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TECHNICAL MEMORANDUM

To:	Kristen Sebasky & Matt Ladewig, ESS Group	Pages:	18
CC:			
Subject:	Indian River Bay Sediment Dispersion Analysis		
From:	Matt Hodge & Kelly Smith, Hodge.WaterResources, LLC		

1.0 EXECUTIVE SUMMARY

The purpose of this memorandum is to describe the likely water quality and benthic impacts resulting from the proposed jet plow installation of a submarine cable through Indian River Bay. The likely impacts include a temporary increase in suspended sediment concentrations and the deposition of sediments over parts of Indian River Bay. The duration of the suspended sediment plume is likely to last between 5 and 24 hours. Maximum sustained concentrations within the suspended sediment plume will be on the order of 7,270 milligrams per liter (mg/L). In the current analysis, we define “higher impacts” as suspended sediment concentrations in excess of 200 mg/L and/or deposition thicknesses greater than 1 millimeter (mm). We define “lower impacts” as suspended sediment concentrations in excess of 25 mg/L and/or deposition thicknesses greater than 0.5 mm. Higher impacts are likely to occur within a 108-meter (m) corridor around the proposed cable route, and lower impacts are likely to occur within a 600-m corridor around the proposed cable route. These values are estimates based on an analysis of available information and professional judgment. Sediment transport modeling was not conducted as a part of this investigation. These estimates are representative of likely conditions that will result from the jet plowing of a submarine cable within Indian River Bay, but the associated degree of uncertainty is large. The remainder of this memorandum provides:

- a summary of the proposed submarine cable project,
- a description of the bay watershed, bathymetry, and tidal conditions in Indian River Bay,
- a characterization of the river bed sediments along the proposed cable route,
- an estimate of the initial suspended sediment plume generated by jet plowing, and
- an analysis of the evolution of the suspended sediment plume in response to the processes of settling, transverse mixing, and advective transport.

2.0 PROJECT DESCRIPTION

US Wind is in the process of developing the Maryland Wind Energy Area (WEA). The proposed submarine cable will connect the WEA to a substation adjacent to the Indian River Bay Power Station in Delaware. The proposed cable route exits the WEA and continues west-northwest until it makes landfall approximately one mile south of the Indian River Inlet. The cable route will pass underground until it enters Indian River Bay. From that point, the proposed cable route passes through the approximate center of Indian River Bay. Figure 1 shows the proposed cable route. Only the portion of the cable route within Indian River Bay is discussed in this memorandum.

The cable will be laid in a trench that will be 0.6 m wide and 2.3 m deep. The cable will be laid with the use of a jet plow. Jet plow technology excavates a trench, lays cable, and backfills the trench simultaneously. The jet plow uses pressured water to fluidize sediments in the sea floor. The cable can then be easily passed through the sediments and laid at the appropriate burial depth. Most of the fluidized sediment remains in the trench. Gravity forces the fluidized sediments to settle on top of the cable, providing immediate backfilling over the cable. The fluidized sediment that does not return to the trench may be transported away from the cable route by ambient conditions.

3.0 AMBIENT CONDITIONS

In Indian River Bay, the transport of suspended sediment away from the proposed cable route will be controlled by tides and freshwater flow from the watershed. Local bathymetry will also play a significant role in determining where suspended sediments will be deposited back onto the bed of the bay.

Indian River Bay is a tidal estuary. 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 provide separation between 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 m. 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. Indian River Bay and Rehoboth Bay are both saltwater waterbodies.

3.1 Watershed and Freshwater Flow

Figure 1 shows the watershed to the Indian River Bay (USGS, 2019). The United States Army Corps of Engineers (USACE) completed a hydrodynamic and eutrophication modeling study of Indian River and Rehoboth Bay (Cerco et al., 1994). As a part of that study, USACE identified 12 sub-basins that drain to the Indian River Bay. The approximate locations where the 12 sub-basins join the bays are shown on Figure 2. The USACE report estimated flows from the 12 sub-basins using the United States Geological Survey (USGS) stream gage on Stockley Branch (Station ID: 01484500) as a reference station. Sub-basin flows were scaled from the reference station flow based on relative contributing watershed area.

Stockley Branch no longer has an active gage, but the Millsboro Pond Outlet (Station ID: 01484525) is an actively-monitored USGS gage. For this analysis, we used the USGS Millsboro Pond Outlet gage as a reference station for scaling flows. It should be noted that the outlet to Millsboro Pond is a spillway that was documented in the USACE report as having a smoothing effect on flows from Stockley Branch (Cerco et al., 1994). However, that smoothing effect does not need to be accounted for in this analysis because we are evaluating long-term average conditions rather than a hydrologic time series.

Figure 3 shows average daily flows at Millsboro Pond for each month over the entire period of record (1986 to 2018) and the corresponding scaled average daily flows for the Indian River Bay Watershed, excluding flows to Rehoboth Bay. The rationale behind excluding flow into Rehoboth Bay is discussed in Section 3.3.

