TECHNICAL MEMO:

FAR-FIELD SURVEYS OF SUSPENDED SEDIMENT PLUMES ASSOCIATED WITH CUTTERHEAD DREDGING IN JONES INLET, LONG ISLAND, NEW YORK

Federal Navigation Project

FINAL

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List of Acronyms

ADCP – Acoustic Doppler Current Profiler
ASTM – American Society for Testing and Materials
BMP – Best Management Practices
GPS – Global Positioning System
HDP – Harbor Deepening Project
NTU – Nephelometric Turbidity Units
OBS – Optical Backscatter Sensor
TSS – Total Suspended Solids
USACE-NYD – Unites States Army Corps of Engineers – New York District
WQ – Water Quality

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, 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). Characterization of the temporal duration, spatial extent and concentration structure of suspended sediment plumes generated by dredging activities, therefore, is critical to enhance the understanding of sediment transport processes and assessment of potential environmental impacts (Puckette 1998).

Previous characterizations of dredging-induced plumes in New York/New Jersey Harbor largely focused on mechanical bucket dredging operations associated with deepening and maintenance of deep-draft vessel navigation channels. During coordination efforts with both state and Federal regulatory agencies a significant knowledge gap relevant to other common dredging practices in the area was identified as hydraulic cutterhead pipeline operations in shallow-draft channels. These operations frequently occur in coastal inlets, which are critical links for fishery resources in movements between open coastal waters and embayments. As part of the United States Army Corps of Engineers New York District's (USACE-NYD) Harbor-wide Water Quality/Total Suspended Solids (WQ/TSS) Monitoring Program, a series of far-field WQ/TSS surveys was conducted between 16 January and 11 February 2014 in Jones Inlet on the south shore of Long Island, New York. Monitoring occurred during maintenance dredging operations involving shoreline placement authorized as a Federal Navigation Project. The objective of these far-field surveys was to assess the spatial extent and temporal dynamics of suspended sediment plumes associated with cutterhead dredging of predominantly medium grain-size sandy sediments from shoals that had accumulated within the navigation channel.

The methodologies employed for this survey were similar to those used previously to survey multiple dredging projects in the New York/New Jersey Harbor, including cutterhead dredging operations in the Kill Van Kull (USACE 2012 and USACE 2013b) and bucket dredging of fine-grained sediments in the Arthur Kill (USACE 2007, USACE 2013c, USACE 2014), Newark Bay (USACE 2008 and USACE 2009), Port Elizabeth Channel (USACE 2010), the Upper Bay (USACE 2011), and South Elizabeth Channel (USACE 2013a). However, because the nature of the sediments being dredged and the geomorphology of the Jones Inlet contract area were substantially different than those represented by the prior far-field surveys, field and data analysis methodologies were modified as described below.

Previous surveys consisted of a combination of mobile Acoustic Doppler Current Profiler (ADCP) transects and instrument arrays deployed at anchored “fixed” stations. In this survey, mobile surveys were conducted using an ADCP mounted on a 25-foot Boston Whaler research vessel. The mobile survey design 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 backscatter) was recorded. Additionally, water samples were collected to directly measure total suspended solids (TSS in mg/L via gravimetric analysis) and optical turbidity across the broadest possible concentration range representative of both within-plume and ambient conditions.

Under the typical survey design, the results of the gravimetric analysis of water samples are used to calibrate the ADCP-derived acoustic backscatter values for conversion to estimates of total suspended solids concentration. However, because of the coarse grained nature of the sediments encountered in this survey area, the compact size of the plume prevented collection of water samples that would allow an accurate conversion of ADCP backscatter to TSS concentration. Instead, raw acoustic backscatter values (dB) were used to assess the extent, intensity and dynamics of the dredge plume. Results from gravimetric TSS analysis of collected water samples were used to provide secondary data on the extent and intensity of the plume. Further details on the ADCP calibration are presented in Section 2.5.

Due to severe winter weather conditions in the contract area, the typical fixed station turbidity surveys using an anchored array of optical backscatter sensors (OBS) could not be conducted safely, as in previous monitoring events. Instead, OBS turbidity profiles of ambient and in-plume conditions were derived from data recorded during water sample collection.

1.1 Study Area

Far-field WQ/TSS surveys were conducted between 16 January and 11 February 2014 in the Jones Inlet Contract Area. Figure 1 shows the area covered during the WQ/TSS surveys, and the approximate positions of the cutterhead dredge in the Jones Inlet channel during each survey. Water depth in the area surveyed ranged between approximately two and ten meters.

1.2 Dredge Operational Setup

The dredge contractor for this study was Weeks Marine, operating the cutterhead dredge *CR McCaskill*, configured with 17,400 total horse-power and a 34-inch intake suction diameter cutter. Sediment was pumped through a combined floating/submerged 30-inch pipeline to a beach discharge located west of the inlet.

An important consideration in examining the plumes created by the cutterhead dredge operating in Jones Inlet is the effect of severe winter weather on how the dredging was conducted. Cutterhead dredges are not true seagoing vessels and are subject to limitations on safe dredging conditions imposed by wave height and wind speed. Given the orientation of the inlet, wave heights exceeding six feet and prevailing winds averaging 20 to 25 mph and gusting above 35 mph from the southwest through southeast quadrants led to temporary shutdowns. For example, during the week of 20-26 January the dredge operated for no more than 14.25 hours on any given day, and for as little as 1.75 hours on two separate days. On several occasions the dredge sought safe harbor in protected waters inside the inlet. Although cutterhead dredging operations may be perceived to be continuous, in reality most are highly punctuated, stop-start processes. In addition to weather constraints, cutterhead dredges frequently experience temporary shutdowns to clear pumps, particularly when encountering debris. At Jones Inlet, multiple shutdowns occurred when the dredge entrained tires, rocks and other debris. Thus the plumes are influenced in terms of their spatial extent and temporal duration by operational factors as well as the characteristics of the sediment being dredged and tidal hydrodynamics.

The dredging project at Jones Inlet entailed the removal of a total of 665,470 cubic yards of sandy sediment from multiple shoals that had accumulated within the Federal navigation channel. Based on daily logs submitted by Weeks Marine, which included information on hours of operation and position of the cutterhead dredge on any given day, the *CR McCaskill* mobilized at Jones Inlet on 9 January 2014 and demobilized on 13 February 2014. During the intervening days the dredge actively pumped for a total of approximately 391 hours. Therefore an average production rate over the course of the project was approximately 1,702 cubic yards per hour. On several days when sea conditions were favorable, production estimates based on slurry density instrumentation aboard the dredge ranged as high as 2,166 cubic yards per hour.

2.0 METHODS

2.1 Hydrodynamic Surveys

Hydrodynamic conditions within the Jones Inlet channel were characterized during both ebb and flood tides using a vessel-mounted Teledyne RD Instruments 1200-kHz Workhorse Monitor Series ADCP. Because current flows during both flood and ebb tides were primarily parallel to the longitudinal axis of the navigation channel, mobile transects to characterize the plume generally were established perpendicular to that axis, with exceptions noted. 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.

For each survey, the observed hydrodynamic conditions were cross-referenced against predicted currents generated from NobleTec Tides & Currents™ software for Jones Inlet. The predicted currents data are presented for each survey date in Appendix A and show the water speed (in m/s; blue bars) and direction (negative values for ebb, positive for flood) and are useful in placing a particular survey within the context of the daily tide cycle.

2.2 Mobile ADCP Suspended Sediment Surveys

Suspended sediment plumes were also characterized using the Workhorse model ADCP. In the field, RD Instruments WinRiver software was used to display plume acoustic signatures in real time and to record data. 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, 50 bins of 0.5-meter depth were used, for a maximum vertical profile range of 25 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, or many types of floating debris).

Once the instrument receives the reflected signals, the WinRiver software can calculate the three-dimensional movement of particles in the water column and thus determine water velocity in each bin. When water samples are collected concurrently, suspended sediment concentration can normally be determined using additional software and analyses (see *Section 2.5 - ADCP Calibration* below). Similarly, navigation data (i.e. GPS positions) collected throughout the monitoring period by the dredge contractor were integrated during post-processing of the ADCP data to determine the distance of each transect segment from the dredge. To characterize plumes over 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; 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 artificially high backscatter from the near-seabed areas. This effect is 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. Consequently, backscatter data from the depth bin representing the seabed/water interface are not useful for estimation of TSS concentration.

2.2.1 Mobile ADCP Survey Design

Prior to initiating the mobile plume surveys, circular transects using the ADCP were conducted around the actively operating dredge to help provide a post-processing reference point for the dredge's location and to obtain a preliminary assessment of the location and acoustic signal of the plume. Subsequent ADCP transects were then conducted across the plume, generally oriented in a direction perpendicular to the channel and extending 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. Thus each set of transects produces a composite three-dimensional depiction of plume structure under prevailing tidal current conditions.

2.2.2 Mobile ADCP Data Presentation

Results for the mobile ADCP plume transects are presented graphically in two ways:

- **Vertical Profile Plots** – Vertical cross-section profiles representing individual transects are examined in detail for backscatter gradient structure of the plume at known, increasing distances from the source.

- **Plan-View Plots** – Backscatter values are presented as composite horizontal "slices" through the plume signature at surface (0-2 meters), middle (2-4 meters), and bottom (4-6 meters) depth intervals.

Because the TSS results from the water samples could not be used to convert ADCP backscatter to TSS in this study, an ambient backscatter cutoff value was chosen for the ADCP transects that most appropriately and clearly delineated the dredge plume from the background condition by removing any natural backscatter "noise." For this study, the value of 96 dB, representative a conservatively low acoustic backscatter level typical of coastal inshore environments, was used as the critical cutoff between ambient and plume conditions for all surveys. Thus, backscatter signatures above 96 dB in intensity are herein considered above background and attributable to the dredge plume unless otherwise noted (e.g., clearly attributable to air entrainment, vessel prop wash, or from other sources of re-suspension such as tug and ship-induced plumes, or from ADCP side-lobe interference).

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 OBS-3A optical turbidity sensors (OBS). Typically, these sensors would be tethered to a taut line and anchored at predetermined depths using a fixed anchor and buoy array. These arrays would be left in position for the duration of a tidal cycle while the research vessel conducted additional survey operations in the area. However, current and weather conditions and the dredge's operational setup and schedule prohibited the safe deployment of the anchored arrays. Instead, OBS turbidity profiles were obtained from data recorded during water sample collection.

Optical backscatter sensors 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 (µS/cm) and battery level (V). Readings were output once per second and saved directly to an onboard laptop computer.

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. The water samples were collected from the research vessel using a custom made pump sampler which consisted of a Rule model 2000 submersible impeller pump with ¾-inch polyester braid reinforced PVC tubing, to which a Campbell Scientific, Inc. OBS-3A optical backscatter sensor (OBS) was mounted. The OBS unit was configured to measure and record depth, temperature, salinity, and turbidity values at one second intervals. The OBS unit was connected via RS-232 serial link to an onboard computer which logged these data using HDR's proprietary Water Sample Collection Control software. This software is designed to time-stamp collections of TSS/Turbidity water samples with one second accuracy, and to easily cross-reference these samples with simultaneously logged OBS and ADCP data. In the in the standard survey design, the cross-referencing of data is used in establishing the ADCP backscatter correlation to TSS concentrations during post-processing.

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). These laboratory results are presented in Table 1, and presented graphically in Figures 14 and 15.

2.5 ADCP Calibration

Sediments dredged during this survey were composed nearly entirely of sand. Because these sediments fall out of suspension more quickly than finer sediments, volumes of any plume containing high concentrations are extremely compact. Because of this, it was not possible to collect a sufficient number of water samples which adequately represented the full range of plume and ambient concentrations, and as a result a reliable conversion of acoustic backscatter data to estimated TSS concentrations using the Sediview method (Land and Bray 2000) could not be conducted for this survey. Instead, raw acoustic backscatter data were used in the analysis of dredge plume intensity and extent.

2.6 Sediment Sample Collection

To determine the sediment characteristics of the survey area, a sample was collected from the sediment bed in the vicinity of the dredge using a ponar grab, on 27 January 2014. The sample was analyzed 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). These laboratory results are presented in Table 5.

3.0 RESULTS

3.1 Hydrodynamic Survey

To characterize hydrodynamic conditions within Jones Inlet, a hydrodynamic survey covering all areas surveyed in mobile ADCP plume surveys was conducted during an ebb tide on 16 January 2014. Transects were conducted approximately perpendicular to the long axis of the Jones Inlet channel. Additionally, hydrodynamic conditions during each mobile ADCP survey were also recorded to aid in the interpretation of plume dynamics, and place the corresponding TSS data in a hydrodynamic context. These results are included as part of the discussion of each mobile ADCP survey in Section 3.1.3 below.

The results of the ebb tide hydrodynamic survey are presented in Figure 2. This survey was conducted from approximately 1045 to 1315 hours on 16 January 2014. In the figure, the “Direction of Travel” arrow indicates the direction in which the research vessel progressed through the survey area while conducting transects. The area surveyed covered the entire width of Jones Inlet Channel, and extended from just south of the red “14” buoy to approximately 450 meters past the marker at the end of the channel. During this survey, depth-average current velocities within the area ranged from near 0 to approximately 1.2 m/s, with the highest velocities recorded in the narrowest portions of the channel. Current direction within the survey area was generally southwest, paralleling the channel.

3.2 Ambient Conditions

A total of 18 ambient water samples were collected at various depths on 27 January and 11 February 2014, and later analyzed in the laboratory for TSS and turbidity. Ambient turbidity values ranged from 2.7 to 6.8 NTU, and the corresponding TSS concentrations ranged between 11 to 37 mg/L (Table 1).

3.3 Mobile ADCP Surveys

3.3.1 27 January 2014 - Ebb Tide

A mobile ADCP plume characterization survey was conducted on 27 January 2014 during a flood tide from approximately 1117 to 1129 hours. The survey consisted of five down-current transects, conducted parallel to the channel (Figures 3a-e). 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 4a through 4c. During this survey, the cutterhead dredge was located just to the northeast of the green “9” buoy. A tug tending the discharge pipe from the cutterhead operations was located approximately 230 meters to the southwest of the dredge. Five down-current transects were conducted to the southeast of the dredge and tug, and parallel to the channel. This transect orientation was used to allow the survey vessel to approach the cutterhead dredge more closely than perpendicular transects would have allowed in light of the dredge and tug positions described above.

Transects T01 and T02 (Figures 3a and 3b) show the influence of tug prop wash throughout the water column. A plume from the cutterhead dredge operations is visible in Transect T03 (Figures 3c), extending 260 meters down-current. At this distance, the plume was detected in a swath approximately 150 meters wide. Because of water depths and the positions of the tug and dredge, the plume was transected at an angle oblique to its long axis. The width of the plume as measured perpendicular to its long axis may have been less than 150 meters. The plume was present throughout the water column, though the highest concentrations were detected closest to the surface. By 320 meters down-current from the source, the plume had dissipated to a lower intensity, and narrowed. By 400 meters down-current (Transect T05, Figure 3e), the plume from the cutterhead dredge had dissipated to near background conditions.

Figure 5 presents the hydrodynamic conditions recorded during the 27 January ebb tide mobile ADCP survey. The area surveyed extended from between the green “9” and red “2” buoys and to the southwest approximately 760 meters, and included the central portion of the channel (between the navigation buoys). During this survey, depth-averaged current velocities within the area ranged from near 0 m/s to approximately 0.8 m/s. Currents within the survey area generally flowed southwest, parallel to the channel. In the western portion of the survey area, currents flowed more southeast, towards the middle of the channel.

3.3.2 27 January 2014 – Flood Tide

A mobile ADCP plume characterization survey was conducted on 27 January during a flood tide from approximately 1211 to 1346 hours (Figures 6a-i). The survey consisted of three up-current transects (Figures 6a through 6c), and six down-current transects (Figures 6d through 6i). 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 is given in Figures 7a through 7c. During this survey, the cutterhead dredge was located just to the northeast of the green “9” buoy. Up-current transects were conducted to the south of the dredge, and down-current transects were conducted to the north. Up- and down-current transects were both oriented perpendicular to the channel.

Up-current conditions presented in Transects A01 through A03 (Figures 6a through 6c) show background conditions (backscatter <96 dB) throughout most of the water column, with a layer of slightly higher backscatter intensity present near the surface in all up-current transects. This signal may represent air bubbles due to surface chop rather than suspended sediment.

Down-current Transects T01 through T06 (Figures 6d through 6i) show the spatial extent of the TSS plume associated with operations of the cutterhead dredge. As shown by ADCP-recorded backscatter, the plume reached its highest concentrations within 110 meters of the source (Transect T01). At this distance, the plume was approximately 150 meters wide. The plume was present throughout the water column, but the greatest backscatter levels were present in the top one-quarter to one-half of the water column. The dredge plume dissipated as distance from the dredge increased (Transects T02-T04), and was detectable at low backscatter intensities approximately 50 meters wide within 360 meters down-current of the dredge, although it still extended throughout the entire water column (T05). By 460 meters down-current (T06), conditions had returned to background. Vessel prop wash is visible in this transect, as noted on the figure.

Figure 8 presents the hydrodynamic conditions recorded during the 27 January flood tide mobile ADCP survey. The area surveyed extended from the red “12” buoy to south of the green “7” buoy, and included only the central portion of the channel (between the navigation buoys). During this survey, depth-averaged current velocities within the area ranged from near 0 m/s to approximately 0.8 m/s. Currents within the survey area generally flowed to the northeast, parallel to the channel. In the northern portion of the survey area, current direction turned towards the northwest, towards the channel north of Point Lookout.

3.3.3 11 February 2014 - Flood Tide

A mobile ADCP plume characterization survey was conducted on 11 February during a flood tide from approximately 1319 to 1511 hours (Figures 9a-9i). The survey consisted of three up-current transects (Figures 9a through 9c), and six down-current transects (Figures 9d through 9i). 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 10a through 10c. During this survey, the cutterhead dredge was located approximately 75 meters northeast of the green "11" buoy. Up-current transects were conducted to the south of the dredge and down-current transects were conducted to the north, terminating near the green "1A" buoy to the west where water depths dropped to below two meters and survey vessel access was limited for navigational safety reasons. Up- and down-current transects were oriented perpendicular to the channel.

Up-current conditions presented in Transects A01 through A03 (Figures 9a through 9c) show background acoustic backscatter levels throughout the water column, with an intense vessel prop wash signal present near the surface, as noted on the figures.

Down-current Transects T01 through T06 (Figures 9d through 9i) show the spatial extent of the plume associated with operations of the cutterhead dredge. Peak plume backscatter levels were observed within 70 meters down-current of the dredge (Transects T01-T02). The plume was detected at its widest (approximately 350 meters wide) within 20 meters down-current of the dredge (Transect T01). The dredge plume extended throughout the water column for its entire extent, but backscatter levels dissipated as distance from the source increased, remaining highest closer to the surface (Transects T03 – T05). The plume was observed up to 180 meters down-current from the source, where it had a width of approximately 80 meters (Transect T06).

Figure 11 presents the hydrodynamic conditions recorded during the 11 February flood tide mobile ADCP survey. The area surveyed was at the northern end of the Jones Inlet channel, extending from the green "13" buoy approximately 550 meters south. During this survey, depth-averaged current velocities within the area ranged from near 0 m/s to approximately 0.7 m/s. Currents within the survey were somewhat variable, but overall flowed towards the northwest, especially in the northern portion of the area.

3.4 OBS Turbidity Surveys

Two OBS turbidity surveys were conducted during two separate flood tides, on 27 January and 11 February 2014. The turbidity (NTU) and depth (meters) values recorded at one second intervals by the OBS unit during these deployments were plotted to show turbidity readings throughout the water column at up- and down-current locations.

3.4.1 27 January 2014 - Flood Tide

Turbidity data were recorded during the collection of water samples on 27 January 2014 during a flood tide. The collection array was deployed down-current from the cutterhead twice, and then deployed once up-current, for approximately ten minutes for each deployment. In Figure 12a turbidity values (NTU, solid lines), and OBS sensor depths (meters, dotted lines) were plotted for the up-current deployment, and in Figure 12b the data were plotted for both down-current deployments. Turbidity readings when the sensor was at a depth of less than 0.5 meters when being deployed and retrieved were excluded from the plots because of optical interference.

