ASSESSMENT OF DREDGING-INDUCED SEDIMENTATION ON WINTER FLOUNDER SPAWNING HABITAT

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ABSTRACT

This study investigates the fate of sediment suspended due to dredging in Newark Bay, New Jersey to characterize exposure of winter flounder spawning habitat. Winter flounder is a recreationally and commercially significant species which has experienced a steady population decline over the last twenty years. Winter flounder eggs are demersal and adhesive. Possible factors affecting spawning habitat are currently being investigated, including net deposition on eggs during dredging operations. To investigate potential egg exposures to elevated sedimentation rates, a numerical modeling study was conducted. The three-dimensional hydrodynamic model CH3D-WES (Curvilinear Hydrodynamic model in Three Dimension, Waterways Experiment Station version) was applied to Newark Bay and adjacent water bodies. The model was calibrated to water level and current data. Bottom stresses during January of 2008 were estimated and analyzed to assess depositional environments in the bay. The Particle Tracking Model (PTM), linked to the Newark Bay CH3D model, was utilized to simulate dredged sediment transport and deposition. The development of tools which reliably predict sediment transport due to dredging operations represents a critical advance to the field of dredged material management. These predictions can be used to assess the impact of dredging and placement operations on contaminant transport, sensitive habitat, endangered species, rehandling, and beneficial use activity. PTM is a Lagrangian particle tracking model specifically designed to assess the fate of specified sediment sources, such as dredging operations. Relevant hydrodynamic processes are provided to PTM from CH3D and PTM includes all relevant sediment and dredging processes. For this application, PTM was used to simulate dredging operations representative of typical conditions for maintenance dredging. Model results from this application quantified deposition in possible winter flounder spawning habitat, primarily in shoals within Newark Bay. Results indicate that deposition in these habitat areas would be significantly less than the amount required to detrimentally impact spawning.

Keywords: Dredging, sediment transport, resuspended sediment, environmental habitat, winter flounder

INTRODUCTION

Motivation

Newark Bay is a tidal embayment in New York Harbor formed at the confluence of the Passaic and Hackensack Rivers (Figure 1). It is part of the New York/New Jersey Harbor Estuary, in the center of one of the most industrialized parts of the nation. Port Newark is the nation’s third largest container port, requiring periodic dredging to accommodate access to its berthing areas. Newark Bay is currently the site of an extensive channel deepening project required to meet future needs. However, a major environmental concern associated with this project has been possible detrimental impacts of sediment resuspended during dredging operations. Specifically, Newark Bay has been identified as a significant habitat for winter flounder (*Pseudopleuronectes americanus*).

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Figure 1. Newark Bay and vicinity

Winter flounder populations have been in steady decline for the last twenty years. Currently there is ongoing research to determine the reasons for this phenomenon (Klein-Macphee et al. 1984, Buckley et al. 1991). This fish species is a favorite target of recreational and commercial fishermen and occurs at various times throughout the harbor complex. Winter flounder spawn in nearshore shallow habitats from December to May. Newark Bay has therefore been identified as winter flounder Essential Fish Habitat by the National Marine Fisheries Service (NMFS). One possible hazard to this species is the effect of deposition of resuspended dredged sediment on its spawning habitat. Conventional wisdom is that sediment deposition exceeding one half of an egg diameter (approximately 0.5mm) causes a reduction in viable hatching (Berry et al. 2002). Therefore knowledge of net sedimentation in flounder spawning habitat is critical to consideration of appropriate protective management practices.

In an effort to minimize environmental risks to flounder, environmental windows have been applied during spawning. Dredging is thereby limited to periods outside the winter flounder spawning season. However, dredging operation associated risk to spawning habitat has not been comprehensively evaluated. The existing dredging windows presume that dredging produces unacceptable risk. The goal of this study is to quantify exposure of spawning habitat to sediment released during dredging operations. Exposure characterization is a key component to determining risk. Exposure and subsequent effects assessments permit risk quantification that improves the ability to apply risk limiting management practices. Exposure characterization in risk assessment and risk management can identify alternative risk controls and reduce potentially unnecessary dredging restrictions.

There is a great need to build tools which aid in exposure characterization based on physical properties and processes. The Particle Tracking Model (PTM) has been developed for this purpose (Lackey and McDonald 2007, Gailani et al. 2007, Lackey and Smith 2008). The current work provides an exposure assessment of winter flounder spawning habitat utilizing PTM. The purpose of this project is primarily to provide a method for future assessments of dredging operations near environmentally sensitive regions as opposed to changing management practices within the Newark Bay area. To that end, this project examines sedimentation exposures created by a *hypothetical* maintenance dredging operation. That is, although the hydrodynamic data and bathymetry are based on field data, details of the dredging operations, such as specific location, equipment, and the length of the operation were determined based on a "typical" dredging operation within the defined study area. In this simulation, 50,000 cy (38,227.7 m^3) of material is dredged in an area adjacent to a suspected winter flounder spawning ground (figure 2) using a clamshell dredge. Dredging is routinely performed within this area (Clarke et al. 2007). Two separate scenarios are simulated for this work. The cases differ based on the predicted amount of sediment resuspended by the dredge. In Case 1 0.79 % of the total sediment dredged is "lost" as resuspended in a plume and dispersed from the site. This value is theorized by the Hayes modeling dredge source term (Hayes et al. 2007). Case 2 uses three times as much sediment mass, 2.37% resuspended by the dredge. This value is more in line with results shown via field data (Hayes et al. 2007). The current state of knowledge estimates that an average loss of 1-3% as resuspended sediment. This may vary due to operational techniques and equipment used during dredging. By looking at two cases at different ends of the predicted spectrum, this work takes into account both theory and observed values.

Figure 2. Depiction of dredging and spawning areas

Newark Bay Physical Characteristics

Newark Bay is a spatially complex estuary connected to Upper New York Bay to the east through the Kill van Kull Waterway, and to Raritan Bay to the Southwest through the Arthur Kill Waterway. Newark Bay receives freshwater discharge from the Passaic and Hackensack Rivers from the northeast (figure 1). Both Upper New York Bay and Raritan Bay are connected to the New York Bight in the Atlantic Ocean through the Lower New York Bay. New York Bay is an extension of the Hudson River in the north and is also connected to Long Island Sound in the east.

The Hudson River Estuary is a typical partially mixed estuary. Gravitational circulation is an important transport mechanism in the estuary. Hunkins (1981) estimated contributions of salt dispersion processes in the Hudson

Estuary. He identified the steady shear of gravitational circulation to be the largest contributor, which also shows significant seasonal variations. Also identified was a significant but weak correlation between wind and currents. Nepf and Geyer (1996) examined intra-tidal variation in stratification and mixing in the Hudson Estuary. They showed a significant role of tidal straining i.e. maintaining stratification during ebb and promoting the growth of a uniform bottom, mixed layer during flood. Vertical stretching was also attributed as an important term in the stratification balancing during ebb. Hellweger et al. (2004) used a model to investigate the circulation and transport pattern of the Hudson Estuary in which large-scale asymmetry was attributed to salinity, whereas small-scale peaks were attributed to tidal trapping by small embayments along the estuary. Oey et al. (1985) built a three-dimensional model of the Hudson-Raritan Estuary which also included the Newark Bay. Their modeling results showed a large subtidal response to wind forcing.

Cerco et al. (1999) described the physical characteristics of Newark Bay and the Kills as well as the rivers. Tidal forcing dominates the bay hydrodynamics (mean tide range = 1.6 m). The Passaic River (mean flow at fall line, $Q_{mean} = 32.5\ m^3/s$) is associated with a larger drainage basin than the Hackensack River ($Q_{mean} = 2.7\ m^3/s$), but the freshwater discharges from both rivers are considered to be minor compared to the major tributary of the Hudson Estuary, the Hudson River ($Q_{mean} = 550\ m^3/s$). At times the anthropogenic freshwater inflows from municipal and industrial discharges exceed the river inflows. The bay remains saline under normal conditions and the vertical distribution of salinity exhibits that of a partially mixed estuary.

