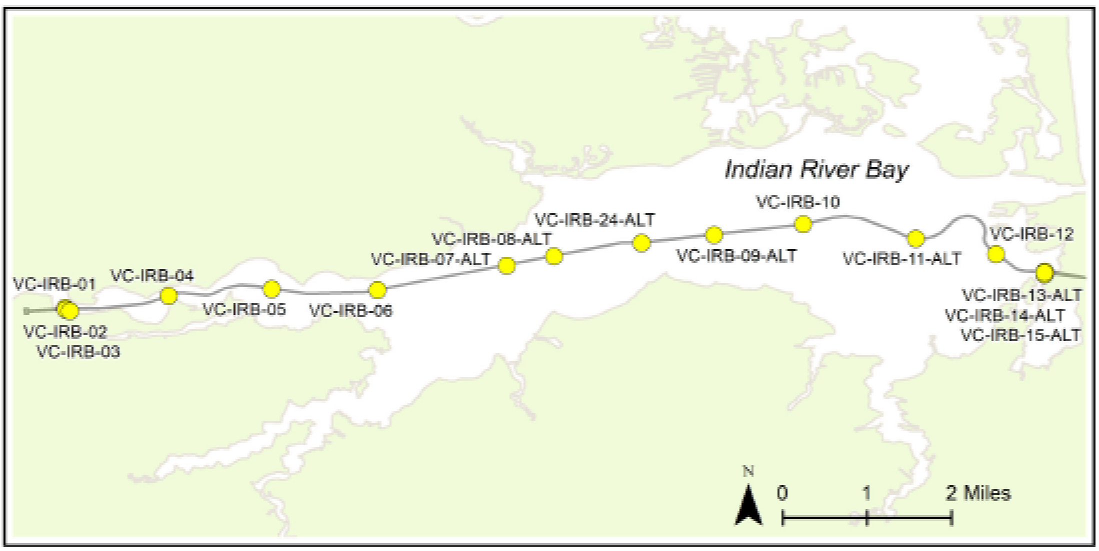
B3. Indian River Bay Sediment Transport Modeling

Suspended Sediment Transport Modeling Study
Indian River Bay Submarine Cable Installation

Maryland Offshore Wind Project



Study Prepared for:

10 Hemingway Drive, 2nd Floor
East Providence, RI 02915

Study Prepared by:

Matt Hodge, PE
Hodge.WaterResources, LLC

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EXECUTIVE SUMMARY

The Maryland Offshore Wind Project includes the construction of as many as 121 wind turbine generators, up to four offshore substations, and one Met Tower in the roughly 80,000-acre Lease area located approximately 27.5 kilometers (km) (17 miles [mi]) offshore. In order to connect to the mainland, US Wind is proposing the installation of a set of submarine cables. These cables include four Offshore Export Cables and 26 Inter-array Cables. All of the Inter-array Cables will connect the turbines to the offshore substations, and the Offshore Export Cables will connect the offshore substations to the point-of-interconnection. The Offshore Export Cables run northwest away from the Lease area and would make landfall at 3R's Beach or Tower Road in Delaware. The cables will be buried to specific target depths below the seafloor utilizing jet plow embedment. After making landfall on the Delaware Shoreline, the Export Cables will be horizontally directional drilled (HDD) from the ocean side to the bayside of Indian River Bay. Additional submarine cables will be laid from approximately one mile south of the Indian River Bay Inlet to Burton Island where they will again make landfall. Placement of the Export Cables in Indian River Bay will be completed by jet plowing.

US Wind requested that Hodge.WaterResources, LLC (HWR) conduct a sediment transport modeling assessment of the likely impacts of the proposed submarine cable installation in Indian River Bay. The assessment used sediment characterization data from vibracore sampling along the main channel of Indian River Bay to determine expected sediment transport away from the cables. HWR used this sediment transport assessment to predict where, and how much, in-situ trench sediment will travel before it is deposited back on the bay floor. The assessment predicts relative water quality impacts (i.e., assumed no ambient suspended sediment concentration) of this acute exposure event.

While water jetting technology (jet plow embedment for this project) is regarded as the most environmentally sensitive installation method for this activity when compared to other installation alternatives like mechanical dredging or displacement plowing, jetting does produce localized and temporary increases in suspended sediment concentrations. The sediment transport model provides predictions of suspended sediment concentrations and the thickness and location of sediment deposited back on the bay floor away from the cable as the jet plow places the cable.

The sediment transport modeling predicts that the sediments suspended by the jet plowing will spread throughout much of Indian River Bay from the Inlet to near the Millsboro Pond Dam, but the sediment will not enter Rehoboth Bay. The model predicts that the north cable may lead to suspended sediment concentrations as high as 300 mg/L exiting Indian River Bay on ebb tides, but the suspended sediment concentrations exiting Indian River Bay as a result of the south cable will be limited to 10 mg/L.

Most of the fluidized sediments lost to the water column are predicted to quickly settle back to the bay floor and deposition thicknesses greater than 0.2 inches (5 mm) will typically occur within 30 meters (95 ft) of the cables regardless of route. Suspended sediment concentrations are predicted to be less than 200 mg/L at distances greater than 1,400 m (4,600 ft) from the Export Cables. Model results indicate that the suspended sediment plume resulting from jet plowing will have a limited duration. Suspended sediment plumes greater than 10 mg/L are predicted to disappear within 24 hours after the completion of jetting operations. The sediment transport modeling results indicate that the proposed jet plow embedment process for cable installation will result in short-term and localized effects.

1.0 INTRODUCTION

The Maryland Offshore Wind Project includes the construction of as many as 121 wind turbine generators, up to four offshore substations, and one Met Tower in the roughly 80,000-acre Lease area located approximately 27.5 kilometers (km) (17 miles [mi]) offshore. In order to connect to the mainland, US Wind is proposing the installation of a set of submarine cables. These cables include four Offshore Export Cables and 26 Inter-array Cables. All of the Inter-array Cables will connect the turbines to the offshore substations, and the Offshore Export Cables will connect the offshore substations to the point-of-interconnection. The Offshore Export Cables run northwest away from the Lease area and would make landfall at 3R's Beach or Tower Road in Delaware. The cables will be buried to specific target depths below the seafloor utilizing jet plow embedment. After making landfall on the Delaware Shoreline, the Export Cables will be horizontally directional drilled (HDD) from the ocean side to the bayside of Indian River Bay. Additional submarine cables will be laid from approximately one mile south of the Indian River Bay Inlet to Burton Island where they will again make landfall. Placement of the Export Cables in Indian River Bay will be completed by jet plowing.

US Wind requested that Hodge.WaterResources, LLC (HWR) conduct a sediment transport modeling assessment of the likely impacts of the proposed submarine cable installation in Indian River Bay. The assessment used sediment characterization data from vibracore sampling along the main channel of Indian River Bay to determine expected sediment transport away from the cables. HWR used this sediment transport assessment to predict where, and how much, in-situ trench sediment will travel before it is deposited back on the bay floor. The assessment predicts relative water quality impacts (i.e., assumed no ambient suspended sediment concentration) of this acute exposure event.

While water jetting technology (jet plow embedment for this project) is regarded as the most environmentally sensitive installation method for this activity when compared to other installation alternatives like mechanical dredging or displacement plowing, jetting does produce localized and temporary increases in suspended sediment concentrations.

The first step to complete this analysis was to simulate hydrodynamic conditions within the study area using a two-dimensional hydrodynamic model. The domain for the modeling includes Indian River Bay from the Inlet to the Millsboro Pond Dam approximately 19.3 km (12 mi) west of the Inlet. The domain also includes Rehoboth Bay. The model domain is shown in Figure 1-1. In the second step of the analysis, the results of the hydrodynamic model are applied to a complementary sediment transport model to characterize predicted suspended sediment concentrations and deposition associated with the jet plow embedment method. The sediment transport model provides predictions of suspended sediment concentrations and the thickness and location of sediment deposited back on the bay floor away from the cable as the jet plow advances.

Indian River Bay is a tidal estuary and is part of Delaware Inland Bays (USGS, 2003). It connects to the Atlantic Ocean through an inlet near Bethany Beach, Delaware. Just northwest of the Indian River Inlet are a series of islands that separate Indian River Bay and Rehoboth Bay. The eastern side of each bay is separated from the Atlantic Ocean by a barrier beach, dunes, and vegetative cover (primarily coastal grasses, scrub brush, and small trees). The Coastal Highway (Delaware Route 1) passes along this strip of land as well. The approximate width of the barrier is 500 meters (1,640 feet [ft]). Many tributaries drain to each of the bays. Other than the Indian River Inlet, there is only one additional channel that connects either of the two bays to other water bodies. The Lewes-Rehoboth Canal connects Rehoboth Bay to the

Delaware Bay. The canal enters Rehoboth Bay next to Thompson Island in the northeastern corner of Rehoboth Bay.

Water depths in Indian River Bay are generally less than 2 m (6.6 ft), but the inlet to the bay is an artificially stabilized channel with a mean depth of approximately 20 m (65.6 ft) (Xu et al., 2006). The tidal range in Indian River Bay varies with proximity to the Inlet. The United States Geological Survey (USGS) maintains two water level gauges in Indian River Bay and one gauge in Rehoboth Bay. The locations of these gauges are shown in Figure 1-1. The mean tidal range at the Inlet is approximately 0.78 m (2.55 ft). The mean tidal range at Rosedale Beach, approximately 12 km (7.5 mi) west of the Inlet, is 0.53 m (1.75 ft). The tidal range in Rehoboth Bay is limited by the exchange of water between Rehoboth Bay and Indian River Bay. The mean tidal range in Rehoboth Bay is 0.47 m (1.55 ft). All tidal ranges are based on analysis of 2021 recorded water levels at the USGS stations.

The interaction between tides and freshwater flow into the estuary is the primary driver of currents. There are many tributaries that drain to Indian River Bay and Rehoboth Bay. The United States Army Corps of Engineers (USACE) previously completed a hydrodynamic model of the two bays and they identified 12 sub-basins that drain to Indian River Bay and Rehoboth Bay (Cerco et al., 1994). These sub-basins are shown in Figure 1-2. Most of the tributaries are ungauged (i.e., flow not measured), but the USGS maintains a flow monitoring gauge at the Millsboro Pond Dam on the Indian River, approximately 19 km (12 mi) west of the Inlet. The Millsboro Pond Dam is the upstream limit of the tidally influenced portion of Indian River. The USGS also maintains a flow monitoring gauge in the Beaverdam Ditch watershed. Beaverdam Ditch does not drain to the Indian River, but the characteristics of the watershed (e.g., slope and soils type) is similar to the tributary watersheds that drain to Indian River Bay and Rehoboth Bay.

US Wind may use one of two alternative cable routes through Indian River Bay. Both routes begin at the same origin point approximately 1.6 km (1 mi) south of the Inlet. The “north” cable route moves immediately northwest until it reaches the thalweg of the Indian River. The north cable route then follows the main channel west. The “south” cable route passes southwest from the origin and then approximately parallels the shoreline along the Holts Landing State Park. The two cable routes meet approximately 5 km (8 mi) west of the Inlet. From that point westward, there is only one proposed cable route until the landfall location on Burton’s Island. Both the north cable route and the south route are shown in Figure 1-1.

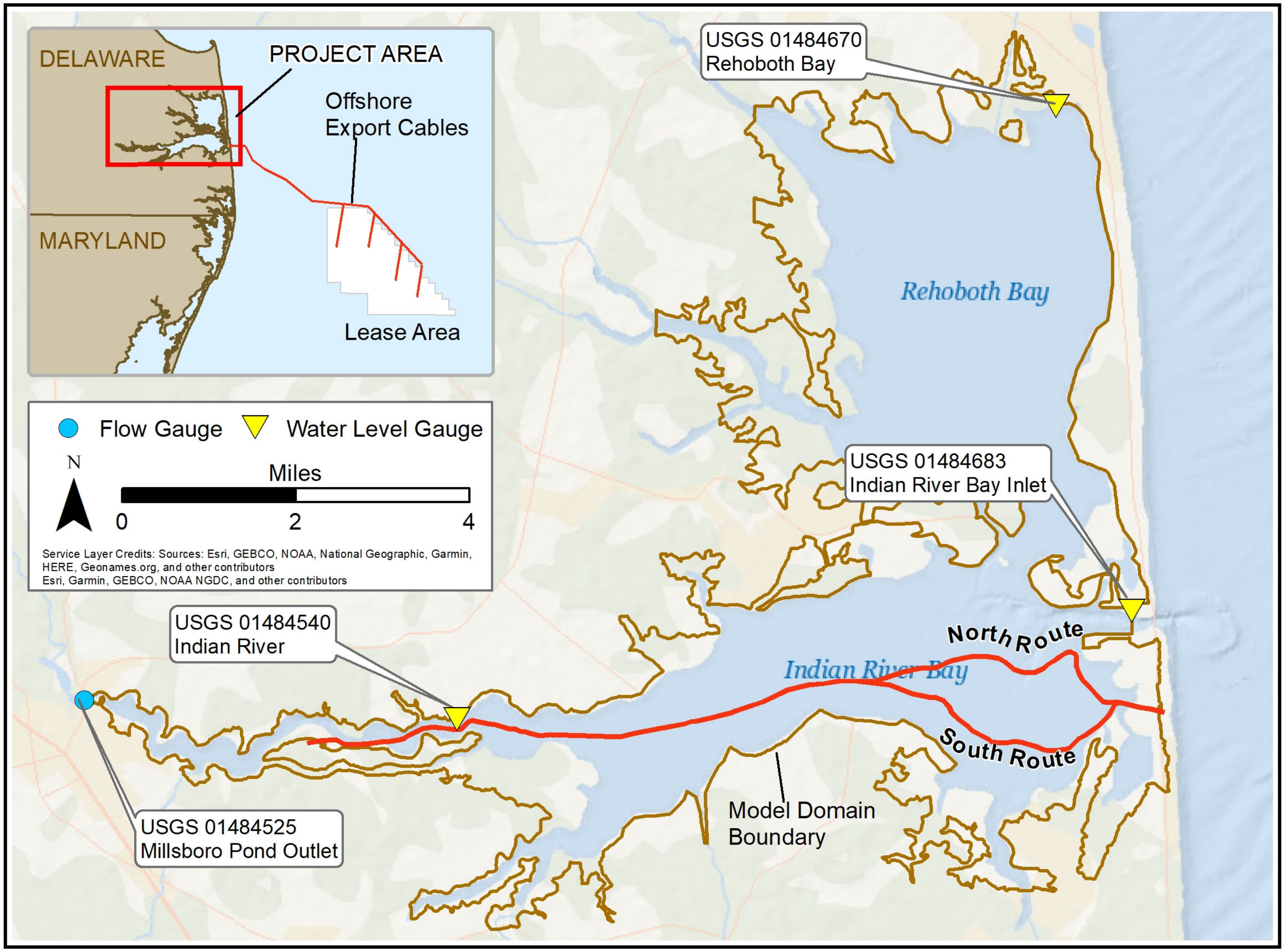

Figure 1-1: Locus Map and USGS Gauging Stations

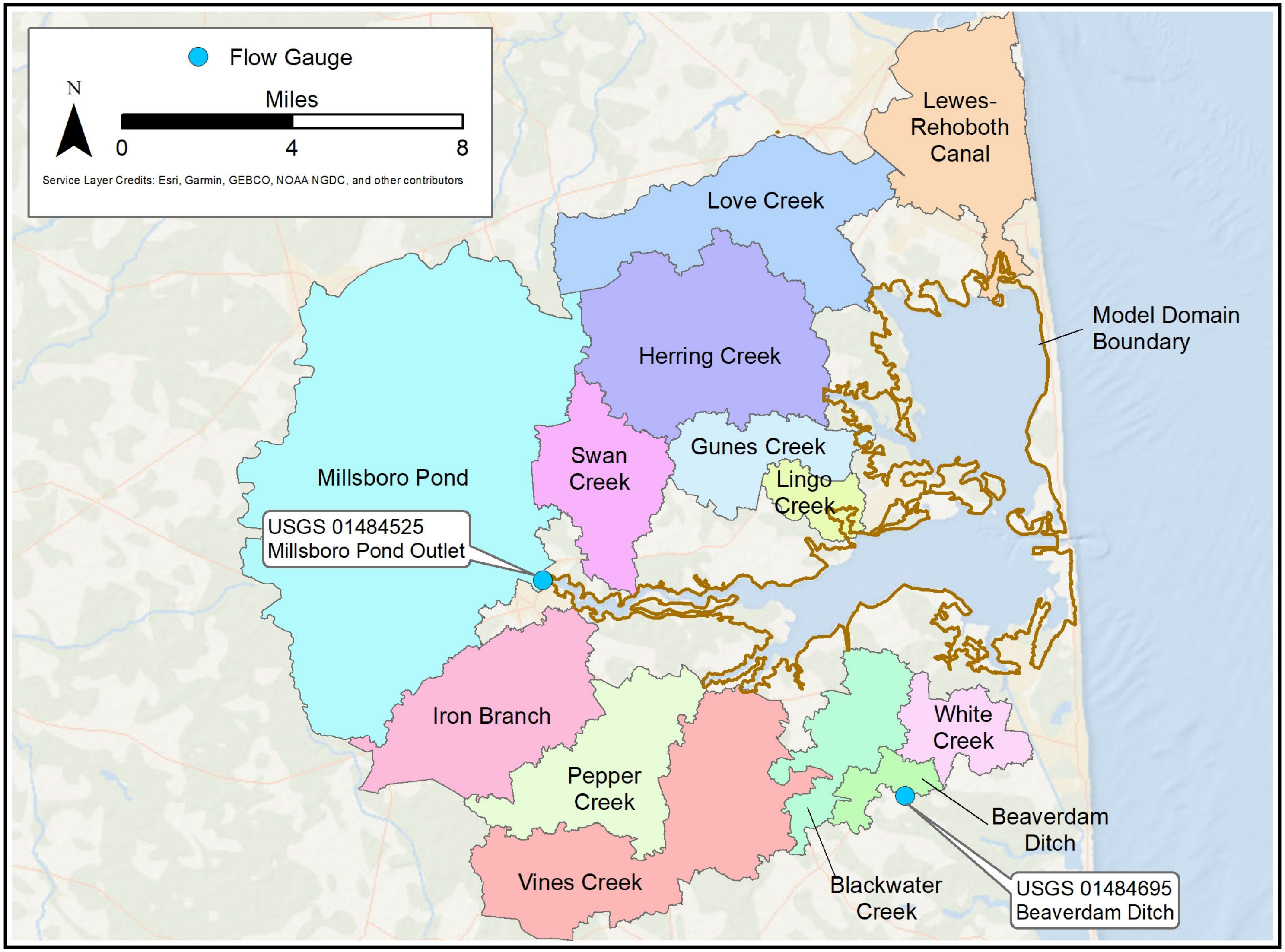

Figure 1-2: Tributary Watersheds to Indian River Bay and Rehoboth Bay

2.0 SUBMARINE CABLE ROUTE SEDIMENT CHARACTERISTICS

A total of 16 vibracore samples were collected along the north cable route in 2017. Additional vibracores were collected in 2022 including along the south cable route, but at the writing of this report, the lab analysis had not been completed. The samples collected in 2017 provide a clear picture of the dominant sediment type along the north cable route. The locations of these vibracore samples are shown in Figure 2-1.

