VINEYARD NORTHEAST

CONSTRUCTION AND OPERATIONS PLAN

VOLUME II APPENDIX

MARCH 2024

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SUBMITTED BY:

VINEYARD NORTHEAST LLC

VINEYARD OFFSHORE

PUBLIC VERSION

Vineyard Northeast COP

Appendix II-P Sediment Dispersion Modeling

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Revision	Date	Description
0	October 2022	Initial submission.
1	November 2022	Updated to include Appendix A: Model Results of Sand Bedform Dredging Simulations and corrected minor typos in Appendix II-P
2	March 2023	Updated to address Bureau of Ocean Energy Management (BOEM) Round 1 Comments (dated January 13, 2023), incorporate the results of the sand bedform dredging simulations into the main body of the report (the dredging results are no longer included in a separate Appendix A), alternate tidal cycles assumed for dumping activities, and make minor corrections.
2	March 2024	Resubmitted without revisions.

SEDIMENT DISPERSION MODELING TECHNICAL REPORT

VINEYARD NORTHEAST LEASE 522

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List of Acronyms

AOI	Area of Interest
BOEM	Bureau of Ocean Energy Management
COP	Construction and Operations Plan
ENC	Electronic Navigational Chart
ESP	Electrical Service Platform
GIS	Geographic Information System
HVAC	high voltage alternating current
HVDC	high voltage direct current
MA WEA	Massachusetts Wind Energy Area
NDBC	National Data Buoy Center
NOAA	National Oceanic and Atmospheric Administration
O&M	Operations and Maintenance
OECC	Offshore Export Cable Corridor
OSAMP	Ocean Special Area Management Plan
PDE	Project Design Envelope
RI/MA WEA	Rhode Island/Massachusetts Wind Energy Area
SSFATE	Suspended Sediment FATE
TSHD	Trailing Suction Hopper Dredge
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
WTG	Wind Turbine Generator

EXECUTIVE SUMMARY

Vineyard Northeast LLC (the "Proponent") proposes to develop, construct, and operate offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0522 (the "Lease Area") along with associated offshore and onshore transmission systems. This proposed development is referred to as "Vineyard Northeast." Vineyard Northeast includes 160 total wind turbine generator (WTG) and electrical service platform (ESP) positions within the Lease Area. Up to three of those positions will be occupied by ESPs and the remaining positions will be occupied by WTGs. Two offshore export cable corridors (OECCs)—the Massachusetts OECC and the Connecticut OECC—will connect the renewable wind energy facilities to onshore transmission systems in Massachusetts and Connecticut.

This appendix to the Vineyard Northeast COP documents the sediment dispersion modeling assessment of the sediment-disturbing offshore cable installation activities associated with the development of Vineyard Northeast. The installation methods are described in detail in the COP (see Section 3.5.4.1 of COP Volume I) and the details of the assumed modeling parameters are documented within this report. Consistent with the Project Design Envelope (PDE), this study has been designed to simulate physical impacts from sand bedform dredging and cable installation along the Connecticut OECC, Massachusetts OECC, and within the Lease Area.

RPS applied customized hydrodynamic and sediment dispersion models to assess potential effects from sediment suspension during construction activities. Specifically, this analysis includes two interconnected modeling tasks:

- Development of a three-dimensional (3D) hydrodynamic modeling application of a domain encompassing Vineyard Northeast activities using the Deflt3D FM modeling suite; and
- Simulations of the suspended sediment fate and transport, including evaluation of seabed deposition and suspended sediment plumes, were performed using an RPS in-house model Suspended Sediment FATE (SSFATE) to simulate installation activities. Velocity fields developed using the Delft3D FM modeling suite were used as the primary forcing for SSFATE.

To characterize the effects associated with the offshore dredging and cable installation activities, a total of 12 scenarios were developed to conservatively represent the range of anticipated construction activities within the Connecticut OECC, the Massachusetts OECC, and the Lease Area. It is proposed that up to two high voltage direct current (HVDC) cable bundles or up to three high voltage alternating current (HVAC) cables may be installed within the Massachusetts OECC and up to two HVDC offshore export cable bundles may be installed within the Connecticut OECC. To assess potential effects of cable installation, one representative cable installation simulation was performed along each of the OECCs. Installation of each cable will take place during separate time periods such that potential effects from installation of one cable will have long since dissipated prior to the start of subsequent cable installations. Based on environmental surveys conducted by the Proponent, sand bedforms were identified within the OECCs and Lease Area. Therefore, dredging is anticipated and was modeled within the OECC and for representative locations within the Lease Area to simulate seabed preparation prior to cable installation.

The dredge scenarios, landfall site, and cable installation scenarios that were modeled include:

- Representative Connecticut Landfall Site HDD Exit Pit Construction
- Representative Connecticut OECC Cable Installation — Jetting
- Representative Connecticut OECC Cable Installation — Mechanical Trenching
- Representative Connecticut OECC Cable Installation — Vertical Injector
- Representative Massachusetts Landfall Site HDD Exit Pit Construction
- Representative Massachusetts OECC Cable Installation — Jetting
- Representative Massachusetts OECC Cable Installation — Vertical Injector
- Representative Lease Area Cable Installation —Typical Jetting
- Representative Lease Area Cable Installation — Maximum Jetting
- Representative Connecticut OECC Sand Bedform Dredging
- Representative Massachusetts OECC Sand Bedform Dredging
- Representative Lease Area Sand Bedform Dredging

Following is a brief overview of the terminology used to describe the methodologies modeled in this study:

- **Horizontal Directional Drilling (HDD):** At the representative landfall locations, HDD will be used to connect the offshore cable to the onshore components, which will require the excavation and subsequent backfill of an exit pit at the seaward end of the HDD.
- **Trailing Suction Hopper Dredge (TSHD):** Suction dredging through a drag arm near the seabed, overflow of sediment laden waters from a hopper and disposal of sediments from the hopper. In this report, it refers to the methodology as applied to all sand bedform sizes where dredging is needed.
- **Cable Installation using Jetting Techniques:** Cable installation is accomplished by jetting techniques (e.g., jet plow, jet trenching, or similar) in areas where sand bedforms do not exist or have been cleared.
- **Cable Installation using Mechanical Trenching:** In hard substrate environments (e.g., clays and rock), use of a chain cutter or rock wheel cutter may be required to create a trench. As the narrow trench is created and sediments are broken apart or fluidized, the cable is lowered into the trench.
- **Cable Installation using Vertical Injector:** Cable installation is achieved in areas with or without sand bedforms using a vertical injector tool, which is a high-volume low-pressure water jetting tool that uses directed water jets to fluidize the seabed and lower the cable via the integral depressor to the bottom of the fluidized trench.

The effects were quantified in terms of the above-ambient total suspended solids (TSS) concentrations, including the seabed deposition of sediments suspended in the water column during cable installation activities, such as including sand bedform dredging, landfall HDD exit pit excavation, and landfall HDD exit pit backfill. Results are presented with respect to the thresholds listed below, which were selected either because they are thresholds of biological significance or provide an effective means of demonstrating the physical effects:

- Water column concentrations thresholds: 10, 25, 50, 100, 200, and 650 micrograms per liter (mg/L);
- Water column exposure durations: one, two, three, four, six, 12, and 24 hours; and
- Seabed deposition: 1, 5, 10, 20, 50, and 100 millimeters (mm).

These analyses provide conservative predictions of suspended sediment concentrations above ambient conditions that could result from the HDD exit pit construction, sand bedform dredging, and cable installation activities associated with Vineyard Northeast. Results from the representative simulations of HDD exit pit construction, sand bedform dredging, and cable installation within the Connecticut OECC and Massachusetts OECC, and sand bedform dredging and cable installation within the Lease Area show that above-ambient TSS concentrations originating from the source are intermittent, depending on the *in-situ* sediment composition; the vertical distribution of the sediment in the water column; and the hydrodynamic forcing conditions. The models show the highest concentrations of induced suspended sediment occur in the vicinity of the activity (e.g., cable installation, dredging, dumping, HDD exit pit construction), as expected; however, these higher concentrations then decrease rapidly with distance. All above-ambient TSS concentrations are predicted to settle out rapidly, with a maximum of four to 12 hours required to fully dissipate.

HDD Exit Pits

For the representative HDD exit pit construction at the landfall site simulations, the above-ambient TSS concentrations may be present throughout the entire water column because sediments were released at the water surface but are predicted to return to ambient conditions within six hours. The plumes of TSS concentrations greater than 10 mg/L were predicted to have longer extents in the Representative Connecticut Landfall Site HDD Exit Pit Construction simulation than in the Representative Massachusetts Landfall Site HDD Exit Pit Construction scenario (Table 3-9), because current speeds near the representative Connecticut landfall site are faster and more complex than at the Massachusetts landfall site. The model predicted the deposition ranges from less than 5 mm for the Representative Massachusetts HDD Exit Pit Construction scenario to less than 100 mm for the representative Connecticut Exit Pit Construction scenario.

Sand Bedform Dredging

The representative sand bedform dredging simulation along the Niantic Beach Approach were predicted to have the largest impact compared with the other sand bedform dredging simulations. This prediction is, in part, due to the *in-situ* sediment composition containing high proportions of fine material; the dredge volume; and the direction of the prevailing currents at the time of dumping and overflow activities. When compared to its counterpart (i.e., Eastern Point Beach Approach), there was a higher proportion of fine material along the Niantic Beach Approach and a larger dredge volume modeled. The higher proportion of fine material was, therefore, present in the water column longer and oscillated with the currents prior to settling or dissipating. Although the main section of the Connecticut OECC is anticipated to have a larger dredge volume, the dump sites were spread across multiple locations, so the plume had time to dissipate partially or fully prior to the occurrence of the next dump and overflow operation. Due to dispersion of the sediment plume by the currents, TSS concentrations were predicted to substantially dissipate within two to three hours and fully dissipate within four to six hours for most of the model scenarios, except for the Niantic Beach Approach and Connecticut OECC, which was predicted to require up to 12 hours to fully dissipate. The model also predicted the cumulative sediment deposition from the representative sand bedform dredging simulations to remain close (<0.09 km) to the drag arm disturbances and to be less than 5 mm. The deposition associated with overflow and dumping exceeded a thickness of 100 mm in every scenario, but was predicted to remain around the dump location with a thickness of 1 to 5 mm occurring in isolated and patchy locations depending on the location of the prevailing currents at the time of release.

Results from the representative simulations of sand bedform dredging within the Connecticut OECC, Massachusetts OECC, and Lease Area show the above-ambient TSS concentrations originating from the source are intermittent along the route and coincide with the representative dredge locations due to drag arm disturbances and the representative dump locations. The *in-situ* sediment composition; the anticipated dredge volume and length of dredging; the vertical distribution of the sediment in the water column; the hydrodynamic forcing conditions; and the depth of the release also contribute to the variability in the extent of the plume, the duration of exposure to TSS concentrations, and pattern of the depositional footprint. For the disturbances associated with the drag arm, TSS concentrations remained localized to the seabed either dissipating quickly or depositing based on the *in-situ* sediment type. Alternatively, dumping and overflow operations created plumes that extended throughout the water column, and although patchy and discontinuous in nature, the plume was exposed to multiple tidal cycles and transported farther from the source prior to dissipating or settling.

Cable Installation

Simulations of several possible inter-array or offshore export cable installation methods using either typical installation parameters (for inter-array and offshore export cable installation) or maximum impact parameters (for inter-array cable installation only) predict a plume that is localized to the seabed. The model also predicts the cumulative sediment deposition from installation will generally occur along (i.e., back into the trench) and adjacent to the cable route. Deposition thicknesses over 1 mm generally stayed close to the cable alignment (≤0.43 km) for all cable installation simulations.

When cable installation was modeled for typical jetting parameters, the TSS concentrations greater than 10 mg/L stayed within 0.12 km and 0.16 km, on average, for the representative Connecticut OECC and Massachusetts OECC simulations, respectively. For both the Connecticut and Massachusetts representative vertical injector scenarios, the mean TSS concentrations greater than 10 mg/L extended slightly farther away from the route centerline than when compared with the cable installation using typical jetting parameters. These predictions are anticipated because the vertical injector simulations were modeled in areas containing high concentrations of fine material that transport readily with subsurface currents.

Cable installation scenarios within the Lease Area were predicted to elevate TSS concentrations greater than 10 mg/L around 0.33 km and 0.72 km for the typical and maximum jetting scenarios, respectively (Table 3-9). A maximum distance of approximately 2.67 km for maximum installation jetting parameters and up to 1.54 km for typical impact installation parameters for the representative inter-array cable installation in the Lease Area are predicted from this modeling assessment. For all cable installation scenarios within the Connecticut OECC, Massachusetts OECC, and Lease Area, above-ambient TSS concentrations substantially dissipate within one to two hours and fully dissipate in less than four to 12 hours.

Summary

These modeling analyses predict suspended sediment concentrations induced by installation of the cables, dredging, and excavation and backfill of the HDD exit pits will largely be of short duration and return to ambient conditions within approximately 12 hours after the activity is completed.

1 INTRODUCTION

Vineyard Northeast LLC (the “Proponent”) proposes to develop, construct, and operate offshore renewable wind energy facilities in Bureau of Ocean Energy Management (BOEM) Lease Area OCS-A 0522 (the “Lease Area”) along with associated offshore and onshore transmission systems. This proposed development is referred to as “Vineyard Northeast.” Vineyard Northeast includes 160 total wind turbine generator (WTG) and electrical service platform (ESP) positions within the Lease Area. Up to three of those positions will be occupied by ESPs and the remaining positions will be occupied by WTGs. Two offshore export cable corridors (OECCs), the Massachusetts OECC and the Connecticut OECC, will connect the renewable wind energy facilities to onshore transmission systems in Massachusetts and Connecticut (Figure 1-1).

This appendix to the Vineyard Northeast Construction and Operations Plan (COP) documents the modeling assessment used to simulate potential sediment-disturbing activities associated with the offshore cable installation processes for Vineyard Northeast. The resuspension of sediments from the various construction activities may cause a localized sediment plume. A sediment plume is a portion of the water column that experiences a temporary increase in the total suspended solids (TSS) concentration above ambient levels. Over time, the plume settles and deposits sediment on the seabed (i.e., a process referred to as sedimentation), which is estimated as the thickness of sediment accumulated on the seabed above ambient conditions.

This report describes the models, modeling approach, inputs, and results used to assess cable installation activities. A description of the relevant environmental data sources is provided in Section 2.1. The Delft3D FM hydrodynamic model and its application to the study area are presented in Section 2.2. Section 3 provides an overview of the SSFATE sediment dispersion model and its generated results for the 12 modeled scenarios.

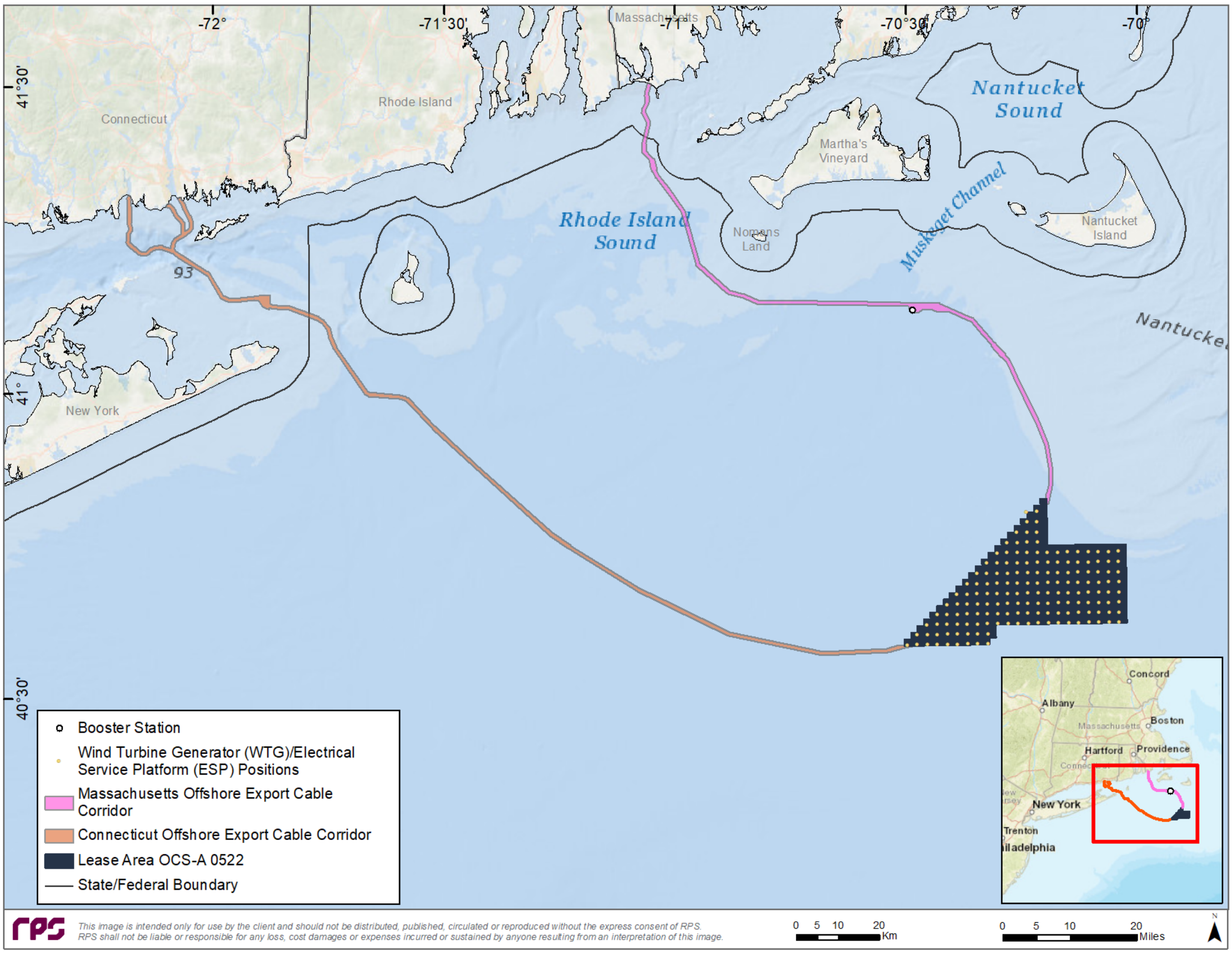

Figure 1-1: Map of Study Area with Indicative Locations for Vineyard Northeast's Offshore Components.

1.1 Study Scope and Objectives

The installation methods are described in detail in the COP (see Section 3.5.4.1 of COP Volume I) and the details of the assumed modeling parameters are documented within this report. Consistent with the PDE, this study has been designed to simulate physical impacts from sand bedform dredging and cable installation along the Connecticut OECC, the Massachusetts OECC, and within the Lease Area.

RPS applied customized hydrodynamic and sediment dispersion models to assess potential effects from sediment suspension during construction activities. This approach is consistent with the modeling approach used for Vineyard Wind 1 and many similar studies that have been previously accepted by state and federal regulatory agencies for pipeline and cable installation (e.g., the Block Island Wind Farm), including harbor dredging and land reclamation activities. Specifically, this analysis includes two interconnected modeling tasks:

1. Development of a three-dimensional (3D) hydrodynamic modeling application of a domain encompassing Vineyard Northeast activities using the Deflt3D FM modeling suite; and
2. Simulation of suspended sediment fate and transport, including evaluation of seabed deposition and suspended sediment plumes associated with installation activities using an RPS in-house model Suspended Sediment FATE (SSFATE). Velocity fields were developed using the Delft3D FM modeling suite using the primary forcing for SSFATE.

To characterize the effects associated with the offshore dredging and cable installation activities, 12 scenarios were developed to conservatively represent the range of anticipated construction activities within the Connecticut OECC (Table 1-1), the Massachusetts OECC (Table 1-2), and the Lease Area (Table 1-3). The Proponent is proposing up to two high voltage direct current (HVDC) cable bundles or up to three high voltage alternating current (HVAC) cables may be installed within the Massachusetts OECC and up to two HVDC offshore export cable bundles may be installed within the Connecticut OECC. To assess potential effects of cable installation, only one representative cable installation simulation was performed along each of the OECCs. Installation of each cable will take place during separate time periods such that potential effects from installation of one cable will have long since dissipated prior to the start of subsequent cable installations. Based on environmental surveys conducted by the Proponent, sand bedforms were identified within the OECCs and the Lease Area. Therefore, dredging is anticipated and was modeled within the OECC and for representative locations within the Lease Area to simulate seabed preparation prior to cable installation.

Sand bedforms are mobile features. Removing the upper portions of the sand bedforms will facilitate cable installation within the stable seabed beneath, thereby ensuring that sand bedform migration will not lead to the exposure of a cable on the seafloor. The amount of sand bedform dredging will vary based on the size of the sand bedforms and the achievable burial depth of the cable installation equipment employed. The installation and burial of the cable will occur after removing any needed sand bedform.

1.2 Project Components

1.2.1 Connecticut OECC

The Connecticut OECC travels from the southwestern tip of Lease Area OCS-A 0522 along the southwestern edge of the MA WEA and then heads between Block Island and the tip of Long Island towards potential landfall sites near New London, Connecticut. As the Connecticut OECC approaches shore, it splits into three variations where it connects to three potential landfall sites. The “Eastern Point Beach Approach” of the Connecticut OECC connects to the Eastern Point Beach Landfall Site, the “Ocean Beach Approach” connects to the Ocean Beach Landfall Site, and the “Niantic Beach Approach” connects to the Niantic Beach Landfall Site (Figure 1-2). This section includes a brief introduction to the modeling performed for the Connecticut OECC. Section 3.2.3.2 more thoroughly discusses the relevant installation details (e.g., the SSFATE model’s methodology, underlying assumptions, and results).

This assessment accounts for the excavation and subsequent backfill of an exit pit at the seaward end of the horizontal directional drilling (HDD) path used to connect the offshore export cables and onshore components at the representative landfall locations. The modeling evaluated one landfall site that can be considered conservatively representative of the other two landfall sites. The Ocean Beach Landfall Site was selected as the conservative representative landfall site based on the following attributes: (1) its central location between the other two sites, (2) its soft sediment classification (e.g., muddy sand), and (3) its proximity to the Thames River which drives faster subsurface currents and more complex hydrodynamic patterns in that region. Due to the high fraction of fine-grained material (i.e., muddy substrate), results from the Ocean Beach Landfall Site serve as a conservative representation of the other two sites.

Prior to cable installation, seabed preparation (in the form of dredging) may be required to clear sand bedforms within the Connecticut OECC. The model assumes using a trailing suction hopper dredge (TSHD) (Table 1-1). A TSHD removes sediment by suction dredging through a drag arm near the seabed. The sediment-water slurry is stored in a hopper, with the majority of coarse material (e.g., sands) settling to the bottom and most of the fine material overflowing with the sediment-laden waters. Overflow occurs once the hopper reaches its maximum capacity, and then the TSHD releases the remaining sediment at select disposal sites within the cable corridor. For this modeling assessment, the dump sites are considered representative and are based on an estimated dredge capacity; however, fewer or more sites may be used during the actual construction activities. To bound the potential impacts for the dredging assessment, modeling was performed along the Niantic Beach approach and the Eastern Point Beach approach. For both approaches, the largest anticipated dredge volume identified within the Connecticut OECC was applied to conservatively assess sediment-related impacts associated with dredging operations.

Cable installation was then simulated within the Connecticut OECC, using its centerline as the representative route (Table 1-1), starting from approximately one kilometer (km) offshore and going towards the Lease Area. In reality, the route may vary within the corridor depending on *in-situ* conditions and installation constraints. Cable installation will be accomplished by jetting techniques (e.g., jet plow, jet trenching, etc.) in areas where sand bedforms do not exist or have been cleared. As with the dredging scenarios in the Connecticut OECC, cable installation using the jetting technique was modeled for the Niantic Beach Approach and Eastern Point Beach Approach. In areas where jetting techniques may not be adequate (e.g., hard-bottom locations), the use of other installation methods may be required depending on the conditions. Two sensitivity analyses were performed to capture the potential use of different techniques by simulating cable installation using a vertical injector tool and mechanical trenching (e.g., a chain cutter). The Vertical Injector segment was selected based on the area within the Connecticut OECC that contained the highest fraction of fine material. This was considered conservative, because fine material takes longer to settle and may be transported farther from the release location; thus, remaining suspended in the water column for longer durations. It is anticipated the mechanical trencher will be used for cable installation for hard substrate segments of the route, and so a representative location southwest of Fishers Island, New York, where currents are known to be very fast, was selected for modeling purposes.

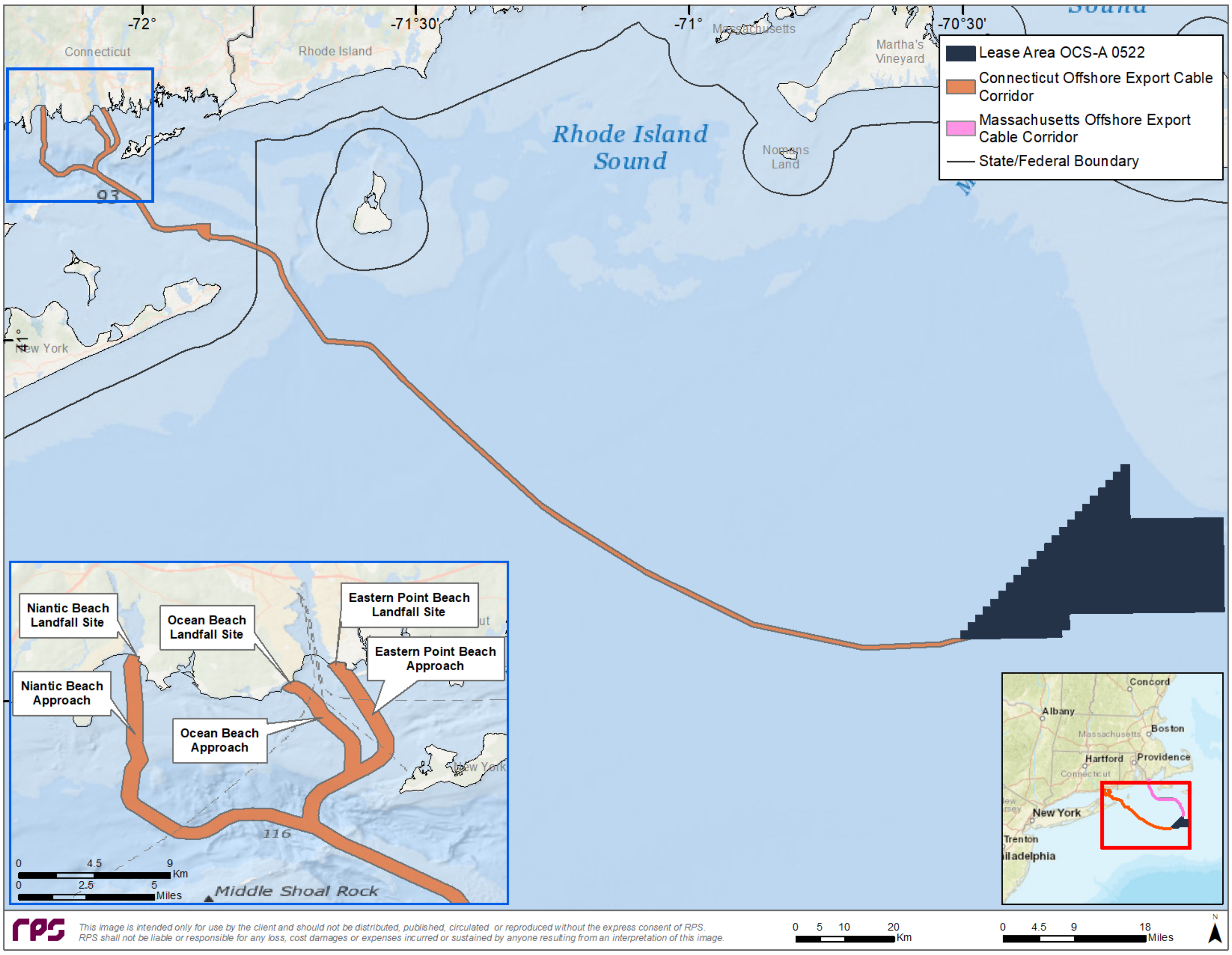

Figure 1-2: Connecticut OECC-related project components.

Table 1-1: Description of modeled scenarios for Vineyard Northeast, specific to the Connecticut OECC.

Scenario Name	Description
Connecticut OECC	
Representative Connecticut Landfall Site HDD Exit Pit Construction	Representative Horizontal Directional Drilling (HDD) exit pit excavation and backfill at Ocean Beach Landfall Site (one of three potential Connecticut landfall sites).
Representative Connecticut OECC Sand Bedform Dredging	Intermittent sand bedform dredging prior to offshore export cable installation along sections of the Connecticut OECC, including the Niantic Beach Approach and the Eastern Point Beach Approach, using a TSHD.
Representative Connecticut OECC Cable Instillation — Jetting	Offshore export cable installation using jetting techniques and assuming typical installation parameters (a two-meter trench depth and slower installation rate) along the Connecticut OECC.
Representative Connecticut OECC Cable Installation — Mechanical Trenching	Representative offshore export cable installation using mechanical trenching (e.g., chain cutter) along a segment of the Connecticut OECC.
Representative Connecticut OECC Cable Installation — Vertical Injector	Representative offshore export cable installation using a vertical injector along a segment of the Connecticut OECC.

1.2.2 Massachusetts OECC

The Massachusetts OECC travels from the northernmost tip of Lease Area OCS-A 0522 along the northeastern edge of the Massachusetts Wind Energy Area (MA WEA) and Rhode Island/Massachusetts (RI/MA) WEA and then traverses Buzzards Bay towards a landfall site in Westport, Massachusetts (Figure 1-3). This section includes a brief introduction to the modeling performed for the Massachusetts OECC. Section 3.2.3.1 more thoroughly discusses the relevant installation details (e.g., the SSFATE model's methodology, underlying assumptions, and results).

Construction of the exit pit was modeled at the Horseneck Beach Landfall Site (Table 1-2). As with the Connecticut OECC, the Massachusetts OECC may require dredging to clear sand bedforms prior to cable installation and assumes the use of a TSHD (Table 1-2). The dump sites used in this assessment within the Massachusetts OECC are considered representative, although fewer or more sites may be used during actual construction activities. Modeling of dredging within the Massachusetts OECC conservatively assumed the largest anticipated dredge volume as identified in preliminary surveys.

Cable installation was then simulated within the Massachusetts OECC, starting from the Horseneck Beach Landfall Site and going towards the Lease Area, assuming the centerline as the representative route (Table 1-2). However, the route may vary within the corridor depending on *in-situ* conditions and installation constraints. A sensitivity analysis was performed to capture the potential use of a vertical injector tool for cable installation at a segment along the cable installation route. The vertical injector segment was selected because it could be exposed to swift currents and coincides with grain sizes, which contain high proportions of fine material.

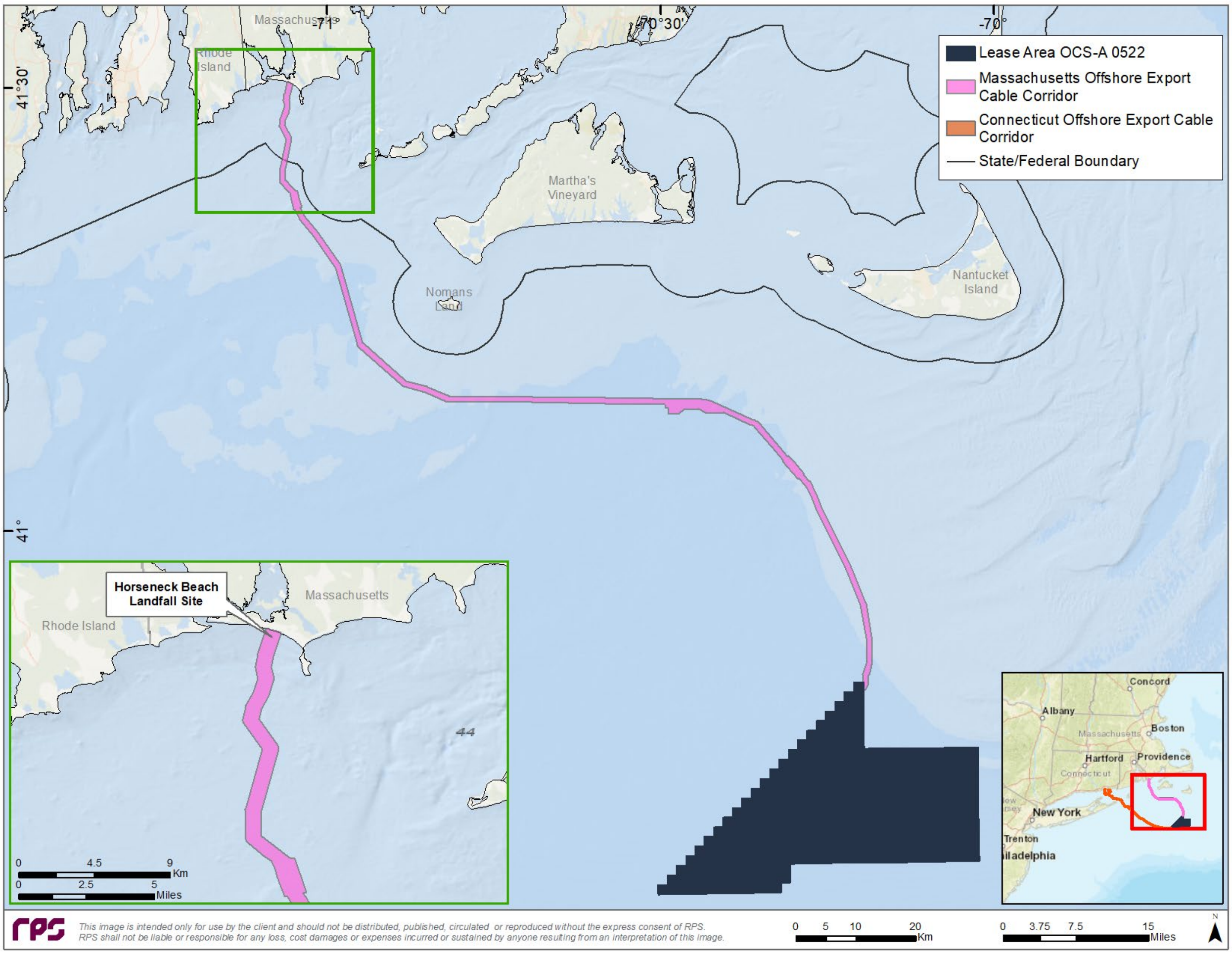

Figure 1-3: Massachusetts OECC-related project components.

Table 1-2: Description of modeled scenarios for Vineyard Northeast, specific to the Massachusetts OECC.

Scenario Name	Description
Massachusetts OECC	
Representative Massachusetts Landfall Site HDD Exit Pit Construction	HDD exit pit excavation and backfill at the Horseneck Beach Landfall Site.
Representative Massachusetts OECC Sand Bedform Dredging	Intermittent sand bedform dredging prior to offshore export cable installation along sections of the Massachusetts OECC using TSHD.
Representative Massachusetts OECC Cable Installation — Jetting	Offshore export cable installation using jetting techniques and assuming typical installation parameters (a two-meter trench depth and slower installation rate) along the Massachusetts OECC.
Representative Massachusetts OECC Cable Installation — Vertical Injector	Representative offshore export cable installation using a vertical injector along a segment of the Massachusetts OECC.

1.2.3 Lease Area

The Lease Area will consist of an array of cables (i.e., inter-array cables) that connect the wind turbines to a central location (Figure 1-4). This section includes a brief introduction to the modeling performed for the Lease Area. Section 3.2.3.1 provides a detailed discussion of the installation (e.g., the SSFATE model's methodology, underlying assumptions, and results).

The northeast corner of the Lease Area was identified as containing sand bedforms; therefore, dredging is anticipated in that area. Modeling was performed along one of the inter-array cables in the northeast corner to capture the potential impacts associated with sand bedform dredging in the Lease Area (Table 1-3). This representative segment assumes the use of a TSHD and that dumping will occur within the Lease Area, but the specific locations may change during the actual construction activities.

To simulate the installation of the inter-array cables, one conservatively representative inter-array cable in the southwest corner of the Lease Area was selected for modeling. This inter-array cable was selected to model a worst-case scenario cable installation within the Lease Area because it contains the highest proportion of fine-grained material and is one of the longest sections of the inter-array cables (Figure 1-4). The longest route corresponds to the largest volume of sediment being released into the environment during the cable installation process. It is representative of other inter-array cable installation because adequate time will occur between inter-array cable installations, thus allowing the sediment plume to disperse and TSS concentrations to return to ambient conditions. It was assumed the inter-array cables would be installed via jetting techniques, but to capture potential variability in jetting parameters (e.g., installation rates and trench depths) two simulations were performed (Table 1-3). One simulation included the use of typical jetting installation parameters (e.g., a slower installation speed and a typical target trench depth) while the other assumed the maximum parameters (e.g., a faster installation rate and a maximum target trench depth).

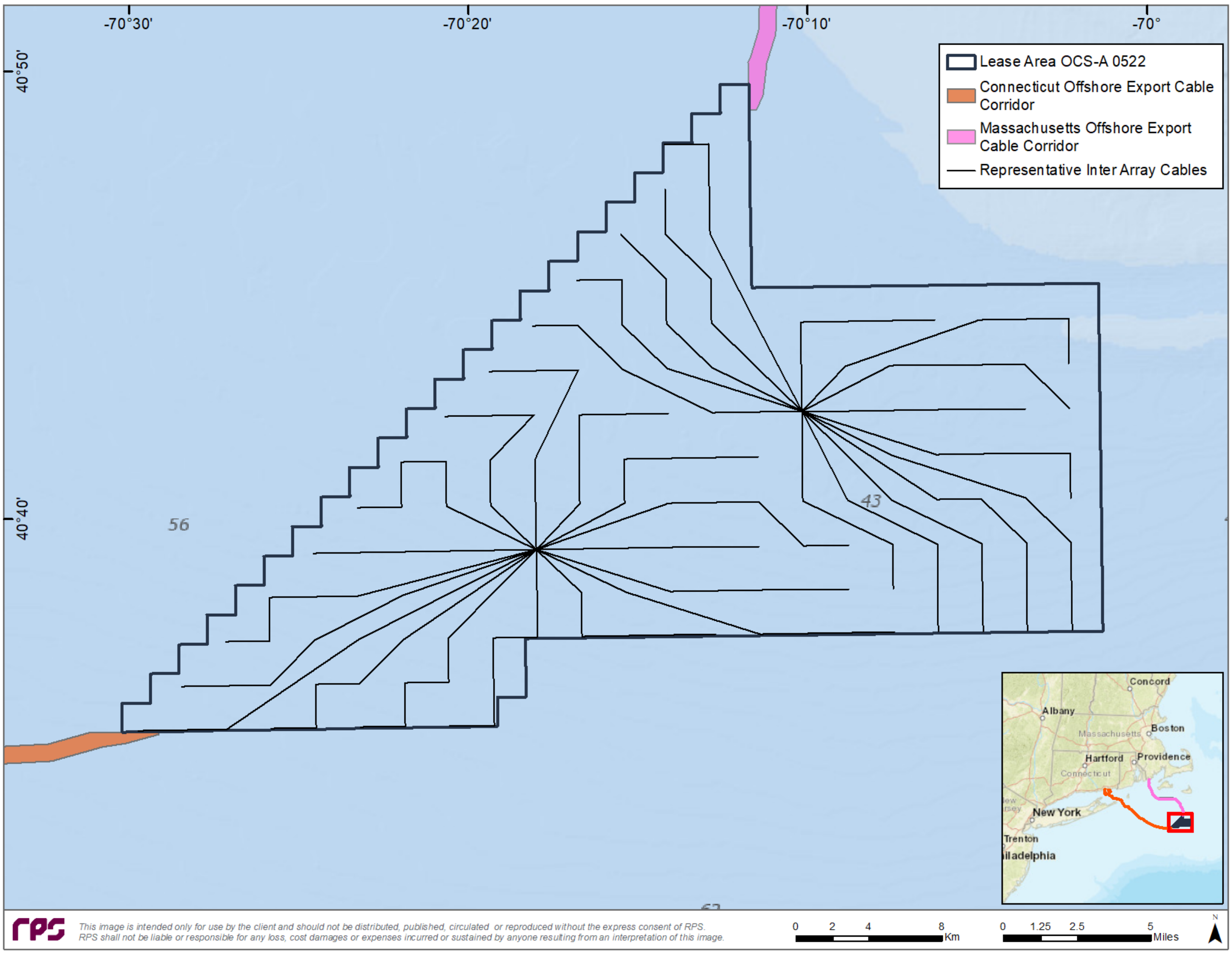

Figure 1-4: Lease Area-related project components.