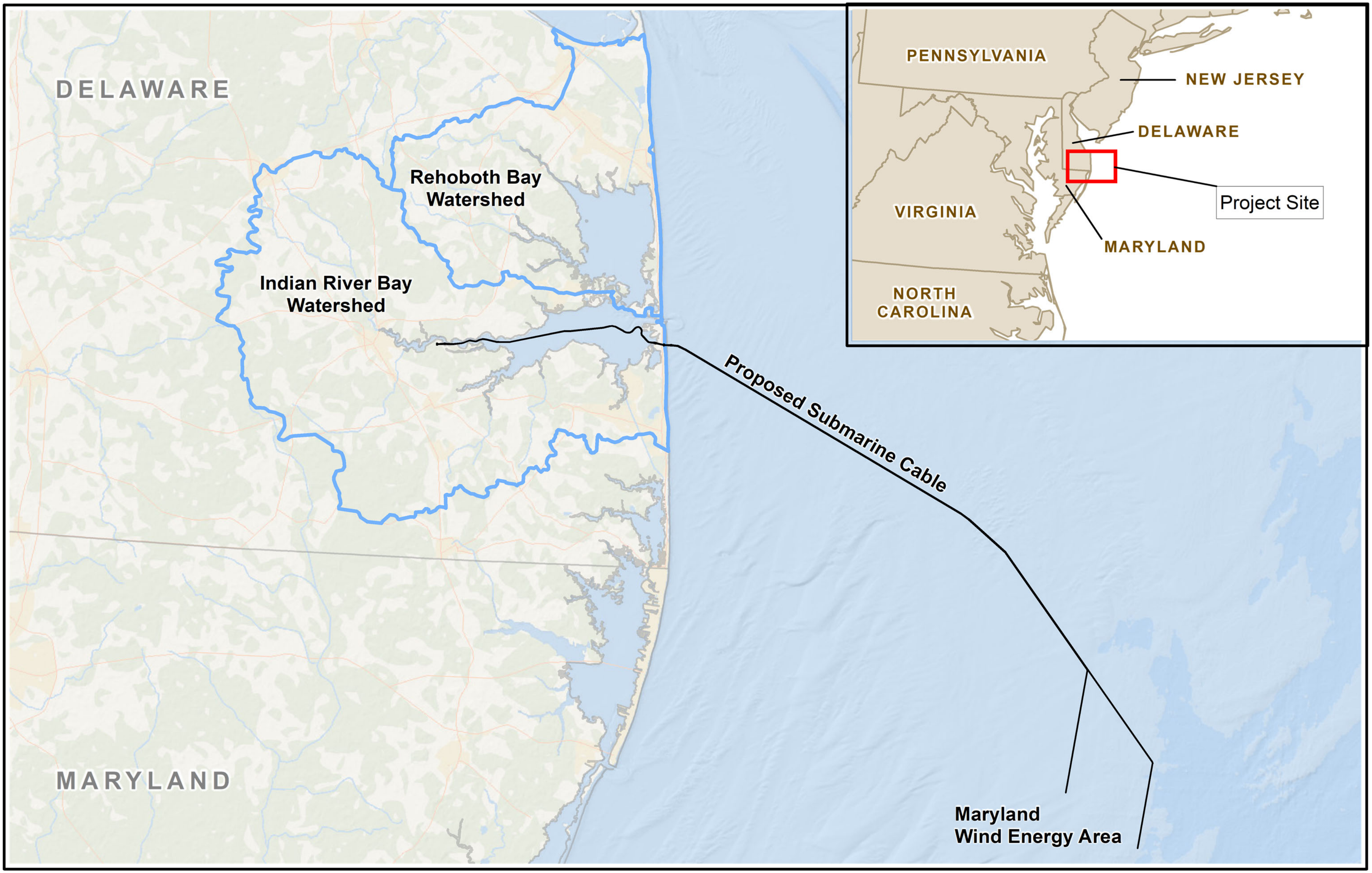

Figure 1: Submarine Cable Overview

Indian River Bay, Delaware

March 13, 2019

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Miles

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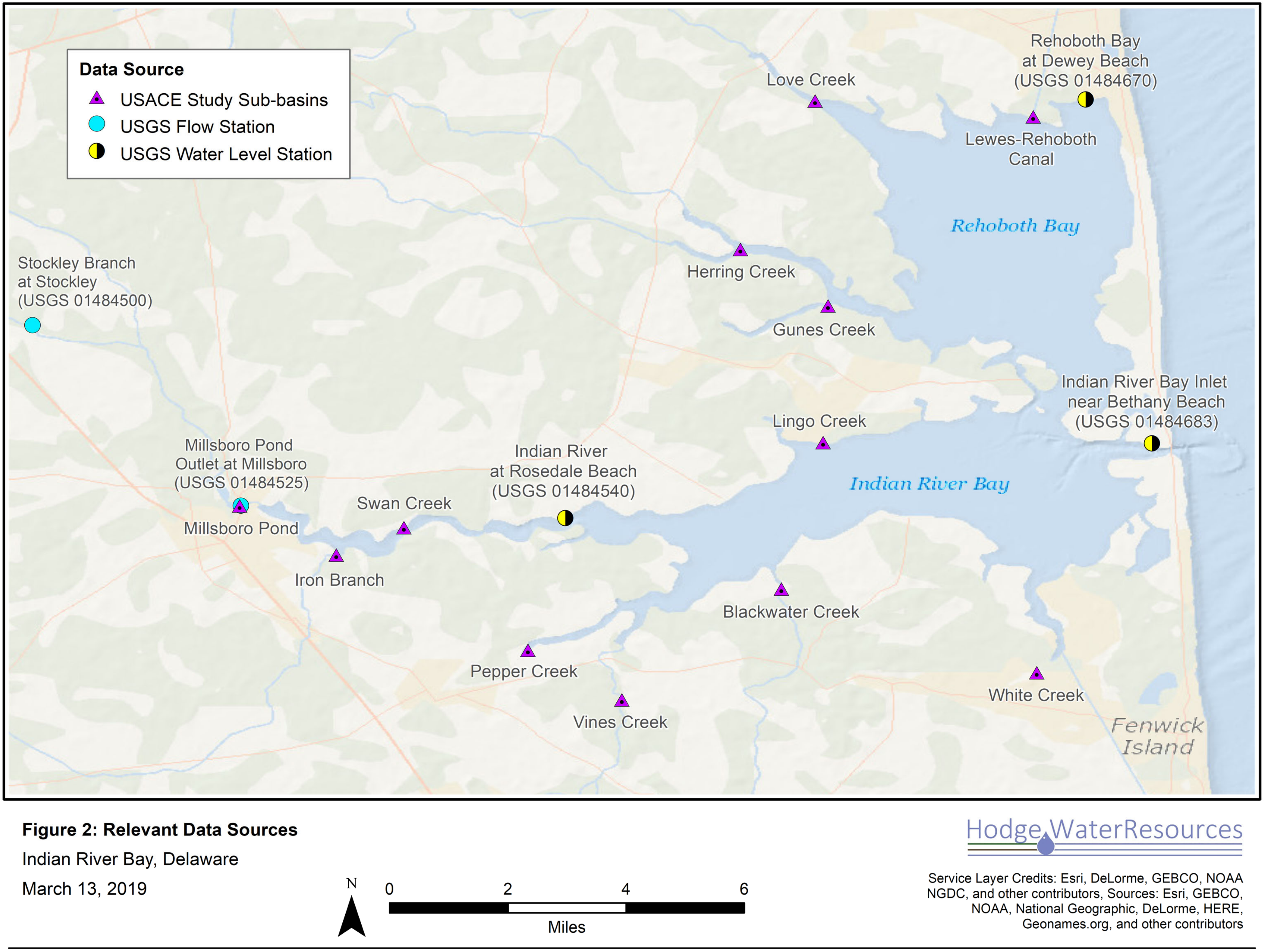

Figure 2: Relevant Data Sources

Indian River Bay, Delaware

March 13, 2019

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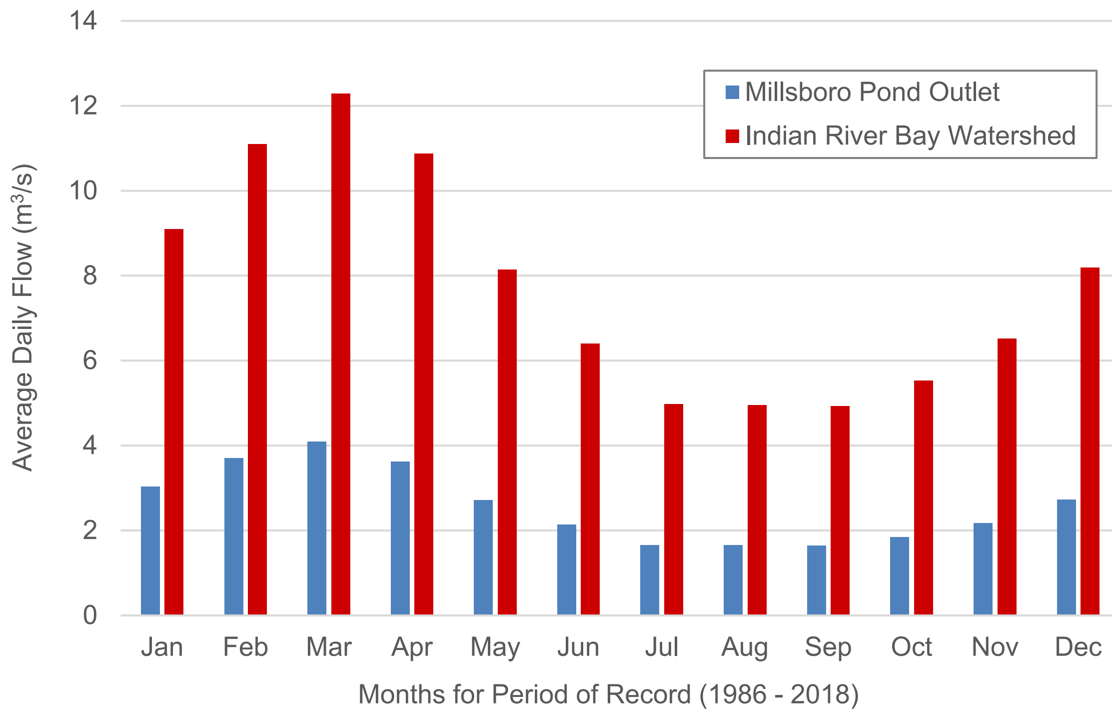

