the tidal Delaware River. Importantly, the concentration of these contaminants in the plume samples were not elevated compared to the background concentrations.

Table 3-2. Point of dredge 11-m pesticide and PCB Aroclor data

Sample ID		**C-11M (EVENT 1 ROUND1)**	**C-11M (EVENT 1 ROUND2)**	**C-11M (EVENT 3 ROUND 1)**	**C-11M (EVENT 3 ROUND 2)**	**DNREC Acute**	**DNREC Chronic**
Lab Report ID		180-6403-3	180-6403-4	180-6807-3	180-6807-4		
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011		
GCSEMI							
4,4'-DDD	µg/L	<0.0012	<0.0012	<0.012	<0.012	1.1	0.001
4,4'-DDE	µg/L	<0.0012	<0.0012	<0.012	<0.012	1.1	0.001
4,4'-DDT	µg/L	<0.0012	<0.0012	<0.012	<0.012	1.1	0.001
Aldrin	µg/L	<0.0012	<0.0012	<0.012	<0.012	3.0	none
alpha-BHC	µg/L	<0.0012	<0.0012	<0.012	<0.012		
alpha-Chlordane	µg/L	<0.0012	<0.0012	<0.012	<0.012		
Aroclor-1016	µg/L	<0.0095	<0.0094	<0.0095	<0.029	none	0.014
Aroclor-1221	µg/L	<0.0095	<0.0094	<0.0095	<0.029	none	0.014
Aroclor-1232	µg/L	<0.0095	<0.0094	<0.0095	<0.029	none	0.014
Aroclor-1242	µg/L	<0.0095	<0.0094	<0.0095	<0.029	none	0.014
Aroclor-1248	µg/L	<0.0095	<0.0094	<0.0095	<0.029	none	0.014
Aroclor-1254	µg/L	<0.0095	<0.0094	<0.0095	<0.029	none	0.014
Aroclor-1260	µg/L	<0.0095	<0.0094	<0.0095	<0.029		
beta-BHC	µg/L	<0.0012	<0.0012	<0.012	<0.012		
Chlordane (technical)	µg/L	<0.012	<0.012	<0.12	<0.12	2.4	0.0043
Chlorpyrifos	µg/L	<0.95	<0.94	<0.95	<0.95	0.083	0.041
delta-BHC	µg/L	<0.0012	<0.0012	<0.012	<0.012		
Dieldrin	µg/L	<0.0012	<0.0012	<0.012	<0.012	0.24	0.056
Endosulfan I	µg/L	<0.0012	<0.0012	<0.012	<0.012	0.22	0.056
Endosulfan II	µg/L	0.00093	<0.0012	<0.012	<0.012	0.22	0.056
Endosulfan sulfate	µg/L	<0.0012	<0.0012	<0.012	<0.012		
Endrin	µg/L	<0.0012	<0.0012	<0.012	<0.012	0.086	0.036
Endrin aldehyde	µg/L	<0.0012	<0.0012	<0.012	<0.012		
Endrin ketone	µg/L	<0.0012	<0.0012	<0.012	<0.012		
gamma-BHC (Lindane)	µg/L	<0.0012	<0.0012	<0.012	<0.012	none	none
gamma-Chlordane	µg/L	<0.0012	<0.0012	<0.012	<0.012		
Heptachlor	µg/L	<0.0012	<0.0012	<0.012	<0.012	0.52	0.0038
Heptachlor epoxide	µg/L	<0.0012	<0.0012	<0.012	<0.012		
Methoxychlor	µg/L	<0.0024	<0.0024	<0.024	<0.024	none	0.03
Parathion	µg/L	<0.95	<0.94	<0.95	<0.95	0.065	0.013
Toxaphene	µg/L	<0.095	<0.094	<0.95	<0.95	0.73	0.0002

Table 3-3. Point of dredge 11-m semi-volatile data. Chronic FCV values were taken from DiToro et al. (2000).

Sample ID		**C-11M (EVENT 1 ROUND1)**	**C-11M (EVENT 1 ROUND2)**	**C-11M (EVENT 3 ROUND 1)**	**C-11M (EVENT 3 ROUND 2)**	**DNREC Acute**	**DNREC Chronic**	**FCV Chronic**
Lab Report ID		180-6403-3	180-6403-4	180-6807-3	180-6807-4			
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011			
MSSEMI								
1,1'-Biphenyl	µg/L	<0.96	<0.96	<0.96	<0.97			
1,2,4-Trichlorobenzene	µg/L	<0.96	<0.96	<0.96	<0.97			
1,2-Dichlorobenzene	µg/L	<0.96	<0.96	<0.96	<0.97			
1,2-Diphenylhydrazine	µg/L	<0.96	<0.96	<0.96	<0.97			
1,3-Dichlorobenzene	µg/L	<0.96	<0.96	<0.96	<0.97			
1,4-Dichlorobenzene	µg/L	<0.96	<0.96	<0.96	<0.97			
2,2'-oxybis[1-chloropropane]	µg/L	<0.19	<0.19	<0.19	<0.19			
2,4,5-Trichlorophenol	µg/L	<0.96	<0.96	<0.96	<0.97			
2,4,6-Trichlorophenol	µg/L	<0.96	<0.96	<0.96	<0.97			
2,4-Dichlorophenol	µg/L	<0.19	<0.19	<0.19	<0.19			
2,4-Dimethylphenol	µg/L	<0.96	<0.96	<0.96	<0.97			
2,4-Dinitrophenol	µg/L	<4.8	<4.8	<4.8	<4.9			
2,4-Dinitrotoluene	µg/L	<0.96	<0.96	<0.96	<0.97			
2,6-Dinitrotoluene	µg/L	<0.96	<0.96	<0.96	<0.97			
2-Chloronaphthalene	µg/L	<0.19	<0.19	<0.19	<0.19			
2-Chlorophenol	µg/L	<0.96	<0.96	<0.96	<0.97			
2-Methylnaphthalene	µg/L	<0.19	0.019	<0.19	0.015			121.03
2-Methylphenol	µg/L	<0.96	<0.96	<0.96	<0.97			
2-Nitroaniline	µg/L	<4.8	<4.8	<4.8	<4.9			
2-Nitrophenol	µg/L	<0.96	<0.96	<0.96	<0.97			
3,3'-Dichlorobenzidine	µg/L	<0.96	<0.96	<0.96	<0.97			
3-Nitroaniline	µg/L	<4.8	<4.8	<4.8	<4.9			
4,6-Dinitro-2-methylphenol	µg/L	<4.8	<4.8	<4.8	<4.9			
4-Bromophenyl phenyl ether	µg/L	<0.96	<0.96	<0.96	<0.97			
4-Chloro-3-methylphenol	µg/L	<0.96	<0.96	<0.96	<0.97			
4-Chloroaniline	µg/L	<0.96	<0.96	<0.96	<0.97			
4-Chlorophenyl phenyl ether	µg/L	<0.96	<0.96	<0.96	<0.97			
4-Nitroaniline	µg/L	<4.8	<4.8	<4.8	<4.9			
4-Nitrophenol	µg/L	<4.8	<4.8	<4.8	<4.9			
Acenaphthene	µg/L	<0.19	<0.19	<0.19	<0.19			95.09
Acenaphthylene	µg/L	<0.19	<0.19	<0.19	<0.19			527.73
Acetophenone	µg/L	<0.96	<0.96	<0.96	<0.97			
Anthracene	µg/L	<0.19	<0.19	<0.19	<0.19			35.56
Atrazine	µg/L	<0.96	<0.96	<0.96	<0.97			
Benzaldehyde	µg/L	<0.96	<0.96	<0.96	<0.97			
Benzidine	µg/L	<19	<19	<19	<19			
Benzo[a]anthracene	µg/L	0.023	0.034	<0.19	0.062			3.79
Benzo[a]pyrene	µg/L	0.019	0.027	<0.19	0.044			1.59
Benzo[b]fluoranthene	µg/L	0.023	0.036	<0.19	0.074			1.13
Benzo[g,h,i]perylene	µg/L	<0.19	<0.19	<0.19	<0.19			
Benzo[k]fluoranthene	µg/L	<0.19	<0.19	<0.19	<0.19			
Bis(2-chloroethoxy)methane	µg/L	<0.96	<0.96	<0.96	<0.97			

Table 3-3. (Continued)

Sample ID		**C-11M (EVENT 1 ROUND1)**	**C-11M (EVENT 1 ROUND2)**	**C-11M (EVENT 3 ROUND 1)**	**C-11M (EVENT 3 ROUND 2)**	**DNREC Acute**	**DNREC Chronic**	**FCV Chronic**
Lab Report ID		180-6403-3	180-6403-4	180-6807-3	180-6807-4			
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011			
MSSEMI								
Bis(2-chloroethyl)ether	µg/L	<0.19	<0.19	<0.19	<0.19			
Bis(2-ethylhexyl) phthalate	µg/L	<1.9	<1.9	<1.9	<1.9			
Butyl benzyl phthalate	µg/L	0.48	0.56	0.2	0.27			
Caprolactam	µg/L	<4.8	<4.8	<4.8	<4.9			
Carbazole	µg/L	<0.19	<0.19	<0.19	<0.19			
Chrysene	µg/L	0.029	0.038	0.029	0.047			3.46
Dibenz(a,h)anthracene	µg/L	<0.19	<0.19	<0.19	<0.19			0.48
Dibenzofuran	µg/L	<0.96	<0.96	<0.96	<0.97			
Diethyl phthalate	µg/L	<0.96	0.17	0.19	<0.97			
Dimethyl phthalate	µg/L	<0.96	<0.96	<0.96	<0.97			
Di-n-butyl phthalate	µg/L	<0.96	<0.96	<0.96	<0.97			
Di-n-octyl phthalate	µg/L	<0.96	<0.96	<0.96	<0.97			
Fluoranthene	µg/L	0.036	0.075	0.045	0.087			12.19
Fluorene	µg/L	<0.19	0.022	<0.19	<0.19			66.17
Hexachlorobenzene	µg/L	<0.19	<0.19	<0.19	<0.19			
Hexachlorobutadiene	µg/L	<0.19	<0.19	<0.19	<0.19			
Hexachlorocyclopentadiene	µg/L	<0.96	<0.96	<0.96	<0.97			
Hexachloroethane	µg/L	<0.96	<0.96	<0.96	<0.97			
Indeno[1,2,3-cd]pyrene	µg/L	<0.19	<0.19	<0.19	<0.19			
Isophorone	µg/L	<0.96	<0.96	<0.96	<0.97			
Methylphenol, 3 & 4	µg/L	<0.96	<0.96	<0.96	<0.97			
Naphthalene	µg/L	<0.19	<0.19	<0.19	0.028			322.0
Nitrobenzene	µg/L	<1.9	<1.9	<1.9	<1.9			
N-Nitrosodimethylamine	µg/L	<0.96	<0.96	<0.96	<0.97			
N-Nitrosodi-n-propylamine	µg/L	<0.19	<0.19	<0.19	<0.19			
N-Nitrosodiphenylamine	µg/L	<0.96	<0.96	<0.96	<0.97			
Pentachlorophenol	µg/L	<0.96	<0.96	<0.96	<0.97	8.72	6.69	
Phenanthrene	µg/L	<0.19	0.071	0.049	0.065			32.43
Phenol	µg/L	<0.19	<0.19	<0.19	<0.19			
Pyrene	µg/L	0.03	0.05	0.036	0.1			17.22

Table 3-4. Point of dredge 11-m total inorganics data. Values highlighted in yellow are above DNREC acute criteria for protection of aquatic life.

Sample ID		**C-11M (EVENT 1 ROUND1)**	**C-11M (EVENT 1 ROUND2)**	**C-11M (EVENT 3 ROUND 1)**	**C-11M (EVENT 3 ROUND 2)**	**DNREC Acute**	**DNREC Chronic**
Lab Report ID		180-6403-3	180-6403-4	180-6807-3	180-6807-4		
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011		
MET							
Aluminum	µg/L	970	1900	1400	1300	750	87
Antimony	µg/L	0.21	0.24	1.1	0.56		
Arsenic	µg/L	4	4.1	1.3	1.5	340	150
Barium	µg/L	31	38	34	33		
Beryllium	µg/L	0.097	0.16	0.14	0.13		
Cadmium	µg/L	<1.0	<1.0	<1.0	<1.0		
Calcium	µg/L	16000	17000	11000	12000		
Chromium	µg/L	7.7	9.6	5.4	4.6		
Cobalt	µg/L	0.85	1.5	1.6	1.3		
Copper	µg/L	11	12	5.9	5.2		
Cyanide, Total	µg/L	<10	<10	<10	<10	22	5.2
Iron	µg/L	1600	2900	2600	2400		
Lead	µg/L	2.6	4.8	4.8	4.4		
Magnesium	µg/L	5800	6400	3900	4200		
Manganese	µg/L	73	150	110	100		
Mercury	ng/L	3.6	7.1	5	6.8	1400	77
Nickel	µg/L	2.6	3.8	3.5	3.2		
Potassium	µg/L	2800	3300	2100	2200		
Selenium	µg/L	<5.0	<5.0	0.49	0.52	20	5.0
Silver	µg/L	<1.0	<1.0	0.043	0.036		
Sodium	µg/L	14000	17000	8800	9400		
Thallium	µg/L	0.016	0.027	0.059	0.045		
Vanadium	µg/L	4.1	5.7	1.5	0.65		
Zinc	µg/L	21	33	28	25		

Table 3-5. Point of dredge 11-m dissolved inorganics data. Values highlighted in green are above DNREC chronic criteria for protection of aquatic life.