Turbidities during the ambient, up-current OBS deployment remained relatively constant throughout the deployment, between approximately 9 and 12 NTU with the exception of several brief spikes of higher values (Figure 12a). These spikes occurred while the sensor was at near-bottom depths, and likely represented bottom impacts rather than ambient turbidity conditions.

Turbidity readings from both down-current deployments show similar results, with overall turbidity values ranging between approximately 9 and 13 NTU, with several brief, unrepresentative spikes to higher values (Figure 12b). Note that the gap in the data between the approximately four and eight minute mark of the second down-current deployment resulted when the OBS unit was at the surface and being towed back into position by the boat.

3.4.2 11 February – Flood Tide

Turbidities and OBS sensor depths recorded during the collection of water samples on 11 February 2014 flood tide are plotted in Figure 13a for the up-current deployment, and Figure 13b for two down-current deployments.

Ambient turbidity readings remained between approximately 5 and 7 NTU throughout the up-current deployment, with only very brief (several seconds in duration) spikes to higher values during deployment and retrieval (Figure 13a).

During both down-current deployments, turbidity readings also remained relatively constant, ranging between approximately 6 and 13 NTU, with very brief deployment artifact spikes (Figure 13b).

3.5 Laboratory Analysis of Water Samples

A total of fifty-four water samples were collected in the project area during the Jones Inlet Far Field Study, in two sets of twenty-seven samples each on 27 January and 11 February 2014, both during flood tides. The laboratory results of turbidity and TSS concentration for these samples are presented in Table 1. TSS concentrations of the 54 water samples ranged from 11 to 48 mg/L and corresponding turbidity concentrations ranged from 3.0 to 7.0 NTU.

As mentioned above, the lack of water samples representing a broad range of suspended sediment conditions precluded a calibration of raw ADCP backscatter data necessary to estimate TSS concentrations. In order to describe the dredge plume in terms of TSS concentrations, the gravimetric TSS result for an individual water sample was plotted at the sample location, in relation to the position of the cutterhead dredge at the time the sample was taken. Results of water samples collected on 27 January 2014 are presented in Figure 14, and those collected on 11 February are plotted in Figure 15. On 27 January, TSS concentrations were essentially equivalent at locations both up-current and approximately 120 to 270 meters down-current of the dredge position (Figure 14). However, for water samples taken on 11 February, all samples with TSS concentrations greater than approximately 20 mg/L were collected from approximately 40 to 110 meters down-current of the dredge. This pattern suggests a TSS plume with concentrations ranging from approximately 20 to 48 mg/L at these distances (Figure 15).

3.6 Sediment Sample

A sediment sample was collected from the seabed in the dredging area of the Jones Inlet Far Field Study and analyzed for grain size distribution, density, and Atterberg Limits. Results of these analyses are presented in Table 5. The sediment sample collected during this survey was comprised almost entirely of sand (98.1%), along with 1% each of silt and clay. The sample contained no gravel. The in-place density of the sample was 1.44 g/cc. Atterberg Limits analysis, which determines the sediment sample's ability to absorb water and show properties of a plastic, found the *in situ* sediments to be non-plastic, typical of sands.

The characteristics of this *in situ* sediment sample are very similar to those of cores taken at ten locations in the project area during a pre-dredging survey (Aqua Survey 2013). Sediments in these cores contained even smaller fine fractions, ranging from 0.0 to 0.3 percent silt and clay-sized particles.

4.0 DISCUSSION

During the course of routine dredging operations, some sediment is re-suspended into the water column. Depending on the type of dredging equipment employed, the geotechnical properties of the sediment being dredged, the prevailing water currents, and other contributing factors, this suspended sediment forms a plume transported down-current from the source. Because suspended sediment plumes are dynamic rather than static phenomena and because they can vary in spatial extent over large areas in short periods of time, particularly when driven by tidal currents, 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).

Previous characterizations of dredging-induced plumes in New York/New Jersey Harbor largely focused on mechanical bucket dredging operations associated with deepening and maintenance of deep-draft vessel navigation channels. During coordination efforts with both state and Federal regulatory agencies a significant knowledge gap relevant to other common dredging practices in the area was identified as hydraulic cutterhead pipeline operations in shallow-draft channels. As part of USACE-NYD's Harbor-wide WQ/TSS Monitoring Program, a series of far-field WQ/TSS surveys was conducted between 16 January and 11 February 2014 in Jones Inlet on the south shore of Long Island, New York. The objective of these far-field surveys was to assess the spatial extent and temporal dynamics of suspended sediment plumes associated with cutterhead dredging of sediments within the navigation channel. Sediments in the contract area, as sampled in these surveys, were composed almost entirely of sand, with very small amounts of silt and clay. Coarse grain sediment particles or aggregates settle rapidly out of suspension, whereas fine grained sediments can remain in suspension for substantially longer durations depending on their state of disaggregation and the influence of cohesion between particles and flocculation in saline waters. Therefore, the results of the present study provide site-specific characterizations of plume dynamics that can be used to support better informed dredging project management decisions as they pertain to Jones Inlet or similar areas.

In this series of surveys, ADCP backscatter data indicated that ambient (background) suspended sediment concentrations in the survey area were generally low throughout the water column. In one survey (27 January flood tide), a naturally occurring layer of slightly higher suspended sediment concentrations was present near the surface, possibly representing air bubbles due to surface chop. Results of gravimetric TSS analysis of water samples indicated that ambient TSS concentrations ranged from 11 to 37 mg/L during the survey period.

Suspended sediment plumes attributable to operations of the cutterhead dredge *CR McCaskill* were detected as ADCP backscatter. Using the intensity of acoustic backscatter as an index of TSS concentration, the areas of highest plume concentrations extended no more than 110 meters down-current from the source. In the zone immediately down-current from the dredge, the comparatively higher TSS concentrations extended throughout the water column, but were more intense and more widely dispersed in the upper portion of the water column. This observation is interesting in that sediment disturbance by a cutter occurs at the seabed/water interface and does not involve "pulling upward" and release of sediments in the manner of a mechanical bucket. However, this operation did involve a relatively large cutterhead (30-inch) working in relatively shallow water. Applying a relatively high rate of cutter rotations per minute to "cut" the coarse sand bed could have resulted in throwing sediment into the upper water column, resulting in the observed plume pattern. The dredge plume had a maximum width of approximately 350 meters at a distance of 20 meters down-current from the source. Width of the plume in the case of a cutterhead includes the lateral distance swept by the cutter as well as the influence of currents dispersing the plume. The plume narrowed as it progressed further from the source, to a width of approximately 50-80 meters before becoming undetectable. The bottom-oriented component of the dredge plume was detected with an acoustic signature above ambient at a maximum distance of 360 meters down-current from the source.

Turbidities recorded both up- and down-current of the dredging operation were very similar, indicating that the dredge plume was not prominent at beyond distances ranging from approximately 40 to 270 meters down-current. However, water samples collected 40 to 110 meters down-current during one of these sensor deployments (11 February 2014 during a flood tide), had somewhat higher TSS concentrations than corresponding up-current results, but not exceeding 48 mg/L.

The Jones Inlet contract area differs in several important aspects from those surveyed previously under USACE-NYD's Harbor-wide WQ/TSS Monitoring Program in particular those surveys of a cutterhead dredge operating in the deep water channel of the Kill Van Kull (USACE 2012 and USACE 2013b) in which measured plumes typically peaked at concentrations between 200-400 mg/L and were generally confined to the lower third of the water column. Jones Inlet by comparison represents a somewhat typical coastal inlet in which a relatively shallow connection is made between oceanic waters and an estuarine embayment. The entrance channel sediments consist predominately of coarse sands, and is subject to moderate tidal current velocities (as opposed to locations in the NY/NJ Harbor with predominantly fine sediments and comparatively slower tidal current velocities).

Results of the present study suggest that dredge plumes produced by hydraulic cutterhead dredges in coastal inlets similar to Jones Inlet will have very small spatial extents and be characterized by relatively low TSS concentrations. Multiple factors contribute to the observed plume dynamics including the existing hydrodynamic conditions at the time of the surveys which ranged between approximately 0 and 0.8 m/s during these surveys. Even in the presence of low to moderate tidal current velocities, however, resuspended sand particles descend rapidly back to the seabed. With the use of a hydraulic cutterhead dredge, the actual sediment disturbance occurs at the seabed and most of the disturbed sediment is removed as a sediment/water slurry into the suction intakes. This entrainment of sediment/water slurry does not "pull" sediment upward and release particles into the upper water column as does a mechanical bucket. As was observed at Jones Inlet, dredging by a relatively large capacity cutterhead dredge such as the *CR McCaskill*, is still subject to frequent interruptions caused by severe winter weather conditions. This factor also contributes to the relatively small volume of sediment comprising a plume at any given time. The very high sand fraction settles out of the plume very quickly, leaving a small mass of fine particles to be carried down-current as a diffuse plume.

Production rates of the *CR McCaskill* averaged 1,702 cubic yards per hour and peaked at 2,166 cubic yards per hour. Estimates of sediment resuspension loss rates for hydraulic dredges range as high as 1.0 percent of the volume of sediment pumped (Hayes *et al.* 2000, Anchor Environmental 2003), which would conservatively yield a total of 6,655 cubic yards of sediment lost to the water column during the course of the Jones Inlet project. Of this, as much as 2.0 percent, or approximately 133.1 cubic yards, would consist of fine sediment particles based on the grain-size distribution of the *in situ* sediment sample (Table 5). Assuming a uniform distribution of fines within the dredged sediment, as much as 0.34 cubic yards of fine sediment would be resuspended per hour of active dredging, which equates to an approximate loss rate of 0.34 kg/sec. This is a very low loss rate as compared to those generated by mechanical dredges operating in predominantly fine sediments. Thus the observed spatial scales and plume structures observed in the Jones Inlet surveys described herein are entirely consistent with the known characteristics of hydraulic dredging practices in coarse sediments.

The results of this study clearly demonstrate the distinct differences in plume dynamics of hydraulic cutterhead operations in shallow versus deep draft channels, and in coarse sand versus higher silt content sediments. In contrast to the latter case, plumes in Jones Inlet were smaller and comprised of low TSS concentrations. In summary, dredging as conducted at Jones Inlet does not represent a significant source of sediment resuspension that can transport appreciable quantities of either coarse or fine sediments beyond very short distances from the dredge. The relatively small, diffuse, compact plumes pose very little risk of dispersing fine sediments to habitats outside of existing navigation channel boundaries.

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Table 1. Laboratory Results of Water Samples - Jones Inlet Far Field TSS Survey (27 January - 11 February 2013)

Sample	Sample Date	Sample Time	Location	Sample Depth (m)	Total Suspended Solids (mg/L)	Turbidity (NTU)
1	1/27/2014	13:06:03	Plume	3.8	35	5.8
2	1/27/2014	13:06:18	Plume	3.8	27	5.6
3	1/27/2014	13:06:33	Plume	3.7	26	5.8
4	1/27/2014	13:07:33	Plume	2.7	27	3.4
5	1/27/2014	13:07:51	Plume	2.4	19	4.5
6	1/27/2014	13:08:08	Plume	2.4	17	4.4
7	1/27/2014	13:09:08	Plume	1.4	13	4.6
8	1/27/2014	13:09:24	Plume	1.4	18	4.7
9	1/27/2014	13:09:40	Plume	1.4	14	3.1
10	1/27/2014	13:22:11	Plume	3.1	27	5.4
11	1/27/2014	13:22:26	Plume	2.9	32	5.4
12	1/27/2014	13:22:40	Plume	3.4	33	5.5
13	1/27/2014	13:23:28	Plume	2.5	23	5.9
14	1/27/2014	13:23:43	Plume	2.5	28	5.7
15	1/27/2014	13:23:57	Plume	2.5	26	6.2
16	1/27/2014	13:28:35	Plume	1.7	37	7.2
17	1/27/2014	13:28:51	Plume	1.8	26	6.5
18	1/27/2014	13:29:08	Plume	1.9	24	6.4
19	1/27/2014	13:53:03	Ambient	5.6	27	5.2
20	1/27/2014	13:53:22	Ambient	5.1	24	6.8
21	1/27/2014	13:53:41	Ambient	5.7	26	3.6
22	1/27/2014	13:54:58	Ambient	3.7	33	4.7
23	1/27/2014	13:55:17	Ambient	3.5	32	4.9
24	1/27/2014	13:55:36	Ambient	3.4	25	3.9
25	1/27/2014	13:57:13	Ambient	2.2	37	3.7
26	1/27/2014	13:57:29	Ambient	2.3	20	4.1
27	1/27/2014	13:57:46	Ambient	2.2	25	3.3
28	2/11/2014	14:42:22	Plume	2.8	20	3.1
29	2/11/2014	14:42:45	Plume	2.8	41	4.1
30	2/11/2014	14:43:06	Plume	2.7	40	3.3
31	2/11/2014	14:43:45	Plume	1.7	47	3.6
32	2/11/2014	14:44:04	Plume	1.7	48	3.8
33	2/11/2014	14:44:24	Plume	1.6	34	4.7
34	2/11/2014	14:44:57	Plume	N/A	17	3.7
35	2/11/2014	14:45:17	Plume	N/A	28	3.3
36	2/11/2014	14:45:37	Plume	N/A	22	3.3
37	2/11/2014	14:57:18	Plume	2.8	20	3.0
38	2/11/2014	14:57:41	Plume	2.8	25	3.3
39	2/11/2014	14:58:01	Plume	2.8	45	3.8
40	2/11/2014	14:58:37	Plume	1.6	29	3.7
41	2/11/2014	14:59:01	Plume	1.6	18	3.3
42	2/11/2014	14:59:29	Plume	1.5	28	2.9
43	2/11/2014	15:00:20	Plume	N/A	21	4.2
44	2/11/2014	15:00:40	Plume	N/A	40	4.0
45	2/11/2014	15:01:00	Plume	N/A	28	3.2

Table 1. Laboratory Results of Water Samples - Jones Inlet Far Field TSS Survey (27 January - 11 February 2013)

Sample	Sample Date	Sample Time	Location	Sample Depth (m)	Total Suspended Solids (mg/L)	Turbidity (NTU)
46	2/11/2014	15:17:25	Ambient	4.6	19	2.9
47	2/11/2014	15:17:47	Ambient	4.9	22	3.0
48	2/11/2014	15:18:10	Ambient	4.4	17	3.2
49	2/11/2014	15:18:47	Ambient	5.3	17	3.3
50	2/11/2014	15:19:07	Ambient	3.4	11	2.9
51	2/11/2014	15:19:29	Ambient	3.5	18	2.7
52	2/11/2014	15:20:20	Ambient	2.7	17	2.9
53	2/11/2014	15:20:40	Ambient	1.9	16	2.9
54	2/11/2014	15:21:03	Ambient	2.2	11	3.8

N/A = Sample depth not available

Table 2. 27 January 2014 Far Field Ebb Tide Survey - Transect Summary Table

Transect Number	Figure Number	Time	Transect Length (m)	Distance From Dredge (m)	Plume Description	Additional Field Remarks
T01	3a	11:17:28	280	200	Tug propwash clearly visible	Parallel to pipe; tug wash influence
T02	3b	11:48:21	621	230		Semi circ around whole setup; possible plume
T03	3c	11:54:58	633	260	Dredge plume throughout water column, strongest near surface	Further, through plume at oblique angle
T04	3d	11:59:42	520	320	Dredge plume begins to dissipate	
T05	3e	12:04:47	559	400	Return to near background conditions	

Table 3. 27 January Far Field Flood Tide Survey - Transect Summary Table

Transect Number	Figure Number	Time	Transect Length (m)	Distance From Dredge (m)	Plume Description	Additional Field Remarks
A01	6a	13:48:14	206	360	Background conditions; backscatter at surface possibly due to air bubbles	
A02	6b	13:46:24	233	400	Background conditions; backscatter at surface possibly due to air bubbles	
A03	6c	13:44:24	190	530	Background conditions; backscatter at surface possibly due to air bubbles	Facing South due to weather/seas
T01	6d	12:15:02	285	110	Dredge plume detected at highest concentrations, throughout water column	Closer to dredge
T02	6e	12:11:44	367	180	Dredge plume dissipates with distance from source, remains throughout water column	Start of Flood; plume on North
T03	6f	12:17:55	204	240	Dredge plume dissipates with distance from source, remains throughout water column	Very shallow water just NW of transect
T04	6g	12:20:39	253	290	Dredge plume dissipates with distance from source, remains throughout water column	
T05	6h	12:23:09	188	360	Dredge plume dissipates with distance from source, remains throughout water column	Shallow shoal just to the W
T06	6i	12:25:42	200	460	Return to background conditions	Propwash

Table 4. 11 February 2014 Far Field Flood Tide Survey - Transect Summary Table

Transect Number	Figure Number	Time	Transect Length (m)	Distance From Dredge (m)	Plume Description	Additional Field Remarks
A01	9a	15:06:39	208	220	Heavy propwash against background conditions	Propwash from other survey vessel
A02	9b	15:08:35	216	230		
A03	9c	15:11:09	184	260		
T01	9d	13:19:48	403	20	Peak dredge plume signal, strongest near surface, throughout water column	
T02	9e	13:55:22	307	70		
T03	9f	13:23:56	281	125	Plume dissipates with distance from source, remains throuhgout water column, strongest at surface	Moving anchors at end
T04	9g	13:51:48	386	150		
T05	9h	13:47:43	463	150		
T06	9i	13:58:22	312	180		

Table 5: Jones Inlet Far Field WQ/TSS Survey Sediment Collection and Analysis Summary Table

Area	Date Sampled	Time Sampled	Grain Size Distribution[1]				Bulk Density[2]	Atterberg Limits[3]		
			Gravel	Sand	Silt	Clay	In Place Density	Liquid Limit	Plastic Limit	Plasticity Index
			(%)	(%)	(%)	(%)	g/cc			
Dredge Field	1/27/2014	14:10	0.0	98.1	1.0	1.0	1.44	0	0	NP