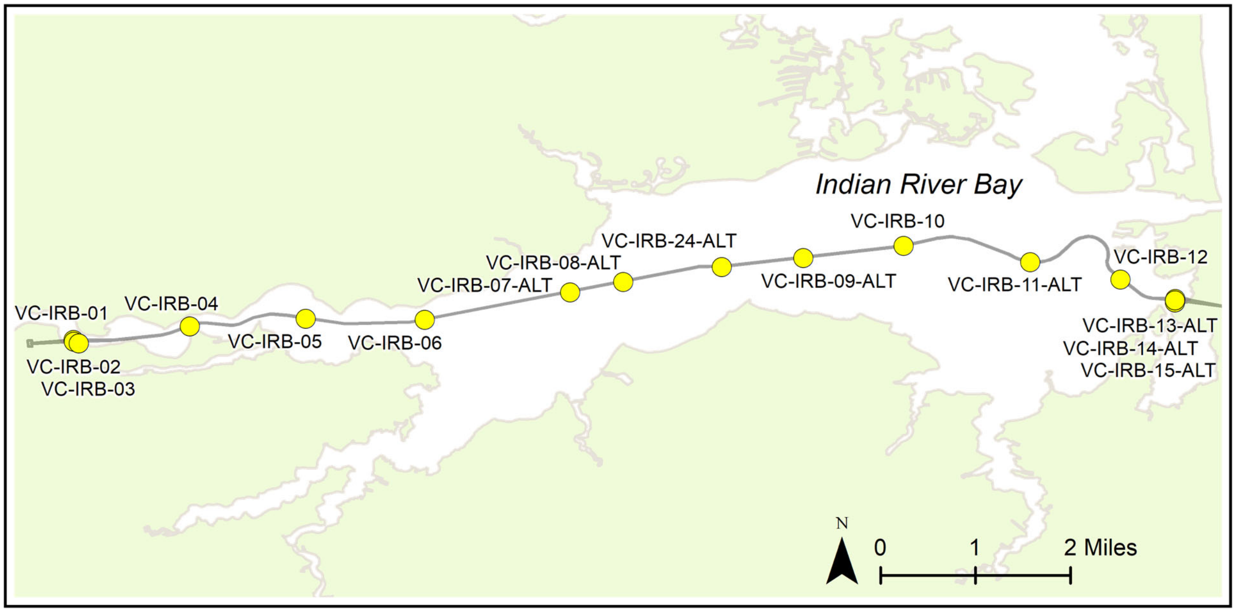

Figure 2-1: Vibracore Sampling Locations

Figure 2-2 shows the percentage of gravel, sand, silts, and clays at each vibracore location. The composition of each vibracore is unique with some vibracore sampling results indicating some portion of gravels or clays, but each vibracore is primarily composed of sands and silts. In 25 of the 30 sieve analyses completed, the cumulative percentage of sand and silt is at least 85%. The overwhelming majority of the sediments that will be suspended during jet plowing will be medium sand-sized to silt-sized granular sediments. The median grain size (D50) of all samples is between 0.051 millimeters (mm) and 0.355 mm.

In addition to sieve analyses, many of the vibracores were measured for specific gravity of the sediment material and bulk density of the sample. Specific gravity measurements indicate that the particle density of sediments ranged from 1,440 to 3,090 kilograms per cubic meter (kg/m^3) with an average value of 2,477 kg/m^3. The bulk density provides an indication of the in-situ compaction of these granular sediments (i.e., how much sand is in a given volume). The bulk density ranged from 970 kg/m^3 to 1,720 kg/m^3 with an average value of 1370 kg/m^3. Based on the consistency of sediment analysis between the vibracore samples, it is an appropriate assumption to consider average values as representative of conditions along the entire Export Cable Corridor.

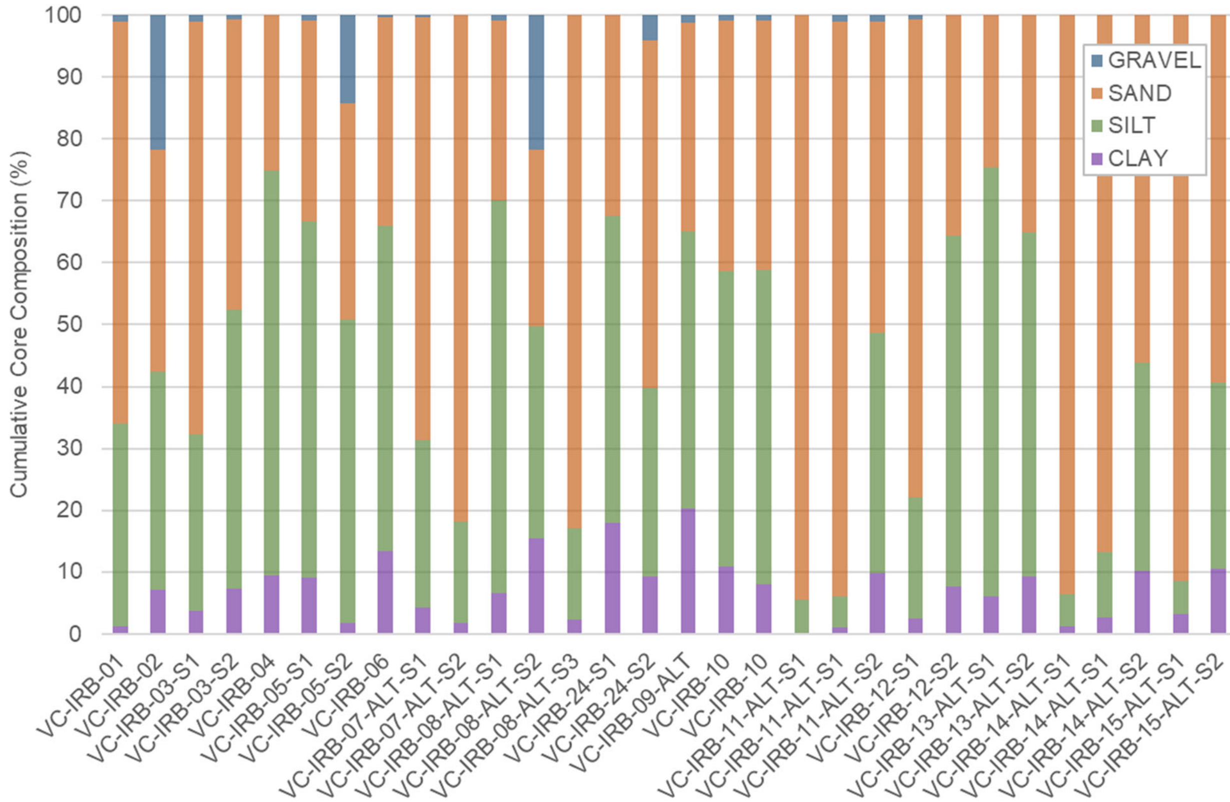

Figure 2-2: Dominant Sediment Type Along Route by Vibracore Location

For the purposes of analysis and modeling, we assumed that the sediment characteristics along the south cable route are the same as the north cable route. If additional sediment sampling (i.e., vibracores) become available, we will reevaluate the validity of this assumption.

3.0 MODEL DESCRIPTION

When sediment is suspended by the jet plow, it may be transported away from the trench by advective transport. Advective transport is the transport of suspended materials by the movement of the suspending media (i.e., water and currents in the water). In order to be able to evaluate current speeds and directions, HWR developed a hydrodynamic model of the Project area using CMS-Flow and then simulated sediment transport using the Particle Tracking Model (PTM).

3.1 CMS-Flow

CMS-Flow is a two-dimensional hydrodynamic circulation model that simulates water levels and current speeds that are driven by tides, wind, or other hydrodynamic forces over a finite volume grid. The Coastal Modeling System (CMS) was originally developed by the Coastal Inlets Research Program (CIRP) at the United States Army Corps of Engineers – Engineering Research and Development Center (USACE-ERDC) Coastal Hydraulics Laboratory (CHL). CMS-Flow is based on the shallow-water equations (Reed et al., 2011). One of the primary benefits of using CMS-Flow is that it incorporates wetting and drying in a stable way allowing for tidal flats and other areas in the intertidal zone to be incorporated into the modeling. Version 5.3 of CMS-Flow is the latest version of CMS-Flow and can be readily linked to the sediment transport model. Version 5.3 was used in this analysis.

3.2 PTM

The sediment transport model selected was PTM version 2.3. PTM is a Lagrangian sediment particle tracker developed to simulate particle (i.e., sediment) transport processes. The model was developed by USACE-ERDC as part of CIRP and the Dredging Operations and Environmental Research Program (MacDonald et al., 2006). The model contains algorithms that appropriately represent particle (sediment) transport, settling, deposition, mixing, and resuspension processes. Suspended sediment in PTM is modeled as a discretized finite number of particles that are transported by flow. These particles are representative of all particles coming from a source. Each particle is assigned a mass of sediment to represent, and each particle has individual characteristics that include grain size and density. The transport and eventual deposition of these representative particles can then be used to determine suspended sediment concentrations and deposition thicknesses.

4.0 HYDRODYNAMIC MODEL APPLICATION

4.1 Model Setup

Figure 4-3 shows the limits of the model domain and indicates each boundary condition applied to the hydrodynamic model. The model domain includes all of Indian River Bay and Rehoboth Bay. The model domain extends from the Indian River Bay Inlet west to the Millsboro Pond Dam. The Lewes Rehoboth Canal is included as a simplified/idealized channel. The model domain includes two tidal boundaries and 11 flow boundaries. These boundaries and their source data are described below.

- **Tidal boundary at Indian River Bay Inlet:** The only direct connection between Indian River Bay and the Atlantic Ocean is the Indian River Bay Inlet. The Inlet is a dredged channel with extremely high currents at both peak flood and peak ebb tides. The USGS monitors water levels on the inland side of the Inlet in a protected harbor on the northern side of the Inlet. The model includes a tidal boundary across the Inlet, and the measurements recorded by the USGS are the basis for specifying this boundary. During model development, HWR concluded that the modifications to the Inlet water level timeseries were necessary in order to optimize the calibration of the model. HWR increased the high tide by 0.250 m (0.820 ft) for each tidal cycle with the increase progressively scaled through flood tides. HWR concluded that this adjustment was appropriate given the location of the water level monitoring station (i.e., in the inner portion of the inlet), the well-known highly turbulent behavior of the Inlet, and the potential for the monitoring station to not fully capture the water level differential driving tidal exchange through the Inlet. Figure 4-1 shows the water levels recorded and the augmented water level time series used at the boundary for a representative week in December 2021.
- **Tidal boundary at Lewes-Rehoboth Canal:** The Lewes-Rehoboth Canal is a navigation channel that connects Rehoboth Bay to Delaware Bay. The Channel is approximately 14 km (8.7 mi) long. The channel is relatively uniform with an average depth of 1.2 m (4 ft) at mean lower low water (NOAA, 2012). The influence of the tidal exchange on Rehoboth Bay from Delaware Bay is limited, but the tidal cycles between Rehoboth Bay and Delaware Bay are almost 90 degrees out of phase. Figure 4-2 shows the water level of both Delaware Bay, as measured at Lewes, Delaware, and Rehoboth Bay. The time series for Delaware Bay informs the tidal boundary at the end of the channel. The canal in the model is an idealized/simplified canal matching the approximate average width, depth, and length of the canal but not matching the actual canal shape.
- **Flow boundary at Millsboro Pond Dam:** The dam at Millsboro Pond releases flow from the Indian River into Indian River Bay and prevents water from flowing upstream beyond the dam. The USGS monitors flowrates at the dam, and those observations inform the flow boundary of the hydrodynamic model.
- **Flow boundary at other tributaries:** There are multiple smaller creeks and streams that drain to the Indian River Bay and Rehoboth Bay. None of these secondary tributaries are gauged. Cerco et al. (1994) addressed this by using the flow rates from a nearby flow gauging station and scaling the flow rate based on watershed size. HWR employed the same approach and used the flow recorded at the Beaverdam Ditch as the reference gauging station. Table 4-1 shows the area of each contributing watershed and the scale factor applied to each tributary. HWR excluded both Millsboro Pond and the Lewes-Rehoboth watersheds because they are addressed separately.

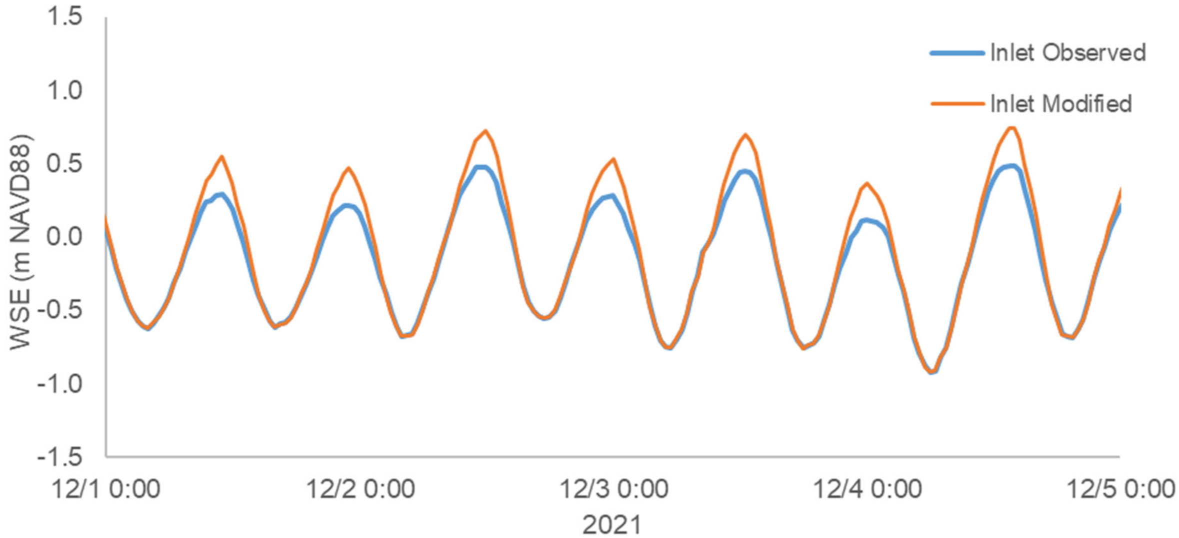

Figure 4-1: Observed WSE and Modified WSE for Tidal Boundary at Indian River Bay Inlet

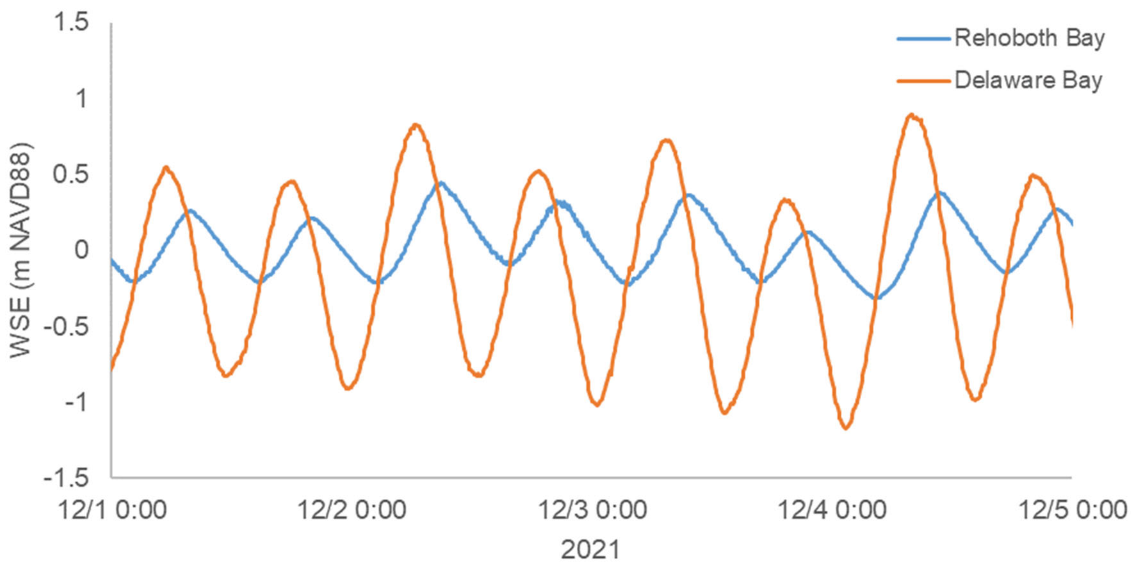

Figure 4-2: Observed WSE at Rehoboth Bay and Delaware Bay (Lewes)

Table 4-1: Tributary Scaling Factors for Indian River Bay and Rehoboth Bay

	Watershed Area		
Tributary	km^2	mi^2	Scale Factor
Beaverdam Ditch	5.92	2.29	--
White Creek	12.22	4.72	2.1
Blackwater Creek	17.52	6.76	3.0
Vines Creek	53.31	20.58	9.0
Pepper Creek	30.69	11.85	5.2
Iron Branch	38.77	14.97	6.6
Swan Creek	24.51	9.46	4.1
Gunes Creek	17.78	6.86	3.0
Lingo Creek	7.50	2.90	1.3
Herring Creek	52.35	20.21	8.8
Love Creek	44.01	16.99	7.4

CMS-Flow uses a Cartesian grid system that includes quadtree telescoping. The telescoping grid allows for variable cell sizes within the model domain. In narrow channels (e.g., the western portion of Indian River Bay approaching Burton Island) the model grid resolution is approximately 20 m (65.6 ft). In contrast, the grid resolution in the middle of Rehoboth Bay is 80 m (262 ft). The variable grid sizing provides computational efficiency while still providing the necessary current velocity and water level information for the sediment transport model to assess jet plow induced suspended sediment concentrations and deposition. Figure 4-3 shows the overall hydrodynamic model grid and highlights areas of interest.