Table 1-3: Description of modeled scenarios for Vineyard Northeast specific to the Lease Area.

Scenario Name	Description
Lease Area	
Representative Lease Area Sand Bedform Dredging	Representative limited sand bedform dredging prior to inter-array cable installation in the northeast corner of the Lease Area using TSHD.
Representative Lease Area Cable Installation — Typical Jetting	Representative inter-array cable installation using jetting techniques and assuming typical installation parameters (a two-meter trench depth and slower installation rate) in the southwest corner of the Lease Area.
Representative Lease Area Cable Installation — Maximum Jetting	Representative inter-array cable installation using jetting techniques and assuming maximum installation parameters (a three-meter trench depth and faster installation rate) in the southwest corner of the Lease Area.

1.3 Thresholds of Concern

The effects were quantified in terms of the above-ambient TSS concentrations, including the seabed deposition of sediments suspended in the water column during cable installation activities, such as sand bedform dredging, landfall HDD exit pit excavation, and landfall HDD exit pit backfill. Results are presented with respect to the thresholds listed below, which were selected either because they are thresholds of biological significance or provide an effective means of demonstrating the physical effects. Thresholds associated with biological significance are documented in Sections 4.5 and 4.6 of COP Volume II, which are the benthic resources and finfish and invertebrate sections, respectively. The thresholds used in this study include:

- Water column concentrations thresholds: 10, 25, 50, 100, 200, and 650 micrograms per liter (mg/L);
- Water column exposure durations: one, two, three, four, six, 12, and 24 hours; and
- Seabed deposition: 1, 5, 10, 20, 50, and 100 millimeters (mm).

2 HYDRODYNAMIC MODELING

RPS applied a 3D Delft3D Flexible Mesh (FM) Flow model in the hydrodynamic modeling area of interest (AOI) to generate current fields for use in sediment dispersion modeling. The following sections describe the following: (1) the Delft3D FM framework; (2) the environmental data used to develop the present application of the model; and (3) the details of the application development, including model setup and discussion of results.

2.1 Environmental Data

As inputs to the hydrodynamic model, environmental data were collected to reproduce the AOI's predominant conditions. The hydrodynamic modeling domain that covers the AOI for sediment dispersion modeling spans from the New Jersey shoreline to the east of Cape Cod and Nantucket. Environmental data including shoreline, bathymetry, winds, tidal elevations, and currents were acquired to (1) understand and characterize the circulation, local to the project components, (2) develop model boundary conditions and forcing, and (3) calibrate as well as validate the model. The locations of various data sources in relation to the project components are shown in Figure 2-1 and summarized in Table 2-1. When applicable, timeseries data were downloaded for the entirety of 2020, as it was the most recent year in which data were available at all observation locations. Analysis and presentation of the data used for the study are presented in subsequent sections.

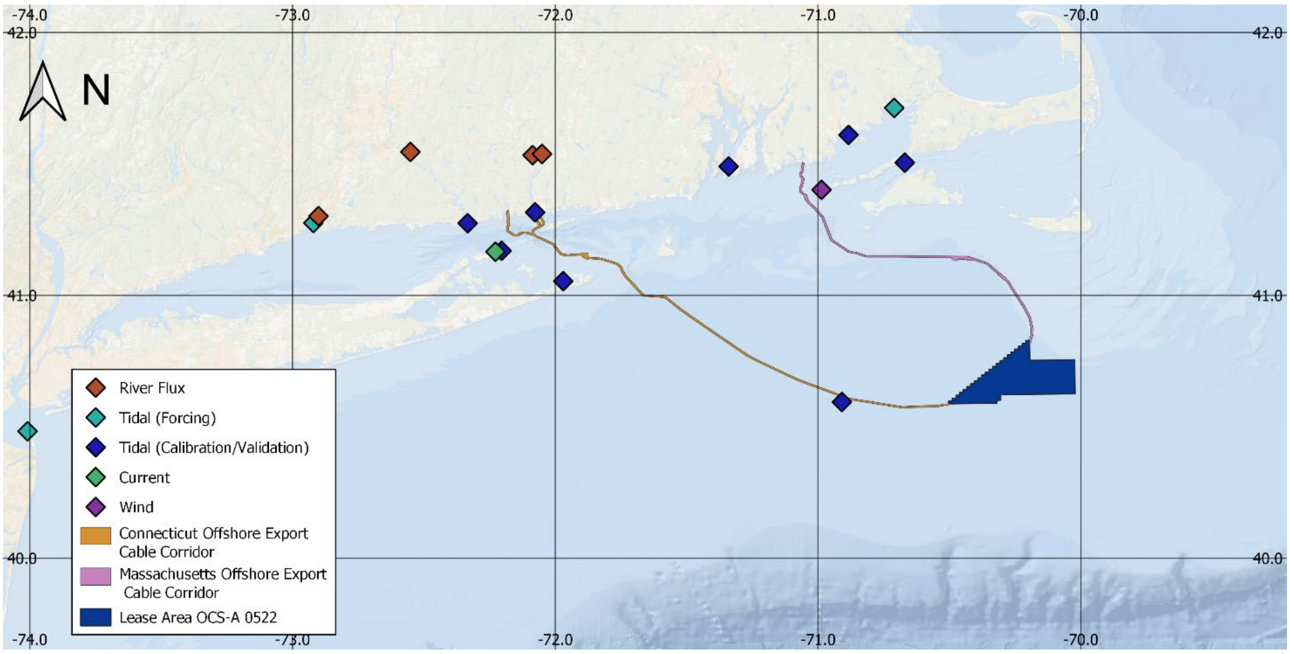

Figure 2-1: Locations of project components, bathymetry coverages, and environmental data observation stations.

Table 2-1: Summary of model and observation data in 2020, used in the modeling study.

Data Source	Name	Location	Time Step	Longitude (°W)	Latitude (°N)
Wind Model Data	ERA5 model	10-meter, Global Model	1-hour	72.2 – 69.2	39.5 – 42.0
Wind Observation	NDBC BUZM3	Buzzards Bay	1-hour	71.033	41.397
Tidal Elevation (Forcing)	NOAA 8465705	New Haven	6-minutes	72.908	41.283
	NOAA 8531680	Sandy Hook	6-minutes	74.010	40.467
	NOAA 8447270	Buzzards Bay	6-minutes	70.617	41.742
Tidal Elevation (Calibration and Validation)	NOAA 8462764	Lyme	6-minutes	72.334	41.274
	NOAA 8461490	New London	6-minutes	72.077	41.316
	NOAA 8511236	Plum Island	6-minutes	72.204	41.169
	NOAA 8510560	Montauk	6-minutes	71.970	41.054
	NOAA 8452660	Newport	6-minutes	71.340	41.490
	NOAA 8447930	Woods Hole	6-minutes	70.670	41.505
	NOAA 8447712	New Bedford	6-minutes	70.884	41.610
	IAPSO1232	IAPSO1232	6-minutes	70.909	40.594
Current Observation	LIS1012	Plum Gut (30.2 m MLW)	6-minutes	72.228	41.166
River Flux	USGS 011230695	Shetucket River	15-minutes	72.042	41.568
	USGS 01127000	Quinebug River	15-minutes	71.983	41.592
	USGS 01196500	Quinnipiac River	15-minutes	72.838	41.450
	USGS 01193050	Connecticut River	15-minutes	72.552	41.538

2.1.1 Bathymetry Data

Bathymetry data were gathered from publicly available data from the National Oceanic and Atmospheric Administration's (NOAA) Electronic Navigational Chart (ENC) for coastal and offshore waters of Massachusetts, Connecticut, Rhode Island, and New York. NOAA soundings (i.e., water depth measurements) inside the project AOI were downloaded from NOAA's ENC Direct to GIS portal (NOAA, 2022). Sounding data were retrieved from their native positioning, which is irregular in spacing, and then interpolated to the hydrodynamic grid to provide complete coverage of water depths within the study area.

A 2021 General Bathymetric Chart of the Oceans (GEBCO) data source was used to fill in the bathymetry and topography data in locations not covered by the ENC data (GEBCO Bathymetric Compilation Group, 2021). In nearshore locations close to the cable routes, 2018 United States (US) Army Corps of Engineering (USACE) topo-bathy LiDAR survey data were used to provide high-resolution bathymetry detail (Doran et al. 2020).

Table 2-2 provides a summary of the bathymetric datasets that were used for the modeling. These bathymetry sources, referenced to mean sea level (MSL), were combined to create a detailed database for the model domain. The dataset was smoothed at the merging and transition areas to remove sharp gradients when moving from one data source to another. The smoothing helped to have a featureless transition among different bathymetric datasets, and to increase the stability of the hydrodynamic model.

Table 2-2: Specifics of bathymetry datasets used for modeling.

Name of Dataset	Owner/Provider	Minimum Horizontal Grid Size
GEBCO (2021)	British Oceanographic Data Centre	~320 m
ENC (2022)	NOAA	~50 m
LiDAR (2018)	USACE	~5 m

2.1.2 Meteorological Observations

To force the surface boundary of the hydrodynamic model, ocean-atmosphere bulk variables were obtained from the ERA5 reanalysis product (Hersbach et al., 2020), which was developed by the European Centre for Medium-Range Weather Forecasts (ECMWF). The global wind data are available on an atmospheric model grid with 0.25 degree (°) horizontal resolution (Hersbach et al., 2018; Hersbach et al., 2020). Gridded data of 1-hour parameters at 10 m elevation, for the entire year of 2020, were collected and used for the modeling domain (see Table 2-1).

To validate the wind-forcing dataset, the ERA5 model output was interpolated from the four neighboring global grid points to the National Data Buoy Center (NDBC) buoy BUZM3 (Figure 2-2) for the modeling period (May-August 2020). To compare the observation with 10 m-wind from ERA5, the observed wind speed was adjusted from a 24.8 m height to a 10 m height, using the Bratton and Womeldorf (2011) equation:

$$V_2 = V_1 \left(\frac{H_2}{H_1}\right)^{\alpha}$$

where an unknown wind velocity (V2) at its known height (H2) can be estimated using a known wind velocity (V1) which was recorded at a different elevation (H1) at the same site location.

As the NDBC stations are in open water, the value of the wind shear exponent (α) was set as 0.1 (Bratton & Womeldorf 2011). Comparing the NDBC's wind measurements and the ERA5 output indicates the ERA5 model adequately captures the direction and wind speed in the study area (see Figure 2-2). Therefore, it is an appropriate wind source for forcing the hydrodynamic model.

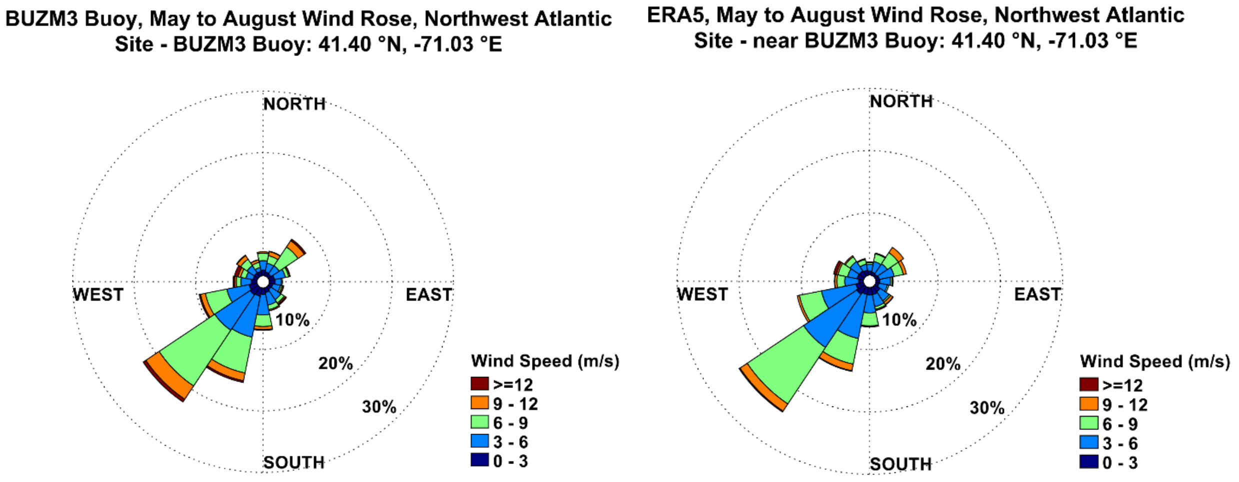

Figure 2-2: Comparison between wind measurement at the NDBC buoy BUZM3 station and interpolated ERA5 data for the same time (May to Aug. 2020).

2.1.3 Sea Surface Height (Tides)

To appropriately force the open boundaries of the hydrodynamic model, surface tidal elevation at the open boundaries should be defined to appropriately model the ingoing and outgoing tidal flow into the domain. The specification of the water surface elevation can be introduced to the model in one of two methods: (1) defining tidal harmonic constituents (e.g., M2, K1, O1, S2, etc.) amplitude and phase, or (2) applying tidal time series. For these purposes, tidal harmonic constituents were used for forcing the model in deep water, while time series were used for both forcing at shallow areas and for model validation.

Based on the first method, nine harmonic constituents (i.e., the phase and amplitude of M2, S2, N2, K1, K2, O1, P1, Q1, and M4), which are the largest constituents in this AOI, were derived from the Oregon State University Tidal Prediction Software (OTPS) at the offshore open boundaries.

OTPS allows extracting harmonic constants from the TOPEX/Poseidon Global Inverse Solution tidal model (TPXO) at given locations (Egbert & Erofeeva, 2002). TPXO was developed by assimilating altimetry and coastal tide gauge data into shallow water Laplace tidal equations on a 1/30° (approximately 3 km) bathymetric grid, based on the Oregon State University Tidal Inversion Software (OTIS; Egbert et al.,1994; Egbert & Erofeeva, 2002). The depth grid for TPXO was made from the GEBCO bathymetry model and from regional bathymetry data (Seifi et al., 2019). The implementation of the TPXO data is further discussed in Section 2.2.3.

Where the resolution of TPXO was not sufficient, sea surface height characteristics were downloaded from available NOAA Tidal Stations (Table 2-1) to develop model forcing at the tidal open boundaries closer to coastlines. Astronomical tidal elevation time series from NOAA Stations 8531680 (Sandy Hook), 8465705 (New Haven) and 8447385 (Buzzards Bay) available at a 6-minute timestep were obtained for the entirety of 2020 (Table 2-1) and fed to the model as timeseries at their associated open boundaries.

Inside the modeling domain, tidal elevation observations were used to calibrate and validate the hydrodynamic model predictions. The annual tide elevation time series from eight stations were obtained for 2020 for calibration and validation (Table 2-1).

2.1.4 River Data

River flux data were collected from four US Geological Survey (USGS) monitoring stations at Shetucket, Quinebug, Quinnipiac, and Connecticut rivers (see Figure 2-1 and Table 2-1), as they contribute to significant discharges near the locations of the cable routes. Discharges from these four rivers impact the flow and circulation of the estuarine environment along the coast. The 15-minute flow rate data from these stations were specified in the model as discharge open boundary conditions as a function of time (see Section 3.2.3).

2.1.5 Ocean Current Observations

This study used ocean current (water column) data from May 1, 2020 to September 1, 2020 to provide observations of the currents as a function of depth, as detailed in Table 2-1. The current observations were used to verify model predictions through comparisons of time series at the time of simulation.

2.2 Delft3D Model Application

The Delft3D FM modeling suite (Deltares, 2022) was used to develop a hydrodynamic model application for the areas offshore northeastern US to capture the circulation patterns and provide the hydrodynamic input for the sediment dispersion modeling. The Delft3D FM modeling suite can carry out simulations of non-steady flows, sediment transports, waves, water quality, morphological developments, and ecology with structured (e.g., rectilinear, curvilinear) or flexible mesh and finite volume code. The mesh can be constructed using a variety of polygonal elements, with up to six side grids. This allows for easy construction of model grids that conform well to complex shorelines and sinuous channels, which can include high degrees of mesh resolution in areas only where it is desired. This modeling suite is widely used for hydrodynamics studies and a standard academic approach that has been validated with lab experiments (Google Scholar, 2022).

2.2.1 Model Description and Scenarios

The hydrodynamic module D-Flow FM, as part of Delft3D FM modeling suite, simulates tidal and/or meteorological forced unsteady flow and transport phenomena (Deltares, 2022). D-Flow FM solves the one-, two- and three-dimensional shallow-water equations (Kernkamp et al., 2011; Lesser et al., 2004). The flow is forced by tide at the open boundaries, freshwater inputs (riverine discharge), and wind stress at the free surface.

D-Flow FM is a multi-dimensional, boundary-fitted hydrodynamic model that operates with either cartesian or spherical coordinates (Deltares, 2022). The unstructured mesh grid utilizes a boundary-fitting technique, which matches the grid coordinates with shoreline and bathymetric feature boundaries for highly accurate representations of areas with complex coastal or riverine geometries. This allows for easy development of model grids that conform well to complex shorelines and sinuous channels and can include high degrees of mesh resolution in areas only where it is desired. D-Flow FM may be applied in either two or three dimensions depending on the nature of the problem and the complexity of the study.

The boundary-fitted model solves a series of non-linear shallow water equations derived from the three-dimensional Navier-Stokes equations with Boussinesq approximation for incompressible free surface flow (Deltares, 2022). In cases where non-hydrostatic modeling is required, additional components can be added to make the equations practically equivalent to the incompressible Navier-Stokes equations.

Two vertical grid co-ordinate systems are available, the sigma-grid system (a more common application initially designed for atmospheric models) and the Z-grid system (for simulations of weakly forced stratified water systems). The sigma-grid has several layers bounded by two sigma-planes, which follow the bottom topography and the free surface (Figure 2-3) to obtain a smooth representation of the topography. The Z-grid has horizontal coordinate lines that are (nearly) parallel with density interfaces (isopycnals) in regions with steep bottom slopes for modeling stratified systems with horizontal density gradient (Deltares, 2022).

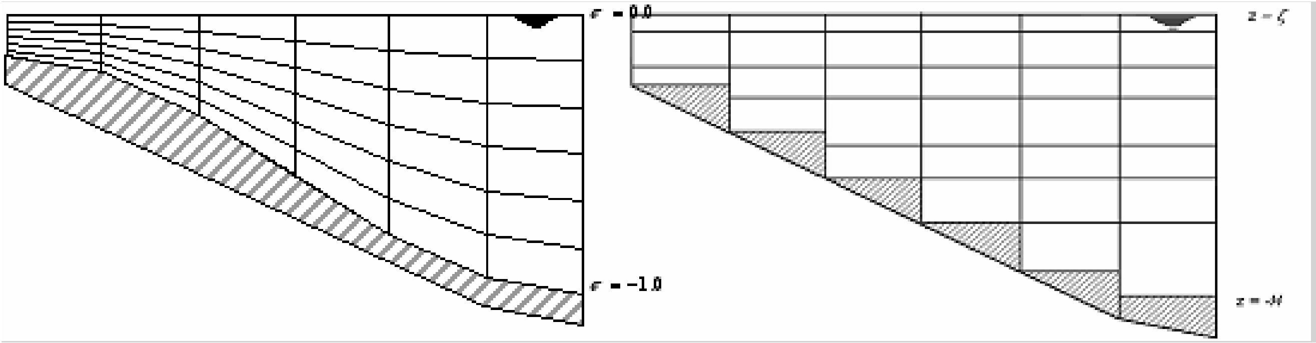

Figure 2-3: Schematic of the D-Flow FM vertical sigma (left) and vertical Z-coordinate (right) systems (Deltares, 2022).

The model was run using a variable time step that is determined based on the metrics of model stability as a function of velocity, water depth, and grid cell size (also known as Courant Number). The maximum model time step was set at 30 seconds. The full model was ultimately run over a four-month period from May through August 2020 to cover the needs of the sediment dispersion modeling input. The model was calibrated for tidal elevation in the first month (May 2020) of modeling period (see Section 2.2.4) and validated in the remaining three months (i.e., June through August 2020) (see Section 2.2.5). The Delft3D modeling was initiated one week prior to the calibration period (April 24, 2020), serving as a warm-up period to allow the boundary condition, and forcing to propagate throughout the domain and reach an optimal state. This warm-up time frame was removed from the hydrodynamic model outputs for use in sediment dispersion modeling.

2.2.2 Model Grid

To appropriately capture the current circulation patterns in the AOI, a flexible mesh grid was developed to cover the study area using the Delft RGFGRID tool. The full extent of the hydrodynamic model grid is represented in Figure 2-4. The model domain includes tidal open boundaries, including the riverine discharge boundary conditions upriver. The domain starts just inside the edge of the continental shelf and extends north towards the coast of Cape Cod. The shoreline for the domain was developed using a 2017 Global Self-consistent, Hierarchical, High-resolution Geography Database (Wessel & Smith, 1996) to define the grid's land and water boundary.

The minimum grid cell's edge length is about 150-200 meters (m) near the coastline with larger grid cell dimensions ranging from approximately 6 to 10 km at the offshore boundary. The goal of the grid development process was to ensure there was sufficient grid resolution throughout the model domain to capture the physics accurately, especially close to the cable routes, while optimizing computational modeling time. The computational grid for the entire domain consists of 76,297 cells and 39,439 nodes.

The Delft model gridding tool, QUICKIN, was then used to grid the bathymetry data assigning a unique depth value to each cell, either through averaging, for multiple values in a designated cell, or interpolating for the occasional cell where no depth data are available (see Section 2.1.1). The resulting grid and associated depths relative to MSL were then manually checked for outliers. The maximum depth in the model bathymetry is 294 m close to the offshore southern open boundary (Figure 2-5).

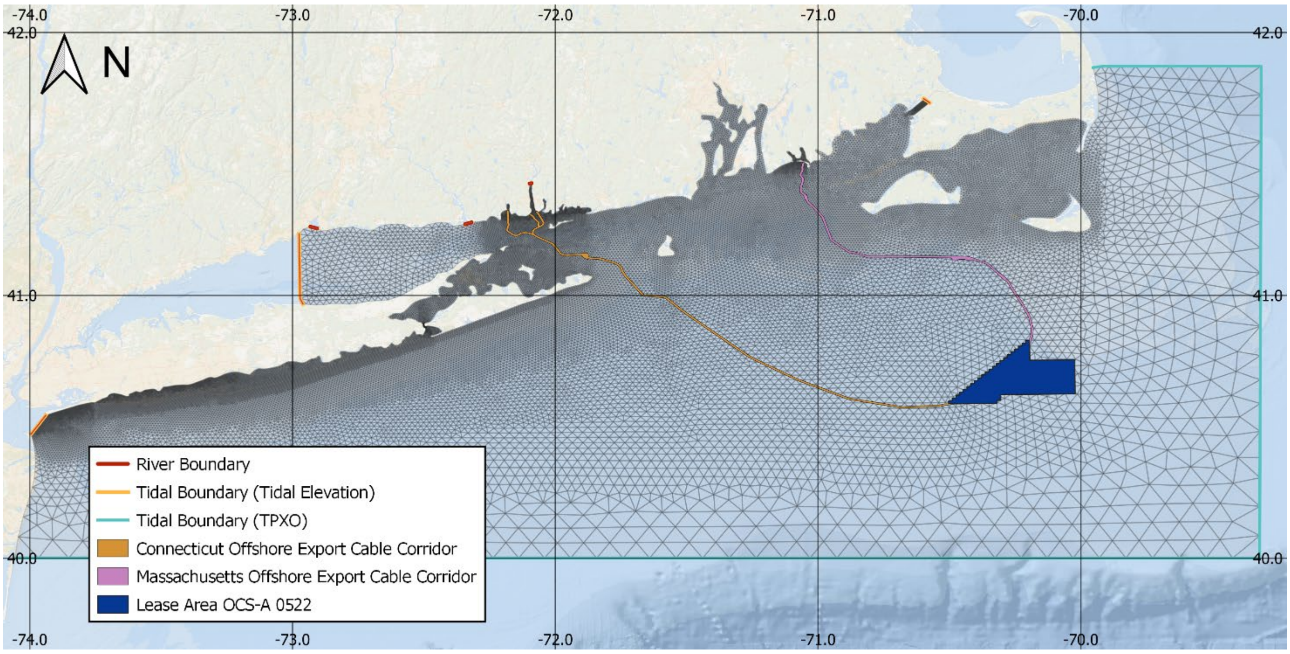

Figure 2-4: D-Flow FM model grid coverage of the Vineyard Wind AOI, and location of open boundaries.

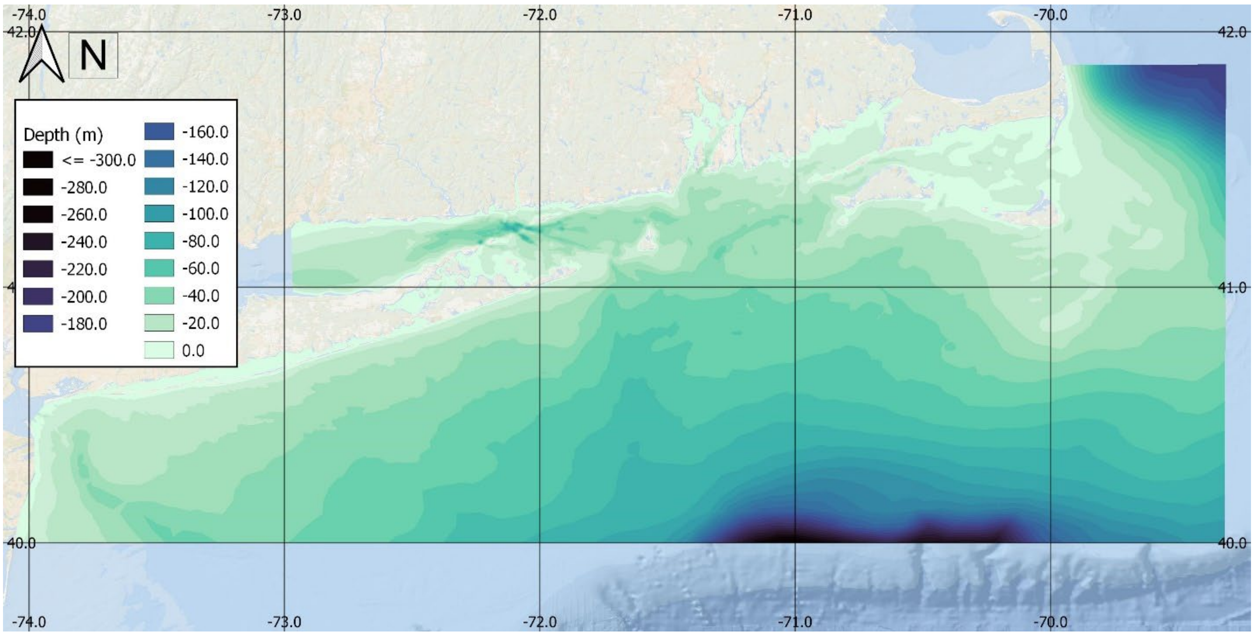

Figure 2-5: Illustration of the bathymetry of the domain interpolated to the D-Flow FM.

2.2.3 Model Boundary Conditions

Model boundary conditions for this application include specification of tidal characteristics and river discharge at open boundaries, in addition to surface winds applied to all cell surfaces. Boundary conditions, as mapped in Figure 2-4, are:

Meteorological Boundary Conditions

The wind forcing at the surface boundary covers the entire gridded area. Meteorological data were obtained from the ERA5 model dataset and applied to the entire grid surface as U (Eastward) and V (Northward) velocities.

Tidal Boundary Conditions

The D-Flow FM model requires water levels, or tidal phase and amplitude, prescribed along open boundaries. For this modeling study, the northern, eastern, and southern open boundaries of the model domain are located on the Atlantic Ocean (see Figure 2-4). These tidal boundaries allow the transfer of external tidal flow into the domain. Tidal amplitude and phases of harmonic constituent were extracted from the TPXO dataset at each offshore boundary node. Water levels were also prescribed along the other three open boundaries in the model domain, closer to coastlines. These water level boundaries conditions were prescribed with time series data from three NOAA stations (Table 2-1) at New Haven, Sandy Hook, and Buzzards Bay.

Riverine Boundary Conditions

River discharges were included from four rivers of Shetucket, Quinebug, Quinnipiac, and Connecticut with significant flows into the model domain. The boundary conditions were specified by a time series extracted from the corresponding USGS gauge and applied to the Delft3D model at 15-minute intervals. The Quinebaug and Shetucket River fluxes were combined into a single flux time series, as the two rivers merge just north of the model grid domain (see Figure 2-4).

2.2.4 Model Calibration

Several parameters in the Delft3D setup were analyzed before finalizing the model for hindcast simulation. These parameters included horizontal resolution of the grid and bottom roughness as a Manning’s n coefficient. To find the optimum setup, sea surface height (SSH) model output from the tidal model run for May 2020 was compared with available tidal data at eight NOAA stations (see Figure 2-1 and Table 2-1). Each iteration of the grid development included additional horizontal grid resolution close to the station until adequate agreement was found between the model and NOAA tide signal. The Manning’s n coefficient, which parameterizes bottom roughness in the model, was also modified to calibrate the model output with the NOAA tide signal. Calibration comparisons of the modeled tide outputs and NOAA harmonic tides are shown in Figure 2-6 and Figure 2-7.

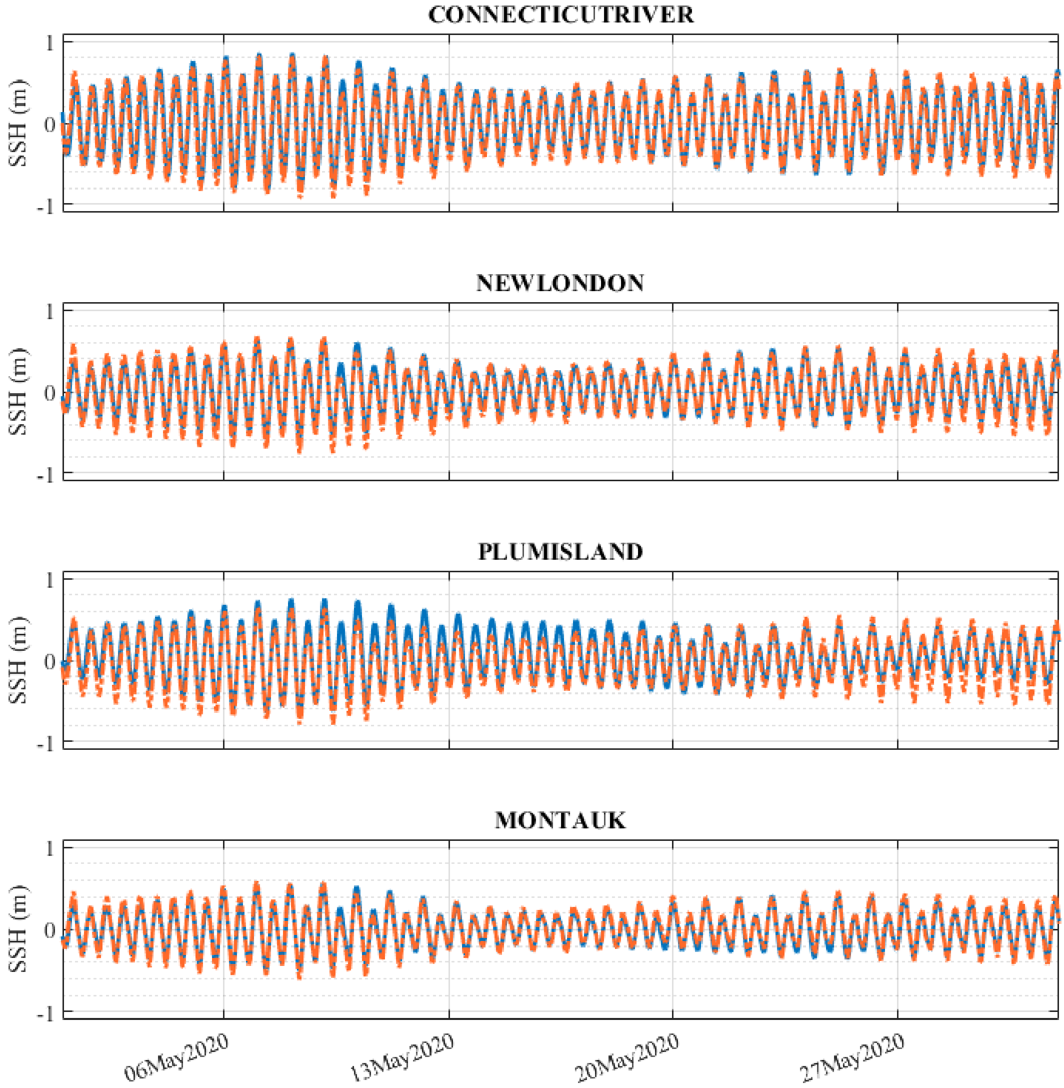

Figure 2-6: SSH of NOAA station (blue) and Delft3D (orange dashed) at the first four of the eight tidal stations (Table 2-1) relative to MSL, during the calibration period (May 2020).

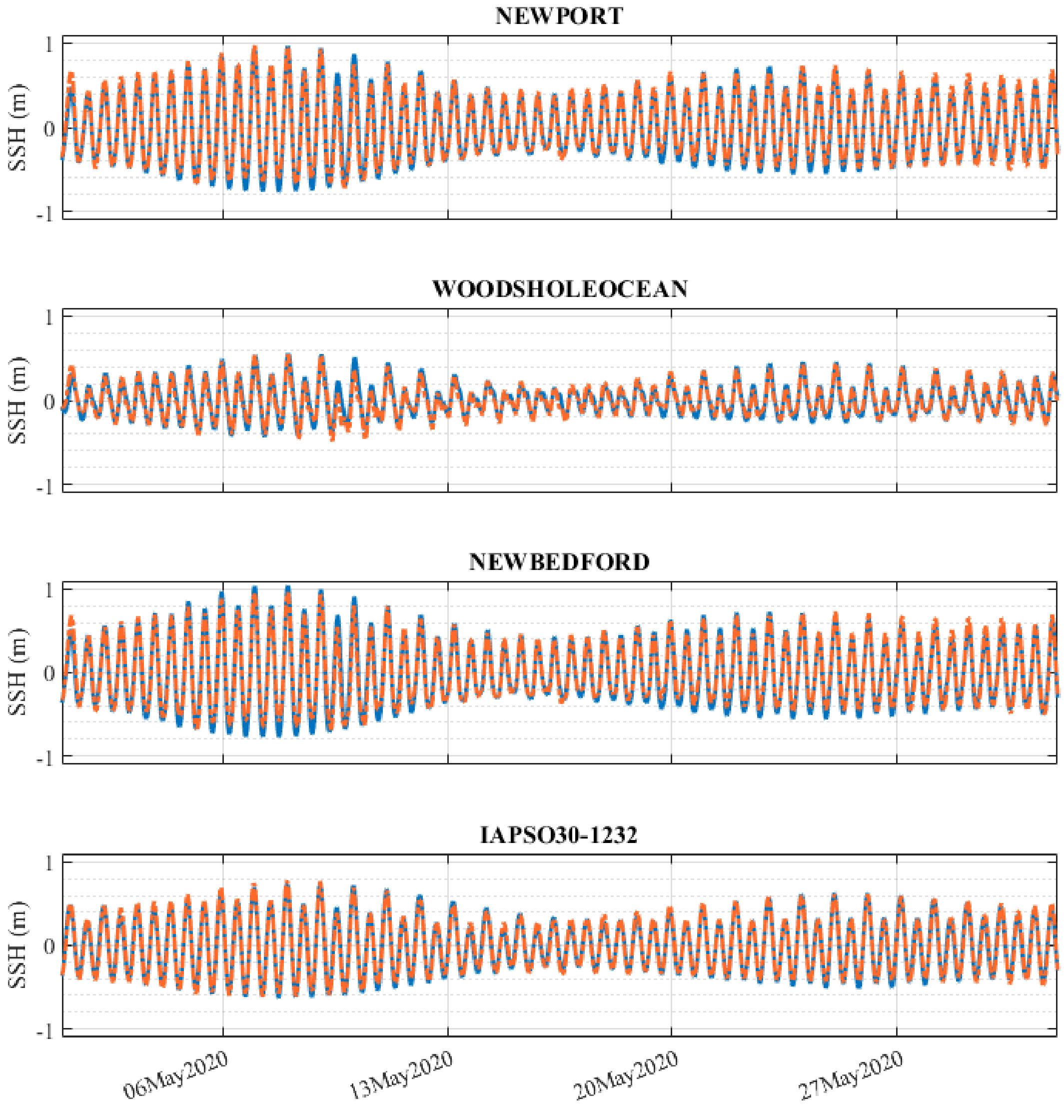

Figure 2-7: SSH of NOAA station (blue) and Delft3D (orange dashed) at the other four of the eight tidal stations (Table 2-1) relative to MSL, during the calibration period (May 2020).

Also Figure 2-8 shows in the comparison of U and V components of current, at the Plum Gut LIS1012 current stations (Figure 2-1) at ~30 m depth. As the figures illustrate, there is good agreement in the magnitude and phase of tidal current in comparison with the measurements. The figure shows the model was able to recreate the semidiurnal tidal pattern and the spring/neap tidal amplitude cycle. Although the Delft3D model seems to underestimate the V component of the current, there is a good performance capturing the magnitude of the U component. The difference between the observation and the model can be contributed to the current depth measurements (discussed further in Section 2.2.5).