Sample ID		**C-11M (EVENT 1 ROUND1)**	**C-11M (EVENT 1 ROUND2)**	**C-11M (EVENT 3 ROUND 1)**	**C-11M (EVENT 3 ROUND 2)**	**DNREC Acute**	**DNREC Chronic**
Lab Report ID		180-6403-3	180-6403-4	180-6807-3	180-6807-4		
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011		
MET							
Aluminum-Diss	µg/L	11	6.9	8.1	4.6		
Antimony-Diss	µg/L	0.38	0.32	0.47	0.41		
Arsenic-Diss	µg/L	6.8	4.9	0.36	<1.0	340	150
Barium-Diss	µg/L	24	26	22	21		
Beryllium-Diss	µg/L	<1.0	0.041	<1.0	<1.0		
Cadmium-Diss	µg/L	<1.0	<1.0	<1.0	<1.0	1.30	0.18
Calcium-Diss	µg/L	18000	20000	14000	14000		
Chromium-Diss	µg/L	7.8	7.2	1.6	1.6	16	11
Cobalt-Diss	µg/L	0.15	0.13	0.076	0.082		
Copper-Diss	µg/L	7.6	7.1	2.4	2.2	8.81	6.11
Iron-Diss	µg/L	55	45	16	7.4		
Lead-Diss	µg/L	0.073	0.047	0.075	0.041	39.53	1.54
Magnesium-Diss	µg/L	6200	6900	3900	4000		
Manganese-Diss	µg/L	8.4	5.8	2.6	4.8		
Nickel-Diss	µg/L	1.3	1.4	1.1	0.98	320.57	35.61
Potassium-Diss	µg/L	2600	3000	1700	1700		
Selenium-Diss	µg/L	1.2	1.1	<5.0	<5.0		
Silver-Diss	µg/L	<1.0	<1.0	<1.0	<1.0	1.49	
Sodium-Diss	µg/L	16000	19000	11000	11000		
Thallium-Diss	µg/L	0.017	0.016	0.019	0.015		
Vanadium-Diss	µg/L	1.5	3	0.71	2.2		
Zinc-Diss	µg/L	7	7.6	4.2	4.5	80.18	80.83

Table 3-6. Point of dredge background pesticide and PCB Aroclor data

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**DNREC**	**DNREC**
Lab Report ID		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2	**Acute**	**Chronic**
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011	12/29/2011	12/29/2011		
GCSEMI									
4,4'-DDD	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	1.1	0.001
4,4'-DDE	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	1.1	0.001
4,4'-DDT	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	1.1	0.001
Aldrin	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	3.0	none
alpha-BHC	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
alpha-Chlordane	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
Aroclor-1016	µg/L	<0.0095	<0.0096	<0.029	<0.029	<0.047	<0.048	none	0.014
Aroclor-1221	µg/L	<0.0095	<0.0096	<0.029	<0.029	<0.047	<0.048	none	0.014
Aroclor-1232	µg/L	<0.0095	<0.0096	<0.029	<0.029	<0.047	<0.048	none	0.014
Aroclor-1242	µg/L	<0.0095	<0.0096	<0.029	<0.029	<0.047	<0.048	none	0.014
Aroclor-1248	µg/L	<0.0095	<0.0096	<0.029	<0.029	<0.047	<0.048	none	0.014
Aroclor-1254	µg/L	<0.0095	0.017	<0.029	<0.029	<0.047	<0.048	none	0.014
Aroclor-1260	µg/L	<0.0095	<0.0096	<0.029	<0.029	<0.047	<0.048		
beta-BHC	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
Chlordane (technical)	µg/L	<0.012	<0.012	<0.12	<0.12	<0.059	<0.060	2.4	0.0043
Chlorpyrifos	µg/L	<0.95	<0.95	<0.95	<0.95	<0.95	<0.95	0.083	0.041
delta-BHC	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
Dieldrin	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	0.24	0.056
Endosulfan I	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	0.22	0.056
Endosulfan II	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	0.22	0.056
Endosulfan sulfate	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
Endrin	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	0.086	0.036
Endrin aldehyde	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
Endrin ketone	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
gamma-BHC (Lindane)	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	none	none
gamma-Chlordane	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
Heptachlor	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062	0.52	0.0038
Heptachlor epoxide	µg/L	<0.0012	<0.0013	<0.012	<0.012	<0.0061	<0.0062		
Methoxychlor	µg/L	<0.0024	<0.0024	<0.024	<0.024	<0.012	<0.012	none	0.03
Parathion	µg/L	<0.95	<0.95	<0.95	<0.95	<0.95	<0.95	0.065	0.013
Toxaphene	µg/L	<0.095	<0.096	<0.95	<0.95	<0.47	<0.48	0.73	0.0002

Table 3-7. Point of dredge background semi-volatile data. Chronic FCV values were taken from DiToro et al. (2000).

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**DNREC Acute**	**DNREC Chronic**	**FCV Chronic**
Lab Report ID		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2			
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011	12/29/2011	12/29/2011			
MSSEMI										
1,1'-Biphenyl	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
1,2,4-Trichlorobenzene	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
1,2-Dichlorobenzene	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
1,2-Diphenylhydrazine	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
1,3-Dichlorobenzene	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
1,4-Dichlorobenzene	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2,2'-oxybis[1-chloropropane]	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
2,4,5-Trichlorophenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2,4,6-Trichlorophenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2,4-Dichlorophenol	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
2,4-Dimethylphenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2,4-Dinitrophenol	µg/L	<4.8	<4.9	<4.9	<4.9	<4.8	<4.8			
2,4-Dinitrotoluene	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2,6-Dinitrotoluene	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2-Chloronaphthalene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
2-Chlorophenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2-Methylnaphthalene	µg/L	<0.19	<0.20	0.02	<0.19	<0.19	<0.19			121.03
2-Methylphenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
2-Nitroaniline	µg/L	<4.8	<4.9	<4.9	<4.9	<4.8	<4.8			
2-Nitrophenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
3,3'-Dichlorobenzidine	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
3-Nitroaniline	µg/L	<4.8	<4.9	<4.9	<4.9	<4.8	<4.8			
4,6-Dinitro-2-methylphenol	µg/L	<4.8	<4.9	<4.9	<4.9	<4.8	<4.8			
4-Bromophenyl phenyl ether	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
4-Chloro-3-methylphenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
4-Chloroaniline	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
4-Chlorophenyl phenyl ether	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
4-Nitroaniline	µg/L	<4.8	<4.9	<4.9	<4.9	<4.8	<4.8			

Table 3-7. (Continued)

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**DNREC Acute**	**DNREC Chronic**	**FCV Chronic**
Lab Report ID		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2			
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011	12/29/2011	12/29/2011			
MSSEMI										
4-Nitrophenol	µg/L	<4.8	<4.9	<4.9	<4.9	<4.8	<4.8			
Acenaphthene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			95.09
Acenaphthylene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			527.73
Acetophenone	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Anthracene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			35.56
Atrazine	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Benzaldehyde	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Benzidine	µg/L	<19	<20	<19	<19	<19	<19			
Benzo[a]anthracene	µg/L	0.026	<0.20	0.089	<0.19	<0.19	<0.19			3.79
Benzo[a]pyrene	µg/L	<0.19	<0.20	0.054	<0.19	<0.19	<0.19			1.59
Benzo[b]fluoranthene	µg/L	0.029	<0.20	0.1	<0.19	<0.19	<0.19			1.13
Benzo[g,h,i]perylene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
Benzo[k]fluoranthene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
Bis(2-chloroethoxy)methane	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Bis(2-chloroethyl)ether	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
Bis(2-ethylhexyl) phthalate	µg/L	<1.9	<2.0	<1.9	<1.9	<1.9	<1.9			
Butyl benzyl phthalate	µg/L	0.48	0.46	0.25	0.21	0.27	0.24			
Caprolactam	µg/L	<4.8	<4.9	<4.9	<4.9	<4.8	<4.8			
Carbazole	µg/L	<0.19	<0.20	0.025	<0.19	<0.19	<0.19			
Chrysene	µg/L	0.019	<0.20	0.067	<0.19	<0.19	<0.19			3.46
Dibenz(a,h)anthracene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			0.48
Dibenzofuran	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Diethyl phthalate	µg/L	0.18	0.15	<0.97	<0.97	<0.96	<0.96			
Dimethyl phthalate	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Di-n-butyl phthalate	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Di-n-octyl phthalate	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Fluoranthene	µg/L	0.041	0.032	0.14	<0.19	<0.19	0.041			12.19
Fluorene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			66.17
Hexachlorobenzene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			

Table 3-7. (Continued)

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**DNREC Acute**	**DNREC Chronic**	**FCV Chronic**
Lab Report ID		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2			
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011	12/29/2011	12/29/2011			
MSSEMI										
Hexachlorobutadiene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
Hexachlorocyclopentadiene	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Hexachloroethane	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Indeno[1,2,3-cd]pyrene	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
Isophorone	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Methylphenol, 3 & 4	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Naphthalene	µg/L	<0.19	<0.20	0.037	0.028	<0.19	<0.19			322.0
Nitrobenzene	µg/L	<1.9	<2.0	<1.9	<1.9	<1.9	<1.9			
N-Nitrosodimethylamine	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
N-Nitrosodi-n-propylamine	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
N-Nitrosodiphenylamine	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96			
Pentachlorophenol	µg/L	<0.96	<0.98	<0.97	<0.97	<0.96	<0.96	8.72	6.69	
Phenanthrene	µg/L	<0.19	<0.20	0.13	<0.19	<0.19	0.045			32.43
Phenol	µg/L	<0.19	<0.20	<0.19	<0.19	<0.19	<0.19			
Pyrene	µg/L	0.032	0.027	0.15	<0.19	<0.19	0.047			17.22

Table 3-8. Point of dredge background total inorganics data. Values highlighted in yellow are above DNREC acute criteria for protection of aquatic life.

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**DNREC Acute**	**DNREC Chronic**
Lab Report ID		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2		
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011	12/29/2011	12/29/2011		
MET									
Aluminum	µg/L	2100	1800	1600	1100	1900	2400	750	87
Antimony	µg/L	0.27	0.23	0.6	0.59	0.73	0.48		
Arsenic	µg/L	3.7	5	1.5	1.3	2	1.5	340	150
Barium	µg/L	39	36	37	31	43	48		
Beryllium	µg/L	0.13	0.12	0.15	0.11	0.13	0.2		
Cadmium	µg/L	<1.0	0.14	<1.0	<1.0	<1.0	0.16		
Calcium	µg/L	18000	18000	12000	12000	18000	18000		
Chromium	µg/L	9	8.5	5.8	4.2	7.6	7.5		
Cobalt	µg/L	1.7	1.3	1.8	1.3	1.7	2.2		
Copper	µg/L	12	11	5.9	4.4	6.1	7.5		
Cyanide, Total	µg/L	<10	<10	<10	<10	<10	<10	22	5.2
Iron	µg/L	3100	2500	3000	1900	3100	4100		
Lead	µg/L	5.3	4	5.4	3.5	5.4	7.5		
Magnesium	µg/L	6500	6600	4300	4000	6600	6900		
Manganese	µg/L	150	110	130	83	170	250		
Mercury	ng/L	12	5.6	8.5	14	13	13	1400	77
Nickel	µg/L	4	3.5	4	3.1	4.2	5.2		
Potassium	µg/L	3300	2800	2300	2200	2600	2600		
Selenium	µg/L	0.51	<5.0	0.52	0.76	1.1	1	20	5.0
Silver	µg/L	0.045	0.049	0.06	0.068	0.051	0.037		
Sodium	µg/L	17000	17000	9500	9500	14000	15000		
Thallium	µg/L	0.033	0.032	0.19	0.28	0.1	0.14		
Vanadium	µg/L	5.1	4.3	3.5	<1.0	3.8	5.1		
Zinc	µg/L	110	20	30	23	43	48		

Table 3-9. Point of dredge background dissolved inorganics data. Values highlighted in green are above DNREC chronic criteria for protection of aquatic life.

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**DNREC Acute**	**DNREC Chronic**
Lab Report ID		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2		
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011	12/29/2011	12/29/2011		
MET									
Aluminum-Diss	µg/L	6.7	5.1	69	13	7.3	5.3		
Antimony-Diss	µg/L	0.53	0.45	0.29	1.1	0.39	0.41		
Arsenic-Diss	µg/L	4.4	2.6	<1.0	<1.0	<1.0	<1.0	340	150
Barium-Diss	µg/L	25	24	23	21	26	25		
Beryllium-Diss	µg/L	0.037	<1.0	<1.0	<1.0	<1.0	<1.0		
Cadmium-Diss	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.30	0.18
Calcium-Diss	µg/L	19000	20000	15000	15000	17000	17000		
Chromium-Diss	µg/L	7.5	6.9	1.5	1.9	1.2	1.3	16	11
Cobalt-Diss	µg/L	0.16	0.13	0.14	0.08	0.1	0.064		
Copper-Diss	µg/L	5.8	6.6	2.6	2.8	1.5	1.3	8.81	6.11
Iron-Diss	µg/L	49	39	130	30	19	14		
Lead-Diss	µg/L	0.052	0.042	0.31	0.1	<1.0	<1.0	39.53	1.54
Magnesium-Diss	µg/L	6800	6800	4200	4100	6500	6500		
Manganese-Diss	µg/L	7.3	2.9	11	6.4	10	3.6		
Nickel-Diss	µg/L	1.7	1.4	1.3	1.1	1.1	0.89	320.57	35.61
Potassium-Diss	µg/L	2900	2700	1800	1800	2000	1900		
Selenium-Diss	µg/L	1.1	1.1	0.46	<5.0	<5.0	0.42		
Silver-Diss	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0	0.97	1.49	
Sodium-Diss	µg/L	19000	18000	11000	11000	15000	15000		
Thallium-Diss	µg/L	0.032	0.026	0.049	0.024	0.024	<1.0		
Vanadium-Diss	µg/L	0.99	0.42	1.5	2.2	0.12	<1.0		
Zinc-Diss	µg/L	6.4	6.5	4.7	4.6	5.9	7.2	80.18	80.83

Table 3-10. PCB homolog concentrations observed at the 11-m depth 200 feet down current of the working cutterhead sampled in Reach B during the 2011 monitoring