The bathymetric data used in the hydrodynamic model is based on the publicly available Coastal National Elevation Database Project (USGS, 2023). HWR incorporated meteorological conditions (i.e., wind speed and direction) into the model based on observations from the National Data Buoy Center station at Lewes, Delaware (NOAA, 2023).

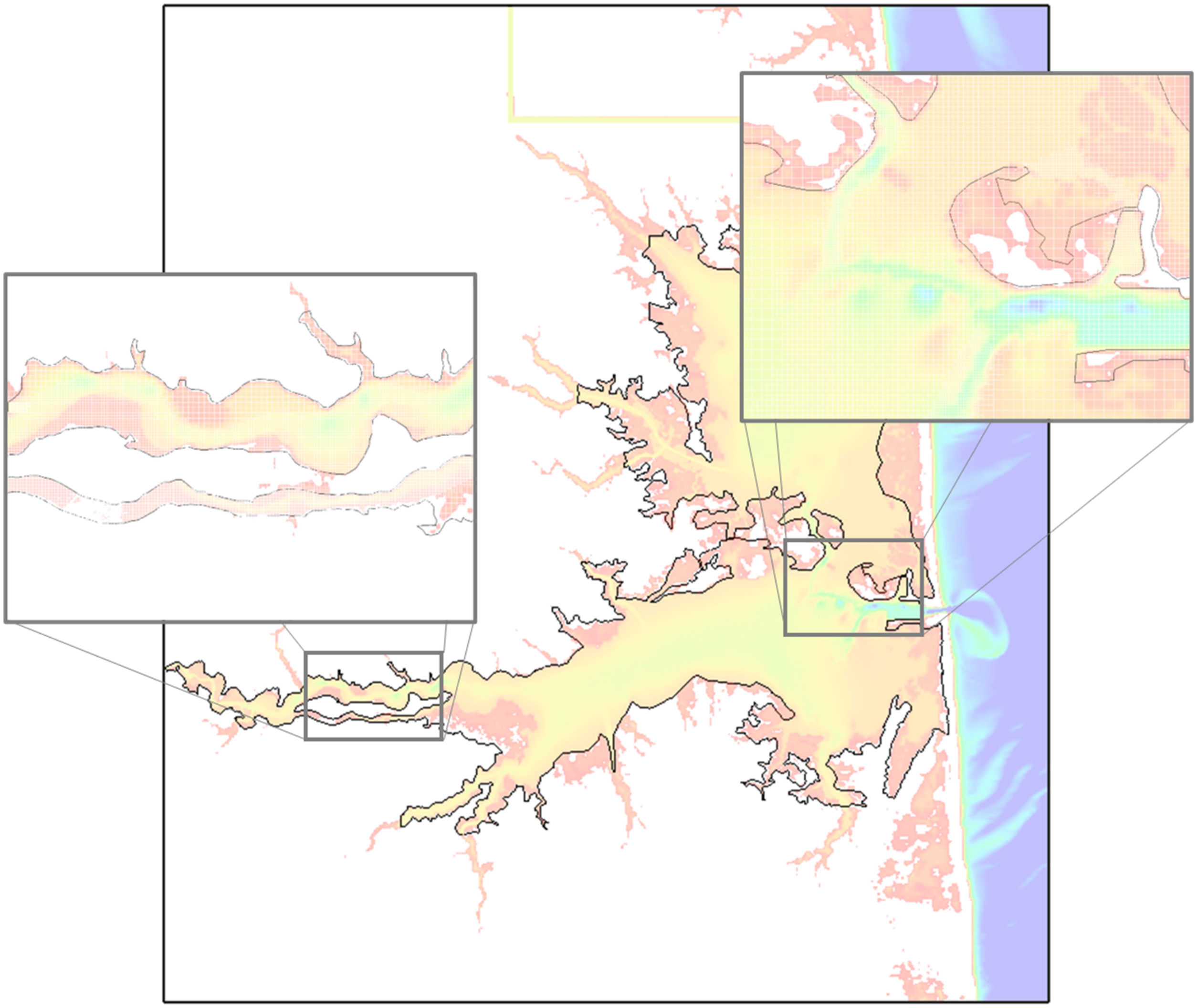

Figure 4-3: Hydrodynamic Model Domain

HWR ran the hydrodynamic model for the period from December 1, 2021 to December 30, 2021 as the calibration period for the hydrodynamic model. After calibrating the model, we then ran the hydrodynamic model for the planned construction period beginning in September 2021[1].

4.2 Model Results and Comparison

To ensure that the hydrodynamic model appropriately simulates currents and tides in the model domain, HWR evaluated model performance for a 30-day period (i.e., a lunar month) from December 1, 2021 through December 30, 2021. HWR selected a 30-day period because the spring/neap pattern can be particularly influential when evaluating tidal estuaries where the inter-tidal zone can play a large role in the

[1] The conditions that will be present during the future installation period are unknown (i.e., tidal range, freshwater flow, wind speed and direction). To account for seasonal variability in boundary conditions, HWR ran the hydrodynamic model for the same period in 2021.

hydrodynamic performance of the model. The desire to capture a range of tidal conditions must be balanced against the effect of the length of comparison periods on performance statistics. For example, the Square of the Pearson Correlation Coefficient (R^2) is a statistic that indicates the degree of correlation between two independent sets of data, and R^2 increases/improves with the length of the comparison period. The “correct” length of the modeled to observed comparison is a matter of professional judgement, and HWR concluded that 30 days is an appropriate duration for this project based on past experience with similar projects. HWR selected this specific period of time (i.e., December 1, 2021 through December 30, 2021) because it is in the middle of the planned construction period for the cable laying project. The predicted model water levels were compared to observed water levels from two USGS water level monitoring stations, one in Indian River Bay at Rosedale Beach (USGS ID: 01484540) and one in Rehoboth Bay at Dewey Beach (USGS ID: 01484670). The location of each gauge is shown in Figure 1-1.

HWR compared predicted water levels from the hydrodynamic model to observed water levels at Rosedale Beach in Indian River Bay (Figure 4-4). The hydrodynamic model shows an equivalent tidal range to the observed data, indicating good model correlation to measured conditions. The mean residual (i.e., the difference between the modeled values and observed values) for water levels is +0.08 m (+0.26 ft). The root mean square error (RMSE) is 0.10 m (0.33 ft).

HWR compared predicted water levels from the hydrodynamic model to observed water levels at Dewey Beach in Rehoboth Bay (Figure 4-4). The hydrodynamic model shows an equivalent tidal range to the observed data, indicating good model correlation to measured conditions. The mean residual is -0.01 m (-0.03 ft). The root mean square error (RMSE) is 0.06 m (0.20 ft).

HWR also looked at R^2 for each water level monitoring station as an additional check on calibration and to evaluate how the model performs across the tidal range that occurs through a full spring-neap tide cycle. Figure 4-6 plots the modeled water levels against the observed water levels at each station. The R^2 values are both high (i.e., 0.94 at Rosedale Beach and 0.93 at Dewey Beach). The model shows good agreement with observed water levels across the full range of tidal conditions.

Taken collectively, the information presented in Figure 4-4 through Figure 4-6 demonstrates that the hydrodynamic model appropriately simulates the hydrodynamic behavior of Indian River Bay and Rehoboth Bay and is acceptable for use in sediment transport modeling.

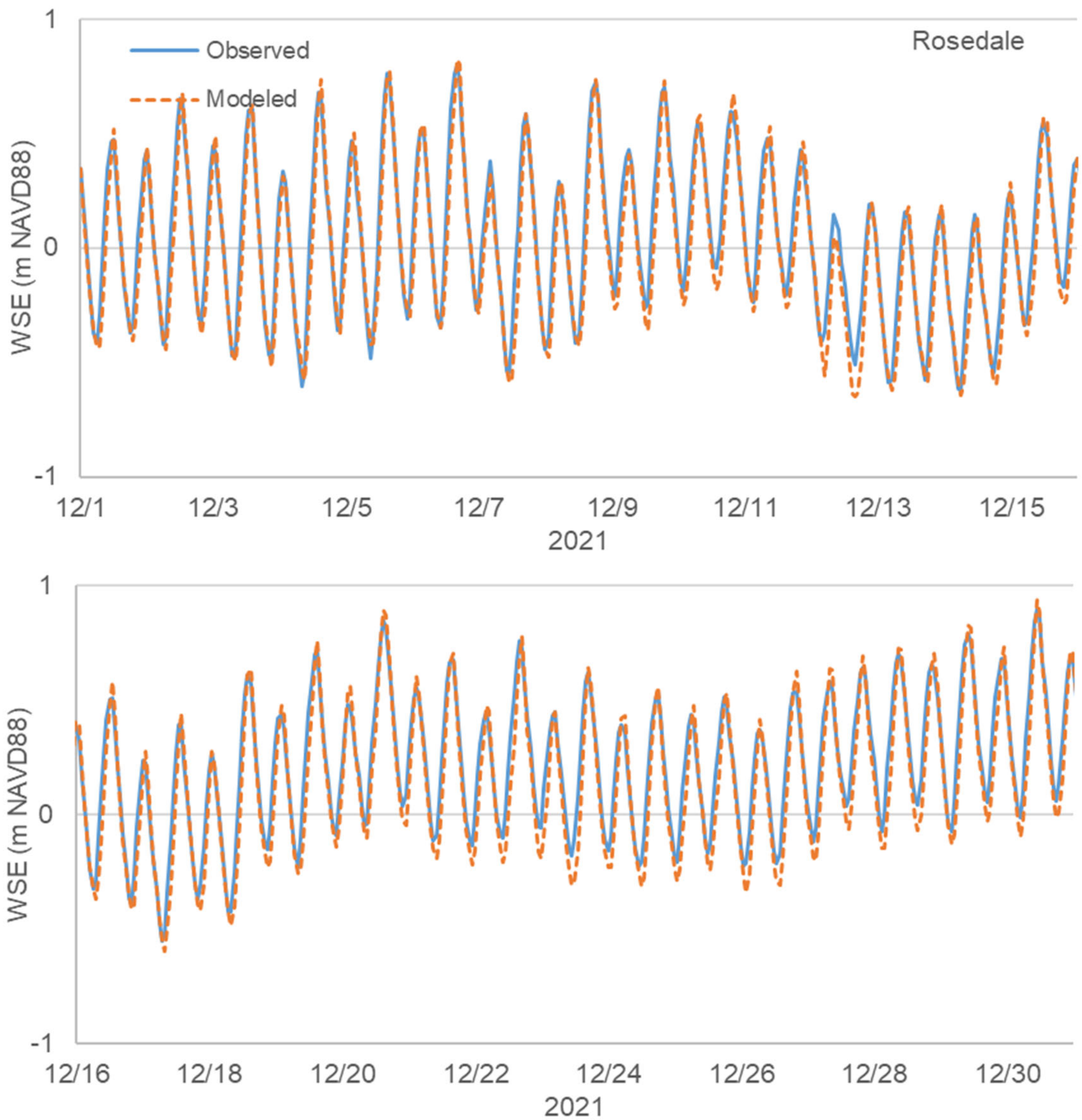

Figure 4-4: Observed and Modeled Water Levels at Rosedale Beach, Indian River Bay

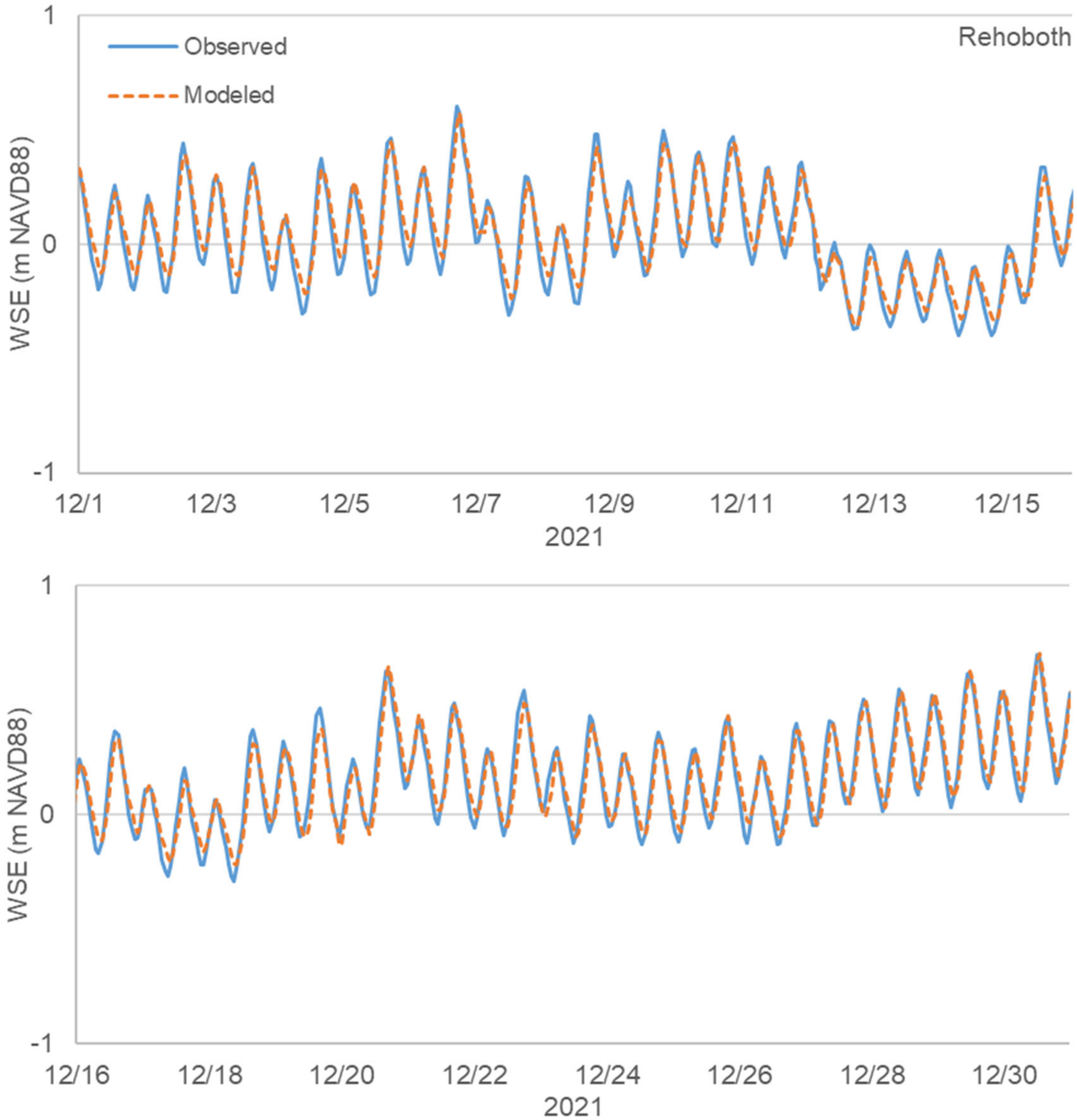

Figure 4-5: Observed and Modeled Water Levels at Dewey Beach, Rehoboth Bay

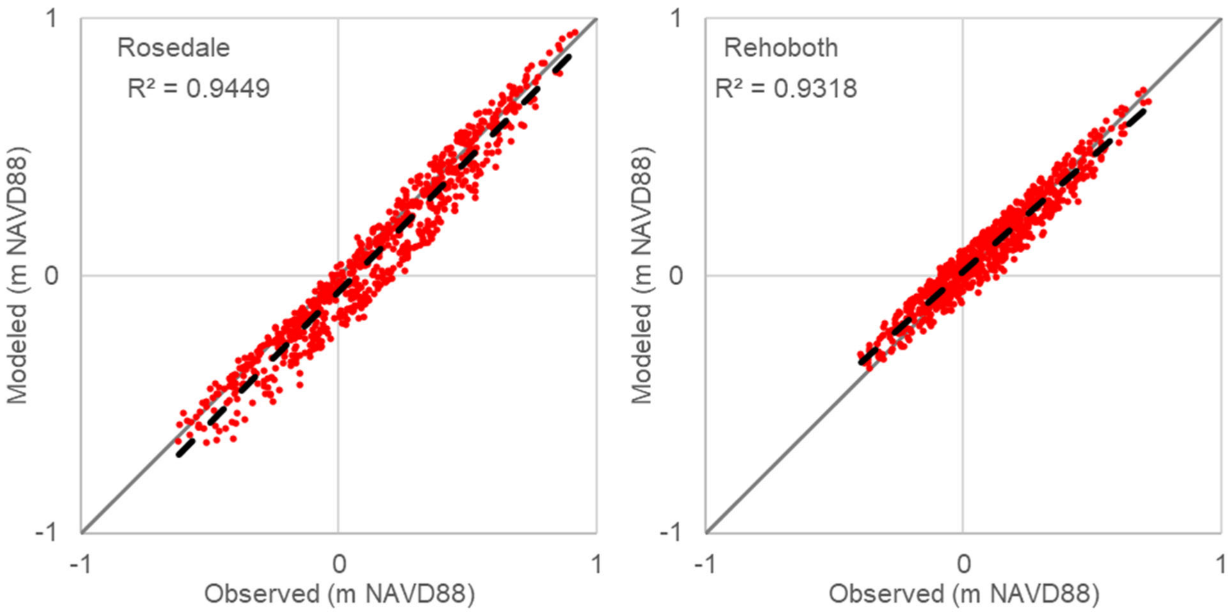

Figure 4-6: Modeled Versus Observed Water Levels

5.0 SEDIMENT TRANSPORT MODEL APPLICATION

The planned jet plowing will include the installation of four Export Cables. Each cable will be placed in a separate jet plowed trench. Jet plowing combines excavation of the trench, cable placement, and backfilling of the trench into a single continuous process. During jet plowing, sediment will be fluidized to allow the placement of the cable. The majority of the fluidized sediment will return to the trench, but some portion of the fluidized sediment will escape the trench. The order of installation and timing of each cable placement will evolve as construction details become finalized. For the purposes of this study, it was assumed that each Export Cable will be installed from east to west with the most southerly cable being installed first. Installation of the next most southerly cable will immediately follow the completion of the first cable and so forth until all four Offshore Export Cables are installed. The Export Cable installation is assumed to start in September and be completed in late March. For the purposes of this study, it is assumed that jet plowing will occur continuously along each cable with no time between the completion of one cable and the beginning of another cable. The assumption of continuous jet plowing results in a substantially shorter construction window. The modeling assumes that the jet plowing begins on September 1 and is completed by October 1. Continuous jet plowing of each cable will not be possible during construction, but in the absence of a detailed construction schedule, the assumption provides a conservative estimate of the suspended sediment concentrations. The inclusion/exclusion of delays between cable laying operations will not cause a material difference in the model results.