METHOD

Transport Model

PTM is an ERDC-developed model designed specifically to track the fate of point-source constituents (sediment, chemicals, debris, etc.) released from local sources such as dredges, placement sites, outfalls, etc. in complex hydrodynamic and wave environments. Each local source is defined independently and may have multiple constituents. Therefore, model results include the fate of each constituent from each local source. PTM simulates transport using pre-calculated periodically saved hydrodynamic (and wave) model output. The hydrodynamic model is not coupled to the sediment transport model and therefore can be run once for multiple PTM simulations. Each particle in PTM represents a specific mass (or number of particulates) of one constituent. Total mass is conserved because particles are conserved. Hydrodynamic output does not need to be conservative, so the user can specify hydrodynamic model output for PTM without concern for conservation of water mass. A random walk method is used, in part, to represent particle diffusion. PTM simulations can be either 3D or 2D. For this application, 3D mode is used.

In addition to the hydrodynamic input (i.e. water surface elevation and velocities) that is used as a forcing for particle dynamics, PTM requires mesh and bathymetry information, and sediment characterization of the native bed sediment (Figure 3). Although PTM does not model native sediment bed transport, it does model interactions between native bed sediments and deposited particles (hiding, burial, etc.); therefore bed sediment characteristics must be described by the user. PTM also needs detailed constituent or source information. The user specifies particle characteristics and processes, including settling, critical stresses, and erosion rates. If processes data are not available, these values may be calculated within the model based on verified theoretical relationships. The specific equations for those processes are discussed in detail by McDonald et al. (2006). Particles can be positively, neutrally, or negatively buoyant. Positively buoyant particles, for example, could represent floating debris, while neutrally buoyant particles may represent chemicals, and negatively buoyant particles may represent sediment.

Current limitations of this model include the lack of effects due to cohesive sediment interaction with the active bed layer. In addition, it should be mentioned that results are only as good as the source terms and hydrodynamic forcing provided. Dredging source terms were, as mentioned previously, developed based on two different methods. A three dimensional hydrodynamic model, CH3D, was utilized to capture flow complexities accurately.

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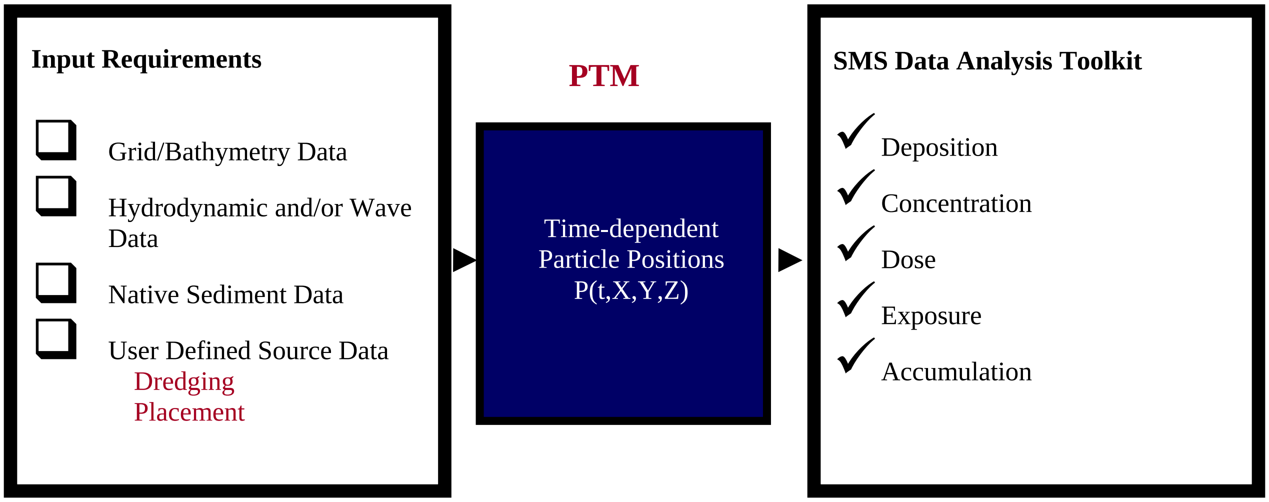

Figure 3. PTM Exposure Assessment Chart

Model output includes time dependent particle positions throughout the domain. Various other attributes such as mass, density, and suspension status are also assigned to each of the output parcels. Elevation in the water column is calculated and stored. PTM setup and execution are done within the ERDC-sponsored Surface Water modeling System (SMS) interface. SMS includes multiple tools for post-processing PTM output to assess distribution of concentration, deposition, and other results at any time during the simulation. These results are processed for each constituent from each source or for combined constituents or sources.

Grid

A structured grid was generated to cover the Newark Bay and adjacent water bodies, including New York Bay and the Hudson River, Raritan Bay, the Passaic River, and the Hackensack River as well as the Long Island Sound and the upper portion of the New York Bight (figure 4). The grid sizes in horizontal plane vary from about 50 m to 5000 m. Higher resolution was allocated in the vicinity of Newark Bay as seen in the right panel of figure 3. A structured grid with 226 by 298 cells in the horizontal plane and 5 layers in the vertical axis was generated. The number of water cells in the surface layer is 9,561, which gives a total number of 47,805 water cells. The initial model grid water depths vary between 3 and 50 m.