Sample ID		**C-11M (EVENT 1 ROUND1)**	**C-11M (EVENT 1 ROUND2)**	**C-11M (EVENT 3 ROUND 1)**	**C-11M (EVENT 3 ROUND 2)**	**DNREC Acute**	**DNREC Chronic**
Lab Report ID		180-6403-3	180-6403-4	180-6807-3	180-6807-4		
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011		
Monochlorobiphenyl	ng/L	<0.038	0.0072	0.0069	0.015		
Dichlorobiphenyl	ng/L	0.15	0.15	0.15	0.2		
Trichlorobiphenyl	ng/L	0.52	0.51	0.43	0.66		
Tetrachlorobiphenyl	ng/L	0.8	0.86	1.3	2		
Pentachlorobipheny	ng/L	0.91	1	1.5	2.1		
Hexachlorobiphenyl	ng/L	0.79	0.91	1.5	2.5		
Heptachlorobiphenyl	ng/L	0.39	0.47	0.7	1		
Octachlorobiphenyl	ng/L	0.15	0.21	0.23	0.31		
Nonachlorobiphenyl	ng/L	0.24	0.46	0.37	0.6		
Decachlorobiphenyl	ng/L	0.28	0.46	0.61	0.68		
Sum of PCB Congeners	ng/L	4.23	5.04	6.80	10.07		14

Table 3-11. PCB homolog concentrations observed at the 11-m depth at upriver and downriver background stations sampled in Reach B during the 2011 monitoring

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**DNREC Acute**	**DNREC Chronic**
Sample Date		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2		
Monochlorobiphenyl	ng/L	0.0056	0.0049	0.0083	0.0049	0.0066	0.0066		
Dichlorobiphenyl	ng/L	0.17	0.11	0.13	0.14	0.11	0.12		
Trichlorobiphenyl	ng/L	0.58	0.37	0.5	0.43	0.42	0.45		
Tetrachlorobiphenyl	ng/L	1	0.71	1.1	0.88	0.92	1.1		
Pentachlorobipheny	ng/L	1.2	0.88	1.3	1.1	1.2	1.5		
Hexachlorobiphenyl	ng/L	1	0.77	1.3	1.1	1.4	1.9		
Heptachlorobiphenyl	ng/L	0.51	0.39	0.57	0.54	0.67	0.77		
Octachlorobiphenyl	ng/L	0.2	0.15	0.23	0.15	0.29	0.26		
Nonachlorobiphenyl	ng/L	0.38	0.29	0.38	0.34	0.54	0.56		
Decachlorobiphenyl	ng/L	0.43	0.4	0.49	0.51	0.59	0.66		
Sum of PCB Congeners	ng/L	5.48	4.07	6.01	5.19	6.15	7.33		14

Table 3-12. Point of Dredge 11-m Dioxin and Furan homolog concentrations observed 200 feet down current of the working cutterhead sampled in Reach B during the 2011 monitoring

Sample ID		**C-11M (EVENT 1 ROUND1)**	**C-11M (EVENT 1 ROUND2)**	**C-11M (EVENT 3 ROUND 1)**	**C-11M (EVENT 3 ROUND 2)**
Lab Report ID		180-6403-3	180-6403-4	180-6807-3	180-6807-4
Sample Date		11/30/2011	11/30/2011	12/13/2011	12/13/2011
Total HpCDD	pg/L	14	13	56	45
Total HpCDF	pg/L	2.1	2.2	12	9.9
Total HxCDD	pg/L	<48	<48	12	13
Total HxCDF	pg/L	<48	<48	9.8	6.3
Total PeCDD	pg/L	<48	<48	1.5	<48
Total PeCDF	pg/L	<48	<48	8.8	5.1
Total TCDD	pg/L	<9.5	<9.5	2.3	4.1
Total TCDF	pg/L	<9.5	<9.5	14	7.4
OCDD	pg/L	150	150	770	540
OCDF	pg/L	3.8	4.4	9.4	7.4
Sum of Dioxin Homologs	pg/L	169.9	169.6	895.8	638.2
DIOXIN TEQs	pg/L	0.067	0.066	0.532	0.447
FURAN TEQs	pg/L	0.02138	0.02244	0.47694	0.15374

Table 3-13. Dioxin and Furan homolog concentrations observed at the 11-m depth at upriver and downriver background stations sampled in Reach B during the 2011 monitoring

Sample ID		**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**	**BGU-11M**	**BGD-11M**
Sample Date		180-6403-1	180-6403-2	180-6807-1	180-6807-2	180-7201-1	180-7201-2
Total HpCDD	pg/L	36	7.8	15	38	89	82
Total HpCDF	pg/L	9.9	< 48	4.2	9.3	19	14
Total HxCDD	pg/L	<48	< 48	3.8	8.9	11	16
Total HxCDF	pg/L	<48	< 48	1.8	5	18	16
Total PeCDD	pg/L	<48	< 48	0.6	<48	2.1	4.1
Total PeCDF	pg/L	<48	< 48	1.8	3.5	19	22
Total TCDD	pg/L	<9.5	< 9.5	2.1	2.7	1.2	1.4
Total TCDF	pg/L	<9.5	< 9.5	10	6.5	27	16
OCDD	pg/L	450	82	150	420	670	690
OCDF	pg/L	11	2.8	3.8	8.9	15	18
Sum of Dioxin Homologs	pg/L	506.9	92.6	193.1	502.8	871.3	879.5
DIOXIN TEQs	pg/L	0.195	0.0362	0.073	0.28	0.871	1.039
FURAN TEQs	pg/L	0.0651	0.00028	0.02538	0.28339	0.8605	0.863

3.3 CONTAMINANT LEVELS RELATIVE TO BACKGROUND

To evaluate whether the dredging activities elevated contaminant concentrations in the dredging area, the minimum, maximum, and average concentrations were calculated for all the 11-m samples taken at the Point of Dredge and compared to the concentrations reported for the background samples. Only parameters that were detected in both cutterhead plume and background samples were included in this comparison. The ratio of mean Point of Dredge concentration to mean background concentration was near or below 1.0 for all parameters. The results of this analysis suggest that concentrations behind the cutterhead were not dramatically altered relative to parameters measured in the background collections (Table 3-14, Figure 3-3).

Table 3-14. Comparison of the minimum, maximum, and average contaminant concentrations observed at the Point of Dredge samples relative to those recorded in the background samples taken near the dredge boat Charleston while working in Reach B during the 2011 monitoring. The final column represents the ratio of the average Point of Dredge concentration to the average background concentration. Ratios above 1.0 indicate Point of Dredge concentrations were higher than background. Ratios less than 1.0 indicate background concentrations were higher than Point of Dredge concentrations.

		Point of Dredge Min	**Point of Dredge Max**	**Ave Point of Dredge**	**Back-ground Min**	**Back-ground Max**	**Ave Back-ground**	**Ratio Dredge/ Back-ground**
GCSEMI								
2-Methylnaphthalene	µg/L	0.015	0.019	0.017	0.020	0.020	0.020	0.85
Benzo[a]anthracene	µg/L	0.023	0.062	0.040	0.026	0.089	0.058	0.69
Benzo[a]pyrene	µg/L	0.019	0.044	0.030	0.054	0.054	0.054	0.56
Benzo[b]fluoranthene	µg/L	0.023	0.074	0.044	0.029	0.100	0.065	0.69
Butyl benzyl phthalate	µg/L	0.200	0.560	0.378	0.210	0.480	0.318	1.19
Chrysene	µg/L	0.029	0.047	0.036	0.019	0.067	0.043	0.83
Diethyl phthalate	µg/L	0.170	0.190	0.180	0.150	0.180	0.165	1.09
Fluoranthene	µg/L	0.036	0.087	0.061	0.032	0.140	0.064	0.96
Naphthalene	µg/L	0.028	0.028	0.028	0.028	0.037	0.033	0.86
Phenanthrene	µg/L	0.049	0.071	0.062	0.045	0.130	0.088	0.70
Pyrene	µg/L	0.030	0.100	0.054	0.027	0.150	0.064	0.84
MET TOTAL								
Aluminum	µg/L	970.0	1900.0	1392.5	1100.0	2400.0	1816.7	0.77
Antimony	µg/L	0.21	1.10	0.53	0.23	0.73	0.48	1.09
Arsenic	µg/L	1.30	4.10	2.73	1.30	5.00	2.50	1.09
Barium	µg/L	31.00	38.00	34.00	31.00	48.00	39.00	0.87
Beryllium	µg/L	0.10	0.16	0.13	0.11	0.20	0.14	0.94
Chromium	µg/L	4.60	9.60	6.83	4.20	9.00	7.10	0.96
Cobalt	µg/L	0.85	1.60	1.31	1.30	2.20	1.67	0.79
Copper	µg/L	5.20	12.00	8.53	4.40	12.00	7.82	1.09
Iron	µg/L	1600.0	2900.0	2375.0	1900.0	4100.0	2950.0	0.81

Table 3-14. (Continued)

		Point of Dredge Min	**Point of Dredge Max**	**Ave Point of Dredge**	**Back-ground Min**	**Back-ground Max**	**Ave Back-ground**	**Ratio Dredge/ Back-ground**
MET TOTAL (Continued)								
Lead	µg/L	2.60	4.80	4.15	3.50	7.50	5.18	0.80
Mercury	ng/L	3.60	7.10	5.63	5.60	14.00	11.02	0.51
Nickel	µg/L	2.60	3.80	3.28	3.10	5.20	4.00	0.82
Selenium	µg/L	0.49	0.52	0.51	0.51	1.10	0.78	0.65
Silver	µg/L	0.04	0.04	0.04	0.04	0.07	0.05	0.76
Thallium	µg/L	0.02	0.06	0.04	0.03	0.28	0.13	0.28
Vanadium	µg/L	0.65	5.70	2.99	3.50	5.10	4.36	0.69
Zinc	µg/L	21.00	33.00	26.75	20.00	110.00	45.67	0.59
MET DISSOLVED								
Aluminum	µg/L	4.60	11.00	7.65	5.10	69.00	17.73	0.43
Antimony	µg/L	0.32	0.47	0.40	0.29	1.10	0.53	0.75
Arsenic	µg/L	0.36	6.80	4.02	2.60	4.40	3.50	1.15
Barium	µg/L	21.00	26.00	23.25	21.00	26.00	24.00	0.97
Beryllium	µg/L	0.04	0.04	0.04	0.04	0.04	0.04	1.11
Chromium	µg/L	1.60	7.80	4.55	1.20	7.50	3.38	1.34
Cobalt	µg/L	0.08	0.15	0.11	0.06	0.16	0.11	0.97
Copper	µg/L	2.20	7.60	4.83	1.30	6.60	3.43	1.41
Iron	µg/L	7.40	55.00	30.85	14.00	130.00	46.83	0.66
Lead	µg/L	0.04	0.08	0.06	0.04	0.31	0.13	0.47
Nickel	µg/L	0.98	1.40	1.20	0.89	1.70	1.25	0.96
Selenium	µg/L	1.10	1.20	1.15	0.42	1.10	0.77	1.49
Thallium	µg/L	0.02	0.02	0.02	0.02	0.05	0.03	0.54
Vanadium	µg/L	0.71	3.00	1.85	0.12	2.20	1.05	1.77
Zinc	µg/L	4.20	7.60	5.83	4.60	7.20	5.88	0.99
DOC	mg/L	3.30	4.30	3.70	2.70	3.40	3.15	1.17
POC	mg/L	1.20	3.20	2.45	0.63	3.00	1.87	1.31
PCBs, DIOXIN AND FURANS								
Sum of PCB congeners	ng/L	4.23	10.7	6.53	4.07	7.33	5.71	1.14
Sum of Dioxin and Furan Homologs	pg/L	169.60	895.80	468.37	92.60	879.5	507.7	0.92

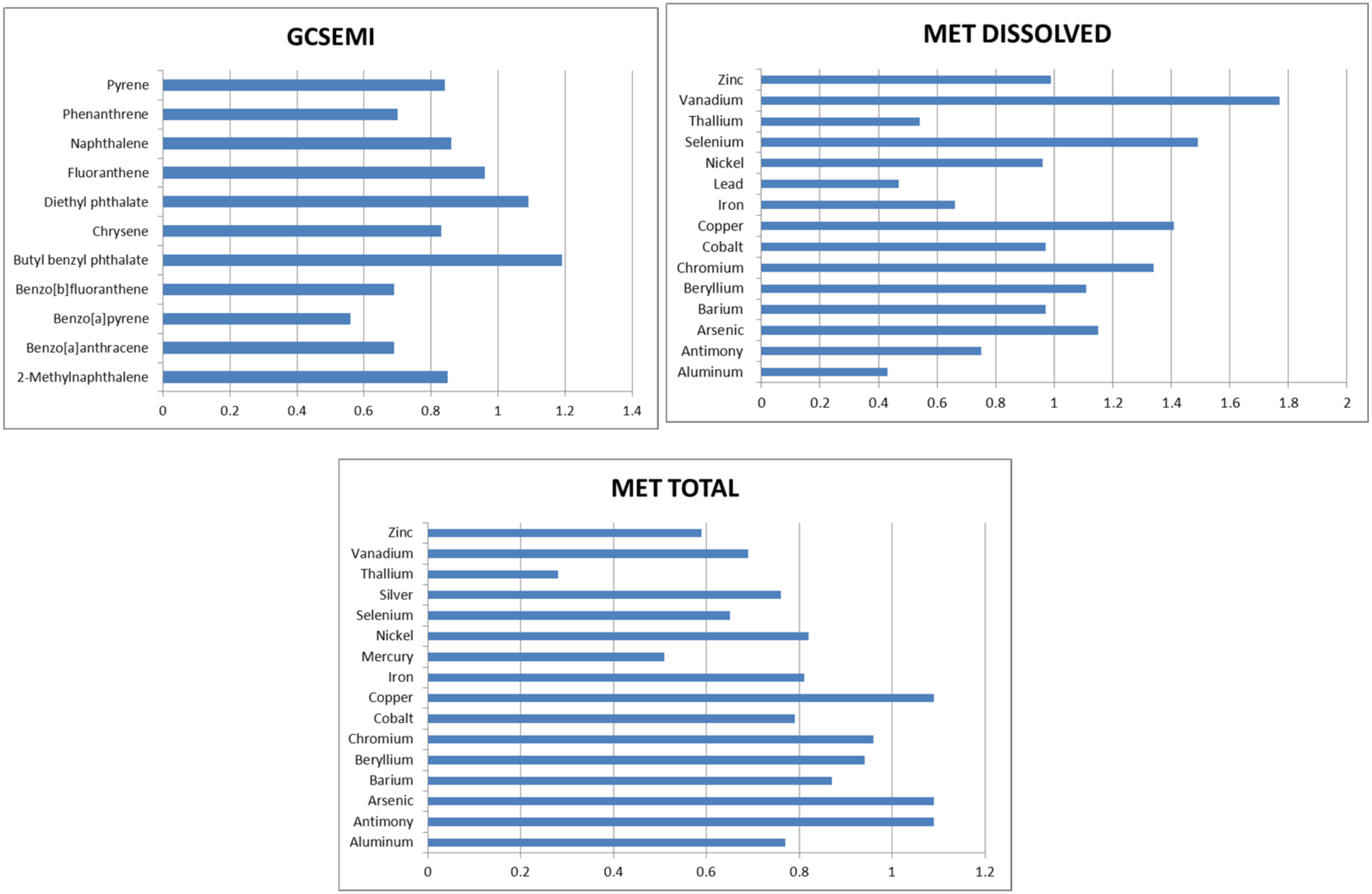


Figure 3-3. Ratios of average point of dredge concentrations versus average background concentrations. Ratio less than 1.0 indicate point of dredge concentrations were lower than background

4.0 POINT OF DREDGE MONITORING DISCUSSION

4.1 INORGANICS

Table 4-1 summarizes the exceedance frequencies for the 11-m depth samples and background samples. Aluminum concentrations were over the DNREC acute criterion in all samples including background but this criterion is dated and does not properly account for the effect of pH on solubility and toxicity according to Greene (2010, see Section 6.2). Dissolved copper was over the chronic criterion in two of the four 11-m Point of Dredge samples and one out of 6 background samples.