[1] ASTM D-422 Method

[2] ASTM D-2937 Method

[3] ASTM D-4318 Method

NP = Non-plastic

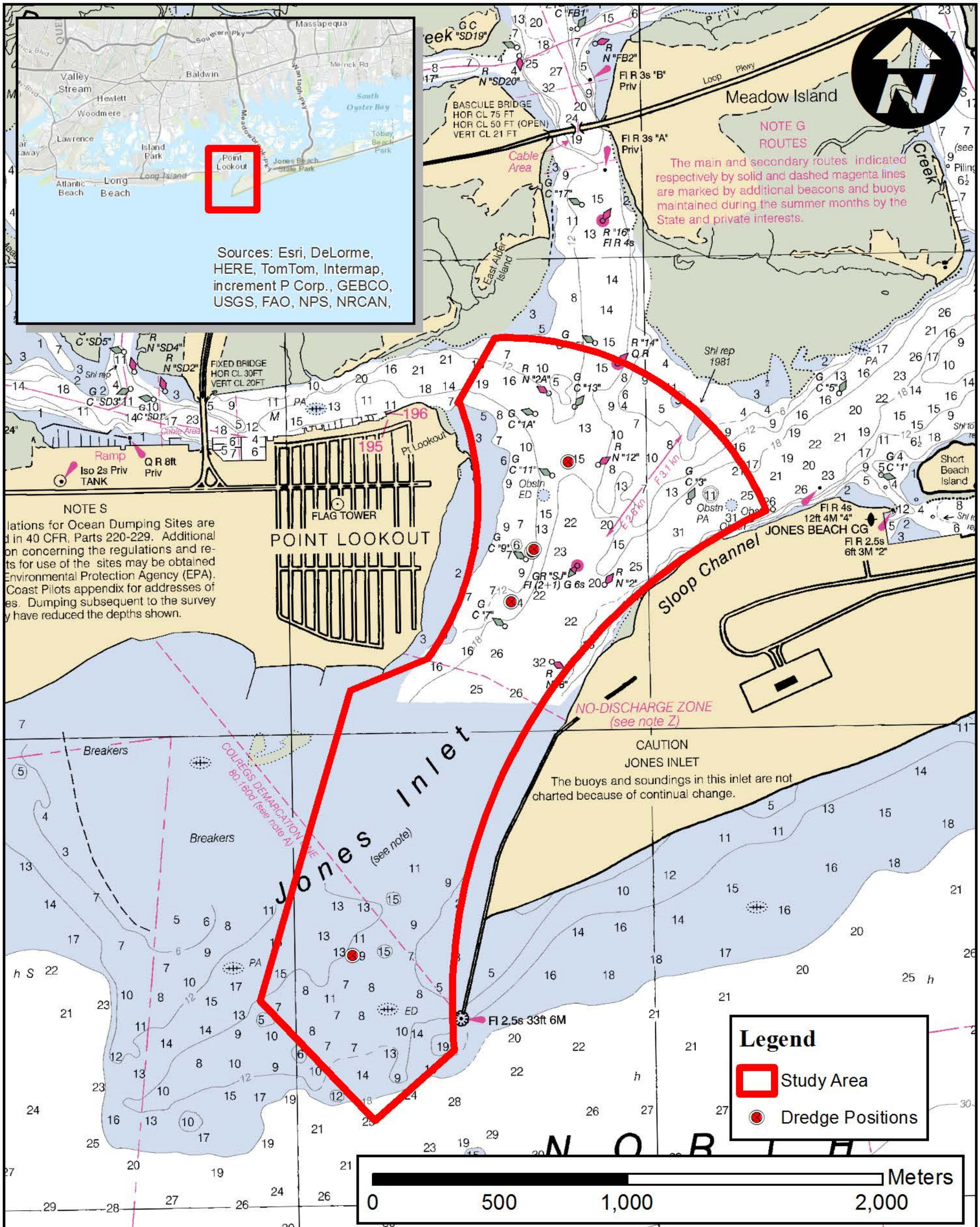


Figure	*USACE Harborwide TSS Far Field Survey Jones Inlet*	Jones Inlet Far-field Study Area	Tide
1			N/A

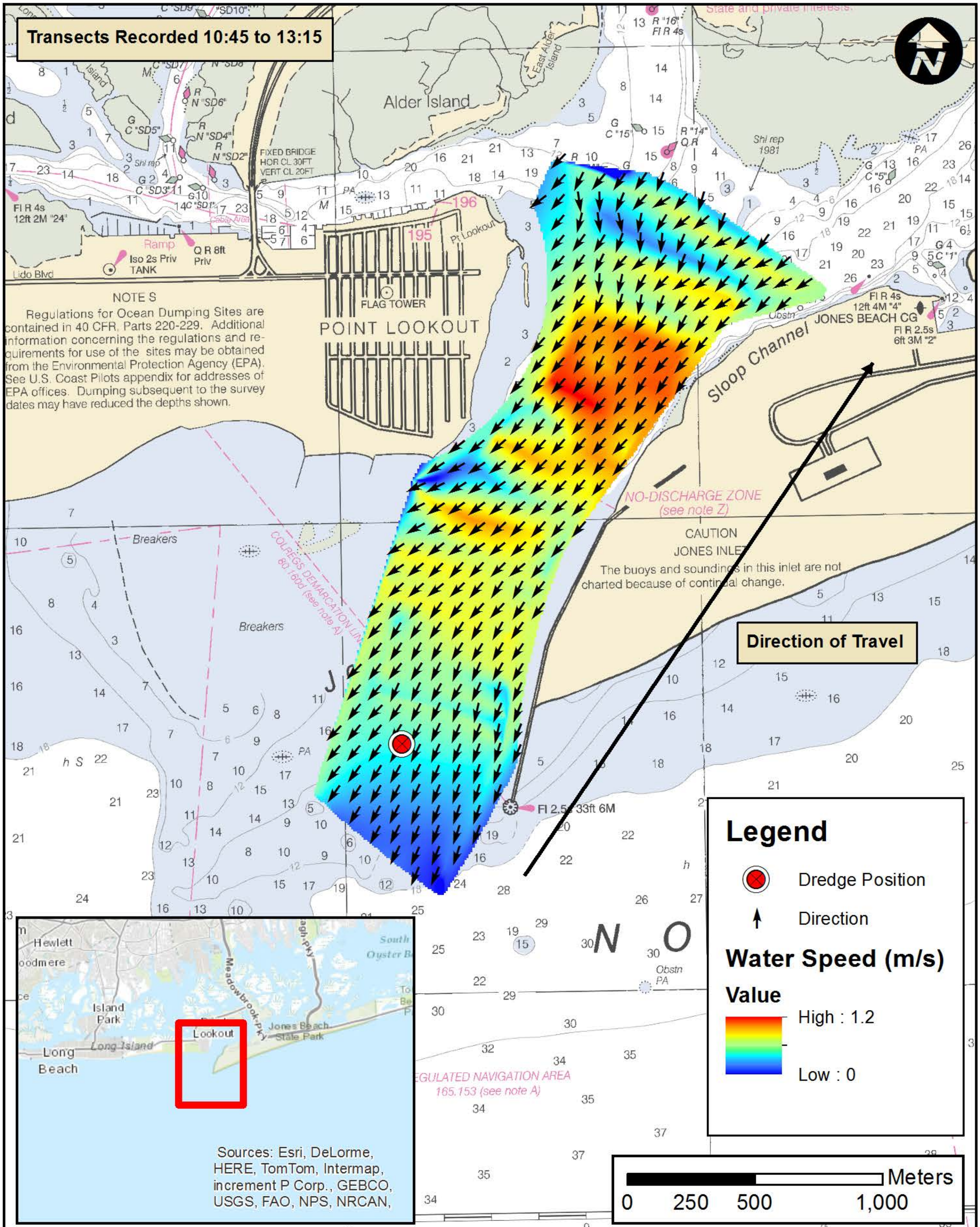
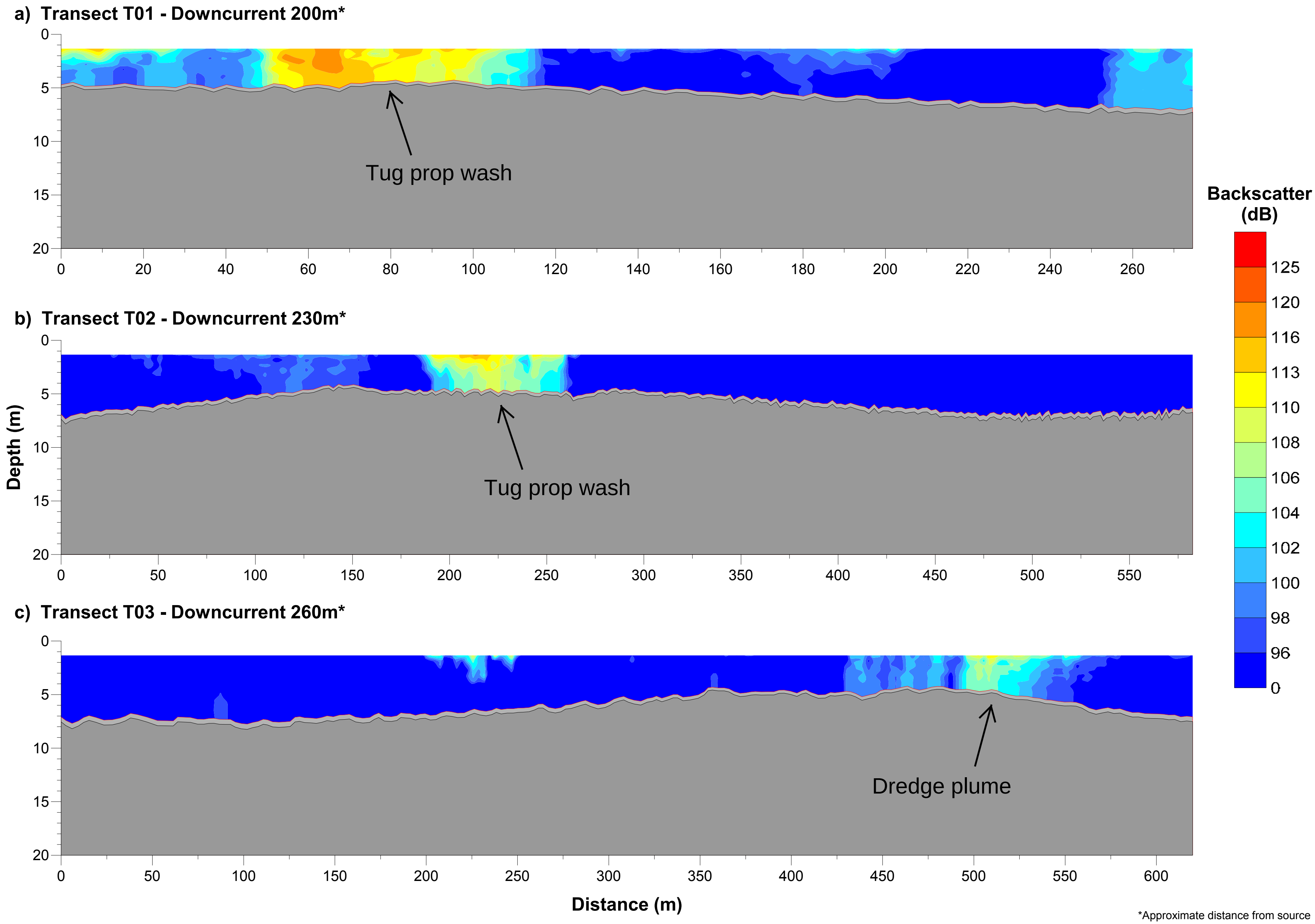
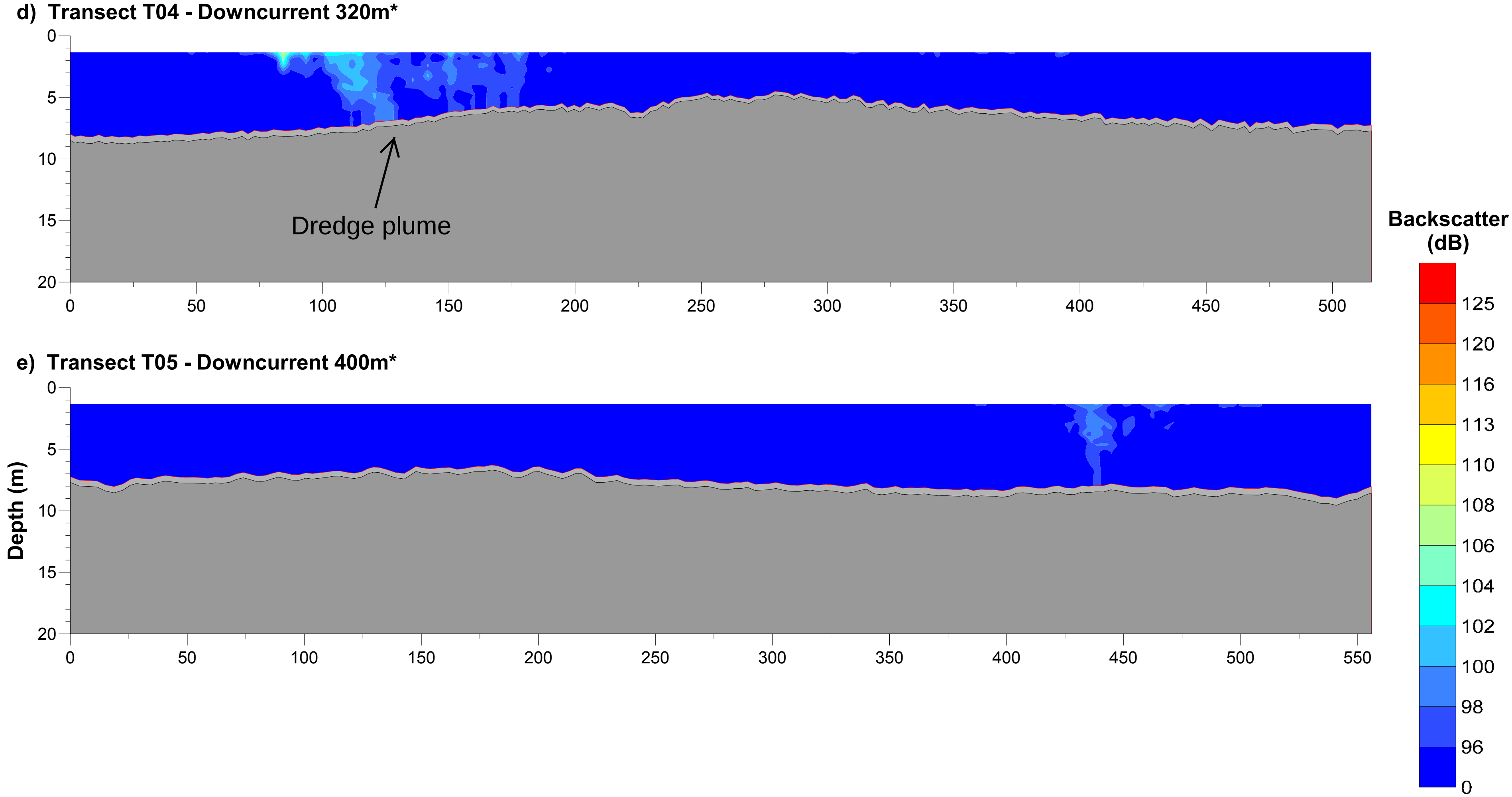


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	Depth Averaged Velocities 16 January 2014	Tide
2			Ebb



*Approximate distance from source

FIGURE	*USACE Harborwide TSS Far Field Survey Jones Inlet*	**Vertical Profiles of ADCP Average Backscatter (dB)**	TIDE
3a-c		**27 January 2014**	**Ebb**



*Approximate distance from source

FIGURE	*USACE Harborwide TSS* *Far Field Survey* *Jones Inlet*	**Vertical Profiles of ADCP Average Backscatter (dB)** **27 January 2014**	TIDE
3d-e			**Ebb**

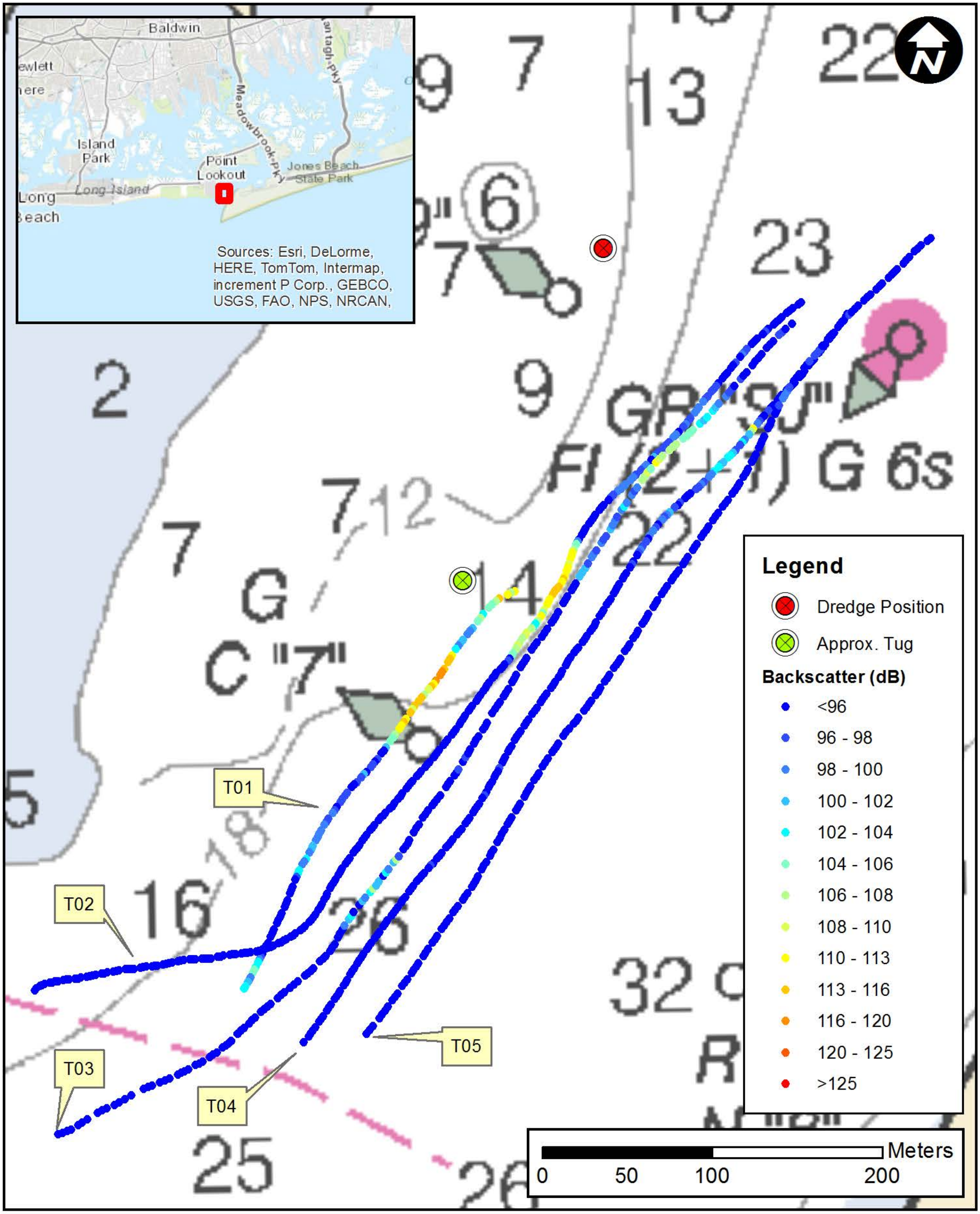


Figure	*USACE Harborwide TSS* *Far Field Survey* *Jones Beach Inlet*	**ADCP Average Backscatter - 27 January 2014** **Surface Depth Interval (0-2m)**	Tide
4a			Ebb

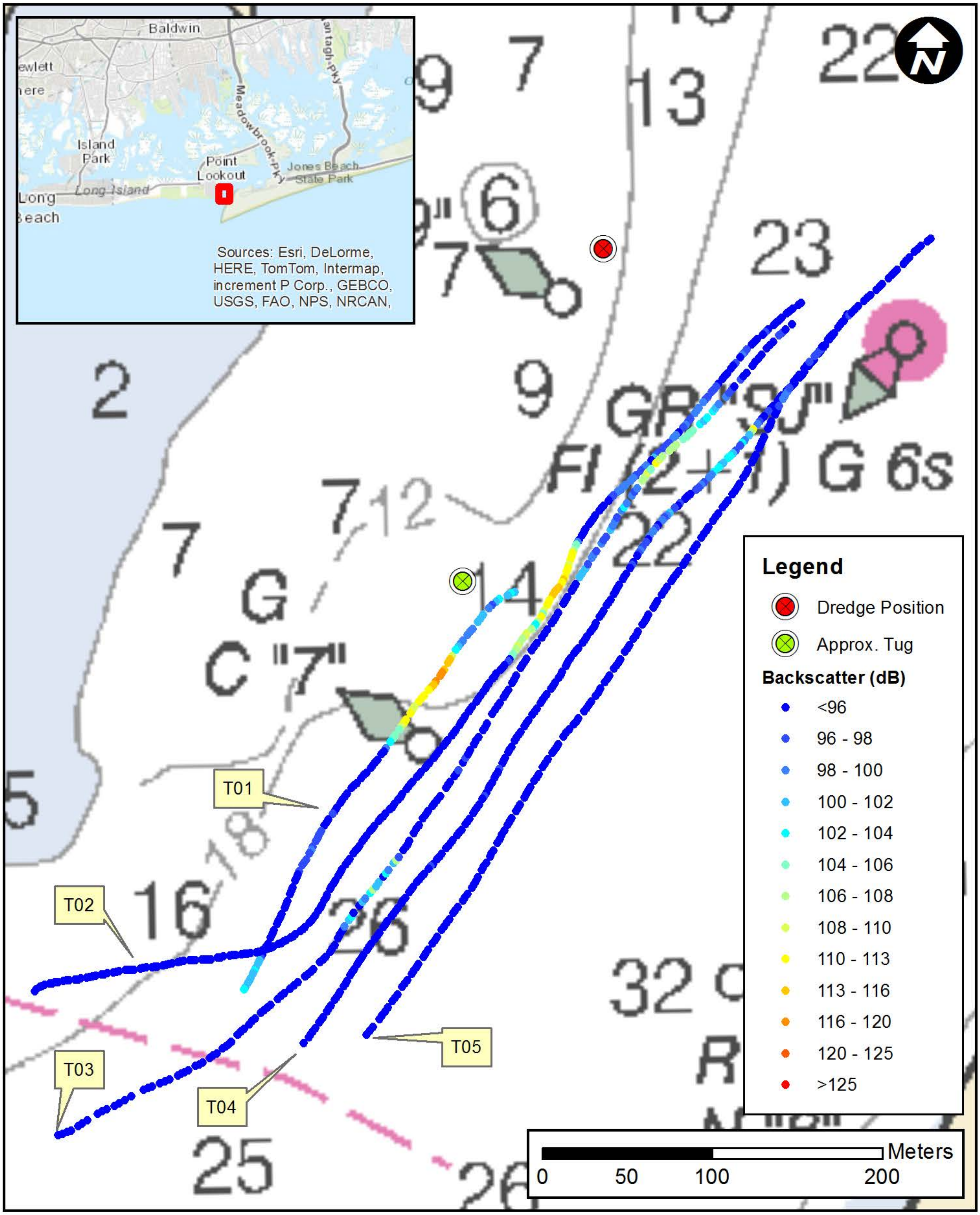


Figure	*USACE Harborwide TSS Far Field Survey Jones Beach Inlet*	**ADCP Average Backscatter - 27 January 2014 Mid Depth Interval (2-4m)**	**Tide**
4b			**Ebb**