Figure 3: Average Daily Freshwater Flow to Millsboro Pond Outlet (Measured) and Indian River Bay Watershed (Scaled Estimate)

3.2 Tidal Behavior

Indian River Bay is a tidally-influenced water body. The USGS maintains three active water level monitoring stations in Indian River Bay and Rehoboth Bay. The stations are Indian River Inlet near Bethany Beach (Station ID: 01484683), Indian River at Rosedale Beach (Station ID: 01484540), and Rehoboth Bay at Dewey Beach (Station ID: 01484670). The location of each station is shown in Figure 2. Table 1 shows the mean high water (MHW), the mean tide level (MTL), and the mean low water (MLW) for each station. Figure 4 shows a timeseries of the three gages during a one-week period in September 2018. Indian River Inlet has the largest tidal range, but the highest water levels occur upstream at the monitoring station at Rosedale Beach. The influence of freshwater flow serves to maintain higher water levels away from the inlet. The tidal range at Rosedale Beach is 0.07 m smaller than at Indian River Inlet. There is also a noticeable phase shift in the tidal signal at Rosedale Beach when compared to the inlet. High tide occurs at the inlet approximately 40 minutes before high tide at Rosedale Beach.

The same phase shift occurs in Rehoboth Bay as well. High tide at the Rehoboth Bay station occurs more than an hour after high tide at the inlet. The tidal range in Rehoboth Bay is 0.42 m, which is 0.38 m smaller than at the inlet. This information indicates that the narrow channel that connects Rehoboth Bay to Indian River Bay limits the exchange of water between the two bays. The tidal range is important because both bays are relatively shallow. Some regions of each bay are in the intertidal zone, where mudflats and salt marshes routinely cycle between wet and dry conditions.

Table 1: USGS Water Level Stations

Station Name	Station ID	Tidal Datum Elevation (m NAVD88)			Tidal Range (m)
		MHW	MTL	MLW	
Indian River Inlet at Bethany Beach	01484683	0.45	0.05	-0.35	0.80
Indian River at Rosedale Beach	01484540	0.51	0.15	-0.21	0.73
Rehoboth Bay at Dewey Beach	01484670	0.25	0.04	-0.17	0.42

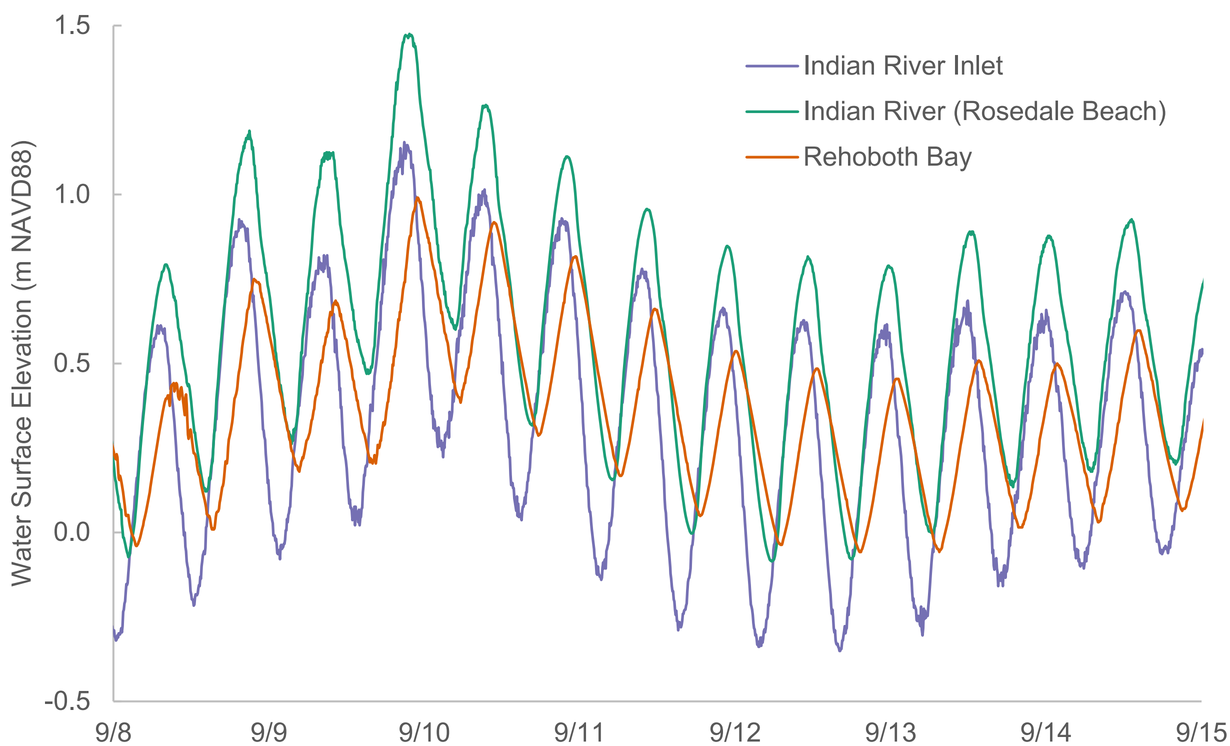

Figure 4: Water Surface Elevations at USGS Tide Monitoring Stations, September 2018

3.3 Bathymetry

Figure 5 shows the bathymetry of Indian River Bay and Rehoboth Bay. The bathymetry elevations shown in Figure 5 are based on updated LiDAR and bathymetric surveys conducted by the USGS in response to Hurricane Sandy. Figure 5 shows the intertidal zone (the area between MHW and MLW based on the metrics for the inlet) in an orange color. The intertidal zone in the bays is primarily limited to the various creeks and rivers that drain to the bays. Suspended sediment in the water column may be preferentially deposited in these intertidal zones during low tides.

The intertidal zone is larger in Rehoboth Bay than it is in Indian River Bay. The proposed submarine cable route passes through the middle of Indian River Bay. The cable is closest to intertidal areas where it makes landfall, just south of the inlet.