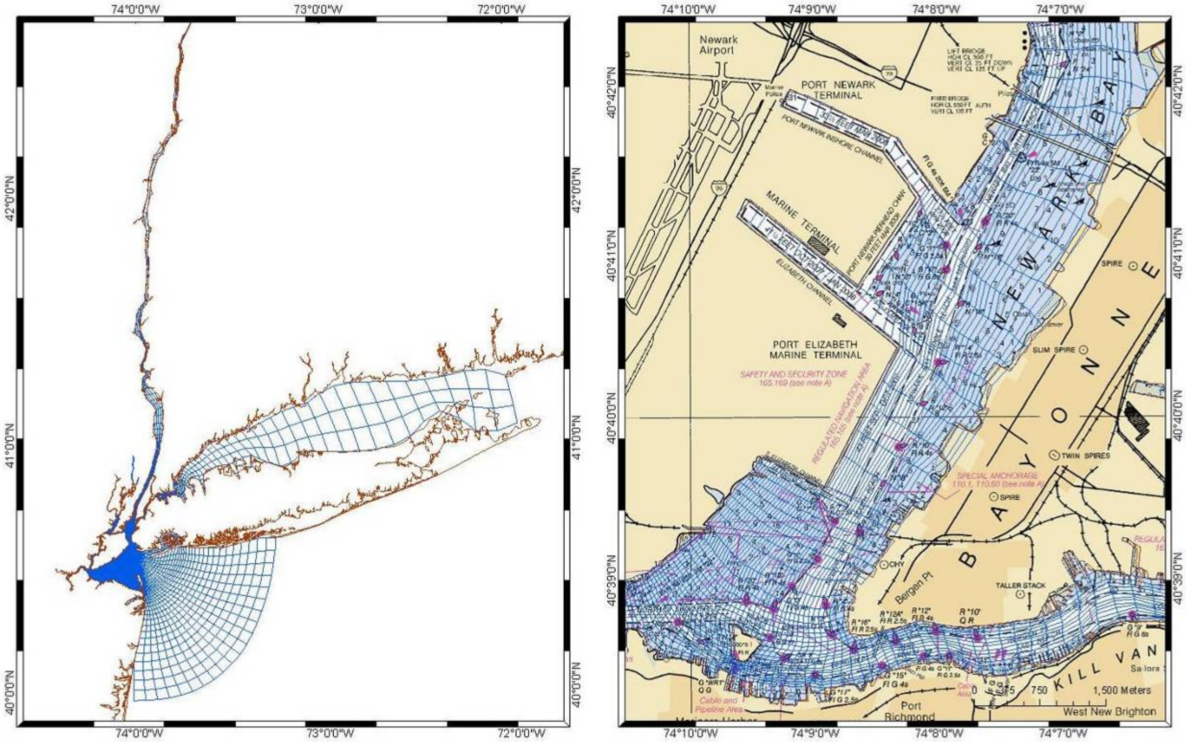

Figure 4. Computational grid a) entire grid, b) zoomed in to focus area

Hydrodynamic model

The numerical hydrodynamic model CH3D-WES (Curvilinear Hydrodynamics in Three Dimensions – Waterways Experiment Station) employs a finite difference solver for Navier-Stokes equation on boundary-fitted grid (Johnson et al. 1991). It also incorporates the k-ε turbulence model. The physical processes impacting circulation and vertical mixing that are modeled include tides, wind, density effects (salinity and temperature), freshwater inflows, turbulence, and the effect of the earth's rotation. Water surface elevation (η) and water velocities (u,v,w) as well as scalar properties such as salinity (S) and temperature (T) in the water column at each grid cell are output from the model. The boundary-fitted coordinate feature of the model provides grid resolution enhancement necessary to adequately represent deep navigation channels and irregular shoreline configurations of the flow system. The curvilinear grid also permits adoption of accurate and economical grid schematization software. The solution algorithm employs an external mode, consisting of vertically averaged equations, which provides a solution for the free surface displacement for input to the internal mode, which contains the full 3D equations. The governing partial differential equations are based on the following assumptions: a) the hydrostatic pressure distribution adequately describes the vertical distribution of fluid pressure, b) the Boussinesq approximation is appropriate, and c) the eddy viscosity approach adequately describes turbulent mixing in the flow.

CH3D was selected for this study because (1) the study needs a 3-dimensional model, and (2) CH3D has been tested over widely varying configurations. The most commonly used version of CH3D is the “sigma-stretch” version as in this study, in which the same number of layers are prescribed in each cell.

Boundary conditions

Two open boundaries were set up. One is an extension of New York Bay to New York Bight and the other is the entrance of the Long Island Sound. At these open boundaries, time varying water levels were imposed. For the New York Bight open boundary, water levels at Atlantic City (NOAA Gage 8534720) and Sandy Hook (NOAA Gage 8531680) were averaged. At the entrance of the Long Island Sound, water levels recorded from Montauk (NOAA

Gage 8510560) in the south and New London (NOAA Gage 8461490) in the north were spatially interpolated. At both open boundaries, constant salinity of 30 ppt and constant temperature of 15°C were imposed.

There are 5 river inflow boundaries. At these boundaries, freshwater discharges were forced. The largest discharge comes from the Hudson River. The Passaic and Hackensack Rivers feed directly into Newark Bay. The Raritan and South Rivers feed to the Raritan Bay. Daily discharge data from the USGS stream gages were extracted.

Daily discharges from the 5 inflow locations show the most dominant freshwater source is the Hudson River, which constitutes about 90 percent of total freshwater in the system. The Passaic River and the Raritan River combined contribute about 10 percent of total freshwater flow. The contributions from the Hackensack River and the South River are insignificant. January and February represent low hydrological forcing. Daily discharges vary over the time.

Tide records from the open boundary gage locations exhibit strong semi-diurnal variation with diurnal inequality and a distinct neap-spring cycle. The tide at the New York Bight open boundary has a larger range than the tide at the entrance of Long Island Sound.

Calibration

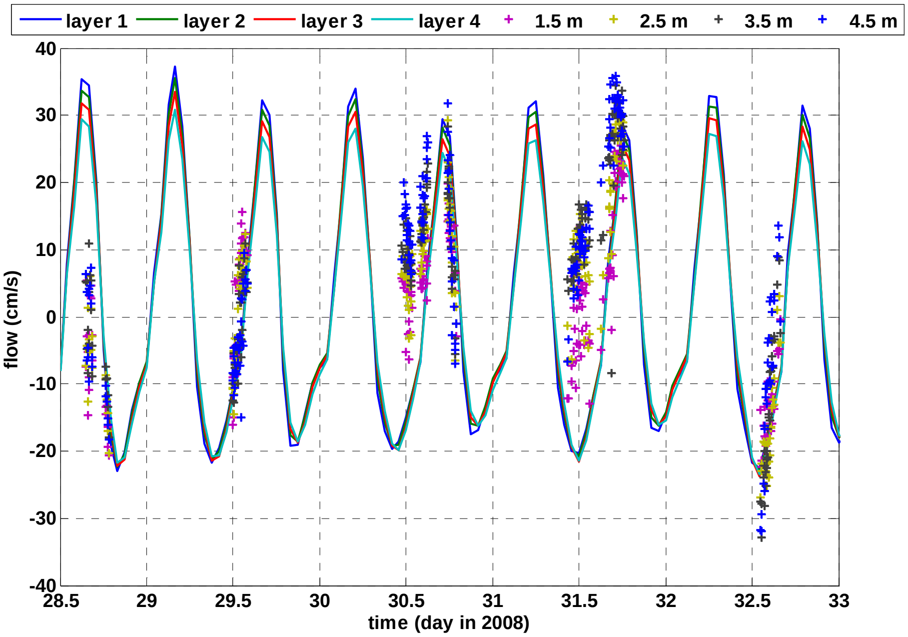

Figure 5. Along-channel flows. Positive sign denotes flood current. Lines represent predicted values and crosses are the ensemble average values from ADCP measurements.

The calibration period was set for 35 day time periods between 1/1/2008 and 2/4/2008 with 5 day spin-up, which yields a total simulation time of 40 days. Neap-spring cycles are reproduced as well. Current simulation is more difficult to assess than water levels. Along-channel currents in the top 4 model layers were compared with along-channel currents measured at 4 levels between 1.5 m and 4.5 m from ADCP surveys were plotted together (Figure 5). Amplitude is in good agreement, whereas the predicted phase is reasonably aligned with observation data.

Native Sediment

Native sediment in the area of interest is mostly in the silt/clay range (Coch 1986). The rivers at the north end and the Lower and Upper Bay at the southern end influence Newark Bay sediment patterns. Fine silt arrives from the Passaic River and fine sand is transported by the Hackensack River. Fine silt underlays the central part of the Bay within the dredging region, grading southward into fine sand and fine silt where it connects with the Arthur Kill and the Kill Van Kull.

Simulation Details

For this simulation 50,000 cy (38,227.7 m^3) is dredged within the region shown in Figure 3 using a clamshell dredge. Dredging takes place over a seven hour period with a one hour break between cycles. It takes approximately four days to complete the dredging. It should be mentioned that operational techniques differ between various dredging operations; however, this specific scenario is based on an observed operation that is taken to be “typical”. Although dredging is completed within a four day period, the simulation is run for a full week to allow for resuspension of material which has already been released and has subsequently deposited.

Source Input

The source in the simulation is designed to represent the transportable resuspended sediment introduced into the water column due to dredging. In PTM this type of dredging source term is represented using a vertical line release. The model releases particles along a vertical line that transects the entire water column. At different points in the water column, the strength of the source or number of particles released is dependent on the predicted amount (in kg) of sediment that should be released at that time. Table 1 shows the various sources of resuspended sediment due to clamshell dredging, the expected source strength in kg/s, and where this source is released within the water column. For a clamshell dredge the sources of interest are particles released during the ascent and descent of the bucket, at impact with the bottom, and from slewing.

Table 1. Clamshell Dredging Source term used for PTM input.

Dredging Source Type	**Case 1 (kg/s)**	**Case 2 (kg/s)**	**Location in water column**
Ascent & Descent	0.015	0.045	Distributed throughout water column
Impact	0.034	0.034	1/2 bucket diameter from bottom
Slewing	0.042	0.042	Distributed over upper 3m
Total %	0.790	2.380	

RESULTS

In this section, three types of results are shown from the simulation: particle positions, bottom shear stress contour maps, and deposition maps. Particle positions are obtained via the PTM simulation. Bottom shear stress results are derived directly from the CH3D hydrodynamic results. Deposition maps result from data analysis of particle positions using the PTM/SMS data analysis toolkit.

