TECHNICAL MEMO:

FAR-FIELD SURVEYS OF SUSPENDED SEDIMENT PLUMES ASSOCIATED WITH HARBOR DEEPENING DREDGING IN NEWARK BAY

S-NB-2/S-AK-1 Contract Area (South Elizabeth Channel) Surveys #1 & #2

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1.0 INTRODUCTION

The resuspension of bottom sediments within aquatic habitats may be induced by a variety of events both natural and anthropogenic. Naturally occurring storms or tidal flows, for example, will influence suspended sediment concentrations within the water column although the timing, duration and intensity of the resuspension may differ from that caused by human activities (Wilber & Clarke 2001). Information on the extent and nature of suspended sediment plumes generated by dredge activities, therefore, is critical to enhance the understanding of sediment transport processes and associated environmental concerns (Puckette 1998).

As part of U.S. Army Corps of Engineers New York District’s (USACE-NYD) Harbor-wide Water Quality/Total Suspended Solids (WQ/TSS) Monitoring Program, two far-field WQ/TSS surveys were conducted within the S-NB-2 portion of the S-NB-2/S-AK-1 contract area of the Harbor Deepening Project (HDP) in the South Elizabeth Channel of Newark Bay, New Jersey (Figure 1). The first of the studies (S-NB-2/S-AK-1 Survey #1) was conducted between 25 and 29 July, 2011, and the second study (S-NB-2/S-AK-1 Survey #2) was conducted between 03 and 07 October, 2011. The objective of these far-field surveys was to assess the spatial extent and temporal dynamics of suspended sediment plumes associated with mechanical dredging of fine-grained sediment. The methodologies employed for this survey were similar to those used previously to survey environmental or “closed” (i.e. with seals and flaps, as per contract specifications) clamshell bucket dredging of fine-grained sediment within the Arthur Kill (USACE 2007), Newark Bay (USACE 2008 and USACE 2009) and Port Elizabeth Channel (USACE 2010), and course-grained sand in Anchorage Channel (USACE 2011); as well as cutterhead dredging of sediments in the Kill Van Kull (USACE 2012a and USACE 2012b).

Mobile surveys were conducted using a vessel-mounted Acoustic Doppler Current Profiler (ADCP) and consisted of parallel transects running perpendicular to the longitudinal axis of the suspended sediment plume. Transects were conducted adjacent to and down-current of the active dredging operation and were run such that the entire spatial extent of the plume’s acoustic signature (i.e. the detectable signature above ambient conditions) was recorded. To calibrate ADCP backscatter with suspended sediment concentrations, water samples were collected concurrently with ADCP data to directly measure TSS concentration (via gravimetric analysis) and turbidity across the broadest possible range of tidal and concentration gradients.
In addition to the mobile ADCP surveys, turbidity measurements were recorded during a variety of tidal conditions at fixed locations and at various water depths using OBS-3A optical turbidity sensors attached to an anchor and buoy array.

1.1 Study Area and Dredge Operational Setup

The dredge contractor for this study was Northeast Dredging Equipment Company, LLC (Northeast Dredging), a joint venture between Donjon Marine Company, Inc. (Donjon) and Cashman Dredging, operating Donjon's dredge the Delaware Bay, configured with an eight (8) cubic-yard capacity Cable Arm Environmental Bucket (S/N: 05406). This bucket features an over-square design with greater width than length to reduce sediment loss during bucket closing. In contrast to conventional “grab” buckets, the Cable Arm environmental bucket produces a relatively level cut when removing bottom sediment, thereby enhancing vertical as well as horizontal control. In addition, overlapping steel side plates with rubber seals reduce sediment squeezing out of the side (known as windrowing). Rubber flaps on the face of the bucket allow air to escape during descent while sealing the top during ascent, thereby slowing the inflow of water and reducing the loss of material due to washout. In addition to the use of an environmental bucket, best management practices (BMPs) were employed by the dredge contractor to reduce overall sediment resuspension. BMPs included restriction of bucket hoist speed to no more than two feet per second and the use of dredging instrumentation and software to ensure full bucket closure.

Far-field WQ/TSS surveys were conducted between 25 and 29 July, 2011 (S-NB-2/S-AK-1 Survey #1), and 03 and 07 October, 2011 (S-NB-2/S-AK-1 Survey #2) in the vicinity of this dredging operation in the S-NB-2/S-AK-1 Contract Area. Figure 1 shows the S-NB-2 Contract Area, the area of WQ/TSS surveys conducted within the Contract Area, and the approximate position of the dredge Delaware Bay during each survey. During Survey #1 (July 2011) the Delaware Bay was located within the South Elizabeth Channel, close to the midpoint of the channel between the shoreline to the west and the Green “#1” navigation buoy located at the mouth of the channel, and close to the bulkhead of Port Elizabeth Marine Terminal. Water depths at this location were approximately 15 meters. During Survey #2 (October 2011), the Delaware Bay was located further to the southwest, on the flats adjacent to the South Elizabeth Channel. In this position, water depths were as shallow as approximately three to five meters on the
south side of the dredge but sloped from approximately 5 to 10 meters on the channel edge to the north of the dredge. Overall, the survey area has a relatively low amount of vessel traffic, with some large deep draft container ships berthing at the Port Elizabeth Marine Terminal, as well as attendant tug and barge traffic.

2.0 METHODS

2.1 Hydrodynamic Survey

Hydrodynamic conditions within the South Elizabeth Channel were assessed during both ebb and flood tides using a vessel-mounted Teledyne RD Instruments 1200-kHz Workhorse Monitor Series ADCP. The mobile transects were conducted perpendicular to the South Elizabeth Channel. ADCP data provided a characterization of prevailing hydrodynamic conditions within the Study Area. Raw data from the hydrodynamic surveys were processed and examined for evidence of stratified flows, tidal eddies, and other patterns that could influence plume dispersion.

The observed hydrodynamic conditions were then cross-referenced against predicted currents generated from NobleTec Tides & Currents™ software for the South Reach of Newark Bay, to place the survey within the context of the daily tidal cycle.

2.2 Survey Design of Mobile ADCP Transects

Suspended sediment plumes were also characterized using the ADCP. In the field, RD Instruments WinRiver software was used for the display of plume acoustic signatures and data recording. The ADCP operates by emitting acoustic pulses into the water column at set time intervals. Each group of pulses, referred to as an "ensemble,” is vertically stratified into discrete, fixed-depth increments, or "bins." The number of bins and size of each bin is a configurable operation parameter of the instrument. In this study, 40 bins of 0.5-meter depth were used, for a maximum profile range of 20 meters. After the instrument emits a pulse, the ADCP then "listens" for the return of any sound (i.e. backscatter) that has been reflected from particles in the water column (in this case, a "particle" is any acoustic reflector, including sediment, plankton, fish, air bubbles etc.). Once the instrument receives the reflected signals, the WinRiver software calculates the three-dimensional movement of particles in the water column and thus determines water velocity in each bin. When water samples are collected concurrently,
suspended sediment concentration can be determined using additional software and analyses (see Section 2.5 - ADCP Calibration below). Dredge positional data (i.e. GPS positions) were collected by the dredge contractor throughout the monitoring period and were integrated during post-processing of the ADCP data to determine the distance each transect was from the dredge. To cover a range of tidal conditions, ADCP backscatter data were collected during various stages of ebb and flood tides during the survey periods.

It is important to note that the ADCP cannot simultaneously receive and emit an acoustic pulse. Thus, when emitting a pulse, the ADCP cannot obtain data from immediately in front of its transducers (in addition to the water above the immersion depth of the instrument itself). This “blanking distance” is a user-defined parameter with limitations imposed by the operating frequency of the ADCP. For the 1200-kHz ADCP used in this survey, the blanking distance is approximately 0.5 meters (i.e. one bin depth).

In addition, acoustic “echoes” reflected from the seabed may interfere with the ADCP signal. The ADCP emits most of its acoustic energy in a very narrowly confined beam (main lobe); however, a small amount of energy is emitted at angles far greater than that of the main lobe. These “side lobes”, despite their low power, can contaminate the echo from the main lobe, typically in the area directly above the seabed. The net effect of this side lobe interference is to show erroneously high backscatter from the near-seabed areas. This effect can be exacerbated in vessel-mounted surveys when the seabed elevation changes rapidly (e.g. during the transition from the shallows to the channel areas or vice-versa). In general, the side lobe distance above the seafloor is equal to approximately 6% of the water depth at that point.

Prior to initiating the mobile plume surveys, circular transects using the ADCP were conducted around the actively operating dredge to assess the location and acoustic strength of the plume. Subsequent ADCP transects were generally oriented in a direction perpendicular to the channel and extended down-current until the plume’s acoustic signatures could no longer be detected against background conditions. Background conditions on the days of the surveys were determined by conducting ambient transects up-current of the plume and outside the active dredging area. Individual transect length was generally determined by bathymetry at the site, but always with the objective of extending beyond the detectable boundaries of the plume. The number, and consequently the spacing, of cross-plume transects were maximized within each designated tidal phase in order to provide complete spatial coverage of the detectable plumes and optimal resolution of internal plume structure.
Results for the mobile ADCP plume transects are presented graphically in three ways:

- **Vertical Profile Plots** – Vertical cross-section profiles representing individual transects are examined in detail for TSS concentration gradient structure of the plume at fixed distances from the source.

- **Plan-View Plots** – TSS concentrations are presented as composite horizontal “slices” through the plume signature at two meter depth increments.

- **Three-dimensional Plot Depiction** – Selected transects are plotted three dimensionally to show the spatial extent of the plume within the channel (note: the depth (Z) axis is exaggerated to show detail better since the X,Y spatial extents are much larger than the Z extents).

For all figures, unless otherwise noted, estimates of TSS concentrations above ambient concentration are assumed to be associated with dredging activities.

### 2.3 Design of Fixed Station Turbidity Surveys

In addition to the mobile ADCP surveys, turbidity measurements were recorded at fixed locations and at various water depths using Campbell Scientific, Inc.’s (formerly D&A Instrument Company) OBS-3A turbidity sensors tethered to a taut line and anchored at predetermined depths using a fixed anchor and buoy array. Optical backscatter sensors (OBS) project a beam of near-infrared light into the water, and measure the amount of light reflected back from suspended particles. The OBS units used in this survey were pre-calibrated by the manufacturer and programmed to measure turbidities in the 0-1,000 Nephelometric Turbidity Unit (NTU) range. The OBS units deployed during the fixed station survey were configured to output depth (meters), turbidity (NTU), temperature (°C), salinity (ppt), conductivity (mS/cm) and battery level (V). Readings were logged internally every 10 seconds at a rate of 25 samples per second for duration of 5 seconds. That is, every 10 seconds the OBS recorded 125 samples (25 samples/sec x 5 sec). All internally recorded data were retrieved from the units at the end of the survey.
2.4 Water Sample Collection

During the far-field surveys, water samples were collected to measure TSS concentrations (mg/L) and turbidity (NTU) throughout the water column, and to calibrate ADCP backscatter data to suspended sediment conditions. The water samples were collected from the survey vessel using a Sea-Bird Electronics SBE32C Compact Carousel Water Sampler equipped with six 1.7L Nisken sample bottles. A Campbell Scientific, Inc. OBS-3A optical backscatter sensor was also mounted to the Carousel Sampler and hardwired directly to an onboard computer. The OBS unit provided depth, temperature, salinity, and turbidity values of the entire water profile. The Carousel Sampler was also hardwired to an onboard computer and featured a magnetically-actuated lanyard release system used to remotely “fire” the sample bottles. A custom application recorded the exact time that each bottle fired to the nearest second.

All the water samples collected in the field were processed in the laboratory by Test America Laboratories, Inc. for optical turbidity (Method SM 2130-B) and for the gravimetric analysis of TSS concentration (Method SM 2540-D). The laboratory results were then used to provide a robust calibration data set to convert the raw ADCP backscatter measurements to estimates of TSS concentration using the Sediview methodology and software as described below.