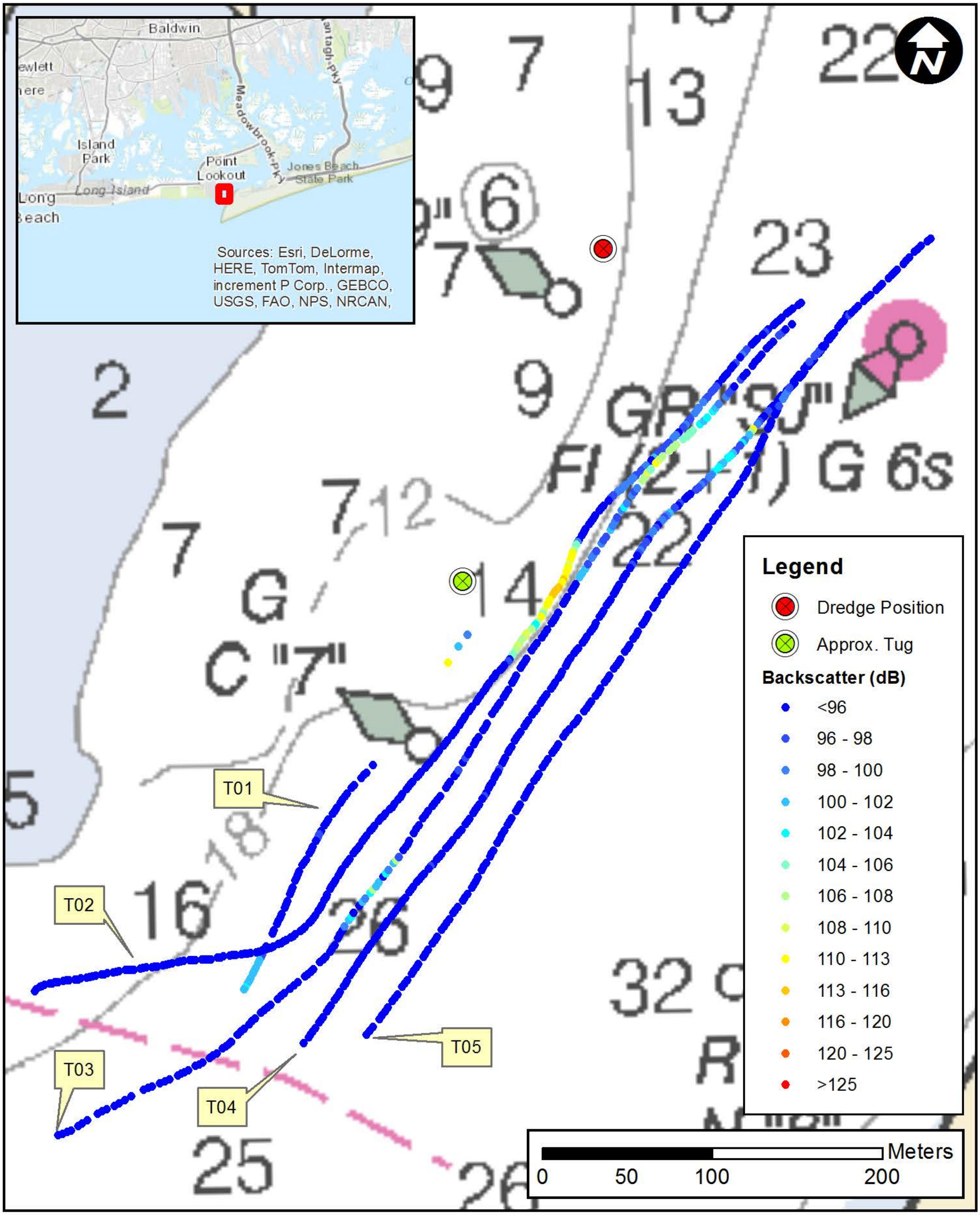


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	ADCP Average Backscatter - 27 January 2014 Bottom Depth Interval (4-6m)	Tide
4c			Ebb

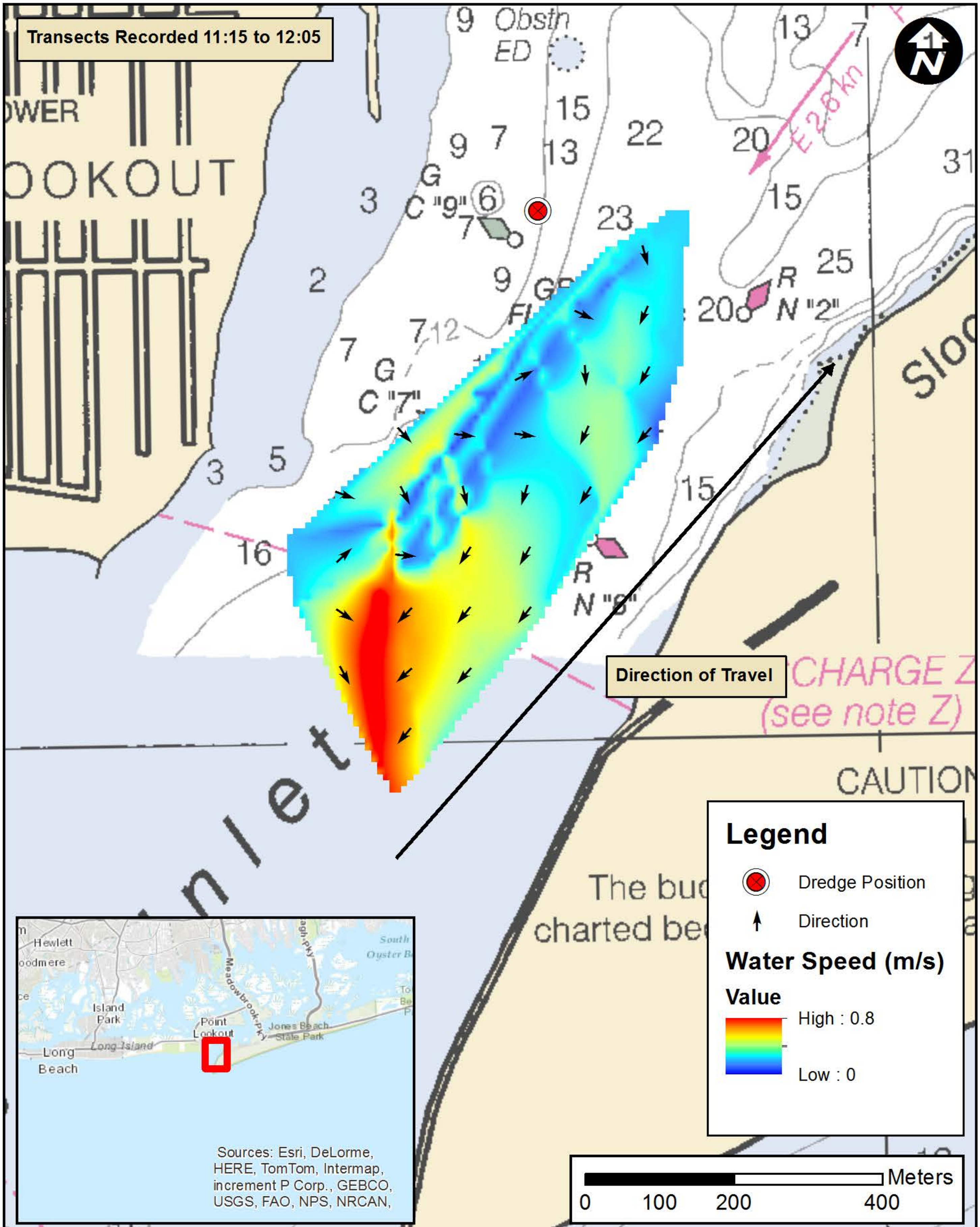


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	Depth Averaged Velocities 27 January 2014	Tide
5			Ebb

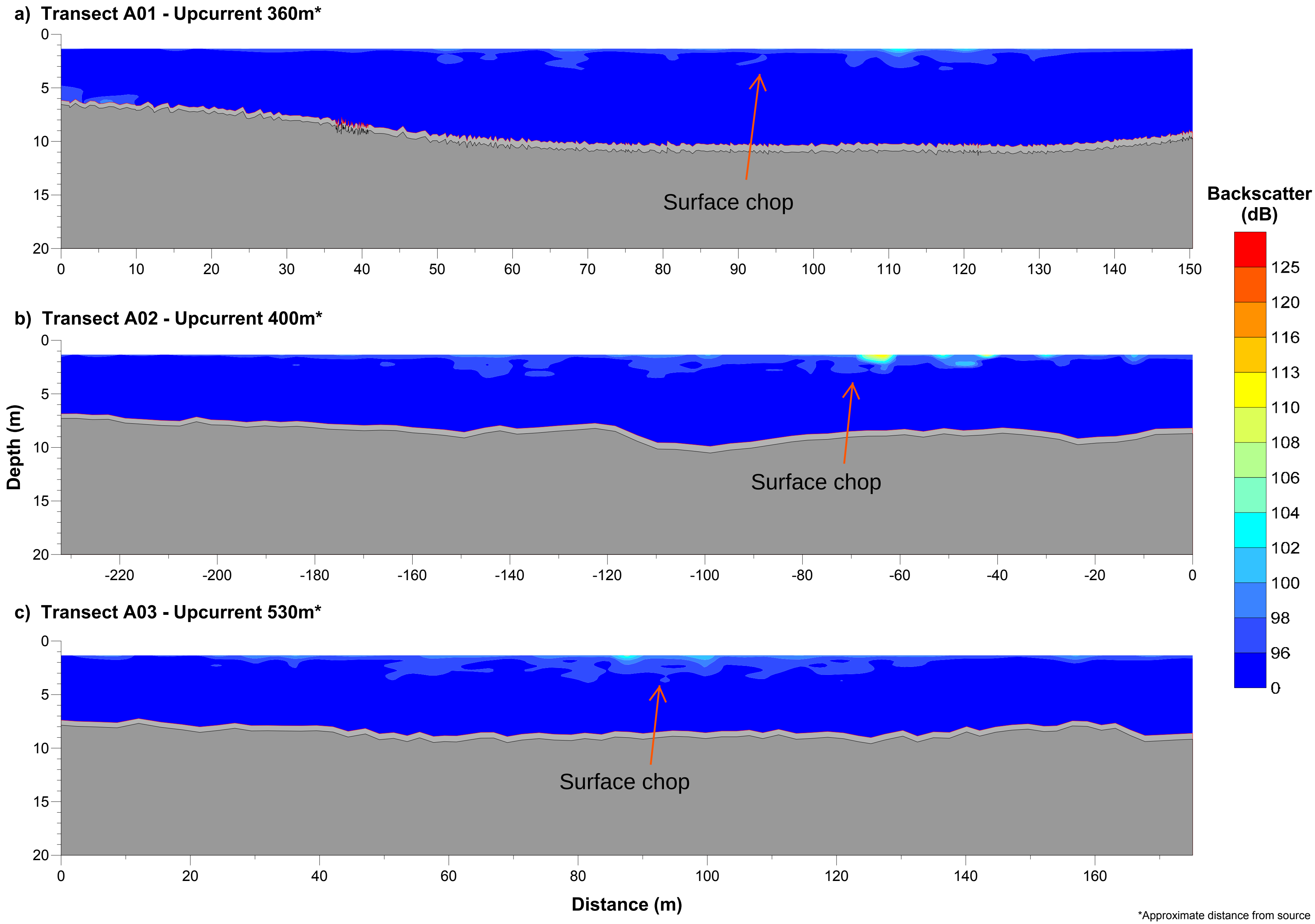


FIGURE	USACE Harborwide TSS Far Field Survey Jones Inlet	Vertical Profiles of ADCP Average Backscatter (dB) 27 January 2014	TIDE
6a-c			Flood

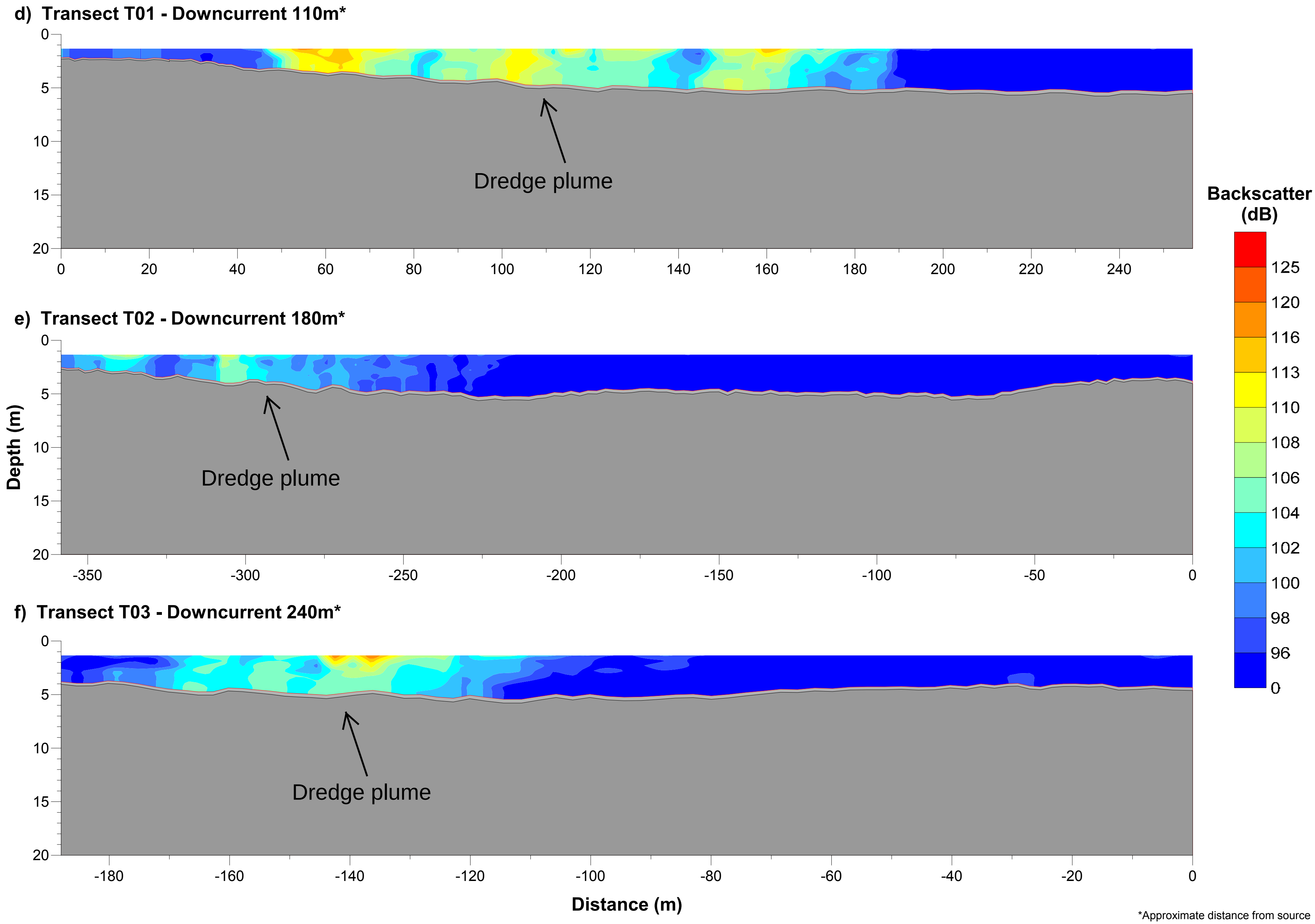


FIGURE	*USACE Harborwide TSS Far Field Survey Jones Inlet*	Vertical Profiles of ADCP Average Backscatter (dB) 27 January 2014	TIDE
6d-f			Flood

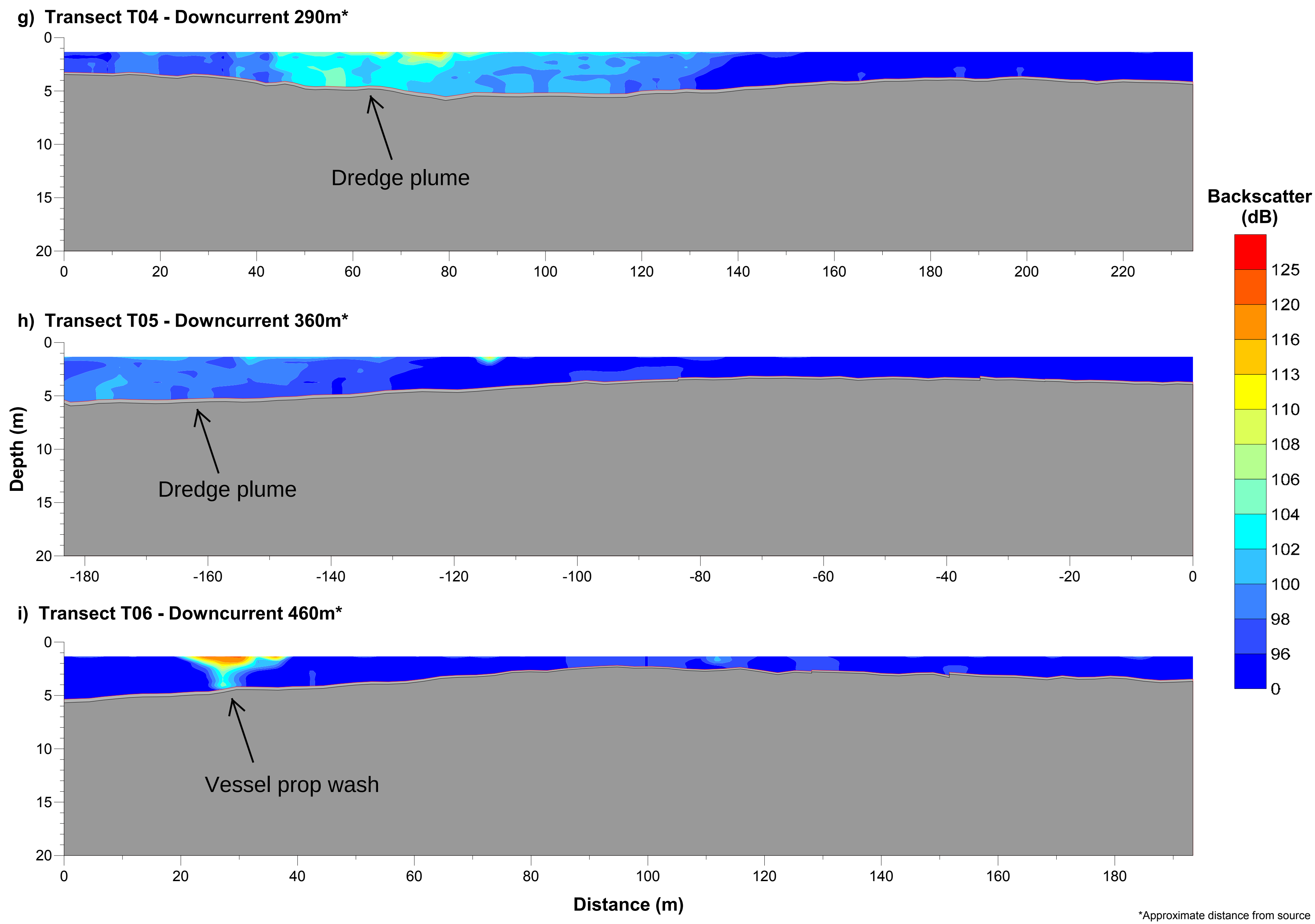


FIGURE	USACE Harborwide TSS Far Field Survey Jones Inlet	Vertical Profiles of ADCP Average Backscatter (dB) 27 January 2014	TIDE
6g-i			Flood