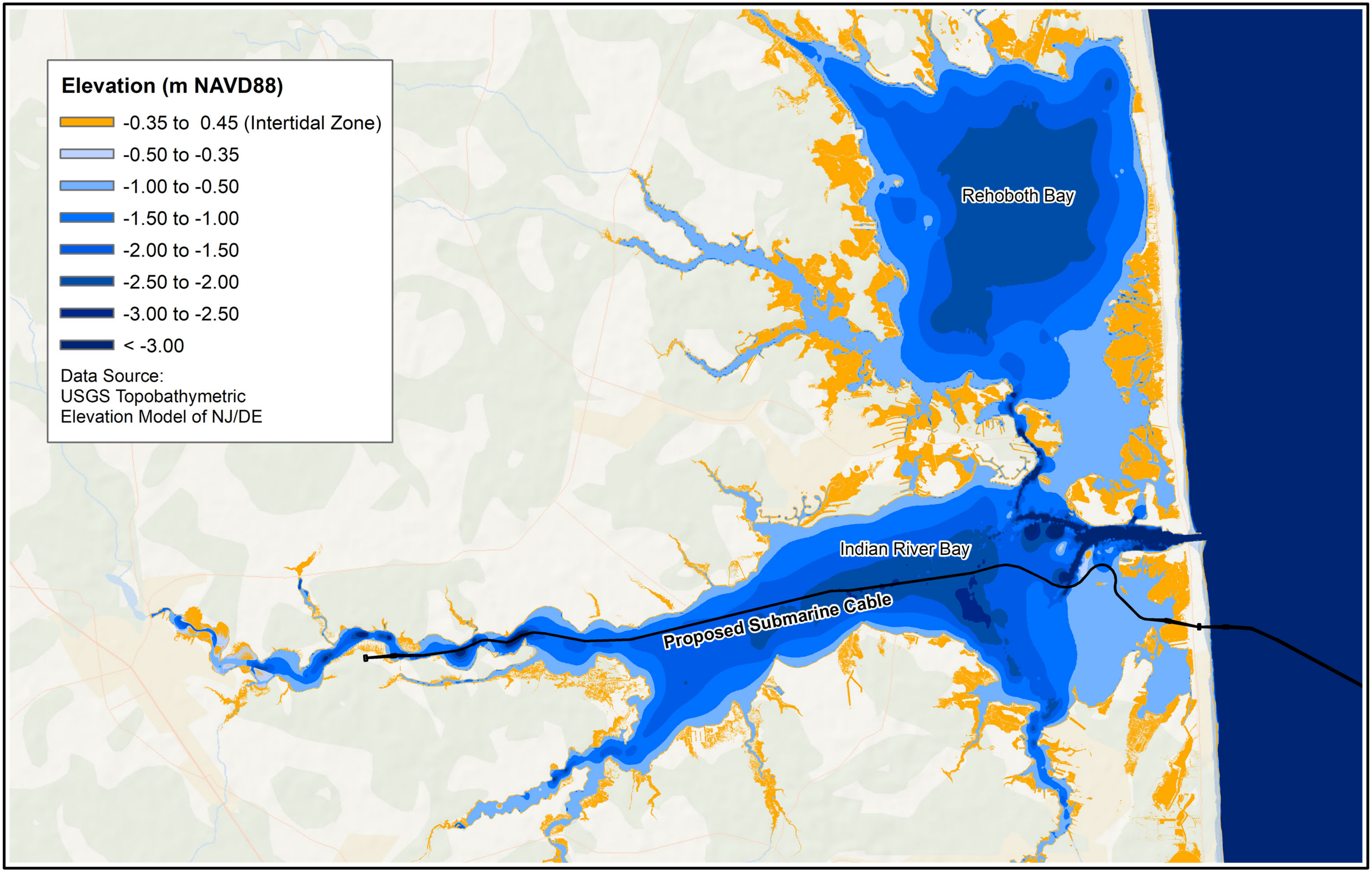

Figure 5: Indian River Bay and Rehoboth Bay Bathymetry

Indian River Bay, Delaware

March 13, 2019

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Miles

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3.4 Flushing Time

Flushing is an important concept in evaluating water quality (e.g., suspended sediment concentrations) in tidal estuaries. Flushing (or flushing time) is a measure of the mean time that a particle resides in an estuary as a result of freshwater flow entering the estuary from the watershed (Fischer et al., 1979). Equation 1 shows the calculation of flushing time as a function of flow rate and distance from the mouth of the estuary.

Equation 1: Flushing Time (Fischer et al., 1979)

$$T_f = \frac{V(x)}{Q_f}$$

Where:

T_f	=	flushing time
Q_f	=	freshwater flow to estuary
$V(x)$	=	volume of the estuary at a given distance (x) from the mouth of the estuary (calculated based on bathymetry) and assuming mean tide level

Jet plowing is scheduled to occur beginning in September 2020. Average freshwater flow for the Indian River Bay watershed in September is 4.9 cubic meters per second (m^3/s). Using this freshwater flow in conjunction with the bathymetry shown in Figure 5 allows for the prediction of flushing time based on position along the proposed cable route and distance from the inlet. Figure 6 shows a graph of the flushing time. The information shown in Figure 6 is a useful tool that can be combined with estimated plume duration to understand whether sediment suspended by the jet plow will exit the bay through the inlet.

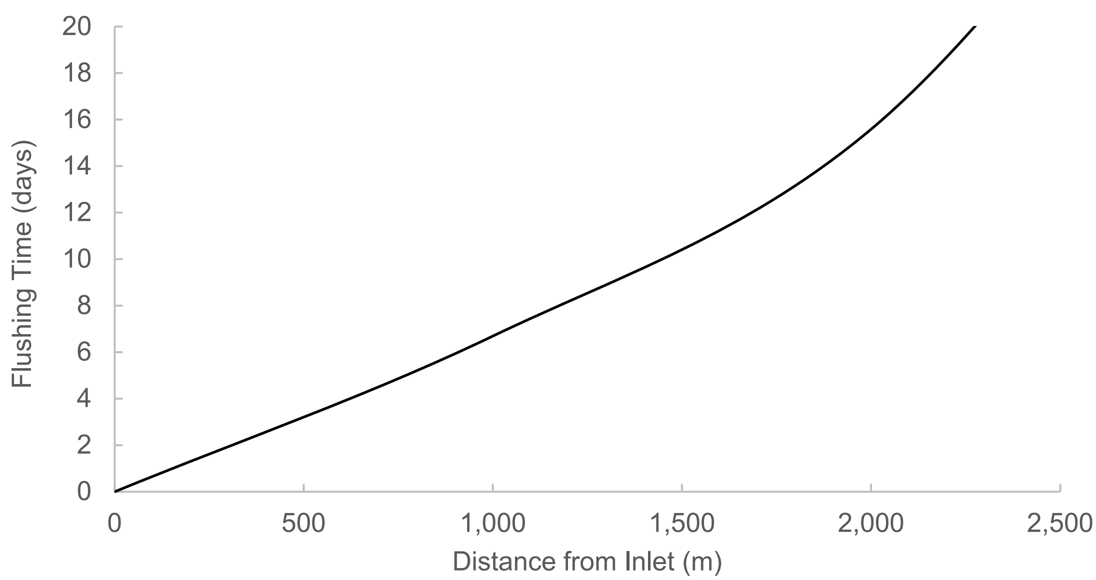

Figure 6: Flushing Time as a Function of Distance from the Indian River Inlet

4.0 CHARACTERIZATION OF SEDIMENTS

Indian River Bay is predominantly a low-energy environment where low current velocities lead to the deposition of fine-grained sediments (i.e., fine sand, silts, and clay particles). Hydrodynamic modeling of Rehoboth Bay conducted on behalf of the Delaware Department of Natural Resources and Environmental Control (DNREC) identified two locations that are not low-energy environments (DNREC, 2007). The Indian River Inlet is a very high-energy environment that is consistently erosional. The bathymetric data shown in Figure 5 demonstrate that the river bed has been significantly scoured on both sides of the inlet. The deep channel between Indian River Bay and Rehoboth Bay is also a high-energy environment. During normal tidal cycles, most of the water that is exchanged between the two bays passes through this channel, creating high current velocities (DNREC, 2007) and scour.