2.5 ADCP Calibration

Following the field data collection effort, the raw acoustic backscatter measurements collected by the ADCP were converted to estimates of suspended sediment concentration using Sediview Software provided by Dredging Research, Ltd. The Sediview Method (Land and Bray 2000) derives estimates of suspended solids concentration in each ADCP data bin by converting relative backscatter intensity to TSS concentration. This process requires collecting a calibration data set consisting of discrete water samples and concurrently recorded ADCP acoustic backscatter data. The degree of confidence that can be placed in the estimates of TSS is directly proportional to the quality of the calibration data set. The quality of the calibration is in turn dependent on the collection of adequate water samples to represent sediments in suspension at all depths in the water column and across the entire gradient of concentrations occurring in ambient as well as plume conditions.
Samples were collected at known locations within the water column, so that individual gravimetric samples could be directly compared with acoustic estimates of TSS concentration for a “bin” of water as close to the water sample as possible. Following the Sediview calibration, the results were then applied to all of the ADCP files recorded during the far-field survey, resulting in an ADCP-derived estimate of TSS concentration for each recorded ADCP bin. Note, because of the continuously changing conditions present in estuaries, it is important to collect water samples frequently, and it may be necessary to perform multiple calibrations specific to the time period where the ADCP data were collected (DRL 2003). This was the case for S-NB-2/S-AK-1 Far Field Survey #2 (week of 03 October 2011). It is also important to collect enough samples to constitute a robust sample size which results in a statistically better calibration. The samples should be collected across the broadest possible range of depths and TSS concentrations as it is occasionally necessary for some outlier samples to be excluded. This is due to the dynamic nature of the sampling environment where it is often difficult to achieve perfect spatial and temporal synchronization of the water samples and ADCP data. For example, outlier samples may exhibit erroneously high TSS based on the disturbance of bottom sediments by the Carousel Sampler (i.e. the Carousel apparatus impacts on the seafloor resulting in localized elevated TSS concentrations), or if the ADCP backscatter exhibited signs of air bubble contamination (e.g. air bubbles will show as extremely high backscatter/TSS estimates but the corresponding water sample for that time/position has relatively low TSS concentration) or interference (e.g. the ADCP beam(s) reflect off the carousel sampler apparatus itself, causing an erroneously high reading) or if the water sample apparatus is out of the area being measured by the ADCP (e.g. spatial desynchronization due to high current velocities).

Because air is injected into the water column as the dredge bucket breaks the air-water interface, and air bubbles are acoustic reflectors, care was exercised in converting acoustic data derived very close to the operating bucket. Air bubbles dissipate by rising to the surface with time. The distance down-current of bubble interference of the signal is therefore influenced by current velocities. Previous surveys were conducted during the monitoring of a closed bucket during maintenance dredging operations in the Providence River, in which the bucket was intentionally plunged through the air-water interface without removing sediment from the bottom (Reine et al. 2006). These surveys were conducted under slow to moderate current flow conditions, and determined that the “bubble signature” pattern dissipated within approximately 50 meters of the source. Therefore, estimates of TSS concentration collected more than 50 meters from the dredge
using the calibrated ADCP for this survey were typically assumed to be free of air bubble interference from the bucket unless otherwise noted.

2.6 Sediment Sample Collection

Sediment samples were collected once per day from both the sediment bed in the vicinity of the dredge using a ponar grab, and from the dredge scow during down periods of active dredging operations. Additional ponar grab samples were collected from the sediment bed on 28 July and 03 October during the hydrodynamic surveys. All of the sediment samples were analyzed in the laboratory by Test America Laboratories, Inc. for sediment grain size distribution (ASTM D-422 Method), density (ASTM D-2937 Method) and Atterberg Limits (ASTM D-4318 Method).

3.0 RESULTS

3.1 S-NB-2/S-AK-1 Far Field Survey #1 (Week of 25 July 2011)

3.1.1 Hydrodynamic Surveys

General hydrodynamic conditions within South Elizabeth Channel and its immediate vicinity were assessed during both ebb (27 and 28 July), and flood tides (26 July). Transects were conducted approximately perpendicular to the South Elizabeth Channel. Additionally, the specific hydrodynamic conditions during each mobile ADCP TSS survey (see below) were also recorded to aid in the interpretation, and place the corresponding TSS data in a hydrodynamic context. These results are discussed along with each TSS survey in Section 3.1.3. The results of the hydrodynamic surveys are discussed below and presented in Figures 2, 3, and 4. For comparison purposes, the predicted currents in the South Reach of Newark Bay for the respective survey day are shown on Figures 2 through 4. Current predictions were generated using NobleTec Tides & Currents™ software. The predicted currents data show the water speed (in m/s; blue bars) and direction (negative values for ebb, positive for flood) and are useful to place a particular survey within the daily tide cycle.

3.1.1.1 26 July 2011 (Flood Tide Hydrodynamic Survey)

Figure 2 presents the results of the hydrodynamic survey conducted on 26 July 2011 during the beginning portion of a flood tide from approximately 12:18 to 13:12. During
the survey depth-averaged current velocities within the area ranged between 0 m/s and approximately 0.25 m/s. Within the South Elizabeth Channel currents generally flowed in a south-easterly direction, however direction of flow throughout the channel was variable, flowing to the south or southwest in some locations. The hydrodynamic survey area extended out from South Elizabeth Channel to the Newark Bay Main Channel, and in this area, currents changed to flow in a northeasterly direction. The greatest current velocities (approximately 0.20 – 0.25 m/s) were also recorded in this area, with velocities observed within the South Elizabeth Channel remaining below approximately 0.15 m/s.

3.1.1.2 27 July 2011 (Ebb Tide Hydrodynamic Survey)

Figure 3 presents the results of the hydrodynamic survey conducted on 27 July 2011 during the first half of an ebb tide from approximately 08:06 to 09:38. During the survey, depth averaged current velocities within the area ranged between 0 and approximately 0.5 m/s. Current direction within the South Elizabeth Channel was highly variable. At the western end of the channel currents flowed mostly in a southwesterly direction, changing gradually towards the southeast in the eastern end of the channel and then swinging back around to a southerly or southwesterly direction near the mouth of the channel. Along the south edge of the channel near the flats, the current direction was more uniformly to the southeast. As was observed previously, the highest current velocities (above 0.25 m/s) were over the flats and in the southeast end of the channel, with current velocities within the majority of the channel less than approximately 0.25 m/s.

3.1.1.3 28 July 2011 (Ebb Tide Hydrodynamic Survey)

Figure 4 presents the results of the hydrodynamic survey conducted on 28 July 2011 during the first half of an ebb tide from approximately 09:16 to 10:37. During the survey, depth averaged current velocities within the area ranged between close to 0 and approximately 0.45 m/s. Similar to the previous two surveys, current direction within the South Elizabeth Channel was highly variable. At the western end of the channel currents flowed mostly in a south-southwesterly direction at low speed (generally less than 0.2 m/s). Moving east down the length of the channel towards the Main Channel of Newark Bay, the currents gradually changed to a more uniform southeasterly direction with increasing speeds. The current speeds in the Main Channel of Newark Bay ranged from approximately 0.25 to 0.30 m/s. The highest current velocities observed during this survey (approximately 0.35 to 0.45 m/s) were seen in an area over the corner of the flats to the southeast of South Elizabeth Channel.
Results of the hydrodynamic surveys show that the current directions in the South Elizabeth Channel during both flood and ebb tides were generally similar to each other. Moreover, there did not appear to be any distinct bi-directional flow pattern as seen in the Main Channel of Newark Bay. During both tides, current speed in South Elizabeth Channel proper was generally low (less than 0.2 m/s) compared to current speeds in the Main Channel of Newark Bay. These results are not surprising given the relatively sheltered “backwater” location of South Elizabeth Channel.

### 3.1.2 Ambient Conditions

It is important to consider that no single TSS measurement adequately represents ambient conditions; instead a range of samples, collected across multiple depth and tidal conditions, is a better representation of the dynamic nature of suspended sediment concentrations in a tidal estuary. Similarly, as noted above, if multiple calibrations are required due to changing conditions, it is important that corresponding ambient samples are collected that can be associated with each condition. During this survey, a total of 70 ambient water samples were collected at various depths and tidal conditions on 26 through 29 July 2011, and later analyzed in the laboratory for TSS and turbidity (Table 1). Ambient turbidity values ranged from 3.3 to 31.8 NTU, and the corresponding TSS values ranged between 21.2 to 80.8 mg/L.

For the purposes of delineating the margins of a sediment plume, it is necessary to determine a single critical TSS concentration, below which are ambient conditions and above which are plume conditions. Because of the naturally heterogeneous distribution of suspended sediment, ambient conditions are often associated with a large range of TSS concentrations and the distribution of these values is rarely symmetric. As a result, the average ambient TSS measured will often underestimate the ambient condition and thus using a percentile approach as a measure of central tendency is more applicable. Choice of which percentile to use is largely a matter of which one most clearly demarcates the plume from the background condition (i.e. removes the natural “noise” of the ambient condition), but typically it ranges from the 50th percentile (median) to 95th percentile. For this study, the 37th percentile of 40 mg/L was used as the TSS critical value which would best provide a clearly visible demarcation of the plume against background conditions. Hence, all acoustically estimated TSS concentrations greater than 40 mg/L are herein considered above background and attributable to the dredge-induced plume unless otherwise noted, e.g., clearly attributable to air entrainment, vessel prop wash, or from
other sources of resuspension such as tug and ship plumes, or from side-lobe interference (see ADCP calibration methods, Section 2.5, for further information).

3.1.3 Mobile ADCP Surveys

3.1.3.1 25 July 2011 (Flood Tide)

The 25 July 2011 mobile ADCP plume characterization was completed during the beginning of a flood tide from approximately 11:42 to 13:27 (Figures 5a-o). The survey consisted of three ambient transects (Figures 5c through 5e), three circle transects (Figures 5a, 5b, and 5f), and nine down-current transects (Figures 5g through 5o). The dredge Delaware Bay changed location after the first two circle transects were completed. The third circle transect (C03) encompasses the location of the dredge when the up-current and down-current transects were recorded. A summary of each of the graphically represented transects is presented in Table 2.

To examine the spatial extent of the plume, a series of plan-view layouts are given in Figures 6a through 6h. During this survey, the dredge Delaware Bay was located approximately 330 meters northwest of the of the green “1” navigation buoy. Ambient transects were conducted northwest of the dredge while down-current transects were southeast of the dredge and oriented perpendicular to the channel. Figure 7 provides a three-dimensional depiction of average TSS values for selected representative transects.

Figures 5c through 5e show up-current TSS concentrations between 0 and 40 mg/L throughout most of the water column. Estimated TSS concentration signatures above ambient (40 mg/L) associated with the dredge operation were limited to within the first 344 meters down-current of the dredge (Transects T01 – T07). In these transects, a clearly defined plume was detectable within the lower half of the water column (depths >7 meters), with peak concentrations of 200-250 mg/L at a depth of around 12-14 meters within 90 meters of the source (Transect T01). Plume width varied from approximately 50-120 meters at various locations, expanding laterally to a maximum width at 126 meters down-current and then narrowing as the plume began to dissipate as the distance from the dredge increased. Because many of the transects extended into shallower water, some side-lobe reflectivity was observed on the slopes.

Figure 8 presents the hydrodynamic conditions recorded during the 25 July 2011 mobile ADCP survey discussed above. During the survey, depth-averaged current velocities within the area ranged between 0 m/s and approximately 0.25 m/s. Within the South
Elizabeth Channel currents generally flowed in a south-easterly direction, but towards the southeast edge of the channel and onto the adjacent flats, currents flowed more to the south to southwest. These observations are consistent with observations of the sediment plume gathered in this survey, where the plume was seen directly to the southeast (down-current) of the dredge locations. The highest current velocities (>0.10 m/s) were observed in a very small area along the south edge of the channel, current velocities in the vast majority of the survey area were under 0.10 m/s. These velocities were relatively low, and are consistent with the relatively short distance (197 m from the dredge) within which the plume was observed during this survey.

### 3.1.3.2 26 July 2011 (Flood Tide)

The 26 July 2011 mobile ADCP plume characterization was completed during the peak of a flood tide from approximately 14:16 to 14:45 (Figures 9a-k). The survey consisted of one circle transect (Figure 9a), three ambient transects (Figures 9b through 9d), and seven down-current transects (Figures 9e through 9k). A summary of each of the graphically represented transects is presented in Table 3.