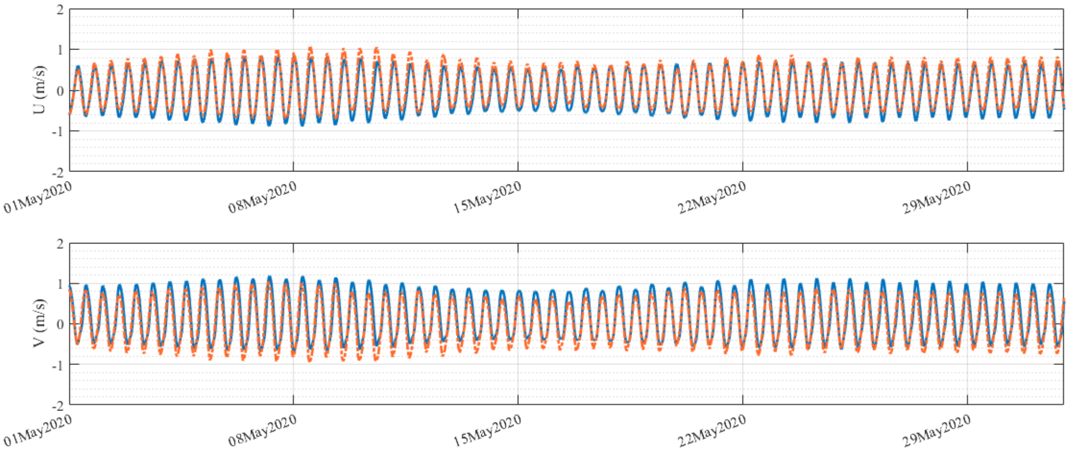

Figure 2-8: Surface current velocity components of NOAA station (blue) and Delft3D (orange dashed) at Plum Gut LIS1012 Station for the calibration period (May 2020).

2.2.5 Model Validation

The Delft3D model was validated for the three-month period beginning on June 1, 2020 through September 1, 2020. Model output SSH during the validation period were compared with available tidal data at eight NOAA stations (Figure 2-9 and Figure 2-10). Also, comparisons of U and V currents at a harmonic current station (see Figure 2-1) is shown in Figure 2-11. The model skill of the Delft3D derived SSH and currents (U and V) were quantitatively examined using several statistical metrics for the comparisons to observations, including Root-Mean Square Error (RMSE) and Mean Absolute Error (MAE). These metrics are used to indicate the accuracy of the predictions and the amount of deviation from the actual values. Descriptions of these statistical metrics are given below.

The RMSE calculates the average magnitude of deviations between two datasets. For our analyses, RMSE will quantify the deviation between measured data (Xobs) and modelled data (Xmodel), where both datasets have the same units. Smaller values suggest better agreement between measured and predicted values. The RMSE is evaluated as follows:

$$RMSE = \sqrt{\frac{1}{N}\sum_{n=1}^{N}(X_{model} - X_{obs})^2}$$

As the errors are squared before they are averaged, RMSE generates a relatively high weight to large errors.

The MAE quantifies the average magnitude of deviations between measured data ($Xobs$) and modelled data ($Xmodel$) as follows:

$$MAE = \frac{1}{N}\sum_{n=1}^{N}|X_{model} - X_{obs}|$$

A smaller value of MAE indicates better agreement between measured and calculated values.

Table 2-3 shows the statistical comparisons of SSH and current components at the NOAA harmonic stations with the model prediction. Statistical analysis of SSH at all eight stations show good agreement between the model and observations. At Plum Gut Station, the statistical analyses of eastward (U component) and northward (V component) velocities show that in general, the model skill is better for the U component of current velocity than the V component with component RMSE of 0.21 m/s and an MAE of 0.19 m/s. The higher error in V component could be associated with the influence of Plum Island in the bathymetry, as it is only a few cells away from the station. The sharp changes in bathymetry between the island and the station, are only represented by two grid cells.

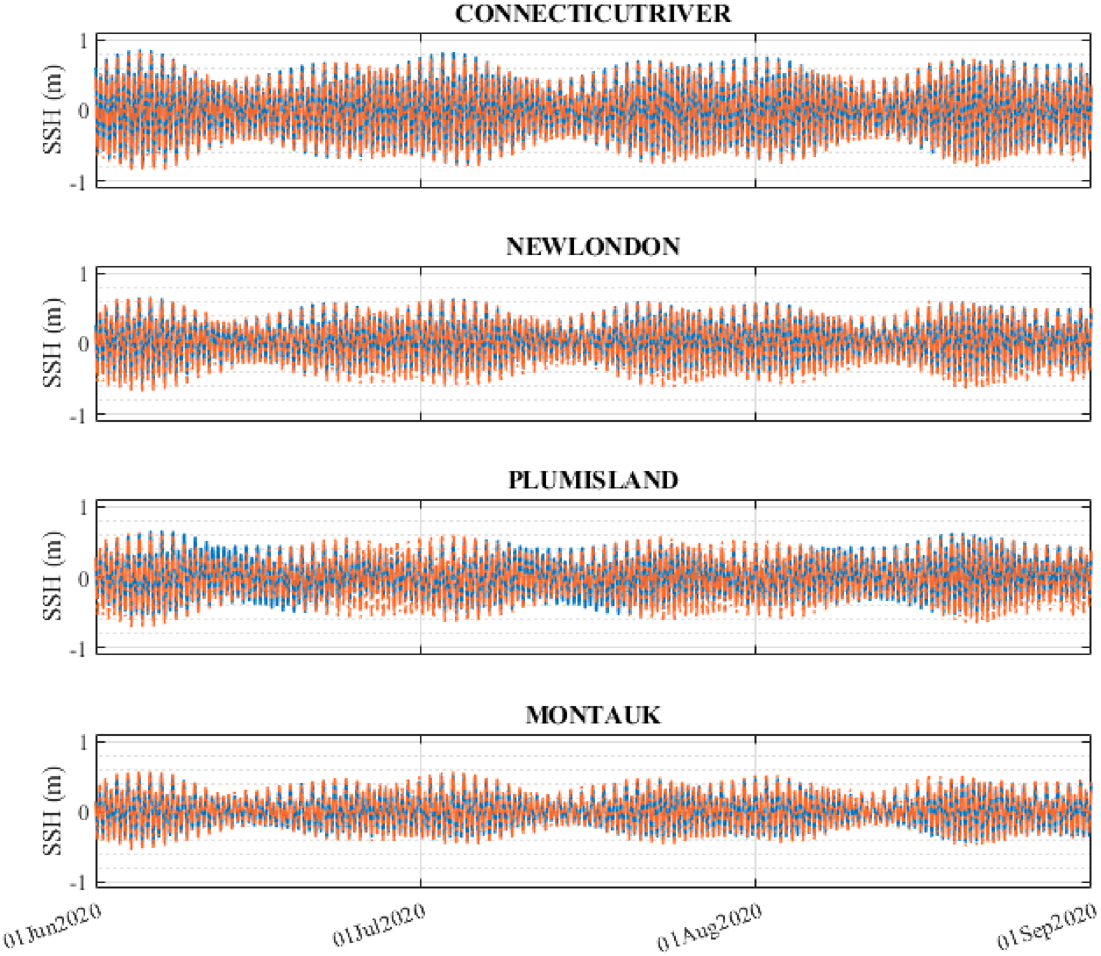

Figure 2-9: SSH of NOAA station (blue) and Delft3D (orange dashed) at the first four of the eight tidal stations (see Table 2-1) during the validation period (June 2020 through August 2020).

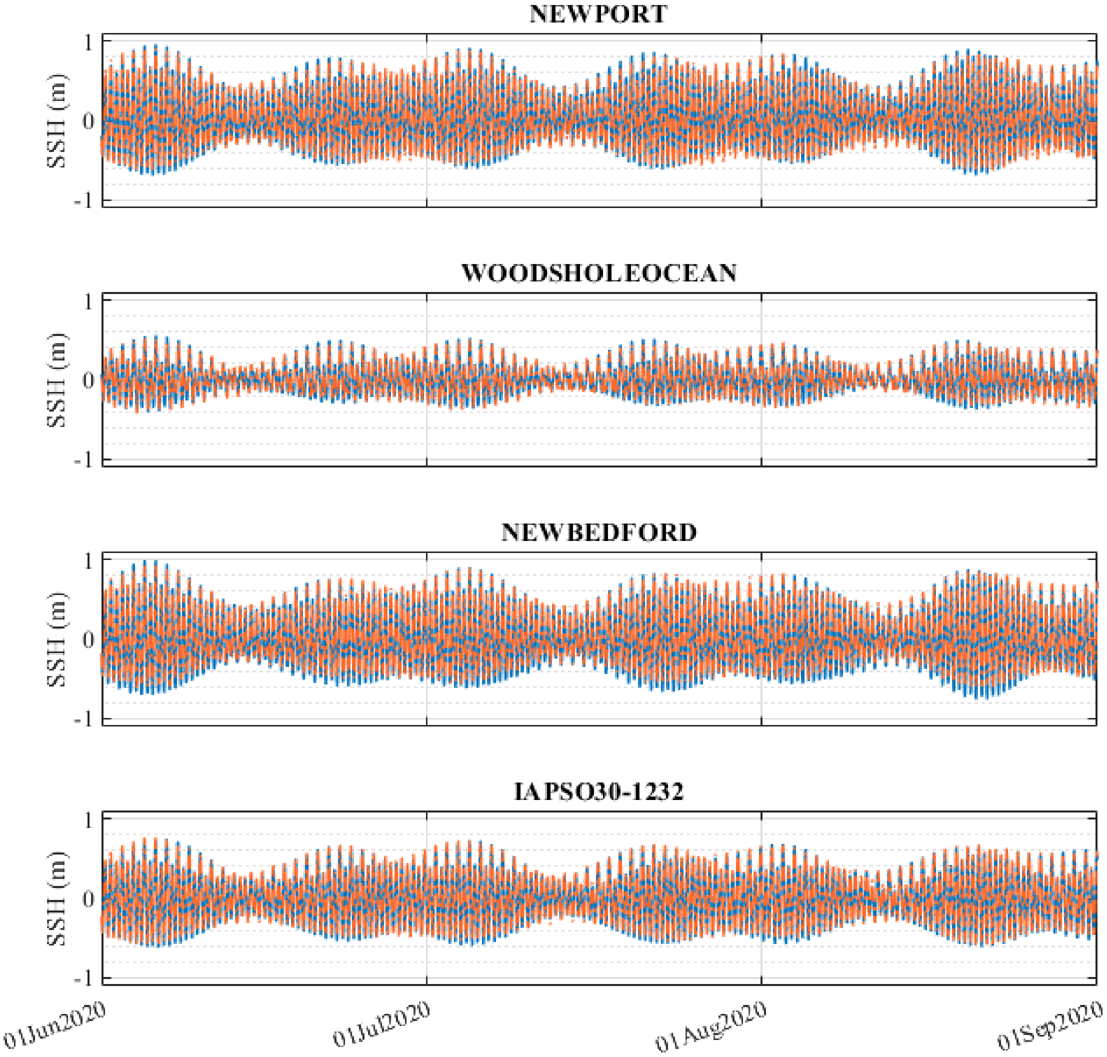

Figure 2-10: SSH of NOAA station (blue) and Delft3D (orange dashed) at the other four of the eight tidal stations (see Table 2-1) during the validation period (June 2020 through August 2020).

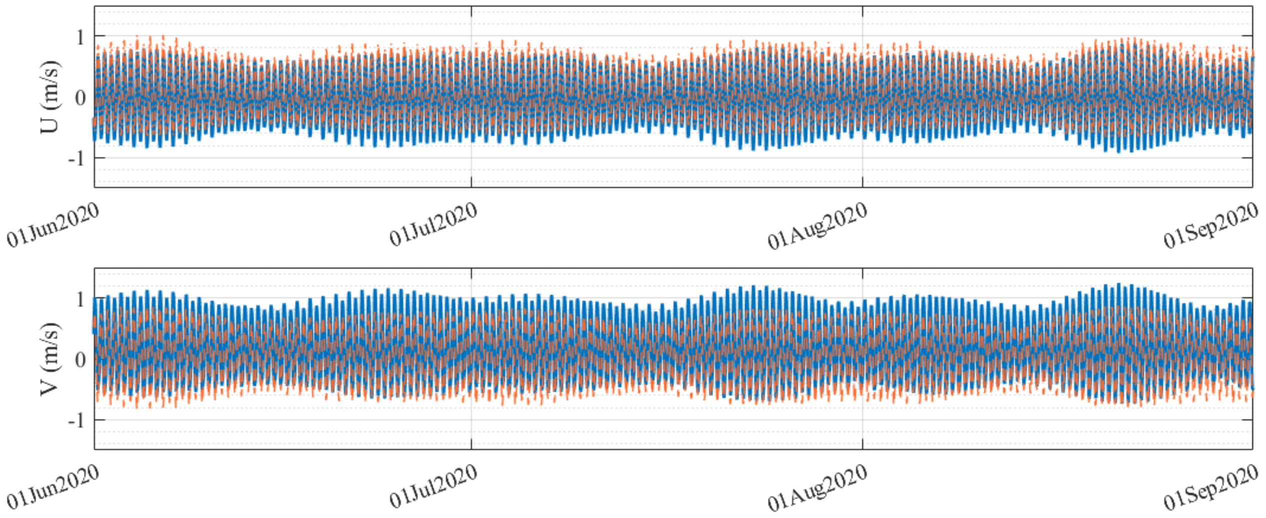

Figure 2-11: U and V current components of NOAA station (blue) and Delft3D (orange dashed) at Plum Gut LIS1012 Station.

Table 2-3: Statistical evaluation of model performance.

Variable	Station	RMSE	MAE
SSH (m)	NOAA 8462764	0.11	0.09
	NOAA 8461490	0.08	0.07
	NOAA 8511236	0.10	0.08
	NOAA 8510560	0.05	0.04
	NOAA 8452660	0.06	0.05
	NOAA 8447930	0.05	0.03
	NOAA 8447712	0.08	0.06
	IAPSO1232	0.02	0.01
U (m/s)	LIS1012 (Plum Gut)	0.21	0.19
V (m/s)	LIS1012 (Plum Gut)	0.28	0.25

2.2.6 Application to Sediment Modeling

Following the model validation, a scenario time period of June 1, 2020 to September 1, 2020 was used as a window of time that could be used as forcing for the sediment dispersion modeling. All forcings and boundary conditions as described in previous sections were included in this simulation, including spatially varying winds from the ERA5 dataset, and open boundary conditions.

3 SEDIMENT MODELING

3.1 SSFATE Modeling Approach

Sediment transport associated with the cable burial activities was simulated using RPS's SSFATE model. The model requires inputs defining the environment (e.g., water depths, currents) and the construction activity loading (e.g., sediment grain size, resuspended volume) to predict the associated sediment plume and seabed deposition. Details of the model and theory are provided in the following sections.

3.1.1 SSFATE Model Description

SSFATE is a three-dimensional Lagrangian (particle) model developed jointly by the USACE' Environmental Research and Development Center and Applied Science Associates (now part of RPS) to simulate sediment resuspension and deposition originally from marine dredging operations. Model development was documented in a series of USACE' Dredging Operations and Environmental Research Program technical notes (Johnson et al. 2000; Swanson et al. 2000), at previous World Dredging Conferences (Anderson et al. 2001), and at a series of Western Dredging Association Conferences (Swanson et al. 2004; Swanson & Isaji 2006). Following dozens of technical studies, which demonstrated successful application to dredging, SSFATE was further developed to include simulation of cable and pipeline burial operations using water jet trenchers (Swanson & Isaji. 2006) and mechanical ploughs as well as sediment dumping and dewatering operations. The current modeling system includes a GIS-based interface for visualization and analysis of model output.

SSFATE computes TSS concentrations in the water column and sedimentation patterns on the seabed resulting from sediment-disturbing activities. The model requires a spatial and time-varying circulation field (typically from hydrodynamic model output), definition of the water body bathymetry, and parameterization of the sediment disturbance (source), which includes sediment grain size data and sediment flux description. The model predicts the transport, dispersion, and settling of suspended sediment released to the water column. The focus of the model is on the far-field processes (i.e., beyond the initial disturbance) affecting the dispersion of suspended sediment. The model uses specifications for the suspended sediment source strengths (i.e., mass flux), vertical distributions of sediments, and sediment grain-size distributions to represent loads to the water column from different types of mechanical or hydraulic dredges, sediment dumping practices, or other sediment-disturbing activities, such as jetting or ploughing for cable or pipeline burial. Multiple sediment types or fractions can be simulated simultaneously, as can discharges from moving sources.

SSFATE has been successfully applied to a number of recent modeling studies with these studies receiving acceptance from federal and state regulatory agencies.

3.1.2 Model Theory

SSFATE addresses the short-term movement of sediments that are disturbed during mechanical ploughing, hydraulic jetting, dredging, and other processes where sediment is suspended into the water column. The model predicts the three-dimensional path and fate of sediment particles based on sediment properties, sediment loading characteristics, and environmental conditions (e.g., bathymetry and currents). The computational model uses a Lagrangian or particle-based scheme to represent the total mass of sediments suspended over time, which provides a method to track suspended sediment without any loss of mass as compared to Eulerian (continuous) models due to the nature of the numerical approximation used for the conservation equations. Thus, the method is not subject to artificial diffusion near sharp concentration gradients and can easily simulate all types of sediment sources.

Sediment particles in SSFATE are divided into five size classes, each having unique behaviors for transport, dispersion, and settling (Table 3-1). For any given location (segment of the route), the sediment characterization is defined by this set of five classes, with each class representing a portion of the distribution and all five classes summing to 100%. The model determines the number of particles used per time step depending on the model time step and overall duration thereby ensuring an equal number of particles is used to define the source throughout the simulation. While a minimum of one particle per sediment size class per time step is enforced, typically multiple particles are used. The mass per particle varies depending on the total number of particles released, the grain size distribution, and the mass flux per time step.

Table 3-1: Sediment Size Classes used in SSFATE.

Description	Class	Type	Size Range (microns)
Fine	1	Clay	0-7
↓	2	Fine silt	8-35
	3	Coarse silt	36-74
Coarse	4	Fine sand	75-130
	5	Coarse sand	>130

Horizontal transport, settling, and turbulence-induced suspension of each particle are computed independently by the model for each time step. Particle advection is based on the relationship that a particle moves linearly, in three-dimensions, with a local velocity obtained from the hydrodynamic field, for a specified model time step. Diffusion is assumed to follow a simple random walk process, with the diffusion distance defined as the square root of the product of an input diffusion coefficient, and at each time step is decomposed into X and Y displacements via a random direction function. The vertical Z diffusion distance is scaled by a random positive or negative direction.

Particle settling rates are calculated using Stokes equations and are based on the size and density of each particle class. Settling of mixtures of particles is a complex process due to interaction of the different size classes, some of which tend to be cohesive and thus clump together to form larger particles that have different settling rates than would be expected based on their individual sizes. Enhanced settlement rates due to flocculation and scavenging are particularly important for clay and fine-silt sized particles (Swanson et al., 2004; Teeter 1998), and these processes have been implemented in SSFATE. These processes are bound by upper and lower concentration limits, defined through empirical studies, which contribute to flocculation for each size class of particles. Above and below these limits, particle collisions are either too infrequent to promote aggregation or so numerous that the interactions hinder settling.

Deposition is calculated as a probability function of the prevailing bottom stress and local sediment concentration and size class. The bottom shear stress is based on the combined velocity due to waves (if used) and currents using the parametric approximation by Soulsby (1998). Sediment particles that are deposited may be subsequently resuspended into the lower water column if critical levels of bottom stress are exceeded, and the model employs two different resuspension algorithms. The first applies to material deposited in the last tidal cycle (Lin et al., 2003). This accounts for the fact that newly-deposited material will not have had time to consolidate and will be resuspended with less effort (lower shear force) than consolidated bottom material. The second algorithm is the established Van Rijn (1989) method and applies to all other material that has been deposited prior to the start of the last tidal cycle. Swanson et al. (2007) summarize the justifications and tests for each of these resuspension schemes. Particles initially released by operations are continuously tracked for the length of the simulation, whether in suspension or deposited.

For each model time step, the suspended concentration of each sediment class as well as the total concentration is computed on a concentration grid. The concentration grid is a uniform rectangular grid in the horizontal dimension with user-specified cell size and a uniform thickness in the vertical dimension (z-grid). The concentration grid is independent of the resolution of the hydrodynamic data used to calculate transport, thus supporting finer spatial differentiation of plume concentrations and avoiding underestimation of concentrations caused by spatial averaging over larger volumes/areas. Model outputs include but are not limited to: water-column concentrations in both horizontal and vertical dimensions; time-series plots of suspended sediment concentrations at points of interest; and thickness contours of sediment deposited on the seafloor. Deposition is calculated as the mass of sediment particles that accumulate over a unit area and is calculated on the same grid as concentration. Because the amount of water in the deposited sediment is unknown, by default, SSFATE converts deposition mass to thickness by assuming no water content.

For a detailed description of the SSFATE model equations governing sediment transport, settling, deposition, and resuspension, the interested reader is directed to Swanson et al. (2007).

3.2 SSFATE Data Needs

The sediment modeling was carried out using RPS in-house model SSFATE. Setup of an SSFATE model scenario consists of defining how each sediment disturbance activity will be parameterized, establishing the sediment source terms, and defining environmental and numerical calculation parameters. For each scenario, the source definition includes:

- Sediment characteristics (e.g., grain size distribution, moisture content) along the route;
- The geographic extent of the activity (point release versus line source [route]);
- Timing and duration of the activity;
- Volumes, cross-sectional areas, and depths of the trench or excavation pit;
- The production rate for each sediment disturbance method;
- Loss (mobilization) rates for each sediment disturbance method; and
- The vertical distribution of sediments as they are initially released to the water column.

The sediment source for dredging and cable installation simulations are defined through a load source file, which defines the location of the sources, mass flux of sediment disturbed through operations, loss rate of the disturbed flux resuspended into the water column, vertical position of the mass introduced to the water column, and grain size distribution of the mass introduced to the water column along the route of installation. A component of the sediment grain size distribution is a definition of the percent solids, which is used in the mass flux calculation. Bed sediments contain some water within interstitial pore spaces, and therefore the trench volume consists of both sediment and interstitial water. Therefore, the percent solid of the sediment sample, as based on laboratory measure of moisture content, is used in the calculation of total mass flux. The sediment source can vary spatially, and therefore the line source file is broken into multiple discrete entries, each representing a segment of the route with uniform characteristics. The segments are defined to capture curved route geometry and provide a continuous route aligned with the installation plan.

A model scenario also requires characterization of the environment, including a definition of the study area’s spatially and time-varying currents (Delft3D output) and water body bathymetry. Model setup also requires specification of the concentration and deposition grid, which is the grid at which concentration and deposition calculations are made. The concentration and deposition grid in SSFATE is independent of the resolution of the bathymetric data (Section 2.1.1) or hydrodynamic model grid (Section 2.2.2); this allows finer resolution which better captures water column concentrations without being biased by numerical diffusion. The concentration and deposition gridding are based on a prescribed square grid resolution in the horizontal plan view and a constant thickness in the vertical. The extent of the concentration is determined dynamically, fit to the extent the sediments travel.

The following sections describe the sediment characteristics used in modeling (Section 3.2.1), model timeframe (Section 3.2.2), and the relevant input parameters used in this assessment (Section 3.2.3 and 3.2.4).

3.2.1 Sediment Characteristics

The sediment characteristics are a key factor of the sediment load definition input to the SSFATE model. The spatially-varying sediment characteristics were developed based on analysis of samples from multiple surveys. The details of the sediment sampling and laboratory analysis are documented in Appendix II-B of the COP; however, an overview of the RPS sediment data analysis as it pertains to the sediment characterization used in the modeling is discussed herein. The objective of the RPS analysis of the sediment data was to develop the sediment characteristics that represent either the upper 2 or 3 m of the seabed, since those are the target depths of cable installation and represent the depth of sediments that may get resuspended during installation activities. Specifically, the objective was to determine the distribution within the five delineated classes used in SSFATE (Table 3-1) and the percentage of the upper seabed that is solid based on the measure of sediment water content, which is a measure of the interstitial pore waters in the sediments.

The sampling included a combination of grab samples that sample the upper few centimeters of the seabed, including vibracores, which provide a vertical profile of sediments that can be analyzed at multiple depths from the profile. All samples were analyzed by a sieve, which is screens out sediments smaller than the specified sieve size. Sieve analysis is performed on multiple sizes to establish a percent finer curve, though it can only resolve the fraction of sands (i.e., coarse sand, fine sand) relative to the SSFATE classifications. Some samples also included hydrometer analysis, which is a laboratory test that can further resolve the fractions in the fine grain size classes (i.e., coarse silt, fine silt, clay). For all stations without hydrometer data, the remaining fraction (percent finer than fine sand) was split evenly between the three classes of coarse silt, fine silt, and clay.

In locations where grab samples coincided with vibracore data, the grab sample data were used to inform the vertical profile of sediment characteristics. The samples taken at depth from a vibracore were paired with the nearest grab sample to develop a composite depth weighted average sediment distribution at each vibracore sample location. In areas where vibracore data was absent and because of the increased frequency of grab samples throughout the Massachusetts OECC and Connecticut OECC, grab samples were used in the modeling assessment. At certain locations, the grab samples contained triplicate measurements and so values used in modeling were determined based on the average of the three samples. Additionally, all vibracore samples contained measurements of the water content while grab samples did not, so the percent solids (determined based on the water content of the sample) were linearly interpolated for the grab samples based on the nearest vibracore samples.

For the line sources (e.g., sand bedform dredging, cable installation), the model interpolated between vibracore and grab sample data depending on the location of the sediment disturbing activity. At the representative Massachusetts Landfall Site, the closest vibracore sample was used for modeling. For the representative Connecticut Landfall Site, no vibracore data were available at the time of the assessment so the nearest grab sample data point was used for these estimates. The grab sample grain size distribution compared well with the nearest vibracore sample and so the percent solids value from that vibracore sample was assumed in the Representative Connecticut Landfall Site HDD Exit Pit Construction modeling. Depending on the installation technique, the target trench depth varied from 2 to 3 m. Therefore, the depth-weighted sediment characteristics used in modeling reflected the target burial depth.

For the Connecticut OECC (Figure 3-1) and the Massachusetts OECC (Figure 3-2), grain size data focused on the 2 m depth-weighted values for the entire route as it was applied for the cable installation by jetting and for sand bedform dredging scenarios. The map insets show the 3 m depth-weighted values for the sensitivity analyses (e.g., vertical injector, mechanical trenching), as those required deeper target installation depths. Grain size data within the Lease Area (Figure 3-3) were compared for the 2 m depth-weighted and the 3 m depth-weighted values. The sand bedform dredging and the typical cable installation scenario used the 2 m depth-weighted data while the maximum cable installation simulation required the 3 m depth-weighted dataset.

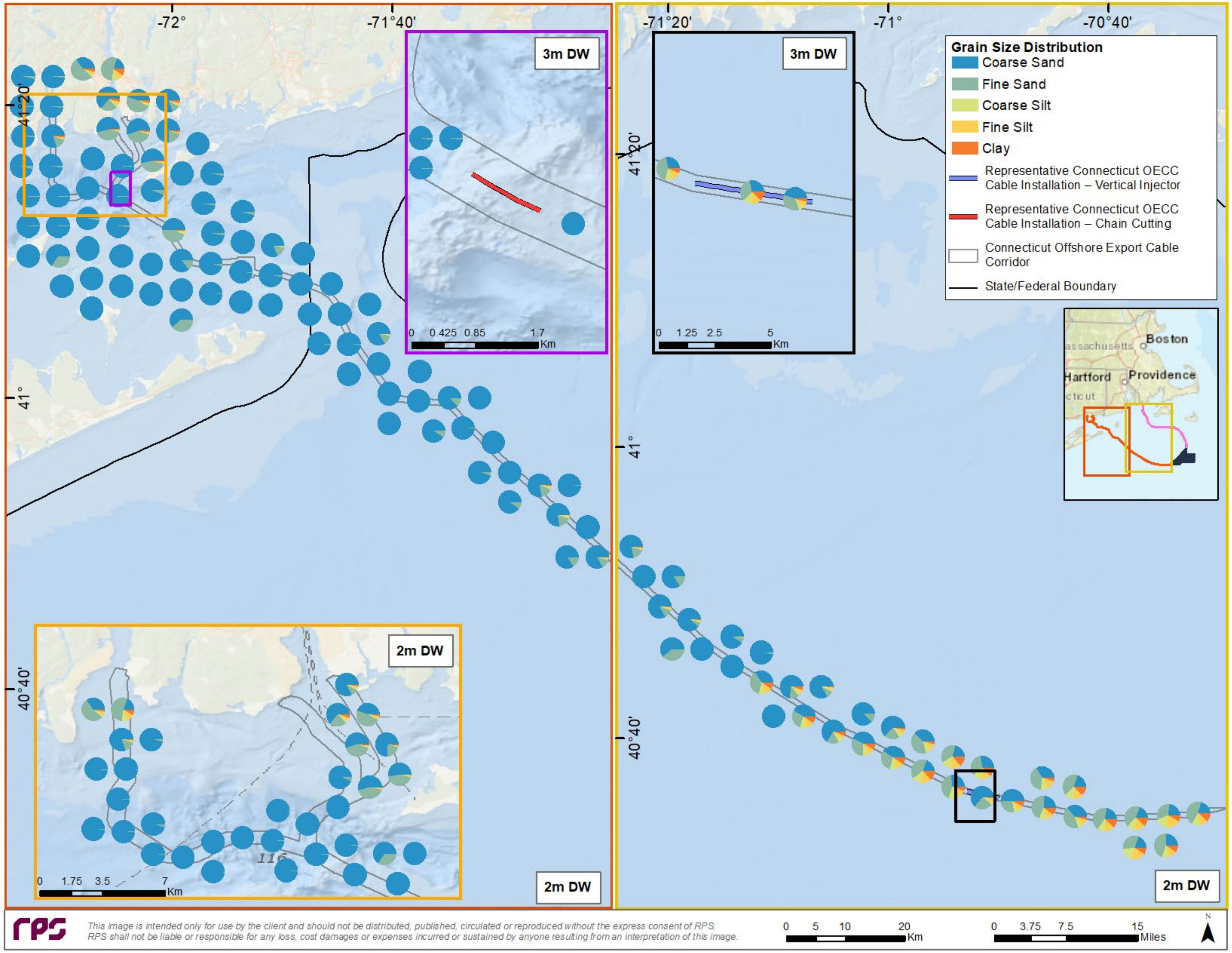

Figure 3-1: Sediment grain size distributions for the Connecticut OECC project components. Note the label in each extent identifies the target depth used to depth-weight (DW) the grain size data.

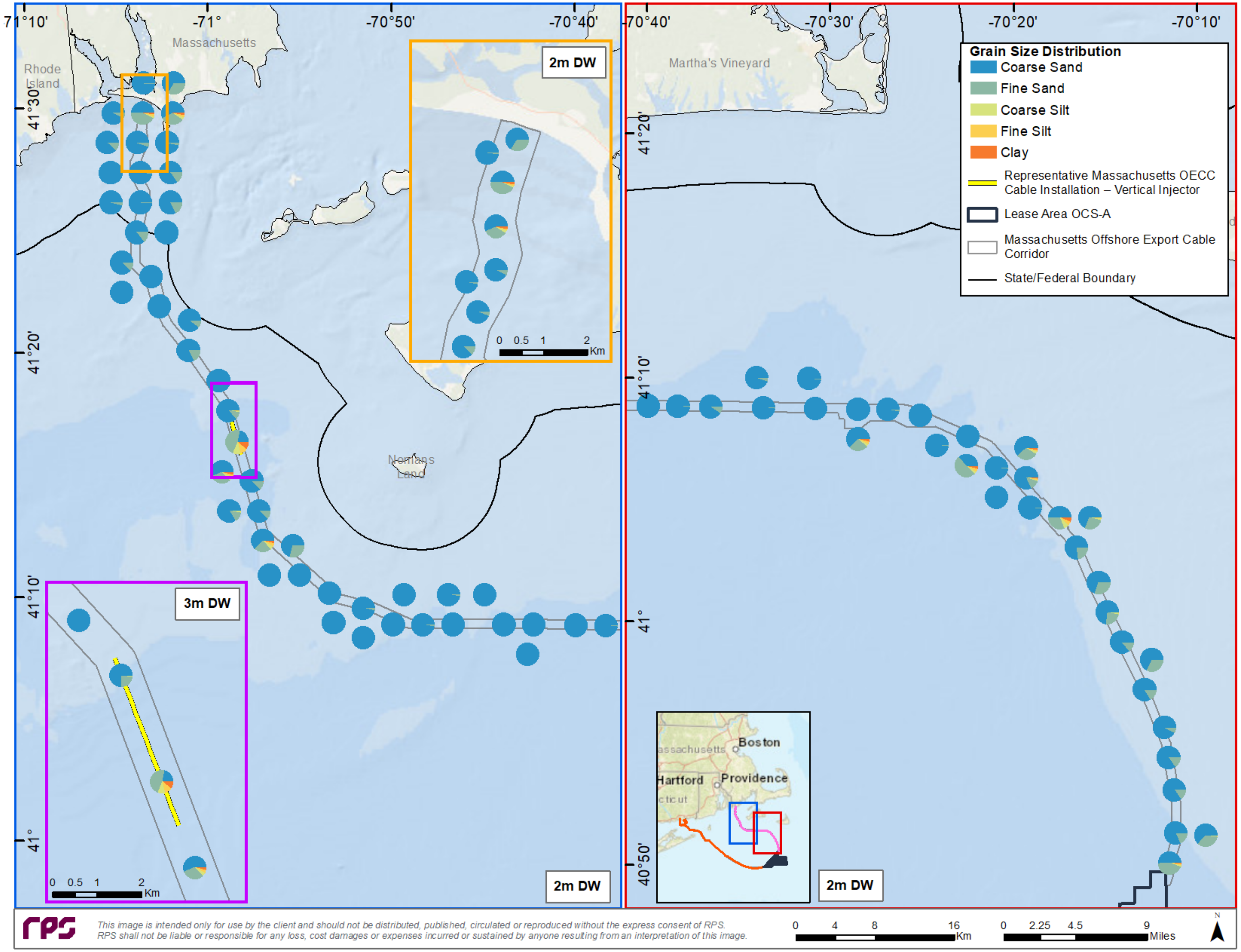

Figure 3-2: Sediment grain size distributions for the Massachusetts OECC project components. Note the label in each extent identifies the target depth used to depth-weight (DW) the grain size data.

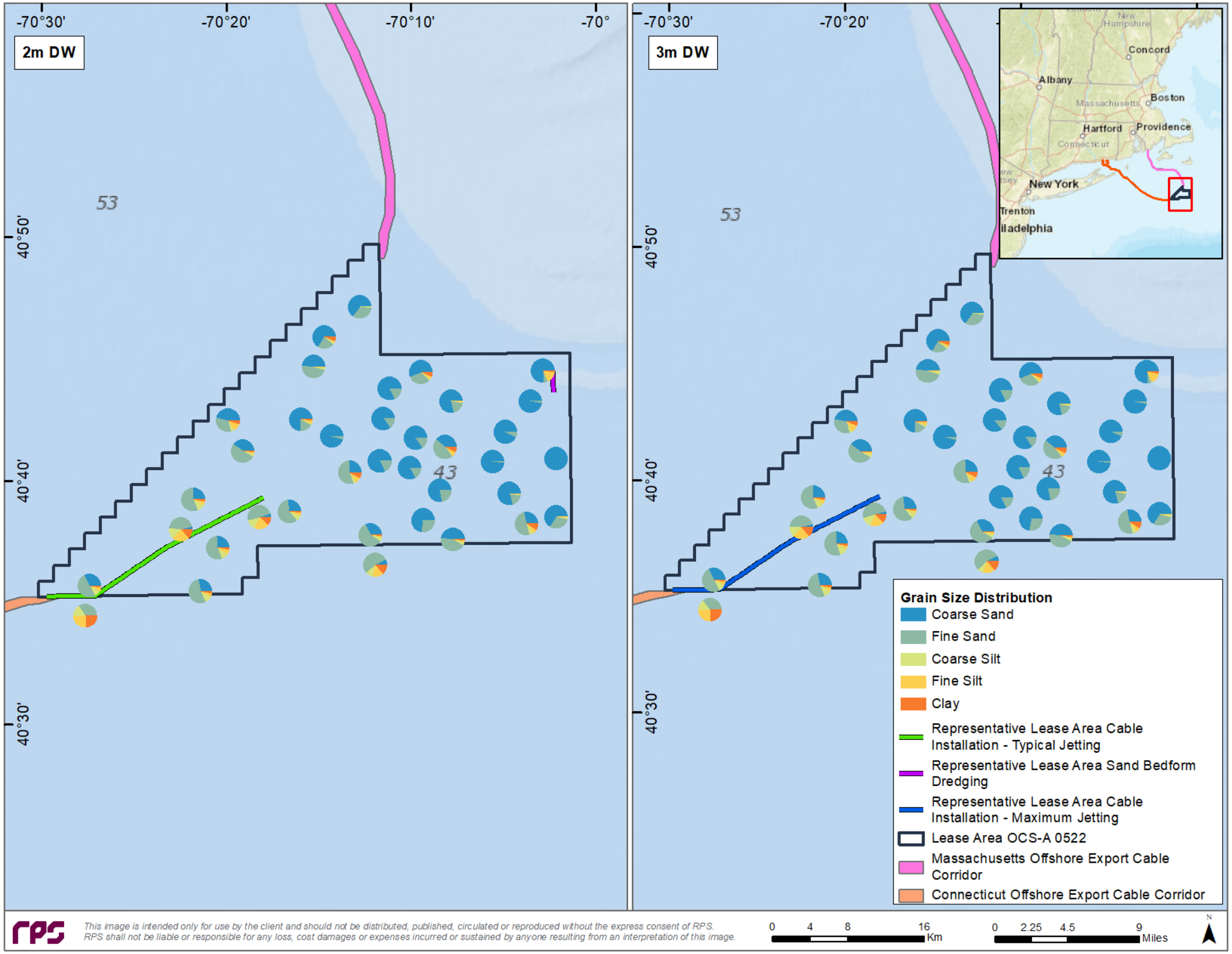

Figure 3-3: Sediment grain size distribution depth weighted (DW) for the upper 2 m (left) and upper 3 m (right) of the seabed in the Lease Area.

3.2.2 Hydrodynamic Forcing

Following the model validation, a scenario time period of June 1, 2020 to September 1, 2020 was used as a window of time that could be used as forcing for the sediment dispersion modeling (Section 2.2). Based on that available validated time period, modeling was performed during the month of June (and first two weeks of July for any scenario that simulated the entire Connecticut OECC) as the highest tide during the validation period occurred in June (Section 2.2.5), resulting in the largest currents in nearshore areas.

The start time for the modeling depended on the duration of the sediment disturbing activity. Activities that extended for longer than 12 hours experienced a minimum of one full tidal cycle (i.e., one ebb tide and one flood tide) which allowed sediment plumes to oscillate with the tides. In those instances, the models were initiated on June 1, 2020.