Particle tracking positions for Case 1 (0.79 % transportable resuspended sediment) are shown in Figure 6 after 3 hours, one day, three days, and five days of simulated time. In the figure, yellow particles represent suspended sediment and red particles represent sediment that has deposited. Initially, most of the sediment is still in suspension. The flow carries the sediment to the northeast towards the Hackensack and Passaic Rivers. After one day, sediment is still being released by the dredge. However much of the sediment that has already been released has been transported outside of the area of interest. Some of the sediment has deposited within the navigation channels near Port Newark. Additional sediment has been transported to the Arthur Kill and Kill Van Kull. Notable is the lack of particles deposited in the suspected winter flounder spawning habitat. After three days, dredging is almost completed. During this particular snapshot, particles have been transported back into the area of interest. A small amount of deposition is evident in the spawning area. By day five, dredging is complete. Most of the sediment has been transported away or has deposited. Deposition within the study area has primarily occurred within channels near Port Newark.

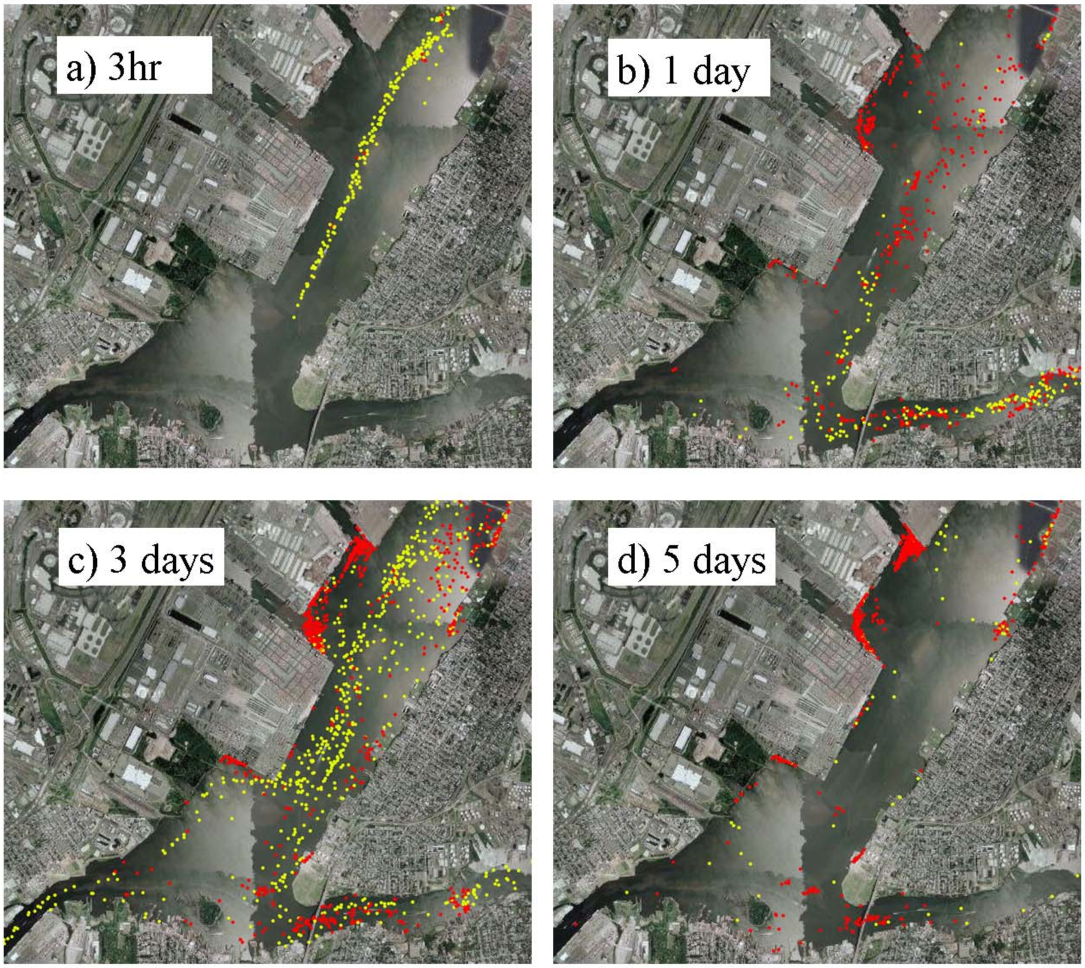

Figure 6. Case 1 particle positions showing sediment in suspension (yellow) and deposited (red).

Case 2 particle position results can be seen in Figure 7. The results are similar to Case 1 except for a visible increase in the number of particles. After three hours, most of the sediment is still in suspension. The initial plume location is depicted as particles diffused across the water column as they get further away from the dredge location. After one day, particles are spread through the system, many of which have been deposited within the channel. At three days deposition has primarily occurred in the Kill Van Kull. After five days, dredging has finished. Many of the particles that were originally deposited have resuspended and been transported out of the system. Results suggest that very little sediment remains deposited in the winter flounder spawning habitat. To get a clearer picture of the transport pattern within this area, the bottom shear stress was calculated.

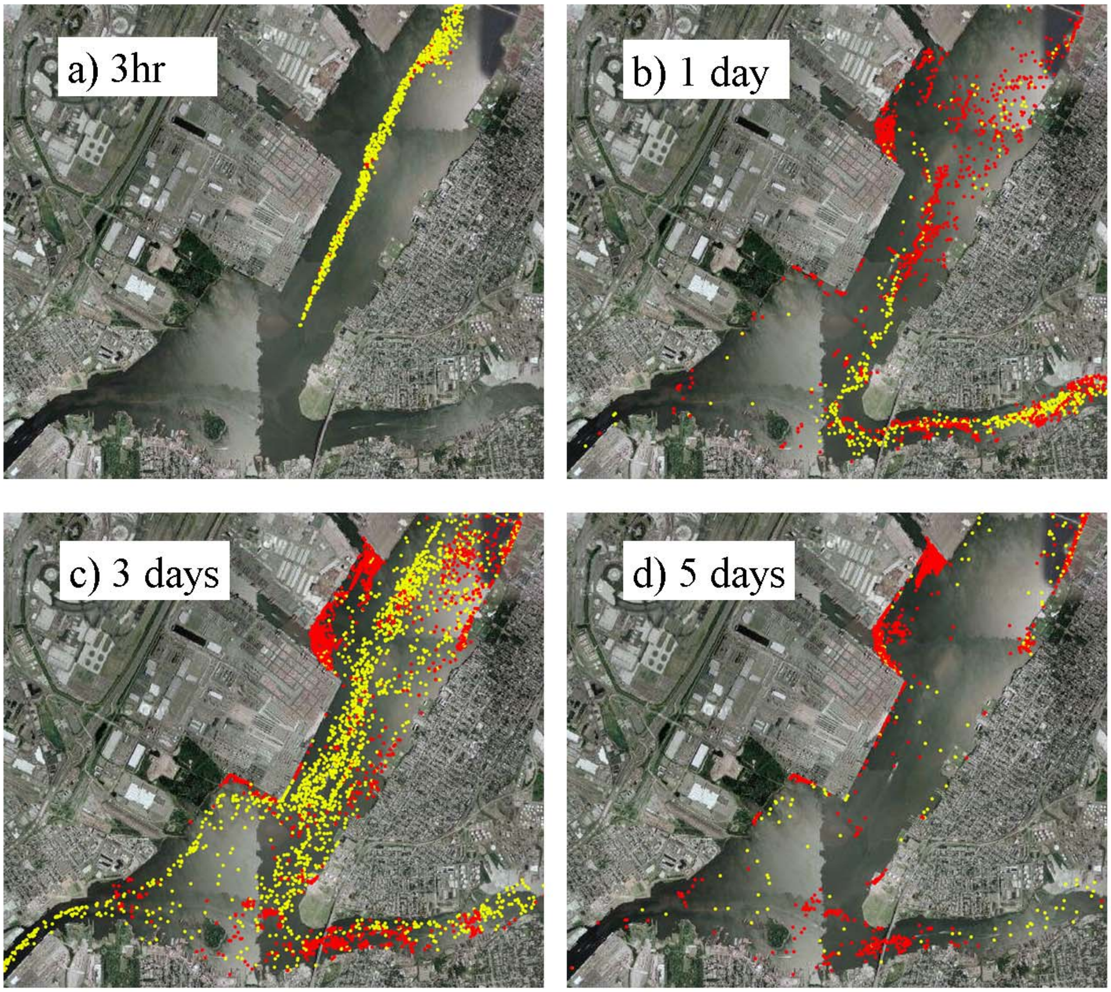

Figure 7. Case 2 particle positions showing sediment in suspension (yellow) and deposited (red).