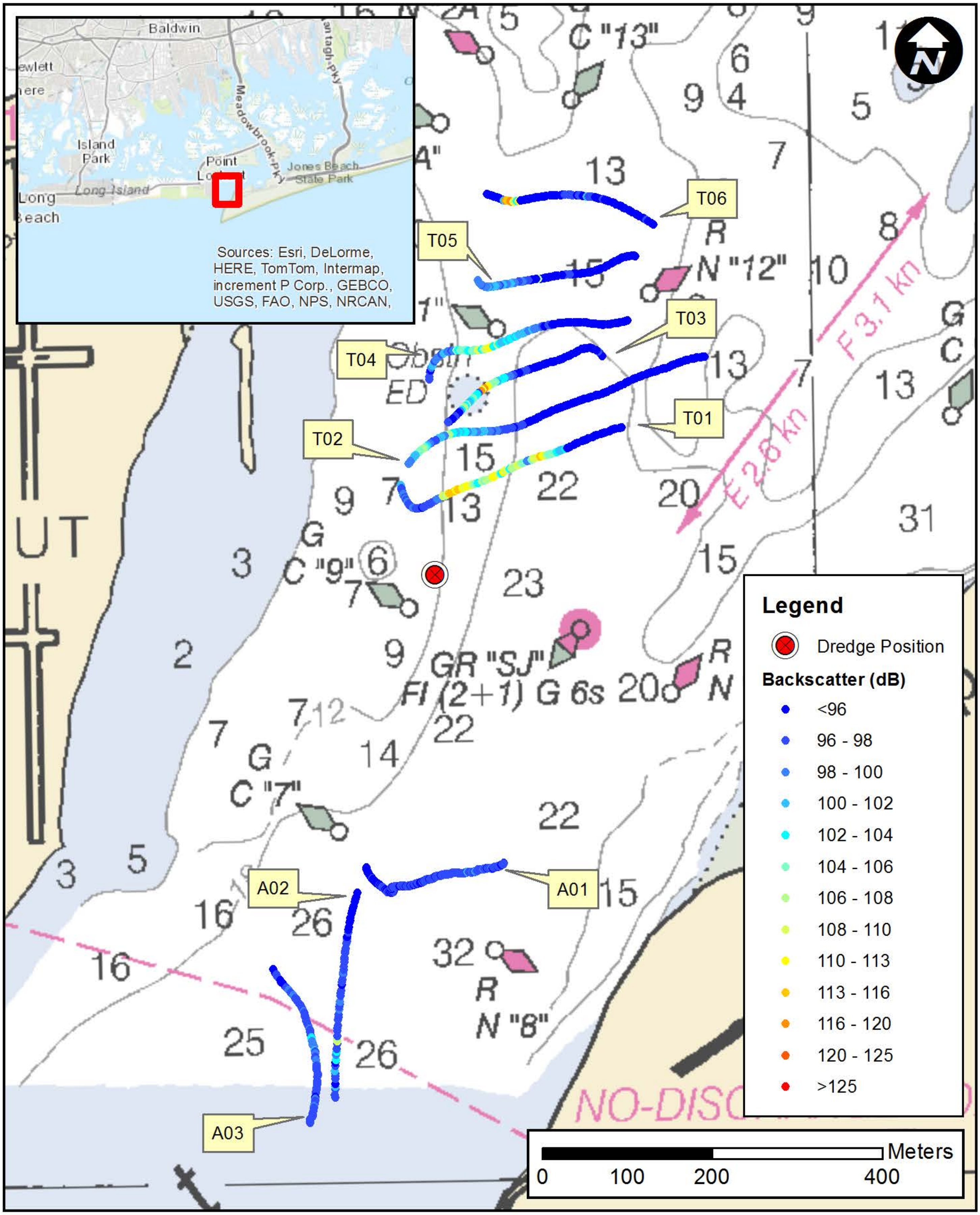


Figure	*USACE Harborwide TSS Far Field Survey Jones Beach Inlet*	**ADCP Average Backscatter - 27 January 2014 Surface Depth Interval (0-2m)**	Tide
7a			Flood

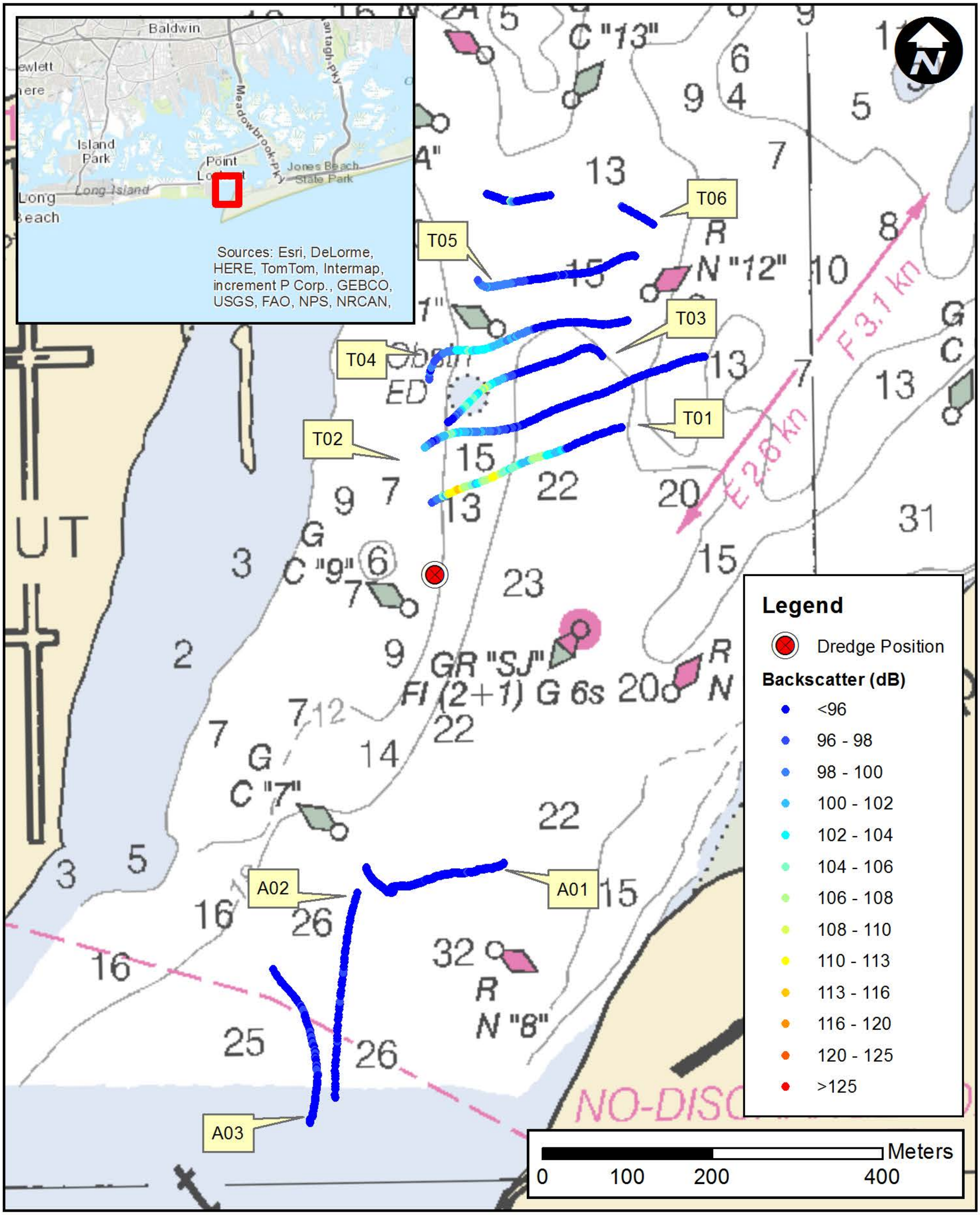


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	ADCP Average Backscatter - 27 January 2014 Mid Depth Interval (2-4m)	Tide
7b			Flood

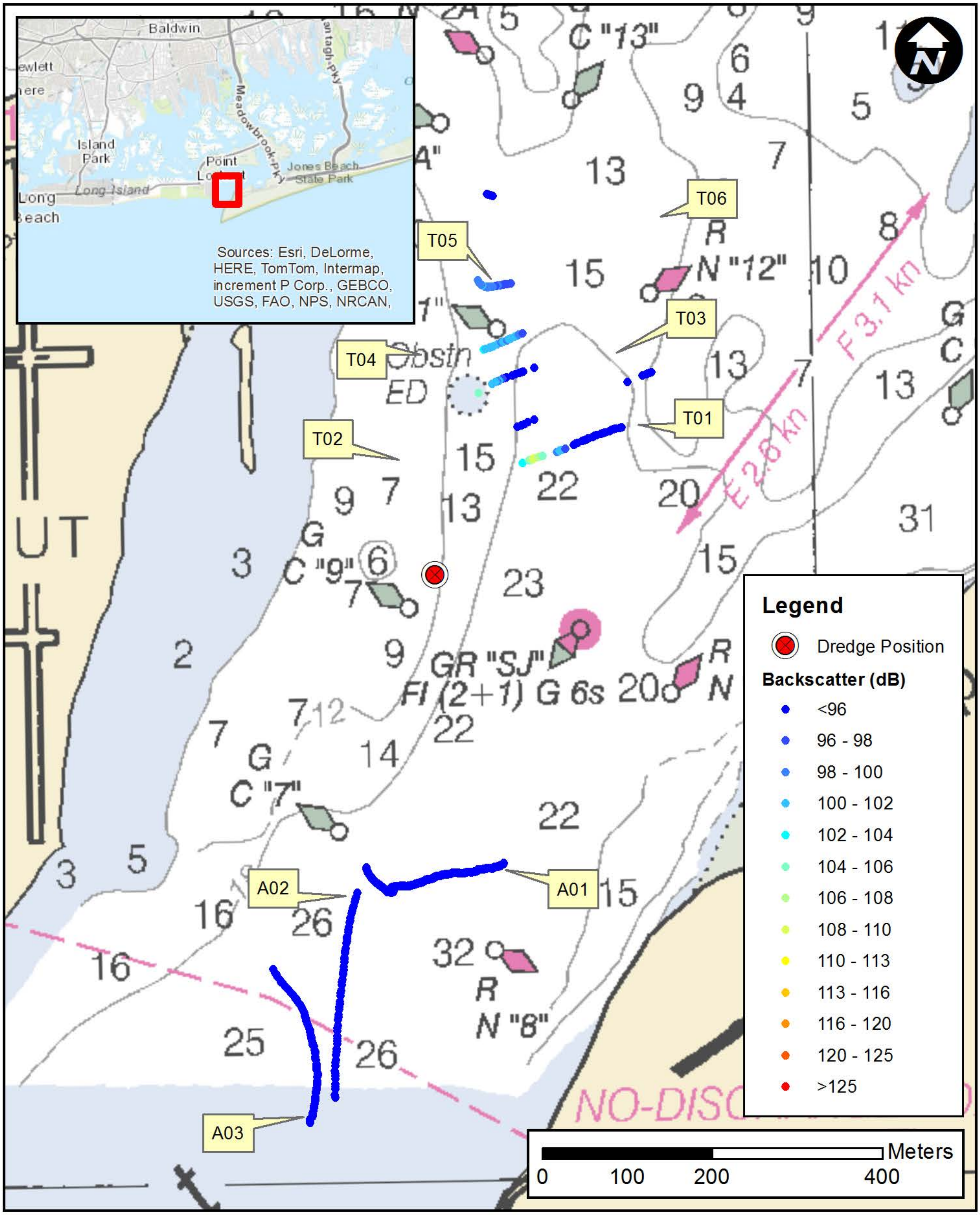


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	ADCP Average Backscatter - 27 January 2014 Mid Depth Interval (4-6m)	Tide
7c			Flood

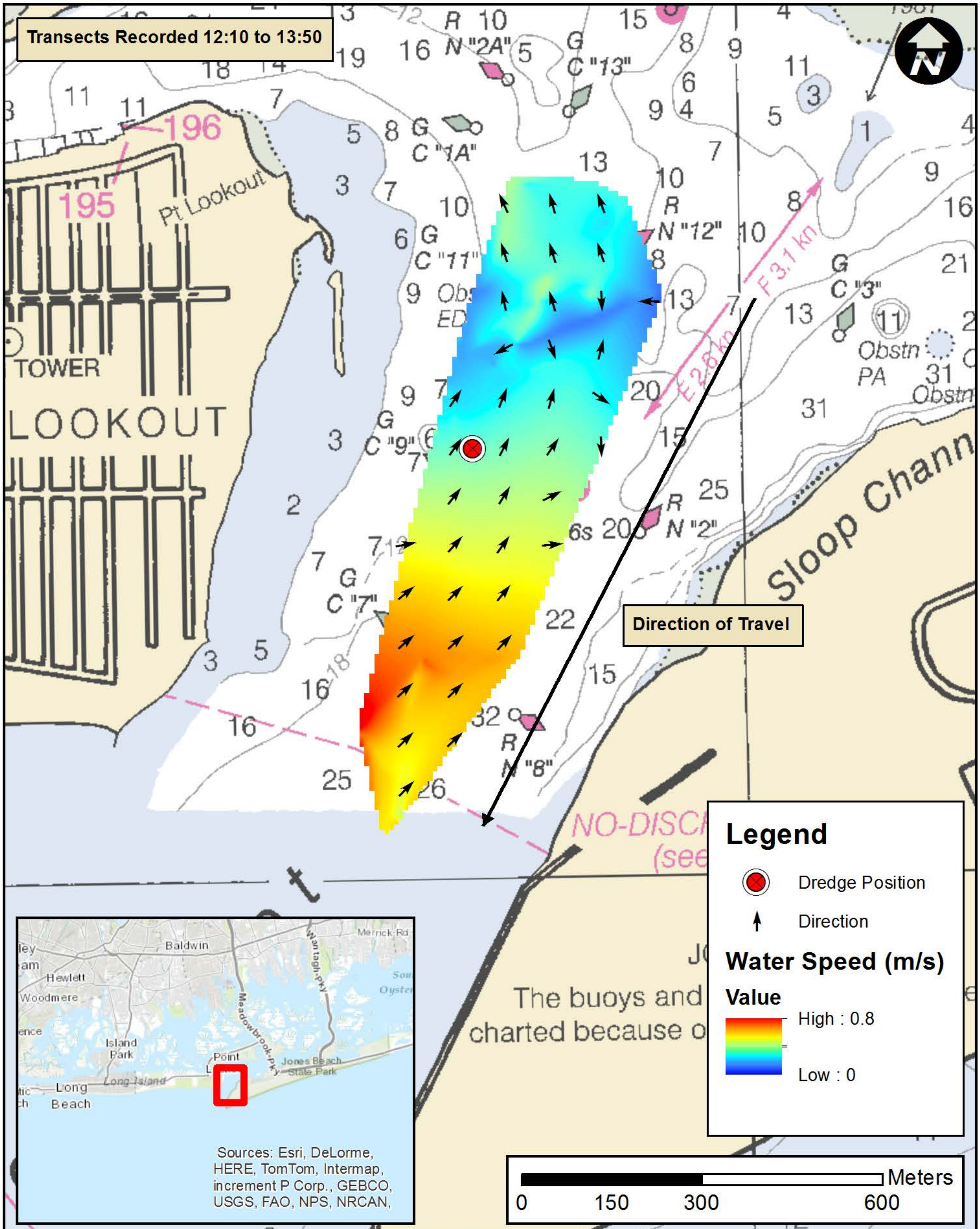


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	Depth Averaged Velocities 27 January 2014	Tide
8			Flood

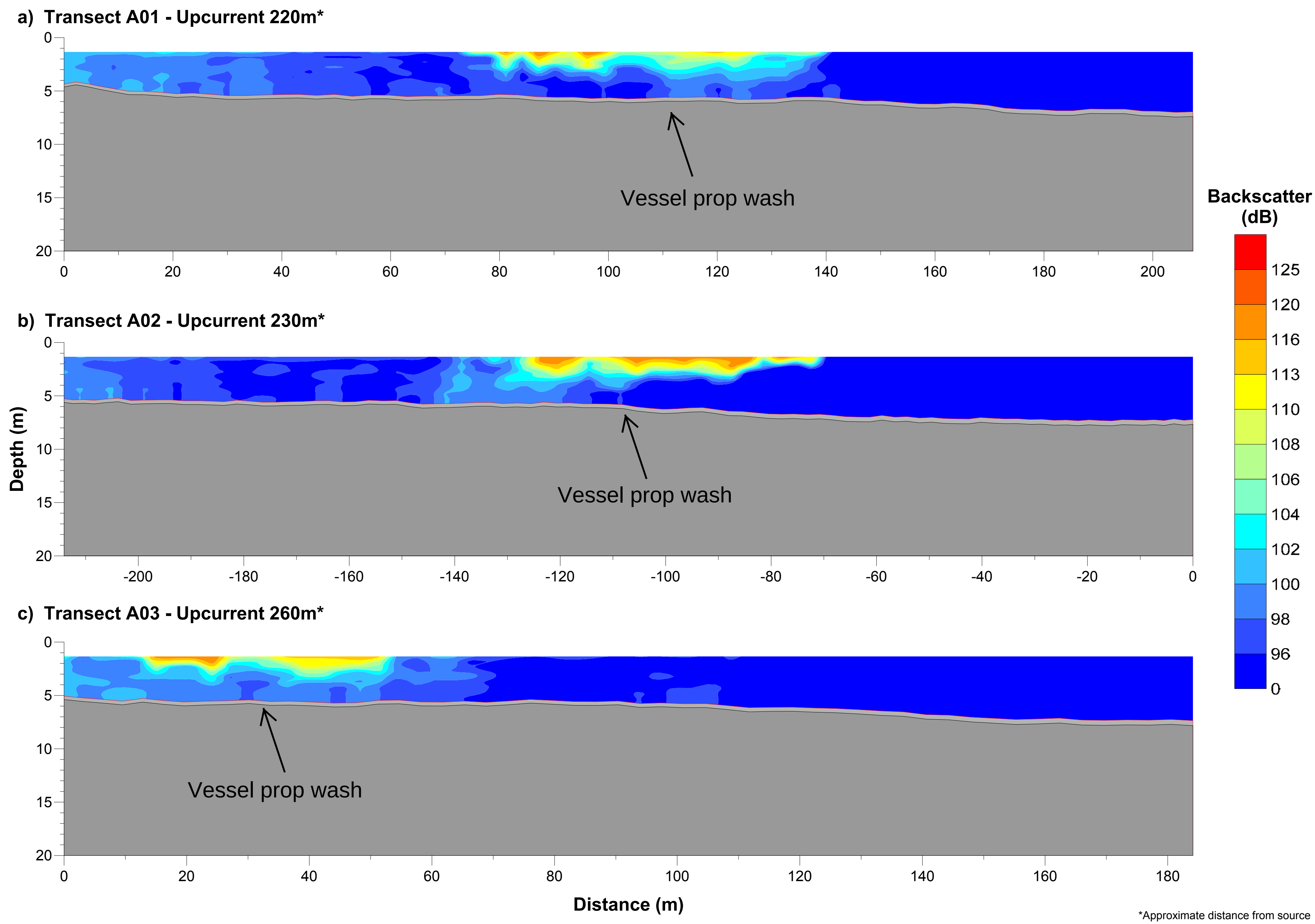


FIGURE	*USACE Harborwide TSS* *Far Field Survey* *Jones Inlet*	**Vertical Profiles of ADCP Average Backscatter (dB)** **11 February 2014**	TIDE
9a-c			Flood