For scenarios when sediment disturbing activities were shorter than 12 hours (i.e., HDD exit pit construction, cable installation by Mechanical Trenching), preliminary studies were preformed to determine which tidal stage (i.e., ebb vs. flood) caused the worst impacts. For both the Connecticut and Massachusetts Landfall Sites HDD Exit Pit Construction simulations, the ebb tide resulted in longer exposures to water column concentrations and larger areas of depositional thickness ≥1 mm. Therefore, the Connecticut and Massachusetts Landfall Sites HDD Exit Pit Construction simulations were started during an ebb tide. For the Connecticut OECC cable installation using a Mechanical Trencher, preliminary assessments found that higher concentrations were reported during the flood tide than during an ebb tide. Thus, the cable installation using a Mechanical Trencher within the Connecticut OECC was evaluated during a flood tide.

3.2.3 Route Definition & Construction Components

Twelve sediment dispersion simulations were performed to encompass the landfall site HDD exit pit construction, sand bedform dredging, and cable installation activities included in the PDE (Table 1-1 to Table 1-3). All of the modeled sand bedform dredging and cable installation simulations within the Connecticut OECC and Massachusetts OECC were selected as the approximate centerline. The modeled inter-array cable installation route and sand bedform dredging within the Lease Area were selected based on a representative layout of the inter-array cables.

To best represent *in-situ* construction activities in the model, the input parameters were selected to reflect the anticipated construction activity based on the equipment type and volume of sediment released to the environment. For line sources (e.g., cable installation, sand bedform dredging), the sediment loading was defined by the route length and the cross-sectional area of the trench, while the point source (e.g., landfall site HDD exit pit construction) depended on the total volume anticipated to be excavated and backfilled. The equipment type defined the production rate (volume per time) and the fraction of the disturbed sediment that will be mobilized to the water column (i.e., resuspension rate or loss rate). The sediment dispersion modeling parameters are summarized below for the various simulations related to the Connecticut OECC, Massachusetts OECC, and the Lease Area.

A key component of the modeling is the delineated geographical extent of the source (Table 3-2). The Vineyard Northeast sand bedform dredging and cable route lengths assessed in this study are broken down in detail below. Some scenarios included modeling for the entire length of the OECCs, while others used representative sections.

Table 3-2: Route definition for the Connecticut OECC, Massachusetts OECC, and Lease Area project components.

Description		Length (km)
Connecticut OECC – Sand Bedform Dredging	Niantic Beach Approach – Intermittent along OECC	2.1
	Eastern Point Beach Approach – Intermittent along OECC	1.7
	From Intersection to Lease Area – Intermittent along OECC	5.1
Connecticut OECC – Cable Installation – Typical Jetting	Niantic Beach Approach	10.88
	Eastern Point Beach Approach	17.08
	From Intersection to Lease Area	162.1
Connecticut OECC – Cable Installation – Mechanical Trenching	Representative Section of OECC	0.85
Connecticut OECC – Cable Installation – Vertical Injector	Representative Section of OECC	4.1
Massachusetts OECC – Sand Bedform Dredging	Intermittent along OECC	1.6
Massachusetts OECC – Cable Installation – Typical Jetting	From Landfall to Lease Area	125.5
Massachusetts OECC – Cable Installation – Vertical Injector	Representative Section of OECC	3.93
Lease Area – Sand Bedform Dredging	Representative Section of Inter-array Cable - Intermittent along inter-array cable	0.74
Lease Area – Inter-array Cable – Typical and Maximum Jetting	Representative Inter-array Cable	18.57

3.2.3.1 Sand Bedform Dredging

For all sand bedform dredging simulations, the dredge was assumed to be a TSHD (Gallio Gallie) because the Connecticut OECC contains bedforms at depths of greater than 80 m and thus requires a TSHD with a dredge arm exceeding 80 m (Table 3-3). This dredging operation assumes one dredger with a hopper capacity of 18,000 cubic meters (m^3), and of that amount sediment and water would fill approximately 97% of the hopper. The sand bedform dredging simulations assume a drag arm sediment mobilization fraction of 0.01 (1%). The production rate was calculated by assuming the intake sediment-water slurry contains 10% solids (Palermo et al., 2008; USACE, 2015). Within the hopper, it was assumed that 80% of the material was sand, once the sediment capacity was reached in the hopper (i.e., 18,000 m^3*0.97*0.8 = 13,968 m^3), overflow and dumping operations began. When modeling hopper overflow operations, a 90% sand storage percent was assumed (Wangli et al., 2007), and the fine-grained sediment laden water was then released at the surface to simulate overflow. The overflow material contained approximately 20% of the excavated volume but was adjusted based on the 90% stand storage value so it contained mostly clay and silts. The remaining material (i.e., 80% of excavated sediment containing mostly sand) would then be dumped approximately 5 m below the surface at specified locations along the OECC and in the Lease Area. For the purpose of this modeling assessment, the dump sites are considered representative, and more or fewer may be used during the actual construction activities.

Table 3-3: Assumed Parameters for Connecticut OECC, Massachusetts OECC, and Lease Area Sand Bedform Dredging.

Dredge Parameters	Units	Values
Total Dredging Production (sediment + water)	m^3/hr	21,004
Sediment Production	m^3/hr	2,100
Hopper Volume	m^3	18,000
Sediment Suspended at Drag Head (as % of total dredged, both fines and coarse)	%	1
Sand Storage in Hopper	%	90
Overflow Percent of Total Dredge Volume	%	20
Dump Percent of Total Dredge Volume	%	80
Operations	hrs/day	24
Time to Fill Hopper*	hrs	6.65

*Assumes continuous dredging along a continuous route, note this did not occur for any of the sand bedform dredge scenarios and so overflow and dumping frequency varied depending on the route definition.

3.2.3.2 Connecticut OECC

Sediment disturbing activities are anticipated to occur with respect to the Connecticut OECC (Table 3-4) include construction of the HDD exit pit (Figure 3-4), sand bedform dredging (Figure 3-5), and cable installation by jetting (Figure 3-6).

At the Ocean Beach Landfall Site, construction of the exit pit was modeled. As noted in Section 1.2.1, the Ocean Beach Landfall Site was selected as the conservative representative landfall site. It was assumed that 100% of the dredged material would be released at the surface to backfill the excavated pit. The model's results can be considered representative of excavation and backfill activities, because adequate time between these two activities would allow any excavation-induced sediment disturbances to disperse back to ambient conditions prior to backfilling.

The worst-case dredge volume was selected for use in this assessment (Table 3-4) and it was assumed that dredging would follow the approximate centerline of the Connecticut OECC. As the final landfall approach has not been confirmed, dredging of the worst-case scenario was modeled for both the Niantic Beach Landfall Approach and the Eastern Point Beach Landfall Approach (which are also representative of the Ocean Beach Landfall Approach), including the connection point to the Lease Area. Results are reported separately for the two landfall approaches as only one will ultimately be used (i.e., they are not anticipated to both be dredged).

Cable installation within the Connecticut OECC starting from both the Niantic Beach Landfall Approach and from the Eastern Point Beach Landfall Approach (which are also representative of the Ocean Beach Landfall Approach) to the Lease Area were modeled. The approaches were modeled and reported separately as only one will ultimately be used. The section of the Connecticut OECC that extends from the connection point to the Lease Area was also modeled and reported separately.

Two additional representative scenarios were modeled to capture the variability in cable installation technique by simulating installation using a vertical injector tool and mechanical trencher (Figure 3-6). The vertical injector is a high-volume low-pressure water jetting tool that uses directed water jets to fluidize the seabed and lower the cable via the integral depressor to the bottom of the fluidized trench. The vertical injector is capable of directly installing the cable in areas with sand bedforms without the need for any separate sand bedform clearing. The vertical injector installation parameters differ from the typical jetting parameters in that the target trench depth is deeper and the production rate is smaller. However, the percent of sediment mobilized and the vertical distribution of sediment in the water column are similar. Compared to the typical jetting technique, simulation of cable installation using mechanical trenching (e.g., chain cutter) occurs much slower (i.e., smaller production rate); has a deeper target trench depth; and has the potential to resuspend a larger percent of the disturbed sediments depending on the substrate type. A 75% mobilization percent was determined based on the target trench depth, the tool width (assumed 250 mm wide cutting distance), and the modeled production rate (BERR, 2008).

Table 3-4: Construction parameters and sediment loading model inputs for Vineyard Northeast specific to the Connecticut OECC.

Connecticut OECC					
Scenario Name	**Trench Cross-Section (m^2)**	**Total Dredge Volume**[a] **(m^3)**	**Production Rate (m^3/hr)**	**Duration of Sediment Loading (days)**	**Percent Mobilized (%)**
Representative Connecticut Landfall Site HDD Exit Pit Construction	N/A	3,750	3,750	0.04	100
Sand Bedform Dredging for Representative Export Cable within the Connecticut OECC	N/A	225,814	2,100[b]	Niantic Beach to Lease Area: 4.5[c] Eastern Point Beach to Lease Area: 4.2[c]	100
Cable Installation for Representative Export Cable within the Connecticut OECC —Typical Jetting Parameters	2	Niantic Beach to Lease Area: 358,345 Eastern Point Beach to Lease Area: 345,935	400	Niantic Beach to Lease Area: 37 Eastern Point Beach to Lease Area: 35.7	25
Cable Installation for Representative Export Cable Segment within the Connecticut OECC — Mechanical Trenching	3	2,559	300	0.4	75
Cable Installation for Representative Export Cable Segment within the Connecticut OECC —Vertical Injector	3	12,371	360	1.4	25

[a] Total dredge volume (m^3) does not account for the percent mobilized or percent solids based on sediment moisture content data.

[b] Assumes 10% solids in the sediment-water slurry (Palermo et al., 2008; USACE, 2015).

[c] This duration accounts for active dredging and dumping operations and does not include steam time.

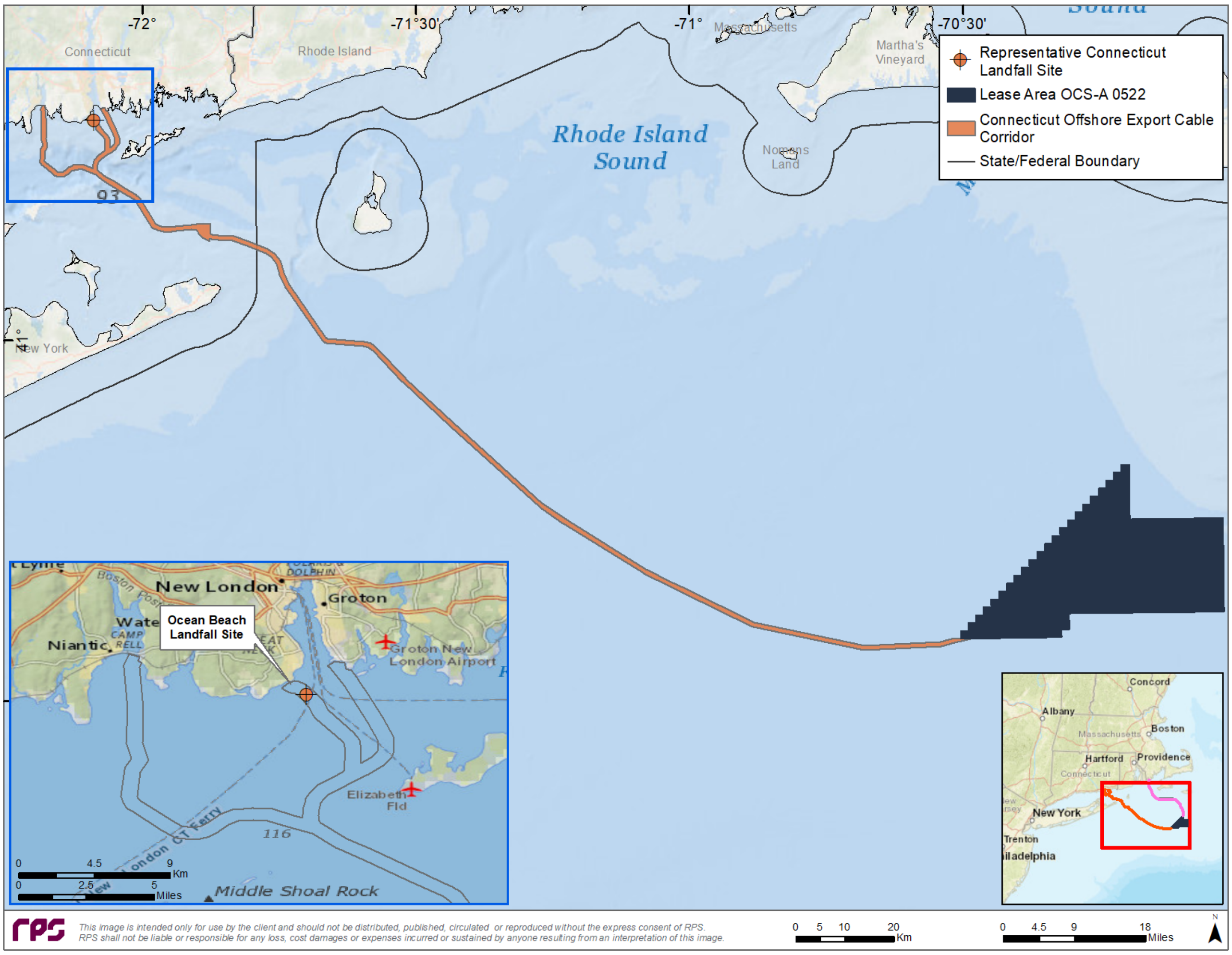

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Figure 3-4: Modeled location of the Representative Connecticut Landfall Site HDD Exit Pit Construction.

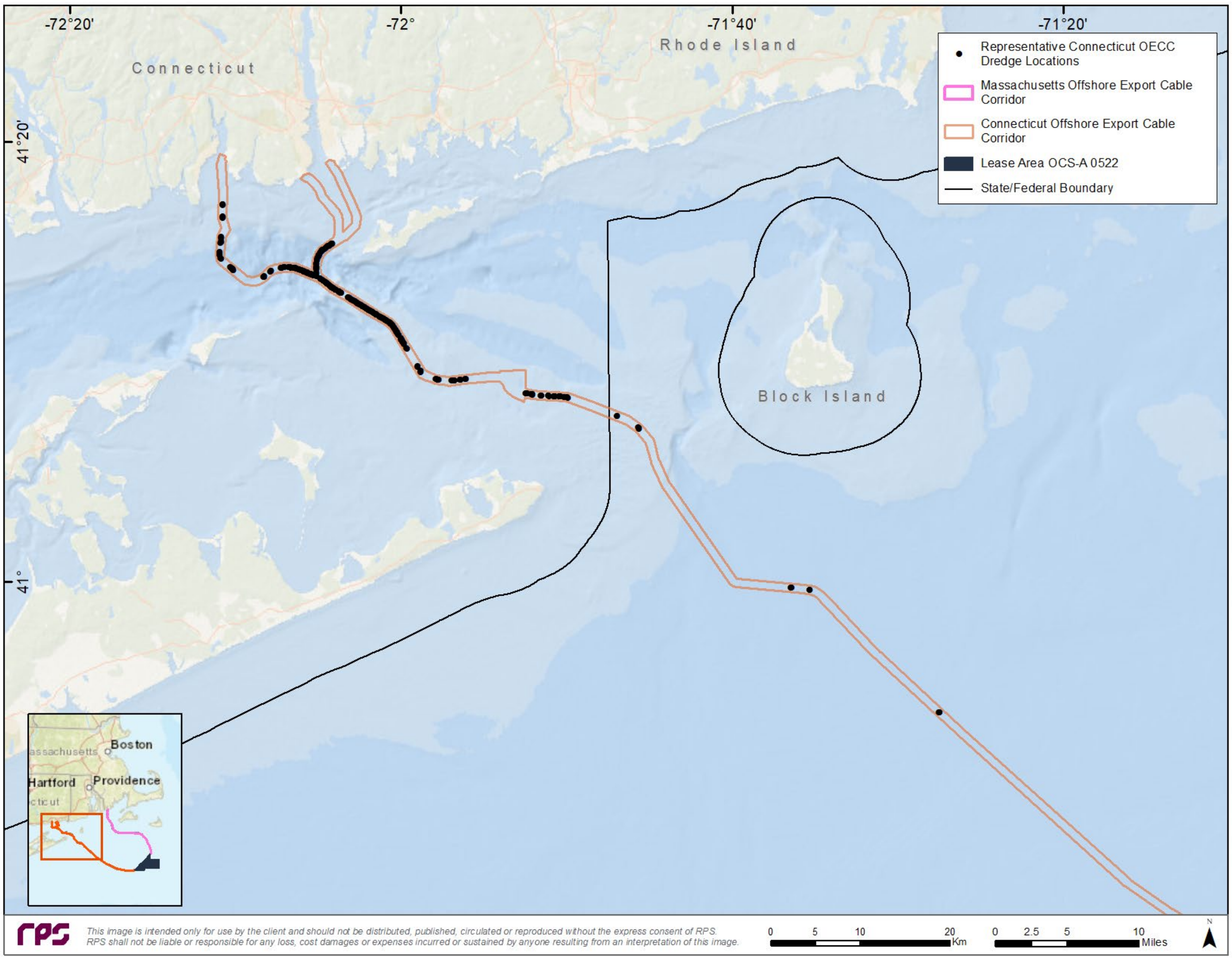

Figure 3-5: Modeled locations of the sand bedform dredging within the Connecticut OECC.

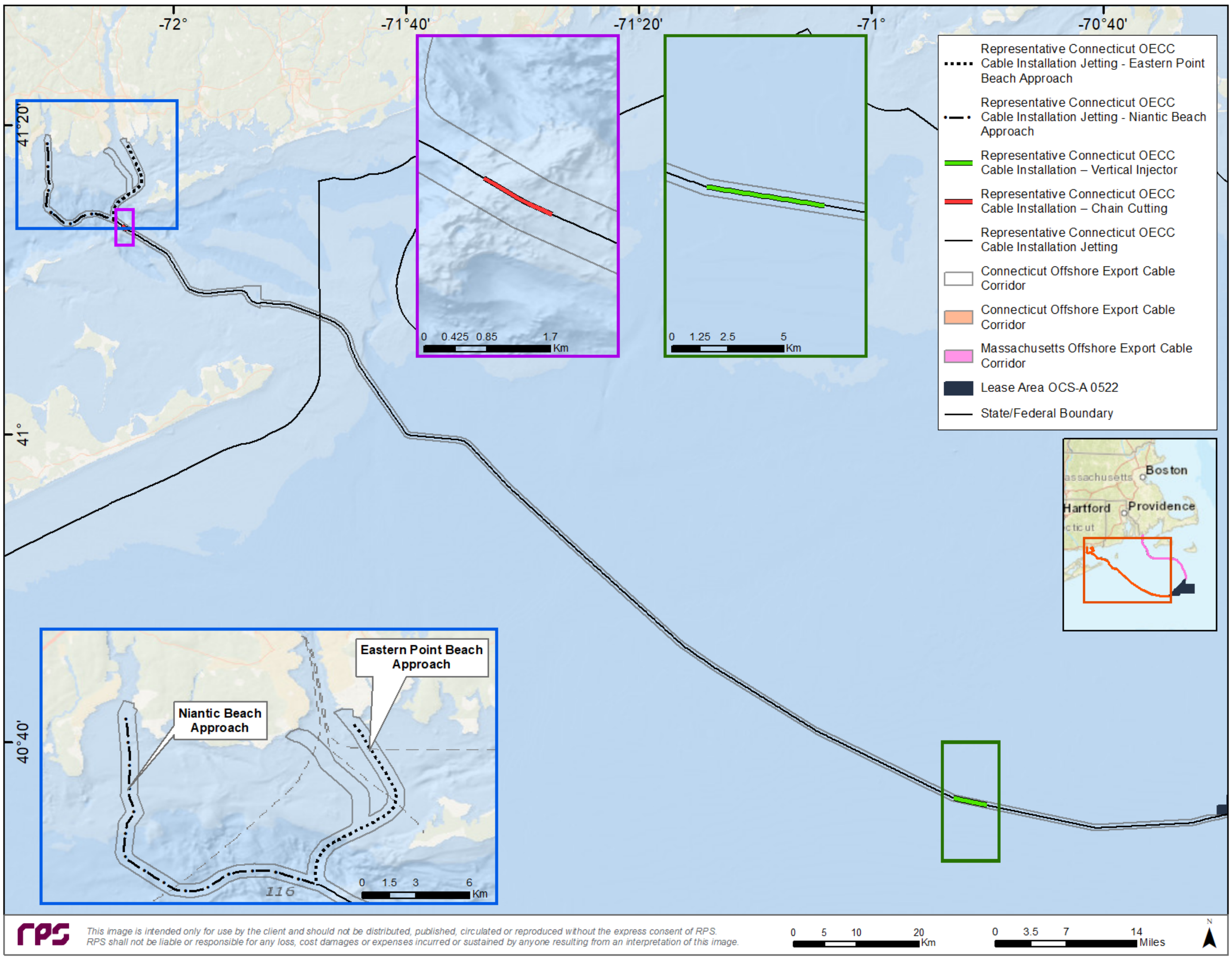

Figure 3-6: Modeled locations of the representative Cable Installation simulations within the Connecticut OECC.

3.2.3.3 Massachusetts OECC

Anticipated sediment disturbing activities within the Massachusetts OECC (Table 3-5) include construction of the HDD exit pit (Figure 3-7), sand bedform dredging (Figure 3-8), and cable installation by jetting (Figure 3-9).

At the Horseneck Landfall Site, construction of the exit pit was modeled. It was assumed that 100% of the dredged material would be released at the surface to backfill the excavated pit. The model's results can be considered representative of excavation and backfill activities because adequate time between these two activities would allow any excavation-induced sediment disturbances to disperse back to ambient conditions prior to backfilling.

Sand bedform dredge volumes within the Massachusetts OECC were determined based on preliminary surveys. The worst-case dredge volume was selected for this assessment (Table 3-5) and it was assumed dredging would follow the approximate centerline of the Massachusetts OECC. Cable installation within the Massachusetts OECC was modeled from the landfall site to the Lease Area using the OECC centerline. The entire route was modeled using typical jetting installation techniques (2 m target trench depth, 25% mobilization; Table 3-5), and a sensitivity analysis was performed using the vertical injector technique (Figure 3-9). This sensitivity analysis allows for comparison between cable installing using jetting techniques and with the vertical injector installation because their installation parameters differ slightly. The vertical injector assumed a deeper trench depth and was modeled with a slower production rate. The vertical injector segment was selected because it is exposed to strong currents in an area containing relatively high fractions of fine material. The combination of those two factors tend to transport suspended sediment farther from the release location and the fine-grained material persists longer in the water column due to is lower density as compared to sand.

Table 3-5: Construction parameters and sediment loading model inputs for Vineyard Northeast specific to the Massachusetts OECC.

Massachusetts OECC					
Scenario Name	**Trench Cross-Section (m^2)**	**Total Dredge Volume[a] (m^3)**	**Production Rate (m^3/hr)**	**Duration of Sediment Loading (days)**	**Percent Mobilized (%)**
Massachusetts Landfall Site HDD Exit Pit Construction	N/A	3,750	3,750	0.04	100
Sand Bedform Dredging for Representative Export Cable within the Massachusetts OECC	N/A	9,295	2,100[b]	0.18[c]	100
Cable Installation for Representative Export Cable within the Massachusetts OECC —Typical Jetting Parameters	2	250,961	400	25.9	25
Cable Installation for Representative Export Cable Segment within the Massachusetts OECC —Vertical Injector	3	11,780	360	1.4	25

[a] Total dredge volume (m^3) does not account for the percent mobilized or percent solids based on sediment moisture content data.

[b] Assumes 10% solids in the sediment-water slurry (Palermo et al., 2008; USACE, 2015).

[c] This duration accounts for active dredging and dumping operations and does not include steam time.

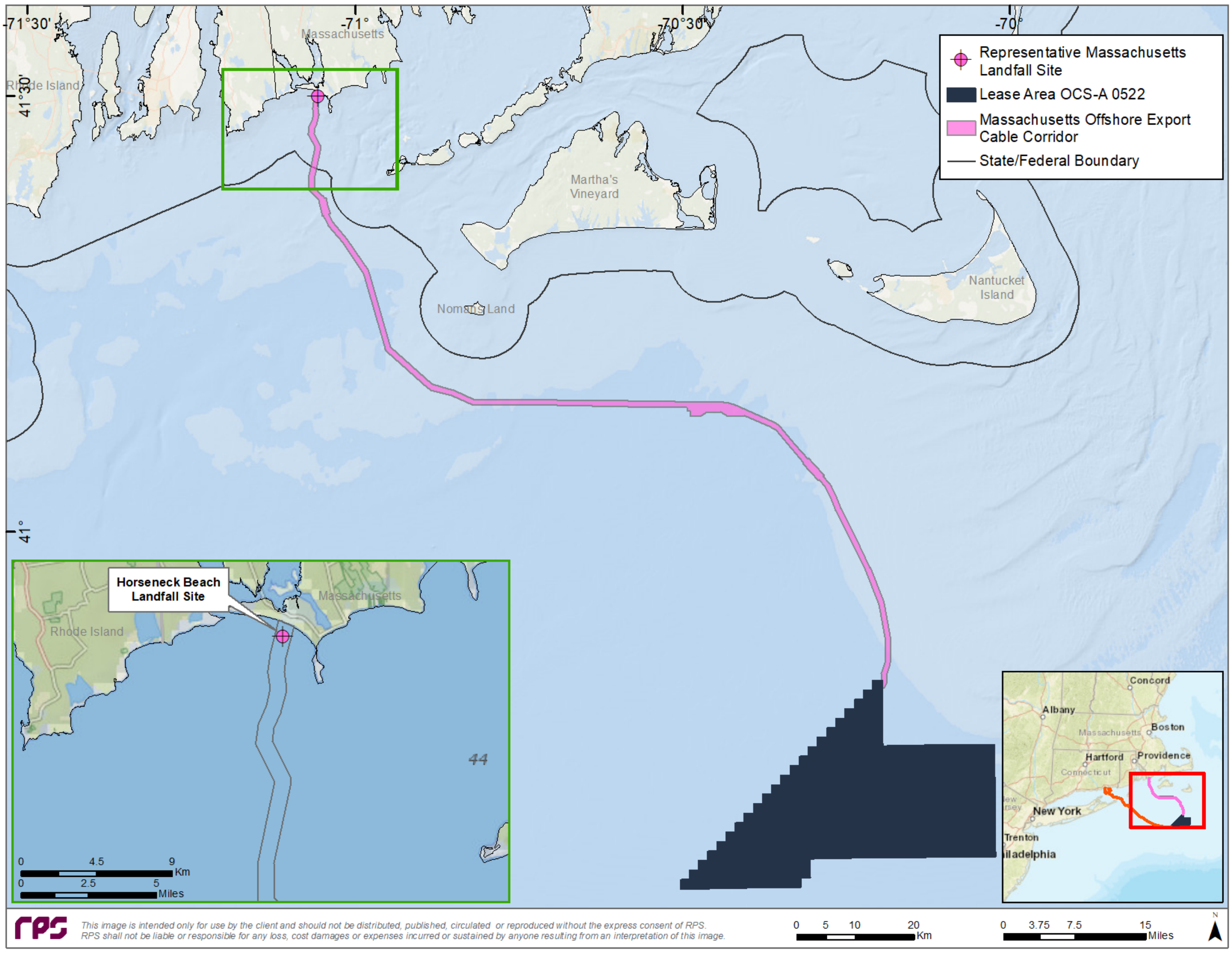

Figure 3-7: Modeled location of the Representative Massachusetts Landfall Site HDD Exit Pit Construction.

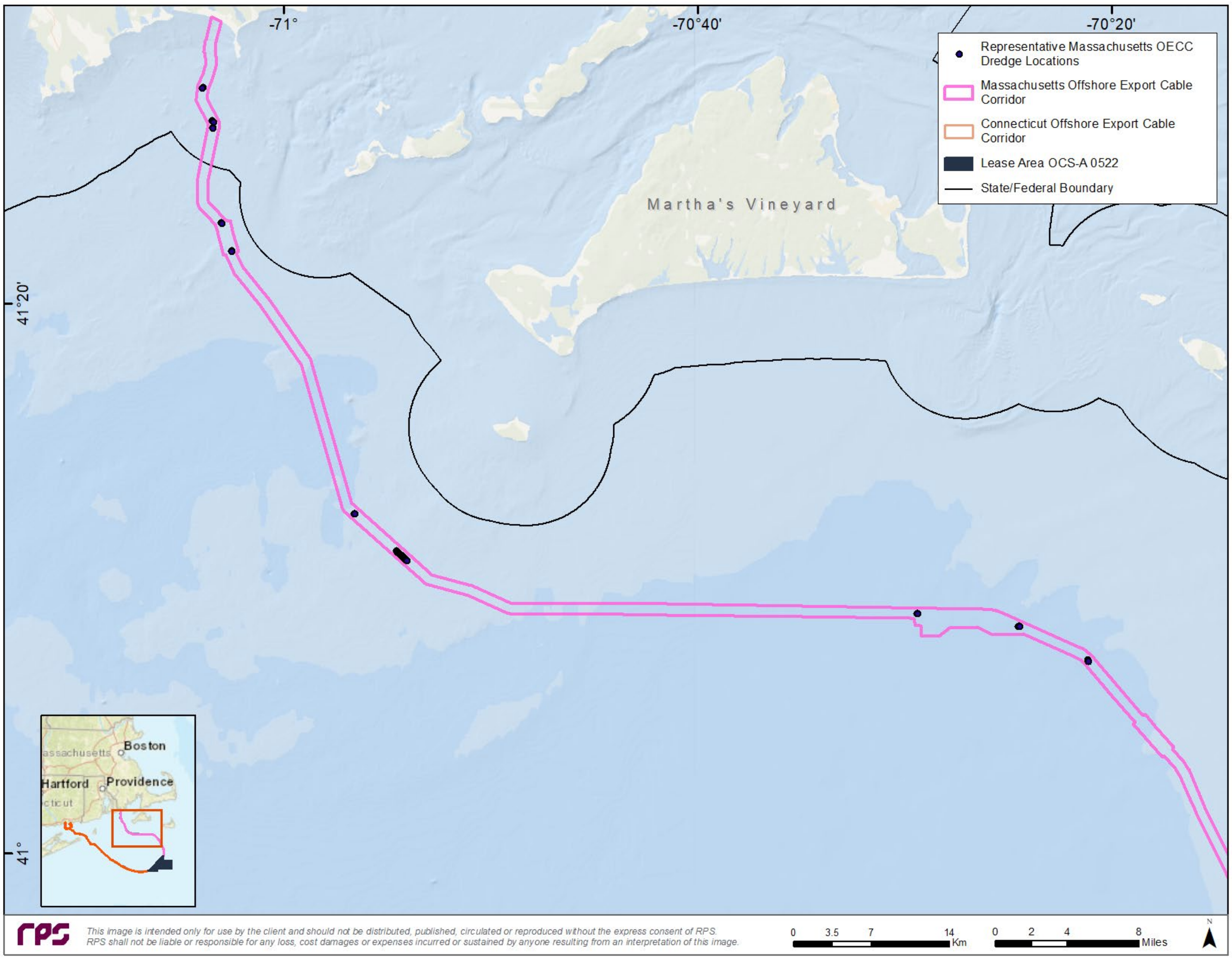

Figure 3-8: Modeled locations of the sand bedform dredging within the Massachusetts OECC.

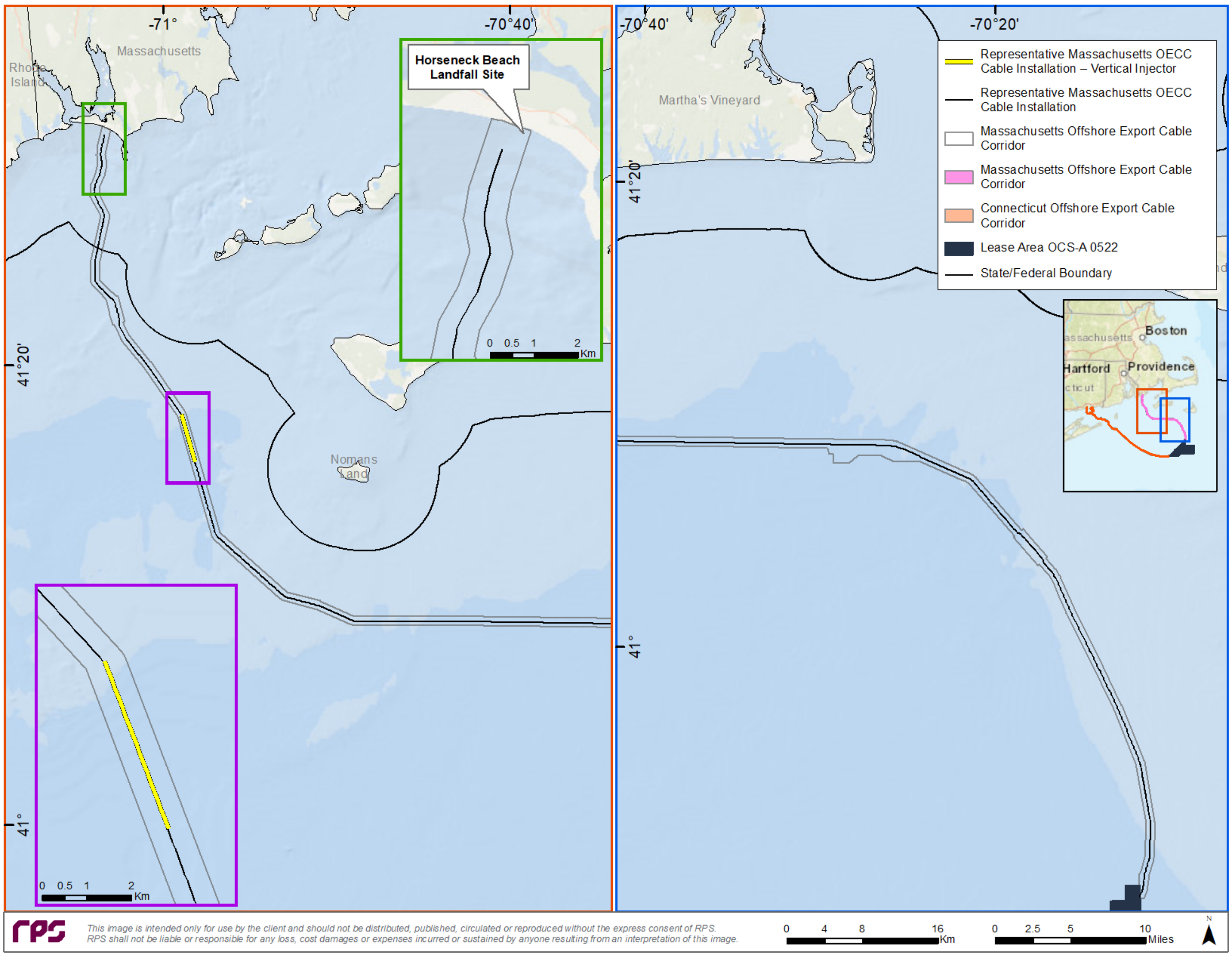

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Figure 3-9: Modeled locations of the representative Cable Installation simulations within the Massachusetts OECC.

3.2.3.4 Lease Area

Sediment disturbing activities that are anticipated to occur with respect to the Lease Area (Table 3-6) include sand bedform dredging and cable installation by jetting using typical and maximum installation parameters (Figure 3-10).

Dredging within the Lease Area is anticipated in the upper northeast corner of the Lease Area given sand bedforms were identified during surveys. The locations of the dredging are not continuous along an inter-array cable, so the dredge volume was spread over the discontinuous patches for a total length of 740 m.

Inter-array cable installation methods captured through this modeling include using typical installation parameters that reflect a conservative estimate of typical installation speed and trench depth. Within the Lease Area, two cable installation simulations were modeled: one with typical parameters and one with “maximum impact” parameters involving deeper penetration and faster installation.

Table 3-6: Construction parameters and sediment loading model inputs for Vineyard Northeast specific to the Lease Area.

Lease Area					
Scenario Name	**Trench Cross-Section (m^2)**	**Total Dredge Volume[a] (m^3)**	**Production Rate (m^3/hr)**	**Duration of Sediment Loading (days)**	**Percent Mobilized (%)**
Sand Bedform Dredging for Representative Inter-array Cable	N/A	8,140	2,100[b]	0.16[c]	100
Cable Installation for Representative Inter-Array Cable —Typical Jetting Parameters	2	37,145	400	3.84	25
Cable Installation for Representative Inter-Array Cable —Maximum Jetting Parameters	3	55,718	900	2.6	35

[a] Total dredge volume (m^3) does not account for the percent mobilized or percent solids based on sediment moisture content data.

[b] Assumes 10% solids in the sediment-water slurry (Palermo et al., 2008; USACE, 2015).

[c] This duration accounts for active dredging and dumping operations and does not include steam time.

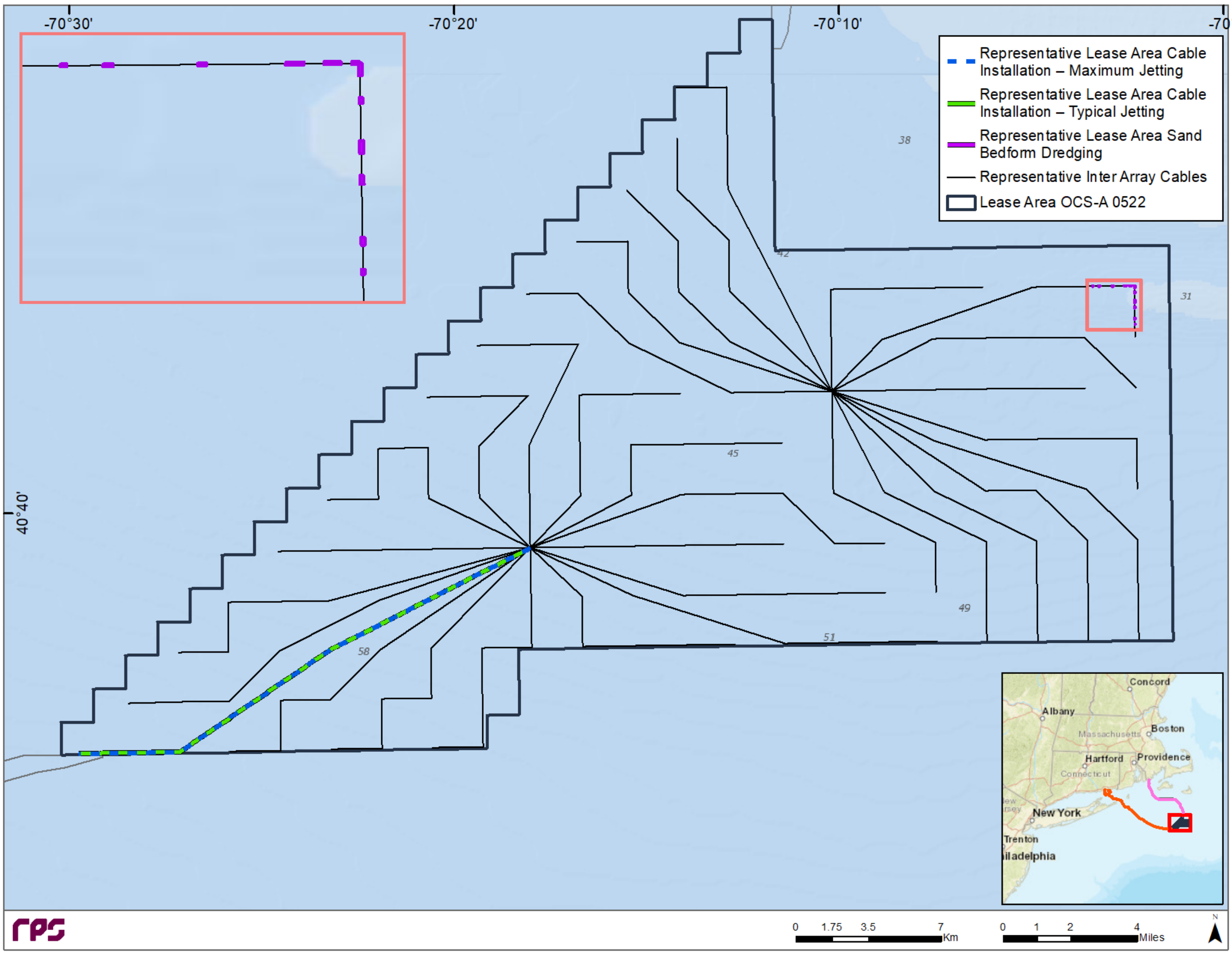

Figure 3-10: Modeled locations of the Lease Area's Representative Sand Bedform Dredging and Inter-array Cable Installation (Typical and Maximum).