To examine the spatial extent of the plume, a series of plan-view layouts are given in Figures 10a through 10h. For this survey, the dredge Delaware Bay was located approximately 400 meters northwest of the green “1” navigation buoy. Ambient transects were conducted northwest of the dredge while down-current transects were southeast of the dredge and oriented perpendicular to the channel. Figure 11 provides a three-dimensional depiction of average TSS values for selected representative transects.

Figures 9b through 9d show up-current TSS concentrations below 70 mg/L throughout most of the water column, with slightly higher concentrations (70-120 mg/L) observed along the bottom (approximately 12 m depth and below). Estimated TSS concentration signatures above ambient (40 mg/L) associated with the dredge operation were limited to within the first 476 meters down-current of the dredge (Transects T01 – T07). In these transects, a clearly defined plume was detectable in the bottom quarter of the water column (depth greater than approximately 12 meters), with peak concentrations of approximately 250 mg/L at a depth of around 14 meters within 102 meters of the source (Transect T01). Plume width remained approximately 100 meters for the extent of the plume, spreading out to cover the entire width of the channel, but not extending beyond the sides of the channel. At Transect T07, 476 meters down-current, the TSS concentrations and distribution pattern were similar to the ambient transects. Since many
of the transects extended into shallower water, some side-lobe reflectivity was observed on the slopes. An anomalous region of high backscatter was detected in Transect T07, however this was likely due to some interference (e.g. physical object) in the ADCP data as evidenced by the loss of bottom tracking (which accounts for the large spike in the seabed elevation).

Figure 12 presents the hydrodynamic conditions recorded during the above 26 July, 2011 mobile ADCP survey. During the survey, depth-averaged current velocities within the area ranged between 0 m/s and approximately 0.35 m/s. Within the South Elizabeth Channel currents generally flowed in a south-easterly direction, but in the western portion of the survey area, currents swept around from a southerly to a southeasterly direction, moving from the west to east. In the eastern half of the channel area, the currents flowed more uniformly to the southeast, this was also where the highest current velocities, from approximately 0.20 up to 0.35 m/s, were observed. In the western portion of the channel, current velocities were below approximately 0.25 m/s.

3.1.3.3 27 July 2011 (Ebb Tide)

The 27 July 2011 mobile ADCP plume characterization was completed during the peak of an ebb tide from approximately 09:44 to 10:42 (Figures 13a to 13l). The survey consisted of two circle transects (Figures 13a and 13b), four ambient transects (Figures 13c through 13f), and six down-current transects (Figures 13g through 13l). A summary of each of the graphically represented transects is presented in Table 4.

To examine the spatial extent of the plume, a series of plan-view layouts are given in Figures 14a through 14h. For this survey, the dredge Delaware Bay was located approximately 450 meters northwest of the green “1” navigation buoy. Ambient transects were conducted northwest of the dredge while down-current transects were southeast of the dredge and oriented perpendicular to the channel. Figure 15 provides a three-dimensional depiction of average TSS values for selected representative transects.

Figures 13c through 13f show up-current TSS concentrations between 0 and 40 mg/L throughout most of the water column, with some smaller areas of slightly higher concentrations (40-70 mg/L) close to the bottom (approximately 12 m depth and below). Estimated TSS concentration signatures above ambient (40 mg/L) associated with the dredge operation were limited to within the first 247 meters down-current of the dredge (Transects T01 – T04). In these transects, a clearly defined plume was detected in the
bottom third of the water column (depth >10 meters), with peak concentrations of 300 mg/L at a depth of around 14 meters within 113 meters of the source (Transect T01). The plume varied from approximately 70-90 meters in width, decreasing in both width and height as the distance from the dredge increased. Since many of the transects extended into shallower water, some side-lobe reflectivity was observed on the channel side slopes.

Figure 16 presents the hydrodynamic conditions recorded during the above 27 July 2011 mobile ADCP survey. During the survey, depth-averaged current velocities within the South Elizabeth Channel were approximately 0.10 m/s or less. Current direction was generally southeast throughout the length of the survey area, but was closer to south-southeast or south towards the western part of the survey area.

### 3.1.3.4 29 July 2011 (Ebb Tide)

The 29 July 2011 mobile ADCP plume characterization was completed during the beginning of an ebb tide from approximately 11:22 to 13:22 (Figures 17a to 17p). The survey consisted of four circle transects (Figures 17a-d), four ambient transects (Figures 17e-h), and six plume transects (Figures 17i-p). A summary of each of the graphically represented transects is presented in Table 5.

To examine the spatial extent of the plume, a series of plan-view layouts are given in Figures 18a through 18h. For this survey, the dredge Delaware Bay was located approximately 170 meters northwest of the green “1” navigation buoy. Ambient transects were conducted up-current (northwest) of the dredge while down-current transects were southeast of the dredge and oriented perpendicular to the channel. Figure 19 provides a three-dimensional depiction of average TSS values for selected representative transects.

Figures 17e-17h show up-current TSS concentrations between 0 and 40 mg/L throughout most of the water column. Estimated TSS concentration signatures above ambient (40 mg/L) associated with the dredge operation were limited to within the first 196 meters down-current (east) of the dredge (Transects T01 – T08). In these transects, a small well-defined plume was detected in the bottom quarter of the water column (depths greater than approximately 11 meters), with peak concentrations of up to approximately 160 mg/L from 81-93 meters from the source (Transects T01 and T02). Plume width varied from approximately 15-35 meters but was largely concentrated to the channel side slopes and did not extend onto the adjacent flats. Because the plume was concentrated at the toe of the side slope, some of the plume signature was masked by side lobe interference and
the two distinct signatures can be seen superimposed on each other (e.g. Transect T02). Furthermore, these same side lobe patterns also were recorded on transects without plume (e.g. Transect T06), as well as on up-current transects (e.g. Transects A01-A04), and thus were not part of the dredge-induced plume.

Figure 20 presents the hydrodynamic conditions recorded during the above 29 July 2011 mobile ADCP survey. During the survey, depth-averaged current velocities within the area ranged between close to 0 m/s to approximately 0.30 m/s. The greatest current velocities (approximately 0.15 to 0.30 m/s) were observed in an area along the southeastern edge of the survey area adjacent to and over the flats. Current velocities in the majority of the rest of South Elizabeth Channel were approximately 0.15 m/s or less. Current direction in the western half of the survey area was generally to the southeast, but towards the mouth of the South Elizabeth Channel the currents were more south-southwest. This variation from the prevailing current direction of the area may account for the small amount of plume observed on the ambient transects conducted within 73 meters of the dredge (Figures 17e and 17f).

3.1.4 Fixed Station Turbidity Surveys

Two fixed station turbidity surveys were conducted, one on 26 July during a flood tide, and one on 29 July during an ebb tide. A total of three fixed arrays were deployed during each survey (one ambient up-current of the dredge, and two down-current of the dredge with the objective to examine turbidity structure within the plume at varying distances from the dredge). The ambient array consisted of one OBS unit tethered at mid-depth while each of the down-current arrays consisted of two OBS units, one tethered at mid-depth and the other at near bottom based on water depth.

3.1.4.1 Flood Tide (26 July 2011)

A fixed station turbidity survey was conducted on 26 July during a flood tide. Figure 21 shows the location of the two down-current arrays and the one up-current array with respect to the dredge position. The down-current arrays were located 150 and 255 meters southeast of the dredge, respectively. The up-current array was located 300 meters to the northwest of the dredge near the end of the channel. The fixed OBS arrays were placed closer to the shoal on the south side of the channel so as to avoid any potential hazards to navigation and to better define any potential plume moving towards the shallow water flats. Figure 22 plots the recorded turbidity values (NTU) from the mid-depth (red line),
and bottom (black line) OBS units. Ambient turbidity is plotted as a blue line and superimposed on both of the down-current plots for comparison.

Overall, mid-water and bottom turbidity readings from both down-current OBS arrays were similar, both between depths and between the near and far arrays. These readings were also similar overall to ambient conditions recorded by the up-current array. Turbidity averaged 8.0 NTU for all down-current arrays, across all depths and the entire length of the survey, compared to an average of 8.5 NTU at the up-current array across the survey.

At one point, the turbidity values for the ambient array rose above those recorded at any depth by both of the down-current arrays. This occurred during a period beginning around 13:33 when turbidities rose rapidly from approximately 10 NTU to around 40 NTU. Up-current turbidity values reached a peak of 41.6 NTU at 13:39 before gradually returning to around 10 NTU by 14:07. A corresponding rise in turbidities was not seen at any of the down-current arrays during this time period. The mobile ADCP survey conducted during the same tide cycle detected the plume down-current (southeast) from the dredge and confined to the bottom half of the water column, at its greatest extent only present at a depth of 8 meters or below. The average depth of the OBS unit on the up-current array was 5.2 meters, so while the exact source of the rise in turbidity recorded by this array is unknown, it is unlikely that it was associated with dredging operations.

Turbidity values recorded by the down-current arrays showed only a few small deviations from ambient levels during this survey. In the largest of these, the bottom turbidity at the closer down-current array, and both bottom and mid-depth turbidity at the far down-current array all showed a brief increase at around 13:21 to 13:24, this was most pronounced at the close array, where turbidity values reached a maximum of 44.1 NTU.

### 3.1.4.2 Ebb Tide (29 July 2011)

A fixed station turbidity survey was conducted on 29 July during an ebb tide. Figure 23 shows the location of the two down-current arrays and the one up-current array with respect to the dredge position. The down-current arrays were located 200 and 270 meters northwest of the dredge, respectively. The up-current array was first located 100 meters to the southeast of the dredge, but then drifted too close to the dredge *Delaware Bay*, and was redeployed at 152 meters southeast of the dredge approximately two hours into the survey. Both positions are shown on Figure 23. The fixed OBS arrays were placed closer
to the shoal on the south side of the channel so as to avoid any potential hazards to navigation and to better define any potential plume moving towards the shallow water flats. Figure 24 plots the recorded turbidity values (NTU) from the mid-depth (red line), and bottom (black line) OBS units. Ambient turbidity values from the first deployment (blue line), and second deployment (purple line) of the up-current array are superimposed on both of the down-current plots for comparison.

Bottom turbidity values recorded at both of the down-current arrays were very similar to each other, with average values of 7.7 and 9.1 NTU for the duration of the deployment for the near and far array, respectively. Both of these arrays also showed no large changes in bottom turbidity at any time during the deployment. At the array farther down-current (270 meters) from the dredge, mid-depth turbidities were slightly lower than those at the bottom, with an average value of 4.8 NTU. All of these readings were consistent with turbidity levels that would fall within the ambient range for this survey, and were similar to the turbidity values recorded during both deployments of the ambient, up-current array, which averaged 4.5 NTU. The mobile ADCP survey conducted during this survey shows a plume with a very limited spatial extent and largely confined to the toe of the channel side slope. Therefore, the OBS array data are consistent with the ADCP data with no evidence of the suspended sediment plume extending beyond 150 meters from the dredge.

The OBS unit set at mid-depth in the down-current array located 200 meters from the dredge malfunctioned during deployment and recorded erroneous values when the sensor shifted and was obscured by a solid object, likely either the tether line or the shackles used to attach the instrument. The data collected by this particular OBS unit during this survey is therefore considered invalid.

### 3.1.5 Laboratory Analysis of Water Samples

A total of 120 water samples were collected in the project area during the week of 25 July 2011. The laboratory results of the optical turbidity and the gravimetric analysis of TSS concentration of those 120 samples are presented in Table 1. To provide a robust data set for calibration of the ADCP backscatter, samples were taken from locations to represent the broadest possible concentration gradient, from ambient to the highest TSS concentrations that could be safely collected in the area of the active dredging operation.
In this study, the TSS concentrations of the 120 water samples ranged from 21.2 to 139 mg/L and turbidity concentrations ranged from 3.3 to 67.6 NTU. Figure 25a plots the paired gravimetric measurements and ADCP acoustic estimates of TSS arranged in concentration versus time order for the 81 water samples used in the Sediview calibration. Note that some of the 120 water samples collected were excluded if they exhibited clear signs of air bubble contamination, interference with the water sampler apparatus, or contact with the sea bottom (see ADCP calibration methods described in section 2.5). Overall, there was a strong agreement ($R^2 = 0.84$) between the acoustic estimates of TSS concentration and the gravimetric measurements (Figure 25b).