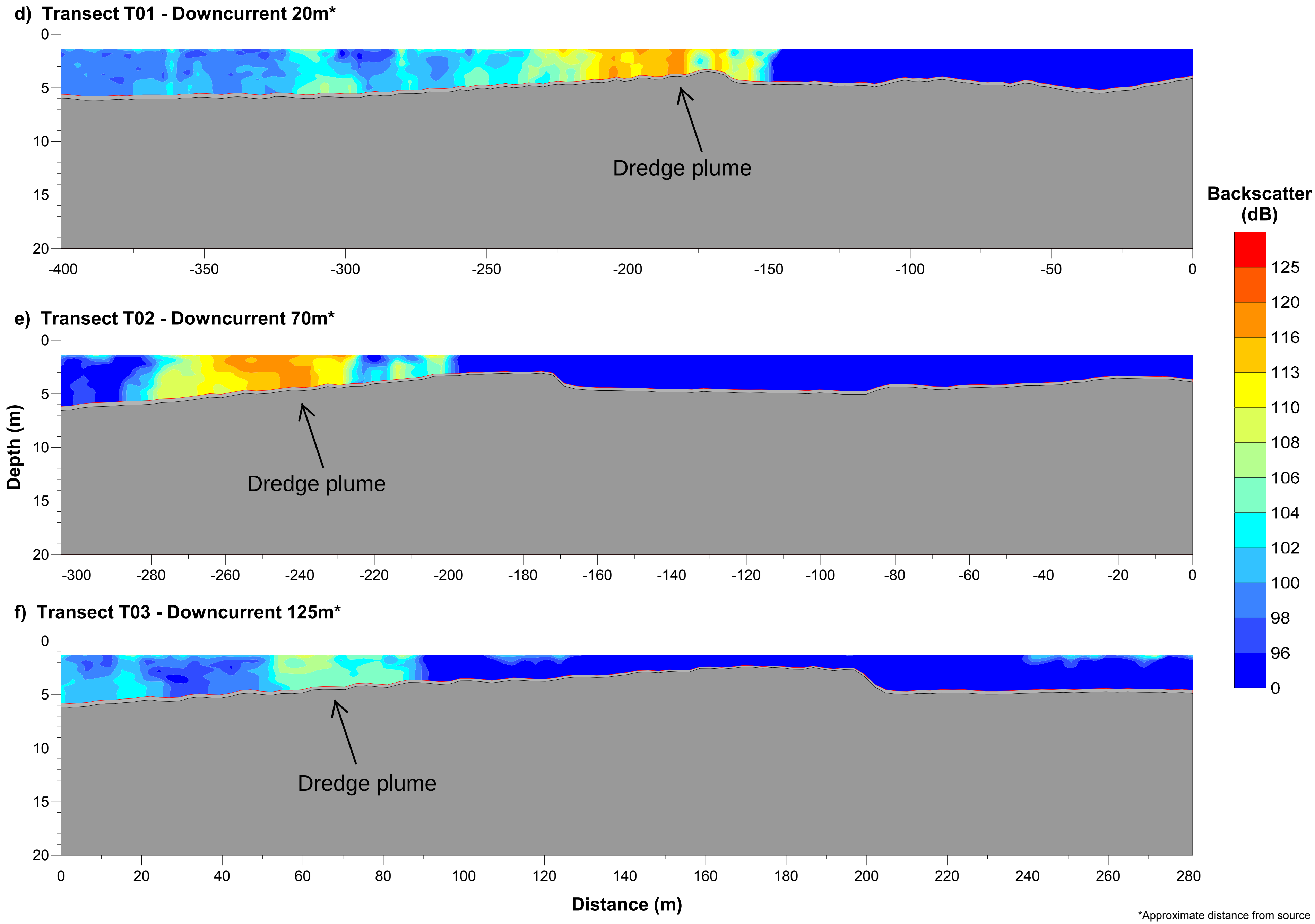
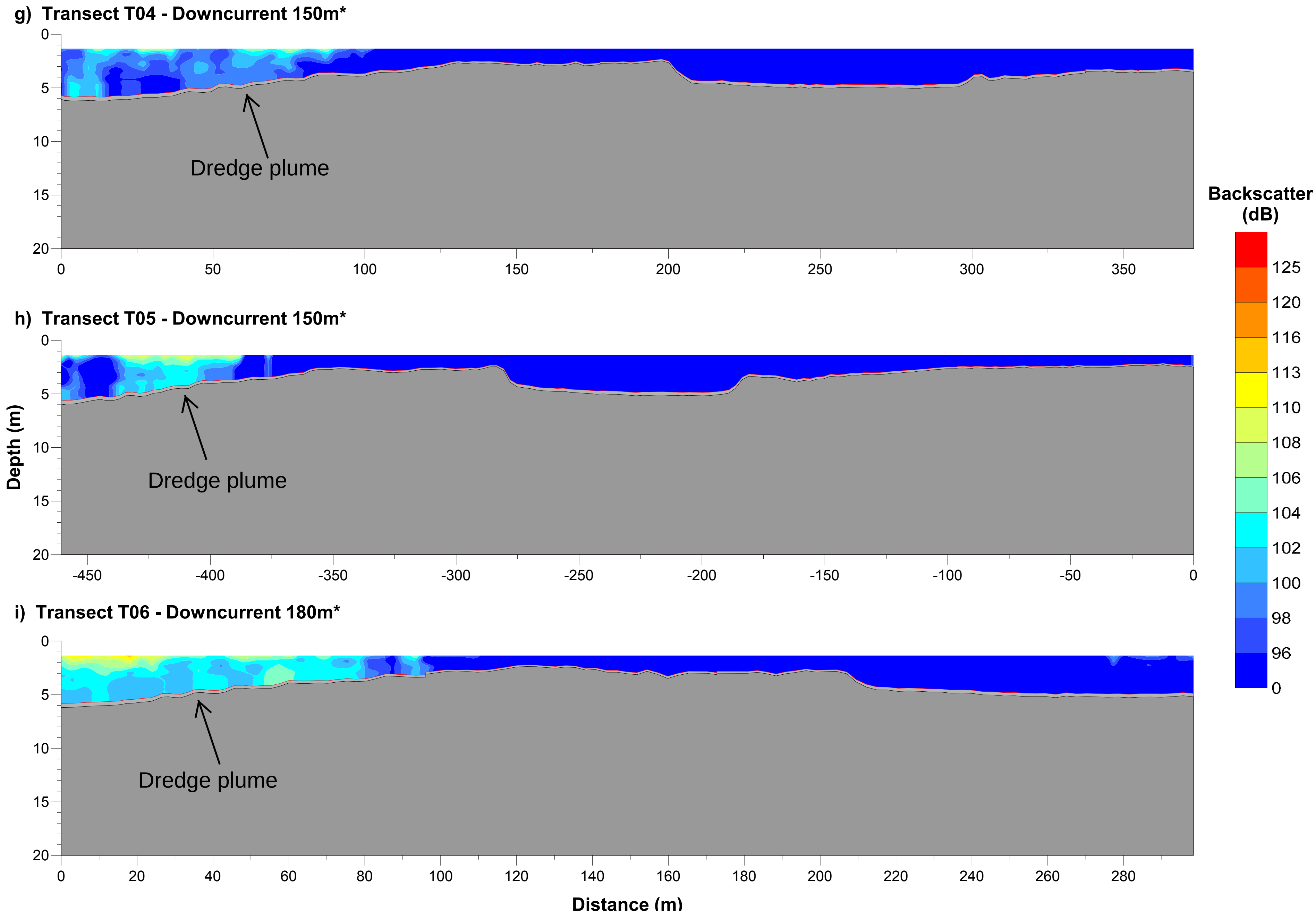


FIGURE	*USACE Harborwide TSS Far Field Survey Jones Inlet*	**Vertical Profiles of ADCP Average Backscatter (dB) 11 February 2014**	TIDE
9d-f			**Flood**



*Approximate distance from source

FIGURE	*USACE Harborwide TSS Far Field Survey Jones Inlet*	Vertical Profiles of ADCP Average Backscatter (dB) 11 February 2014	TIDE
9g-i			Flood

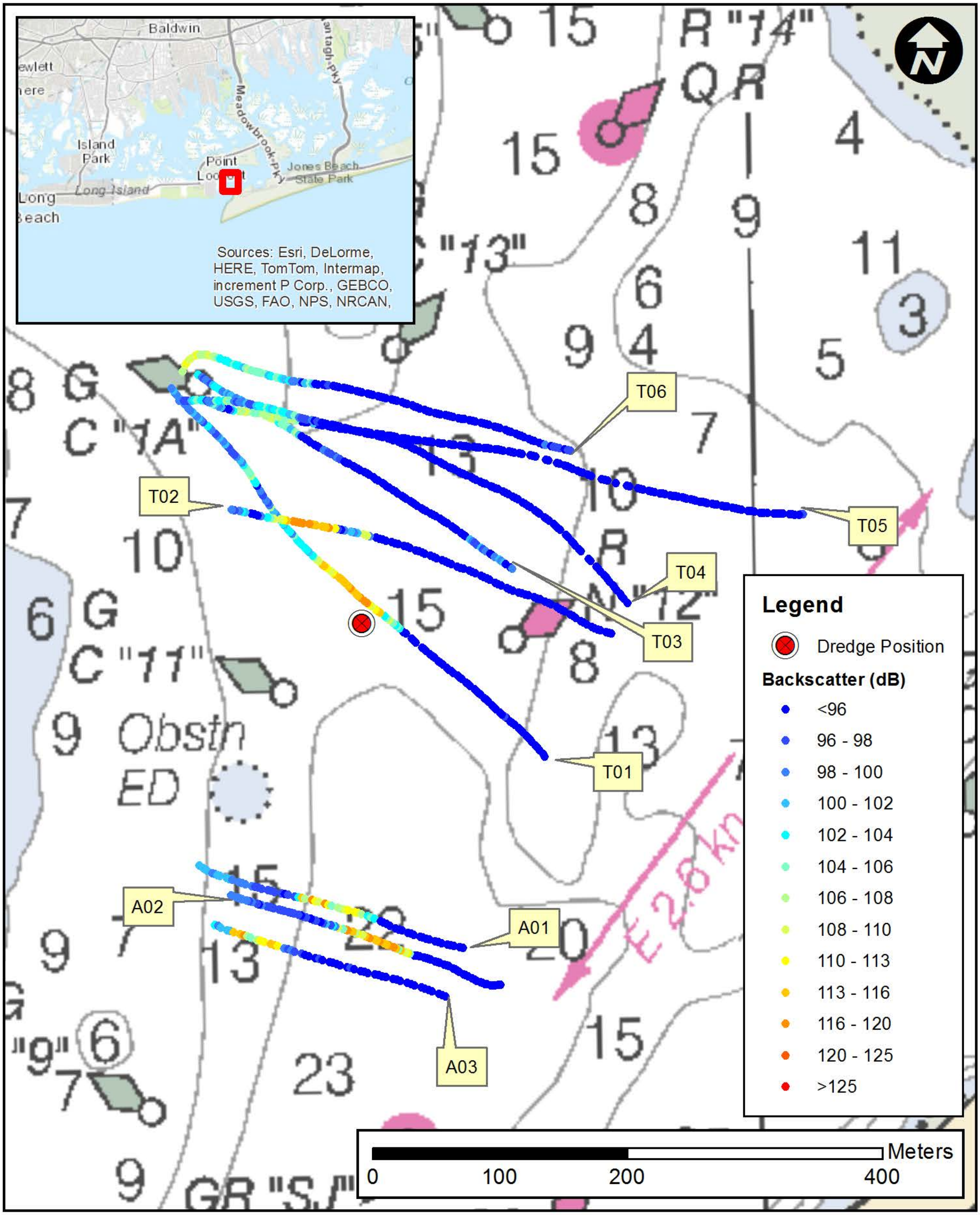


Figure	*USACE Harborwide TSS Far Field Survey Jones Beach Inlet*	**ADCP Average Backscatter - 11 February 2014** **Surface Depth Interval (0-2m)**	Tide
10a			Flood

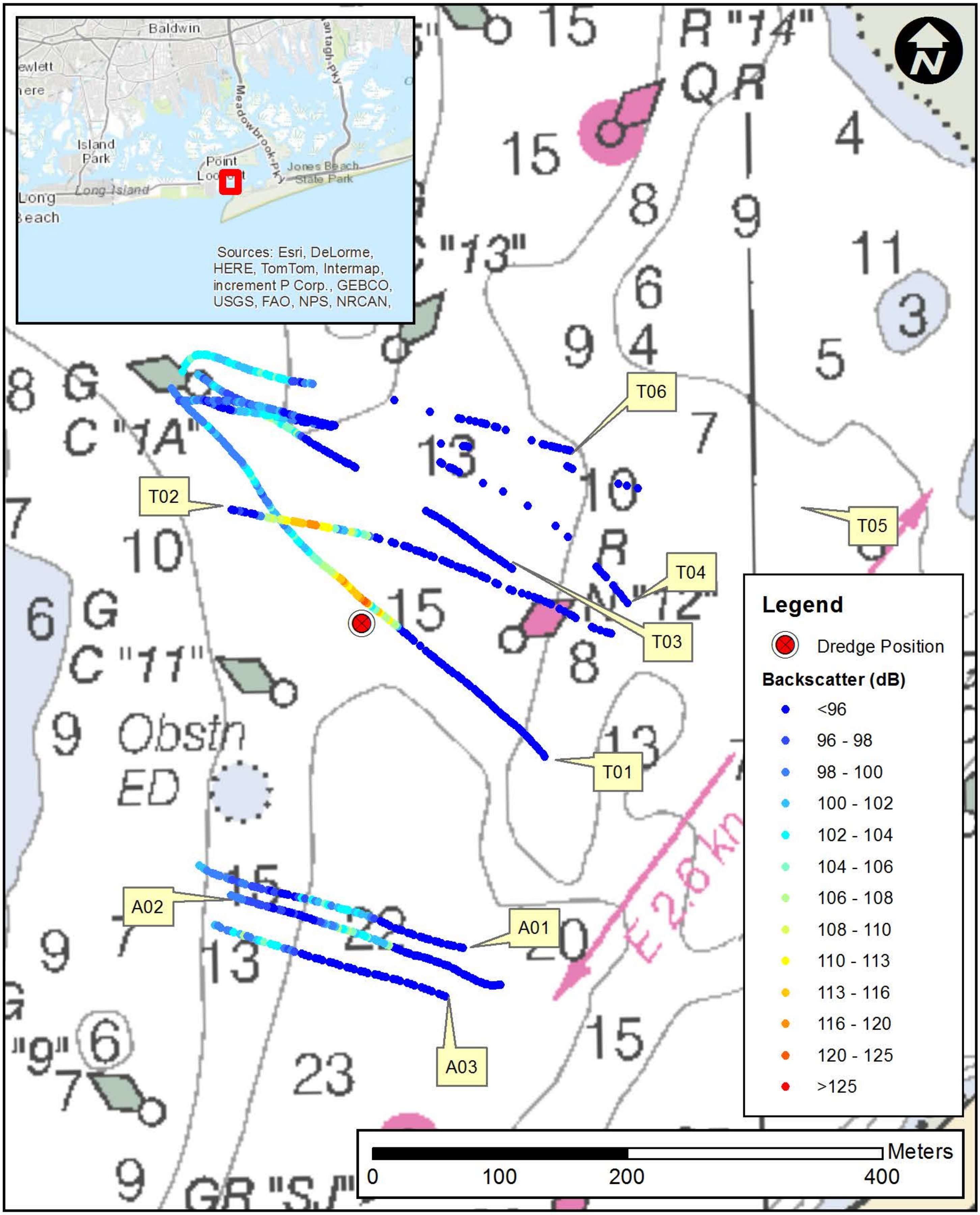


Figure	*USACE Harborwide TSS Far Field Survey Jones Beach Inlet*	ADCP Average Backscatter - 11 February 2014 Mid Depth Interval (2-4m)	Tide
10b			Flood

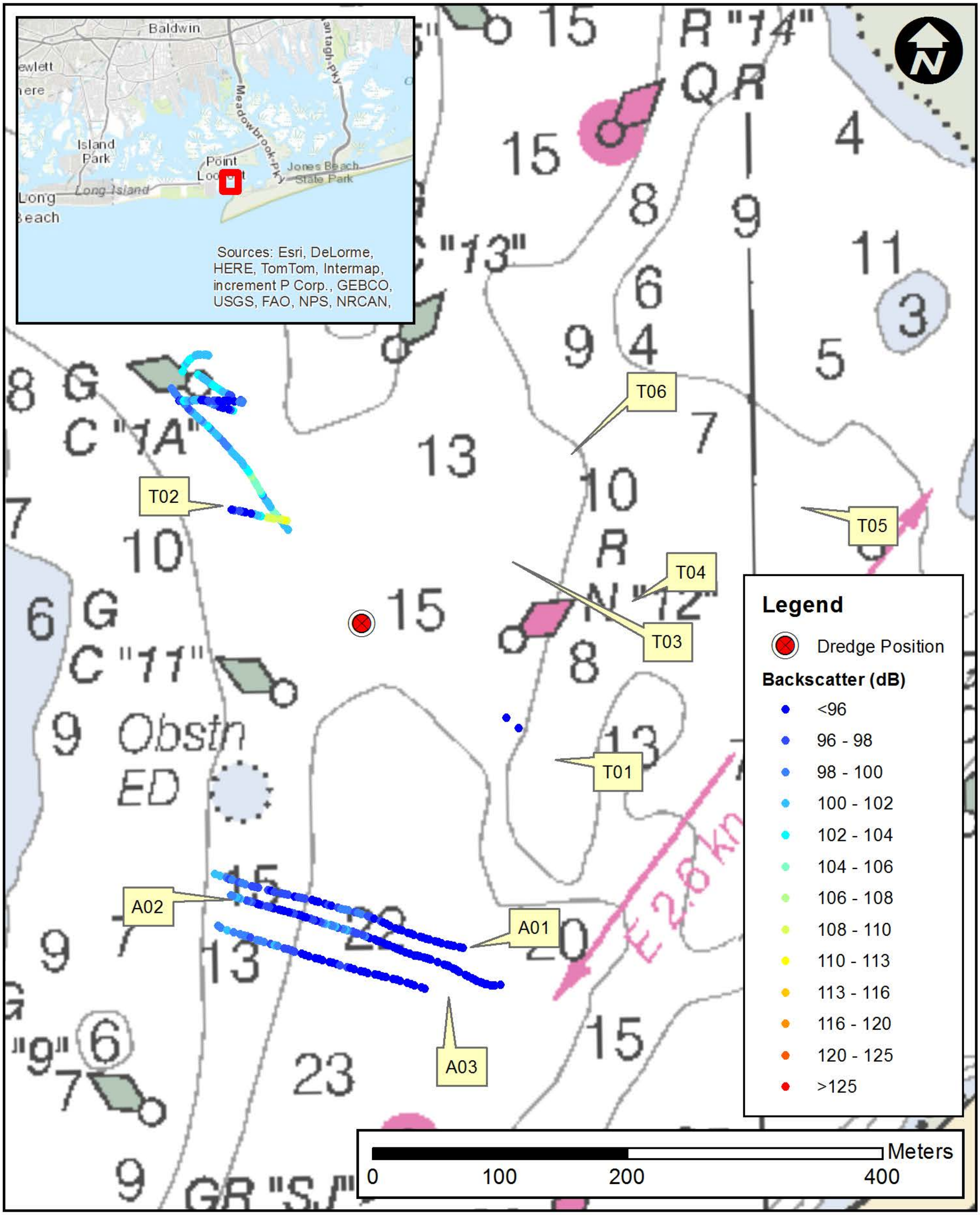


Figure	*USACE Harborwide TSS Far Field Survey Jones Beach Inlet*	**ADCP Average Backscatter - 11 February 2014 Bottom Depth Interval (4-6m)**	Tide
10c			Flood