3.2.4 Sediment Loading Vertical Initialization

In addition to the sediment loading rate and mobilization fraction, the model requires specification of the vertical location of sediment resuspension, which varied by installation method. Vertical initialization locations and other dredging related parameters are typically estimated empirically on the basis of field measurements of sediment flux through cross-sections of the plume or derived from numerical source models (Mills & Kemps, 2016). The vertical initialization for TSHD operations (Table 3-7) and cable installation techniques (Table 3-8) vary depending on the equipment type.

Table 3-7: Vertical Distribution of Suspended Sediment Mass Associated with Dredging, Overflow, and Dredged Material Release.

Drag Arm			Overflow			Dumping		
Individual Bin Percent	**Cumulative Percent**	**Meters Above Bottom**	**Individual Bin Percent**	**Cumulative Percent**	**Meters Below Surface**	**Individual Bin Percent**	**Cumulative Percent**	**Meters Below Surface**
5	100	3	100	100	0	100	100	5
10	95	2						
28	85	1						
28	57	0.66						
29	29	0.33						

Table 3-8: Vertical Distribution of Suspended Sediment Mass Associated with Cable Installation Techniques.

Jetting Techniques			Vertical Injector			Mechanical Trencher		
Individual Bin Percent	**Cumulative Percent**	**Meters Above Bottom**	**Individual Bin Percent**	**Cumulative Percent**	**Meters Above Bottom**	**Individual Bin Percent**	**Cumulative Percent**	**Meters Above Bottom**
5	100	3	5	100	3	20	100	2.5
10	95	2	10	95	2	20	80	2
28	85	1	28	85	1	20	60	1.5
28	57	0.66	28	57	0.66	20	40	1
29	29	0.33	29	29	0.33	20	20	0.5

3.3 Sediment Modeling Results

SSFATE simulations were performed for each sediment disturbance activity. For all dredging and cable installation scenarios, sediment concentrations were computed on a grid with resolution of 50 m x 50 m in the horizontal, while landfall scenarios used a smaller horizontal grid (10 m x 10 m) to capture complex coastal hydrodynamic processes. Depending on the length of the simulation and the depth of sediment disturbing activities the vertical dimensions were either 0.5 m or 1 m. The model time step for the cable installation was 10 minutes and five minutes for dredging and landfall scenarios. Model-predicted concentrations are “excess” concentrations above background (i.e., a concentration of 0 mg/L is assumed for the ambient concentration).

Results from the model runs are presented through a set of figures and tables showing the predictions of suspended sediment concentration and relative thickness of sediment deposition expected to occur along the proposed OECC’s and Lease Area because of construction activities. Maps of instantaneous above-ambient TSS concentrations; maximum above-ambient TSS concentrations; durations of time for which above-ambient TSS of ≥10 mg/L occur; and seabed deposition (in mm) are provided. Tables quantifying the maximum extent to concentration and depositional thresholds for each installation technique; the modeled area exceeding TSS thresholds for specific durations, as well as areas of seabed deposition exceeding thickness thresholds, are summarized for each scenario.

Additional information about standard graphical outputs for each scenario are provided below:

- **Maps of Instantaneous TSS Concentrations**: These maps show an example snapshot of TSS concentrations at a single moment in time; thus, conveying the spatial and temporal variability of the sediment plume in a way that cannot be depicted by cumulative maps. The plan view shows the maximum concentration throughout the water column at that snapshot time, and the vertical cross-section shows the cross-sectional variability of concentrations along a transect. These instantaneous maps show that the plume is not a continuous blanket of sediment, but rather narrow, heterogeneous patches that individually persist for minutes to hours at a single location.
- **Maps of Time-integrated Maximum TSS Concentrations**: Predicted suspended sediment concentrations are presented as a composite of maximum concentrations predicted to always occur during sediment-disturbing activities and locations throughout the model simulation. This map shows the maximum time-integrated water column concentration from the entire water column in scaled plan view, and a non-scaled inset, showing a cross-sectional view of maximum TSS concentrations in the water column. The concentrations are shown as contours using mg/L. The entire area within the contour is at or above the concentration defined by the contour itself. Most importantly, it should be noted that these maps show the maximum TSS concentration that occurred throughout the entire simulation and therefore: (1) these concentrations do not persist throughout the entire simulation and may occur during just one- or several-time steps (time step = five or 10 minutes); and (2) these concentrations do not occur concurrently throughout the entire modeled area but are the time-integrated spatial views of maximum predicted concentrations. It should be emphasized that the maximum predicted sediment plume concentration or extent will not exist at any one time during the installation.
- **Maps of Duration of TSS Concentrations Greater than 10 mg/L:** These maps show the number of hours that the TSS concentrations are expected to be equal to or greater than 10 mg/L.
- **Maps of Seabed Deposition**: These maps show the predicted deposition on the seabed that would occur once the activity has been completed. The thickness levels are shown as contours (in mm) and the entire area within the contour is at or above the thickness defined by the contour itself. The contours have been delineated at levels either tied to biological significance (i.e., 1 mm and 2 mm) or to facilitate viewing the results.

3.3.1 Connecticut OECC

Depending on the landfall approach, the sediment composition varies from gravely sand to muddy sand, with higher contents of fine-grained material present near the coastline. The sediment type changes to primarily coarse sand and fine sand as the OECC moves offshore. The composition transitions to a mixture of sand, silt, and clay as the OECC approaches the Lease Area.

This section presents results from the simulations of seabed preparation and cable installation activities in the Connecticut OECC. Results are presented separately for each of the model scenarios:

- Representative Connecticut OECC Sand Bedform Dredging – TSHD:
    - Niantic Beach Approach
    - Eastern Point Beach Approach
    - Connecticut OECC
- Representative Connecticut Landfall Site HDD Exit Pit Construction
- Representative Connecticut OECC Cable Installation — Jetting
- Representative Connecticut OECC Cable Installation — Mechanical Trenching
- Representative Connecticut OECC Cable Installation — Vertical Injector

Representative Sand Bedform Dredging using TSHD — Niantic Beach Approach

The instantaneous map illustrates that the overflow and dumping plume is patchy and discontinuous throughout the water column (Figure 3-11). As the plume is transported by subsurface currents, the concentrations dissipate and settle. Intermittent dredging along the Niantic Beach Approach was predicted to cause plumes localized to the seabed due to drag arm disturbances (Figure 3-12). Once the hopper reached capacity, the TSHD sailed to two representative dumping locations within existing sand bedforms, and overflow and dumping operations were modeled by alternating between the two locations. Overflow and dumping operations caused plumes that extended vertically throughout the water column, with the overflow portion lingering longer due to the higher fraction of fine material suspended in the overflow water. As it took longer to settle, the fine material was transported by currents and oscillated laterally with each tidal cycle. The remaining coarse material that was dumped settled relatively quickly to the seabed, depositing around the release location, with slight bias away from the site due to current forcing. Based on the total dredge volume, the hopper would reach capacity and require subsequent overflow and dumping to occur seven times during dredging operations.

The dumping and overflow operations were simulated by alternating between two representative dump locations as opposed to repeated dump/overflows at the same location simply because it was the closest location that contained existing sand bedforms. This was simulated to reduce the hours of exposure to elevated water column concentrations. The relatively higher concentrations (e.g., ≥650 mg/L) were predicted closer to the dump site, with lower concentrations (10-25 mg/L) spanning east and west of the site with respect to the current action at the time of dumping and overflow operations in the simulation (Figure 3-12). All TSS concentrations are predicted to dissipate within six to 12 hours (Figure 3-13).

After being released near the surface during overflow or just below the surface when dumping, the coarse sediment settles first to the seabed creating a depositional footprint centered around the dump sites with deposition extending east and west due to the influence of oscillating subsurface currents. The thickest deposits remain near the release location (i.e., deposition > 100 mm), with thinner deposits (i.e., deposition between 1 and 5 mm) extending laterally from the release location (Figure 3-14). The maximum extent to the 1 mm and 20 mm contours was predicted to be approximately 1.77 km and 0.43 km, respectively (Table 3-16).

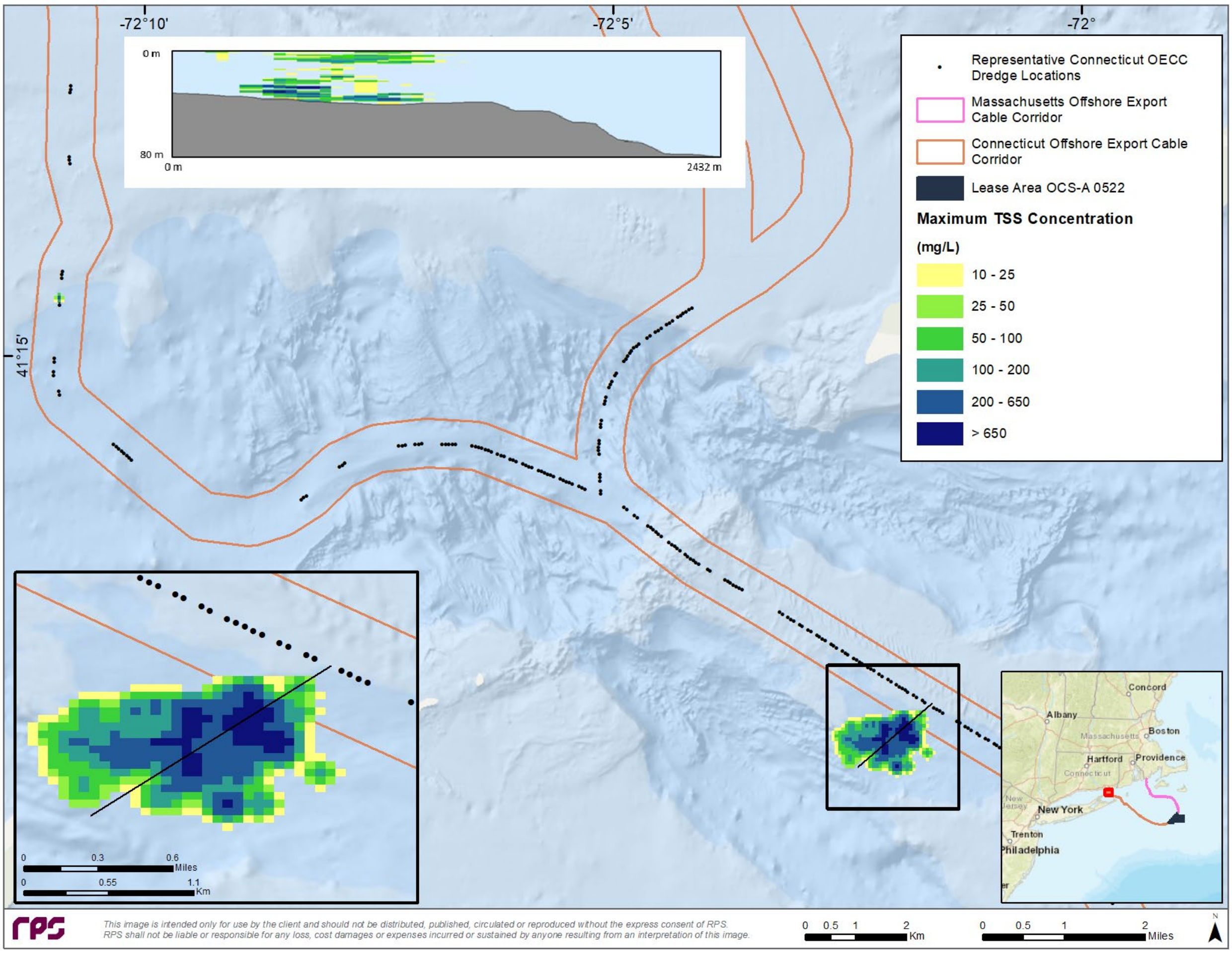

Figure 3-11: Snapshot of instantaneous TSS concentrations for a time step during the Representative Sand Bedform Dredging using TSHD — Niantic Beach Approach simulation.

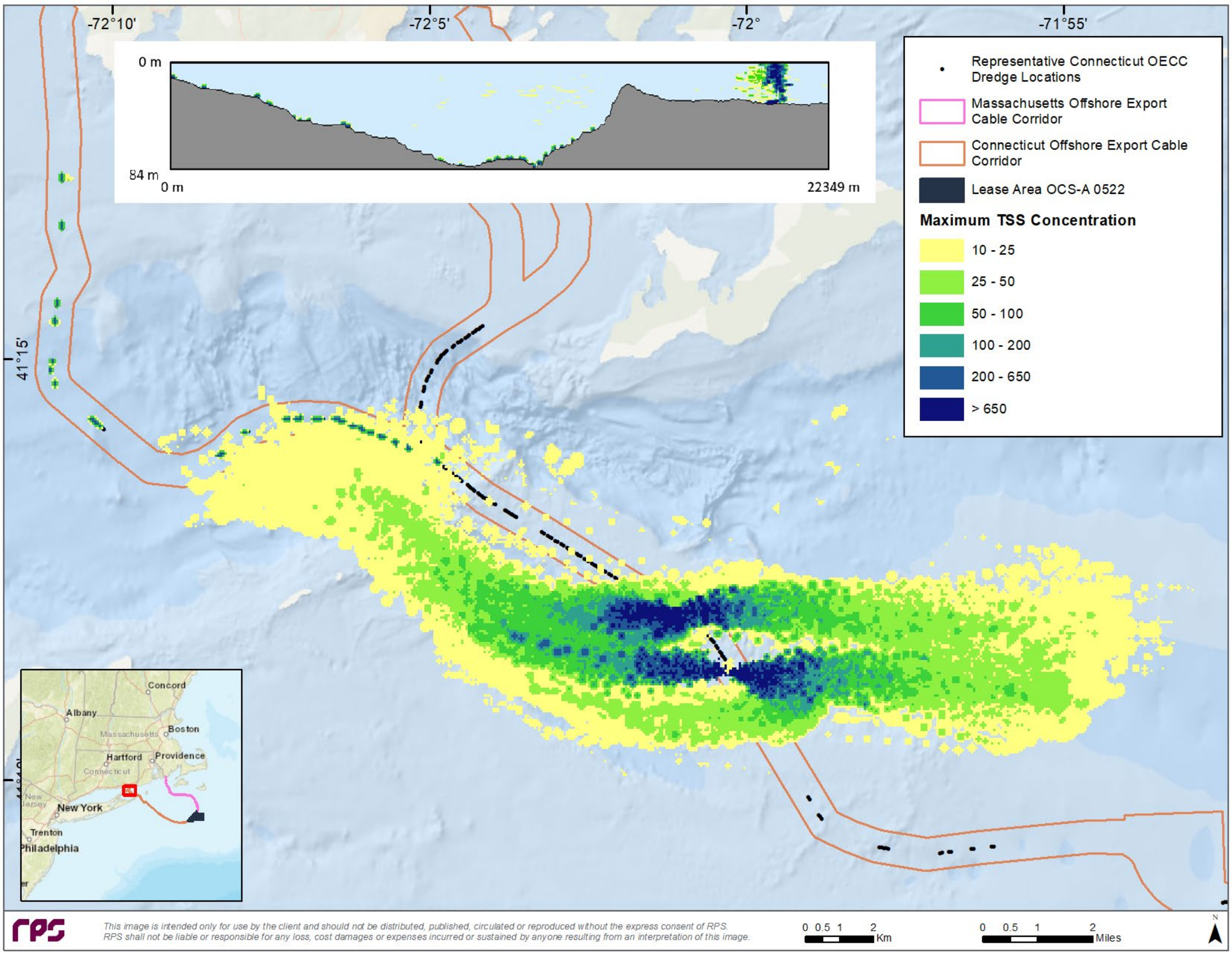

Figure 3-12: Map of time-integrated maximum concentrations associated with the Representative Sand Bedform Dredging using TSHD — Niantic Beach Approach simulation.

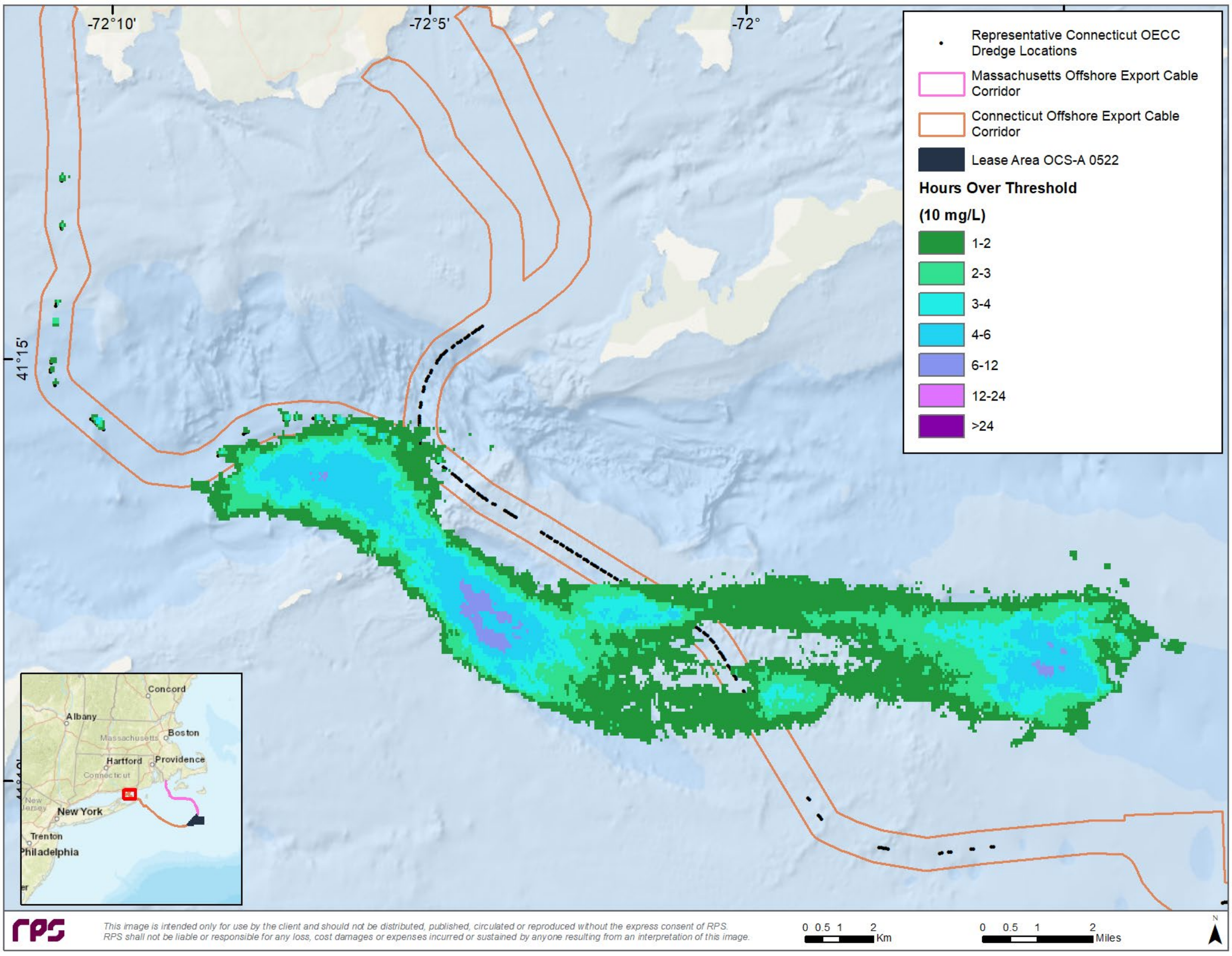

Figure 3-13: Map of duration of TSS ≥ 10 mg/L associated with the Representative Sand Bedform Dredging using TSHD — Niantic Beach Approach simulation.

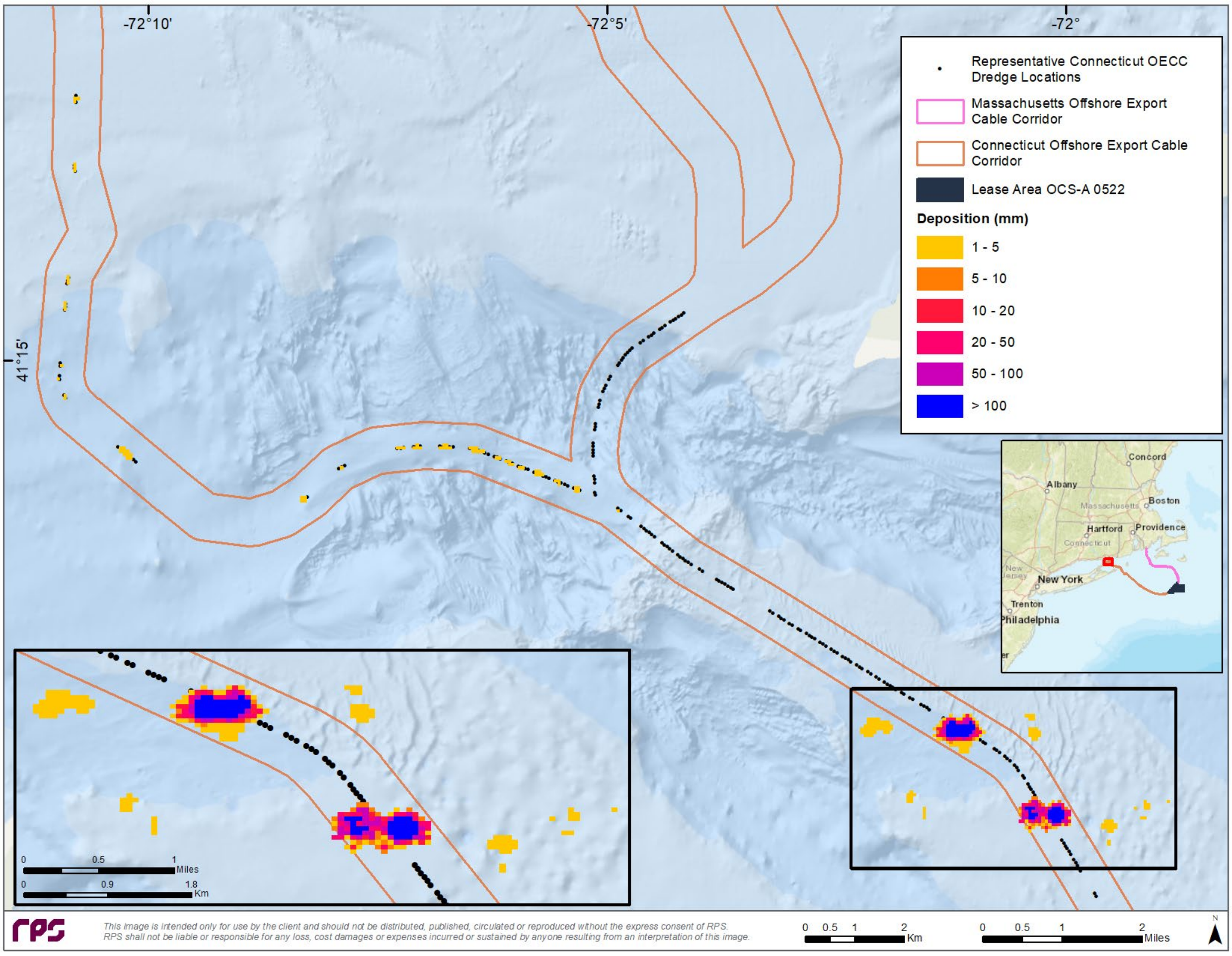

Figure 3-14: Map of deposition thickness associated with the Representative Sand Bedform Dredging using TSHD — Niantic Beach Approach simulation.

Representative Sand Bedform Dredging using TSHD - Eastern Point Beach Approach

A snapshot of the instantaneous TSS map illustrates the plume associated with one of the dumping and overflow occurrences (Figure 3-15), and how the plume is patchy throughout the water column rather than being continuous. The model shows the highest concentrations of dredging-induced suspended sediment occur in the vicinity of the dump location, as expected; however, these higher concentrations then decrease spanning away from the OECC as the plume is transported by the currents and the heavier material settles.

Intermittent dredging was simulated along the Eastern Point Beach Approach which resulted in plumes localized to the seabed due to drag arm disturbances (Figure 3-16). Once the hopper reached capacity, the TSHD sailed to a representative dumping location (i.e., within the closest existing sand bedforms) and overflow and dumping operations were modeled. Overflow and dumping operations resulted in plumes that extended vertically throughout the water column, with the overflow portion lingering longer due to the higher fraction of fine material suspended in the overflow water. As it took longer to settle, the fine material was transported by currents and oscillated with each tidal cycle. The remaining coarse material that was dumped settled relatively quickly to the seabed, depositing in proximity to the release location.

Based on the total dredge volume, the hopper would reach capacity and require subsequent overflow and dumping to occur six times during dredging operations. The extent of the suspended sediment plume shown (Figure 3-16) is much larger than what would occur at any one-time during cable installation. In contrast, Figure 3-15 provides an example snapshot of TSS concentrations at a single moment in time, characterized by a smaller footprint with heterogeneous patches that may individually persist for minutes to hours at a single location. TSS concentrations ≥650 mg/L are predicted perpendicular to the dump location with concentrations dissipating below that level within four to six hours. The duration of water column TSS concentrations ≥10 mg/L (Figure 3-17) tends to be higher in areas east and west of the dump site because the six dumping and overflow occurrences happened within the same vicinity as that was the nearest existing sand bedform. TSS concentrations are predicted to be <10 mg/L within six to 12 hours.

For the drag arm disturbances, the depositional footprint follows along the dredge locations within the OECC and is not predicted to exceed 5 mm thickness. Near the dump site depositional thicknesses are predicted to be greater than 100 mm (Figure 3-18). The maximum distance to the 1 mm and 20 mm contour is predicted to extend approximately 0.48 km and 0.39 km, respectively (Table 3-16). Due to the influence of the drag arm depositional thicknesses, the mean extent to the 1 mm thickness threshold is slightly smaller than the 20 mm mean extent.

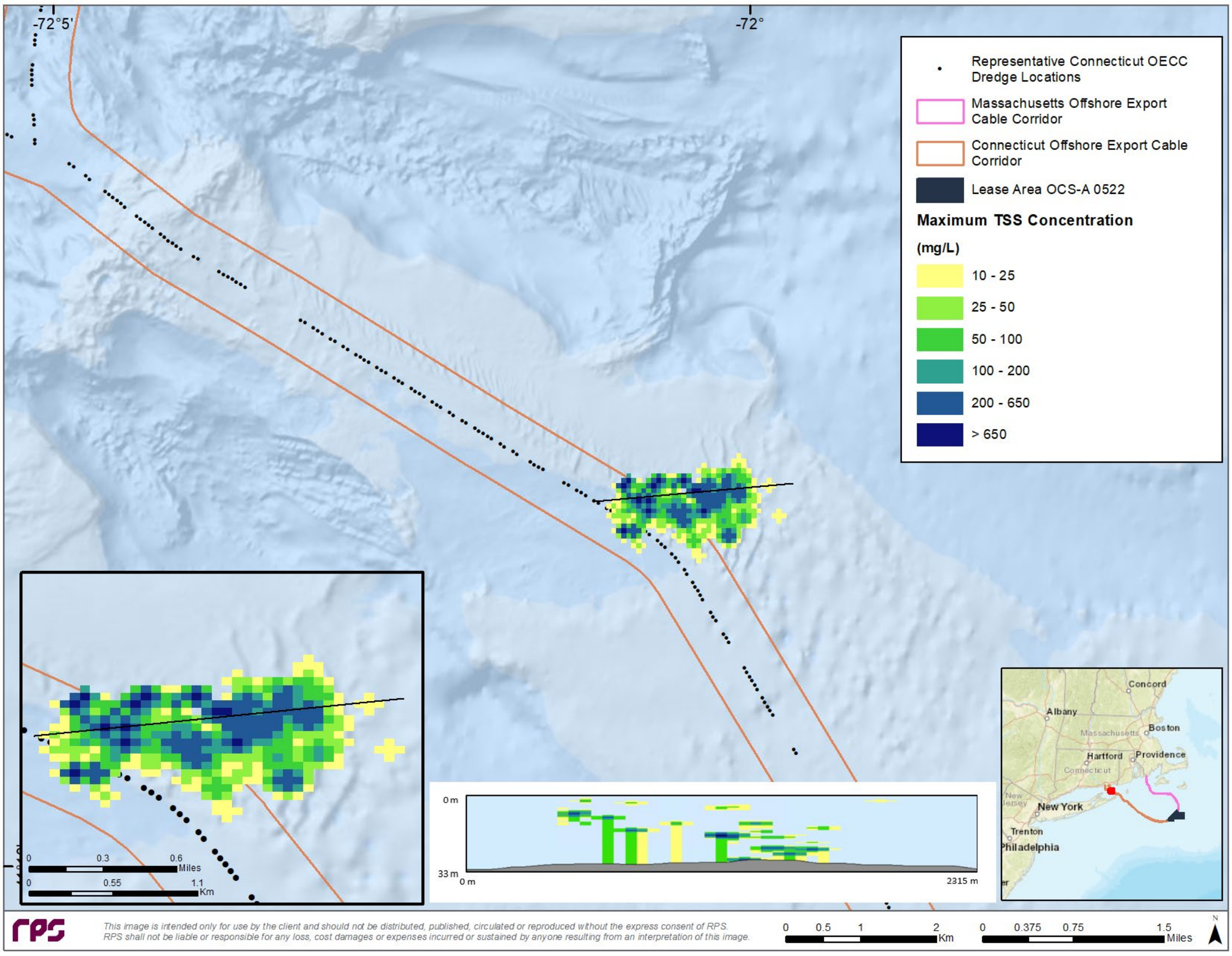

Figure 3-15: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Sand Bedform Dredging using TSHD — Eastern Point Beach Approach.

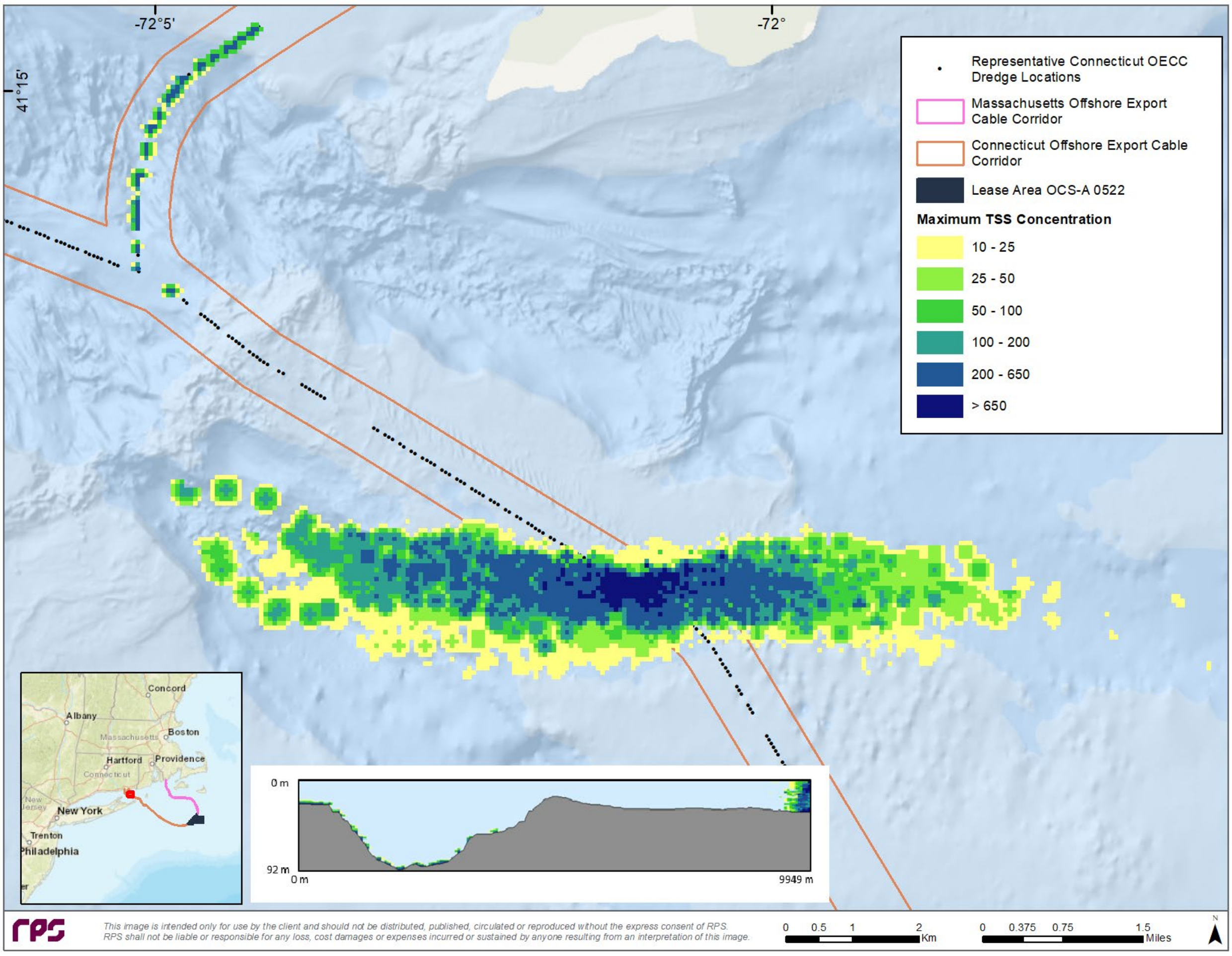

Figure 3-16: Map of time-integrated maximum concentrations associated for the Representative Sand Bedform Dredging using TSHD — Eastern Point Beach Approach simulation.

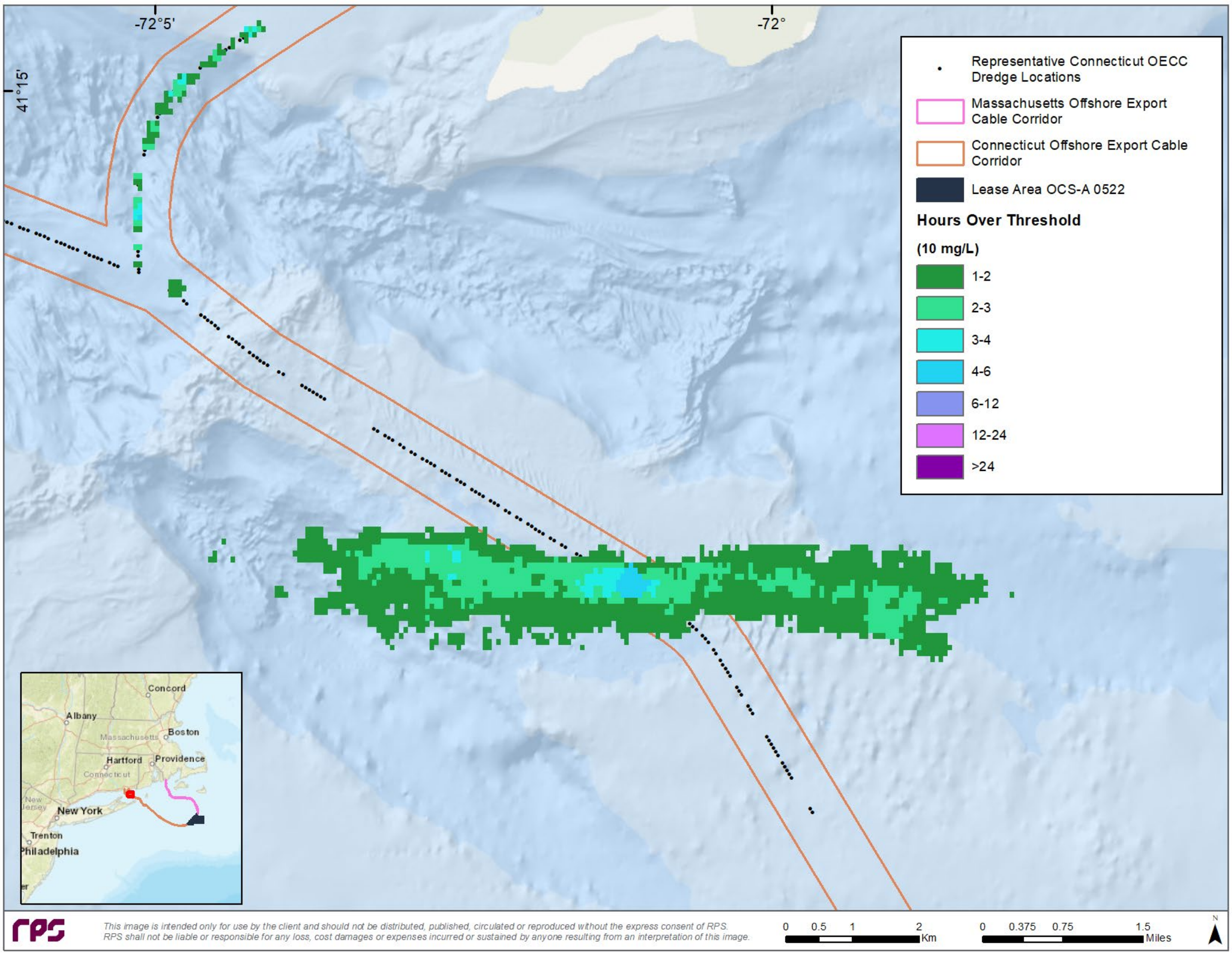

Figure 3-17: Map of duration of TSS ≥ 10 mg/L associated with the Representative Sand Bedform Dredging using TSHD — Eastern Point Beach Approach simulation.