Table 4-1. Summary of water quality exceedances observed during the Reach B Point of Dredge Monitoring program.

	11-m			**Background (11-m)**		
	N	**> Acute**	**> Chronic**	**N**	**> Acute**	**> Chronic**
Aluminum	4	4		6	6	
Copper - Dissolved	4		2	6		1

Analysis of mean inorganic concentrations in the 11-m Point of Dredge collections relative to mean background levels indicated that the action of the cutterhead did not alter down-current concentrations in the water column. Forty-five comparisons of total and dissolved Point of Dredge concentrations versus background concentrations resulted in plume/background ratios near 1.0 suggesting little if any change in concentration behind the working cutterhead occurred (see Table 3-14). Given that the TSS monitoring behind the working dredge indicated that the cutterhead did not create large turbidity plumes (Figure 3-2), it can be concluded that most of the dredged material was entrained into the hydraulic pipeline and not released to the water column at the point of dredging, a key finding of this work. Nearly identical results were reported for the 2010 Reach C Deepening environmental monitoring.

4.2 PESTICIDES

Among the 31 pesticides and PCB Aroclors included in the Point of Dredge and background sampling none were detected suggesting that pesticides were not mobilized to the water column during the Reach B deepening. DDT and its breakdown products DDE and DDD were occasionally measured in concentrations slightly over chronic criteria during the Reach C study (Burton and Pasquale 2011), but a similar frequency of exceedances was observed in background samples. For the Reach C monitoring effort most of the pesticides and PCB Aroclors were undetected in point of dredge and background samples. Endosulfan II was detected in 1 out of 4 point of dredge samples while Aroclor 1254 was observed in 1 out of 6 background samples.

4.3 PCBs/DIOXINS AND FURANS

High resolution PCBs, Dioxin and Furan testing was conducted on all four 11-m plume and all six background samples. No sample had a sum of congeners over DNREC's chronic criterion for protection of aquatic life. All Point of Dredge and background samples were above DNREC's human health water quality criterion (0.064 ng/L) for PCBs. While there are no direct water quality criteria established for protection of aquatic life for dioxins and furans in the Delaware River, the sum of homologs suggests Point of Dredge concentrations were in a similar range to those observed in the background samples (Tables 3-12 and 3-13). DNREC does have a human health criterion for Dioxins and Furans expressed as 2,3,7,8-TCDD TEQ (0.0051 pg/L). The toxic equivalence for a sample is the sum of the concentration for specific congeners multiplied by its associated Toxicity Equivalence Factor (TEF). A listing of these TEFs is presented on page 31 of DNREC's surface water standards as amended on July 11, 2004 (Appendix C). The resulting TEQ's ranged from 0.00028 to 1.039 pg/L for all 11-m plume and 11-m background samples. Both plume and background samples were typically over the 0.0051 pg/L human health TEQ for Dioxins and Furans. PCBs, Dioxins and Furans were detected in all point of dredge and background samples.

4.4 PAHs

Most of the organic compounds were not detected in the plume and background samples. For the 11 parameters that were detected, mean concentrations in the plume were the same or lower than background based on the plume/background ratio analysis presented in Table 3-14. Although DNREC does not have aquatic life criteria for PAHs, criteria are available in the peer reviewed literature (DiToro et al. 2000). None of the detected concentrations exceed those criteria. Among the 72 semi-volatile compounds assessed only 13 were detected in similar frequencies between point of dredge and background samples. The 13 detected compounds included: 2-Methylnaphthalene, Benzo[a]anthracene, Benzo[a]pyrene, Benzo[b]fluoranthene, Butyl benzyl phthalate, Carbazole, Chrysene, Diethyl phthalate, Fluoranthene, Fluorene, Naphalene, Phenanthrene, and Pyrene.

5.0 CONFINED DISPOSAL FACILITY MONITORING

5.1 CDF MONITORING FIELD METHODS

The weir discharge from the Pedricktown South CDF was sampled using an ISCO® automatic sampler to obtain daily TSS samples throughout the discharge period. The sampler consists of a peristaltic pump, controlled by a computer, which allows for collecting fixed amounts of water into sample containers over a period of time. The samples were collected through Teflon tubing that was suspended next to the weir structure in the CDF. The sample routine for this project was designed to collect water at 6-hour intervals. Sample jars for TSS were filled over the course of 3-4 days. Daily samples of TSS were analyzed separately. All other samples were taken as grab samples by running the automatic sampler on manual and filling each parameter's respective collection jar. Background samples were collected in the river as part of the Point of Dredge collections (see Section 2.0).

Given the high-pressure flow out of the influent pipe, a grab sample of the sediment slurry (influent) was taken using a swing-arm sampler with individual sample containers fixed onto one end. The sample container was lowered into the influent flow, at the point where the dredged material was falling into the accumulated dredged material in the CDF. This is an area of rapid mixing, which allowed for sampling the influent as close to the hydraulic pipeline discharge point as possible. In the laboratory the influent sample was allowed to settle and only the sediment portion was extracted for chemical testing. Table 5-1 summarizes the sampling dates and number of samples collected at each site during the monitoring period.

Table 5-1. Summary of sampling dates by location for the Pedricktown South CDF monitoring conducted during the deepening of Reach B in the Delaware River in 2011/2012

Sample Site	Sample Dates	N
Weir	11/18 11/21 11/28 12/1 12/5 12/8 12/12 12/14 12/20 12/22 12/28 12/29 1/3/2012	13
Inlet	11/18 12/12 12/20 12/29	4

5.2 CDF MONITORING LABORATORY METHODS

Samples were packed with ice in coolers and shipped the same day via over-night mail to the TestAmerica environmental analytical laboratory in Pittsburgh, PA. This laboratory is accredited by the National Environmental Laboratory Accreditation Conference (NELAC) for analysis of non-potable water and solids. NELAC is a cooperative association of States and Federal agencies, formed to establish and promote mutually acceptable national performance standards for the operation of environmental laboratories. The standards cover both analytical testing of environmental samples and the laboratory accreditation process. The goal of NELAC is to foster the generation of environmental laboratory data of known and acceptable quality on which to base public health and environmental management decisions. TestAmerica's NELAC accreditation documents that the laboratory adheres to all NELAC quality assurance requirements. Specific requirements vary between analytical methods, but in general include the analysis of method blanks, laboratory control samples (LCS), matrix spikes (MS) and matrix spike duplicates (MSD). Specific criteria for each analytical method are documented in method-specific standard operating procedures (SOPs) maintained by each laboratory, and may include calibration linearity requirements, initial and continuing calibration verifications, calibration blanks, and instrument tuning requirements. Details on the QA/QC results are included in the certificates of analyses presented in Appendix D.

Table 5-2 summarizes the analytical methods used for each parameter category. Bulk sediment results were all reported on a dry weight basis. All samples were appropriately labeled upon collection, shipped and stored at 4 ºC until analysis. All samples were processed within required hold times unless flagged in the certificate of analysis. Contaminant data were submitted in MS Excel spreadsheets for data analysis and reporting purposes. Copies of the laboratory certificates are included in Appendix D.

Table 5-2. List of parameter specific laboratory methods used for the monitoring program

Parameter	Analytical Method	Preparation Method
Inorganics		
ICP-MS (6020)	SW846 6020	SW846 3005A
ICP-MS (6020)	SW846 6020	SW846 3010
ICP-MS (6020)	SW846 6020	SW846 3050B
Mercury, Low Level Mercury, CVA Fluorescence	CFR136A 1631E	EPA 1631
Cyanide, Total	SW846 9012A	SW846 9012A
Pesticides		
Organochlorine Pesticides SW846 8081A Low Level	SW846 8081A LOW	
Organophosphorous Compounds by GC	SW846 8141A	SW846 3510
Organophosphorous Compounds by GC	SW846 8141A	SW846 3541
Organics		
Semivolatile Organics GCMS BNA 8270C	SW846 8270C	
Particulates		
Total Residue as Percent Solids	SM20 2540G	
Total Suspended Solids SM 2540 D	SM20 2540D	SM20 2540D
Dissolved Organic Carbon 5310B	SM20 5310B	
POC Method 440.0 440.0	EPA 440.0	
PCBs/Dioxins		
PCBs by SW-846 8082 PCBs (8082) Low Level	SW846 8082 Low	SW846 3541
PCB Screen	KNOX PCB Screen	
PCBs, HRGC/HRMS	EPA-22 1668A	
Dioxins/Furans, HRGC/HRMS	EPA-5 1613B	EPA-5 1613

5.3 CDF MONITORING DATA ASSESSMENT METHODS

Potential environmental impact of the CDF discharge was evaluated using a number of different approaches including comparisons to DNREC's freshwater protection of aquatic life and human health water quality criteria after proper consideration of instream mixing and fate processes, estimating the mass balance of contaminants removed by the dredging to loadings released at the discharge weir, and statistical analyses to determine if concentrations were increased at the weir relative to background levels. Several of DNREC's water quality criteria are hardness-based and as such mean background hardness (63.9 mg/L) observed in the Point of Dredge background samples was used to calculate water quality criteria for those parameters. Freshwater aquatic life criteria were used, as measured salinity over the dredging period was consistently below 5.0 PPT.

DRBC acute aquatic life criteria apply in receiving waters after proper consideration of mixing, fate processes, and other factors (e.g., salinity). With regard to mixing, current regulations and standard practice in DE, NJ, and the DRBC allow for near-field mixing of discharges and receiving waters prior to acute criteria compliance. Specifically, section 4.20.5 A.1 of the DRBC's Water Quality Regulations (DRBC, 2010) allows for near-field mixing zones where acute aquatic life criteria can be exceeded. The DRBC's chronic aquatic life criteria and human health water quality criteria apply under complete mix conditions as specified in section 4.20.5.A.4 of the DRBC Water Quality Regulations (far-field mixing). In applying the complete mix assumption, different Estuary net advective 'design flows' are used for chronic aquatic life criteria and human health criteria. For chronic aquatic life criteria, a combination of 7Q10 for all tributaries plus 2500 cfs at the Delaware River at Trenton is used (section 4.30.7.B.2). Similarly, the harmonic mean flow is used for human health criteria for carcinogens and a 30Q5 flow is used for human health criteria for systemic toxicants (section 4.30.7.B.2). Both the near-field and far-field analyses factor in mean background concentrations measured during the monitoring program. Data and analyses for this assessment are provided in Appendix D.

6.0 CONFINED DISPOSAL FACILITY MONITORING RESULTS

6.1 CDF EFFLUENT CHARACTERIZATION

Tables 6-1 through 6-4 summarize the concentrations observed for pesticides, total inorganics, dissolved inorganics, and semi-volatile organics, for all 13 weir samples, respectively. The tables present mean, minimum, and maximum observed concentrations. High resolution PCB, Dioxin and Furan analyses were conducted on four of the weir samples. The sum of PCB homologs ranged from 35.1 ng/L to 158.9 ng/L in the weir samples while Dioxin and Furan TEQ's ranged from 0.99 to 8.53 pg/L for all samples (Table 6-5).