The Rehoboth Bay Sediment Management Plan (DNREC, 2007) provides a summary of available sediment characterization information for Rehoboth Bay and Indian River Bay. Sediments in the bays are typically fine to very fine (i.e., silts) and are mostly characterized as mud with the presence of sand. Mud will typically be composed of silts and clays with a high-water content.

4.1 Vibracore Sampling Along Cable Route

Alpine Ocean Seismic Survey, Inc. (Alpine) conducted a sediment characterization survey along the Indian River Bay portion of the proposed cable route in 2017. The survey included a total of 30 vibracore samples collected along the proposed cable route within Indian River Bay. The location of each vibracore is shown on Figure 7.

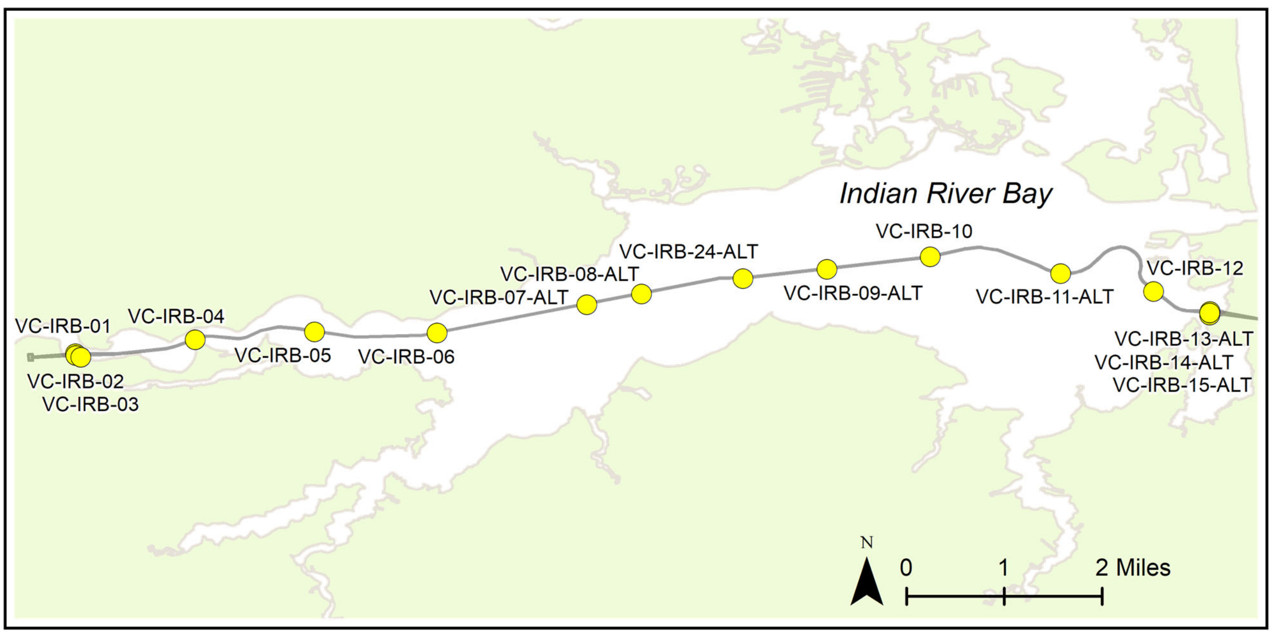

Figure 7: Vibracore Locations in Indian River Bay

The sediment samples collected along the proposed cable route are consistent with the characterization provided in the DNREC Sediment Management Plan. The sediments are primarily fine sands, silts, and clay sized particles. Figure 8 shows the composition of each vibracore sample arranged from west to east. Duplicate vibracore samples and vibracore locations that are close to each other are shown in numerically ascending order (left to right). Figure 8 shows that the sediments vary along the cable route, but sediment characterization along the proposed cable route does not show a longitudinal trend.