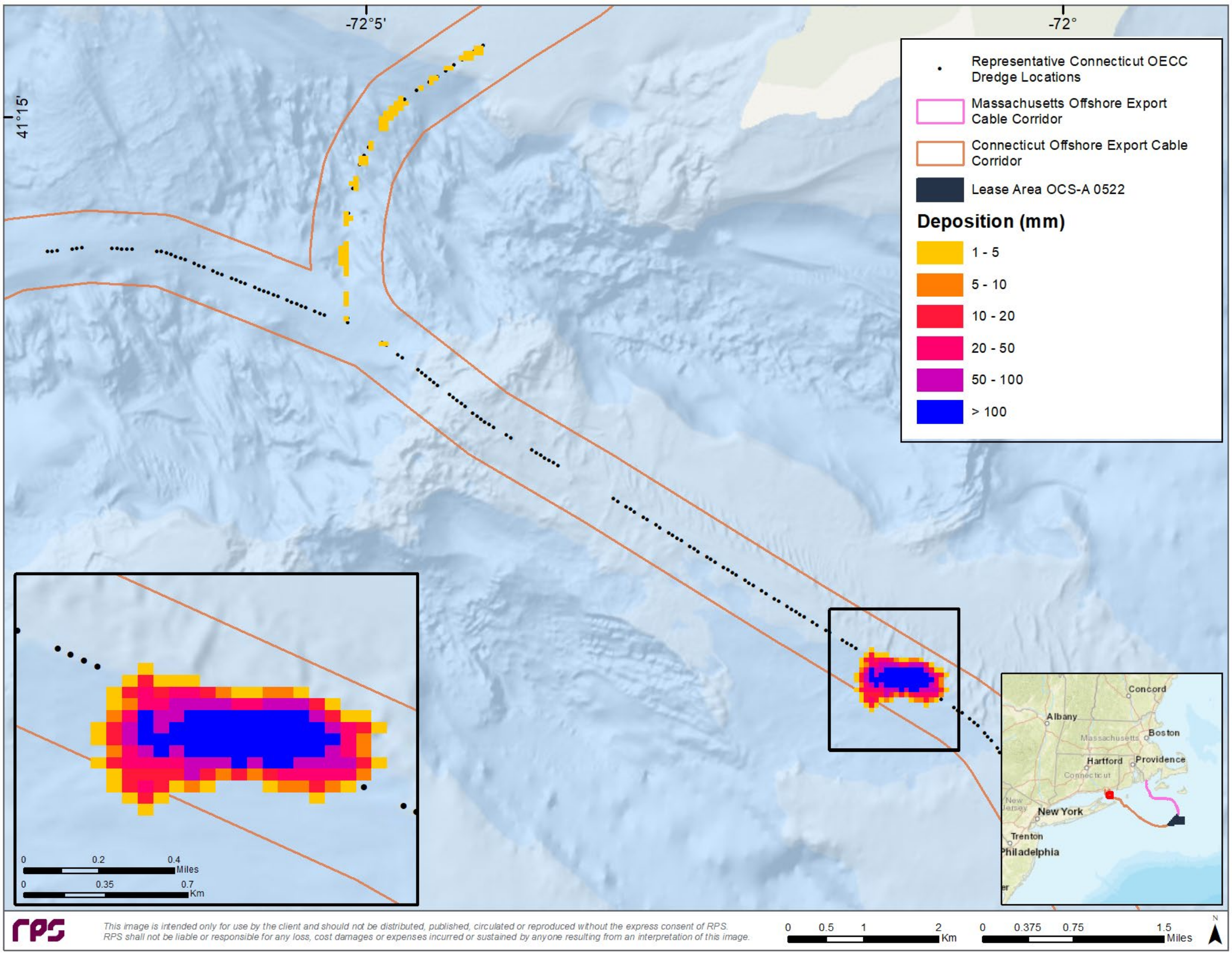

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Figure 3-18: Map of deposition thickness associated with the Representative Sand Bedform Dredging using TSHD — Eastern Point Beach Approach simulation.

Representative Sand Bedform Dredging using TSHD — Connecticut OECC

Intermittent dredging was simulated within the Connecticut OECC from the intersection of the two approaches towards the Lease Area. As with the Niantic Beach Approach and Eastern Point Beach Approach simulations, the drag arm disturbances caused plumes localized to the seabed while overflow and dumping operations created plumes that extended throughout the water column. Based on the total dredge volume, the hopper would reach capacity and require overflow and dumping to occur 10 times throughout dredging operations. One major difference between the simulations for representative dredging within the Niantic Beach Approach, Eastern Point Beach Approach, and the main Connecticut OECC section is the location of the dump site varied for the main Connecticut OECC section depending on where the dredger was at the time its hopper reached capacity. So, although more sediment was dredged for the main Connecticut OECC section, it was released in different locations, which allowed for the TSS concentrations to either partially or completely dissipate prior to the next dumping or overflow operation occurring.

A snapshot of the instantaneous concentrations from the representative sand bedform dredging within the Connecticut OECC shows the dump and overflow plume as patchy throughout the water column, with higher concentrations scattered throughout (Figure 3-19). The snapshot of a single moment during the modeling simulation supports the time-integrated maximum water column concentration map as it captures the highest reported concentration located throughout the entire water (Figure 3-20). The time-integrated maximum water column concentration map is much larger than what would occur at any one-time during cable installation and illustrates the multiple dump sites simulated for the main section of the representative sand bedform dredging within the Connecticut OECC.

The time-integrated maximum water column concentration map (Figure 3-20) contains an inset that shows the cross-sectional view of the plume throughout the entire length of the representative dredging locations. Due to the release of sediments near or at the surface for the dumping and overflow operations, respectively, the sediment is transported by subsurface currents as it settles to the seabed which extends the plume in the prevailing direction of the currents. As the plume transports with the currents away from the release location, it disperses and settles, thus reducing water column concentrations until they return to background conditions. Based on these dredge volumes and representative dumping locations, it is predicted that TSS concentrations ≥650 mg/L are to dissipate within two to three hours (Figure 3-21). The majority of TSS concentrations ≥10 mg/L are predicted to dissipate within six hours with small patches requiring up to 12 hours.

The depositional footprint falls along the representative dredge locations, with a small fraction due to drag arm operations and the larger fraction attributed to dump and overflow occurrences (Figure 3-22). The thickest deposits coincide with the dump locations and generally remain centered around those sites. Depending on the prevailing current at the time of dumping and overflow, the depositional footprint was stretched primarily towards the west, with much smaller patches predicted to the east, containing depositional thicknesses between 1 and 5 mm. The maximum extent to the 1 mm and 20 mm contours was predicted to be approximately 1.03 km and 0.33 km, respectively (Table 3-16).

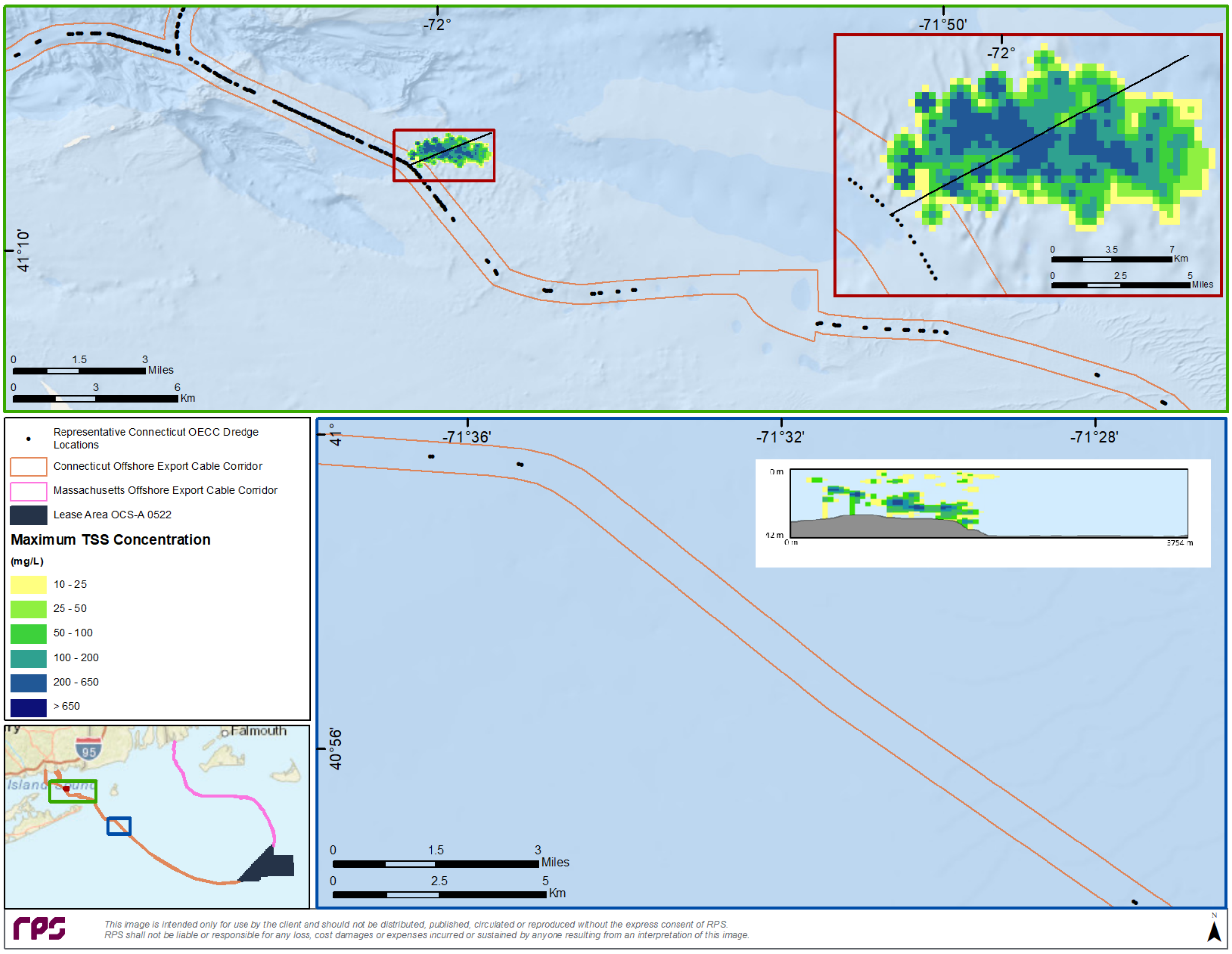

Figure 3-19: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Sand Bedform Dredging using TSHD — Connecticut OECC simulation.

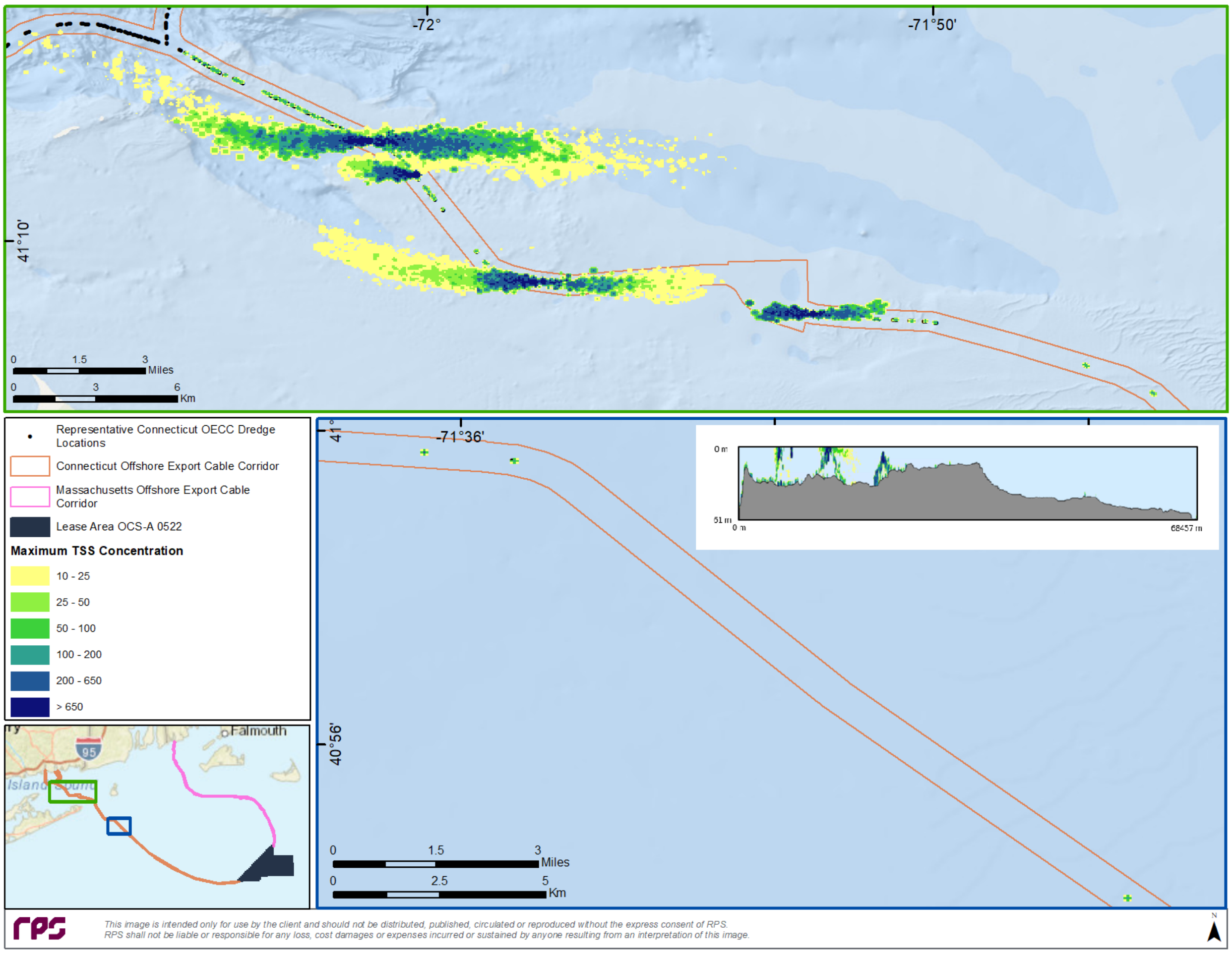

Figure 3-20: Map of time-integrated maximum concentrations associated with the Representative Sand Bedform Dredging using TSHD — Connecticut OECC simulation.

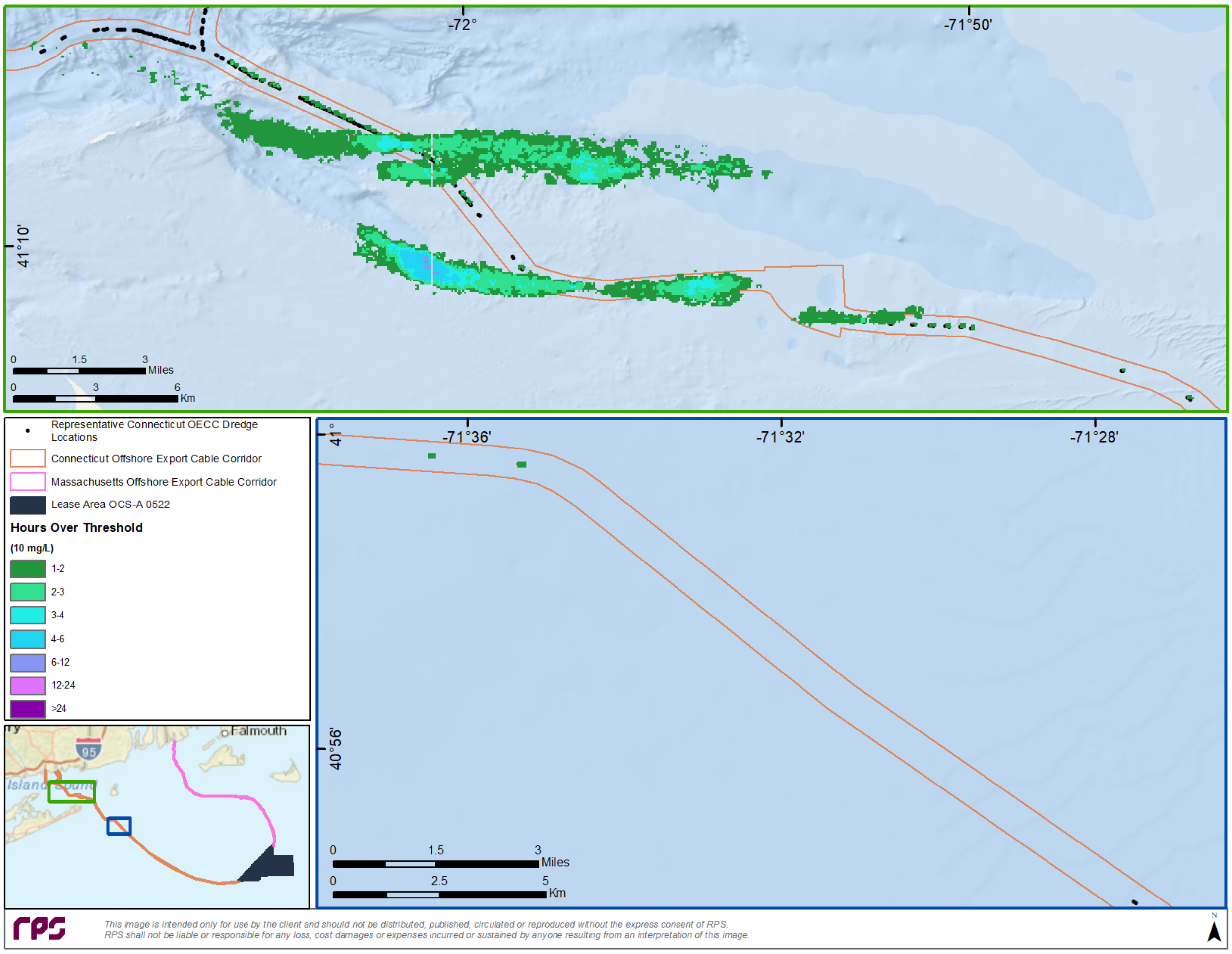

Figure 3-21: Map of duration of TSS ≥ 10 mg/L associated with the Representative Sand Bedform Dredging using TSHD — Connecticut OECC simulation.

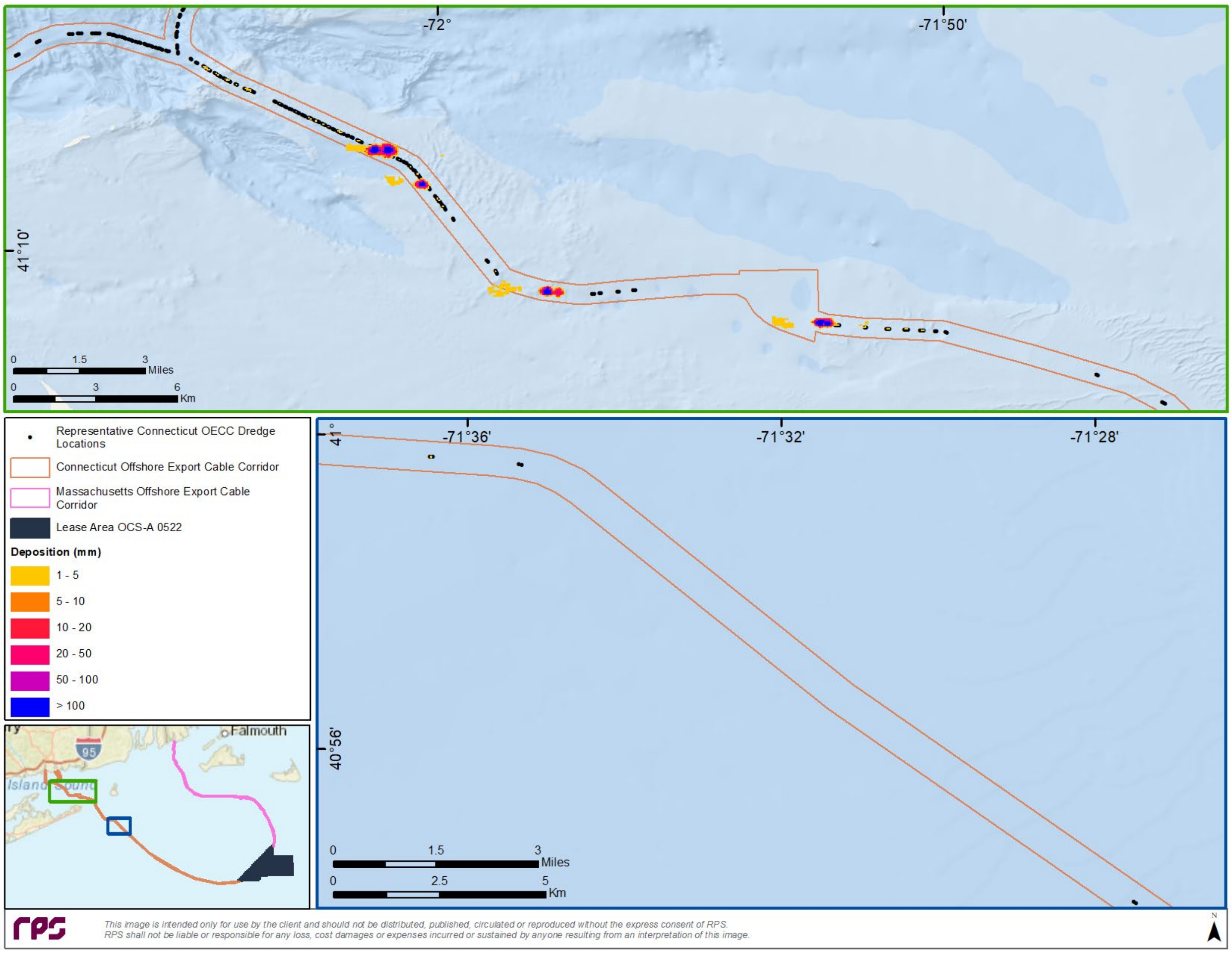

Figure 3-22: Map of deposition thickness associated with the Representative Sand Bedform Dredging using TSHD — Connecticut OECC simulation.

Representative Connecticut Landfall Site HDD Exit Pit Construction

Modeling of the Representative Connecticut Landfall Site HDD Exit Pit Construction was performed within the Ocean Beach Landfall Approach, south of New London Harbor within an area of muddy substrate. This simulation is representative of the excavation (assuming side-casting of material) and backfill operations as 100% of the dredged material was released at the water surface over one hour. Backfilled sediment was released during an ebb tide. As the tide ebbs out of Long Island Sound and from the Thames River, the plume becomes trapped within an eddy at the mouth of the river. This results in relatively high concentrations (e.g., ≥200 mg/L) that extend east/northeast (Figure 3-23). However, these concentrations are not predicted to last longer than one hour because they dissipate due to advection induced by tidal changes and river outflow, and because the coarse sediment settles rapidly once released. Similarly, TSS concentrations ≥10 mg/L are not predicted to last more than three hours (Figure 3-24). After being released to the surface, the coarse sediment settles first to the seabed creating a depositional footprint that extends east/northeast of the release location, followed by the finer material which lingers longer in the water column but eventually settles. The thickest deposits remain near the release location, and the thicknesses between 1 mm and 5 mm extend across the channel (Figure 3-25). The maximum extent to the 1 mm and 20 mm contours was predicted to be approximately 1.23 km and 0.12 km, respectively (Table 3-16).

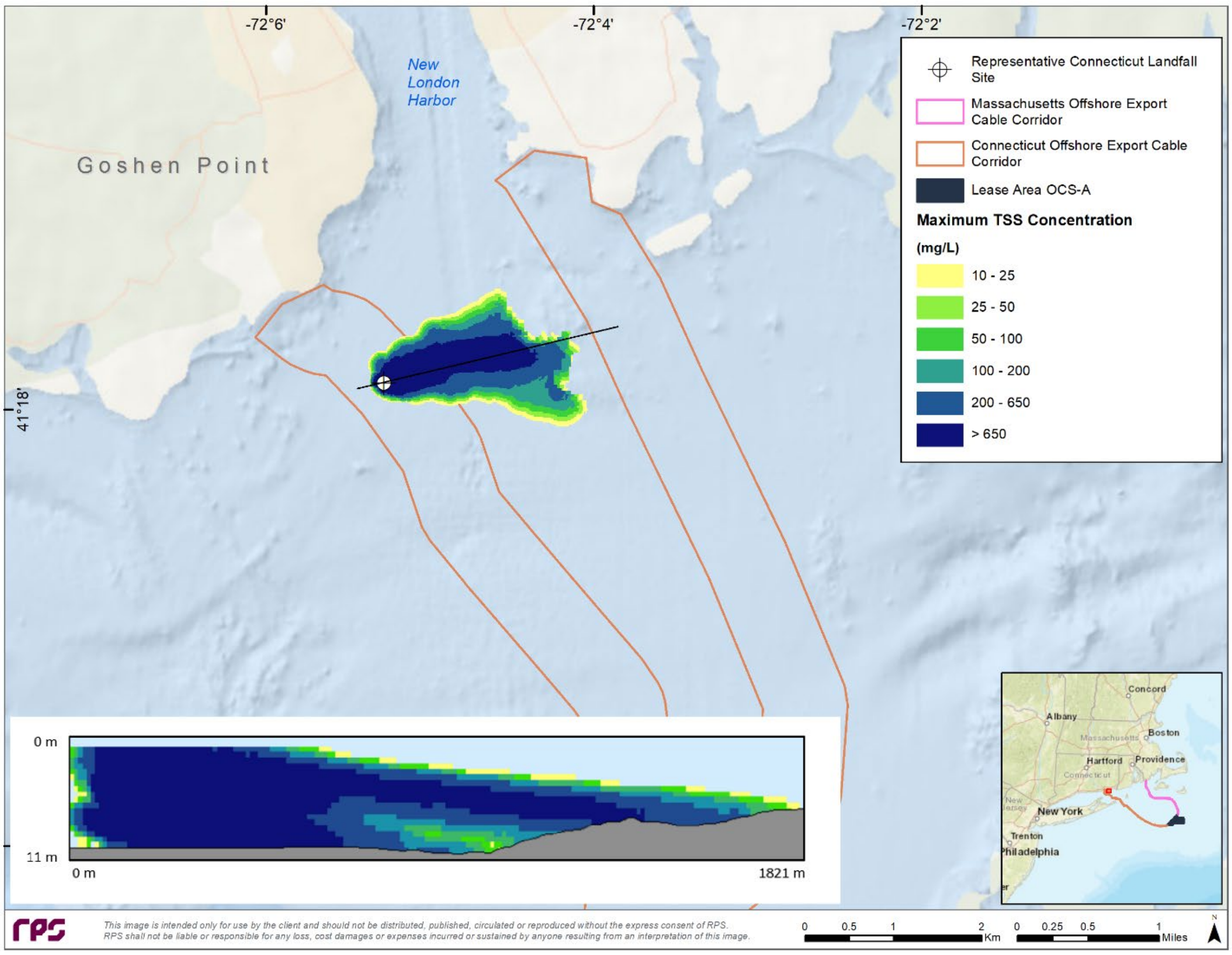

Figure 3-23: Map of time-integrated maximum concentrations associated with the representative Connecticut Landfall Site HDD Exit Pit Construction simulation.

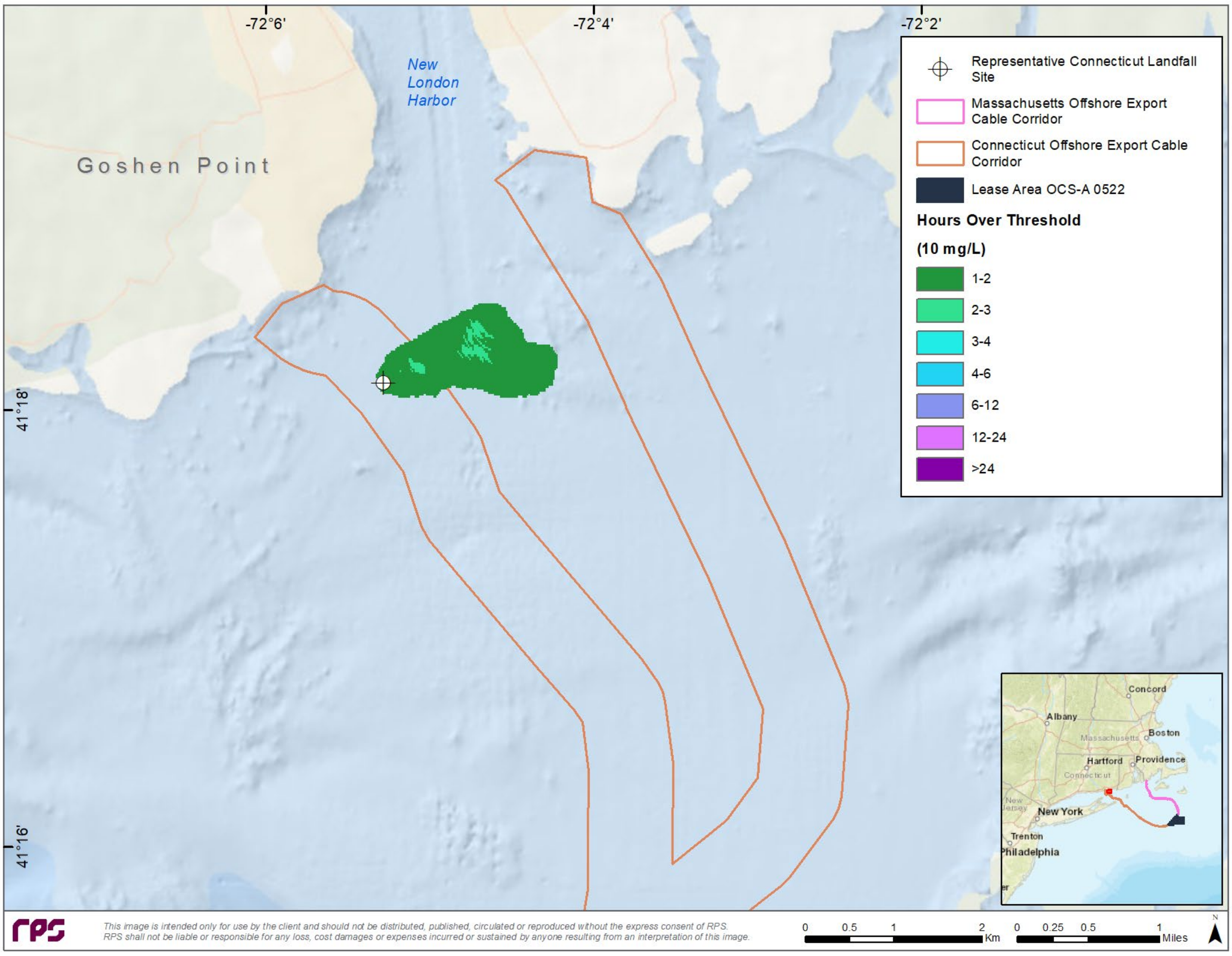

Figure 3-24: Map of duration of TSS ≥ 10 mg/L associated with the representative Connecticut Landfall Site HDD Exit Pit Construction simulation.

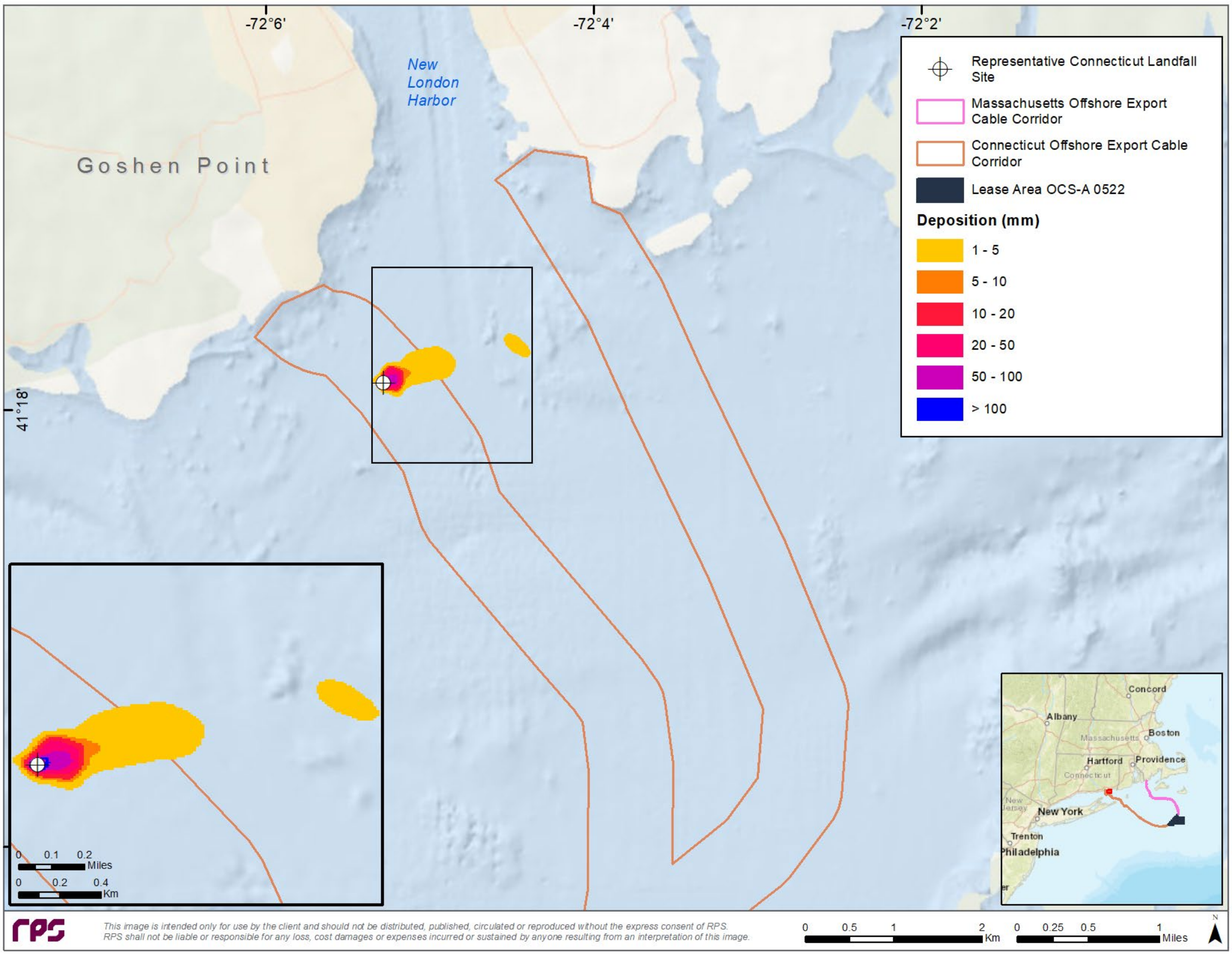

Figure 3-25: Map of deposition thickness associated with the Representative Connecticut Landfall Site HDD Exit Pit Construction simulation.

Representative Connecticut OECC Cable Installation — Jetting

Modeling of the Representative Connecticut OECC Cable Installation using typical jetting techniques was performed for the entire length of the Connecticut OECC. Simulations were performed from both the Niantic Beach Landfall Approach and Eastern Point Beach Landfall Approach. For the ease of displaying the model and comparing results, the two approaches were mapped together; however, cable installation is not anticipated in both approaches and would not occur simultaneously. Results from these two approaches is representative of the Ocean Beach Landfall Approach as it falls between the other two sites so it would experience similar hydrodynamic forcing conditions, has similar *in-situ* conditions (e.g., water depth), and consists of similar sediment characteristics.

The instantaneous map illustrates the transient nature of the plume and how it is influenced by the prevailing current at that moment in time (Figure 3-26). The model shows that the highest concentrations of installation-induced suspended sediment occur in the vicinity of the installation device, as expected; however, these higher concentrations then decrease rapidly with distance as the operating device advances along the cable corridor.

The time-integrated maximum water column concentration map shows the cross-section from the intersection of the two landfall approaches to the Lease Area (Figure 3-27 and Figure 3-28). These results illustrate that the cable installation via jetting techniques cause a subsurface plume that remains localized to the seabed. Near the shoreline, the plume oscillates with the currents due to the higher fraction of fine material present and the perpendicular nature of the currents to the route. As the sediment becomes coarser, the plume remains close to the route centerline and settles out quickly. Once the installation simulation approaches the Lease Area and returns to an area of fine-grained material, the plume extends away from the centerline (as shown by the yellow 10-25 mg/L contour in Figure 3-27 and Figure 3-28).

The extent of the suspended sediment plume shown in Figure 3-27 and Figure 3-28 is much larger than what would occur at any one-time during cable installation. In contrast, Figure 3-26 provides an example snapshot of TSS concentrations at a single moment in time, characterized by narrow, heterogeneous patches that may individually persist for minutes to hours at a single location. This location was selected as a conservatively extensive snapshot of a plume induced by jetting because it was in an area containing high fractions of fine material where transport was directed away from the corridor by subsurface currents. A typical plume would likely be smaller in extent and have lower predicted suspended sediment concentration.

The duration of water column TSS concentrations ≥10 mg/L (Figure 3-29 and Figure 3-30) tends to be higher in areas with fine material (e.g., close to shoreline, near the Lease Area) because fine sediments (e.g., clays, silts) tend to remain suspended in the water column longer; coarse sediment (e.g., fine sand, coarse sand) settles faster. For both landfall approaches, water column concentrations are not predicted to be ≥10 mg/L for more than four hours, and from the connection point to the Lease Area, water column concentrations ≥10 mg/L return to ambient levels within six hours.

The depositional footprint follows along the route centerline with the majority of the footprint containing thicknesses of less than 5 mm, and isolated patches resulting in thicknesses between 5 and 10 mm (Figure 3-31 and Figure 3-32). The maximum distance to the 1 mm contour along the Connecticut OECC is predicted to extend approximately 0.43 km (Table 3-16).