Bottom Shear Stress

In addition to PTM results, the hydrodynamics from CH3D were examined to determine areas of high shear stress which indicate the potential for resuspension of deposited fine-grained sediment. This section also gives some indication of potential deposition.

Bottom stress from CH3D is expressed as

$$\vec{\tau}_b = \rho C_D \vec{V}_b \left| \vec{V}_b \right| \tag{1}$$

where τ_b is bottom stress, ρ is water density, V_b is velocity in the bottom layer, and C_D is the drag coefficient (~0.0025). The drag coefficient varies with the thickness of the bottom layer and bottom roughness, but is set as constant in this study.

To investigate the temporal and spatial evolution of bottom stress, a cross-section was selected (Figure 8) to cover the shoal in the west and the tidal channel in the east. Figure 9 shows the depth profile from west to east along the cross section. The suspected winter flounder spawning area is within the shoal and the dredged region is within the immediately adjacent tidal channel.

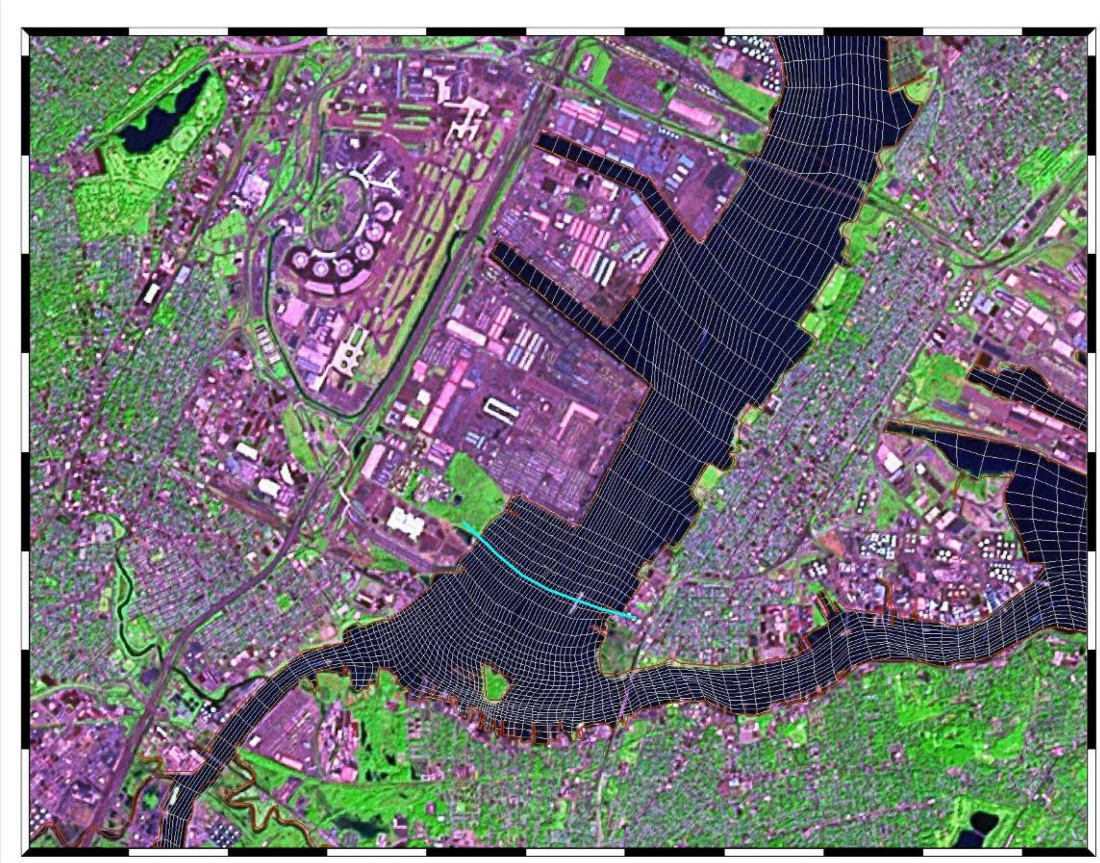

Figure 8. Cross-section set up. A cross section in West-East direction was set across the light blue line

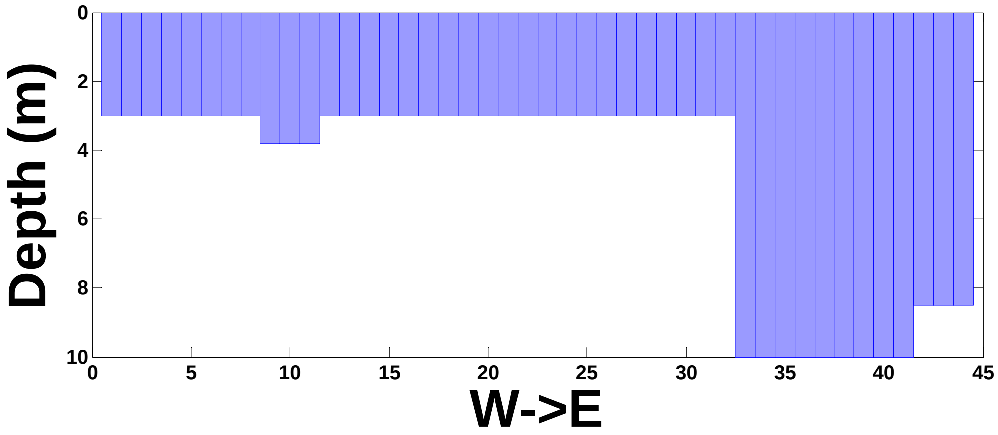

Figure 9. Depths across the cross section.

The shear stress response of the channel and shoal are markedly different (Figure 10- bottom). The top figure indicates that there is no difference in water levels across the cross-section. In the figure blue lines represent the hydrodynamics over the shoal and green lines represent the channel hydrodynamic results. Flows (velocities) over the shoal lead those over the channel in both flood and ebb. In the channel, flood (positive) flow is stronger and of shorter duration than ebb flow. Over the shoal, ebb and flood flows are nearly symmetrical in terms of amplitude, but flood flow has shorter duration than ebb flow. The corresponding bottom stresses for flood occur over shorter duration than those for ebb. This demonstrates the ebb-flood asymmetry in bottom stresses in the channel. Figure 10 shows that the maximum values of shear stress in the channel are greater than 0.5Pa and that maximum values in the shoal are approximately 0.1Pa.