### 3.1.6 Sediment Samples

A total of nine sediment samples were collected (four from the dredge scow and five from the dredge area) during the week of 25 July 2011. The laboratory results of these sediment collections for grain size distribution, density and Atterberg Limits are presented in Table 6. Sediment samples collected during the S-NB-2/S-AK-1 Far-field Survey #1 were comprised mostly fine sand, silt, and clay, with silt comprising between 23% and 78% of each sample collected. Each of the samples collected also consisted of 14% to 35% clay and 3% to 46% fine sand. Across all nine samples, the average grain size distribution was: Gravel (6%), Coarse Sand (1%), Medium Sand (4%), Fine Sand (20%), Silt (48%), and Clay (21%). None of the samples collected contained more than 20% of medium sand or coarser material, with the exception of the dredge area samples taken on 26 and 27 July, which each contained 21% gravel. The in-place density of the sediment samples ranged between 0.459 and 1.120 g/cc (Table 6).

### 3.1.7 Dredging Operations — Bucket Cycles

To examine the bucket cycle sequence, a video record was obtained of 10 complete cycles during an ebb tide on 29 July, 2011. The video was then analyzed for time increments for each component of the cycle (Figure 26). The average total elapsed time per cycle was 102 seconds. A certain degree of variability in cycle component elapsed times can be seen across the 10 cycles in Figure 26. The shortest cycle was 72 seconds, whereas the longest cycle was 165 seconds. These results were consistent with the variability seen in mechanical bucket dredging operations observed during previous harbor deepening monitoring surveys (USACE 2007 and USACE 2011).
Average time for each component of the dredge cycle was: Descent (22 seconds), Grab (7 seconds), Raise (21 seconds), Slew Over (29 seconds), Dump (10 seconds), and Slew Back (12 seconds).

3.2 S-NB-2/S-AK-1 Far Field Survey #2 (Week of 03 October 2011)

3.2.1 Hydrodynamic Surveys

General hydrodynamic conditions within South Elizabeth Channel and its immediate vicinity were assessed during both ebb (03 October) and flood tides (05 October). Transects were conducted approximately perpendicular to the South Elizabeth Channel. Additionally, the specific hydrodynamic conditions during each mobile ADCP TSS survey (see below) were also recorded to aid in the interpretation, and place the corresponding TSS data in a hydrodynamic context. These results are discussed along with each TSS survey in Section 3.2.3. The results of the hydrodynamic surveys are discussed below and presented in Figures 27 and 28.

For comparison purposes, the predicted currents in the South Reach of Newark Bay for the respective survey day are shown on Figures 27 and 28. Current predictions were generated using NobleTec Tides & Currents™ software. The predicted currents data show the water speed (in m/s; blue bars) and direction (negative values for ebb, positive for flood) and is useful to place a particular survey within the daily tide cycle.

3.2.1.1 03 October 2011 (Ebb Tide Hydrodynamic Survey)

Figure 27 presents the results of the hydrodynamic survey conducted on 03 October 2011 during the first half of an ebb tide from approximately 14:58 to 15:54. During the survey, depth averaged current velocities within the area ranged from 0 to approximately 0.50 m/s. The highest current velocities (approximately 0.35 to 0.50 m/s) were observed in a narrow area along the corner of the flats to the south of South Elizabeth Channel. Current velocities within the South Elizabeth Channel were observed to be less than 0.20 m/s, and velocities in the area of the Main Channel of Newark Bay which was covered by this survey were generally observed to be between approximately 0.20 and 0.30 m/s. Current direction observed during this survey varied with location. In the Main Channel of Newark Bay and along the corner of the flats to the south of the South Elizabeth Channel the direction was generally to the south and west. Within the South Elizabeth Channel the
current direction varied from west-southwest closer to the bulkhead at the north side of the channel to south-southeast closer to the flats at the south side of the channel.

3.2.1.2 05 October 2011 (Flood Tide Hydrodynamic Survey)

Figure 28 presents the results of the hydrodynamic survey conducted on 05 October 2011 during the first half of a flood tide from approximately 12:16 to 14:43. During the survey, depth-averaged current velocities within the area ranged from near 0 m/s up to approximately 0.50 m/s. The greatest current velocities (above 0.20 m/s) were observed along the flats to the south of the South Elizabeth Channel. The very highest velocities (approximately 0.35 to 0.50 m/s) were observed in a small area at the corner of these flats to the southeast of the channel. Current directions observed in the South Elizabeth Channel and over nearby flats during this survey were generally eastward. At the eastern end of the survey area, towards the Newark Bay Main Channel, current direction turned more towards the northeast.

3.2.2 Ambient Conditions

A total of 41 ambient water samples were collected at various depths on 03-07 October 2011, and later analyzed in the laboratory for TSS and turbidity (Table 7). Ambient turbidity values ranged from 5.2 to 18.4 NTU, and the corresponding TSS values ranged between 8.0 to 49.2 mg/L. However, for the purposes of delineating the margins of a sediment plume, it is necessary to determine a single critical TSS concentration, below which are ambient conditions and above which are plume conditions. For this study, the 58th percentile of 40 mg/L was used as the TSS critical value which would best provide a clearly visible demarcation of the plume against background conditions. Hence, all acoustically estimated TSS concentrations greater than 40 mg/L are herein considered above background and attributable to the dredge-induced plume unless otherwise noted, e.g., clearly attributable to air entrainment, vessel prop wash, or from other sources of resuspension such as tug and ship plumes, or from side-lobe interference (see ADCP calibration methods, Section 2.5, for further information).

3.2.3 Mobile ADCP Surveys

3.2.3.1 04 October 2011 (Flood Tide)

The 04 October 2011 mobile ADCP plume characterization was completed during the beginning portion of a flood tide from approximately 13:12 to 15:21 (Figures 29a-n). The survey consisted of one circle transect (Figure 29a), three ambient transects (Figures 29l
through 29n), and ten down-current transects (Figures 29b through 29k). A summary of each of the graphically represented transects is presented in Table 8.

To examine the spatial extent of the plume, a series of plan-view layouts are given in Figures 30a through 30g. During this survey, the dredge Delaware Bay was located approximately 325 meters west-northwest of the green “1” navigation buoy. Ambient transects were conducted northwest of the dredge and oriented perpendicular to the channel, while down-current transects were southeast of the dredge and oblique to the channel. Figure 31 provides a three-dimensional depiction of average TSS values for selected representative.

Figures 29l through 29n show up-current TSS concentrations between 0 and 40 mg/L throughout most of the water column. In this survey, the dredge was situated outside of the channel in the shallow water flats to the south. Circle transect C01 recorded some backscatter activity at the 8-10 meter depth interval along the channel side slopes just to the north and east of the dredge (Figure 30d), although some of this backscatter could be attributed to side-lobe reflectivity. Estimated TSS concentration signatures above ambient (40 mg/L) associated with the dredge operation within the South Elizabeth Channel were primarily limited to within the first 434 meters down-current of the dredge (Transects T01 – T09). In these transects, a light plume was detected within the bottom quarter (depths greater than approximately 11 meters) of the water column, with peak concentrations of approximately 90 mg/L close to the bottom and within 174 meters of the source (Transect T01). Plume width varied from approximately 50-150 meters at various locations. Because many of the transects extended into shallower water, some side-lobe reflectivity was observed on the slopes.

Figure 32 presents the hydrodynamic conditions recorded during the above 4 October 2011 mobile ADCP survey. During the survey, depth-averaged current velocities within the area ranged between close to 0 to approximately 1.30 m/s. However, the very high current velocities (approximately 0.50-1.30 m/s) observed in a small area over the flats to the south of South Elizabeth Channel were likely artifacts of the ADCP surveying in very shallow water (~1.5 m deep at the time of the survey). Current velocities in the surrounding area were between approximately 0.20 and 0.30 m/s, which were more typical of the hydrodynamic conditions. In the remaining areas of South Elizabeth Channel, current velocities were approximately 0.20 m/s or less. At both the western and eastern ends of the channel, current directions were observed to range from southeast to
southwest, and in an area between this and along the Port Elizabeth bulkhead, current direction was variable and current velocity very low.

### 3.2.3.2 06 October 2011 (Ebb Tide)

The 06 October 2011 mobile ADCP plume characterization was completed during the beginning portion of an ebb tide from approximately 08:42 to 09:43 (Figures 33a-o). The survey consisted of one circle transect (Figure 34a), three ambient transects (Figures 33m through 33o), and eleven down-current transects (Figures 33b through 33l). A summary of each of the graphically represented transects is presented in Table 9.

To examine the spatial extent of the plume, a series of plan-view layouts are given in Figures 34a through 34g. For this survey, the dredge Delaware Bay was located approximately 400 meters west-northwest of the green “1” navigation buoy. Ambient transects were conducted northwest of the dredge and oriented perpendicular to the channel, while down-current transects were conducted both north of the dredge (parallel to the channel), and southeast of the dredge (perpendicular to the channel). This was due to the position of the dredge in very shallow water and the extent and direction of the plume (Figures 34a-g, Table 9). Figure 35 provides a three-dimensional depiction of average TSS values for selected representative transects.

Figures 33m through 33o show up-current TSS concentrations between 0 and 40 mg/L throughout most of the water column. Estimated TSS concentration signatures above ambient (40 mg/L) associated with the dredge operation were limited to within the first approximately 164 meters down-current of the dredge (Transects T02 – T05, T07 - T08). In these transects, a clearly defined plume was detected extending from the top to the bottom of the water column (Transects T02, T03). As the plume began to dissipate, it remained only in the top third (approximately 5 meters depth and above) of the water column (Transect T04, T07-T08) as a result of the prevailing current pattern and physical components of the water column (i.e., temperature, salinity and water density). Peak TSS concentrations within the plume reached approximately 200 mg/L close to the bottom and within 46 meters of the source (Transect T02). Plume width varied from approximately 50-185 meters at various locations, in general being more spread out closer to the source and becoming narrower as the distance from the dredge increased. Since many of the transects extended into shallower water, side-lobe reflectivity was observed on the slopes. Heavy side-lobe reflectivity was recorded along the bottom of Transect T08. This
transect was recorded along the bank (i.e. parallel to the channel slope), causing side-lobe reflectivity with no apparent depth change.

Figure 36 presents the hydrodynamic conditions recorded during the above 06 October 2011 mobile ADCP survey. During the survey, depth-averaged current velocities within the area ranged from close to 0 m/s to approximately 0.25 m/s. The highest current velocities (approximately 0.15-0.25 m/s) were observed in areas over the flats to the south of South Elizabeth Channel. In the remaining areas of South Elizabeth Channel, current velocities were approximately 0.10 m/s or less. Current directions observed during this survey were overall oriented towards the east-southeast and out of the channel. The plume observed during this survey was generally to the northeast of the dredge and remained relatively close to the dredge, which was consistent with the relatively slow current velocities observed, and the northeasterly to southeasterly current direction.

3.2.3.3 07 October 2011 (Ebb Tide)

The 07 October 2011 mobile ADCP plume characterization was completed during an ebb tide from approximately 09:09 to 10:54 (Figures 37a through 37i). The survey consisted of three ambient transects (Figures 37g through 37i), and six down-current transects (Figures 37a through 37f). A summary of each of the graphically represented transects is presented in Table 10.

To examine the spatial extent of the plume, a series of plan-view layouts are given in Figures 38a through 38g. For this survey, the dredge Delaware Bay was located approximately 550 meters west-northwest of the green “1” buoy. Ambient transects were conducted northwest of the dredge and oriented perpendicular to the channel, while down-current transects were conducted north of the dredge and parallel to the channel. This was due to the position of the dredge in very shallow water and the extent and direction of the plume (Figures 38a-g, Table 10). Figure 39 provides a three-dimensional depiction of average TSS values for selected representative transects.