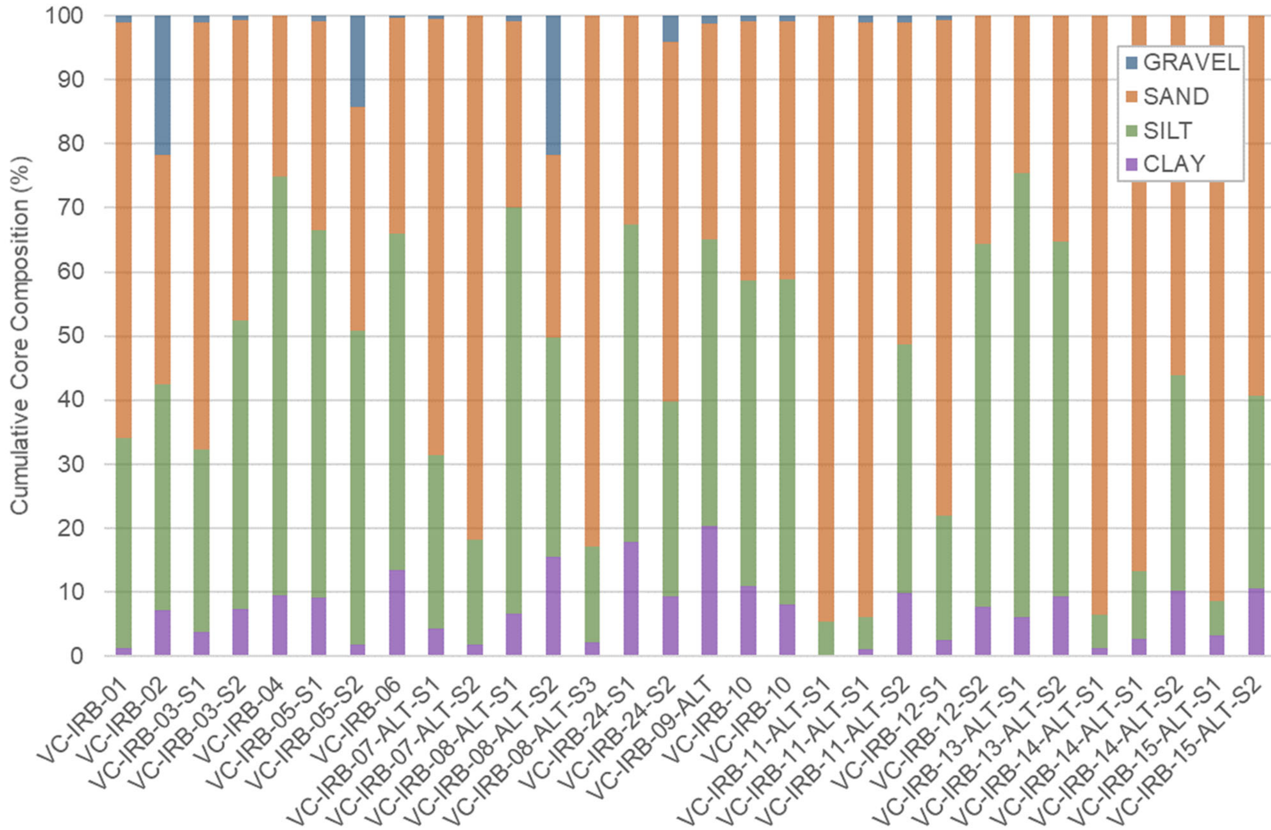

Figure 8: Vibracore Locations in Indian River Bay

The water content of the vibracore samples ranged from 15.5% to 93.1% with a mean value of 40.4%. Visual observations made during extraction of the vibracore samples indicate that in-situ sediments are primarily mud. The vibracore samples all demonstrated either low or medium plasticity. This is an indication of low clay content and non-cohesive sediments.

Fine-grained, high-water-content sediments are easily fluidized by a jet plow. Fine-grained sediments do not readily settle back into the trench. Particle settling is primarily a function of grain size and ambient currents for non-cohesive sediments. Table 2 provides particle size distribution metrics for each vibracore sample in the form of the sediment diameters that divide the smallest 10%, 30%, 50%, and 60% of the sample's mass from the remainder of the sample. The metrics are shorthanded as the D_{10}, D_{30}, D_{50}, and D_{60}, respectively. The sediment diameters corresponding to each percentile category (D_{10}, D_{30}, D_{50}, and D_{60}) were averaged across all samples. The average D_{50} across all vibracore samples is 0.144 mm, which is consistent with a fine sand characterization (Lindeburg, 2008). The average D_{10}, the average D_{50}, and the fine sand characterization are used in the subsequent sediment dispersion analysis for Indian River Bay.

Table 2: Representative Grain Size of Vibracore Samples

Sample ID	D_{10} (mm)	D_{30} (mm)	D_{50} (mm)	D_{60} (mm)
VC-IRB-01	0.037	0.064	0.285	0.388
VC-IRB-02	0.031	0.055	0.281	1.428
VC-IRB-03-S1	0.042	0.068	0.227	0.289
VC-IRB-03-S2	0.037	0.052	0.070	0.190
VC-IRB-04	0.006	0.039	0.051	0.058
VC-IRB-05-S1	0.007	0.045	0.057	0.066
VC-IRB-05-S2	0.044	0.055	0.073	1.519
VC-IRB-06	--	0.043	0.056	0.066
VC-IRB-07-ALT-S1	0.041	0.071	0.295	0.433
VC-IRB-07-ALT-S2	0.049	0.206	0.310	0.366
VC-IRB-08-ALT-S1	0.013	0.043	0.055	0.062
VC-IRB-08-ALT-S2	--	0.050	0.090	2.148
VC-IRB-08-ALT-S3	0.050	0.218	0.310	0.358
VC-IRB-24-S1	--	0.017	0.051	0.062
VC-IRB-24-S2	0.008	0.058	0.210	0.565
VC-IRB-09-ALT	--	0.036	0.053	0.065
VC-IRB-10	0.002	0.042	0.061	0.079
VC-IRB-10	0.007	0.045	0.062	0.078
VC-IRB-11-ALT-S1	0.140	0.246	0.355	0.422
VC-IRB-11-ALT-S1	0.138	0.240	0.349	0.417
VC-IRB-11-ALT-S2	0.005	0.050	0.060	0.212
VC-IRB-12-S1	0.048	0.109	0.180	0.220
VC-IRB-12-S2	0.011	0.045	0.059	0.069
VC-IRB-13-ALT-S1	0.038	0.048	0.057	0.062
VC-IRB-13-ALT-S2	0.007	0.043	0.058	0.068
VC-IRB-14-ALT-S1	0.090	0.124	0.150	0.163
VC-IRB-14-ALT-S1	0.062	0.118	0.145	0.159
VC-IRB-14-ALT-S2	0.005	0.085	0.085	0.106
VC-IRB-15-ALT-S1	0.080	0.118	0.144	0.158
VC-IRB-15-ALT-S2	0.004	0.059	0.090	0.110
Average	**0.038**	**0.083**	**0.144**	**0.346**

4.2 Settling Velocity from Stokes' Law

The predicted settling velocity of non-cohesive sediments can be estimated using Stokes' Law. Equation 2 shows the calculation of settling velocity as a function of grain size, particle density, and the kinematic viscosity of water. Equation 2 also includes any assumed values.

Equation 2: Settling Velocity by Stokes' Law (Lindeburg, 2008)

$$v_s = \frac{(SG_P - 1) * D^2 * g}{18 * v}$$

Where:

v_s	=	settling velocity
D	=	grain size
g	=	acceleration due to gravity (9.81 m/s^2)
SG_P	=	specific gravity of particle (2.65)
v	=	kinematic viscosity of water (1x10^{-6} m^2/s)

The estimated settling velocity for the average D_{50} grain size is 1.86 centimeters per second (cm/s), while the estimated settling velocity for the D_{10} grain size is 0.13 cm/s. The overwhelming majority of suspended sediments (sediments with a grain size larger than D_{10}) will settle at velocities that are equal to or greater than 0.13 cm/s. In a typical water depth of 1.5 m, the majority of the sediments will settle in less than 20 minutes. Approximately 10% (based on the average D_{10} grain size) will have slower settling velocities. This portion of disturbed sediments will remain in the water column for an extended period and may be transported away from the cable route. Typical settling velocities for fine silts is 0.01 cm/s (Lindeburg, 2008).

5.0 SUSPENDED SEDIMENT IMPACTS IN INDIAN RIVER BAY FROM JET PLOWING

The jet plowing along the proposed cable route will disturb river bed sediments in Indian River Bay. This activity will create a plume of suspended sediment. The suspended sediment plume will have a water quality impact on Indian River Bay and potentially Rehoboth Bay. The extent and duration of that impact will be a function of the initial release of suspended sediment, advective transport, transverse mixing, flushing, and settling velocity. Many of these processes are dynamic in both time and space. In the following discussion, we make estimates of how each element will influence the suspended sediment plume. Each of these estimates is made without an evaluation of variability. They are approximations that appropriately characterize individual mechanisms, but they may not completely capture how the mechanisms interact. Our goal in characterizing these mechanisms is to make an estimate of the duration and extent of the suspended sediment impacts resulting from jet plowing in Indian River Bay.

5.1 Initial Release of Suspended Sediments

During jet plowing, a portion of the fluidized sediments will be lost from the trench and released to the water column, creating a plume of suspended sediment. In the immediate vicinity of the jet plow, mixing of suspended sediment and ambient water will be driven by the momentum of the jetted water. The behavior of sediment in this "near-field" region is beyond the scope of this study. The near-field behavior will not influence the water quality impacts of jet plowing. Once the momentum from jetting has dissipated, "far-field" processes (e.g., dispersion, advection, and settling) will control the movement of the sediment plume.