Table 6-1. Concentrations (µg/L) of pesticides observed among the weir samples at the 2011 Pedricktown South CDF monitoring project

	N	# of Detections	Mean	Stderr	Min	Max	DNREC Acute	DNREC Chronic
4,4'-DDD	13	0	0.000	0.000	0	0	1.1	0.001
4,4'-DDE	13	0	0.000	0.000	0	0	1.1	0.001
4,4'-DDT	13	0	0.000	0.000	0	0	1.1	0.001
Aldrin	13	0	0.000	0.000	0	0	3.0	none
alpha-BHC	13	0	0.000	0.000	0	0		
alpha-Chlordane	13	0	0.000	0.000	0	0		
Aroclor1016	13	0	0.000	0.000	0	0	none	0.014
Aroclor1221	13	0	0.000	0.000	0	0	none	0.014
Aroclor1232	13	0	0.000	0.000	0	0	none	0.014
Aroclor1242	13	0	0.000	0.000	0	0	none	0.014
Aroclor1248	13	3	0.007	0.014	0	0.037	none	0.014
Aroclor1254	13	2	0.004	0.010	0	0.028	none	0.014
Aroclor1260	13	2	0.003	0.008	0	0.025		
beta-BHC	13	1	0.0005	0.002	0	0.0063		
Chlordane (technical)	13	0	0.000	0.000	0	0	2.4	0.0043
Chlorpyrifos	13	0	0.000	0.000	0	0	0.083	0.041
delta-BHC	13	1	0.0003	0.001	0	0.0039		
Dieldrin	13	0	0.000	0.000	0	0	0.24	0.056
Endosulfan I	13	0	0.000	0.000	0	0	0.22	0.056
Endosulfan II	13	0	0.000	0.000	0	0	0.22	0.056
Endosulfan sulfate	13	0	0.000	0.000	0	0		
Endrin	13	0	0.000	0.000	0	0	0.086	0.036
Endrin aldehyde	13	0	0.000	0.000	0	0		
Endrin ketone	13	0	0.000	0.000	0	0		
gamma-BHC (Lindane)	13	0	0.000	0.000	0	0	none	none
gamma-Chlordane	13	0	0.000	0.000	0	0		
Heptachlor	13	1	0.001	0.002	0	0.0072	0.52	0.0038

Table 6-1. (Continued)

	N	**# of Detections**	**Mean**	**Stderr**	**Min**	**Max**	**DNREC Acute**	**DNREC Chronic**
Heptachlor epoxide	13	0	0.000	0.000	0	0		
Methoxychlor	13	0	0.000	0.000	0	0	none	0.03
Parathion	13	0	0.000	0.000	0	0	0.065	0.013
Toxaphene	13	0	0.000	0.000	0	0	0.73	0.0002

Table 6-2. Concentrations (µg/L) of total inorganics observed among the weir samples at the 2011 Pedricktown South CDF monitoring

	N	**# of Detections**	**Mean**	**Stderr**	**Min**	**Max**	**DNREC Acute**	**DNREC Chronic**
Aluminum	13	13	11307.692	5142.869	6400	19000	750	87
Antimony	13	13	1.039	0.321	0.69	1.6		
Arsenic	13	13	9.408	5.512	6.1	26	340	150
Barium	13	13	114.077	27.569	89	170		
Beryllium	13	13	0.531	0.230	0.26	0.91		
Cadmium	13	9	0.137	0.104	0	0.31		
Calcium	13	13	26923.077	3353.146	21000	34000		
Chromium	13	13	28.462	13.709	15	52		
Cobalt	13	13	5.992	1.635	4	9.2		
Copper	13	13	17.538	6.851	11	33		
Cyanide	13	13	0	0	0	0	22	5.2
Iron	13	13	11238.462	4555.681	6500	20000		
Lead	13	13	23.231	14.601	11	52		
Magnesium	13	13	23538.462	5043.401	18000	34000		
Manganese	13	13	1433.846	488.203	830	2500		
Mercury (ng/L)	13	13	50.615	34.150	17	110	1400	77
Nickel	13	13	13.662	3.852	8.9	21		
Potassium	13	13	10707.692	2094.223	8500	15000		
Selenium	13	11	1.337	0.911	0	2.8	20	5.0
Silver	13	13	0.160	0.106	0.069	0.38		
Sodium	13	13	47000.000	10946.841	32000	63000		
Thallium	13	13	0.148	0.072	0.051	0.29		
Vanadium	13	13	23.385	11.493	11	45		
Zinc	13	13	81.769	28.729	53	140		

Table 6-3. Concentrations (µg/L) of dissolved inorganics observed among the weir samples at the 2011 Pedricktown South CDF monitoring

	N	**# of Detections**	**Mean**	**Stderr**	**Min**	**Max**	**DNREC Acute**	**DNREC Chronic**
Aluminum	13	13	208.292	573.121	4.3	2100		
Antimony	13	13	1.086	0.420	0.51	2.1		
Arsenic	13	13	2.938	2.173	0.79	8.6	340	150
Barium	13	13	48.692	6.848	37	58		
Beryllium	13	2	0.017	0.048	0	0.17		
Cadmium	13	0	0.000	0.000	0	0	1.30	0.18
Calcium	13	13	26923.077	2985.005	22000	31000		
Chromium	13	13	2.792	1.823	1.4	8.1	16	11
Cobalt	13	13	1.342	0.377	0.85	2		
Copper	13	13	5.592	1.363	3.7	7.9	8.81	6.11
Iron	13	13	297.169	846.119	9.2	3100		
Lead	13	10	0.771	2.128	0	7.8	39.53	1.54
Magnesium	13	13	24461.538	6971.554	14000	34000		
Manganese	13	13	1137.692	461.684	500	1800		
Nickel	13	13	4.562	0.840	3.6	6.1	320.57	35.61
Potassium	13	13	9538.462	1795.150	7100	14000		
Selenium	13	11	1.157	0.806	0	3.2		
Silver	13	2	0.009	0.021	0	0.061	1.49	
Sodium	13	13	51538.462	11913.685	37000	69000		
Thallium	13	10	0.054	0.038	0	0.12		
Vanadium	13	13	3.964	3.934	0.4	11		
Zinc	13	13	9.638	6.992	4.5	32	80.18	80.83

Table 6-4. Concentrations (µg/L) of semi-volatiles observed among the weir samples at the 2011 Pedricktown South CDF monitoring. Chronic FCV values were taken from DiToro et al. (2000).

	N	# of Detections	Mean	Stderr	Min	Max	DNREC Acute	DNREC Chronic	FCV Chronic
1,1'-Biphenyl	13	1	0.005	0.019	0	0.069			
1,2,4-Trichlorobenzene	13	0	0.000	0.000	0	0			
1,2-Dichlorobenzene	13	0	0.000	0.000	0	0			
1,2-Diphenylhydrazine	13	1	0.006	0.023	0	0.082			
1,3-Dichlorobenzene	13	0	0.000	0.000	0	0			
1,4-Dichlorobenzene	13	0	0.000	0.000	0	0			
2,2'-oxybis[1-chloropropane]	13	0	0.000	0.000	0	0			
2,4,5-Trichlorophenol	13	1	0.012	0.042	0	0.15			
2,4,6-Trichlorophenol	13	0	0.000	0.000	0	0			
2,4-Dichlorophenol	13	0	0.000	0.000	0	0			
2,4-Dimethylphenol	13	0	0.000	0.000	0	0			
2,4-Dinitrophenol	13	0	0.000	0.000	0	0			
2,4-Dinitrotoluene	13	0	0.000	0.000	0	0			
2,6-Dinitrotoluene	13	0	0.000	0.000	0	0			
2-Chloronaphthalene	13	0	0.000	0.000	0	0			
2-Chlorophenol	13	0	0.000	0.000	0	0			
2-Methylnaphthalene	13	9	0.025	0.023	0	0.071			121.03
2-Methylphenol	13	0	0.000	0.000	0	0			
2-Nitroaniline	13	0	0.000	0.000	0	0			
2-Nitrophenol	13	0	0.000	0.000	0	0			
3,3'-Dichlorobenzidine	13	0	0.000	0.000	0	0			
3-Nitroaniline	13	0	0.000	0.000	0	0			
4,6-Dinitro-2-methylphenol	13	0	0.000	0.000	0	0			
4-Bromophenyl phenyl ether	13	0	0.000	0.000	0	0			
4-Chloro-3-methylphenol	13	0	0.000	0.000	0	0			
4-Chloroaniline	13	1	0.008	0.031	0	0.11			
4-Chlorophenyl phenyl ether	13	0	0.000	0.000	0	0			

Table 6-4. (Continued)

	N	# of Detections	Mean	Stderr	Min	Max	DNREC Acute	DNREC Chronic	FCV Chronic
4-Nitroaniline	13	0	0.000	0.000	0	0			
4-Nitrophenol	13	0	0.000	0.000	0	0			
Acenaphthene	13	1	0.006	0.022	0	0.079			95.09
Acenaphthylene	13	1	0.004	0.016	0	0.056			527.73
Acetophenone	13	0	0.000	0.000	0	0			
Anthracene	13	0	0.000	0.000	0	0			35.56
Atrazine	13	0	0.000	0.000	0	0			
Benzaldehyde	13	11	0.391	0.376	0	1.1			
Benzidine	13	0	0.000	0.000	0	0			
Benzo[a]anthracene	13	3	0.018	0.052	0	0.19			3.79
Benzo[a]pyrene	13	1	0.011	0.039	0	0.14			1.59
Benzo[b]fluoranthene	13	2	0.015	0.047	0	0.17			1.13
Benzo[g,h,i]perylene	13	2	0.011	0.033	0	0.12			
Benzo[k]fluoranthene	13	1	0.008	0.028	0	0.1			
Bis(2-chloroethoxy)methane	13	0	0.000	0.000	0	0			
Bis(2-chloroethyl)ether	13	0	0.000	0.000	0	0			
Bis(2-ethylhexyl) phthalate	13	0	0.000	0.000	0	0			
Butyl benzyl phthalate	13	12	0.245	0.106	0	0.43			
Caprolactam	13	0	0.000	0.000	0	0			
Carbazole	13	3	0.007	0.016	0	0.052			
Chrysene	13	2	0.014	0.042	0	0.15			3.46
Dibenz(a,h)anthracene	13	1	0.005	0.017	0	0.061			0.48
Dibenzofuran	13	1	0.005	0.019	0	0.069			
Diethyl phthalate	13	5	0.083	0.119	0	0.34			
Dimethyl phthalate	13	0	0.000	0.000	0	0			
Di-n-butyl phthalate	13	1	0.123	0.444	0	1.6			
Di-n-octyl phthalate	13	0	0.000	0.000	0	0			
Fluoranthene	13	8	0.042	0.080	0	0.3			12.19
Fluorene	13	5	0.017	0.028	0	0.095			66.17
Hexachlorobenzene	13	0	0.000	0.000	0	0			

Table 6-4. (Continued)

	N	# of Detections	Mean	Stderr	Min	Max	DNREC Acute	DNREC Chronic	FCV Chronic
Hexachlorobutadiene	13	0	0.000	0.000	0	0			
Hexachlorocyclopentadiene	13	0	0.000	0.000	0	0			
Hexachloroethane	13	0	0.000	0.000	0	0			
Indeno[1,2,3-cd]pyrene	13	2	0.010	0.031	0	0.11			
Isophorone	13	2	0.015	0.037	0	0.11			
Methylphenol, 3 & 4	13	1	0.007	0.025	0	0.091			
Naphthalene	13	10	0.051	0.040	0	0.13			322.0
Nitrobenzene	13	0	0.000	0.000	0	0			
N-Nitrosodimethylamine	13	0	0.000	0.000	0	0			
N-Nitrosodi-n-propylamine	13	0	0.000	0.000	0	0			
N-Nitrosodiphenylamine	13	0	0.000	0.000	0	0			
Pentachlorophenol	13	0	0.000	0.000	0	0	8.72	6.69	
Phenanthrene	13	8	0.050	0.054	0	0.18			32.43
Phenol	13	0	0.000	0.000	0	0			
Pyrene	13	9	0.043	0.076	0	0.29			17.22

Table 6-5. Results of high resolution PCB, Dioxin, and Furan tests for weir samples collected during the 2011 monitoring at the Pedricktown South CDF

Boring ID:		**WIER1118**	**WIER1205**	**WIER1220**	**WIER1228**
Sample Date:		**11/18/2011**	**12/05/2011**	**12/20/2011**	**12/28/2011**
Monochlorobiphenyl (total)	ng/L	0.16	0.029	0.061	0.043
Dichlorobiphenyl (total)	ng/L	1.6	0.33	0.62	0.42
Trichlorobiphenyl (total)	ng/L	6.7	0.88	2.5	1.5
Tetrachlorobiphenyl (total)	ng/L	28	3.7	13	5.5
Pentachlorobiphenyl (total)	ng/L	32	4.8	7.1	5.1
Hexachlorobiphenyl (total)	ng/L	23	6	10	7.4
Heptachlorobiphenyl (total)	ng/L	11	2.5	5.4	3
Octachlorobiphenyl (total)	ng/L	7.4	1.5	2.1	1.5
Nonachlorobiphenyl (total)	ng/L	21	4.4	5.9	4.6
Decachlorobiphenyl (total)	ng/L	28	5.6	8.1	6
Sum of PCB Congeners	ng/L	158.86	29.739	54.781	35.063
Total HpCDD	pg/L	770	230	570	430
Total HpCDF	pg/L	210	46	120	85
Total HxCDD	pg/L	170	42	130	110
Total HxCDF	pg/L	92	19	54	41
Total PeCDD	pg/L	26	<48	19	16
Total PeCDF	pg/L	87	6.7	45	34
Total TCDD	pg/L	15	4.9	13	11
Total TCDF	pg/L	120	14	54	51
OCDD	pg/L	7900	2400	5400	4100
OCDF	pg/L	300	47	150	89
Sum of Dioxin and Furan Homologs	pg/L	9690	2809.6	6555	4967
DIOXIN TEQs	pg/L	8.53	1.29	7.25	5.46
FURAN TEQs	pg/L	7.205	0.9947	5.26	3.3589

6.2 NEAR-FIELD CORMIX EVALUATION OF CDF MONITORING RESULTS

Mean concentrations of total aluminum in the weir samples were all over the DNREC acute criterion of 750 µg/L. According to Greene (2010), the aluminum criterion is dated and fails to properly account for the effect of pH on solubility and toxicity. Greene (2010) conducted geochemical speciation modeling that indicated for the range of pH values observed in the Delaware Estuary, the majority of the aluminum exists in the solid, non-toxic form. Greene's analysis suggested that only 4% of the total aluminum observed in the estuary exists in the toxic form of the metal. As such, the detected concentrations of total aluminum discharged from the Pedricktown South CDF are not considered detrimental to aquatic life in the Delaware River system and near and far field evaluations were not conducted for aluminum. Evidence that existing aluminum concentrations are not detrimental to aquatic life comes from the results of ambient chronic bioassays performed on surface water samples by the DRBC and others over the period 2005 to 2009 (MacGillivray et. al. 2011). That work revealed no chronic toxicity to multiple test species in the tidal Delaware River despite concentrations of total aluminum consistently above the aquatic life criterion.

No weir sample concentrations of pesticides, inorganics, or semi-volatile organic parameters were above DNREC acute aquatic life criteria. From a regulatory perspective, acute water quality criteria for the protection of aquatic life must be met at the edge of the zone of initial dilution (ZID). Based on DNREC's mixing zone guidelines, the ZID distance is defined as five times the local water depth or 50 times the discharge length scale, whichever is smaller. In this part of the Delaware Estuary the tidal range is six feet. For the Deepening of Reach B the Pedricktown South discharge pipes were reconfigured to extend out from the river bank to deeper sub-tidal water to improve mixing and avoid shore hugging plumes. If a near field evaluation was needed (i.e., any contaminant concentration was over acute criteria) an average water depth of twenty feet would be selected making the edge of the ZID 100 feet. For informational purposes the expected amount of dilution of the discharge at the edge of the ZID CORMIX mixing zone model results from a similar CDF study at Chesapeake City (Schreiner et al. 2000) are provided in Table 6-3. These analyses were performed for a CDF with a similar discharge configuration into a deep tidal area and represent a reasonable estimate of initial mixing that would be expected to occur at the Pedricktown South CDF. Results of that study predicted that at 100 feet from the discharge point the dilution factor would be about 20 percent during tidal flow.