Figures 37g through 37i show up-current TSS concentrations between 0 and 40 mg/L through the top half to two-thirds (top 7-10 meters) of the water column. The up-current transects (transects A01-A03) showed a layer of ambient resuspension between approximately 50-80 mg/L in the lower half (below approximately 7 meters) of the water column. The highest up-current concentrations were seen at 109 meters from the dredge,
in the transect farthest up-current (transect A03, Figure 37i), and were potentially due to a naturally occurring resuspension of sediments (caused by tidal flows and shallow water depths) or a residual plume from the preceding tidal phase. The latter could be due to the lack of current flow to diffuse the plume and the shallow water depths. Estimated TSS concentration signatures above ambient (40 mg/L) associated with the dredge operation were limited to within the first approximately 151 meters down-current of the dredge (Transects T01 – T05). In these transects, a clearly defined plume was detected extending from the top to the bottom of the water column, with peak concentrations of approximately 200 mg/L within the bottom 1-2 meters of the water column and within 48 meters of the source (Transect T01). Plume width varied from approximately 100-200 meters at various locations, spreading out further closer to the source and becoming less extensive as the distance from the dredge increases. Since many of the transects extend into shallower water, some side-lobe reflectivity was observed on the slopes and bottom.

Figure 40 presents the hydrodynamic conditions recorded during the above 07 October 2011 mobile ADCP survey. During the survey, depth-averaged current velocities within the area ranged from close to 0 m/s to approximately 0.20 m/s. The highest current velocities (approximately 0.15-0.20 m/s) were confined to a small area at the edge the flats to the south of South Elizabeth Channel. In the remaining areas of South Elizabeth Channel, current velocities were approximately 0.10 m/s or less. Current directions observed during this survey were generally towards the east and south.

3.2.4 Fixed Station Turbidity Surveys

Two fixed station turbidity surveys were conducted, one on 05 October during a flood tide, and one on 06 October during an ebb tide. A total of three fixed arrays were deployed during each survey (one ambient up-current of the dredge, and two down-current of the dredge with the objective to examine turbidity structure within the plume at varying distances from the dredge). The ambient array consisted of two OBS units, one tethered at one-quarter of the total water column depth (near surface) and one at mid-depth. Each of the down-current arrays consisted of two OBS units, one tethered at one-quarter of the total water column depth (near surface), and one at three-quarters of total water depth (near bottom). Each of the fixed arrays (both ambient and down-current) was located within the vicinity of the active dredging operation.
3.2.4.1 Flood Tide (05 October 2011)

A fixed station turbidity survey was conducted on 05 October during a flood tide. Figure 41 shows the location of the two down-current arrays and the one up-current array with respect to the dredge position. The down-current arrays were located 85 and 300 meters southeast of the dredge, respectively. The up-current array was located 370 meters northwest of the dredge. The fixed OBS arrays were placed close to or on top of the shoal on the south side of the channel so as to avoid any potential hazards to navigation and to better define any potential plume moving onto the shallow water flats. Figure 42 plots the recorded down-current turbidity values (NTU) from the mid-depth (red line), and bottom (black line) OBS units. Ambient turbidity is plotted from the near-surface (blue line) and near-bottom (purple line) up-current OBS units and superimposed on both of the down-current plots for comparison.

Throughout the duration of the survey, down-current arrays recorded very similar surface and bottom turbidity values to the surface and mid-depth turbidity values recorded by the up-current ambient array. Average surface and bottom turbidities from the near down-current array were 3.6 and 3.4 NTU respectively, from the far down-current array 6.2 and 5.8 NTU respectively, while average ambient surface and bottom turbidities from the up-current array were 4.0 and 5.4, respectively. None of the turbidity readings from any of the OBS units in this survey showed any large variations above ambient levels, and no readings above 9.1 NTU were recorded at any array. According to the daily field report for this date, active dredging was occurring throughout the deployment period of the arrays.

3.2.4.2 Ebb Tide (06 October 2011)

A fixed station turbidity survey was conducted on 06 October during an ebb tide. Figure 43 shows the location of the two down-current arrays and the one up-current array with respect to the dredge position. The down-current arrays were located 120 and 405 meters southeast of the dredge, respectively. The up-current array was located 320 meters northwest of the dredge. The fixed OBS arrays were placed close to or on top of the shoal on the south side of the channel so as to avoid any potential hazards to navigation and to better define any potential plume moving onto the shallow water flats. Figure 44 plots the recorded turbidity values (NTU) from the mid-depth (red line), and bottom (black line) OBS units. Ambient turbidity is plotted from the near-surface (blue line) and near-bottom (purple line) up-current OBS units and superimposed on both of the down-current plots for comparison.
Overall, turbidity values recorded at the down-current arrays during this survey did not differ greatly from those recorded at the up-current ambient array (Figure 44). Average surface and bottom turbidities from the near down-current array were 7.4 and 6.0 NTU respectively, from the far down-current array 5.8 and 3.6 NTU respectively, while average ambient surface and bottom turbidities from the up-current array were 4.2 and 5.0, respectively. At the closer (120 meters from the dredge) down-current array, near-surface, and to a lesser extent near-bottom turbidities did climb somewhat above ambient values for a period of time. This occurred between approximately 09:53 and 10:25, when near-surface turbidities rose from around 6 NTU to a peak of 20.9 NTU. Near-bottom turbidities during the same span of time peaked at 13.7 NTU.

### 3.2.5 Laboratory Analysis of Water Samples

A total of 94 water samples were collected in the project area during the week of 03 October, 2011. The laboratory results of the optical turbidity and the gravimetric analysis of TSS concentration of those 94 samples are presented in Table 7. To provide a robust data set for calibration of the ADCP backscatter, samples were taken from locations to represent the broadest possible concentration gradient from ambient to the highest TSS concentrations that could be safely collected in the area of the active dredging operation.

In this study, the TSS concentrations of the 94 water samples ranged from 8 to 103 mg/L and turbidity concentrations ranged from 3.9 to 53.2 NTU. Figures 45a, 46a, and 47a plot the paired gravimetric measurements and ADCP acoustic estimates of TSS arranged in concentration versus time order for the 64 water samples used in the Sediview calibrations. Note that some of the 94 water samples collected were excluded if they exhibited clear signs of air bubble contamination, interference with the water sampler apparatus, or contact with the sea bottom (see ADCP calibration methods described in section 2.5). Also note that a Sediview calibration was performed for each mobile ADCP survey rather than for the entire survey week. This is due to the fact that water conditions changed enough between each survey day that a single calibration spanning the entire survey could not be achieved. Overall, there was a strong agreement ($R^2 = 0.91, 0.85, \text{and } 0.76$) between the acoustic estimates of TSS concentration and the gravimetric measurements (Figures 45b, 46b, 47b) for each calibration period.
3.2.6 Sediment Samples

A total of nine sediment samples were collected (four from the dredge scow and five from the dredge area) during the week of 03 October, 2011. The laboratory results of these sediment collections for grain size distribution, density and Atterberg Limits are presented in Table 11. Sediment samples collected during the S-NB-2/S-AK-1 Far-Field Survey #2 were comprised mostly of silt, fine sand, and clay, with silt comprising between 20% and 65% of each sample collected. Each of the samples collected also consisted of 4% to 52% fine sand and 6% to 32% clay. Each sample contained only 0.2% to 20% medium sand and coarser material. The in-place density of the sediment samples ranged between 0.461 and 1.32 g/cc (Table 11).

3.2.7 Dredging Operations — Bucket Cycles

To examine the bucket cycle sequence, a video record was obtained of 13 complete cycles during a flood tide on 06 October, 2011. The video was then analyzed for time increments for each component of the cycle (Figure 48). The average total elapsed time per cycle was 87 seconds. A certain degree of variability in cycle component elapsed times can be seen across the 13 cycles in Figure 48. The shortest cycle was 67 seconds, whereas the longest cycle was 109 seconds.

Average time for each component of the dredge cycle was: Descent (21 seconds), Grab (9 seconds), Raise (13 seconds), Slew Over (22 seconds), Dump (9 seconds), and Slew Back (10 seconds).

4.0 DISCUSSION

During the course of normal dredging operations, some sediment is resuspended into the water column. In many cases, this suspended sediment is evident as a visible turbidity plume within the immediate vicinity of the dredge operation. Because suspended sediment plumes are dynamic rather than static phenomena and because they vary over large areas in short periods of time, particularly when driven by tidal forces, characterizing plumes can present a difficult challenge. Data collected at arbitrarily determined points in time at fixed locations are inadequate to assess dredge plume structure. However, advanced acoustic technologies offer advantages in capturing data at appropriate spatial and temporal scales to allow more accurate interpretation of plume dynamics (Tubman & Corson 2000).
As part of USACE-NYD’s Harbor-wide WQ/TSS Monitoring Program, two far-field WQ/TSS surveys were conducted during the weeks of 25 July 2011 and 03 October 2011 within the S-NB-2/S-AK-1 contract area of the South Elizabeth Channel in Newark Bay, New Jersey. The objective of the far-field survey was to assess the spatial extent and temporal dynamics of suspended sediment plumes associated with environmental or “closed” clamshell bucket dredging of fine-grained sediment. The methodologies employed for this survey were similar to those used previously to survey WQ/TSS within the Arthur Kill (USACE 2007), Newark Bay (USACE 2008 and USACE 2009), and Port Elizabeth Channel (USACE 2010), and course-grained sand in Anchorage Channel (USACE 2011); as well as cutterhead dredging of sediments in the Kill Van Kull (USACE 2012a and USACE 2012b). However, direct comparisons between studies are inexact due to the varying hydrodynamic conditions and sediment types within the different study areas. Sediment conditions in the S-NB-2/S-AK-1 contract area were predominantly fine sand, silt, and clay (Tables 6 and 11). Fine grained sediments such as these can remain in suspension for longer than coarser sediments might.

The acoustic backscatter patterns and dimensions observed during the far-field surveys conducted within the S-NB-2/S-AK-1 contract area were varied depending on the tide and the location of the dredge operating within South Elizabeth Channel. In nearly all mobile ADCP surveys conducted, however, the suspended sediment plume was confined to the lower half of the water column and did not extend outside of the navigation channel. Exceptions to this were the two surveys conducted on an ebb tide during the week of 03 October 2011, when the plume was observed throughout the water column close to the dredge. In these cases, the dredge was positioned partially over the channel side slopes and over the flats adjacent to South Elizabeth Channel and the total water column was shallower than in previous surveys. However, even during these surveys the plume descended to the bottom half of the water column within 100 meters of the dredge. Peak suspended sediment concentrations were typically 300 mg/L or less within approximately 100 meters of the dredge platform and dissipated to background conditions within approximately 300 meters of the dredge. Even at its greatest observed distance from the dredge, the plume remained confined either entirely within the South Elizabeth Channel, or just along the edge and slopes of the adjacent flats.

Prevailing currents in the South Elizabeth Channel were highly variable, sometimes exhibiting a more or less uniform direction and sometimes exhibiting eddying characteristics with different current directions observed within a small area. As noted,
current characteristics in South Elizabeth Channel differed from those observed previously in larger channels such as the main channel of Newark Bay or the Anchorage Channel of the Upper Bay (USACE 2008, 2009, 2011). Likely because of its position directly to the south of the Port Elizabeth bulkhead and to the north of a large area of flats, the hydrodynamics of South Elizabeth Channel are more complex. As described previously in Section 3.2.1, during an ebb tide, water heading south and west out of the Newark Bay Main Channel appears to be pulled around the bulkhead and turned westward into the South Elizabeth Channel before turning south and eastward and funneling out of the channel and over the flats. By comparison, during a flood tide, water pulled over the flats and entering the South Elizabeth Channel is then funneled eastward out of the channel before turning north and east into the Newark Bay Main Channel.