5.1 Model Setup

The sediment transport model (PTM) uses the same model domain as the hydrodynamic model (CMS-Flow). PTM requires additional inputs that represent the operation of the jet plow and characterize the sediment suspended into the water column. The anticipated fluidization depth, channel width, and jet plow progress rate are shown in Table 5-1 for the Export Cables.

Table 5-1: Jet Plowing Characterization

Segment Description	Fluidization Depth		Embedment Speed	
	m	ft	m/hr	ft/hr
Export Cables	2.0	6.6	100	330

The amount of sediment that is lost to the water column is a function of sediment characteristics, jet plow operation, and ambient current speeds. HWR did not find any published research on appropriate estimates for loss rate in silty/sandy sediment, but based on previous experience and other modeling studies, 25% is a common assumed value for jet plowing in many types of sediments. The loss rate of 25% was used in the modeling of jet plowing in Little Bay, a tidal estuary, in New Hampshire (RPS, 2015). Subsequent monitoring of a test run of jet plowing indicated that the modeling results were consistent with observed conditions (Normandeau, 2019). While not definitive, this work supports the use of 25% as the loss rate in an estuary.

The rate of suspended sediment generation (on a volume basis) is the product of trench width, excavation depth, advancement rate, sediment composition, and the loss rate. To calculate the rate of suspended sediment generation on a mass basis, it is necessary to understand the physical properties of the sediments that will be fluidized.

The modeling requires the specification of a median grain size, an estimate of particle sorting (i.e., standard deviation for grain-size distribution), specific gravity, and bulk density. The vibracore samples discussed in Section 2.0 of this report provide sufficient information to characterize the sediment along the Export Cable Corridor as summarized in Table 5-2. The model simulates a normal distribution of sediment around the median grain size; therefore, the modeled sediment grain sizes range from fine-grained particles (e.g., silts) to coarse sands.

Table 5-2: Cable Route Sediment Characterization

Sediment Characteristic	Value	Units
Mean Median Grain Size (D50)	0.144	mm
Mean Particle Density	2,477	kg/m^3
Mean Bulk Density	1,369	kg/m^3
Standard Deviation*	1.25	phi

* Standard deviation determined based on matching particle distribution from model runs to measured vibracore distribution.

5.2 Model Results

The CMS-Flow model demonstrated the ability to reproduce observed water levels (i.e., comparison to the USGS gauges in Indian River Bay and Rehoboth Bay). Project specific sediment data along the Export Cable Corridor was used to characterize the sediments. The combination of an appropriate hydrodynamic model and a site-specific sediment characterization means that the results from the sediment transport model can be considered an appropriate prediction of sediment transport behavior resulting from jet plowing.

The sediment transport model predicts that coarse-grained suspended sediments will settle back to the seafloor in immediate proximity to the Export Cables while the fine-grained sediment will settle more slowly and spread further from the Export Cables. In the following discussion of model results, we present the results for the north cable route and the south cable route separately.

5.2.1 Predicted Suspended Sediment Concentrations from Jet Plow Embedment

The sediment transport modeling predicted suspended sediment concentrations for all planned cables. The north cable route moves northwest towards the Indian River Bay Inlet and then travels west approximately paralleling the Indian River Bay thalweg. This path also matches the path of the fastest currents on both flood and ebb tides. The highest suspended sediment concentrations occur along the cable route, but the sediment plume does spread north and south away from the cable route. This behavior is most apparent near the Inlet, but also evident in the vicinity of Pepper Creek and Vines Creek. The south cable route shows a lower concentration plume near the Inlet, but higher concentrations further south.

The sediment transport model results for the Export Cables predict that the suspension of in-situ seafloor sediments from the jet plow will not result in suspended sediment concentrations greater than 200 mg/L above ambient conditions beyond distances of approximately 1,120 m (3,675 ft) for the north cable and 1,340 m (4,396 ft) for the south cable, laterally away from the cables. Jet plow induced suspended sediment concentrations greater than 50 mg/L are not predicted to occur more than 1,210 m (3,970 ft) for the north cable and 1,660 m (5,446 ft) for the south cable from the cables. All suspended sediment concentrations greater than 50 mg/L above ambient conditions are predicted to dissipate in less than 12 hours after the passage of the jet plow. The model analysis predicts that increases in suspended sediment concentrations above 10 mg/L over ambient will also be of short duration, dissipating within 24 hours after the completion of jetting operations.

The shore of Indian River Bay limits the extent of the sediment plume. The lateral spread of the sediment plume is predicted to be largest in the eastern portion of Indian River Bay where the bay is widest. The longitudinal spread of the sediment plume is largest at the Inlet where ebb tides pull the sediment plume out into the Atlantic Ocean and near the Millsboro Pond Dam where flood tides push the sediment plume upstream beyond Burton Island. Both the lateral and longitudinal spread are similar for each cable routes. The east to west currents dominate the hydrodynamic behavior of Indian River Bay preventing the plume spreading northward into Rehoboth Bay. The maximum extents of the suspended sediment plume are shown in Figure 5-1. The timing of jet plowing with respect to tides may change the direction of the suspended sediment plume, but the total excursion from the cable is expected to be consistent with excursions shown in this report. Table 5-3 provides mean and maximum distances for a given suspended sediment concentration. These distances are reported for the north cable and south cable separately.

Table 5-3: Mean and Maximum Suspended Sediment Displacement from Cables

Suspended Sediment Concentration	Mean Distance		Maximum Distance	
mg/L	m	ft	m	ft
North Cable				
200	123	405	1,123	3,685
100	200	655	1,184	3,884
50	273	894	1,204	3,949
10	588	1,930	1,975	6,481
South Cable				
200	96	316	1,338	4,390
100	185	607	1,607	5,274
50	333	1,091	1,653	5,424
10	574	1,882	2,008	6,589

Appendix A is a series of figures that present the same information as Figure 5-1, but at a smaller scale to allow a more detailed investigation of the model results. The maximum predicted suspended sediment concentration occurs at different depths within the water column, at different locations in the model, and can occur at any point in time between the start of jet plowing and the return to ambient conditions following the end of jet plowing. This means that the plume of suspended sediment shown in Figure 5-1 and Appendix A is much larger than what would occur at any single time during cable installation.

Figure 5-2 provides a graph comparing displacement from the Offshore Export Cables and predicted suspended sediment concentration. This figure provides a concise summary of the spatially distributed data that is presented in Figure 5-1.

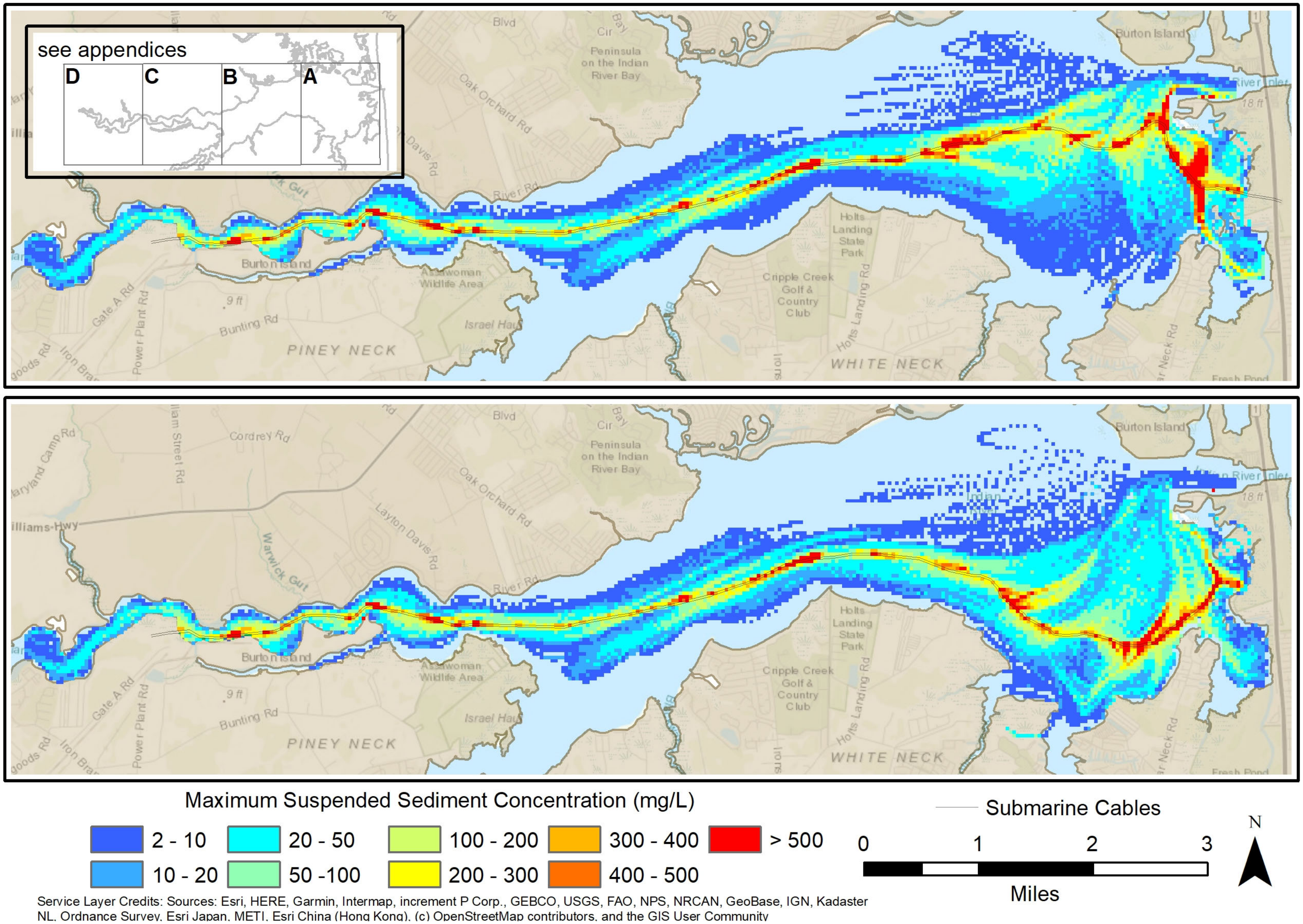

Figure 5-1: Modeled Predicted Maximum Suspended Sediment Concentrations

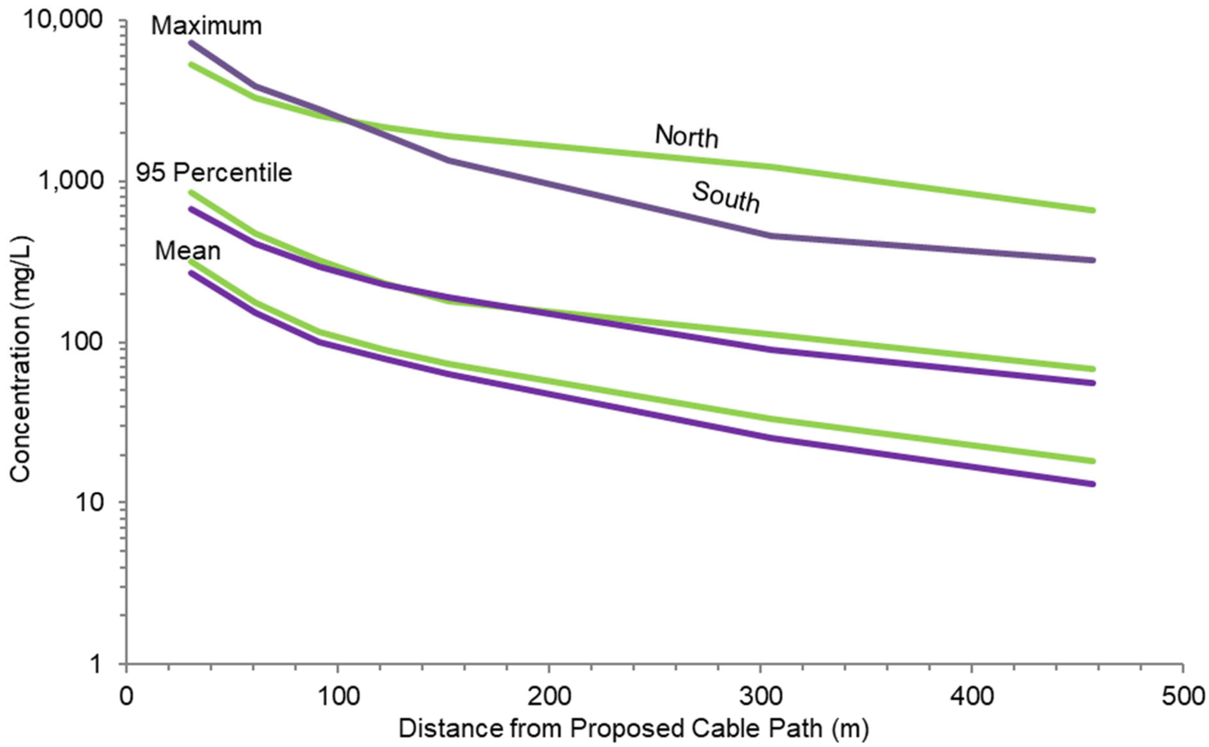

Figure 5-2: Predicted Suspended Sediment Concentration versus Distance from Cables

The suspended sediment results summarized in this section are the result of advective transport of sediments by ambient conditions (e.g., currents). This transport can be referred to as far-field effects. Near-field effects are the transport caused by the momentum-driven flow of water from the jet plow fluidization. This study does not take into account near-field effects, which occur within a range of less than 30 m (100 ft) of the jet plow operation. When interpreting the results of the sediment transport models, suspended sediment concentrations are typically highest at the point of the jet plow moving through the seafloor. This area is known to be an area of high turbulent mixing as a result of the swept flow of the jet plow that is designed to pull suspended sediment material into the jetted trench. Such rapidly changing suspended sediment concentrations are not reflected in the model. It is common practice to exclude near-field behavior from sediment transport models. The model assumes uniform distribution within the near-field region in both the horizontal and vertical directions. Consequently, the highest concentrations in the model may not necessarily occur at the height above the seafloor where sediment is disturbed by the jet plow. In cases where there is not adequate water depth above the seafloor to generate uniform sediment distribution, the maximum suspended sediment concentrations are assumed to occur near the water surface. This is a conservative assumption because suspended sediment that is higher in the water column will take longer to settle and have more time to be transported away from the cables.

The model results show that the majority of suspended sediments settle out relatively quickly. Finer-grained sediments (e.g., silts) remain suspended for longer periods of time and do make up approximately one third of the sediment released to the water column. In general, the model results indicate that suspended sediment concentrations attributable to the jet plowing will drop below 10 mg/L well within 24 hours after the end of jet plowing. The impact of the suspended sediment plume will be limited in both extent and duration.

5.2.2 Predicted Suspended Sediment Deposition from Jet Plow Embedment

The model results show that sediment deposition associated with jet plow embedment will be limited to a narrow corridor along the Export Cables. Figure 5-3: Modeled Predicted Maximum Suspended Sediment Concentrations and Appendix B show the total predicted deposition of sediment on the seafloor from jet plowing activity associated with cable installation. Both the maximum excursion and the average excursion from the Export Cables for different deposition thicknesses have been determined. The maximum excursion and mean excursion for various deposition thicknesses are shown in Table 5-4.