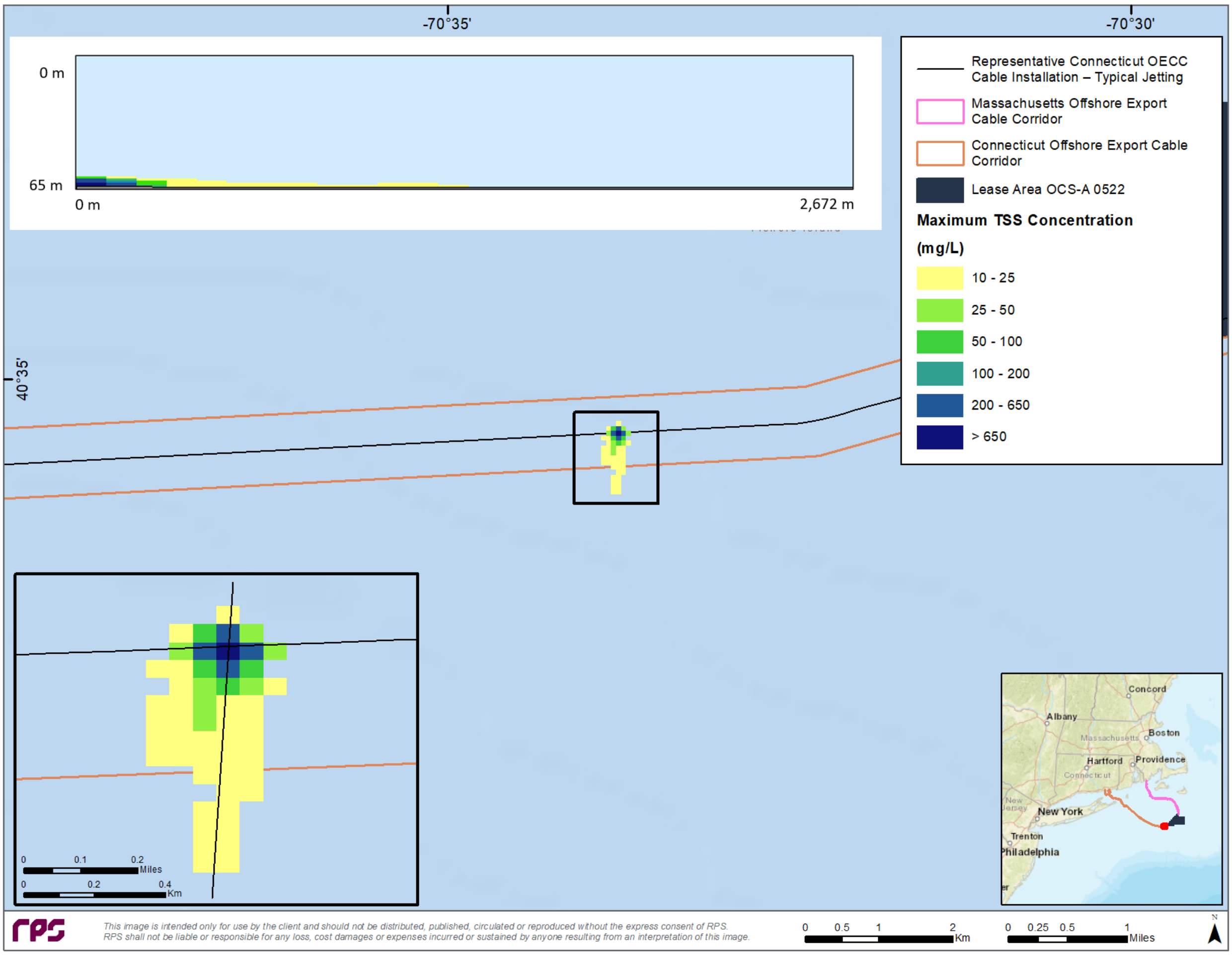

Figure 3-26: Snapshot of instantaneous TSS concentrations for a time step during the simulation for the Representative Connecticut OECC Cable Instillation — Jetting simulation.

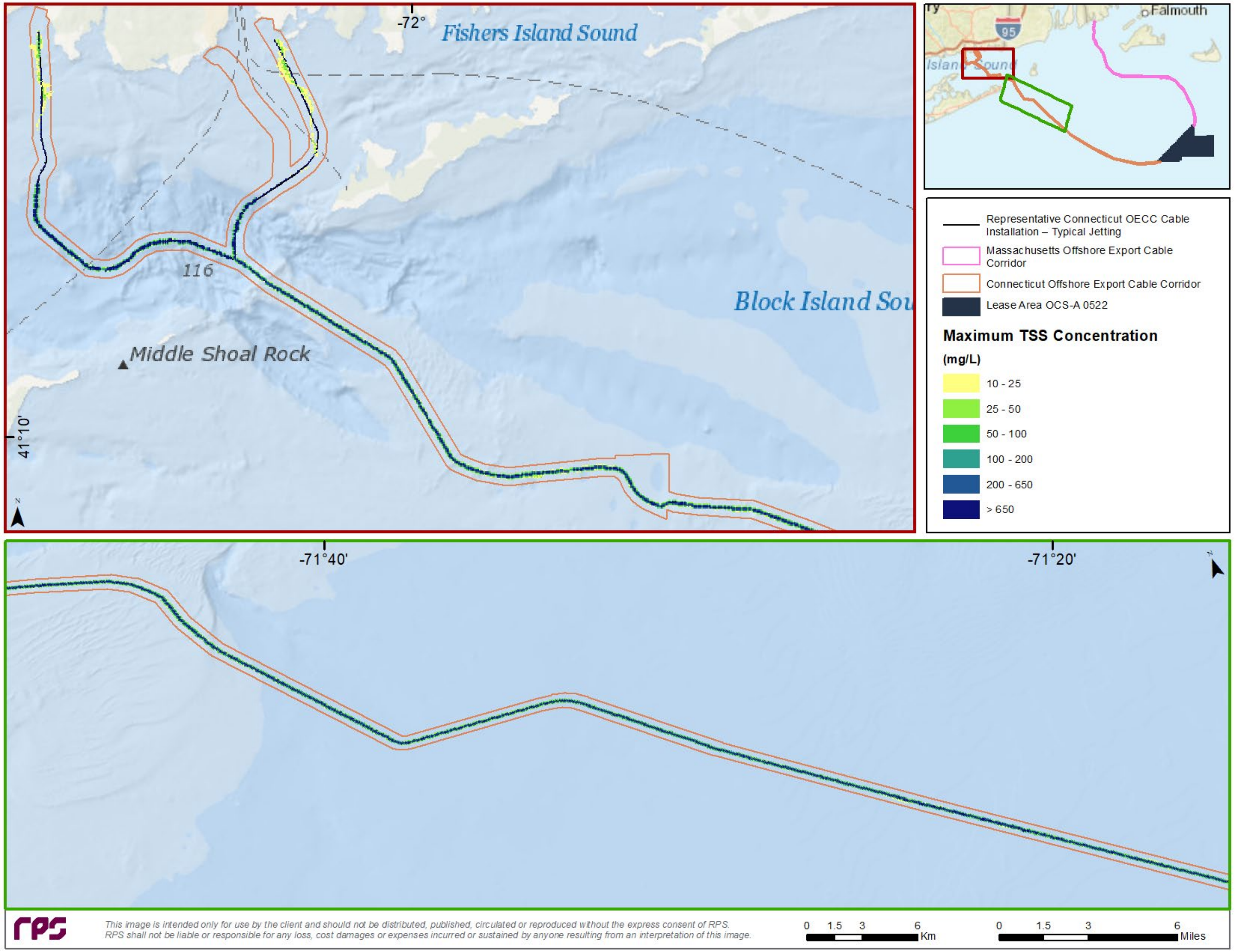

Figure 3-27: Map of time-integrated maximum concentrations associated for the Representative Connecticut OECC Cable Instillation — Jetting simulation (Panel 1 of 2).

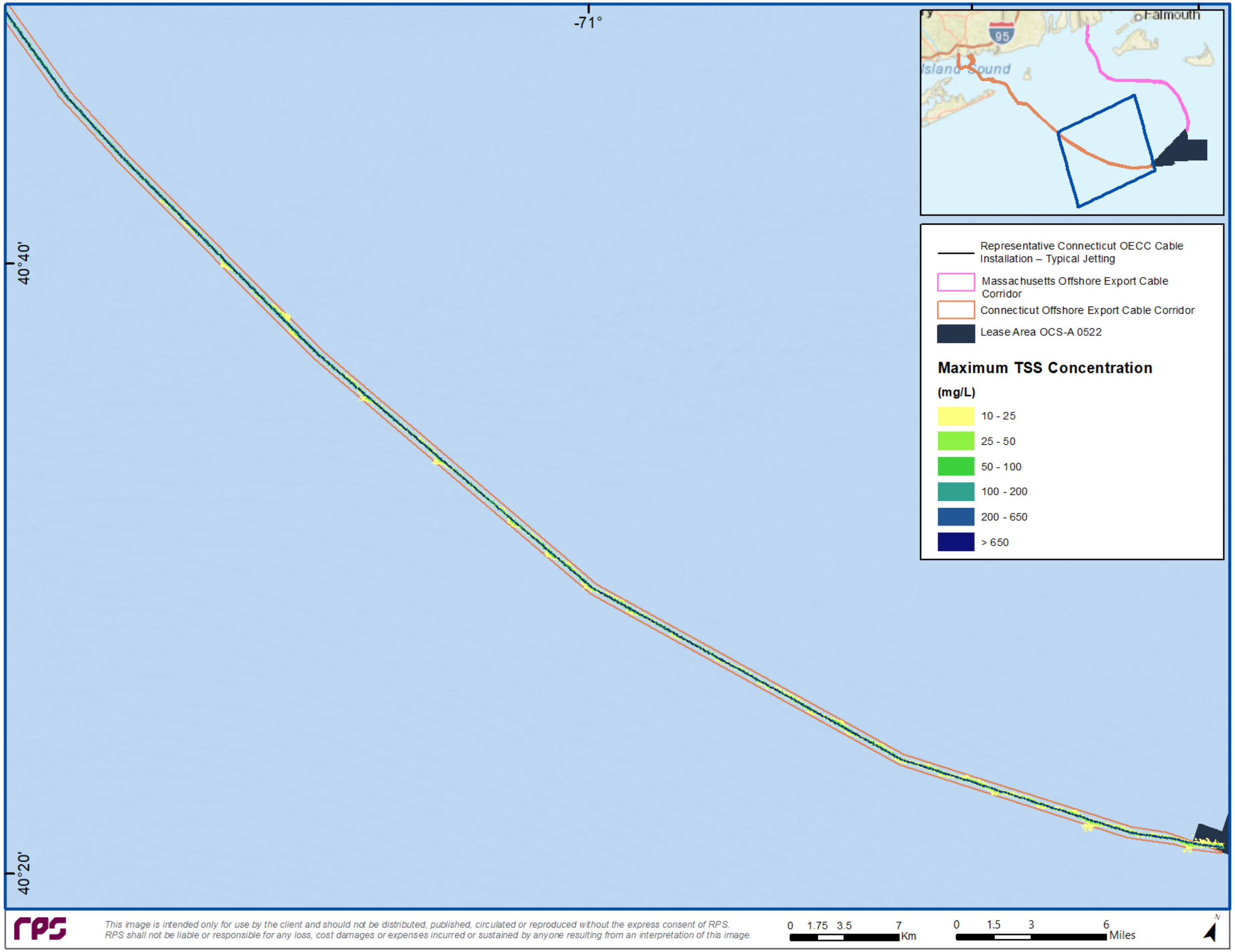

Figure 3-28: Map of time-integrated maximum concentrations associated for the Representative Connecticut OECC Cable Instillation — Jetting simulation (Panel 2 of 2).

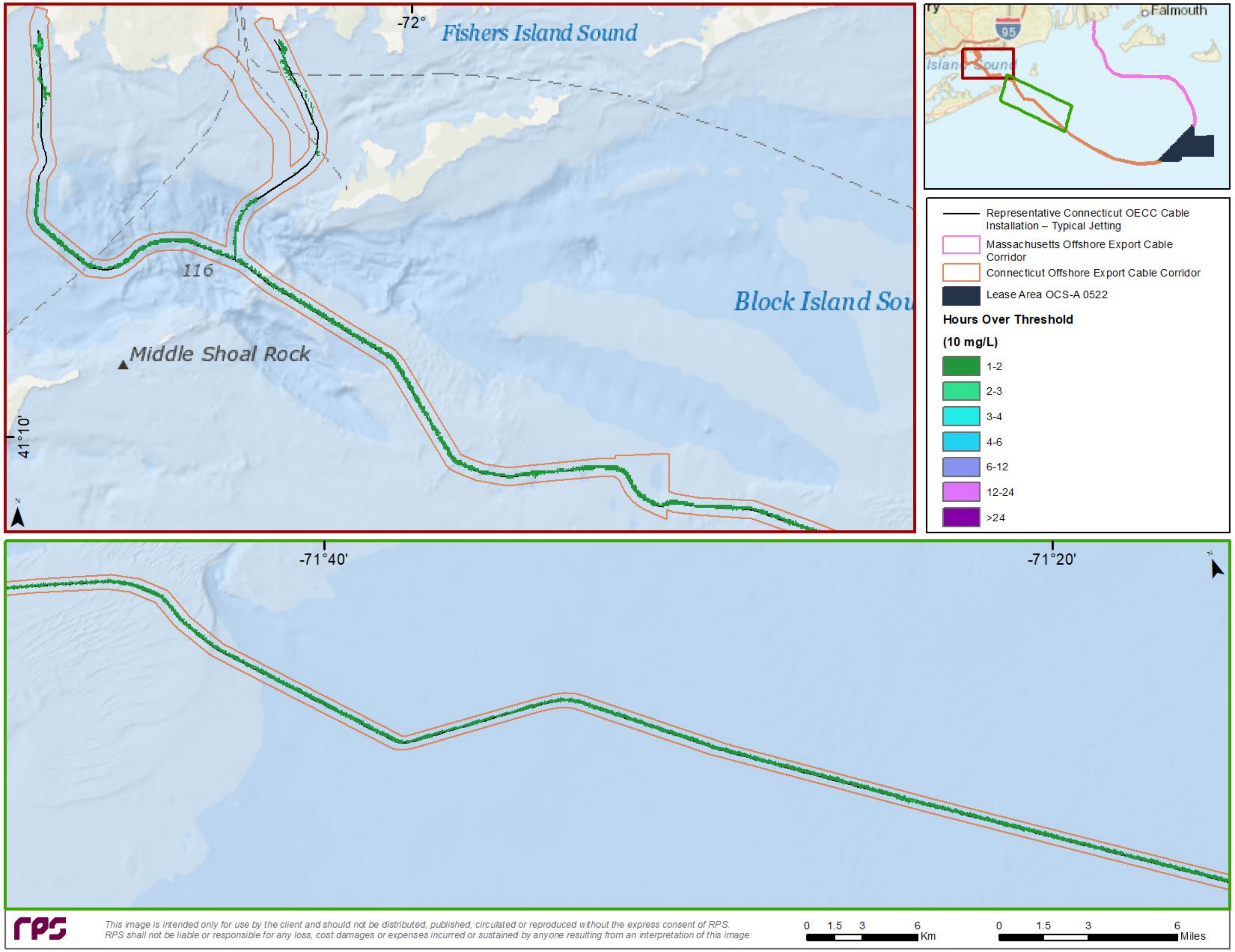

Figure 3-29: Map of duration of TSS ≥ 10 mg/L associated with the Representative Connecticut OECC Cable Instillation — Jetting simulation (Panel 1 of 2).

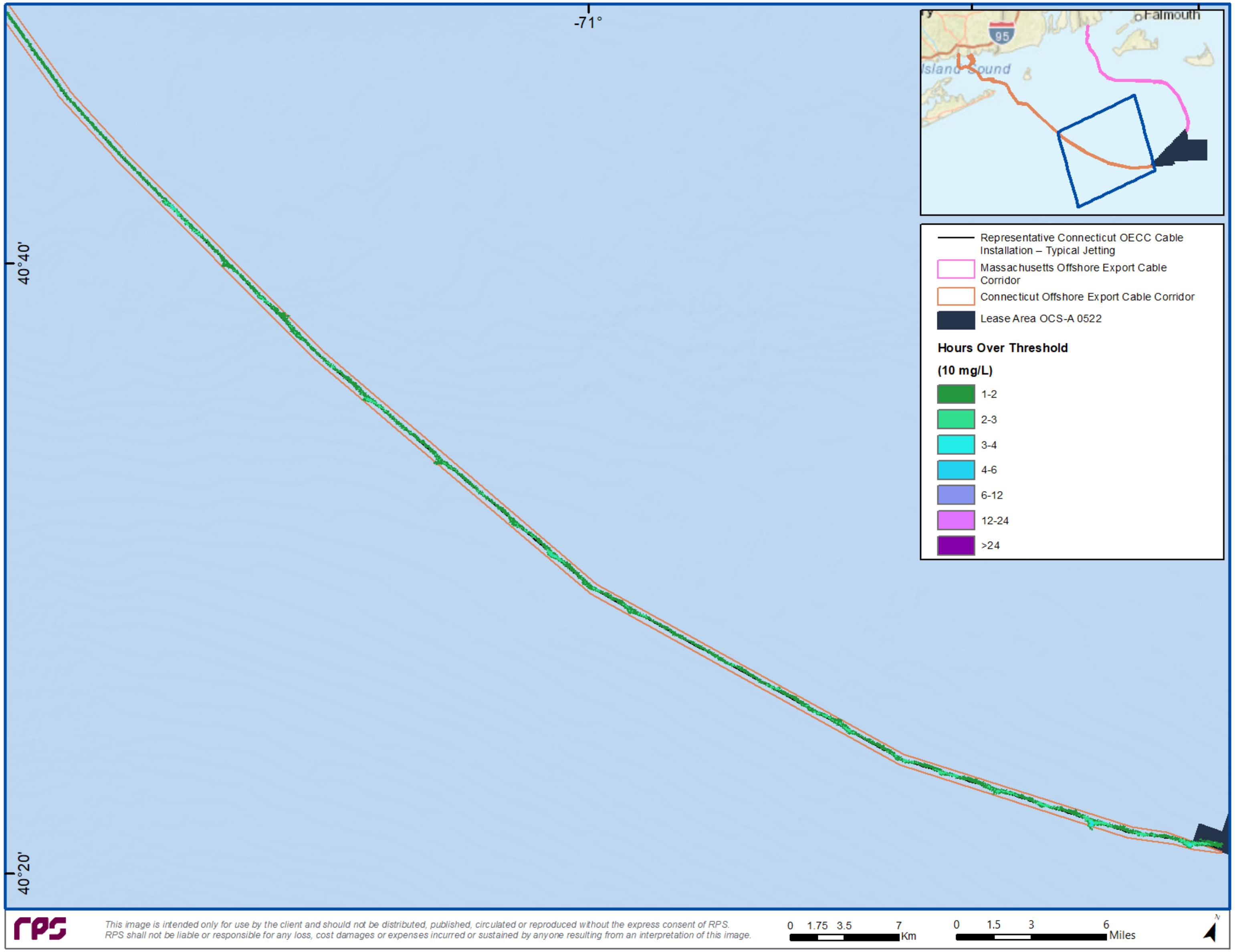

Figure 3-30: Map of duration of TSS ≥ 10 mg/L associated with the Representative Connecticut OECC Cable Instillation — Jetting simulation (Panel 2 of 2).

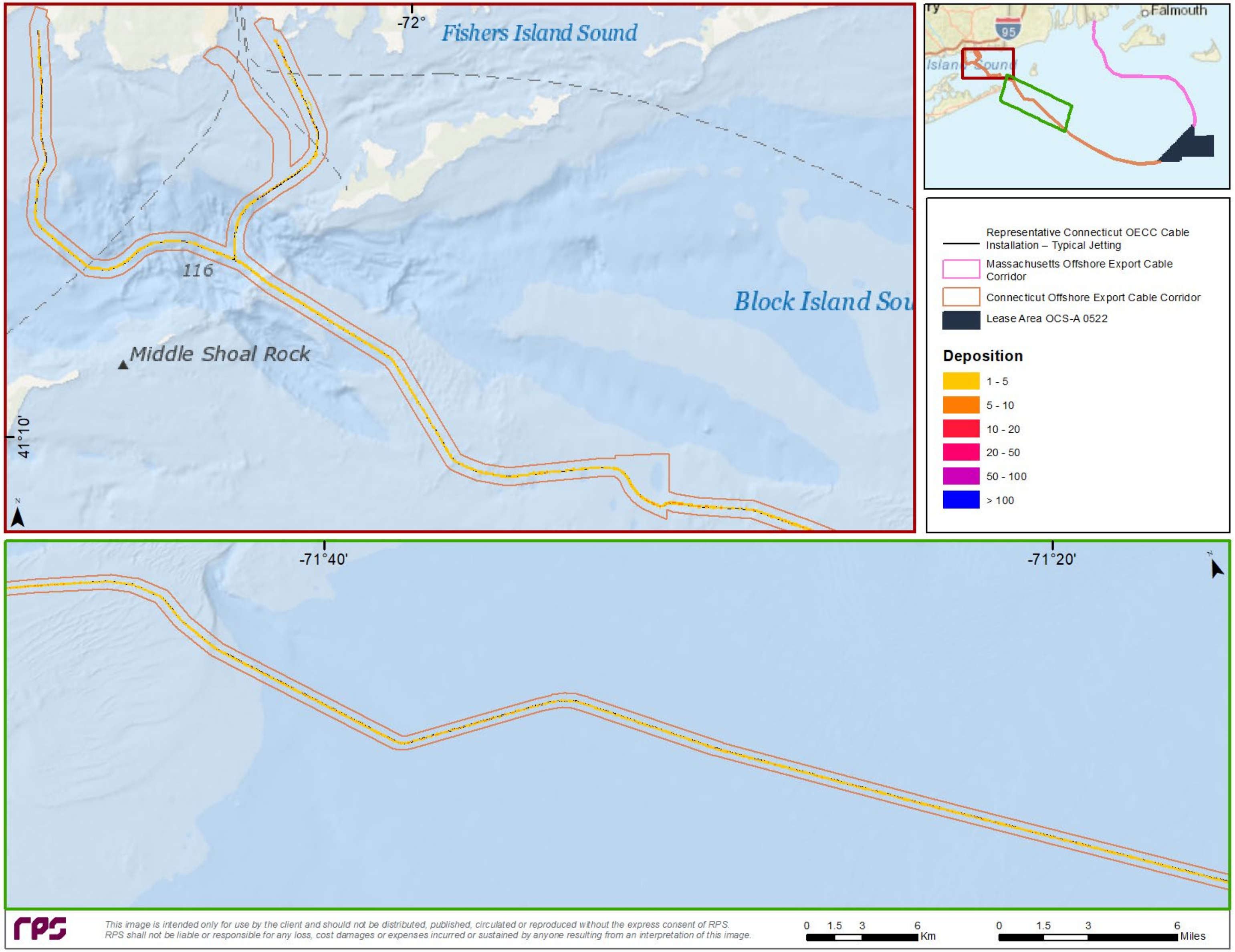

Figure 3-31: Map of deposition thickness associated with the Representative Connecticut OECC Cable Instillation — Jetting simulation (Panel 1 of 2).

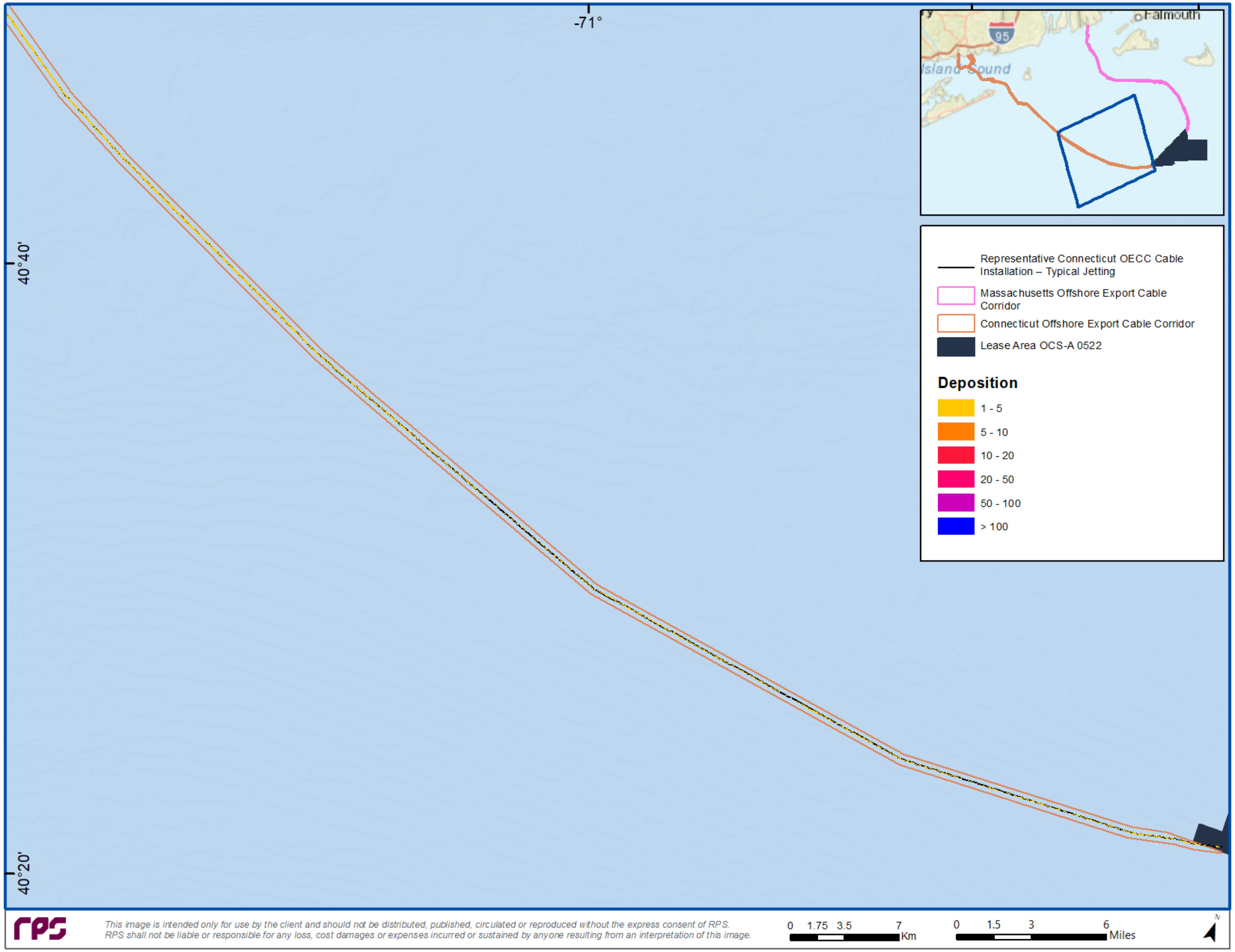

Figure 3-32: Map of deposition thickness associated with the Representative Connecticut OECC Cable Instillation — Jetting simulation (Panel 2 of 2).

Representative Connecticut OECC Cable Installation — Mechanical Trenching

To understand how a different installation technique would cause sediment related impacts, a sensitivity analysis was performed in an area containing hard substrate within the Connecticut OECC. This scenario was modeled during a flood tide because it produced the largest suspended sediment plume due to the prevailing currents within the channel. Compared with the typical installation parameters using jetting techniques, the mechanical trencher was modeled using a slower installation rate to account for the relatively slower progress when cutting through consolidated sediments or rock. Additionally, a deeper target trench depth was simulated, and it was conservatively estimated that 75% of the dredged material was resuspended within the bottom 2.5 m of the water column. As indicated by the model, and shown in the instantaneous map, the plume remains localized to the seabed and centered over the trench (Figure 3-33). As indicated by the instantaneous snapshot (Figure 3-33), during that timestep, the lighter material was transported southeast prior to dissipating and settling.

The time-integrated maximum water column concentration map shows the cross-section for the entire length of the mechanical trenching simulation along the route centerline (Figure 3-34). The sediment characteristics within this region tend to consist primarily of sand, thus resulting in higher concentrations centered over the route that dissipate and settle within three hours (Figure 3-35). The coarse material settles quickly which results in depositional thickness that range between 10 and 20 mm (Figure 3-36). Due to the rapid settling, the footprint of deposition matches the footprint of the time-integrated maximum concentration map.

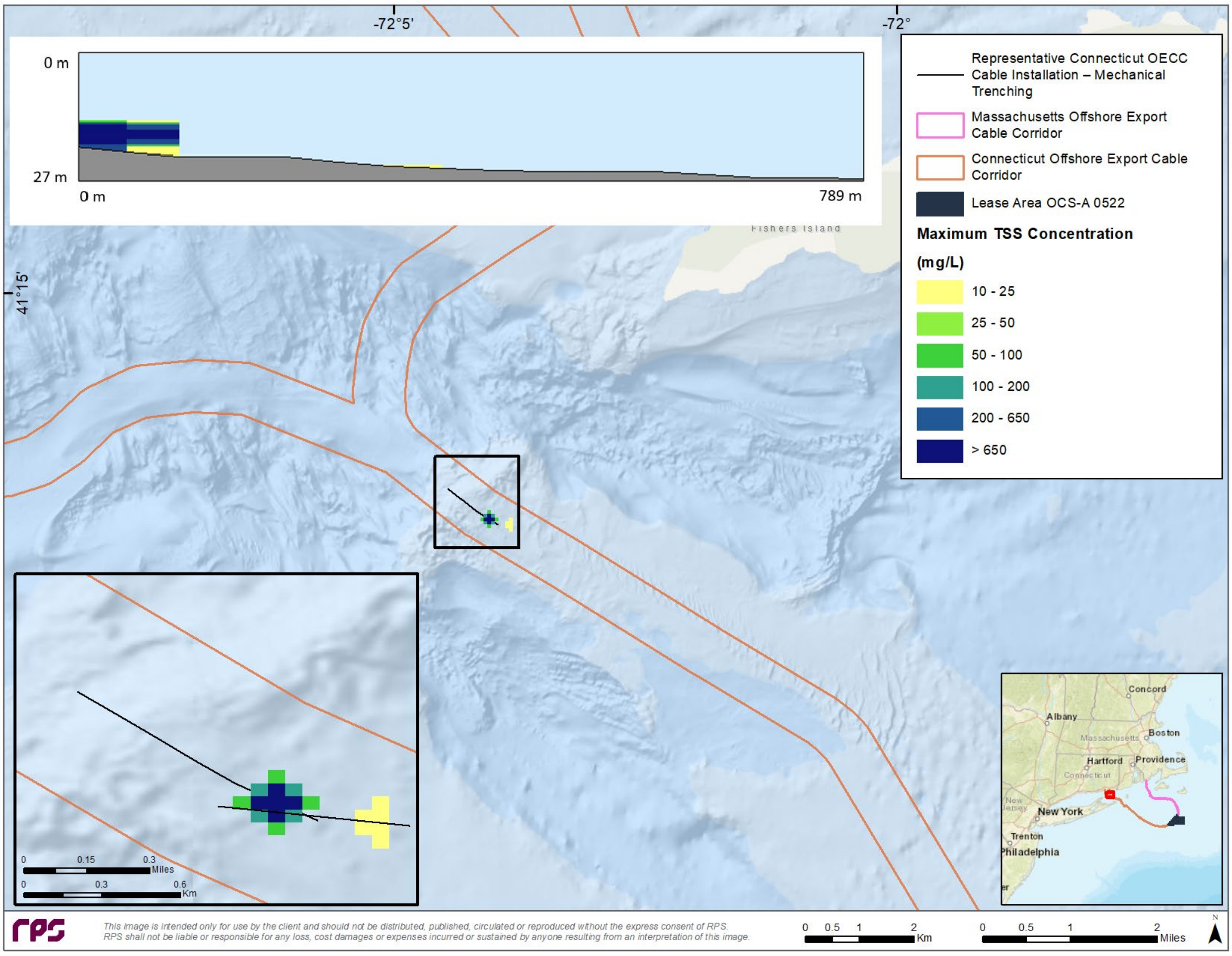

Figure 3-33: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Connecticut OECC Cable Installation — Mechanical Trenching simulation.

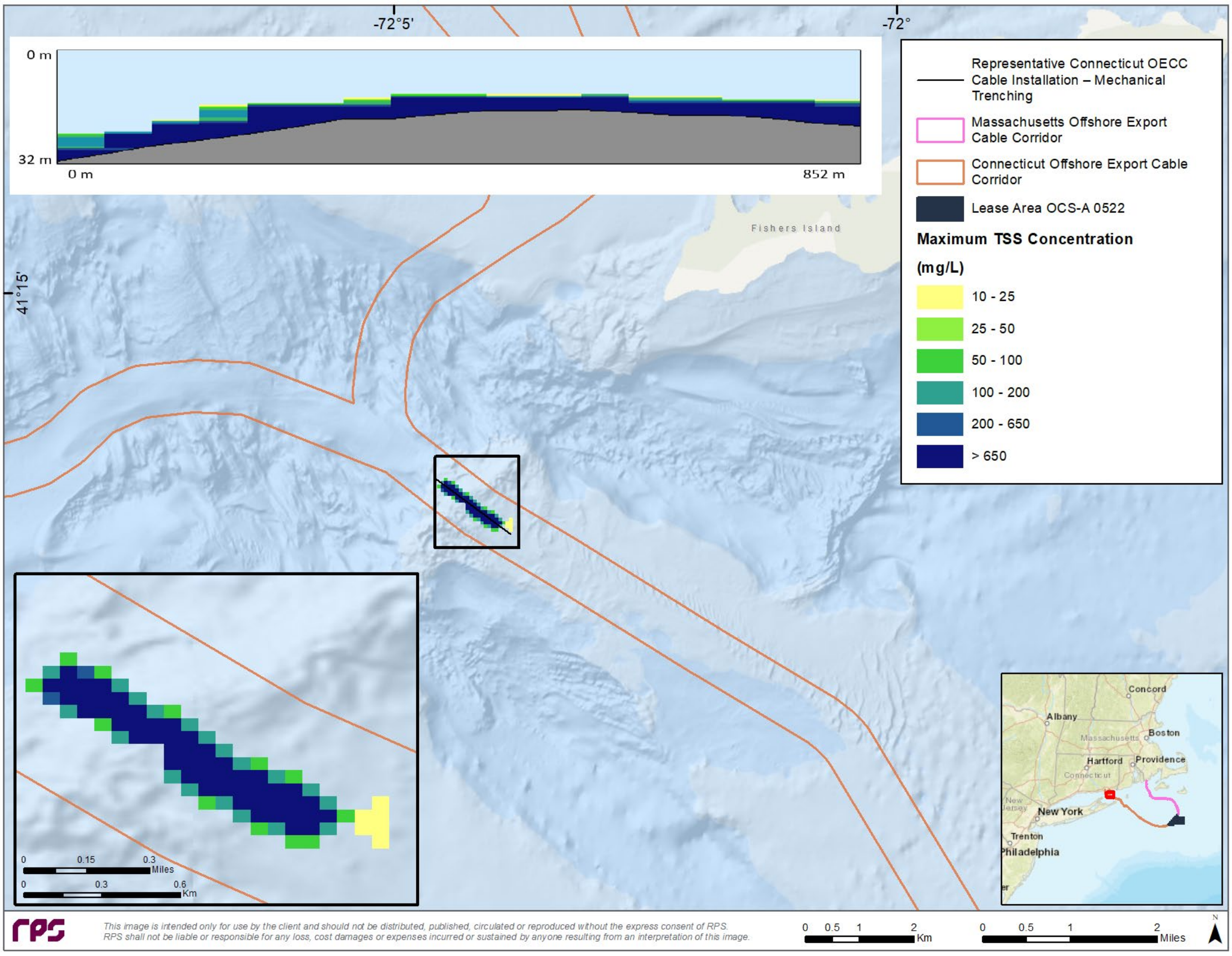

Figure 3-34: Map of time-integrated maximum concentrations associated with the Representative Connecticut OECC Cable Installation — Mechanical Trenching simulation.

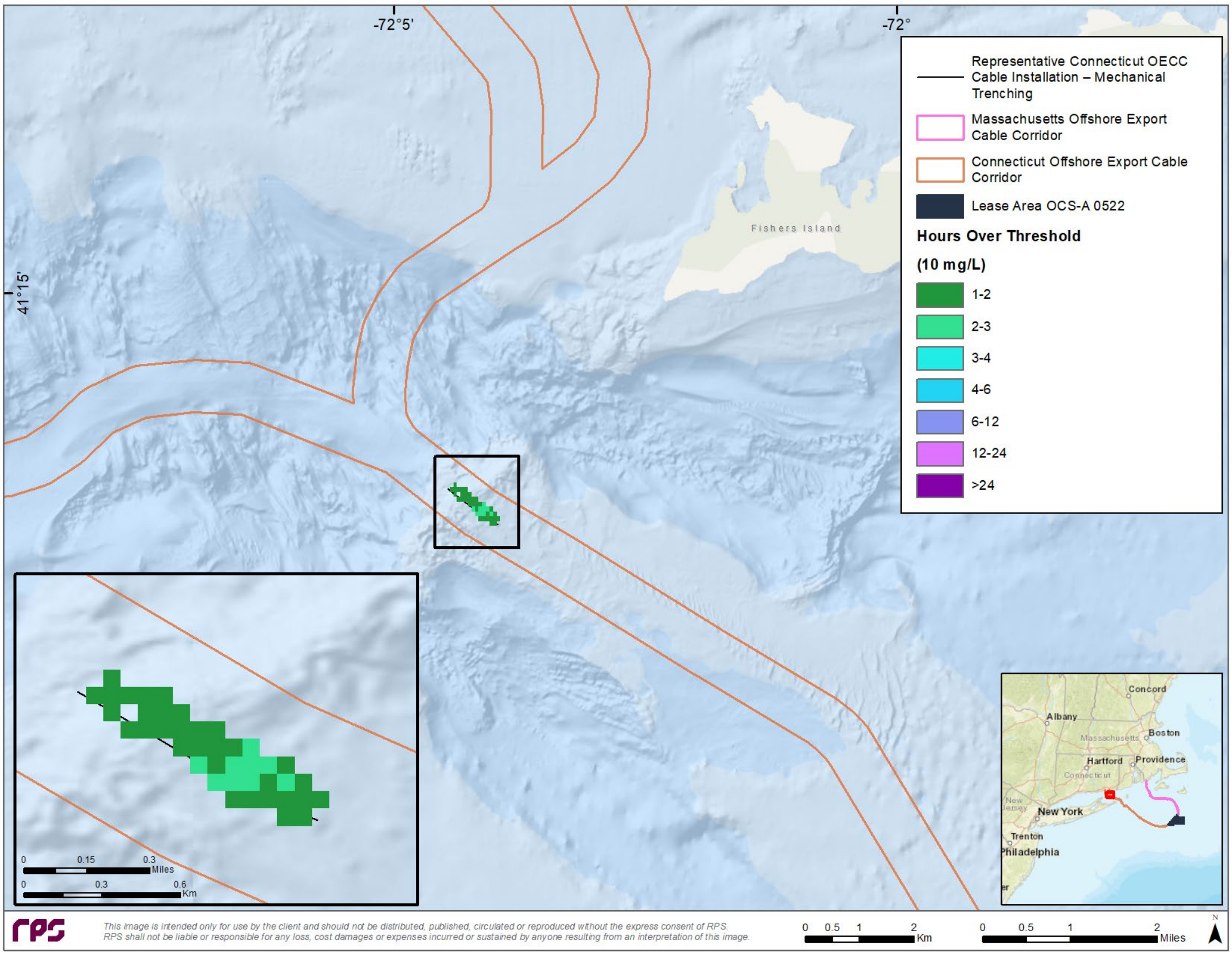

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Figure 3-35: Map of duration of TSS ≥ 10 mg/L associated with the Representative Connecticut OECC Cable Installation — Mechanical Trenching simulation.