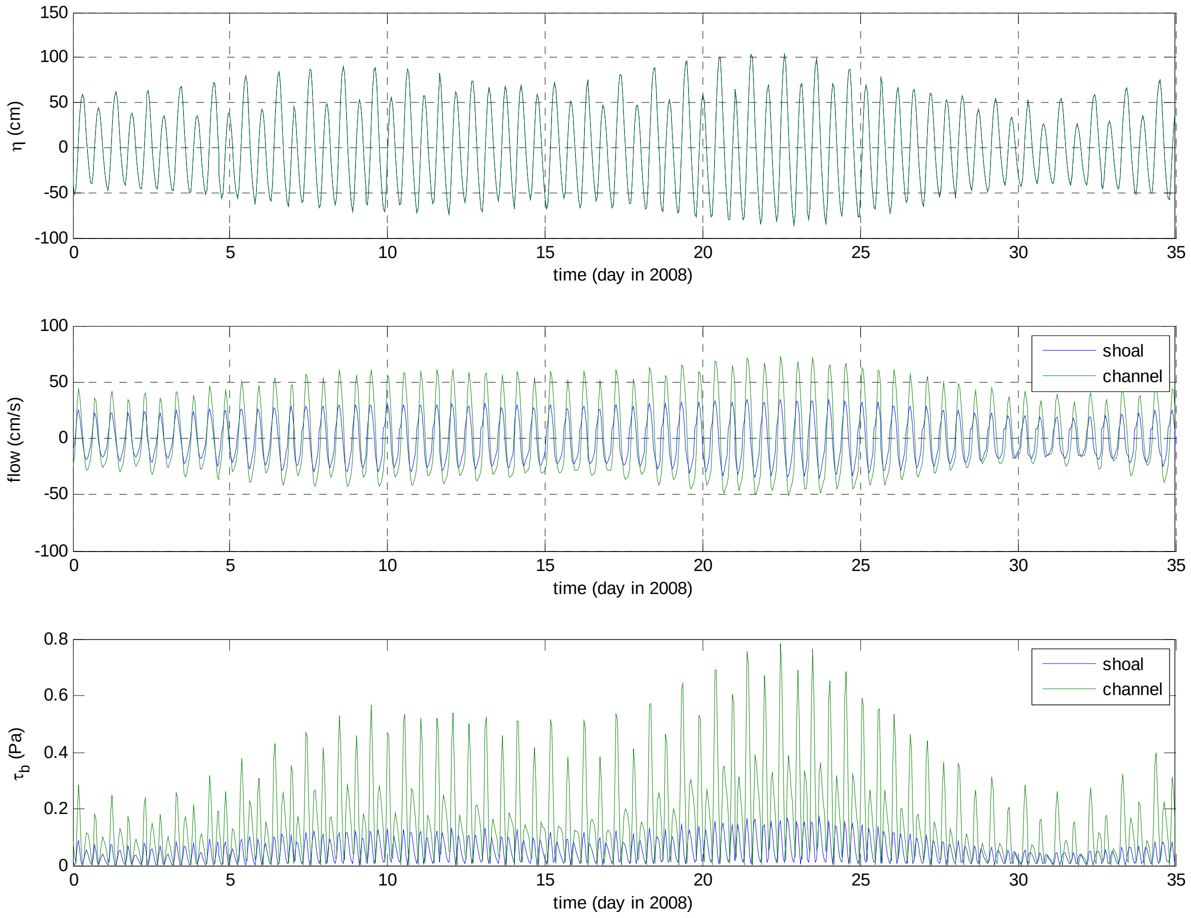

Figure 10. Time series of water level, flow, and bottom stress at shoal (blue) and channel (green).

Sediment is suspended if the shear stress of the fluid exceeds the critical shear stress required for initiation of sediment movement. The maps in Figure 11a-d show contours of bed stress at peak ebb, slack before flood, peak flood, and slack before ebb. Low shear stresses are shown in blue and shear stresses of at least 0.1 Pa are indicated in red. As shear stress is directly dependent on velocity, the figure also gives an indication of changes in velocity magnitude. Velocity vectors signifying direction are also shown in the figures. Figure 11e illustrates a map of the area of interest, representing in blue the suspected winter flounder spawning ground on the shoal and in red the dredging area in the channel. At peak ebb (Figure 11a) shear stress within the channel is greater than 0.1Pa. However the shear stress on the shoal remains below 0.07Pa. Shear stress values increase at peak flood to values greater than 0.1 on the shoal as well as in the channel.

If a representative critical shear stress for fine-grained suspension of 0.12 Pa is applied in this analysis, it is possible to determine general areas of suspension. Although a reasonable approximation for the low density fine-grained surface layer, this critical shear stress is used herein to represent potential changes in scour areas. Actual critical shear stress is site specific. With this assumption, it is reasonable to conclude that resuspension is probable during peak ebb and flood within the channel. On the shoal, resuspension of sediment is most likely during the peak flood, but only possible in some areas of the shoal during the peak ebb. As the shear stress decreases to zero during the slack before the flood and ebb (i.e. velocity decreases to zero), it is likely that sediment will settle into the channel and shoal momentarily. It should also be noted that there is an area adjacent to the shoal and the land boundary which has consistently low levels of shear stress (generally less than 0.04Pa). This is the South Elizabeth Channel. Depths in this area are greater and flow velocities decrease. Consistent low values of shear stress indicate a great potential for deposition.

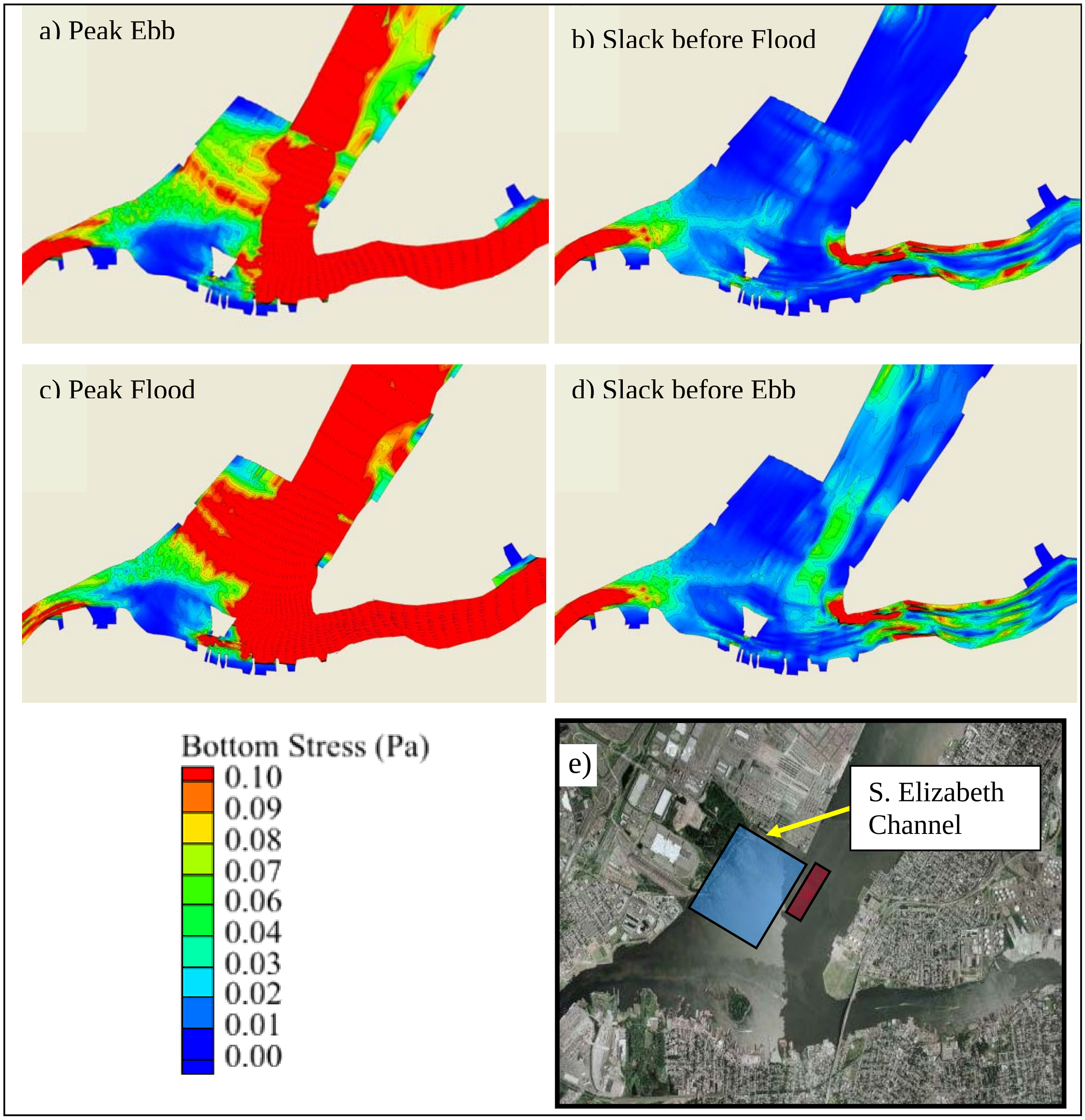

Figure 11. Contours of bottom stress and map of the area of interest.