Table 5-4: Mean and Maximum Deposition Displacement from Cables

Deposition Thickness		Mean Distance		Maximum Distance	
mm	in	m	ft	m	ft
North Cable					
0.5	0.02	109	358	1,116	3,661
1.0	0.04	69	226	1,106	3,629
2.0	0.08	40	131	665	2,182
5.0	0.20	29	95	268	879
South Cable					
0.5	0.02	61	201	673	2,209
1.0	0.04	42	138	269	883
2.0	0.08	29	96	251	825
5.0	0.20	24	78	210	688

The sediment deposition pattern follows the cable routes. Most of the deposition is predicted to occur along the Export Cables. The model results predict that the average excursion from the Export Cables for deposition greater than 0.20 inches (5 mm) will be less than 30 m (98 ft) for the north cable and less than 25 m (82 ft) for the south cable. The model predicts that the mean excursion for deposition thicknesses of 0.04 inches (1 mm) will be less than 70 m (230 ft) for the north cable and less than 45 m (147 ft) for the south cable.

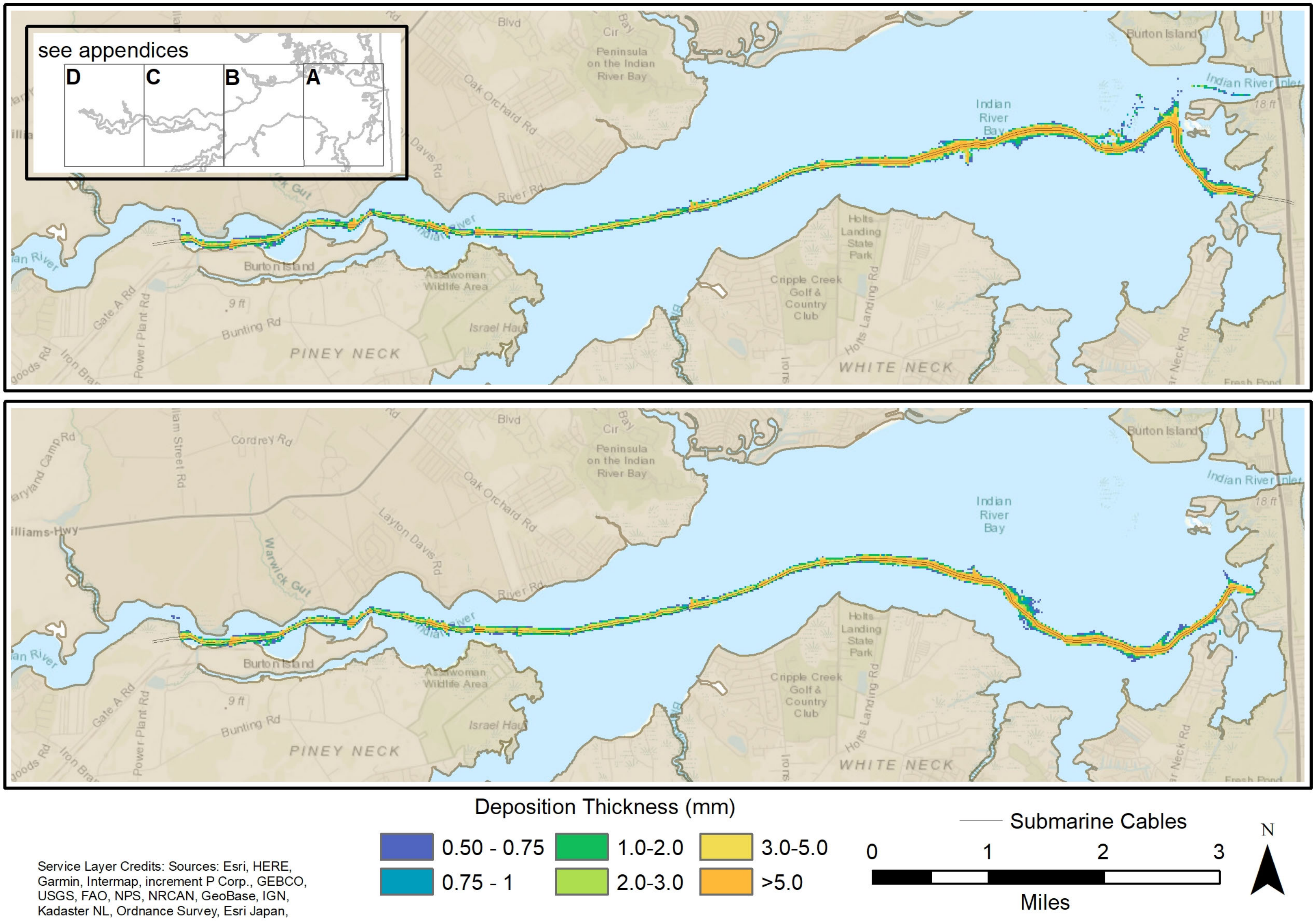

Figure 5-3: Modeled Predicted Maximum Suspended Sediment Concentrations

6.0 SEDIMENT TRANSPORT MODEL FINDINGS AND CONCLUSIONS

The sediment transport modeling predicts that the sediments suspended by the jet plowing will spread throughout much of Indian River Bay from the Inlet to the Millsboro Pond Dam. The sediment will not enter Rehoboth Bay. The model predicts that the north cable may lead to suspended sediment concentrations as high as 300 mg/L exiting Indian River Bay on ebb tides, but the suspended sediment concentrations exiting Indian River Bay as a result of jet plowing for the south cable will be limited 10 mg/L or less.

Most of the fluidized sediments lost to the water column are predicted to quickly settle back to the seafloor and deposition thicknesses greater than 0.2 inches (5 mm) will typically occur within 30 meters (95 ft) of the cables regardless of route. Suspended sediment concentrations are predicted to be less than 200 mg/L at distances greater than 1,400 m (4,600 ft) from the Export Cables. Model results indicate that the suspended sediment plume resulting from jet plowing will have a limited duration. All suspended sediment plumes greater than 10 mg/L are predicted to disappear within 24 hours after the completion of jetting operations. In conclusion, the sediment transport modeling results indicate that the proposed jet plow embedment process for cable installation will result in short-term and localized effects.

7.0 REFERENCES

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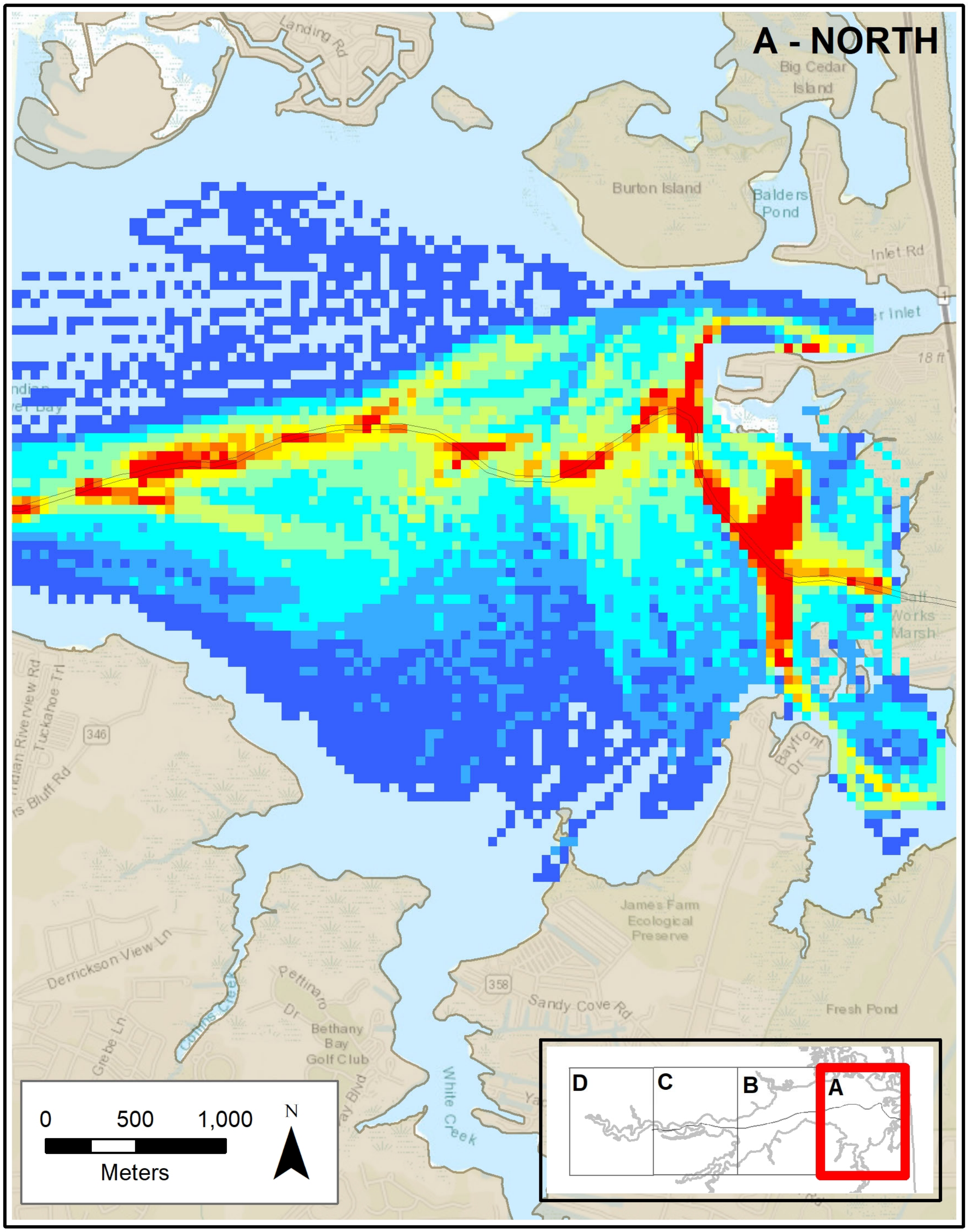
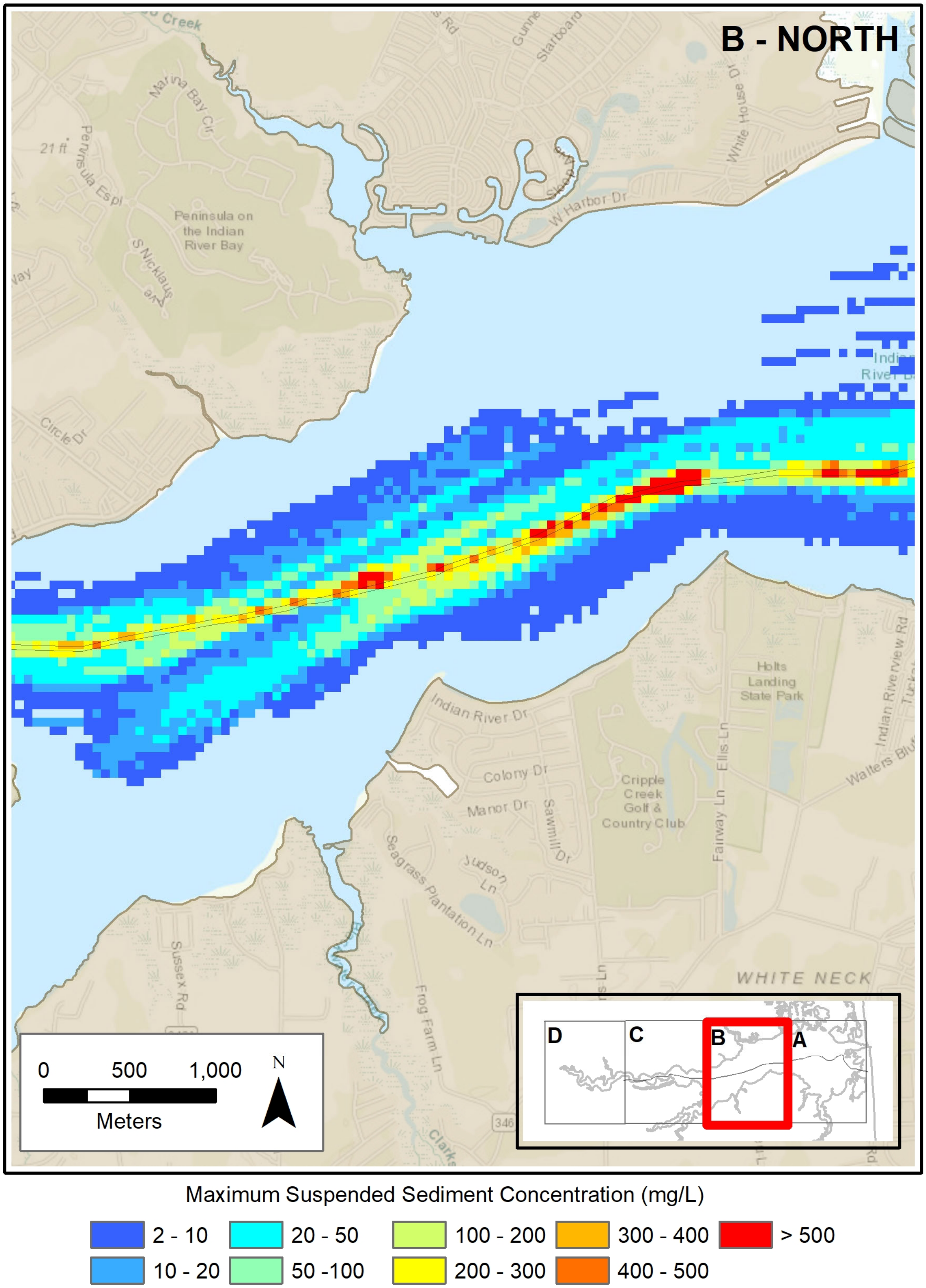
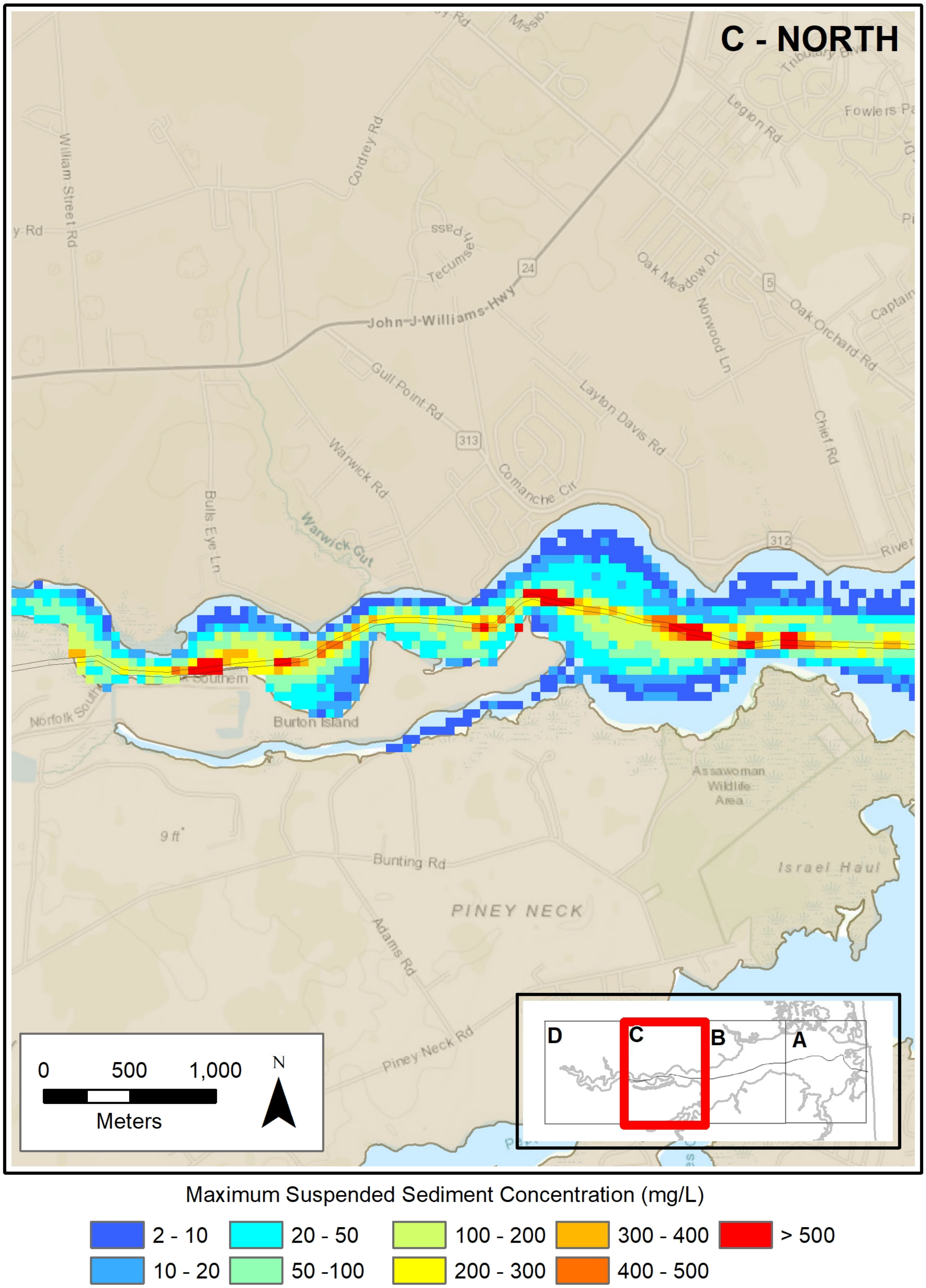
Appendix A: Maximum Suspended Sediment Concentration Figures