In order to assess how far-field processes will move sediment, it is necessary to make an assumption about the initial suspended sediment concentration immediately after the jet plow has passed. For the purposes of this analysis, we have assumed that after near-field mixing, the suspended sediment will be uniformly distributed throughout the water column as well as laterally away from the proposed cable route. Water depths vary along the cable route depending on bathymetry, and they vary in time depending on tides. We have assumed a typical water depth of 1.5 m based on the bathymetry and tidal information previously described in this memorandum. We assume a lateral extent of the uniform distribution of sediments to be two times the water depth (i.e., 3 m) on either side of the proposed cable route centerline.

US Wind anticipates that the sediment loss rate from jet plowing will be less than 30%. Other modeling analyses of jet plowing in New England and the Mid-Atlantic have assumed sediment loss rates of 25-30% (ASA, 2002; ESS, 2013; HDR, 2014). Observational data collected during construction of the Block Island Wind Farm indicated that actual loss rates may be below the 25-30% range (BOEM, 2017). For the purposes of this analysis, a conservative sediment loss rate of 30% was used.

The proposed excavation for the cable will be 0.6 m wide and 2.3 m deep. The total sediment lost to the water column can be calculated with these trench dimensions and some additional information from the vibracore samples. The average water content of the vibracore samples is 40.4%, and we can use this as an approximation of in-situ void space in the sediments. Typical density of sediment particles is approximately 2,650 kilograms per cubic meter (kg/m^3). Equation 3 shows how this information was used to calculate the total mass of sediment released to the water column per foot of cable placed by jet plowing.

Equation 3: Mass of Suspended Sediment Released Per Foot of Jet Plowing

$$m = W * H * (1 - WC) * L * \rho$$

Where:

m	=	mass of suspended sediment per foot of jet plowing
W	=	trench width
H	=	trench depth
WC	=	water content of in-situ sediments
L	=	sediment loss rate
ρ	=	sediment density

Applying the above stated assumptions to Equation 3 yields 654 kilograms (kg) of sediment released per linear meter of jet plowing. Distributing that sediment uniformly throughout the 6 m (3 m either side of cable) by 1.5 m (typical water depth) region of assumed near-field mixing extents yields a suspended sediment concentration of 72.7 kg/m^3 or 72,700 mg/L. Approximately 90% of that sediment will have a settling velocity of 0.13 cm/s or greater. This means that in a typical water depth of approximately 1.5 m, 90% of the sediment will settle back to the riverbed within the first 20 minutes after it is disturbed. If we remove 90% of the sediment from the water column, the remaining concentration of suspended sediment will be 7,270 mg/L. It is important to note that the previous and subsequent discussion of suspended sediment concentrations refers to the suspended sediment concentrations above ambient concentrations.

The sediment that remains suspended in the water column after the first few minutes following the passage of the jet plow will be silt-sized sediments or finer. These extant suspended sediments will not readily settle and will be transported by advection and dispersion. These sediments will eventually settle in the low energy environment that characterizes most of Indian River Bay as previously discussed. We assume a settling velocity for silts of 0.01 cm/s. Using that settling velocity and the typical water depth of 1.5 m, the estimated duration of the suspended sediment plume is 4.2 hours. This estimate does not take into account the potential for turbulent behavior to push sediments upwards into the water column, but it does assume the full 1.5 m of water depth. Given these counterbalancing assumptions, this estimate is reasonable based on the information available.

5.2 Evaluation of Duration and Extent of Suspended Sediment Plume

The estimated sustained initial concentration of suspended sediment is 7,270 mg/L following the passage of the jet plow. Silt and non-cohesive clay sized particles do not readily settle. These particles will be transported by ambient currents. Indian River Bay has a large tidal influence. Ambient currents will move sediment towards the mouth of the bay on ebb tides and inland on flood tides. The net movement of the sediments will be towards the mouth. The previously calculated flushing time is a good indicator of how long it would take suspended sediment to exit Indian River Bay through the inlet. Figure 6 shows that at a distance of 500 m, the flushing time is approximately 3 days. Given that the overall length of the cable route is greater than 15,000 m and the estimated settling time is 4.2 hours, we conclude that the flushing time for most of the proposed cable route is long relative to settling time; we do not anticipate much of the suspended sediment exiting the bay.

At the same time that the suspended sediment is being transported longitudinally along Indian River Bay, the plume will also be spreading laterally as a result of transverse mixing. Transverse mixing includes the influence of advection away from the cable route (e.g., local eddies) and dispersion. It is not possible to accurately and precisely predict transverse mixing without the use of numerical models. The three-dimensional and temporal variability of currents in an estuary are two of the primary reasons that numerical models are typically employed to analyze the movement of a suspended sediment plume.

Analytical solutions are available to estimate transverse mixing, but researchers who have compared these analytical solutions to observed conditions have found significant variation in transverse mixing (Fischer et al., 1979). Fischer et al. (1979) provide a method for calculating the lateral spread of a plume based on the assumption of a normal distribution throughout the plume cross-section and that four standard deviations (σ) include 95% of the total mass along the cross-section.

Equation 4 and Equation 5 assume a continuous source of neutrally-buoyant material. Equation 4 includes the determination of shear velocity (U^*). We have used the calculation of shear velocity for open channel flow for Indian River Bay. We believe this assumption is appropriate based on the geometry of the bay. The determination of a transverse mixing coefficient and its application to suspended sediment do not align perfectly with the physics that control a suspended sediment plume, but they have been implemented in sediment transport models like the Particle Tracking Model (PTM) (Macdonald et al., 2006). We believe that they provide a reasonable approximation for the lateral spread of the suspended sediment plume resulting from jet plowing.

Equation 4: Transverse Mixing Coefficient & Shear Velocity Coefficient (Fischer et al., 1979)

$$\varepsilon_t = 0.6dU^* \qquad U^* = \sqrt{gdS}$$

Where:

ε_t	=	transverse mixing coefficient
d	=	water depth
U^*	=	shear velocity
g	=	acceleration due to gravity (9.81 m/s^2)
S	=	slope of the channel (assumed to be 0.00004)

Equation 5: Width of Plume (Fischer et al., 1979)

$$b = 4 * \sigma = 4 * \sqrt{2 * D * t} = 4 * \sqrt{2 * \varepsilon_t * t}$$

Where:

b	=	width of the plume
σ	=	standard deviation
D	=	diffusion coefficient
ε_t	=	transverse mixing coefficient
t	=	time since release

The settling time for extant suspended sediment has already been calculated to be approximately 4.2 hours. Applying that settling time to Equation 5 results in a corresponding plume width of approximately 102 m. Adding in the initial width of 6 m yields a total plume width of 108 m at 4.2 hours. Equation 5 assumes a normal distribution, with the highest concentrations occurring at the middle of the plume. A normal distribution means that most of the suspended sediment will be centered on the cable route and not at the edges of the 108-m width. Considering a uniform distribution provides a reference point. A uniform distribution would result in a suspended sediment concentration of 402 mg/L, but since we know the distribution will be closer to a normal distribution, we also know that the concentrations at the edges of the 108-m corridor will be much less than 402 mg/L.