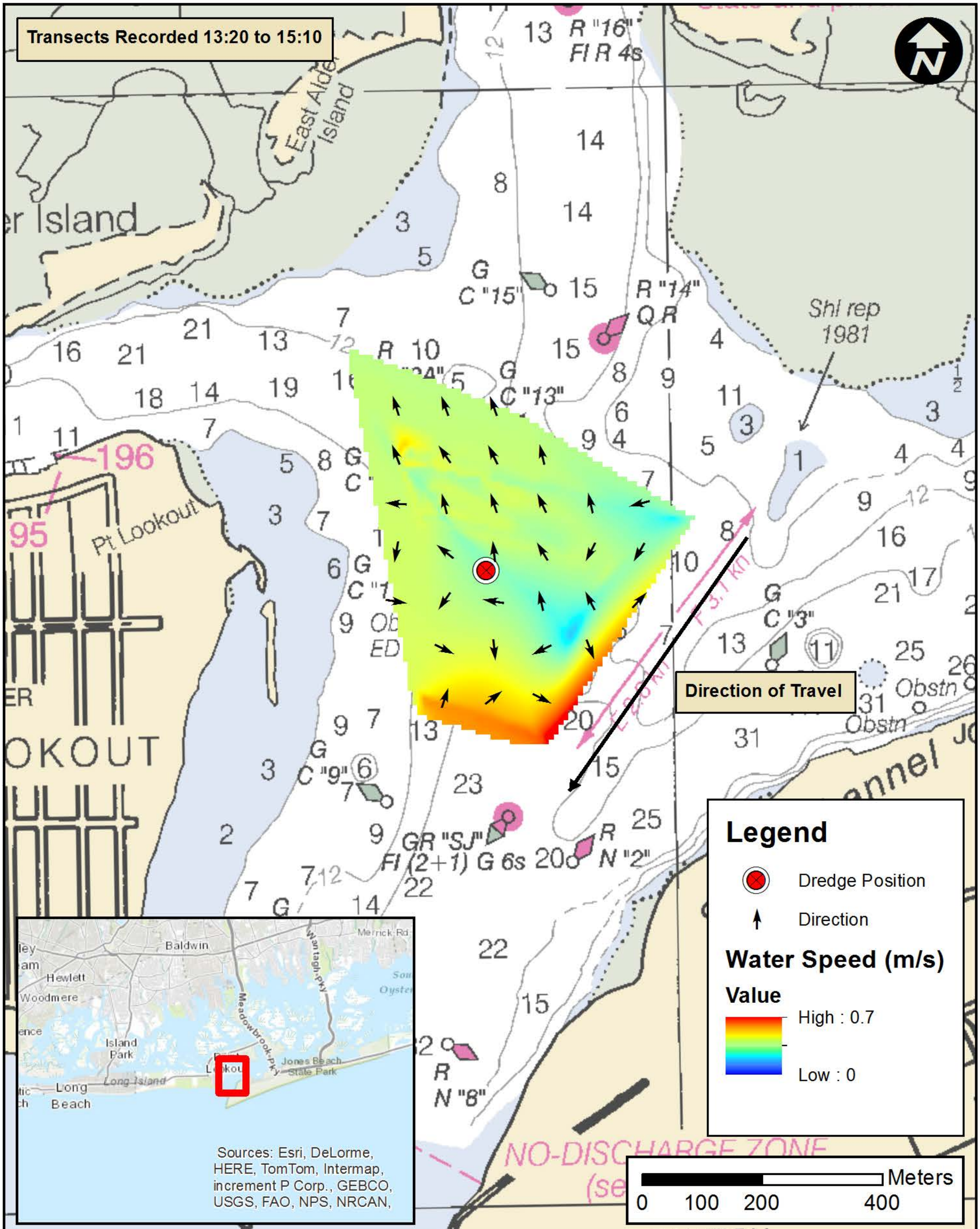
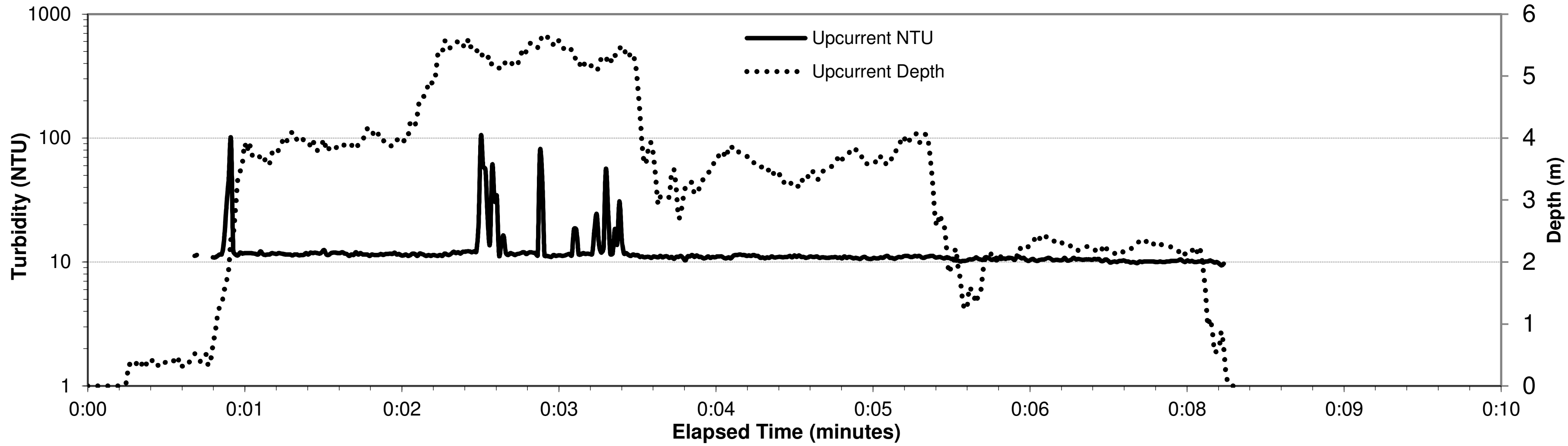


Figure	*USACE Harborwide TSS*	**Depth Averaged Velocities**	**Tide**
11	*Far Field Survey Jones Beach Inlet*	**11 February 2014**	**Flood**

a) Upcurrent from Dredge



b) Downcurrent from Dredge

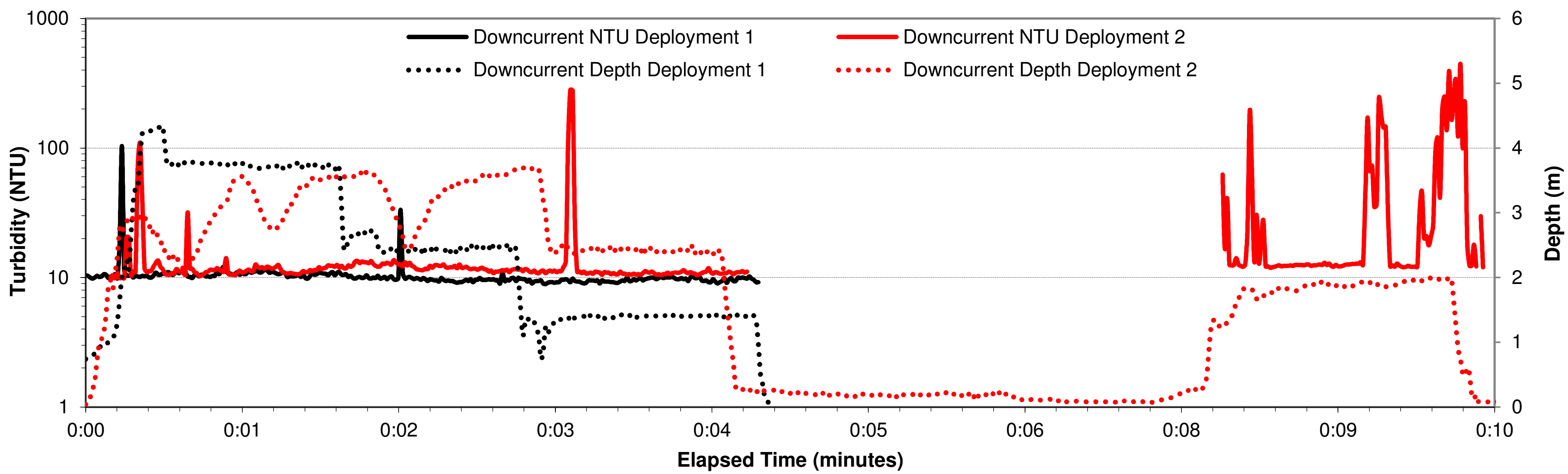
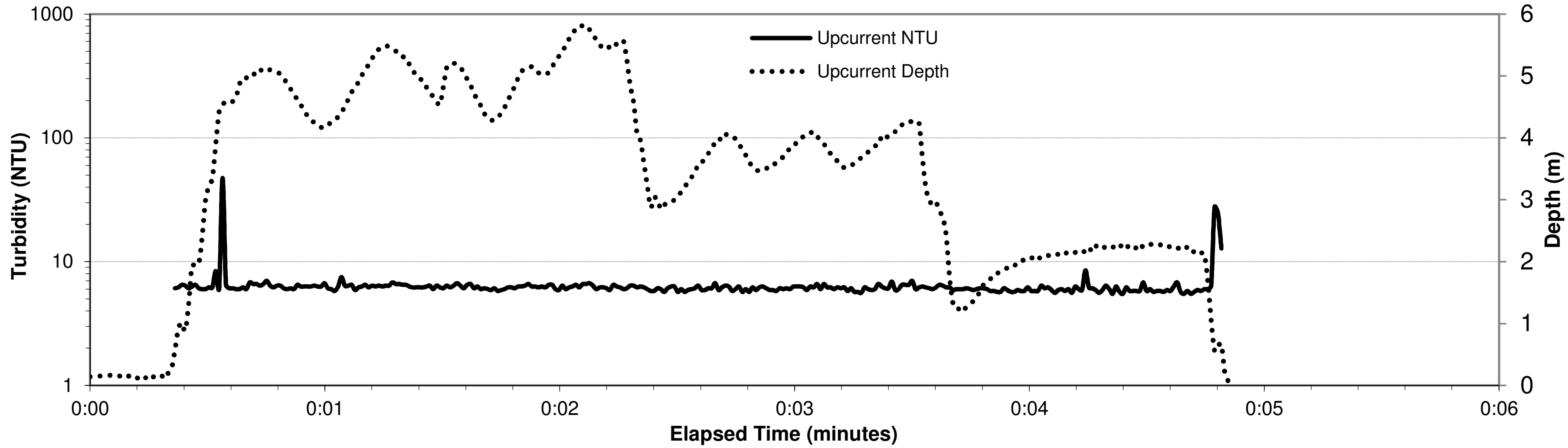


Figure	*USACE Harborwide TSS* *Far Field Survey* *Jones Beach Inlet*	**OBS Turbidities a) Upcurrent and b) Downcurrent of Dredge** **27 January 2014 TSS Survey**	**Tide**
12			**Flood**

a) Upcurrent from Dredge



b) Downcurrent from Dredge

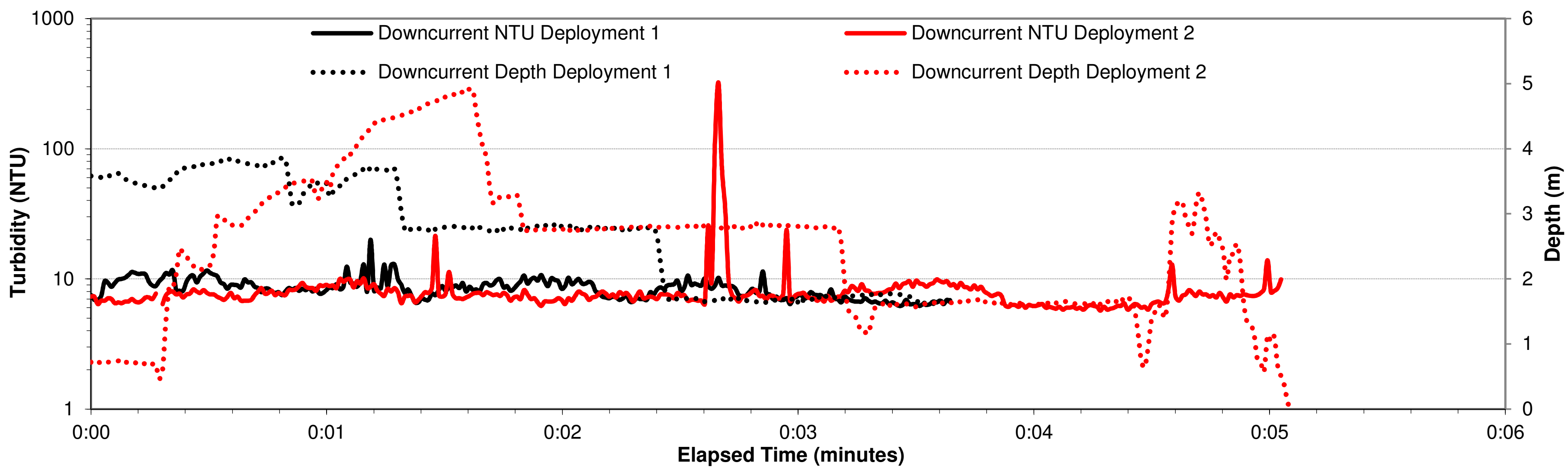


Figure	*USACE Harborwide TSS Far Field Survey Jones Beach Inlet*	**OBS Turbidities a) Upcurrent and b) Downcurrent of Dredge 11 February 2014 TSS Survey**	Tide
13			Flood

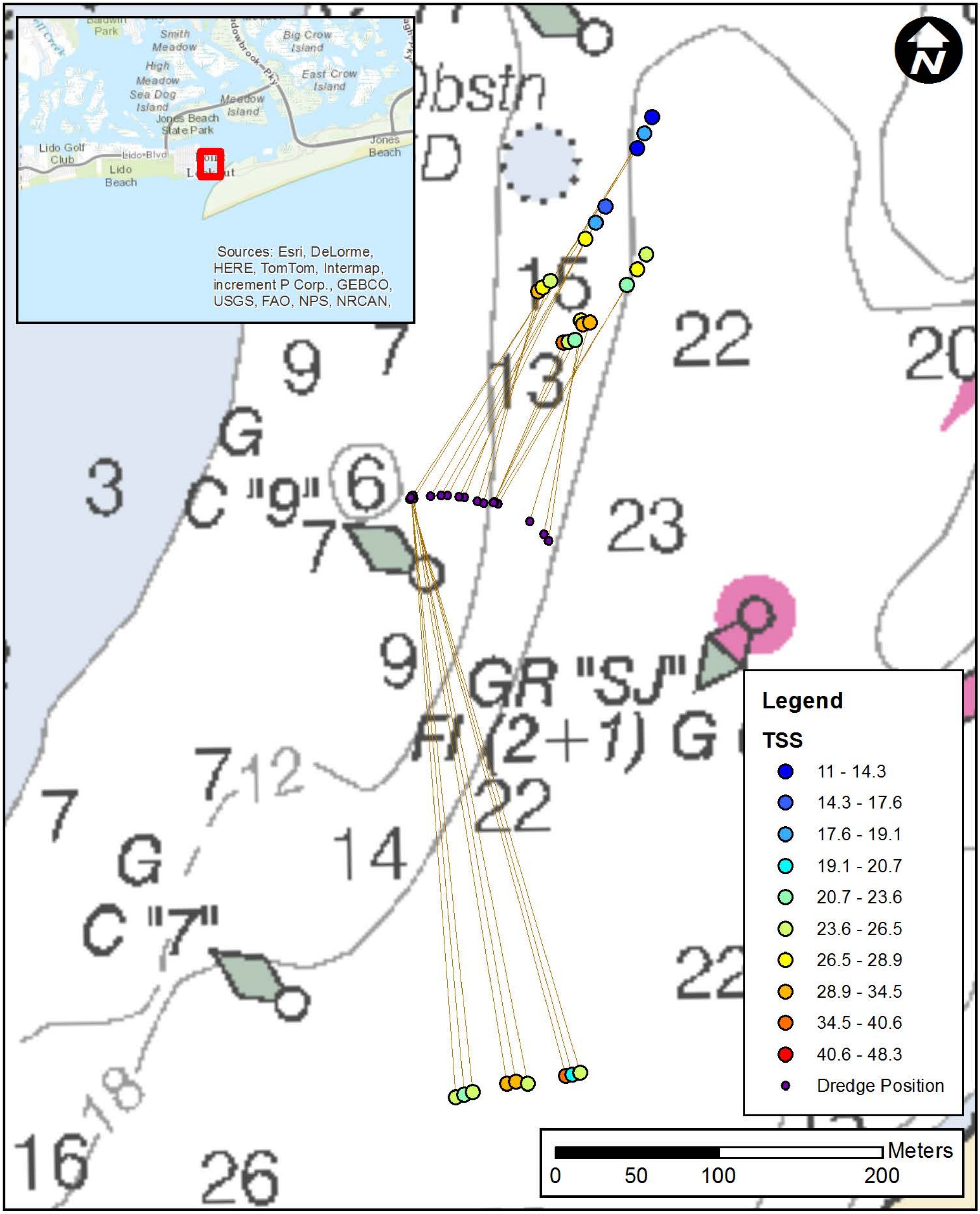


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	Water Sample TSS Values and Associated Dredge Positions 27 January 2014	Tide
14			Flood