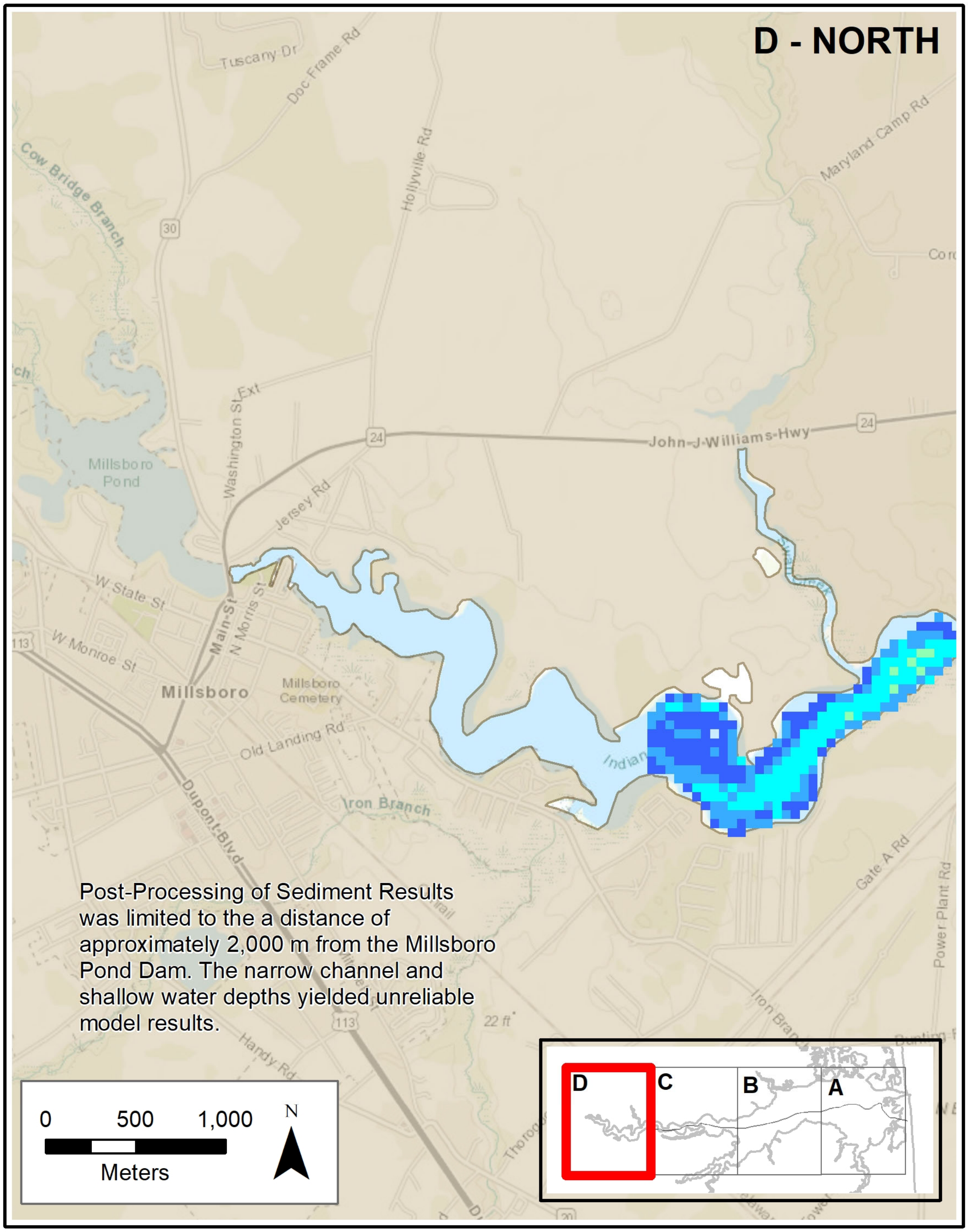


Maximum Suspended Sediment Concentration (mg/L)

2 - 10	20 - 50	100 - 200	300 - 400	> 500
10 - 20	50 -100	200 - 300	400 - 500	

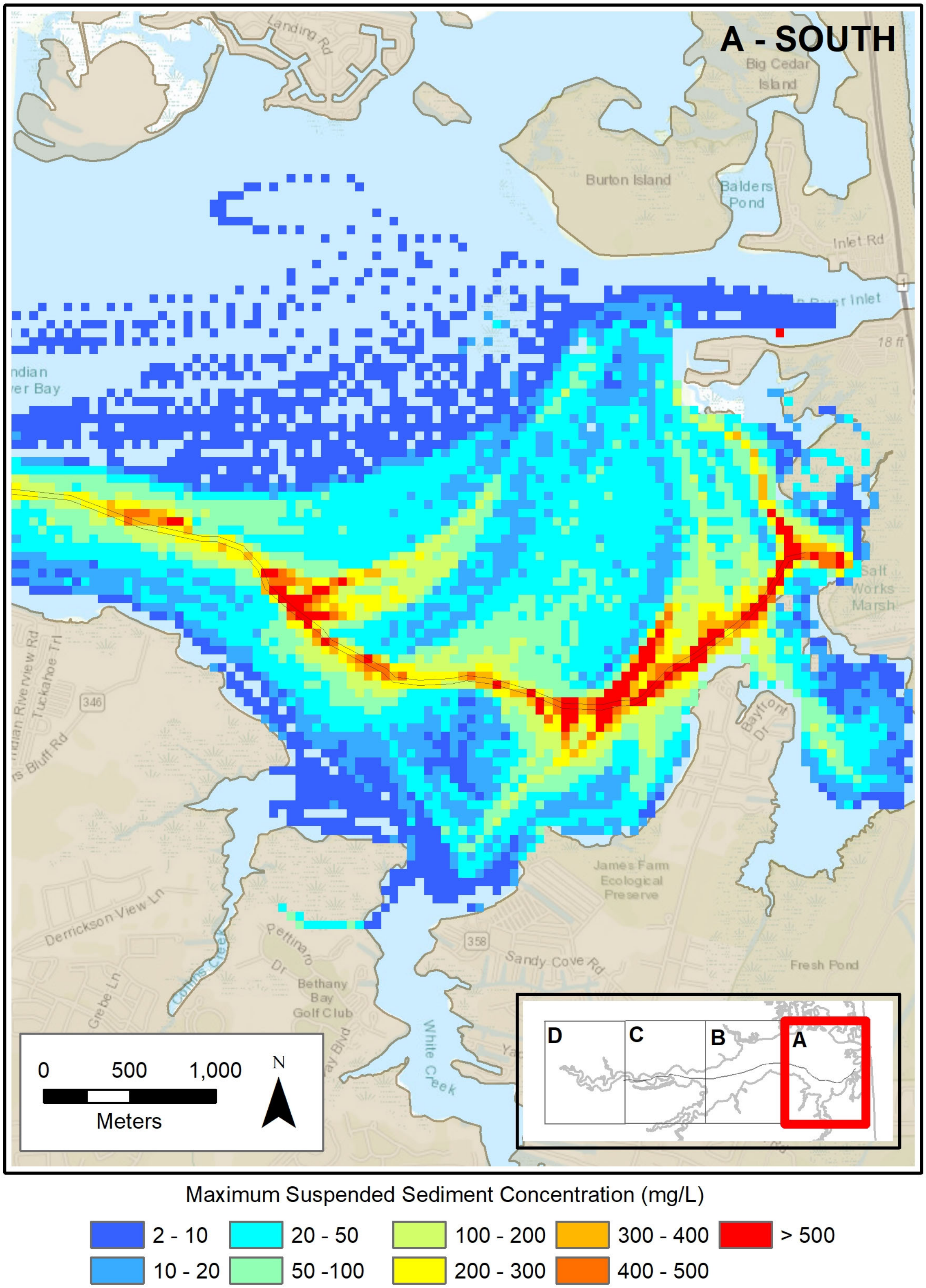

B - NORTH
0
500
1,000
Meters
N
D
C
B
A
Peninsula on the Indian River Bay
Holts Landing State Park
Cripple Creek Golf & Country Club
WHITE NECK
Indian River Dr
Colony Dr
Manor Dr
W Harbor Dr
Maximum Suspended Sediment Concentration (mg/L)
2 - 10
10 - 20
20 - 50
50 -100
100 - 200
200 - 300
300 - 400
400 - 500
> 500

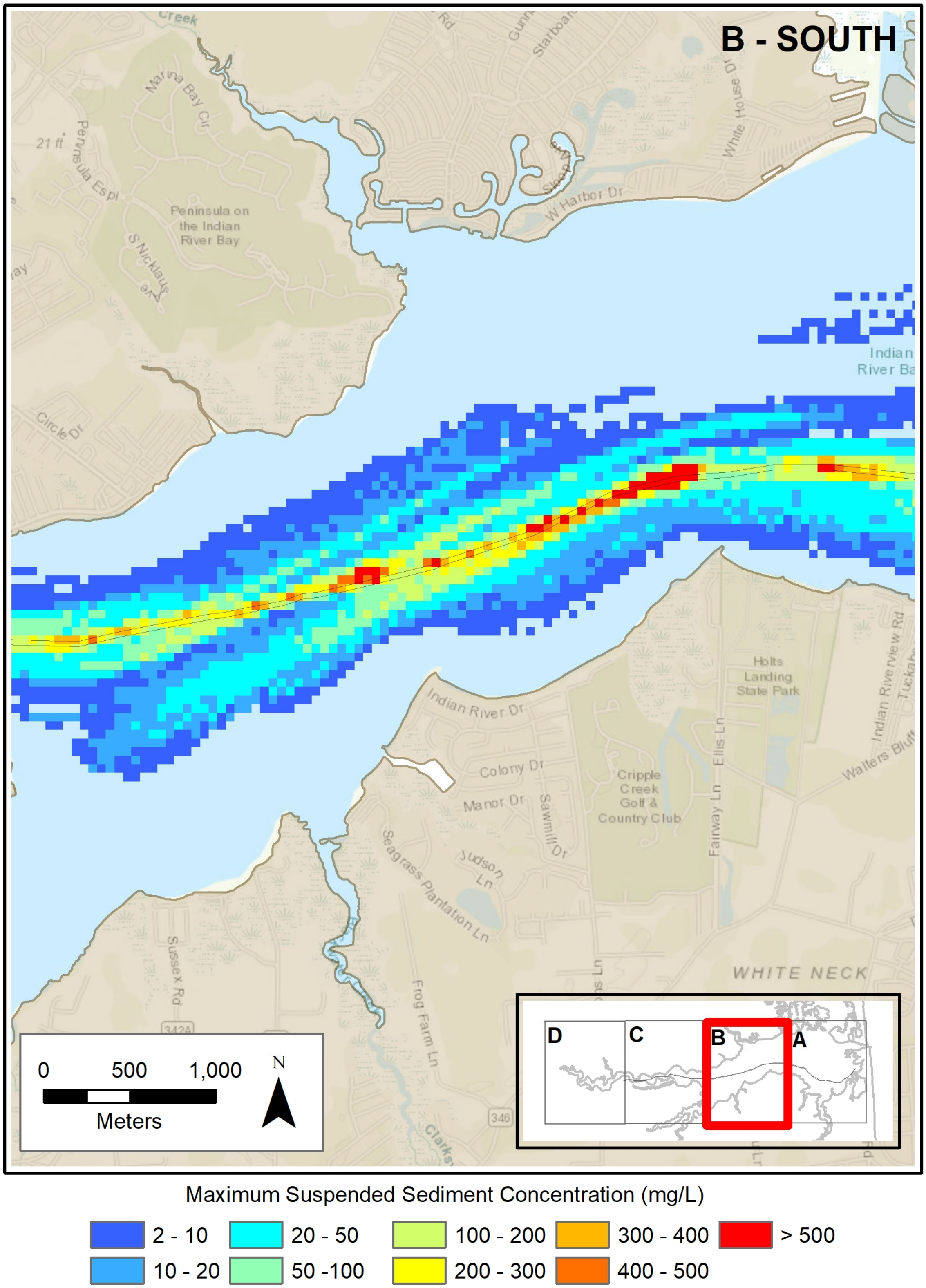

C - NORTH
0
500
1,000
Meters
N
D
C
B
A
Maximum Suspended Sediment Concentration (mg/L)
2 - 10
10 - 20
20 - 50
50 -100
100 - 200
200 - 300
300 - 400
400 - 500
> 500

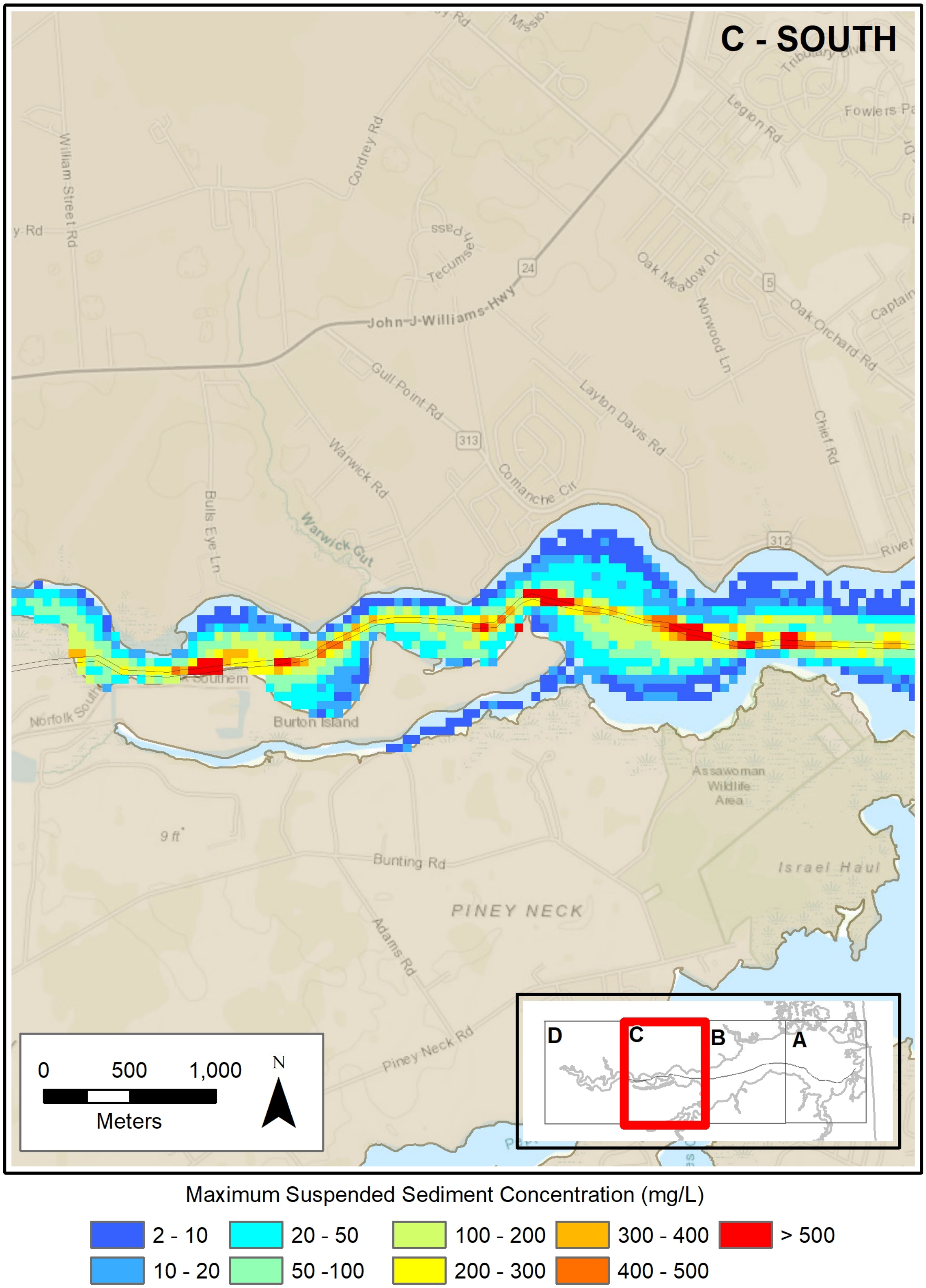


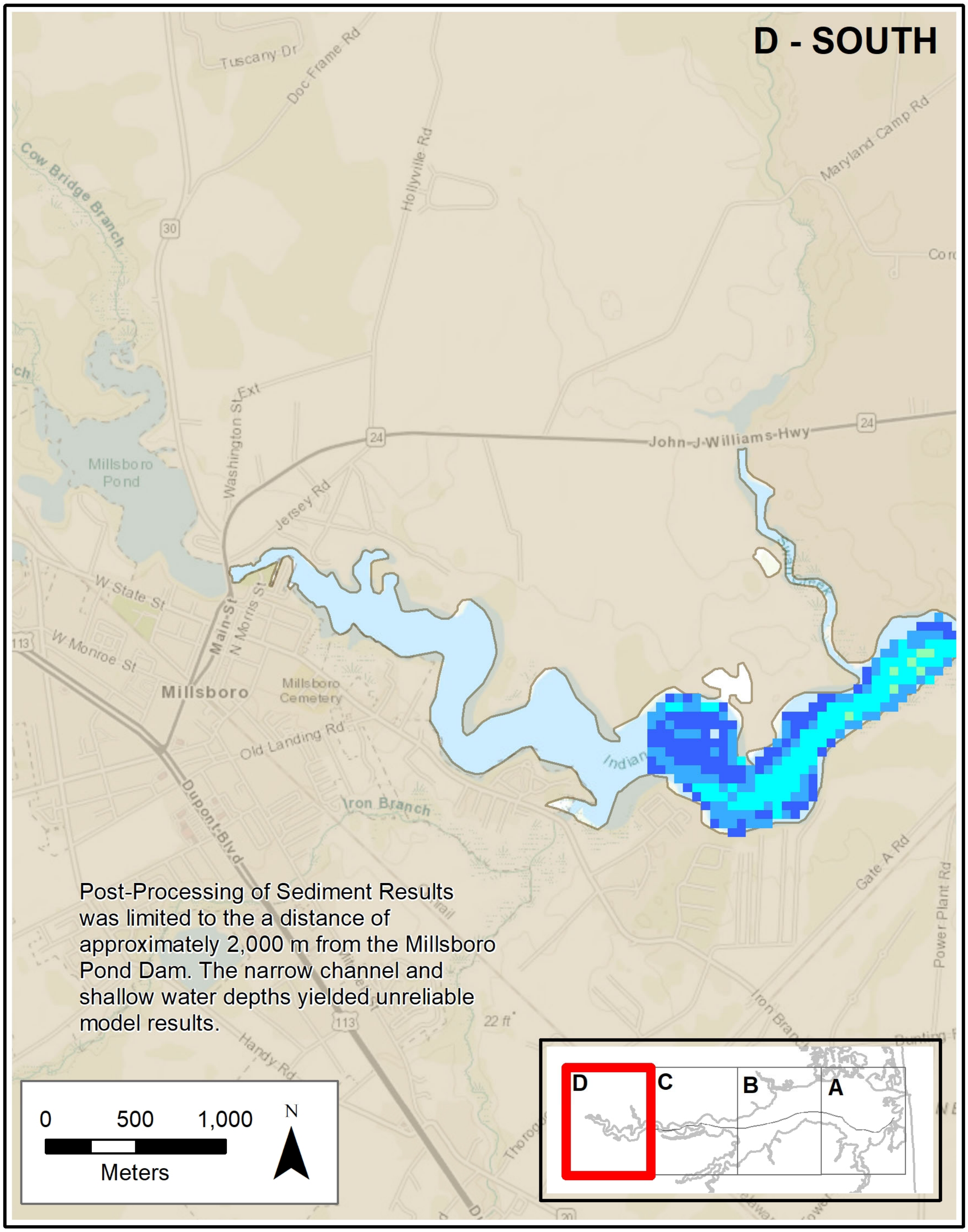
Maximum Suspended Sediment Concentration (mg/L)