Deposition maps for Case 1 (0.79% transportable resuspended sediment) and Case 2 (2.37% transportable resuspended sediment) are shown in Figures 12 and 13 respectively. Values of deposition are calculated only in the area framed by the white rectangle. Deposition levels are colored blue for maximum values (greater than 0.01mm) and red for values of deposition of approximately 0.001. Areas of deposition less than 0.001 are left blank. It should be mentioned that these are snapshots in time chosen specifically to focus on areas of maximum deposition (greater than 0.01mm) based on the results of this simulation. Figure 12a (1/16/08 3pm) shows that maximum levels of deposition after one day are located in the northeastern section of the suspected spawning area. However, as shown in Figure 11, the South Elizabeth Channel is in this area. Sediment frequently deposits within this side channel which was dredged to 44 ft (13.4 meters) in the fall of 2007. Seen in Figure 12b (1/17/08 8pm), after two days, maximum levels of deposition are located within in the central region of the framed area. After five days (Figure 12c at 1/20/2008 6pm), most of the sediment has been transported away from the suspected spawning habitat. These results are supported by the shear stress diagrams shown in Figures 10 and 11. The shear stress continuously oscillates causing sediment to deposit and then resuspend in a cyclic manner. However, during periods of resuspension, high velocities have the ability to advect the sediment into other areas of the bay.

These same trends are shown in Case 2 (Figure 13). However, in this scenario values of deposition are larger. In Figure 13a, the same area of deposited sediment within the port channel is evident. After 2 days (Figure 13b) a large deposition region in the center of the suspected spawning habitat has developed. Finally after five days (13c) very little sediment remains deposited in the area of interest. As sediment settles in the spawning habitat, it is eventually resuspended and transported as the bottom shear stress increases.

A screening level characterization of the effect of depositing sediment on winter flounder eggs is performed using the subsequent rule of thumb:

$$\begin{aligned} EggBurialDepth &= \tfrac{1}{2}\, EggDiameter \\ &= 0.5mm \end{aligned} \tag{2}$$

It can be seen in the deposition plots that the deposition levels are much lower than 0.5mm in both cases. However a more extensive analysis is performed via a time series of deposition utilizing data obtained from the maximum deposition region near the center of the shoal seen in Figures 12b and 13b. This area is marked by the white star in Figure 14a. Time series of the five day simulations are shown in the Figure 14b graph for both Case 1 and Case 2. Case 1 values, which represent a smaller source strength, stay primarily below 0.01mm. In Case 2, the maximum value is approximately 0.03mm. The peaks in the graph illustrate the phenomenon of sediment depositing and then resuspending before being transported outside of the area of interest. After each peak, the following peak appears to decrease in strength. This is most likely because more of the sediment is transported away and deposited elsewhere. In Case 1, eventually the peaks decay to zero. The Case 2 time series also contains a decaying peak trend, but it does not reach zero. It is possible that a longer simulation would be beneficial to show the complete decay of the peak values.

In both Case 1 and Case 2, the maximum value is much smaller than the 0.5mm which is the predicted depth that characterizes egg burial. Although dredging occurs in the channel directly adjacent to the suspected spawning habitat, it appears that sediment is primarily transported to other areas.

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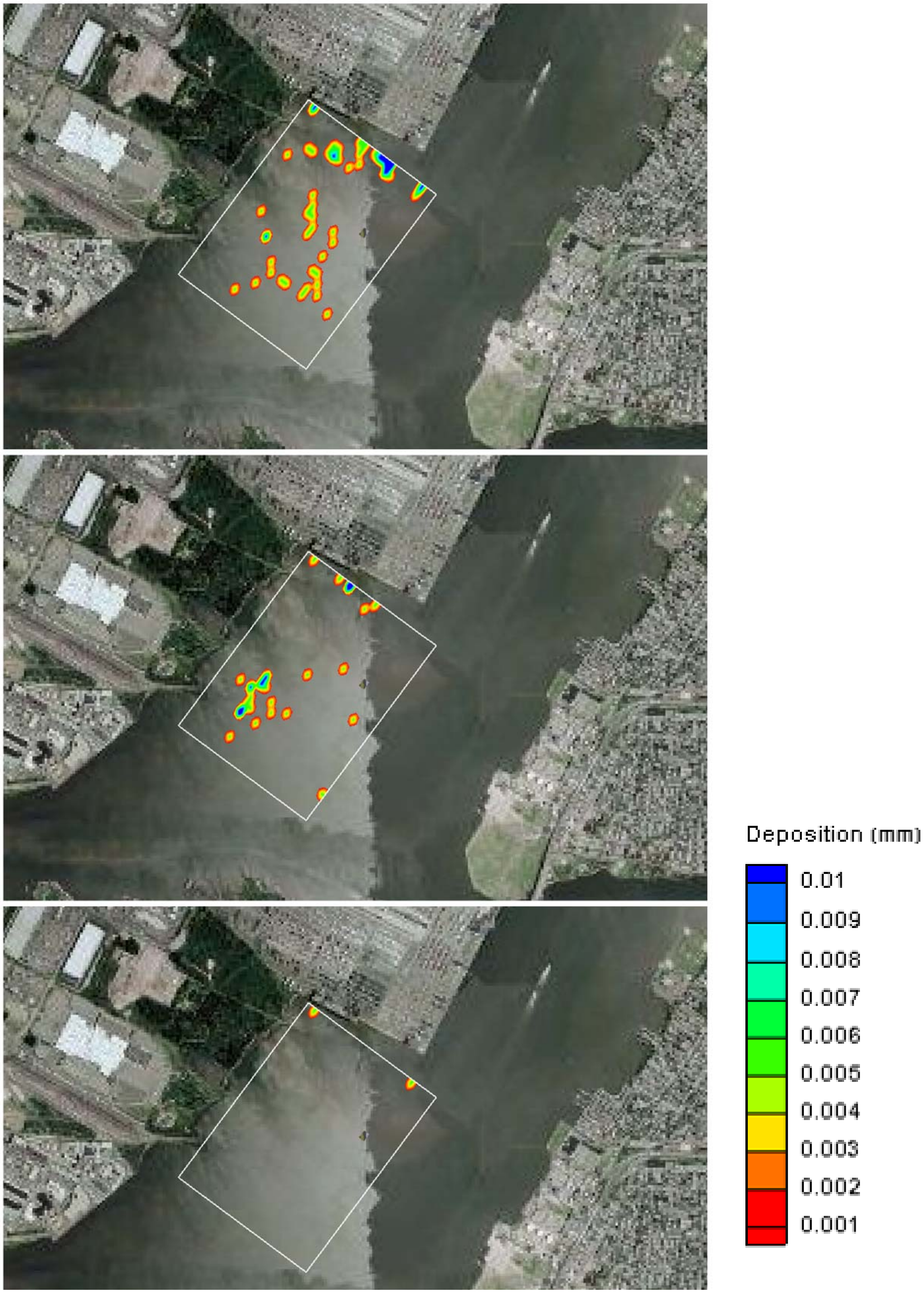

Figure 12. Case 1 deposition maps after a) one day, b) two days, and c) five days.