Table 6-6. Estimated dilution rates of Pedricktown South deep water discharge using Chesapeake City CDF dilution factors.

Flood Tide								
Distance from pipe (m)	0	2	4.2	5	10	25	50	100
% original plume	100	39.50	36.56	31.62	24.72	20.16	18.31	17.64
Ebb Tide								
Distance from pipe (m)	0	2	4.2	5	10	25	50	100
% original plume	100	50.76	51.27	39.97	31.42	22.56	22.90	22.82

6.3 FAR-FIELD EVALUATION OF CDF MONITORING RESULTS

Chronic water quality criteria for the protection of aquatic life apply after consideration of complete mixing in the water body. Chronic criteria were evaluated with a far-field assessment. Sample concentrations of several parameters were above their respective chronic criteria in a few weir samples. Again, chronic criteria do not apply in the weir discharge. For these parameters the mass balance loadings (see Section 6.8) were mixed with a river flow volume equivalent to 56 days of the net 7Q10 discharge flows for a section of the Delaware River near the Pedricktown South CDF. The 7Q10 is the 7-day, 10-year low flow past a particular location across a body of water. In the present case it's the 7-day low flow with a 10-year recurrence interval based on 90 + years of flow monitoring in the Delaware River (132.64 m^3/sec or 80,220,672 m^3 for 1 week). Using the background concentrations observed during the Point of Dredge monitoring period, the discharge loads for 1.5 months from the CDF weir was added to the 7Q10 flow over a 56 day period to estimate far field concentrations. CDF loadings did not change background concentrations of any parameter due to the high amount of far-field dilution and relatively low loadings discharging from the weir (Table 6-7). As such, chronic water quality criteria for the protection of aquatic life were met during the monitoring period.

Consideration of DNREC human health criteria also requires a far-field evaluation. Human health criteria include systemic toxicants and human carcinogens. DNREC (2004) defines a systemic toxicant as a toxic substance that has the ability to cause effects within the body at sites distant from the entry point due to its absorption and distribution. DNREC defines a carcinogen as a substance that increases the risk of benign or malignant neoplasms (tumors) in humans or other animals. In accordance with DNREC section 4.6.3.3.2.1 the Delaware River is not State designated as a Public Water Supply Source. Therefore only the "Fish Ingestion" criteria in Table 2 of DNREC (2004) section 4.6.3.3.2.1 apply. The "Fish and Water Ingestion" criteria do not apply.

Human health criteria also apply after consideration of complete mixing in the water body. Sample concentrations of several parameters were above their respective human health criteria in a few weir samples. For these parameters the mass balance loadings (see Section 6.8) were mixed with a river flow volume equivalent to 56 days of the net mean harmonic discharge flows for a section of the Delaware River near the Pedricktown South CDF, based on 90 + years of flow monitoring in the Delaware River (283.67 m^3/sec or 171,563,616 m^3 for 1 week). Using the background concentrations observed during the Point of Dredge sampling, the discharge loads for 1.5 months from the CDF weir were added to the net mean harmonic flow over a 56 day period to estimate far-field concentrations. CDF loadings essentially did not change background concentrations of any parameter due to the high amount of far-field dilution and relatively low loadings discharging from the weir (Table 6-7). As such, the weir discharge did not cause any human health water quality criteria to be exceeded after complete mixing.

6.4 POLYAROMATIC HYDROCARBON TOXICITY

Polyaromatic Hydrocarbons (PAHs) were detected in the weir and background samples. PAHs are of interest in the Delaware Estuary due to the large presence of petro-chemical refineries, heavy industry, and past oil spills. Studies in the estuary have routinely detected PAHs in channel sediments. Although DNREC does not have aquatic life criteria for PAHs, criteria are available in the peer reviewed literature (DiToro et al. 2000). None of the detected concentrations exceed those criteria (Table 6-4).

Table 6-7. Results of far field analysis using 7Q10 and mean harmonic flow for weir parameters with at least one observation over chronic or human health criteria for carcinogens. Dioxins and Furans are included for informational purposes.

Analyte	**Unit**	**Ave Weir Concentration**	**Total kg Discharged from Weir in 1.5 Months**	**Average Background Concentration**	**Concentration Resulting from Weir Discharge Using 7Q10 Flow for 56 Days**	**Concentration Resulting from Weir Discharge Using Mean Harmonic Flow for 56 Days**	**DNREC Freshwater Chronic Aquatic Life Criteria µg/L**	**Lowest DNREC Human Health Criteria µg/L**
Benzo[a]anthracene	µg/L	0.018	0.057	0.019	0.0191	0.0190	NA	0.18
Benzo[a]pyrene	µg/L	0.0108	0.034	0.009	0.0091	0.0090	NA	0.018
Dibenz(a,h)anthracene	µg/L	0.0047	0.015	0	0.0000	0.0000	NA	0.018
Heptachlor	µg/L	0.0006	0.002	0	0.0000	0.00000	0.0038	0.000079
Aroclor-1248	µg/L	0.0073	0.023	0	0.0000	0.00002	0.014	0.000064
Aroclor-1254	µg/L	0.0042	0.013	0.0028	0.00282	0.00281	0.014	0.000064
Aroclor-1260	µg/L	0.0031	0.01	0	0.0000	0.00001	0.014	0.000064
Beryllium*	µg/L	0.017	0.05	0.0062	0.006	0.006	NA	0.024
Copper*	µg/L	5.92	18.73	3.433	3.462	3.447	6.11	NA
Lead*	µg/L	0.771	2.44	0.084	0.088	0.086	1.54	NA
Mercury*	µg/L	0.05062	0.160	0.01102	0.0113	0.011	0.077	NA
PCB sum of Congeners	µg/L	0.069611	0.220	0.005705	0.0060	0.0059	0.014	0.000064
Dioxin and Furan sum of Congeners	µg/L	0.0060054	0.019	0.0005077	0.000537	0.000522	NA	5.1E-09

*Expressed as dissolved concentration

6.5 STATISTICAL ANALYSIS

Prior to statistical testing, all chemical data were examined using the Shapiro–Wilk test to determine if the data were normally distributed to meet the assumptions of ANOVA modeling. Ninety percent of the parameters were not normally distributed so all data were converted to natural logs for further statistical analyses. When a particular parameter was not detected 1/2 the detection limit was used. Calcium, sodium, magnesium, manganese, and potassium were excluded from the statistical analyses due to their non-toxic nature.

Two types of ANOVA testing were performed on the data. The first tested for significant differences in parameter groups that included GCSEMI (pesticides), MET (total inorganics), MET-DISS (dissolved inorganics), and MSSEMI (semi-volatile organics) by sample type (background and weir; Table 6-8). The second ANOVA was conducted for each individual parameter to determine if there were parameter specific differences among sample types (Table 6-9). Only significant differences ($p < 0.05$) are presented in Table 6-9. For each ANOVA test Duncan's Multiple Range tests were included to determine which of the mean concentrations among the two treatment groups (background and weir) were different from each other. In the summary tables means with similar letters are not significantly different from each other.

Among parameter groupings there were no significant differences in concentrations detected for pesticides and semi-volatile organics between the background and weir samples (Table 6-8). However significant differences were detected in the total and dissolved inorganic tests. For total inorganics, mean concentrations in the background and weir samples were significantly different from each other. Inorganic weir concentrations were all significantly higher than background. Table 6-9 presents the parameter specific significant ANOVA results for the total and dissolved inorganics.

Table 6-8. ANOVA results of parameter grouping by sample type

Analyte Group	Analyte	p-value	Duncan's groupings		N		Mean value	
			Background	Weir	Background	Weir	Background	Weir
GCSEMI	Pesticides	0.2461	A	A	186	403	0.034	0.042
MSSEMI	Semi-volatile Organics	0.8873	A	A	432	936	0.605	0.600
MET	Total Inorganics	0.0018	B	A	114	247	257.978	1206.483
MET-DISS	Dissolved Inorganics	0.0057	B	A	102	221	6.401	34.708

Table 6-9. ANOVA results of significant inorganic parameters by sample type

Analyte Group	Analyte	p-value	Duncan's groupings		N		Mean value	
			Background	Weir	Background	Weir	Background	Weir
MET	Aluminum	<.0001	B	A	6	13	1816.667	11307.692
MET	Antimony	0.0005	B	A	6	13	0.483	1.039
MET	Arsenic	<.0001	B	A	6	13	2.500	9.408
MET	Barium	<.0001	B	A	6	13	39.000	114.077
MET	Beryllium	0.0002	B	A	6	13	0.140	0.531
MET	Chromium	<.0001	B	A	6	13	7.100	28.462
MET	Cobalt	<.0001	B	A	6	13	1.667	5.992
MET	Copper	0.0005	B	A	6	13	7.817	17.538
MET	Iron	<.0001	B	A	6	13	2950.000	11238.462
MET	Lead	<.0001	B	A	6	13	5.183	23.231
MET	Mercury	0.0002	B	A	6	13	11.017	50.615
MET	Nickel	<.0001	B	A	6	13	4.000	13.662
MET	Silver	0.0198	B	A	6	13	0.052	0.160
MET	Vanadium	<.0001	B	A	6	13	3.717	23.385
MET	Zinc	0.0047	B	A	6	13	45.667	81.769
MET-DISS	Antimony	0.003	B	A	6	13	0.528	1.086
MET-DISS	Barium	<.0001	B	A	6	13	24.000	48.692
MET-DISS	Cobalt	<.0001	B	A	6	13	0.112	1.342
MET-DISS	Copper	0.0072	B	A	6	13	3.433	5.592
MET-DISS	Nickel	<.0001	B	A	6	13	1.248	4.562
MET-DISS	Vanadium	0.0476	B	A	6	13	0.955	3.964

A Multi-dimensional analysis using the Primer-E Ltd. statistical package was also performed on the data to visually present differences and similarities in contaminant concentrations between sample type (background and weir) by parameter grouping (pesticides, total inorganics, dissolved inorganics, and semi-volatile organics). Primer-E output placed the samples into natural groupings of similar chemical compositions and constructed a map of sample similarity on a two dimensional unit-less plot. The closer two points are on the MDS plot the more similar the samples are to each other. By plotting all the data for each parameter grouping by sample type we can determine how similar or different the background and weir data are relative to each other. The MDS plots using all the data showed that the pesticide and semi-volatile background and weir points are superimposed on each other suggesting that the treatment groups were similar (Figure 6-1). However for the total and dissolved inorganic groups weir and background samples are more dispersed in space. This result indicates that the chemical composition of the weir samples was distinctly different from the background samples taken during the Point of Dredge sampling.

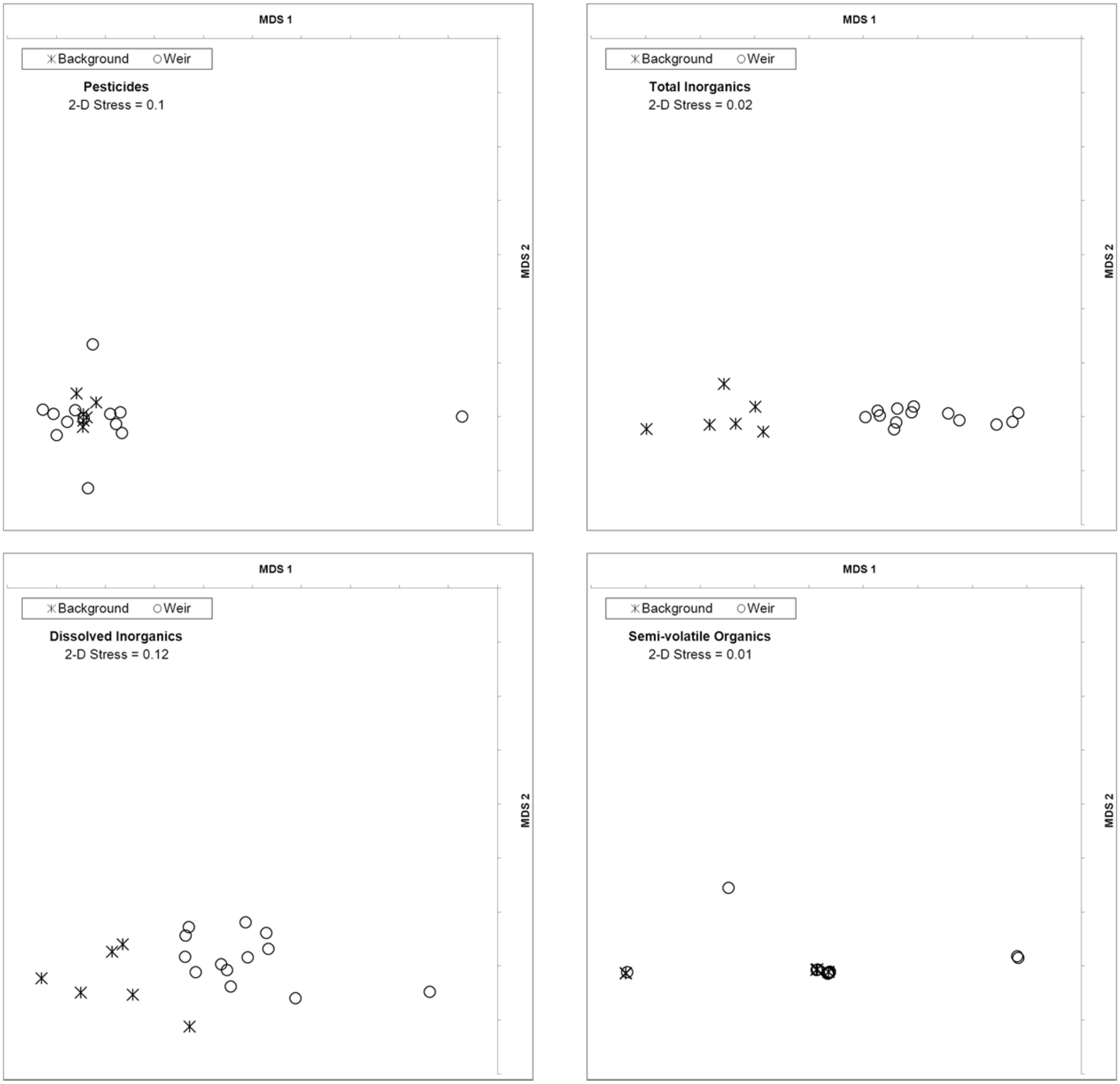


Figure 6-1. MDS plots all data by sample group for the background and weir sample types

6.6 TOTAL SUSPENDED SOLIDS

Figure 6-2 presents the daily TSS measurement for the weir discharge of the Pedricktown South CDF. During the beginning of the monitoring period TSS levels were generally above 250 mg/L after which TSS levels dropped to well below 250 mg/L. There was one spike in the time series in mid-December to over 900 mg/L but adjustments to the weir boards lowered TSS levels to well below 200 mg/L for the remainder of the dredging period. The generally low TSS levels observed in the weir samples indicates that the Pedricktown South CDF was working in optimum fashion as the heavy sediment loads seen at the inlet (Figure 6-3) were removed by the time the water reached the weir for discharge back into the Delaware River (Figure 6-4). For the Reach B deepening the discharge pipes were extended out into the tidal river beyond the low tide line to avoid the weir discharge water entering directly on the mud flats and to improve mixing. The CDF was calculated to be 99.8 percent efficient at removing solids from the aquatic environment.