Because of these current patterns, and depending on the position of the dredge, the plume was often observed to collect within the channel boundaries on the same side of the dredge (eastern side) during both an ebb and flood tide as was the case during the 25 July and 26 July flood surveys (plume primarily to the east and north of dredge) and 27 July ebb survey (primarily to the east and south of dredge). Mobile ADCP surveys conducted during the week of 03 October 2011 were affected by the position of the dredge Delaware Bay. During this survey, the dredge was positioned over the channel side slopes and over the flats to the south of South Elizabeth Channel such that ADCP transects were recorded not only perpendicular to the channel both up-current and down-current, but also parallel to the channel, in order to give the most complete picture of the suspended sediment plume possible. In these surveys, the plume was shown to quickly dissipate within 300 meters of the dredge which was confirmed by the deployment of the OBS arrays in which down-current (between 85 and 405 meters from the dredge) turbidity over the flats was largely similar to ambient turbidity within the channel.
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Table 1. Laboratory Results of Water Samples, S-NB-2/S-AK-1 Far Field Survey #1 (25-29 July 2011)

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Table 1. Laboratory Results of Water Samples, S-NB-2/S-AK-1 Far Field Survey #1 (25-29 July 2011)

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Table 1. Laboratory Results of Water Samples, S-NB-2/S-AK-1 Far Field Survey #1 (25-29 July 2011)

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<th>Sample</th>
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<td>Plume Description</td>
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<td>Distance From Dredge (m)</td>
<td>Plume Description</td>
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Table 5. 29 July 2011 Far Field Ebb Tide Survey - Transect Summary Table

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<tr>
<th>Transect Number</th>
<th>Figure Number</th>
<th>Time</th>
<th>Transect Length (m)</th>
<th>Distance From Dredge (m)</th>
<th>Plume Description</th>
<th>Additional Field Remarks</th>
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<tr>
<td>C01</td>
<td>17a</td>
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<td>475</td>
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<td>Circle Transects to locate plume</td>
<td>Prop Wash ens 224</td>
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<td>C02</td>
<td>17b</td>
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<td>460</td>
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<td>Circle to located plume</td>
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<td>43</td>
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<td>105</td>
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<tr>
<td>T01</td>
<td>17i</td>
<td>11:54:54</td>
<td>127</td>
<td>81</td>
<td>Plume present on toe of side slope at concentrations up to 160 mg/L. Overlaps with side lobe interference</td>
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<td>T02</td>
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<td>T04</td>
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<td>Plume begins to dissipate, present in bottom of water column</td>
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<td>T05</td>
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<td>T08</td>
<td>17p</td>
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<td>137</td>
<td>196</td>
<td>Very little visible plume, with low concentrations, is present on bottom</td>
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Table 6. Sediment Collection and Analysis Summary Table.
S-NB-2/S-AK-1 Far Field Survey #1 (25-29 July 2011)

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<th>Sample Location</th>
<th>Date Sampled</th>
<th>Time Sampled</th>
<th>Gravel (%)</th>
<th>Coarse Sand (%)</th>
<th>Medium Sand (%)</th>
<th>Fine Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>In Place Density (g/cc)</th>
<th>Liquid Limit (%)</th>
<th>Plastic Limit (%)</th>
<th>Plasticity Index</th>
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1 ASTM D-422 Method
2 ASTM D-2937 Method
3 ASTM D-4318 Method
Table 7. Laboratory Results of Water Samples, S-NB-2/S-AK-1 Far Field Survey #2 (03-07 October 2011)

<table>
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<tr>
<th>Sample</th>
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<th>Turbidity (NTU)</th>
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<td>10:39:07</td>
<td>Plume</td>
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</tr>
<tr>
<td>72</td>
<td>10/7/2011</td>
<td>9:47:19</td>
<td>Plume</td>
<td>85.0</td>
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<tr>
<td>73</td>
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<td>Plume</td>
<td>84.5</td>
<td>44.2</td>
</tr>
<tr>
<td>74</td>
<td>10/7/2011</td>
<td>9:47:22</td>
<td>Plume</td>
<td>78.5</td>
<td>42.2</td>
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</table>
### Table 7. Laboratory Results of Water Samples, S-NB-2/S-AK-1 Far Field Survey #2 (03-07 October 2011)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Sample Date</th>
<th>Sample Time</th>
<th>Location</th>
<th>Total Suspended Solids (mg/L)</th>
<th>Turbidity (NTU)</th>
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<tbody>
<tr>
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<td>9:47:41</td>
<td>Plume</td>
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<td>76</td>
<td>10/7/2011</td>
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<td>45.2</td>
</tr>
<tr>
<td>77</td>
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<td>9:58:17</td>
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<td>96.0</td>
<td>51.2</td>
</tr>
<tr>
<td>78</td>
<td>10/7/2011</td>
<td>9:58:18</td>
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<td>Plume</td>
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<td>7.7</td>
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<td>12.7</td>
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<td>Ambient</td>
<td>37.2</td>
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<td>Ambient</td>
<td>38.8</td>
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<td>Ambient</td>
<td>24.8</td>
<td>6.9</td>
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<td>5.9</td>
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<td>Ambient</td>
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<td>13.1</td>
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<td>Transect Number</td>
<td>Figure Number</td>
<td>Time</td>
<td>Transect Length (m)</td>
<td>Distance From Dredge (m)</td>
<td>Plume Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------</td>
<td>---------------</td>
<td>---------------------</td>
<td>--------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>C01</td>
<td>29a</td>
<td>13:12:07</td>
<td></td>
<td>67</td>
<td>No Plume - side lobe present</td>
</tr>
<tr>
<td>T01</td>
<td>29b</td>
<td>13:31:04</td>
<td>312</td>
<td>174</td>
<td>Light plume along bottom - side lobe present</td>
</tr>
<tr>
<td>T02</td>
<td>29c</td>
<td>13:38:53</td>
<td>230</td>
<td>102</td>
<td>Dredging and plume occurring on channel slope</td>
</tr>
<tr>
<td>T03</td>
<td>29d</td>
<td>13:43:18</td>
<td>349</td>
<td>165</td>
<td>Light plume along bottom</td>
</tr>
<tr>
<td>T04</td>
<td>29e</td>
<td>13:53:23</td>
<td>345</td>
<td>217</td>
<td>Standing plume along bottom of channel</td>
</tr>
<tr>
<td>T05</td>
<td>29f</td>
<td>13:57:51</td>
<td>429</td>
<td>245</td>
<td>Tug wake at surface</td>
</tr>
<tr>
<td>T06</td>
<td>29g</td>
<td>14:03:36</td>
<td>334</td>
<td>259</td>
<td>Light plume along bottom</td>
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<tr>
<td>T07</td>
<td>29h</td>
<td>14:07:31</td>
<td>328</td>
<td>352</td>
<td>Light plume along bottom - beginning to dissipate</td>
</tr>
<tr>
<td>T08</td>
<td>29i</td>
<td>14:12:19</td>
<td></td>
<td>355</td>
<td>Light plume along bottom - beginning to dissipate</td>
</tr>
<tr>
<td>T09</td>
<td>29j</td>
<td>14:14:47</td>
<td>194</td>
<td>434</td>
<td>No visible plume</td>
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<tr>
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<td>29k</td>
<td>14:19:06</td>
<td>313</td>
<td>396</td>
<td>No visible plume - side lobe present</td>
</tr>
<tr>
<td>A01</td>
<td>29l</td>
<td>15:13:32</td>
<td>295</td>
<td>139</td>
<td>Possible lingering plume near bottom - side lobe present</td>
</tr>
<tr>
<td>A02</td>
<td>29m</td>
<td>15:17:43</td>
<td>344</td>
<td>195</td>
<td>No visible plume - side lobe present</td>
</tr>
<tr>
<td>A03</td>
<td>29n</td>
<td>15:21:53</td>
<td>244</td>
<td>338</td>
<td>No visible plume - side lobe present</td>
</tr>
<tr>
<td>Transect Number</td>
<td>Figure Number</td>
<td>Time</td>
<td>Transect Length (m)</td>
<td>Distance From Dredge (m)</td>
<td>Plume Description</td>
</tr>
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<tr>
<td>C01</td>
<td>33a</td>
<td>8:42:43</td>
<td>293</td>
<td>60</td>
<td>Plume present in shallow, near surface water - heavy side lobe</td>
</tr>
<tr>
<td>T01</td>
<td>33b</td>
<td>8:48:17</td>
<td>154</td>
<td>220</td>
<td>No plume - possible sidelobe from bulkhead</td>
</tr>
<tr>
<td>T02</td>
<td>33c</td>
<td>8:51:05</td>
<td>156</td>
<td>46</td>
<td>Plume present throughout water column</td>
</tr>
<tr>
<td>T03</td>
<td>33d</td>
<td>8:53:26</td>
<td>166</td>
<td>83</td>
<td>Plume beginning to dissipate - side lobe present</td>
</tr>
<tr>
<td>T04</td>
<td>33e</td>
<td>8:55:52</td>
<td>212</td>
<td>127</td>
<td>Plume nearly completely dissipated, in top of water column</td>
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<tr>
<td>T05</td>
<td>33f</td>
<td>8:58:49</td>
<td>188</td>
<td>164</td>
<td>No visible plume - possible fish/debris</td>
</tr>
<tr>
<td>T06</td>
<td>33g</td>
<td>9:01:30</td>
<td>205</td>
<td>194</td>
<td>Possible plume in top of water column</td>
</tr>
<tr>
<td>T07</td>
<td>33h</td>
<td>9:04:33</td>
<td>212</td>
<td>140</td>
<td>Possible plume in top of water column</td>
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<td>Plume present, primarily near surface, extending to bottom - heavy side lobe present</td>
</tr>
<tr>
<td>T09</td>
<td>33j</td>
<td>9:12:51</td>
<td>210</td>
<td>281</td>
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<td>33k</td>
<td>9:16:28</td>
<td>226</td>
<td>217</td>
<td>No plume, possible fish/debris - side lobe present</td>
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<td>T11</td>
<td>33l</td>
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<td>164</td>
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<tr>
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<td>33m</td>
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<td>75</td>
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<td>33n</td>
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<td>147</td>
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<td>177</td>
<td>208</td>
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<td>Transect Number</td>
<td>Figure Number</td>
<td>Time</td>
<td>Transect Length (m)</td>
<td>Distance From Dredge (m)</td>
<td>Plume Description</td>
</tr>
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<tr>
<td>T01</td>
<td>37a</td>
<td>9:09:26</td>
<td>197</td>
<td>48</td>
<td>Plume throughout entire water column</td>
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<tr>
<td>T02</td>
<td>37b</td>
<td>9:12:08</td>
<td>247</td>
<td>54</td>
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<tr>
<td>T03</td>
<td>37c</td>
<td>9:15:26</td>
<td>248</td>
<td>90</td>
<td>Plume throughout entire water column, starting to dissipate - side lobe present</td>
</tr>
<tr>
<td>T04</td>
<td>37d</td>
<td>9:19:12</td>
<td>340</td>
<td>114</td>
<td>Plume throughout water column, almost entirely dissipated</td>
</tr>
<tr>
<td>T05</td>
<td>37e</td>
<td>9:23:52</td>
<td>318</td>
<td>151</td>
<td>No plume present - possible fish/debris</td>
</tr>
<tr>
<td>T06</td>
<td>37f</td>
<td>9:28:23</td>
<td>251</td>
<td>167</td>
<td>Unable to get closer to bulkhead due to ships</td>
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<tr>
<td>A01</td>
<td>37g</td>
<td>10:48:06</td>
<td>141</td>
<td>27</td>
<td>Higher ambient concentration (40-70 mg/L) visible in bottom of water column</td>
</tr>
<tr>
<td>A02</td>
<td>37h</td>
<td>10:51:08</td>
<td>177</td>
<td>74</td>
<td>Higher ambient concentration (40-80 mg/L) visible along bottom, sidelobe present</td>
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<tr>
<td>A03</td>
<td>37i</td>
<td>10:54:23</td>
<td>163</td>
<td>109</td>
<td>Higher ambient concentration (40-80 mg/L) visible along bottom, sidelobe present</td>
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Table 11. Sediment Collection and Analysis Summary Table.
S-NB-2/S-AK-1 Far Field Survey #2 (03-07 October 2011)

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Date Sampled</th>
<th>Time Sampled</th>
<th>Gravel (%)</th>
<th>Coarse Sand (%)</th>
<th>Medium Sand (%)</th>
<th>Fine Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
<th>In Place Density (g/cc)</th>
<th>Liquid Limit (%)</th>
<th>Plastic Limit (%)</th>
<th>Plasticity Index</th>
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<td>10/3/2012</td>
<td>14:25</td>
<td>2.1</td>
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<td>57.5</td>
<td>32.0</td>
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<td>10:00</td>
<td>8.9</td>
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<td>32</td>
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<td>1.010</td>
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</tr>
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1 ASTM D-422 Method
2 ASTM D-2937 Method
3 ASTM D-4318 Method
Depth Averaged Velocities 26 July 2011 - Flood Tide Hydrodynamic Survey