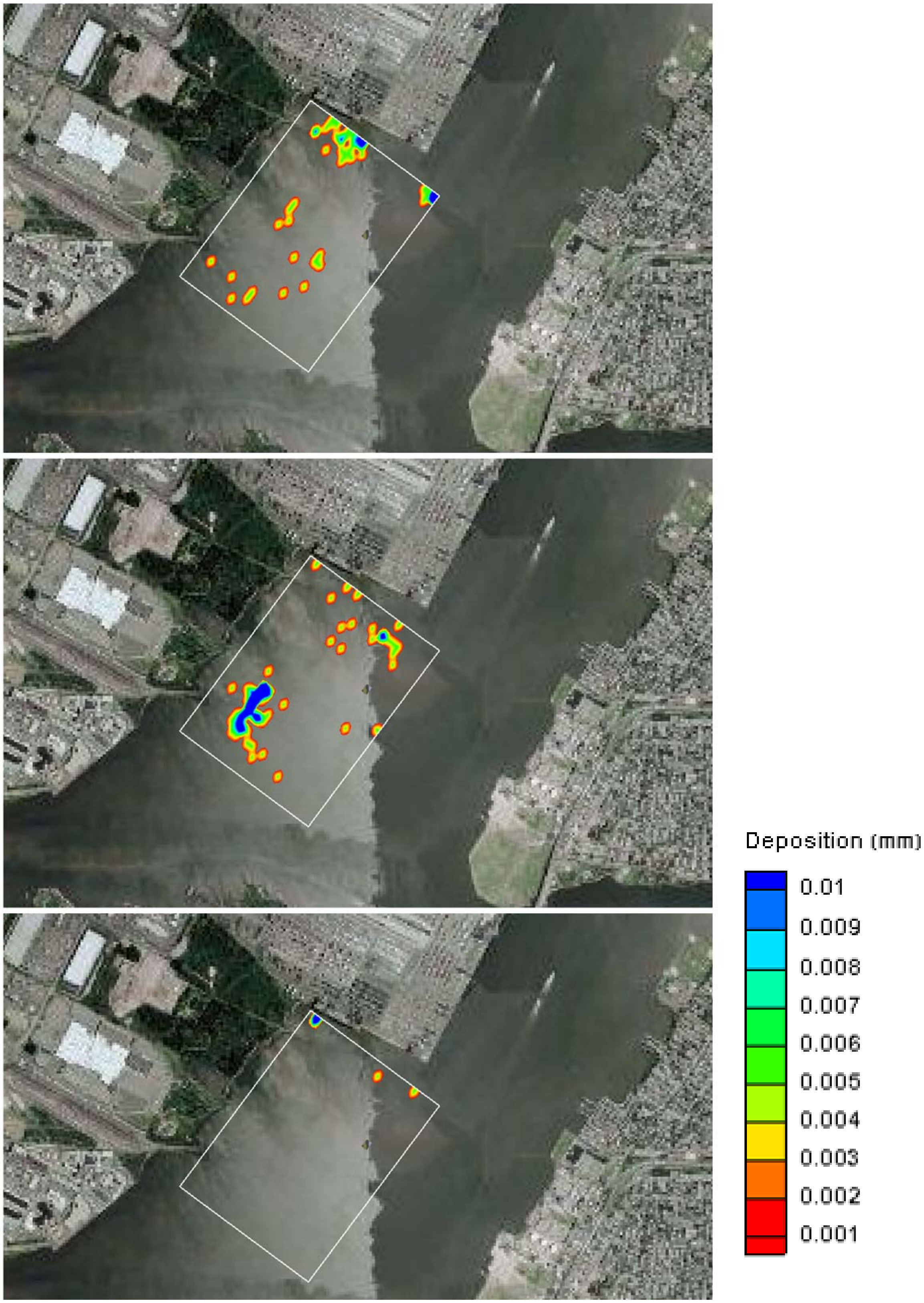

Figure 13. Case 2 deposition maps after a) one day, b) two days, and c) five days.

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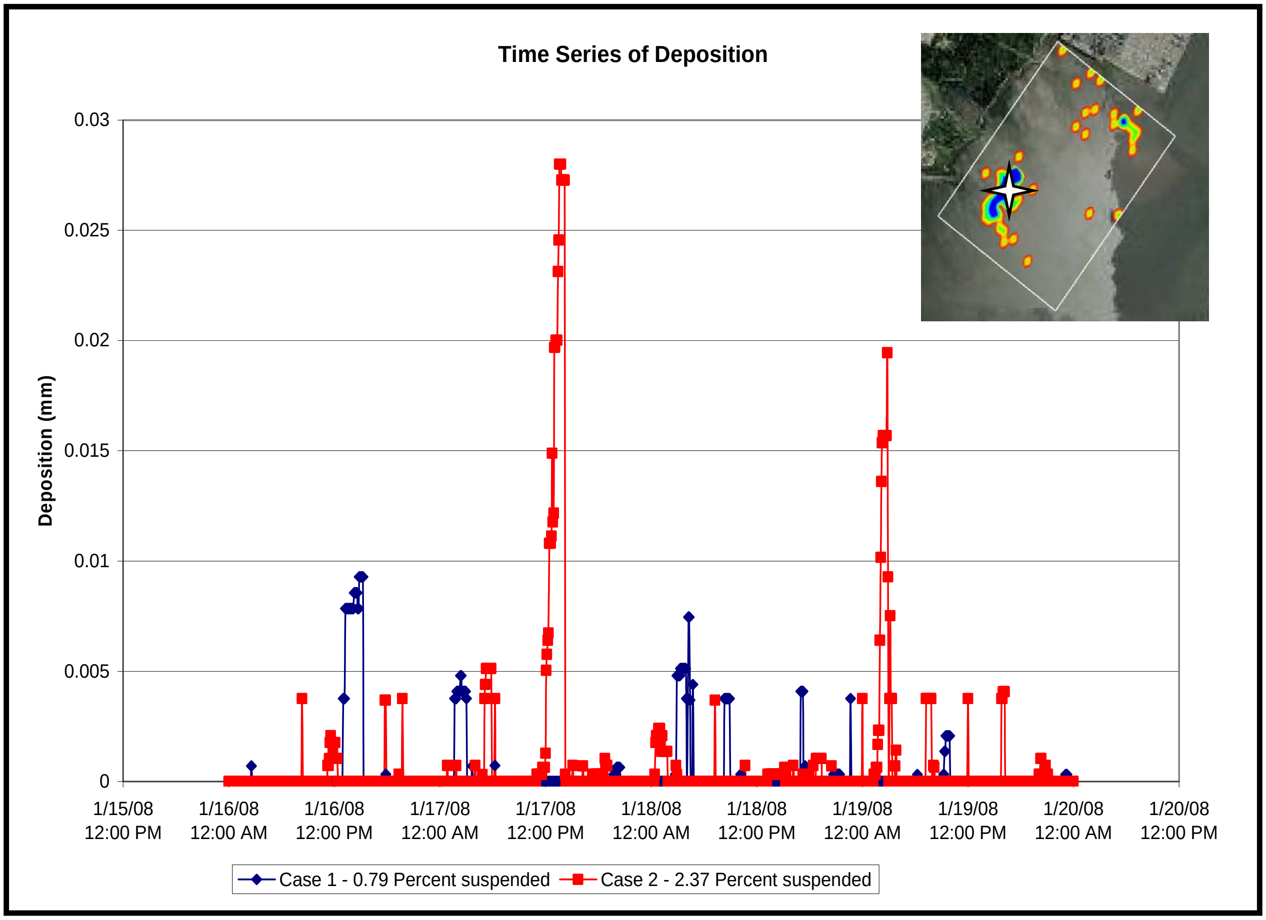

Figure 14. Time series of water level, flow, and bottom stress at shoal (blue) and channel (green).

CONCLUSIONS

A hypothetical dredging operation of 50,000cy (38,227.7 m^3) is simulated for the Newark Bay area using the Particle Tracking Model. Hydrodynamic transport forcing was generated by CH3D, a three dimensional hydrodynamic model. Two cases were simulated. Case 1 used a source strength equivalent to a 0.79 percent loss of the dredged material, whereas Case 2 used a source strength equivalent to 2.37 percent. In these simulations particle positions, bottom shear stress maps, and deposition maps were developed. Based on conventional criteria, levels of sediment deposition on eggs for Case 1 and Case 2 (maximum values of 0.01mm and 0.03mm respectively) were below the level (0.5mm) at which detrimental effects would hypothetically be seen for this particular dredging simulation. This dredging operation would not negatively impact suspected winter flounder spawning habitat.

Several questions are raised by the results shown within this work which could be addressed with additional simulations. What would be the effect of changing the dredging operation? In this particular case dredging is completed in 4 days. If more sediment was dredged, longer dredging periods were arranged, dredging locations were changed, or different management practices utilized, variations in deposition levels would most likely develop. Another interesting question is, at what point is a critical amount of dredging performed which raises deposition levels beyond an acceptable criterion? Methods demonstrated in the present study could address these questions and represent an improved capability for characterizing exposures and therefore risk associated with sediment resuspended and deposited during dredging operations.

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