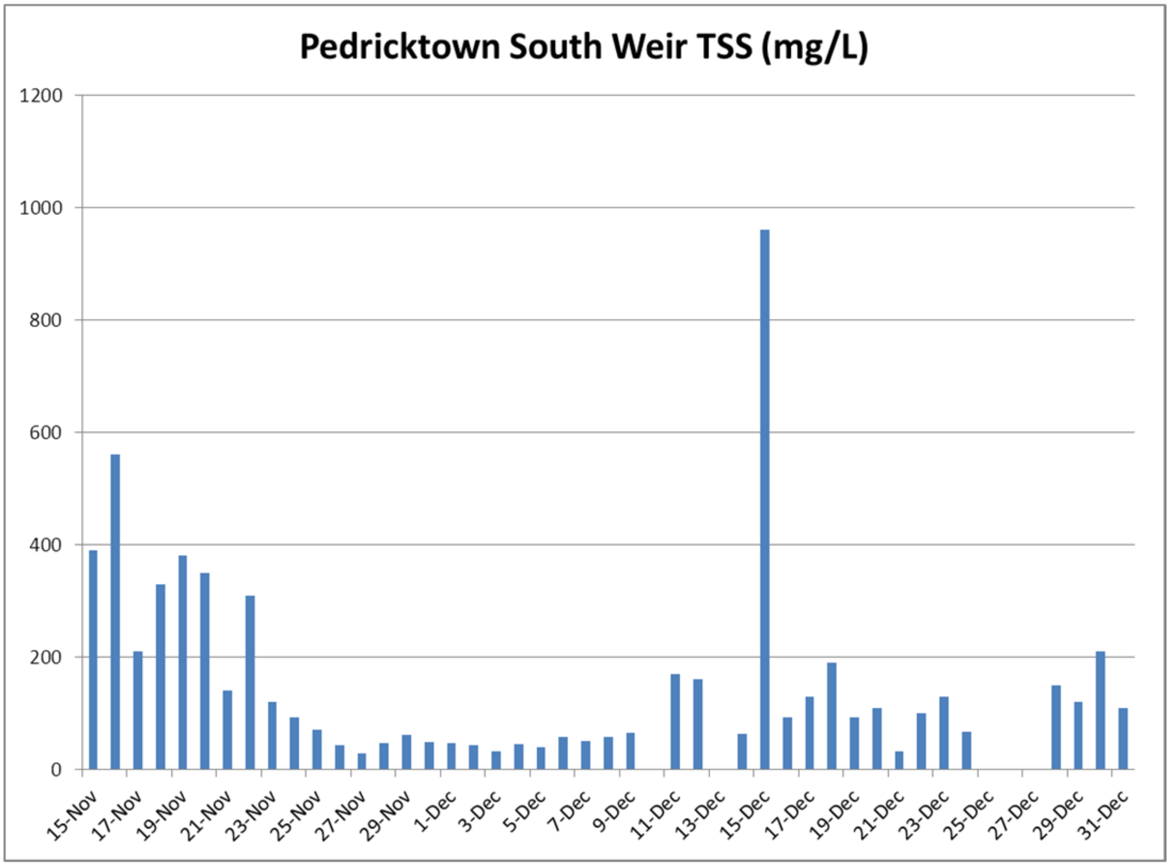


Figure 6-2. Weir TSS (mg/L) observed at Pedricktown South CDF in 2011

Figure 6-3. Dredged slurry being pumped into a typical CDF along the banks of the Delaware River

Figure 6-4. Pedricktown South weir discharge pipe reconfiguration for the Reach B Deepening

6.7 MASS BALANCE EVALUATION

The act of hydraulic dredging removes Delaware River sediments and associated contaminants and places them in a CDF where the pumped slurry is dewatered. Most of the contaminants in the sediment settle out and remain in the upland disposal site while a small fraction stays in suspension and is ultimately discharged back into the river through the weir. Previous studies funded by the Philadelphia District evaluating maintenance dredging operations in the Marcus Hook area indicated that over 95% of the contaminants are sequestered in the CDF (Burton and Farrar 2003), a net benefit from an aquatic toxicology perspective. CDF retention efficiencies can be calculated by multiplying the mean contaminant concentration in the inlet samples by an estimate of the total kilograms of material pumped into the CDF and comparing that to similar estimates of total kilograms of contaminants discharged at the weir over a prescribed period of time.

To evaluate the CDF efficiencies for the Reach B deepening work, dredging logs from the Charleston were obtained and the accumulative cubic yards pumped into Pedricktown South (588,678 cubic meters) was entered into a mass balance spread sheet. Total cubic yards of dredged material were converted to total kg of dry sediment by multiplying cubic yards by dry bulk density of the dredged material and accounting for unit conversions. Dry bulk density of the dredged material was based on an analysis of site specific data for Reach B (Burton and Farrar 2003). All inlet sample data were used to calculate average inlet contaminant concentrations. Using the weir discharge flow data recorded by ISCO ultra sonic flow meters installed in the discharge pipes the total liters discharged for the monitoring time period was calculated (Appendix D). Multiplying the total discharge (3,164,604,000 liters) by the mean weir concentrations measured among all weir samples provides an estimate of the total kilograms of contaminants that were released back into the Delaware River. Only parameters detected in both the inlet and weir samples were included in the analysis and non-detections were assumed to be zero. Total inorganic data, which includes dissolved inorganics, was used for this analysis.

The estimated contaminant sequestering efficiencies for the Pedricktown South CDF were mostly above 99% (Table 6-10). The semi-volatile organic Benzaldehyde had the lowest retention efficiency of 39.69 % while Butyl benzyl phthalate had a retention rate of 69.02%. The few pesticides observed in both weir and inlet samples had retention efficiencies of 92% or better. Inorganic retention rates ranged from 97.28 to 99.8%. Similarly, semi-volatile organic retention efficiencies were mostly 98% or better. Of particular note were the retention efficiencies of the sum of PCB congeners (measured using a smaller subset of samples with high resolution laboratory methods). The mass balance analysis indicated that 20.9 kg of PCBs were pumped into the CDF and only 0.22 kg was released back into the Delaware River through the weir discharge. The retention rate of PCBs in the CDF was 98.9%.

Table 6-10. Mass balance estimate and estimated CDF sequestering efficiencies (%) at Pedricktown South among the various contaminants detected in both the inlet and weir samples in 2011.

Total Liters Discharged from weir			3,164,604,000				
Total Kg pumped into Pedricktown South			256,327,963				
Weir/Inlet Parameters Detected	**Ave Weir Con.**	**Unit**	**Total kg Discharged from Weir**	**Ave Inlet Con.**	**Unit**	**Total kg into CDF**	**Percent (%) Sequestered in CDF**
GCSEMI							
Aroclor1248	0.0073	µg/L	0.023	17.7500	µg/kg	4.550	99.4917
Aroclor1260	0.0031	µg/L	0.010	16.0000	µg/kg	4.101	99.7626
beta-BHC	0.0005	µg/L	0.002	0.9250	µg/kg	0.237	99.3532
Heptachlor	0.0006	µg/L	0.002	0.0975	µg/kg	0.025	92.9869
MET							
Aluminum	11307.69	µg/L	35784.368	19750.00	mg/kg	5062477.268	99.2931
Antimony	1.04	µg/L	3.289	0.47	mg/kg	121.115	97.2846
Arsenic	9.41	µg/L	29.772	15.50	mg/kg	3973.083	99.2507
Barium	114.08	µg/L	361.008	99.75	mg/kg	25568.714	98.5881
Beryllium	0.53	µg/L	1.680	1.20	mg/kg	307.594	99.4539
Cadmium	0.14	µg/L	0.433	0.91	mg/kg	233.899	99.8147
Chromium	28.46	µg/L	90.069	60.75	mg/kg	15571.924	99.4216
Cobalt	5.99	µg/L	18.963	16.75	mg/kg	4293.493	99.5583
Copper	17.54	µg/L	55.502	38.50	mg/kg	9868.627	99.4376
Iron	11238.46	µg/L	35565.280	36750.00	mg/kg	9420052.639	99.6225
Lead	23.23	µg/L	73.516	62.00	mg/kg	15892.334	99.5374
Mercury	50.62	ng/L	0.160	53.25	µg/kg	13.649	98.8265
Nickel	13.66	µg/L	43.233	33.75	mg/kg	8651.069	99.5003
Selenium	1.34	µg/L	4.231	1.43	mg/kg	365.267	98.8417
Silver	0.16	µg/L	0.505	0.50	mg/kg	127.523	99.6039
Thallium	0.15	µg/L	0.469	0.22	mg/kg	56.392	99.1690
Vanadium	23.38	µg/L	74.003	60.50	mg/kg	15507.842	99.5228
Zinc	81.77	µg/L	258.767	220.00	mg/kg	56392.152	99.5411
MSSEMI							
1,1'-Biphenyl	0.0053	µg/L	0.017	3.2500	µg/kg	0.833	97.9837
2-Methylnaphthalene	0.0254	µg/L	0.080	20.5000	µg/kg	5.255	98.4712
4-Chloroaniline	0.0085	µg/L	0.027	43.2500	µg/kg	11.086	99.7585
Acenaphthene	0.0061	µg/L	0.019	3.6750	µg/kg	0.942	97.9585
Acenaphthylene	0.0043	µg/L	0.014	8.4750	µg/kg	2.172	99.3725
Benzaldehyde	0.3908	µg/L	1.237	8.0000	µg/kg	2.051	39.6949
Benzo[a]anthracene	0.0180	µg/L	0.057	44.7500	µg/kg	11.471	99.5034

Table 6-10. (Continued)

Weir/Inlet Parameters Detected	Unit	Ave Weir Con.	Total kg Discharged from Weir	Ave Inlet Con.	Unit	Total kg into CDF	Percent (%) Sequestered in CDF
MSSEMI (Continued)							
Benzo[a]pyrene	0.0108	µg/L	0.034	61.0000	µg/kg	15.636	99.7820
Benzo[b]fluoranthene	0.0148	µg/L	0.047	60.5000	µg/kg	15.508	99.6986
Benzo[g,h,i]perylene	0.0108	µg/L	0.034	50.7500	µg/kg	13.009	99.7380
Benzo[k]fluoranthene	0.0077	µg/L	0.024	32.0000	µg/kg	8.202	99.7032
Butyl benzyl phthalate	0.2446	µg/L	0.774	9.7500	µg/kg	2.499	69.0256
Carbazole	0.0072	µg/L	0.023	4.6250	µg/kg	1.186	98.0698
Chrysene	0.0142	µg/L	0.045	59.7500	µg/kg	15.316	99.7060
Dibenz(a,h)anthracene	0.0047	µg/L	0.015	12.0000	µg/kg	3.076	99.5172
Diethyl phthalate	0.0831	µg/L	0.263	12.2500	µg/kg	3.140	91.6273
Fluoranthene	0.0421	µg/L	0.133	72.2500	µg/kg	18.520	99.2810
Fluorene	0.0167	µg/L	0.053	9.5000	µg/kg	2.435	97.8307
Indeno[1,2,3-cd]pyrene	0.0099	µg/L	0.031	38.0000	µg/kg	9.740	99.6776
Methylphenol, 3 & 4	0.0070	µg/L	0.022	11.7500	µg/kg	3.012	99.2645
Naphthalene	0.0510	µg/L	0.161	39.2500	µg/kg	10.061	98.3958
Phenanthrene	0.0503	µg/L	0.159	50.0000	µg/kg	12.816	98.7578
Pyrene	0.0432	µg/L	0.137	79.7500	µg/kg	20.442	99.3308
High Resolution PCBs, Dioxins and Furans							
Mean Sum of PCB Congeners	69.611	ng/L	0.220	81.763	ng/g	20.958	98.95
Mean Sum of Dioxin and Furan Congeners	6005.4	pg/L	0.019	4714.3	pg/g	1.208	98.43

7.0 CONFINED DISPOSAL FACILITY MONITORING DISCUSSION

7.1 INORGANICS

Among the inorganics discharged from the Pedricktown South CDF no sample concentrations were over DNREC's freshwater acute criteria for protection of aquatic life during the 1.5 month monitoring period, except for aluminum. Aluminum concentrations were over the DNREC acute criterion in all 13 weir samples as well as background samples taken at the Point of Dredging, but the criterion is dated and does not properly account for the effect of pH on solubility and toxicity according to Greene (2010). All aluminum concentrations were over acute criteria during the 2010 Reach C study as well (Burton and Pasquale 2011). Of the 13 weir samples collected over the Reach B monitoring period 3 mercury, 4 dissolved copper, and 1 dissolved lead sample was over their respective chronic criteria. For these parameters with observed concentrations above DNREC chronic freshwater criteria for the protection of aquatic life and those over DNREC's human health criteria, a far-field assessment was conducted to determine the contaminant concentration after complete mixing for this location in the Delaware Estuary. One and a half months of contaminant load discharged from the CDF was added to observed background concentrations and diluted by the appropriate flows for both aquatic life and human health criteria. The result was that no parameter increased background concentrations. As such, DNREC chronic freshwater criteria for the protection of aquatic life and DNREC human health criteria were met during the 1.5 month monitoring period. Furthermore, mass balance calculations using inlet concentrations and CDF discharge loadings demonstrated that typically 99 percent of dredged inorganics stayed in the CDF. Nearly identical results were reported for the 2010 Reach C monitoring program[1].