Transects Recorded 1218 to 1312
Transects Recorded 0806 to 0938

Figure

USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

Depth Averaged Velocites
27 July 2011 - Ebb Tide Hydrodynamic Survey

Tide
Ebb
Figure 4

USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

Depth Averaged Velocities
28 July 2011 - Ebb Tide Hydrodynamic Survey

Tide
Ebb
Vertical Profiles of ADCP Average TSS
25 July 2011 - Flood Tide

a) Transect C01 - Circle Transect 90m*

b) Transect C02 - Circle Transect 82m*

c) Ambient A01 - Upcurrent 74m*

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
25 July 2011 - Flood Tide

- **d)** Ambient A02 - Upcurrent 137m*
- **e)** Ambient A03 - Upcurrent 240m*
- **f)** Transect C03 - Circle Transect 82m*

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
25 July 2011 - Flood Tide

- Transect T01 - Downcurrent 90m*
- Transect T02 - Downcurrent 126m*
- Transect T03 - Downcurrent 141m*

*Approximate distance from source
**Vertical Profiles of ADCP Average TSS**

25 July 2011 - Flood Tide

- **j)** Transect T04 - Downcurrent 197m*
- **k)** Transect T05 - Downcurrent 233m*
- **l)** Transect T06 - Downcurrent 298m*

*Approximate distance from source

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>USACE Harborwide TSS Far Field Survey S-NB-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>5j-I</td>
<td>Vertical Profiles of ADCP Average TSS</td>
</tr>
<tr>
<td></td>
<td>25 July 2011 - Flood Tide</td>
</tr>
</tbody>
</table>
**FIGURE**

**USACE Harborwide TSS**

**Far Field Survey**

**S-NB-2**

**Vertical Profiles of ADCP Average TSS**

25 July 2011 - Flood Tide

---

m) Transect T07 - Downcurrent 344m*

n) Transect T08 - Downcurrent 426m*

o) Transect T09 - Downcurrent 476m*

---

*Approximate distance from source
Ambient TSS = 40 mg/L
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Meters
0  75  150  300

Figure 6b  USACE Harborwide TSS Far Field Survey HDP Contract Area: S-NB-2

ADCP Average TSS - 25 July 2011 2-4 Meter Depth Interval

Tide
Flood
Figure USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 25 July 2011
4-6 Meter Depth Interval

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Ambient TSS = 40 mg/L

Meters

0  75  150  300
Ambient TSS = 40 mg/L
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 6c
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 25 July 2011
8-10 Meter Depth Interval

Tide
- Flood
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 6f
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 25 July 2011
10-12 Meter Depth Interval

Tide
Flood
Ambient TSS = 40 mg/L

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 6g
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 25 July 2011
12-14 Meter Depth Interval

Tide
Flood
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 6h
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 25 July 2011
14-16 Meter Depth Interval

0 75 150 300 Meters
Tide
Flood

161 - 200
Figure 7
USACE Harborwide TSS
Far Field Survey
HDP Contract Area S-NB-2
ADCP Average TSS Values, 3D View of Selected Transects
25 July 2011

= Dredge Location
Z scale exaggerated 6X
Transects Recorded 1142 to 1327
FIGURE 9a-c

USACE Harborwide TSS
Far Field Survey
S-NB-2

Vertical Profiles of ADCP Average TSS
26 July 2011 - Flood Tide

a) Transect C01 - Circle Transect 107m*
b) Ambient A01 - Upcurrent 85m*
c) Ambient A02 - Upcurrent 105m*

*Approximate distance from source
d) Ambient A03 - Upcurrent 174m*

e) Transect T01 - Downcurrent 102m*

f) Transect T02 - Downcurrent 150m*

Vertical Profiles of ADCP Average TSS
26 July 2011 - Flood Tide

FIGURE 9d-f

USACE Harborwide TSS
Far Field Survey
S-NB-2

TIDE
Flood

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
26 July 2011 - Flood Tide

- g) Transect T03 - Downcurrent 206m*
- h) Transect T04 - Downcurrent 246m*
- i) Transect T05 - Downcurrent 313m*

*TSS (mg/L)

*Approximate distance from source
FIGURE 9j-k
USACE Harborwide TSS
Far Field Survey
S-NB-2

Vertical Profiles of ADCP Average TSS
26 July 2011 - Flood Tide

j) Transect T06 - Downcurrent 384m*
k) Transect T07 - Downcurrent 476m*

TSS (mg/L)

*Approximate distance from source
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 10a
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 26 July 2011
0-2 Meter Depth Interval

Tide
Flood
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 10b
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 26 July 2011
2-4 Meter Depth Interval

Tide
Flood
Ambient TSS = 40 mg/L
Figure HDP Contract Area: S-NB-2

Ambient TSS = 40 mg/L

ADCP Average TSS - 26 July 2011
6-8 Meter Depth Interval

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Tide
- Flood

USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2
Ambient TSS = 40 mg/L

Figure 10e  USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 26 July 2011
8-10 Meter Depth Interval

Legend

Dredge Position

Avg. TSS (mg/L)

- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Meters
Ambient TSS = 40 mg/L

USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 26 July 2011
10-12 Meter Depth Interval
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure
10g

USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 26 July 2011
12-14 Meter Depth Interval

Tide
Flood

Meters
0 75 150 300

N
AdCP Average TSS Values, 3D View of Selected Transects
26 July 2011

Figure 11

USACE Harborwide TSS
Far Field Survey
HDP Contract Area S-NB-2

TSS (mg/l)

Z scale exaggerated 6X

= Dredge Location
Depth Averaged Velocities 26 July 2011 - Flood Tide TSS Survey

I

USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

Tide
Flood
**Vertical Profiles of ADCP Average TSS**

**27 July 2011 - Ebb Tide**

- **a)** Transect C01 - Circle Transect 82m*
- **b)** Transect C02 - Circle Transect 77m*
- **c)** Ambient A01 - Upcurrent 66m*

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
27 July 2011 - Ebb Tide

- **g) Transect T01 - Downcurrent 113m***
- **h) Transect T02 - Downcurrent 150m***
- **i) Transect T03 - Downcurrent 213m***

**FIGURE**
USACE Harborwide TSS
Far Field Survey
S-NB-2

Vertical Profiles of ADCP Average TSS
27 July 2011 - Ebb Tide

*Approximate distance from source*
Vertical Profiles of ADCP Average TSS

27 July 2011 - Ebb Tide

**j)** Transect T04 - Downcurrent 247m*

**k)** Transect T05 - Downcurrent 302m*

**l)** Transect T06 - Downcurrent 326m*

*Approximate distance from source
Ambient TSS = 40 mg/L

Legend
- Dredge Position
- Avg. TSS (mg/L)
  - 251 - 300
  - 201 - 250
  - 161 - 200
  - 121 - 160
  - 101 - 120
  - 91 - 100
  - 81 - 90
  - 71 - 80
  - 61 - 70
  - 51 - 60
  - 41 - 50
  - 0 - 40

Figure 14a
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 27 July 2011
0-2 Meter Depth Interval

Tide
- Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 14b
USACE Harborwide TSS Far Field Survey HDP Contract Area: S-NB-2

ADCP Average TSS - 27 July 2011
2-4 Meter Depth Interval

Tide
- Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

ADCP Average TSS - 27 July 2011
6-8 Meter Depth Interval
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 14e
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 27 July 2011
8-10 Meter Depth Interval

Tide
Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 14f
USACE Harborwide TSS Far Field Survey HDP Contract Area: S-NB-2
ADCP Average TSS - 27 July 2011 10-12 Meter Depth Interval
USACE Harborwide TSS Far Field Survey
HDP Contract Area S-NB-2
ADCP Average TSS Values, 3D View of Selected Transects
27 July 2011

TSS (mg/l)

Z scale exaggerated 6X

= Dredge Location

Figure 15

Tide

Ebb
Figure 16
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

Depth Averaged Velocities
27 July 2011 - Ebb Tide TSS Survey

Transects Recorded 0944 to 1042
FIGURE 17a-c

Vertical Profiles of ADCP Average TSS
29 July 2011 - Ebb Tide

USACE Harborwide TSS
Far Field Survey
S-NB-2

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
29 July 2011 - Ebb Tide

**d) Transect C04 - Circle Transect**

**e) Ambient A01 - Upcurrent 34m**

**f) Ambient A02 - Upcurrent 73m**

*Approximate distance from source*
Vertical Profiles of ADCP Average TSS
29 July 2011 - Ebb Tide

- g) Ambient A03 - Upcurrent 117m*
- h) Ambient A04 - Upcurrent 166m*
- i) Transect T01 - Downcurrent 81m*

*TSS (mg/L)

*Approximate distance from source
m) Transect T05 - Downcurrent 134m*

n) Transect T06 - Downcurrent 151m*

o) Transect T07 - Downcurrent 170m*

USACE Harborwide TSS
Far Field Survey
S-NB-2

29 July 2011 - Ebb Tide

*Approximate distance from source
FIGURE 17p

Usace Harborwide TSS
Far Field Survey
S-NB-2

Vertical Profiles of ADCP Average TSS
29 July 2011 - Ebb Tide

*p) Transect T08 - Downcurrent 196m*

*Approximate distance from source*
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 18a: USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 29 July 2011
0-2 Meter Depth Interval

Tide
- Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure 18d
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 29 July 2011
6-8 Meter Depth Interval
Tide
Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/L)
- 251 - 300
- 201 - 250
- 161 - 200
- 121 - 160
- 101 - 120
- 91 - 100
- 81 - 90
- 71 - 80
- 61 - 70
- 51 - 60
- 41 - 50
- 0 - 40

Figure
18h

USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 29 July 2011
14-16 Meter Depth Interval

Tide
Ebb
Figure 19: USACE Harborwide TSS Far Field Survey HDP Contract Area S-NB-2

ADCP Average TSS Values, 3D View of Selected Transects
29 July 2011

Tide

Ebb
Figure 21
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

Location of OBS Vertical Arrays and Dredge Position
26 July 2011

Legend
- Dredge Position
- OBS Arrays
- Upcurrent
- Downcurrent

Legend
- Dredge Position
- OBS Arrays
- Upcurrent
- Downcurrent

Meters
0 75 150 300
a) 150 meters Down Current from Dredge

b) 255 meters Down Current from Dredge

*Number in parentheses is average depth of instrument over period recorded

---

**Figure 22**

**USACE Harborwide TSS**

**Far Field Survey**

**S-NB-2**

**Surface and Bottom OBS Turbidities at a) 150 m and b) 255 m Downcurrent of Dredge.**

**Ambient Station Located 300 m Upcurrent of Dredge**

**26 July 2011 TSS Survey**

**Tide**

**Flood**
a) 200 meters Downcurrent from Dredge

Instrument likely shifted during deployment such that turbidity sensor was obscured by tethering apparatus.

b) 270 meters Downcurrent from Dredge

*Number in parentheses is average depth of instrument over period recorded
Comparison of Gravimetric and ADCP Estimates of TSS Concentration

**a)** Concentration vs. Time

**b)** ADCP Concentration vs. Gravimetric Concentration

**Figure**

USACE Harborwide TSS
Far Field Survey
S-NB-2

**25a-b**

Comparison of Gravimetric and ADCP Estimates of TSS Concentration

a) Concentration vs. Time  
b) ADCP Concentration vs. Gravimetric Concentration

S-NB-2/S-AK-1  Far Field Survey #1 (25 July - 29 July 2011)
Elapsed Time of Six Separate Components of Dredge Cable Arm Bucket Cycles

29 July 2011

Figure

USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

Tide
Ebb
Depth Averaged Velocities 05 October 2011 - Flood Tide Hydrodynamic Survey

USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

Transects Recorded 1216 to 1443

Figure
28

Tide
Flood

05 October 2011 - Flood Tide Hydrodynamic Survey
FIGURE 29a-c

USACE Harborwide TSS
Far Field Survey
S-NB-2

Vertical Profiles of ADCP Average TSS
04 October 2011 - Flood Tide

TSS (mg/L)