2 - 10	20 - 50	100 - 200	300 - 400	> 500
10 - 20	50 -100	200 - 300	400 - 500	


A - SOUTH
Big Cedar Island
Burton Island
Balders Pond
Inlet Rd
Indian River Bay
Salt Works Marsh
James Farm Ecological Preserve
Sandy Cove Rd
Fresh Pond
White Creek
Bethany Bay Golf Club
Derrickson View Ln
0
500
1,000
Meters
N
D
C
B
A
Maximum Suspended Sediment Concentration (mg/L)
2 - 10
10 - 20
20 - 50
50 -100
100 - 200
200 - 300
300 - 400
400 - 500
> 500


B - SOUTH
Peninsula on the Indian River Bay
Indian River Bay
Holts Landing State Park
Cripple Creek Golf & Country Club
WHITE NECK
0
500
1,000
Meters
N
D
C
B
A
Maximum Suspended Sediment Concentration (mg/L)
2 - 10
10 - 20
20 - 50
50 -100
100 - 200
200 - 300
300 - 400
400 - 500
> 500

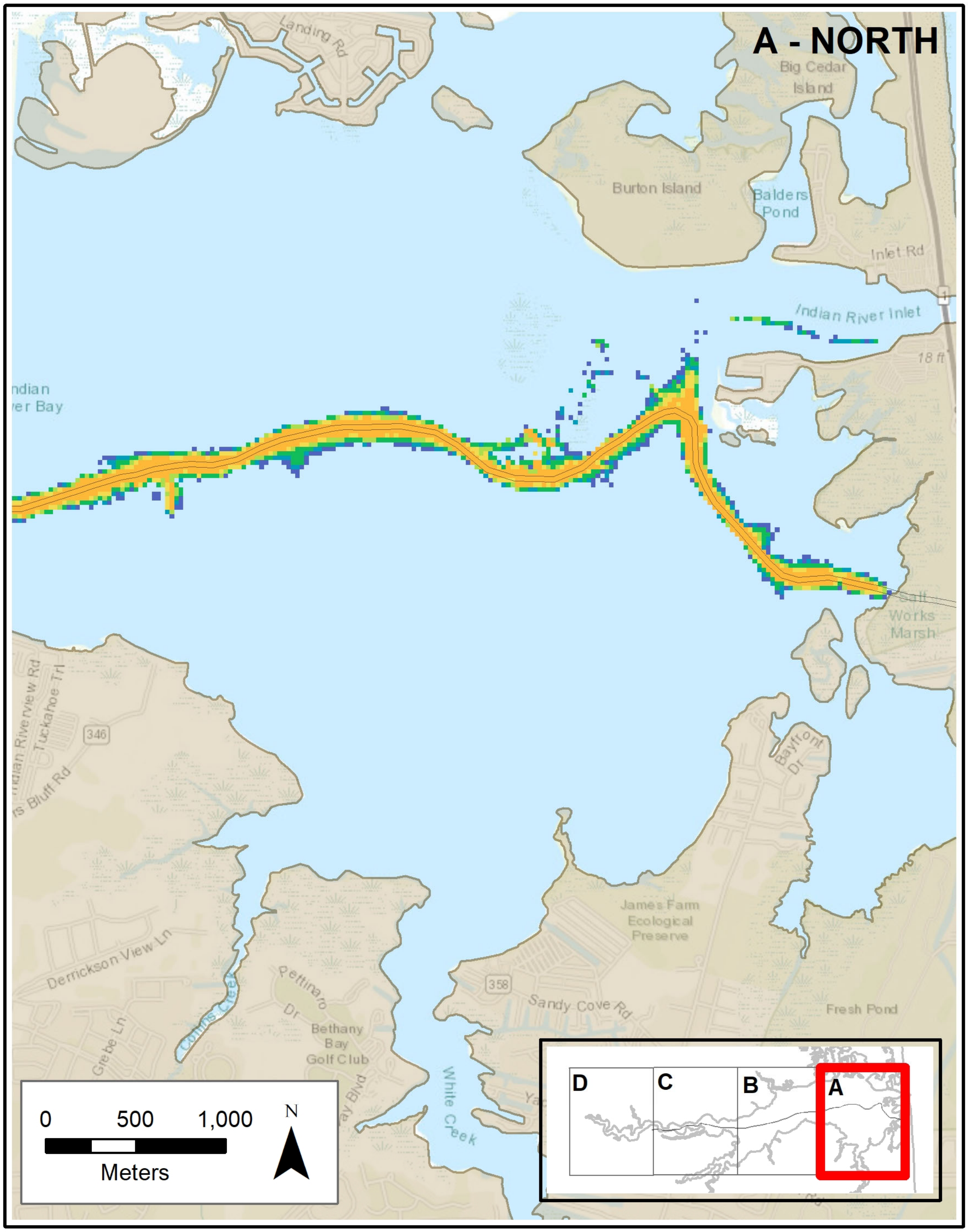

C - SOUTH
John-J-Williams-Hwy
Cordrey Rd
William Street Rd
Gull Point Rd
Warwick Rd
Warwick Gut
Bulls Eye Ln
Comanche Cir
Layton Davis Rd
Oak Meadow Dr
Norwood Ln
Oak Orchard Rd
Legion Rd
Chief Rd
Burton Island
Assawoman Wildlife Area
Israel Haul
PINEY NECK
Bunting Rd
Adams Rd
Piney Neck Rd
9 ft
0
500
1,000
Meters
N
D
C
B
A
Maximum Suspended Sediment Concentration (mg/L)
2 - 10
10 - 20
20 - 50
50 -100
100 - 200
200 - 300
300 - 400
400 - 500
> 500



Maximum Suspended Sediment Concentration (mg/L)

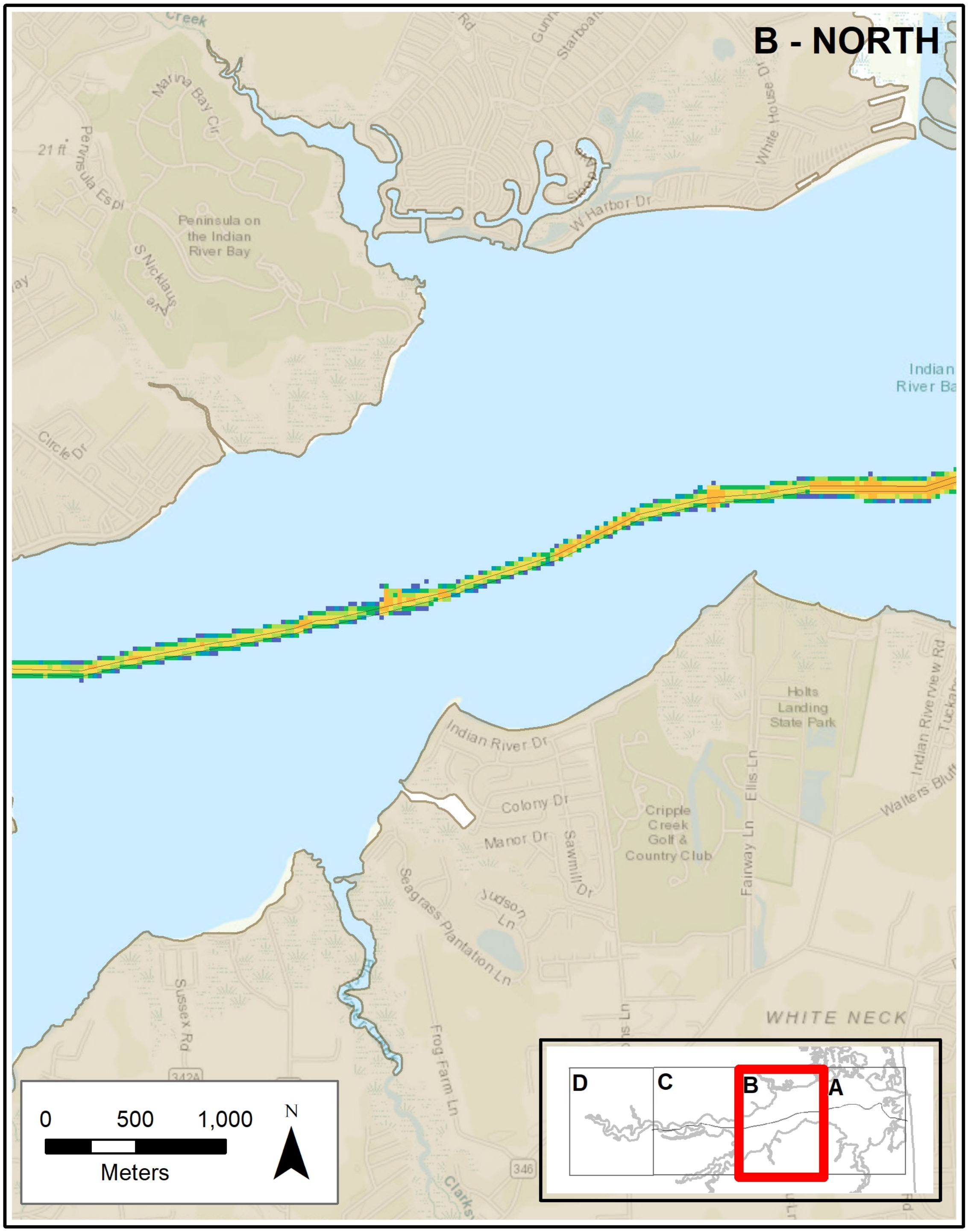
2 - 10 | 20 - 50 | 100 - 200 | 300 - 400 | > 500
10 - 20 | 50 -100 | 200 - 300 | 400 - 500

Appendix B: Total Deposition Thickness Figures



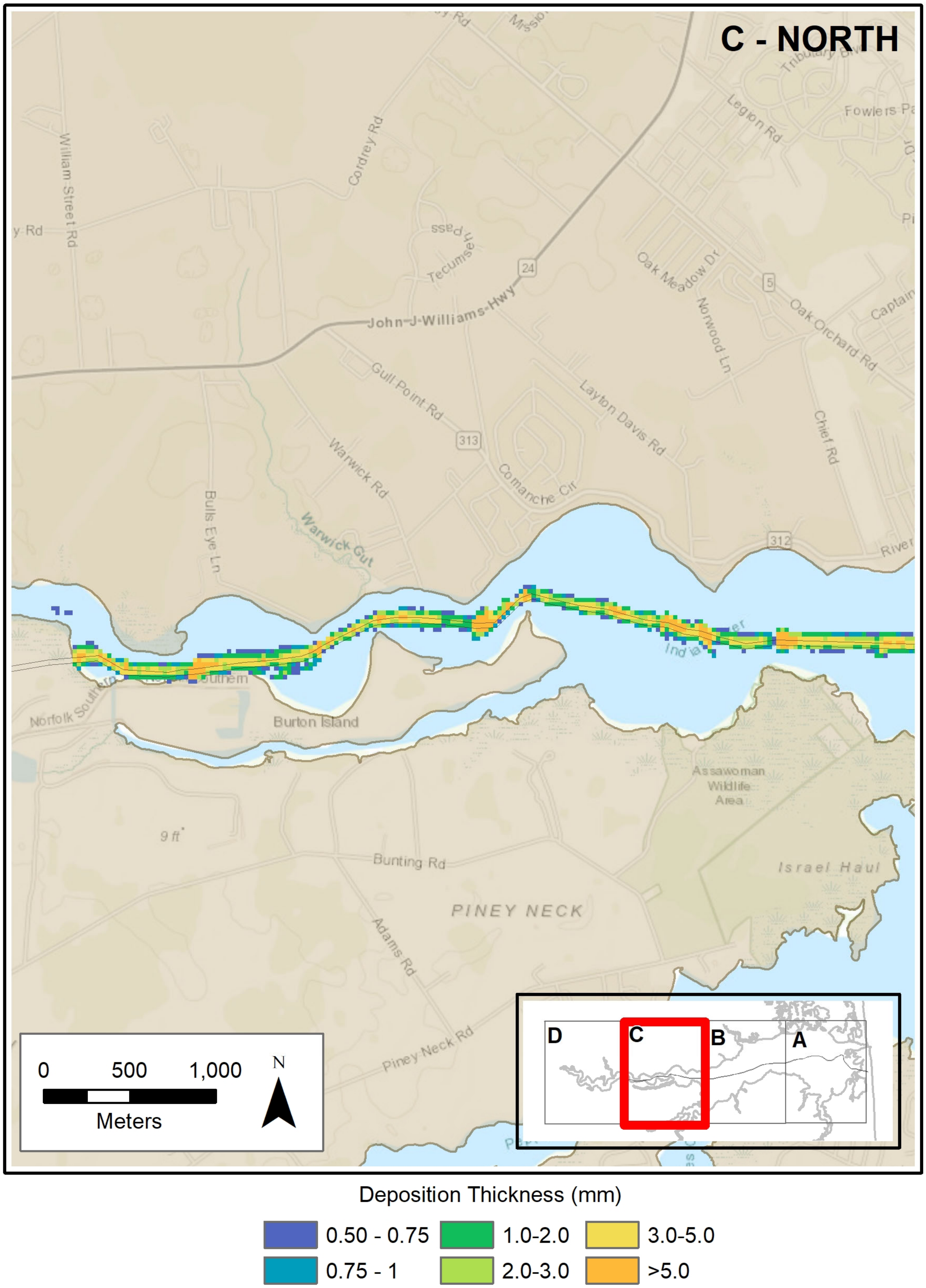
Deposition Thickness (mm)

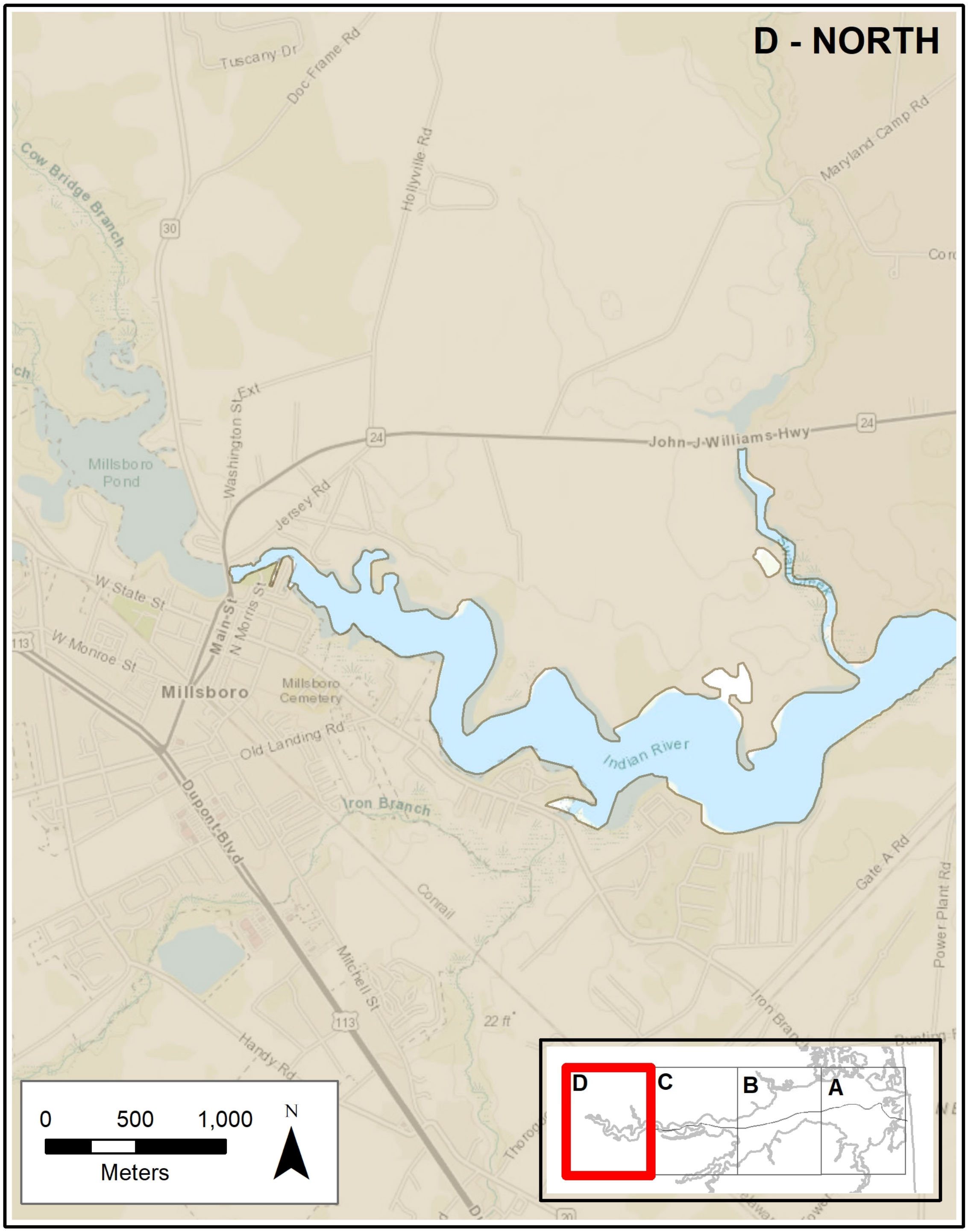
0.50 - 0.75	1.0-2.0	3.0-5.0
0.75 - 1	2.0-3.0	>5.0