Additional detailed analysis of the movement of the suspended sediment plume and the deposition thicknesses is not possible without the use of numerical modeling tools. However, based on our experience in previous sediment transport studies, we can make some general assessments of suspended sediment movement and deposition thicknesses. In previous studies, we have used the following thresholds for defining water quality impacts.

Suspended Sediment Defined Thresholds		**Sediment Deposition Defined Thresholds**	
Higher Impacts:	> 200 mg/L	Higher Impacts:	> 1 mm
Lower Impacts:	25 – 200 mg/L	Lower Impacts:	0.5 – 1 mm

Based on our experience conducting numerical modeling analyses of similarly sized sediments, we estimate that higher impacts are likely to occur within the 108-m corridor determined by Equation 5. The duration of the higher suspended sediment impacts will be on the order of 5 hours (consistent with the settling time calculated in Section 5.1). We estimate that lower impacts will occur over a much larger range, likely on the order of 300 m from the proposed cable route. The duration of lower suspended sediment impacts is likely to last between 5 and 24 hours.

6.0 CONCLUSIONS

We have investigated the hydrodynamic conditions that exist in Indian River Bay, the sediment conditions along the proposed submarine cable route, and the transport of sediment through flushing, settling, and mixing. Based on this analysis, we have identified a 108-m corridor where higher sediment impacts are likely to be experienced. The duration of higher suspended sediment concentrations is likely to be less than 5 hours based on the estimated settling time for silt-sized particles (4.2 hours). We have also estimated a 600 m corridor where lower impacts may occur (300 m from the proposed cable route on either side). The duration of the suspended sediment plume in this region is likely to last between 5 and 24 hours. Figure 9 maps both impact corridors relative to the proposed cable route.

Flushing time in Indian River Bay (shown in Figure 6) is long relative to the anticipated duration of the suspended sediment plume. Therefore, we conclude that it is unlikely that much of the sediment that is suspended by jet plowing will exit Indian River Bay through the inlet. Based on the same information and the proposed cable route, we conclude that it is unlikely that much suspended sediment will enter Rehoboth Bay.

There are some areas within Indian River Bay that may be more sensitive to sediment deposition or suspended sediment than others. We conducted a preliminary investigation to identify the following potentially sensitive receptors:

- The cooling water intake for Delmarva Power and Light facility (sensitive to suspended sediment).
- Tidal wetlands along the shoreline of Indian River Bay (sensitive to suspended sediment and deposition).
- Shellfish harvesting areas (sensitive to suspended sediment and deposition).

Calculating the potential impacts to these receptors is beyond the scope of this analysis. It is also important to note that the analysis presented in this memorandum does not use numerical modeling techniques. Therefore, all the determinations made in this memorandum are estimates based on available information. The extent, duration, resolution, and location of the higher-impact corridor identified in this analysis would be different if more comprehensive analysis techniques (i.e., numerical modeling) were employed. The combination of uncertainty associated with the level of analysis presented in this memorandum and the uncertainty with regards to impact thresholds should be considered when evaluating the findings of this analysis.

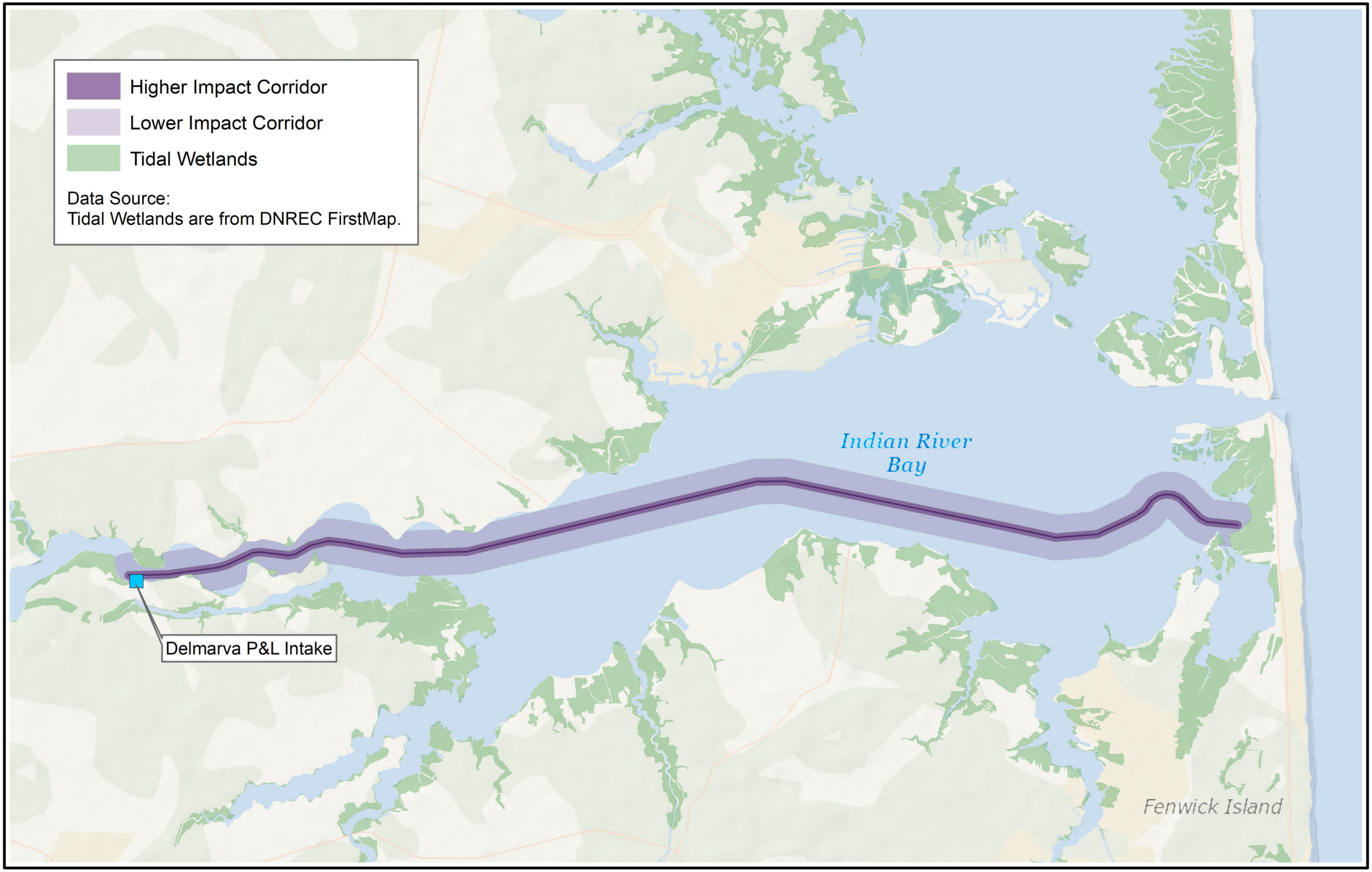

Figure 9: Estimated Extent of Suspended Sediment Plume and Deposition

Indian River Bay, Delaware

March 21, 2019

HodgeWaterResources

Service Layer Credits: Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors
Sources: Esri, GEBCO, NOAA, National Geographic, DeLorme, HERE, Geonames.org, and other contributors

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