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
04 October 2011 - Flood Tide

- **d)** Transect T03 - Downcurrent 165m*
- **e)** Transect T04 - Downcurrent 217m*
- **f)** Transect T05 - Downcurrent 245m*

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
04 October 2011 - Flood Tide

- Transect T06 - Downcurrent 259m*
- Transect T07 - Downcurrent 352m*
- Transect T08 - Downcurrent 355m*

*Approximate distance from source
**TSS (mg/L)**

**j) Transect T09 - Downcurrent 434m**

**k) Transect T10 - Downcurrent 396m**

**l) Ambient A01 - Upcurrent 139m**

*Approximate distance from source*
Vertical Profiles of ADCP Average TSS

04 October 2011 - Flood Tide

**Ambient A02 - Upcurrent 195m***

**Ambient A03 - Upcurrent 338m***

*Approximate distance from source*
Ambient TSS = 40 mg/L

Legend

- Dredge Position

Avg. TSS (mg/l)

- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Figure

30b

USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 04 October 2011
4-6 Meter Depth Interval

Tide

Flood
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Figure 30c
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 04 October 2011
6-8 Meter Depth Interval

Tide
Flood
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- Red: 300 - 400
- Orange: 250 - 300
- Yellow: 200 - 250
- Dark Yellow: 150 - 200
- Light Yellow: 100 - 150
- Green: 90 - 100
- Light Green: 80 - 90
- Cyan: 70 - 80
- Blue: 60 - 70
- Dark Blue: 50 - 60
- Blue: 40 - 50
- Light Blue: 0 - 40

Figure
- USACE Harborwide TSS Far Field Survey
- HDP Contract Area: S-NB-2

ADCP Average TSS - 04 October 2011
- 8-10 Meter Depth Interval

Tide
- Flood
Figure 30e
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 04 October 2011
10-12 Meter Depth Interval

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Tide
Flood

Ambient TSS = 40 mg/L
Ambient TSS = 40 mg/L
Figure 31
USACE Harborwide TSS Far Field Survey HDP Contract Area S-NB-2
ADCP Average TSS Values, 3D View of Selected Transects 04 October 2011

TSS (mg/l)

● = Dredge Location
Z scale exaggerated 6X

Tide
Flood
USACE Harborwide TSSFar Field Survey
HDP Contract Area: S-NB-2

Depth Averaged Velocities
04 October 2011 - Flood Tide TSS Survey

Figure 32

Transects Recorded 1312 to 1522

<table>
<thead>
<tr>
<th>Speed (m/s)</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
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<td>300</td>
</tr>
<tr>
<td>1.2</td>
<td>250</td>
</tr>
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<td>1.1</td>
<td>200</td>
</tr>
<tr>
<td>1.0</td>
<td>150</td>
</tr>
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<td>0.9</td>
<td>100</td>
</tr>
<tr>
<td>0.8</td>
<td>50</td>
</tr>
<tr>
<td>0.7</td>
<td>0</td>
</tr>
</tbody>
</table>

0 75 150 300
Vertical Profiles of ADCP Average TSS
06 October 2011 - Ebb Tide

a) Circle Transect C01

b) Transect T01 - Downcurrent 220m*

c) Transect T02 - Downcurrent 46m*

*Approximate distance from source

USACE Harborwide TSS
Far Field Survey
S-NB-2

TIDE
Ebb
Vertical Profiles of ADCP Average TSS
06 October 2011 - Ebb Tide

- **d)** Transect T03 - Downcurrent 83m*
- **e)** Transect T04 - Downcurrent 127m*
- **f)** Transect T05 - Downcurrent 164m*

*Approximate distance from source
Vertical Profiles of ADCP Average TSS

06 October 2011 - Ebb Tide

- Transect T08 - Downcurrent 96m*
- Transect T07 - Downcurrent 140m*
- Transect T06 - Downcurrent 194m*

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
06 October 2011 - Ebb Tide

- Ambient A03 - Upcurrent 208m*
- Ambient A02 - Upcurrent 147m*
- Ambient A01 - Upcurrent 75m*

*Approximate distance from source
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Figure 34a
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2
ADCP Average TSS - 06 October 2011
2-4 Meter Depth Interval

Tide
Ebb
Ambient TSS = 40 mg/L
Figure 34c

USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 06 October 2011
6-8 Meter Depth Interval

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Ambient TSS = 40 mg/L

Meters
0 75 150 300

Tide
Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Figure 34e
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 06 October 2011
10-12 Meter Depth Interval

Tide
Ebb
Figure A03

Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Meters
0 75 150 300

Figure 34f
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 06 October 2011
12-14 Meter Depth Interval

Tide
Ebb
Ambient TSS = 40 mg/L
Figure 35
USACE Harborwide TSS Far Field Survey
HDP Contract Area S-NB-2
ADCP Average TSS Values, 3D View of Selected Transects
06 October 2011

TSS (mg/l)

Z scale exaggerated 6X

Dredge Location

<table>
<thead>
<tr>
<th>Figure</th>
<th>USACE Harborwide TSS Far Field Survey HDP Contract Area S-NB-2</th>
<th>ADCP Average TSS Values, 3D View of Selected Transects 06 October 2011</th>
<th>Tide</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td></td>
<td></td>
<td>Ebb</td>
</tr>
</tbody>
</table>
Transects Recorded 0842 to 0943
Vertical Profiles of ADCP Average TSS

07 October 2011 - Ebb Tide

- a) Transect T01 - Downcurrent 48m*
- b) Transect T02 - Downcurrent 54m*
- c) Transect T03 - Downcurrent 90m*

[Graphs showing TSS values with color gradients for each transect, with approximate distances from source noted.]
d) Transect T04 - Downcurrent 114m*

TSS (mg/L)

e) Transect T05 - Downcurrent 151m*

f) Transect T06 - Downcurrent 167m*

Vertical Profiles of ADCP Average TSS
07 October 2011 - Ebb Tide

*Approximate distance from source
Vertical Profiles of ADCP Average TSS
07 October 2011 - Ebb Tide

- g) Ambient A01 - Upcurrent 27m*
- h) Ambient A02 - Upcurrent 74m*
- i) Ambient A03 - Upcurrent 109m*

*TSS (mg/L)*

*Approximate distance from source*
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Figure 38a  USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 07 October 2011
2-4 Meter Depth Interval

Tide
Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Figure 38b
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 07 October 2011
4-6 Meter Depth Interval

Tide
Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

ADCP Average TSS - 07 October 2011
6-8 Meter Depth Interval

Figure 38c
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

Tide
Ebb
Ambient TSS = 40 mg/L

Legend
- Dredge Position

Avg. TSS (mg/l)
- Red: 300 - 400
- Orange: 250 - 300
- Yellow: 200 - 250
- Green: 150 - 200
- Blue: 100 - 150
- Light blue: 90 - 100
- Light green: 80 - 90
- Light yellow: 70 - 80
- Light purple: 60 - 70
- Dark purple: 50 - 60
- Dark blue: 40 - 50
- Dark green: 0 - 40

Figure 38e
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 07 October 2011
10-12 Meter Depth Interval

Tide
Ebb
Ambient TSS = 40 mg/L

Legend
○ Dredge Position

Avg. TSS (mg/l)
- 300 - 400
- 250 - 300
- 200 - 250
- 150 - 200
- 100 - 150
- 90 - 100
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 0 - 40

Figure 38f
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

ADCP Average TSS - 07 October 2011
12-14 Meter Depth Interval

Tide
Ebb
<table>
<thead>
<tr>
<th>Figure</th>
<th>USACE Harborwide TSS Far Field Survey HDP Contract Area S-NB-2</th>
<th>ADCP Average TSS Values, 3D View of Selected Transects 07 October 2011</th>
<th>Tide</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td></td>
<td></td>
<td>Ebb</td>
</tr>
</tbody>
</table>
**Figure 40**

**USACE Harborwide TSS**
**Far Field Survey**
**HDP Contract Area: S-NB-2**

**Depth Averaged Velocities**
**07 October 2011 - Ebb Tide TSS Survey**

<table>
<thead>
<tr>
<th>Transects Recorded 0909 to 1054</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Speed (m/s)</th>
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<tbody>
<tr>
<td>0.6</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>0.4</td>
</tr>
<tr>
<td>0.3</td>
</tr>
<tr>
<td>0.2</td>
</tr>
<tr>
<td>0.1</td>
</tr>
<tr>
<td>0.0</td>
</tr>
</tbody>
</table>

**Meters**

<table>
<thead>
<tr>
<th>0</th>
<th>75</th>
<th>150</th>
<th>300</th>
</tr>
</thead>
</table>

**Tide**
- Ebb
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

Location of OBS Vertical Arrays and Dredge Position
05 October 2011

Legend
- Dredge Position
- OBS Arrays
- Location
- Upcurrent
- Downcurrent

Meters

<table>
<thead>
<tr>
<th>Figure</th>
<th>USACE Harborwide TSS Far Field Survey</th>
<th>Location of OBS Vertical Arrays and Dredge Position 05 October 2011</th>
</tr>
</thead>
</table>
a) 85 meters Down Current from Dredge

Near Bottom (2.2 m)*  Near Surface (1.3 m)*  Ambient Near Surface (2.1 m)*  Ambient Mid (5.5 m)*

b) 300 meters Down Current from Dredge

Near Bottom (2.9 m)*  Near Surface (1.1 m)*  Ambient Near Surface (2.1 m)*  Ambient Mid (5.5 m)*

*Number in parentheses is average depth of instrument over period recorded

Figure 42
USACE Harborwide TSS Far Field Survey S-NB-2
Surface and Bottom OBS Turbidities at a) 85 m and b) 300 m Downcurrent of Dredge.
Ambient Station Located 370m Upcurrent of Dredge
05 October 2011 TSS Survey
Tide Flood
Location of OBS Vertical Arrays and Dredge Position
06 October 2011

Legend
OBS Arrays
Location

Legend
OBS Arrays
Location

Figure 43
USACE Harborwide TSS
Far Field Survey
HDP Contract Area: S-NB-2

Location of OBS Vertical Arrays and Dredge Position
06 October 2011

Tide
Ebb
a) 120 meters Down Current from Dredge

![Graph showing turbidity data at 120 meters downcurrent from a dredge.]

b) 405 meters Down Current from Dredge

![Graph showing turbidity data at 405 meters downcurrent from a dredge.]

*Number in parentheses is average depth of instrument over period recorded.
Comparison of gravimetric and ADCP estimates of TSS concentration

- **Figure 45a-b**
  - **USACE Harborwide TSS Far Field Survey S-NB-2**
  - **Comparison of gravimetric and ADCP estimates of TSS concentration**
  - **40 October 2011 TSS Survey**
  - **Tide Flood**

**a)** Concentration vs. Time

**b)** ADCP Concentration vs. Gravimetric Concentration

**y = 1.0213x**

**R^2 = 0.9086**
Comparison of gravimetric and ADCP estimates of TSS concentration

- **a)** Concentration vs. Time
- **b)** ADCP Concentration vs. Gravimetric Concentration

**Figure 46a-b**

**USACE Harborwide TSS**
Far Field Survey  
S-NB-2

**Comparison of gravimetric and ADCP estimates of TSS concentration**

- **a)** Concentration vs. Time
- **b)** ADCP Concentration vs. Gravimetric Concentration

06 October 2011 TSS Survey
Comparison of gravimetric and ADCP estimates of TSS concentration

a) Concentration vs. Time  b) ADCP Concentration vs. Gravimetric Concentration

**Figure 47a-b**

USACE Harborwide TSS
Far Field Survey
S-NB-2

**Comparison of gravimetric and ADCP estimates of TSS concentration**

a) Concentration vs. Time  b) ADCP Concentration vs. Gravimetric Concentration

07 October 2011 TSS Survey

**Tide**

Ebb
Figure 48
USACE Harborwide TSS Far Field Survey
HDP Contract Area: S-NB-2

Elapsed Time of Six Separate Components of Dredge Cable Arm Bucket Cycles
06 October 2011

Tide Flood