Deposition Thickness (mm)

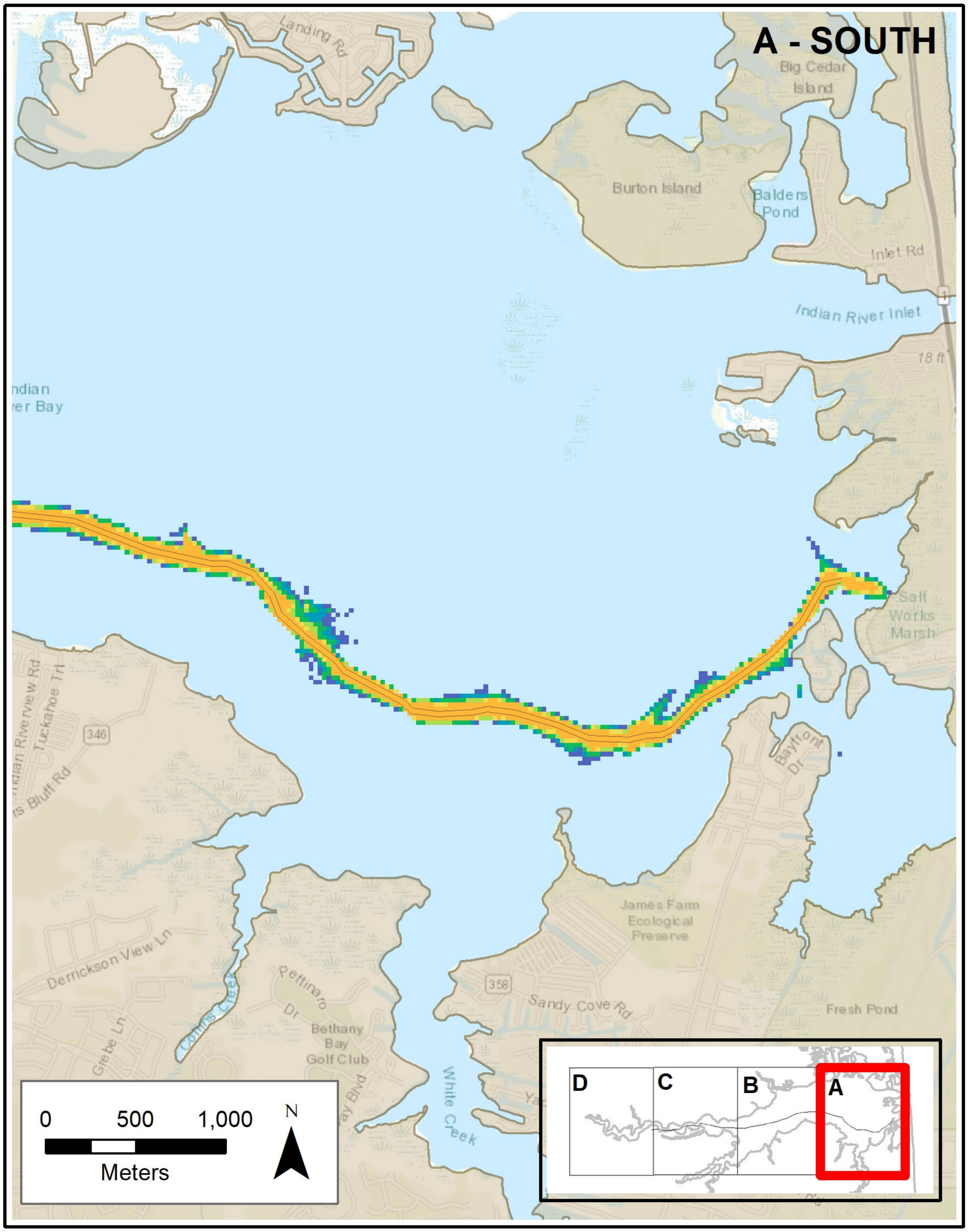
0.50 - 0.75	1.0-2.0	3.0-5.0
0.75 - 1	2.0-3.0	>5.0


C - NORTH
John-J-Williams-Hwy
Burton Island
PINEY NECK
Assawoman Wildlife Area
Israel Haul
Bunting Rd
Piney Neck Rd
0
500
1,000
Meters
N
D
C
B
A
Deposition Thickness (mm)
0.50 - 0.75
0.75 - 1
1.0-2.0
2.0-3.0
3.0-5.0
>5.0



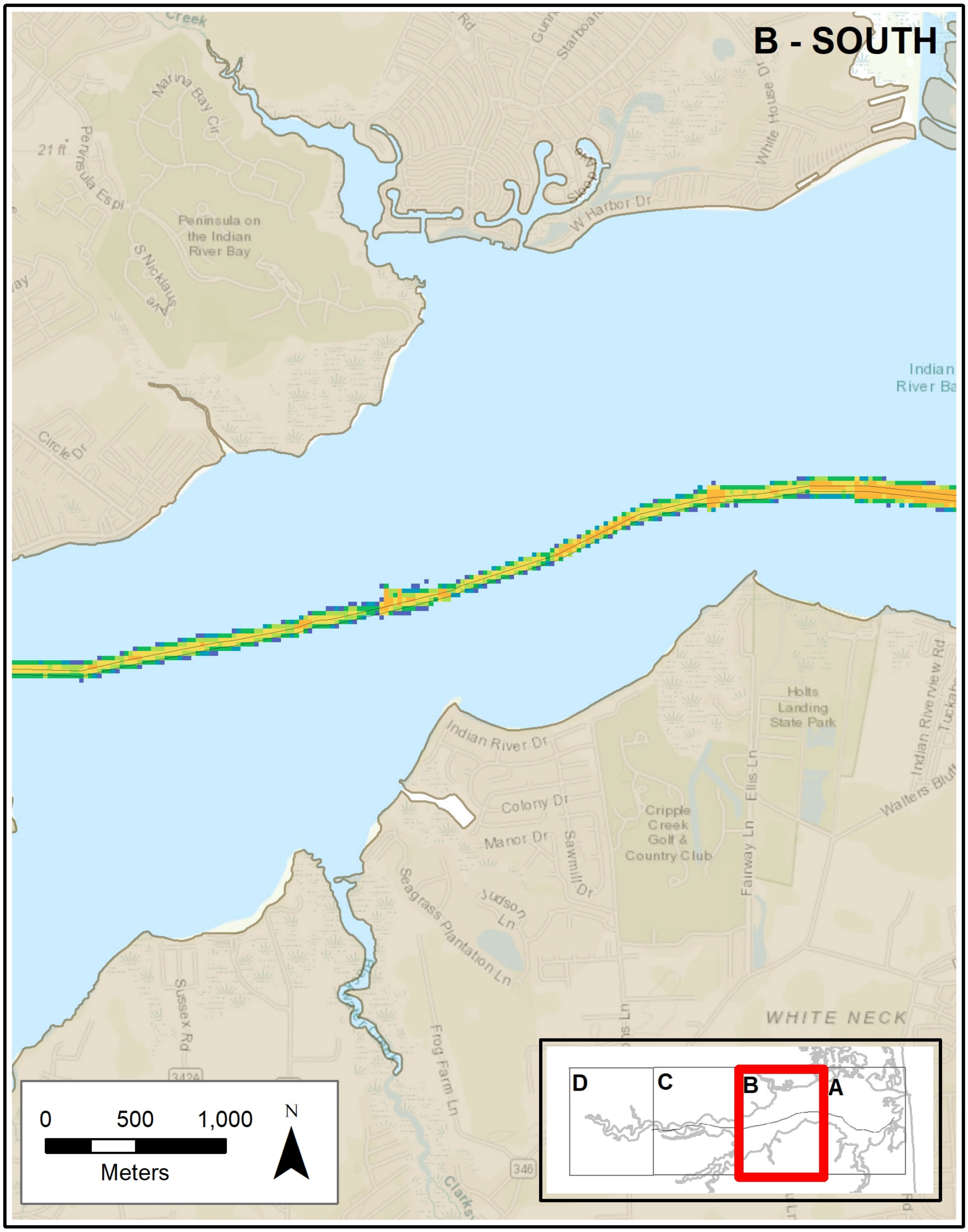
Deposition Thickness (mm)

0.50 - 0.75	1.0-2.0	3.0-5.0
0.75 - 1	2.0-3.0	>5.0



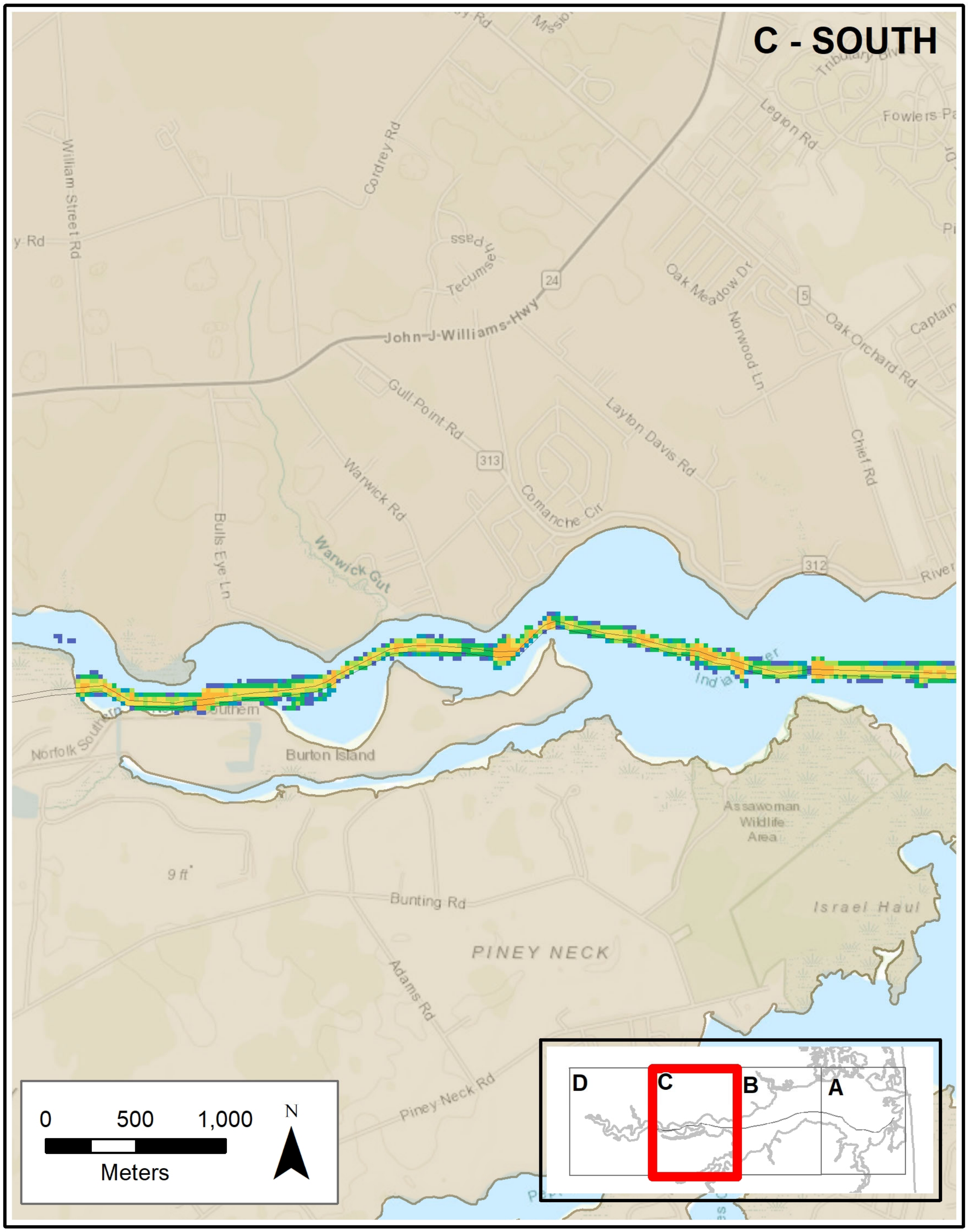
Deposition Thickness (mm)

0.50 - 0.75	1.0-2.0	3.0-5.0
0.75 - 1	2.0-3.0	>5.0



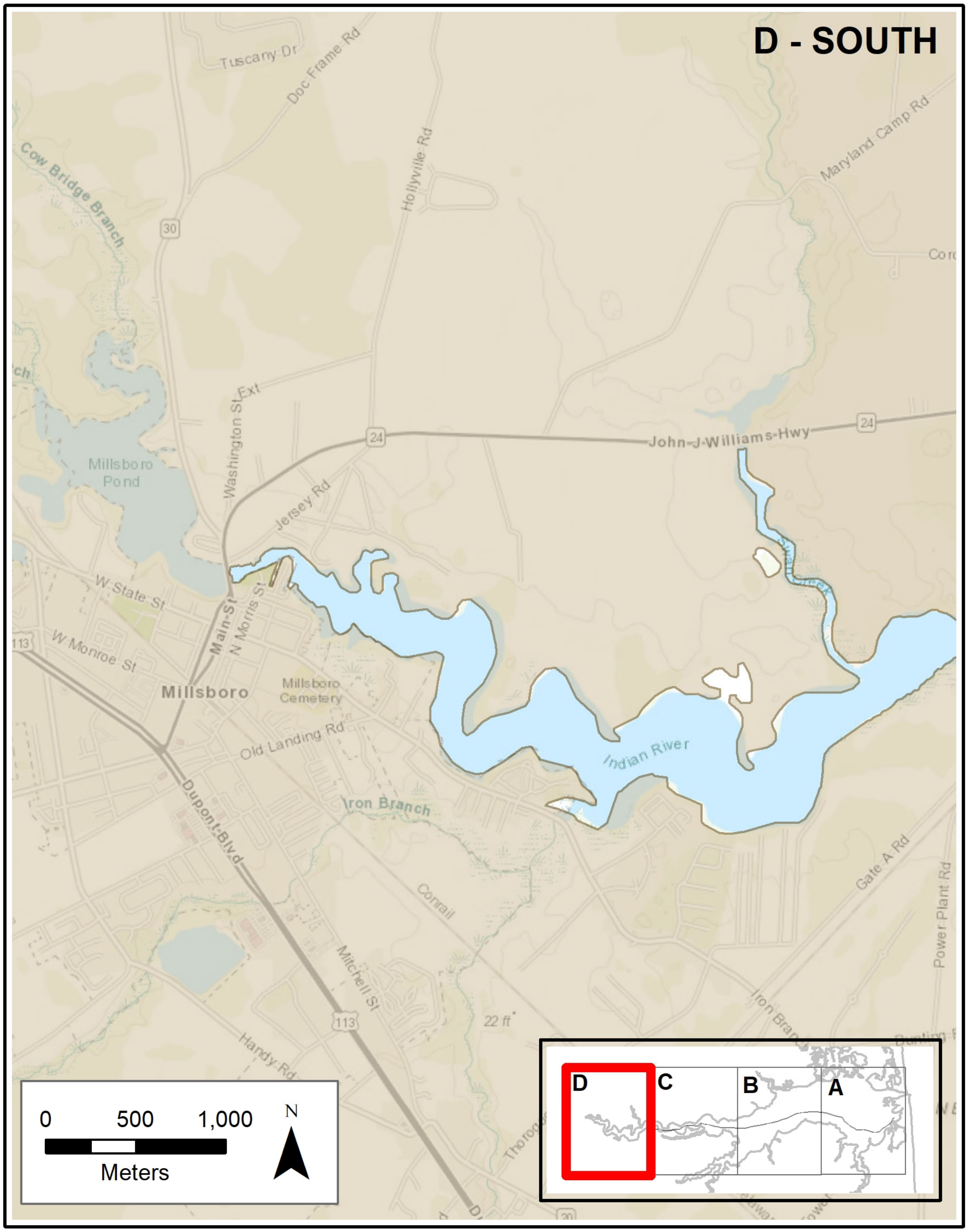
Deposition Thickness (mm)

0.50 - 0.75	1.0-2.0	3.0-5.0
0.75 - 1	2.0-3.0	>5.0



Deposition Thickness (mm)

0.50 - 0.75	1.0-2.0	3.0-5.0
0.75 - 1	2.0-3.0	>5.0



Deposition Thickness (mm)

0.50 - 0.75	1.0-2.0	3.0-5.0
0.75 - 1	2.0-3.0	>5.0