7.2 PESTICIDES

No pesticide had an observed sample concentration at the discharge over DNREC's freshwater acute criteria for protection of aquatic life during the 1.5 month monitoring period. Only Heptachlor had one sample concentration above the DNREC chronic criterion for protection of aquatic life and the human health criterion. The far field assessment as conducted for Heptachlor indicated that when 1.5 months of contaminant load discharged from the CDF was added to observed background concentrations and diluted by the low flows for 56 days there was no increase in background concentrations. As such, DNREC chronic freshwater criteria for the protection of aquatic life and DNREC human health criteria for pesticides were met during the 1.5 month monitoring period. The mass balance analysis showed that typically 99 percent of the pesticides entering the CDF were retained by the CDF. For heptachlor, 93% was retained in the CDF. In addition, ANOVA analysis of the pesticide data indicated that there were no significant differences between weir and background concentrations. Reach C monitoring data collected in 2010 supported a similar conclusion.

7.3 PCBs

There is no DNREC acute freshwater criterion for protection of aquatic life for PCBs. All four weir samples analyzed for PCB congeners and five samples analyzed for PCB aroclors had concentrations above the chronic criterion for protection of aquatic life (14 ng/L), and all samples including background were above the DNREC human health carcinogen criterion (0.064 ng/L). However, the far field assessment indicated that background concentrations of PCBs were not increased when 1.5 months of the PCB load discharged from the CDF was added to observed background concentrations and diluted by the low flows for 56 days. Mass balance calculations indicated that 27.4 kg of PCBs were removed from the bottom of Reach B and pumped into the CDF while only a small fraction (0.22 kg) was released back into the Delaware River through the weir discharge.

7.4 PAHs

Although DNREC does not have aquatic life criteria for PAHs, criteria are available in the peer reviewed literature (DiToro et al. 2000). None of the detected concentrations exceed those criteria. There are DNREC human health carcinogen criteria for several PAHs. Several PAH parameters had a few sample concentrations above DNREC human health carcinogen criteria. The far field assessment indicated that when 1.5 months of contaminant loads discharged from the CDF was added to observed background concentrations and diluted by 56 day low flows no parameter increased background concentrations. As such, DNREC human health criteria for PAHs were met during the 1.5 month monitoring period. The mass balance analysis showed that greater than 97 percent of the PAHs entering the CDF were retained by the CDF. In addition, ANOVA analysis of the semi-volatile organic data indicated that there were no significant differences between weir and background concentrations.

8.0 EQUILIBRIUM PARTITIONING EVALUATION OF CONTAMINANTS RELEASED DURING DREDGING OF REACH B

Greene (2010) used equilibrium partitioning to evaluate the likelihood that levels of PCBs and inorganics in the sediments of Reach C could cause toxicity to aquatic benthic life during dredging of that area. The Greene (2010) model was designed to estimate sediment pore-water concentrations based on measured sediment concentrations and parameter specific solubility using equilibrium partitioning theory. That assessment evaluated whether deepening of Reach C of the main navigation channel was likely to cause exceedances of applicable water quality criteria for the protection of aquatic life and human health for the PCBs and inorganics considered. Separate assessments were done for acute aquatic life criteria immediately behind a working dredge (the 'near-field' assessment), as well as for chronic aquatic life and human health criteria following complete mixing of the contaminant mass released during dredging from the cutterhead and the CDF (the 'far-field' assessment). Spreadsheet models were prepared by DNREC as part of their assessment which include the methods and assumptions of the model. Results of that assessment for near-field concentrations behind the dredge indicated that acute toxicity is unlikely due to PCBs or inorganics mobilized during deepening. Likewise, the assessment of far-field concentrations in Reach C due to deepening indicated levels of PCBs and inorganics were well below chronic aquatic life criteria and less than human health criteria, particularly for inorganics.

To provide an alternative assessment from the Point of Dredge and CDF monitoring described here for Reach B the same modeling methods were used to evaluate the potential releases of toxic contaminants. This section presents that evaluation for inorganics and PCBs. Methods used in this evaluation mirror those in Greene (2010). Median and maximum values of recently sampled Reach B inorganics (Table 3.1 in Burton 2011, Appendix E) were used in the '*Near-Field Metals Conc behind Cutterhead Dredge-Reach B.xls*' spreadsheet model for evaluation of acute aquatic life criteria. Median inorganics values were used in '*Far-Field Metals Concentrations – Reach B.xls*' for evaluation of chronic aquatic life criteria and human health criteria. Median values of total PCBs (Table 3.5 in Burton 2011) were used in '*Near-Field PCB Conc behind Cutterhead Dredge–Reach B.xls*' for evaluation of acute aquatic life criteria. Maximum values of total PCBs (Table 3.5 in Burton 2011) were used in '*Far-Field PCB Concentrations – Reach B.xls'* for evaluation of PCBs with chronic aquatic life criteria. Total volume of sediment removed during the Reach B deepening was estimated as 769,916 cubic yards over a period of 1.5 months. The Excel spreadsheets are presented in Appendix D.

All model parameters from the original DNREC Reach C near-field model were used unchanged except for sediment total contaminant concentration data. Similarly, all model parameters from the original Reach C far-field model were used unchanged except for the sediment concentration, total volume of sediment dredged, dredging period, and CDF removal efficiency, which were obtained from Table 6-10. Sources of these values are indicated in the spreadsheets presented in Appendix D.

In the near-field model for inorganics, median and maximum sediment concentrations were used to estimate toxicity based on various water quality and human health criteria. The model used equilibrium partitioning to estimate dissolved concentrations that would occur during the dredging process and compares these values to acute and chronic freshwater criteria applicable to the Delaware Estuary. The model predictions of contaminant releases within sediment pore-water indicate that no inorganic considered exceeded any of the criteria evaluated for median or maximum values from Reach B. The final model calculation is for toxic units based on predicted dissolved or total phase maximum concentrations at 250 mg/L TSS and dissolved or total phase aquatic life criteria using the minimum of acute or chronic freshwater criteria. Values less than one indicate the concentration does not exceed criteria. The magnitude of values smaller than one indicates how much the inorganic concentration is below the most stringent criteria (e.g., the maximum arsenic concentration would be 0.6% of the most stringent water quality criterion value and so on). Table 8-1 indicates that the maximum predicted inorganic concentrations using high TSS values were all well below the most stringent criteria. These results are very conservative since TSS concentrations at the cutterhead during the dredging process were much less than the 250 mg/L values used for these results (Figure 3-2), so dissolved inorganic concentrations are expected to be much less than predicted for the higher TSS value.

In the near-field model for total PCBs, maximum sediment total concentrations were used to estimate toxicity based on various water quality criteria. The models used equilibrium partitioning to estimate dissolved concentrations that would occur during the dredging process and compares these values to acute and chronic freshwater criteria applicable to the Delaware Estuary. Results indicate that the maximum dissolved PCB value of 143 ng/L from Reach B did not exceed the most restrictive criterion evaluated (1,000 ng/L) using a TSS value of 250 mg/L. These results are very conservative since TSS concentrations during the dredging process were much less than the 250 mg/L values used for these results (Figure 3-2), so dissolved total PCB concentrations are expected to be much less than predicted for the higher TSS value.

In the far-field inorganics and PCB models, median sediment concentrations from Reach B were applied along with the total volume of dredged sediment. Results predict the potential for very small dissolved concentrations (4.9 pg/L for total PCBs) would be released during the dredging process, well below any applicable water quality or human health criteria (Table 8-2 for inorganics). Results also indicate that the benefit of removing the dredged material to a CDF where 97-99% of contaminants would be sequestered (see Table 6-10) far exceeds the risk of release of a small amount to the water column of the estuary during the dredging process. A benefit to risk ratio was calculated for each inorganic by dividing the mass of inorganics removed from the Delaware River by the mass of dissolved inorganics released during dredging (at the cutterhead and from the CDF). The benefit (removal of inorganics from the Delaware River) appears to far exceed potential risks associated with the release of dissolved, bioavailable inorganics. Results for Reach B are consistent with the results for Reach C presented by Greene (2010).

Table 8-1. Summary of Worst-Case Predictions of Toxic Units in Reach B for freshwater criteria (< 1 indicates no exceedance of worst-case toxic aquatic life criteria)

Contaminant	Maximum	Median
Arsenic	0.006	0.003
Cadmium	0.101	0.044
Chromium	0.274	0.129
Copper	0.145	0.064
Lead	0.256	0.052
Mercury	0.004	0.001
Nickel	0.020	0.016
Selenium	0.009	0.004
Silver	0.004	0.001
Zinc	0.029	0.011

Table 8-2. Far-field inorganic concentrations and risk/benefit of dredging from Reach B (Burton and Pasquale, 2011; Burton 2011)

	units	Antimony	Arsenic	Cadmium	Chromium	Copper	Lead	Mercury	Nickel	Selenium	Silver	Zinc
Concentration in sediments	mg/kg dry	0.3	10.8	0.88	50.9	31.1	48.5	0.157	28.6	1.5	0.19	117
Dissolved inorganic concentration resulting from dredging project during 7Q10	µg/L	0.000034	0.003338	0.000032	0.008278	0.002138	0.000348	0.000004	0.005104	0.000238	0.000004	0.004026
Most restrictive of aquatic life or human health criteria	µg/L	1600.0	10.0	0.2	11.0	3.1	1.8	0.8	8.2	4200.0	40000.0	81.0
Benefit (inorganic removed from the Estuary)	kg	183	6688	547	31622	19288	30102	97	17746	926	118	72620
Risk (dissolved inorganic released to the Estuary)	kg	0.8	82.2	0.8	203.8	52.6	8.6	0.09	85.5	5.9	0.1	99.1
Benefit:Risk Ratio		216	81	690	155	366	3511	1022	208	158	1179	733

9.0 CONCLUSIONS

Dredging for the second portion (lower Reach B) of the Delaware River Deepening Project began on November 9, 2011. Potential water quality impacts were intensely monitored at the Pedricktown South Federally owned dredged material containment facility and at the point of active dredging in lower Reach B. The following conclusions are made based on environmental monitoring data collected for this effort:

- A near-field assessment of contaminant concentrations within the zone of initial dilution for the CDF discharge point indicates that DNREC acute water quality criteria for the protection of aquatic life were met during the dredging operation;

- A far-field assessment of contaminant loads discharged from the CDF indicates that no parameter increased background concentrations, as such DNREC chronic freshwater criteria for the protection of aquatic life, and DNREC human health criteria were met during the dredging operation;

- Suspended solids and contaminant levels down-current of the cutterhead was consistent with or less than background levels, indicating that acute water quality criteria for the protection of aquatic life were met at the point of dredging; and

- A mass balance evaluation of the contaminant load entering and leaving the CDF indicates a large net removal of contaminants from the Delaware River.

10.0 REFERENCES

Burton and Farrar. 2003. Contaminant Sequestering and Water Quality Discharges at Confined Disposal Facilities. *In*: M. Pellei and A. Porta (eds.), Remediation of Contaminated Sediments—2003. Proceedings of the Second International Conference on Remediation of Contaminated Sediments (Venice, Italy; 30 Sep–3 Oct 2003). ISBN 1-57477- 143-4, published by Battelle Press, Columbus, OH, www.battelle.org/bookstore.

Burton, W. 2011. Sediment Quality Analysis for Reach B of the Main Channel Deepening Project. Report prepared by Versar for the U.S. Army Corps of Engineers, Philadelphia, PA.

Burton, W. and J. Pasquale. 2011. Delaware River Reach C Main Channel Deepening Project. Killcohook (Cells 2 and 3) Confined Disposal Facility Monitoring and Water Quality Monitoring at the Point of Dredging.

Delaware Department of Natural Resources and Environmental Control. 2004. State of Delaware Surface Water Quality Standards as Amended, July 11, 2004.

Delaware River Basin Commission. 2010. Administrative Manual – Part III Water Quality Regulations as Amended, December 8, 2010.

DiToro, M, J.A. McGrath, and D.J. Hansen. 2000. Technical Basis for Narcotic Chemical and Ploycyclic Aromatic Hydrocarbon Criteria. I. Water and Tissue. Environmental Toxicology and Chemistry, Vol. 19, No. 8. pp.

Greene, R. 2010. An Evaluation of Toxic Contaminants in the Sediments of the Tidal Delaware River and Potential Impacts Resulting from Deepening the Main Navigation Channel in Reach C. Delaware Department of Natural Resources and Environmental Control, Division of Water Resources Watershed Assessment Branch, Dover, DE.

MacGillivray R., D.E Russell, S.S. Brown, T.J Fikslin, R. Greene, R.A. Hoke, C.Nally, and L O'Donnell. 2011. Monitoring the Tidal Delaware River for Ambient Toxicity. Integrated Environmental Assessment and Management. Vol. 7. No. 3 pp. 466-477

Schreiner, S.P., J. Farrar, and G. Hunt. 2000. Assessment of Potential Contaminant Impacts for the Chesapeake and Delaware Canal deepening Project. Prepared for U.S.A.C.E. Philadelphia District by Versar Inc. W. Burton, principal investigator. Delivery order No. 0076.09.

APPENDIX A
SCOPES OF WORK

APPENDIX B
POINT OF DREDGE MONITORING DATA AND ANALYSIS

APPENDIX C
STATE OF DELAWARE SURFACE WATER QUALITY STANDARDS

APPENDIX D
PEDRICKTOWN SOUTH CDF MONITORING DATA AND ANALYSIS

APPENDIX E
SEDMENT QUALTY ANALYSIS FOR REACH B OF THE MAIN CHANNEL DEEPENING PROJECT