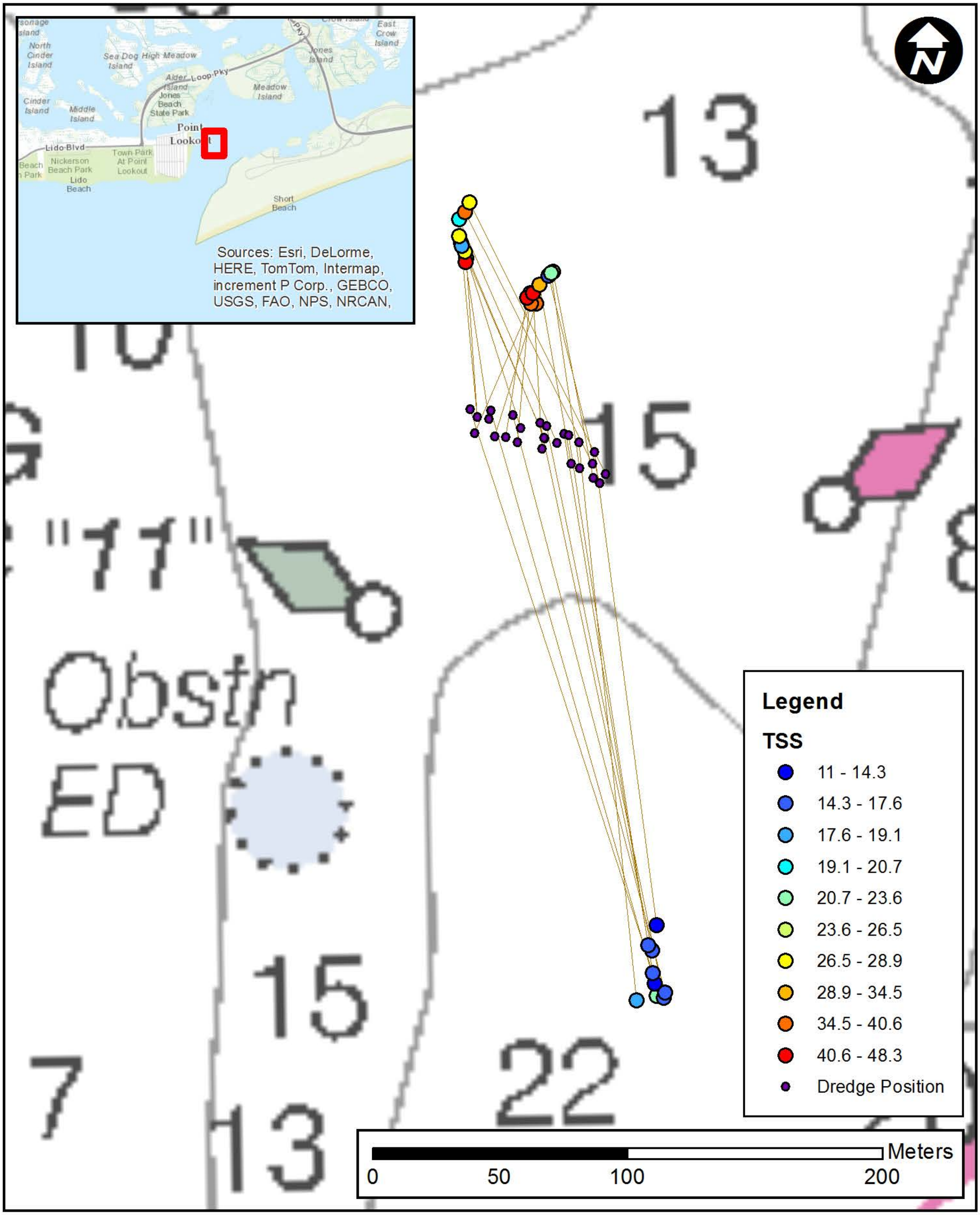


Figure	USACE Harborwide TSS Far Field Survey Jones Beach Inlet	Water Sample TSS Values and Associated Dredge Positions 11 February 2014	Tide
15			Flood

Appendix A:

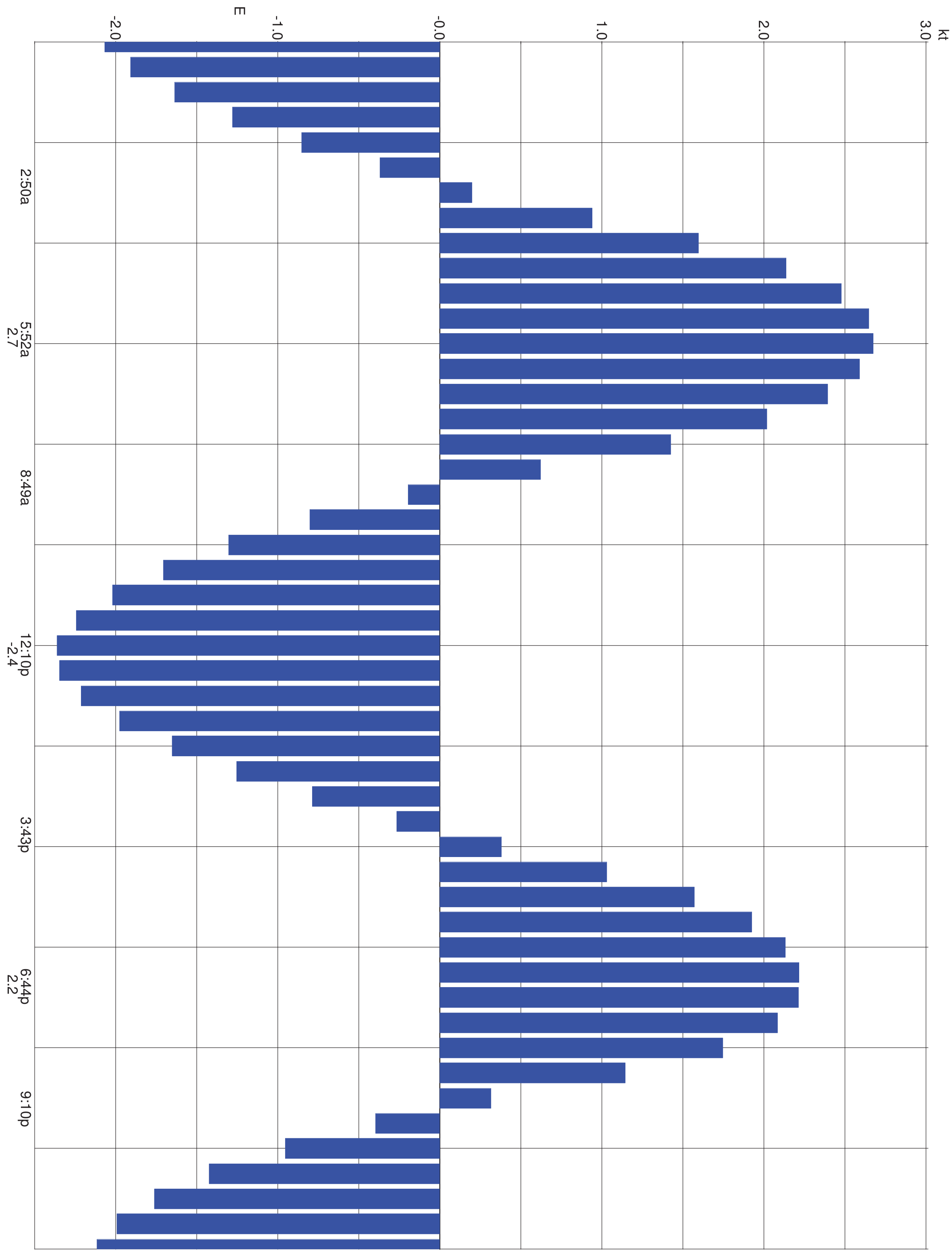
Predicted Currents for Jones Inlet Survey Dates

Currents:Jones Inlet

based on The Narrows, midchannel New York (NOAA)
40° 35 30 N 73° 34 W

Thursday, January 16, 2014

Slack	Max Flood & Ebb			
2:50a	5:52a	2.7 kt	35°	fld
8:49a	12:10p	2.4 kt	217°	ebb
3:43p	6:44p	2.2 kt	35°	fld
9:10p				



(EST)	Current
12:00a	2.1 kt ebb
12:30a	1.9 kt ebb
1:00a	1.6 kt ebb
1:30a	1.3 kt ebb
2:00a	0.9 kt ebb
2:30a	0.4 kt ebb
3:00a	0.2 kt fld
3:30a	0.9 kt fld
4:00a	1.6 kt fld
4:30a	2.1 kt fld
5:00a	2.5 kt fld
5:30a	2.6 kt fld
6:00a	2.7 kt fld
6:30a	2.6 kt fld
7:00a	2.4 kt fld
7:30a	2.0 kt fld
8:00a	1.4 kt fld
8:30a	0.6 kt fld
9:00a	0.2 kt ebb
9:30a	0.8 kt ebb
10:00a	1.3 kt ebb
10:30a	1.7 kt ebb
11:00a	2.0 kt ebb
11:30a	2.2 kt ebb
12:00p	2.4 kt ebb
12:30p	2.3 kt ebb
1:00p	2.2 kt ebb
1:30p	2.0 kt ebb
2:00p	1.7 kt ebb
2:30p	1.3 kt ebb
3:00p	0.8 kt ebb
3:30p	0.3 kt ebb
4:00p	0.4 kt fld
4:30p	1.0 kt fld
5:00p	1.6 kt fld
5:30p	1.9 kt fld
6:00p	2.1 kt fld
6:30p	2.2 kt fld
7:00p	2.2 kt fld
7:30p	2.1 kt fld
8:00p	1.7 kt fld
8:30p	1.1 kt fld
9:00p	0.3 kt fld
9:30p	0.4 kt ebb
10:00p	1.0 kt ebb
10:30p	1.4 kt ebb
11:00p	1.8 kt ebb
11:30p	2.0 kt ebb
12:00a	2.1 kt ebb

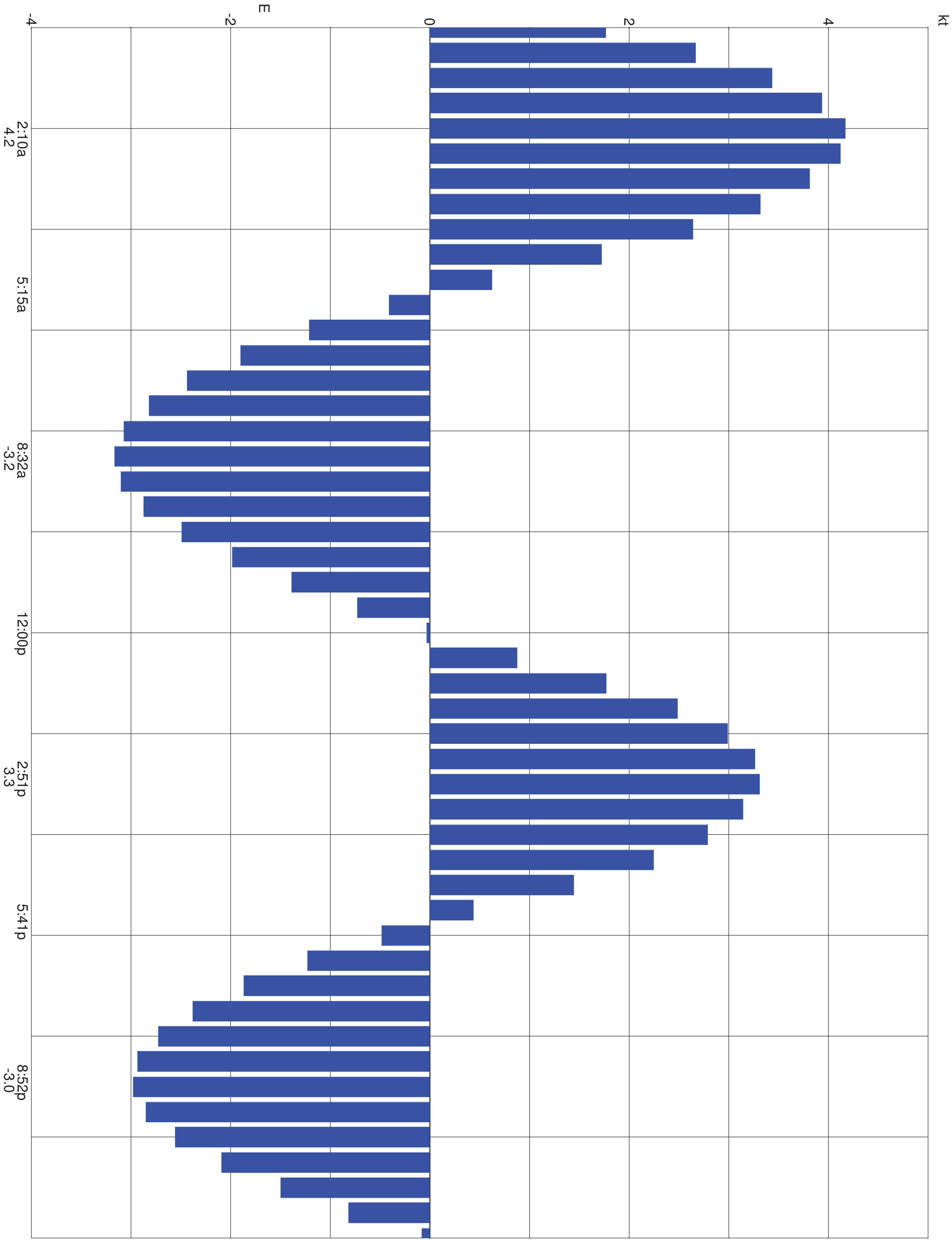
Currents:Jones Inlet

based on The Narrows, midchannel New York (NOAA)
40° 35 30 N 73° 34 W

Monday, January 27, 2014

Slack	Max Flood & Ebb			
	2:10a	4.2 kt	35°	fld
5:15a	8:32a	3.2 kt	217°	ebb
12:00p	2:51p	3.3 kt	35°	fld
5:41p	8:52p	3.0 kt	217°	ebb

(EST)	Current
12:00a	1.8 kt fld
12:30a	2.7 kt fld
1:00a	3.4 kt fld
1:30a	3.9 kt fld
2:00a	4.2 kt fld
2:30a	4.1 kt fld
3:00a	3.8 kt fld
3:30a	3.3 kt fld
4:00a	2.6 kt fld
4:30a	1.7 kt fld
5:00a	0.6 kt fld
5:30a	0.4 kt ebb
6:00a	1.2 kt ebb
6:30a	1.9 kt ebb
7:00a	2.4 kt ebb
7:30a	2.8 kt ebb
8:00a	3.1 kt ebb
8:30a	3.2 kt ebb
9:00a	3.1 kt ebb
9:30a	2.9 kt ebb
10:00a	2.5 kt ebb
10:30a	2.0 kt ebb
11:00a	1.4 kt ebb
11:30a	0.7 kt ebb
12:00p	0.0 kt slk
12:30p	0.9 kt fld
1:00p	1.8 kt fld
1:30p	2.5 kt fld
2:00p	3.0 kt fld
2:30p	3.3 kt fld
3:00p	3.3 kt fld
3:30p	3.1 kt fld
4:00p	2.8 kt fld
4:30p	2.2 kt fld
5:00p	1.4 kt fld
5:30p	0.4 kt fld
6:00p	0.5 kt ebb
6:30p	1.2 kt ebb
7:00p	1.9 kt ebb
7:30p	2.4 kt ebb
8:00p	2.7 kt ebb
8:30p	2.9 kt ebb
9:00p	3.0 kt ebb
9:30p	2.8 kt ebb
10:00p	2.6 kt ebb
10:30p	2.1 kt ebb
11:00p	1.5 kt ebb
11:30p	0.8 kt ebb
12:00a	0.1 kt slk

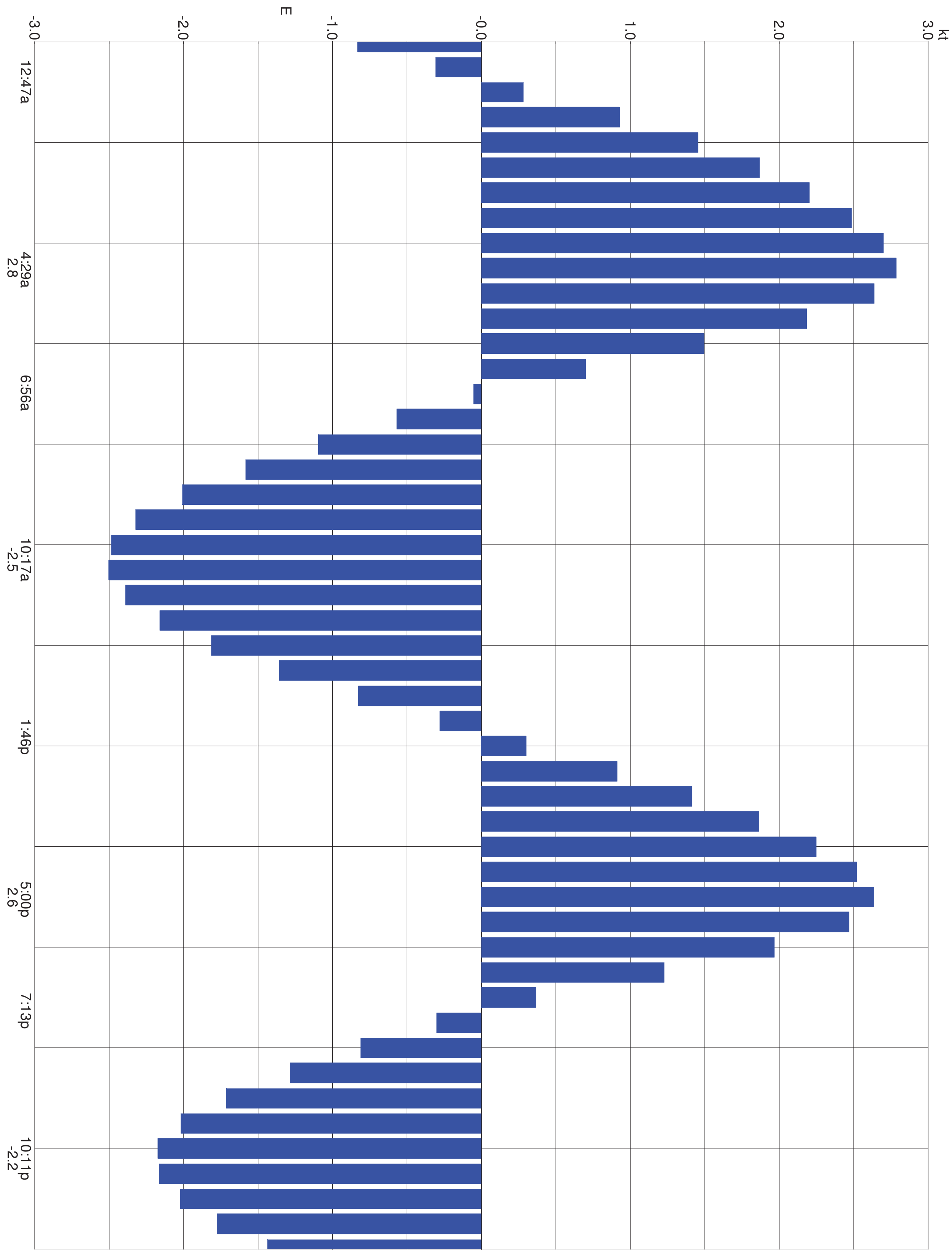


Currents:Jones Inlet

based on The Narrows, midchannel New York (NOAA)
40° 35 30 N 73° 34 W

Tuesday, February 11, 2014

Slack	Max Flood & Ebb		
12:47a	4:29a	2.8 kt	35° fld
6:56a	10:17a	2.5 kt	217° ebb
1:46p	5:00p	2.6 kt	35° fld
7:13p	10:11p	2.2 kt	217° ebb



(EST)	Current
12:00a	0.8 kt ebb
12:30a	0.3 kt ebb
1:00a	0.3 kt fld
1:30a	0.9 kt fld
2:00a	1.5 kt fld
2:30a	1.9 kt fld
3:00a	2.2 kt fld
3:30a	2.5 kt fld
4:00a	2.7 kt fld
4:30a	2.8 kt fld
5:00a	2.6 kt fld
5:30a	2.2 kt fld
6:00a	1.5 kt fld
6:30a	0.7 kt fld
7:00a	0.1 kt slk
7:30a	0.6 kt ebb
8:00a	1.1 kt ebb
8:30a	1.6 kt ebb
9:00a	2.0 kt ebb
9:30a	2.3 kt ebb
10:00a	2.5 kt ebb
10:30a	2.5 kt ebb
11:00a	2.4 kt ebb
11:30a	2.2 kt ebb
12:00p	1.8 kt ebb
12:30p	1.4 kt ebb
1:00p	0.8 kt ebb
1:30p	0.3 kt ebb
2:00p	0.3 kt fld
2:30p	0.9 kt fld
3:00p	1.4 kt fld
3:30p	1.9 kt fld
4:00p	2.2 kt fld
4:30p	2.5 kt fld
5:00p	2.6 kt fld
5:30p	2.5 kt fld
6:00p	2.0 kt fld
6:30p	1.2 kt fld
7:00p	0.4 kt fld
7:30p	0.3 kt ebb
8:00p	0.8 kt ebb
8:30p	1.3 kt ebb
9:00p	1.7 kt ebb
9:30p	2.0 kt ebb
10:00p	2.2 kt ebb
10:30p	2.2 kt ebb
11:00p	2.0 kt ebb
11:30p	1.8 kt ebb
12:00a	1.4 kt ebb