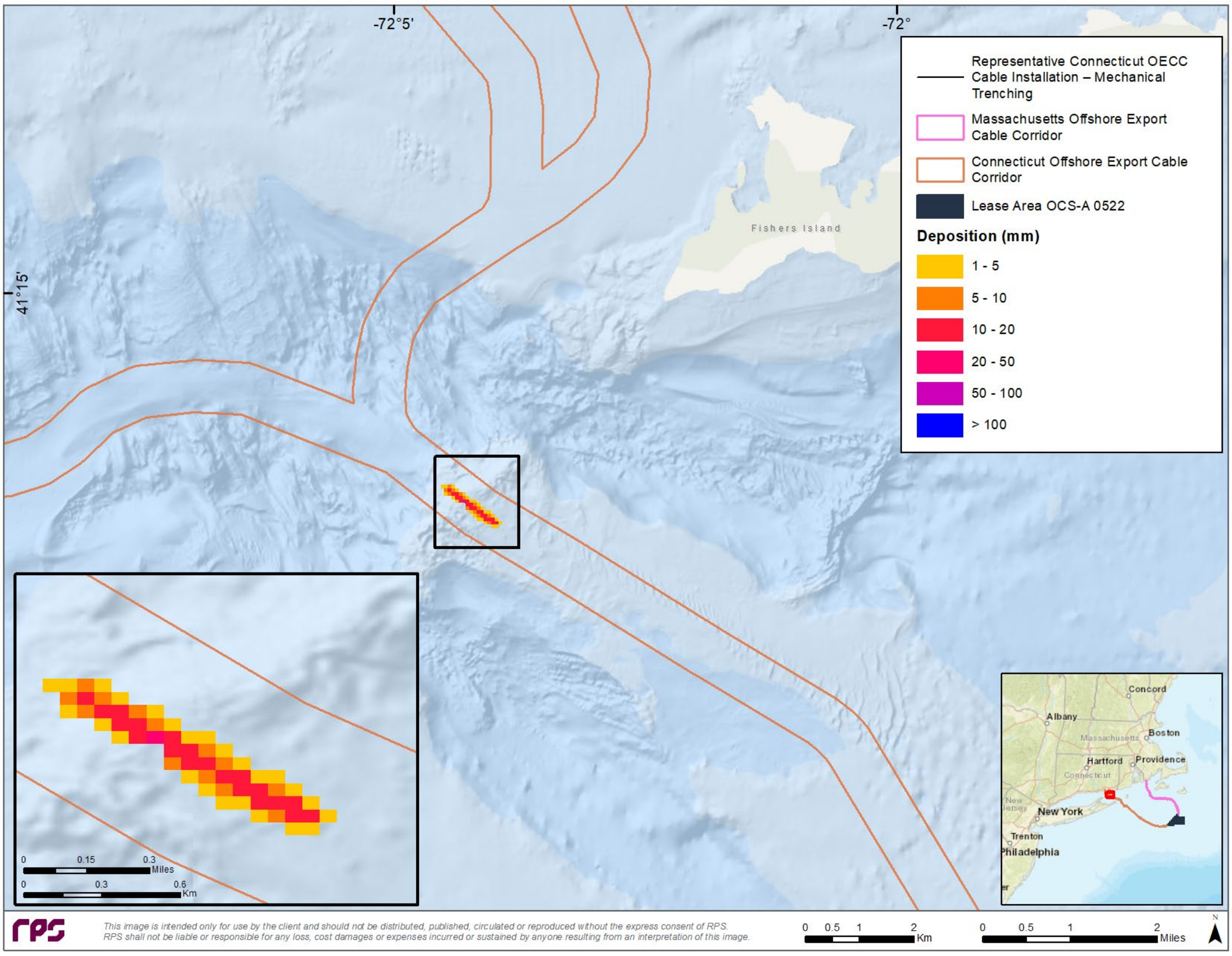

Figure 3-36: Map of deposition thickness associated with the Representative Connecticut OECC Cable Installation — Mechanical Trenching simulation.

Representative Connecticut OECC Cable Installation — Vertical Injector

In addition to the representative Mechanical Trenching simulation, a representative simulation was performed to simulate cable installation within the Connecticut OECC using a vertical injector. The simulation was performed within an area containing high fractions of fine material to evaluate a potential worst-case scenario when predicting water column concentrations. The instantaneous snapshot illustrates the influence of the currents at the time, and the cross-sectional view (inset map) shows the plume was localized to the seabed (Figure 3-37).

A map of the time-integrated maximum water column concentrations captures the highest reported concentrations in each grid cell, cumulatively over the duration of the simulation (Figure 3-38). The maximum predicted suspended sediment concentration occurs at different depths within the water column; at different locations within the concentration grid cell; and can occur at any point in time between the start of installation and the return to ambient conditions following the end of installation activities. The inset map in Figure 3-38 follows the length of the cable installation route and the plan view captures the influence of the oscillating currents on the subsurface plume.

The elevated levels of suspended sediment (>50 mg/L) are predicted to dissipate within three hours, while concentrations ≥10 mg/L within isolated patches require six hours to dissipate (Figure 3-39). The duration of the water column TSS concentrations ≥10 mg/L footprint is similar in extent to the time-integrated maximum water column concentration map and follows a similar pattern of oscillation with the currents.

Due to the simulation being performed in an area of high fine material (e.g., silts, clays), the depositional footprint is centered around the route (Figure 3-40). Depositional thicknesses were not predicted to exceed 5 mm based on the simulation parameters and the location of the simulation. The maximum extent to the 1 mm deposition contour was approximately 0.15 km (Table 3-16).

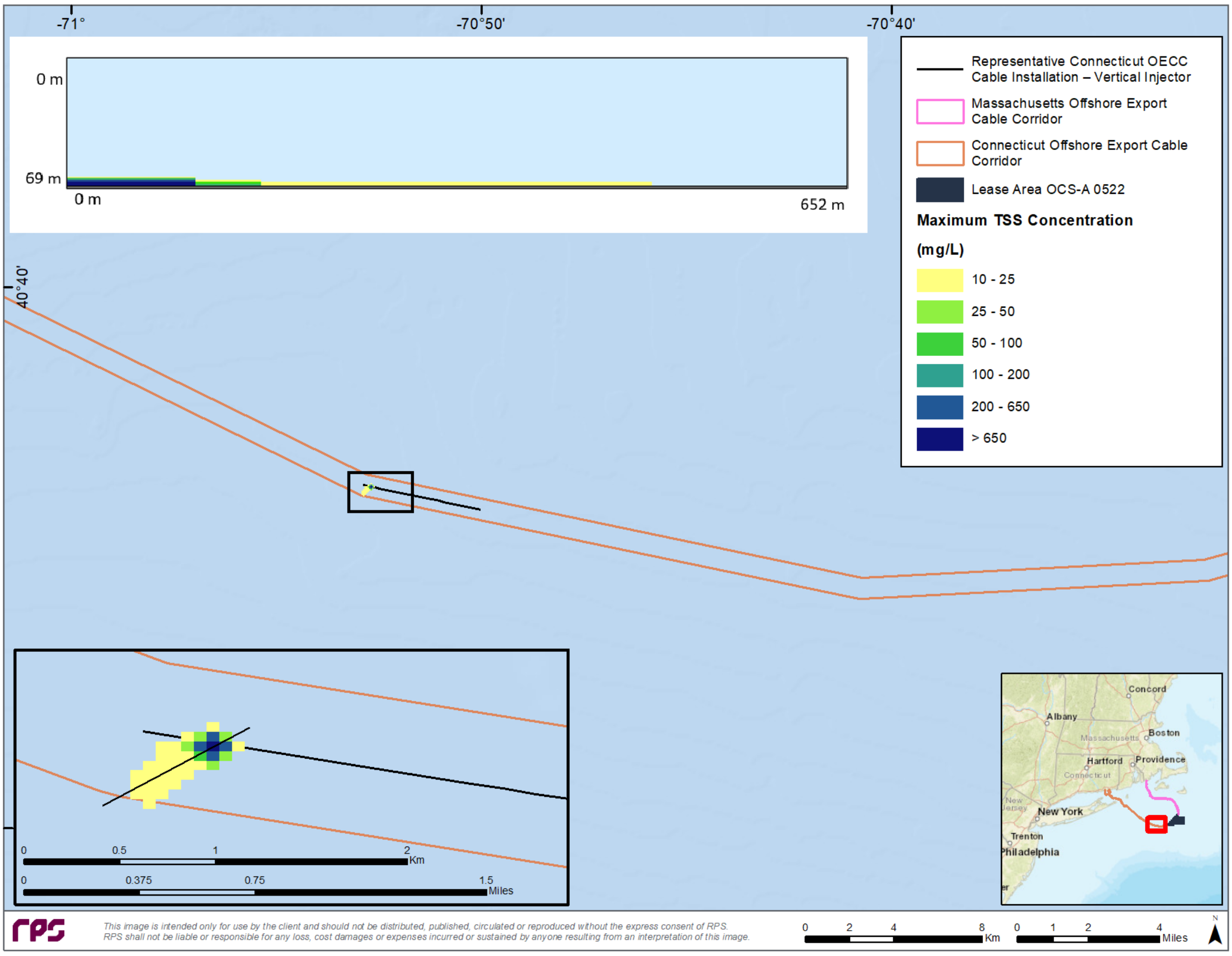

Figure 3-37: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Connecticut OECC Cable Installation — Vertical Injector simulation.

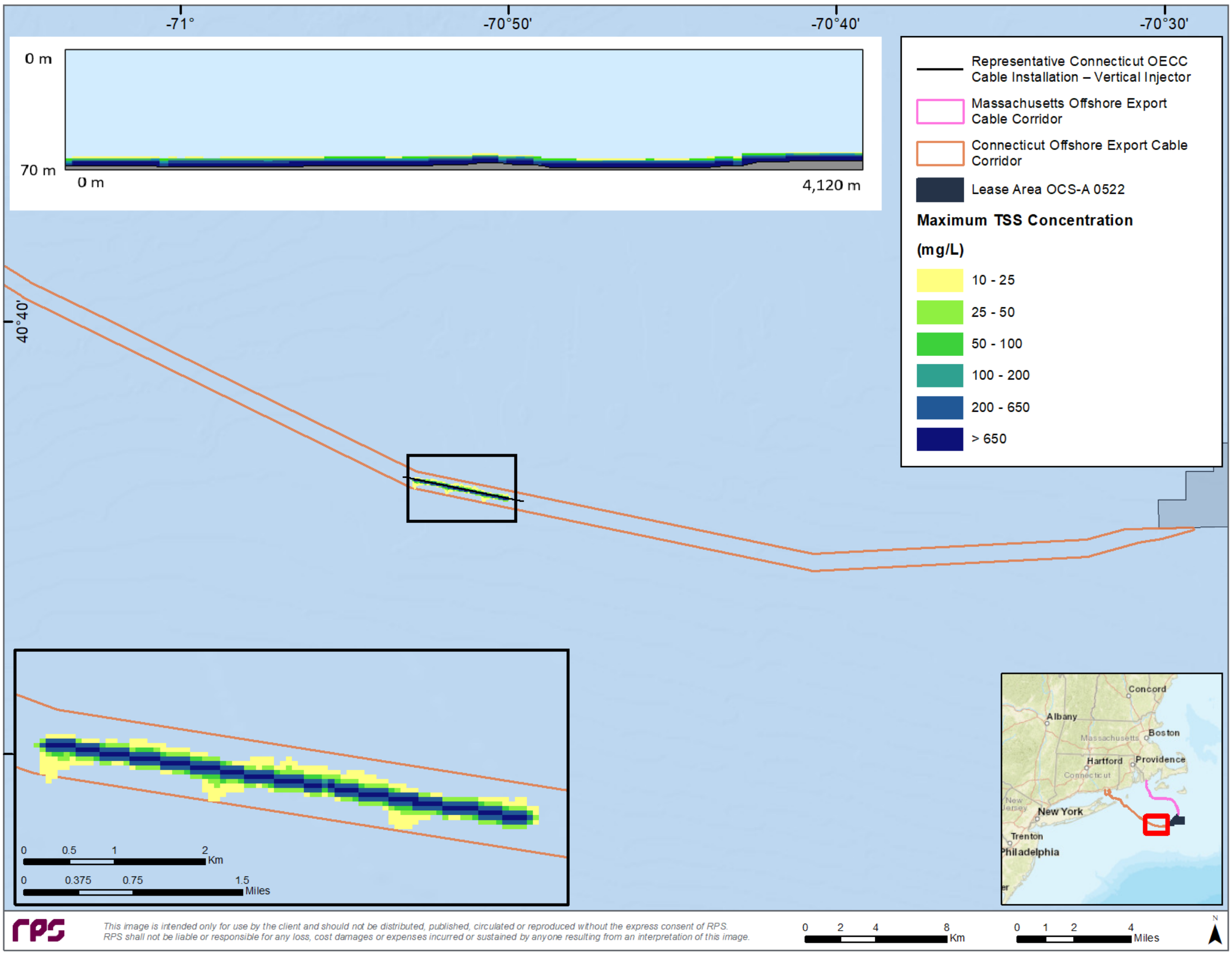

Figure 3-38: Map of time-integrated maximum concentrations associated with the Representative Connecticut OECC Cable Installation — Vertical Injector simulation.

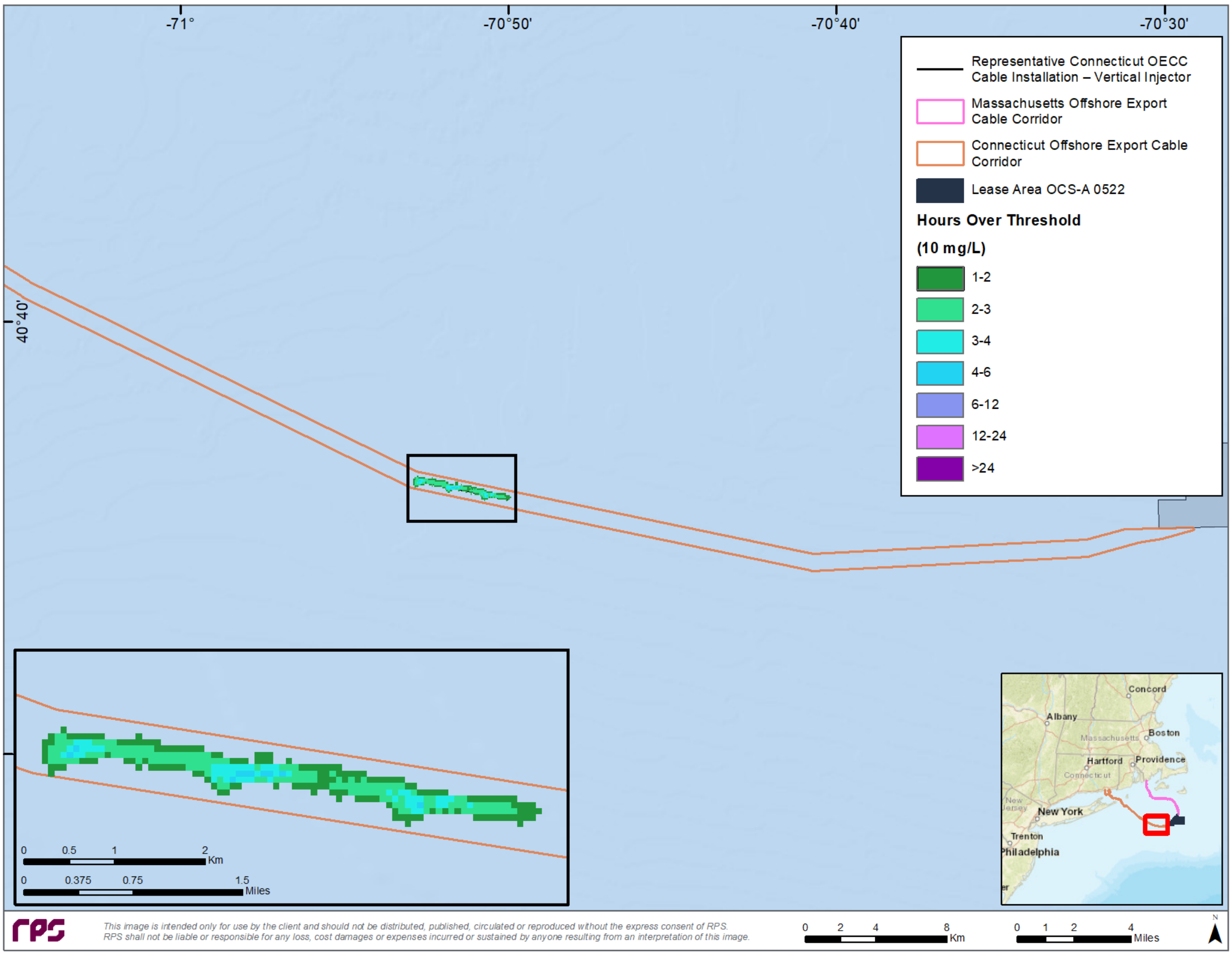

Figure 3-39: Map of duration of TSS ≥ 10 mg/L associated with the Representative Connecticut OECC Cable Installation — Vertical Injector simulation.

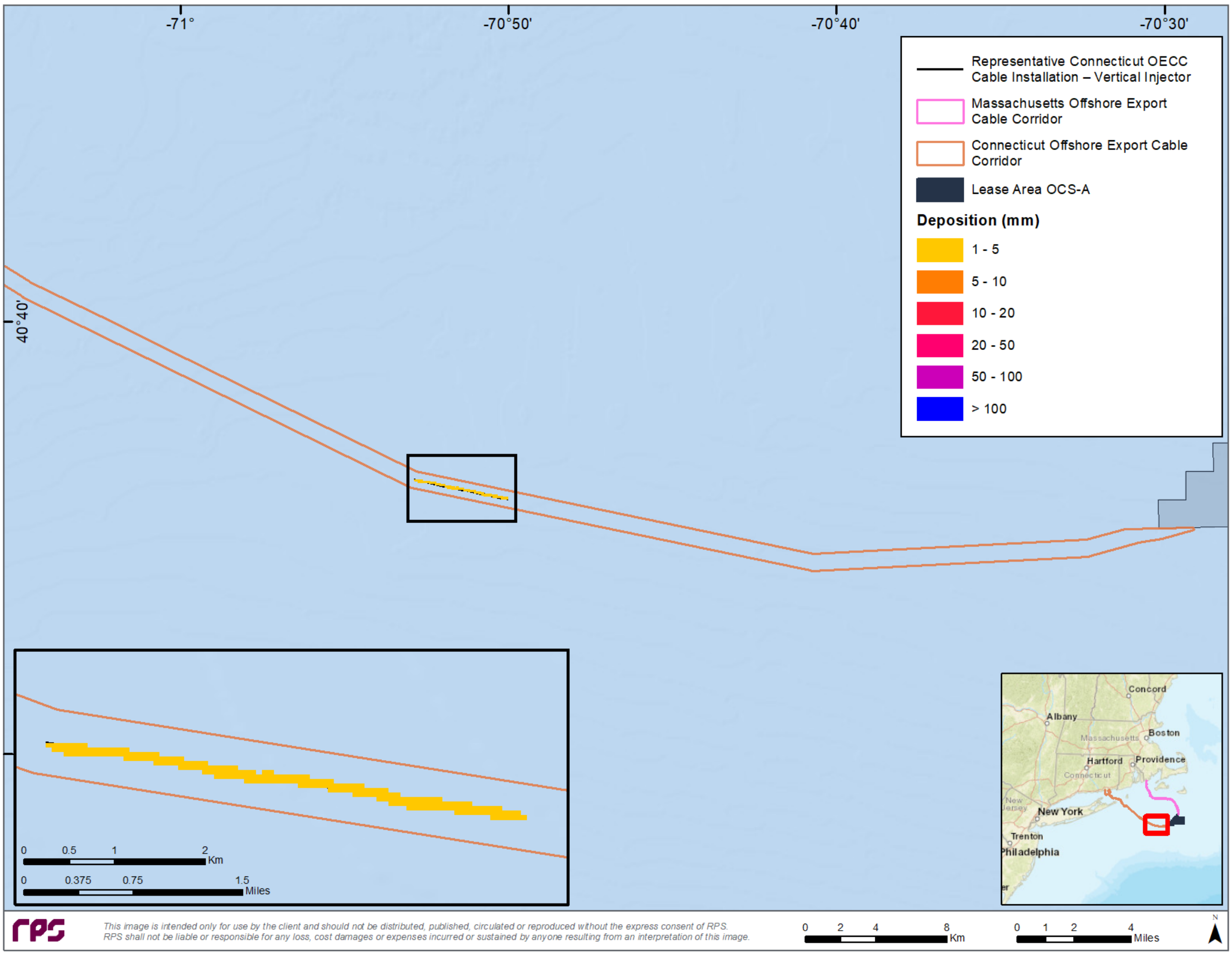

Figure 3-40: Map of deposition thickness associated with the Representative Connecticut OECC Cable Installation — Vertical Injector simulation.

3.3.2 Massachusetts OECC

Near the Massachusetts landfall approach, the composition of sediment contains a mixture of coarse and fine sand with minimal fractions of coarse silt, fine silt, and clay. As the OECC moves offshore, the sediment becomes mostly coarse and fine sand with intermittent patches of fine material scattered throughout. Patches containing higher fractions of fine material include sites southwest and south of Martha’s Vineyard, Massachusetts. As the OECC approaches the Lease Area the composition consists of primarily fine sand and coarse sand.

This section presents results from the simulations of seabed preparation and cable installation activities in the Massachusetts OECC. Results are presented separately for each of the model scenarios:

- Representative Massachusetts OECC Sand Bedform Dredging using – TSHD
- Representative Massachusetts Landfall Site HDD Exit Pit Construction
- Representative Massachusetts OECC Cable Installation — Jetting
- Representative Massachusetts OECC Cable Installation — Vertical Injector

Representative Sand Bedform Dredging using TSHD – Massachusetts OECC

Intermittent dredging was simulated within the Massachusetts OECC with operations starting west of Martha’s Vineyard and continuing towards the Lease Area. Drag arm disturbances caused plumes localized to the seabed while overflow and dumping operations created plumes that extended throughout the water column. Based on the total dredge volume, the hopper would reach capacity and require overflow and dumping to occur one time at the end of dredging operations. Overflow and dumping were modeled to occur at a representative location with existing sand bedforms. The portion of sediment associated with overflow tended to oscillate with the currents and be transported farther from the release location because it consisted of high fractions of fine material. Alternatively, coarse material released during dumping settled relatively quickly due to its higher density.

A snapshot of the instantaneous concentrations from the representative sand bedform dredging within the Massachusetts OECC shows the dump and overflow plume as patchy throughout the water column and is transient in time and space depending on the local currents (Figure 3-41). This snapshot was taken within an area of relatively high fractions of fine material following dumping and overflow operations. The time-integrated maximum water column concentration map (Figure 3-42) contains an inset that shows the cross-sectional view of the plume throughout the entire length of the representative dredging locations.

TSS concentrations tended to remain along the route centerline and local to the seabed for the drag arm disturbances. Alternatively, the plume associated with dumping and overflow operations was spread throughout the water column and transported in a cyclical fashion due to the timing of the scenario with the changing of current direction. TSS concentrations were predicted to exceed 650 mg/L, but these elevated TSS concentrations rapidly dissipated or settled prior to two hours (Figure 3-43). TSS concentrations ≥10 mg/L were not predicted to persist for more than six hours (Figure 3-43).

Seabed deposition for this scenario exceeded 100 mm near the dump location, with thickness between 1 mm and 5 mm extending south from the dump site (Figure 3-44). Depositional thicknesses between 1 mm and 5 mm occurred at the dredge locations in association with drag arm disturbances (Table 3-15). The maximum distance to the 1 mm and 20 mm contour is predicted to extend approximately 1.27 km and 0.1 km, respectively (Table 3-16).

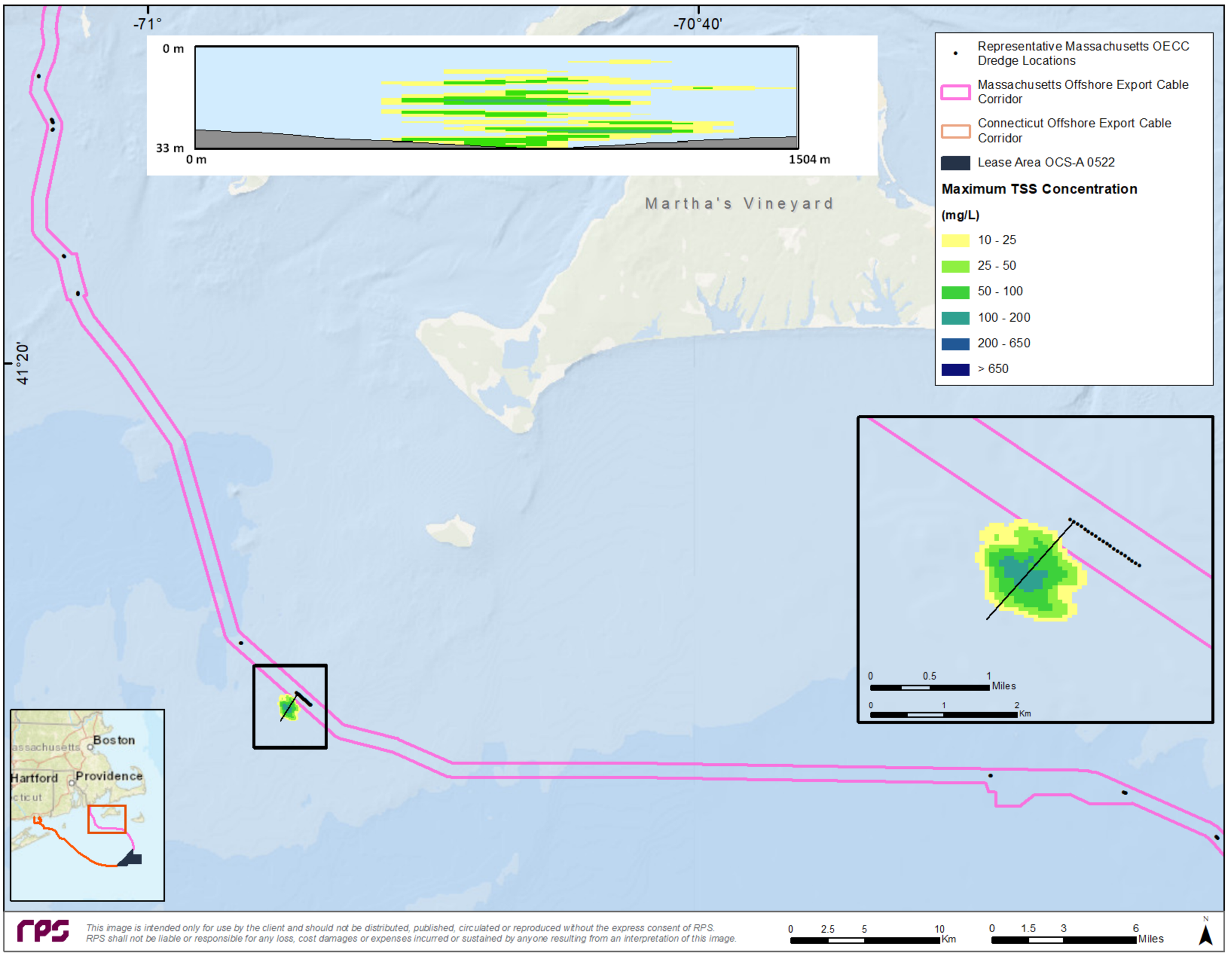

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Figure 3-41: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Sand Bedform Dredging using TSHD – Massachusetts OECC simulation.

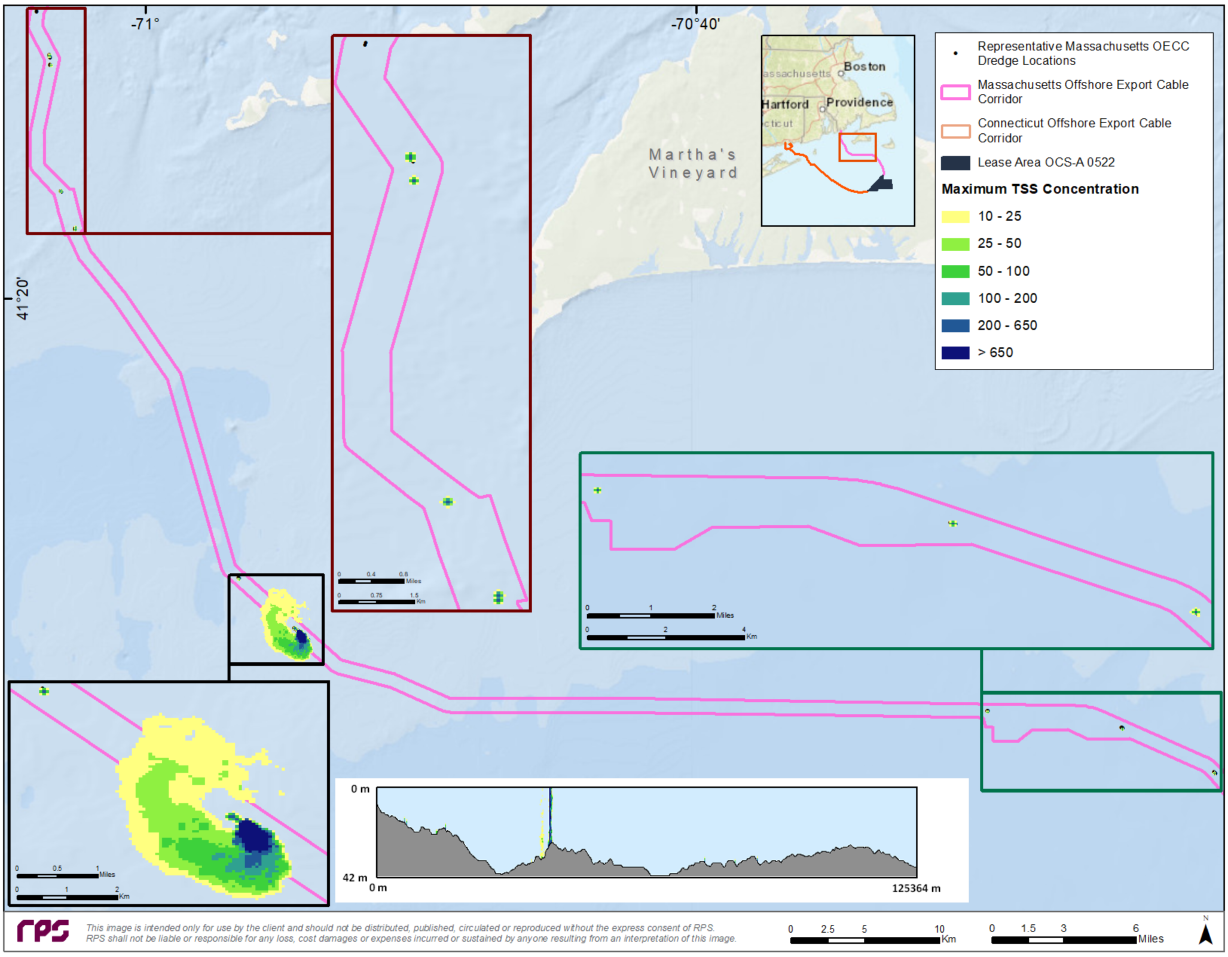

Figure 3-42: Map of time-integrated maximum concentrations associated with the Representative Sand Bedform Dredging using TSHD – Massachusetts OECC simulation.

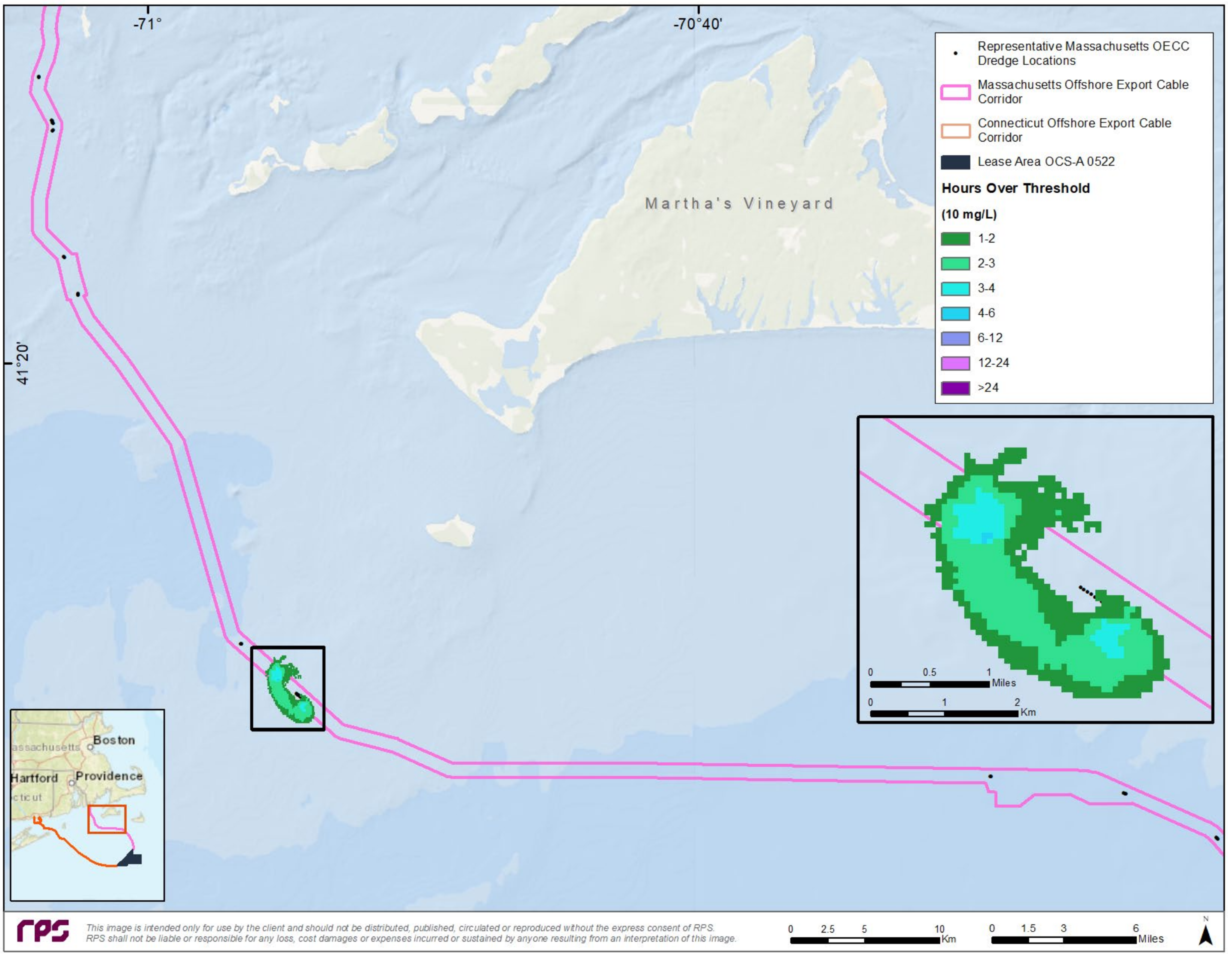

Figure 3-43: Map of duration of TSS ≥ 10 mg/L associated with the Representative Sand Bedform Dredging using TSHD – Massachusetts OECC simulation.

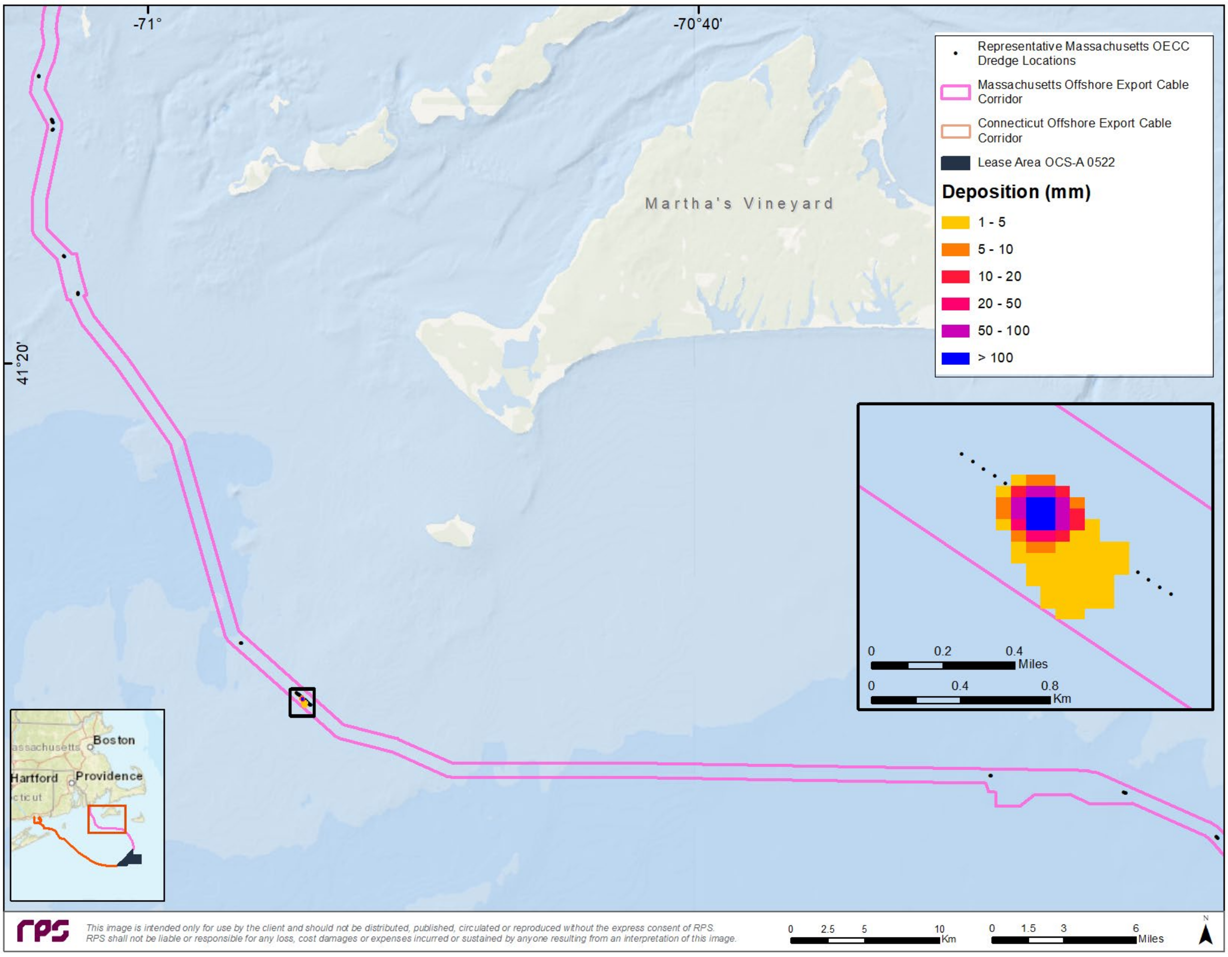

Figure 3-44: Map of deposition thickness associated with the Representative Sand Bedform Dredging using TSHD – Massachusetts OECC simulation.

Representative Massachusetts Landfall Site HDD Exit Pit Construction

Modeling of the Representative Massachusetts Landfall Site HDD Exit Pit Construction was performed at Horseneck Beach, Massachusetts, in an area that contains mostly sand with a small proportion of clay. This simulation can be considered representative of the excavation (assuming side-casting of material) and backfill operations as 100% of the dredged material was released at the water surface over one hour. Backfilled sediment was released during an ebb tide. Due to the relatively protected nature of the site, currents tended to be relatively weak, which caused a localized plume centered around the release location (Figure 3-45). The highest concentrations fall within the center of the plume (>650 mg/L) and diminish radially to 10 mg/L at the edges. Even with the relatively weak currents, TSS concentrations above ambient conditions were not predicted to last for more than six hours (Figure 3-46) and settle out due to the large fraction of coarse material. The depositional footprint was smaller than the plume footprint with the thickest deposits centered around the release location with thinner deposits skewed slightly west of the source (Figure 3-47).

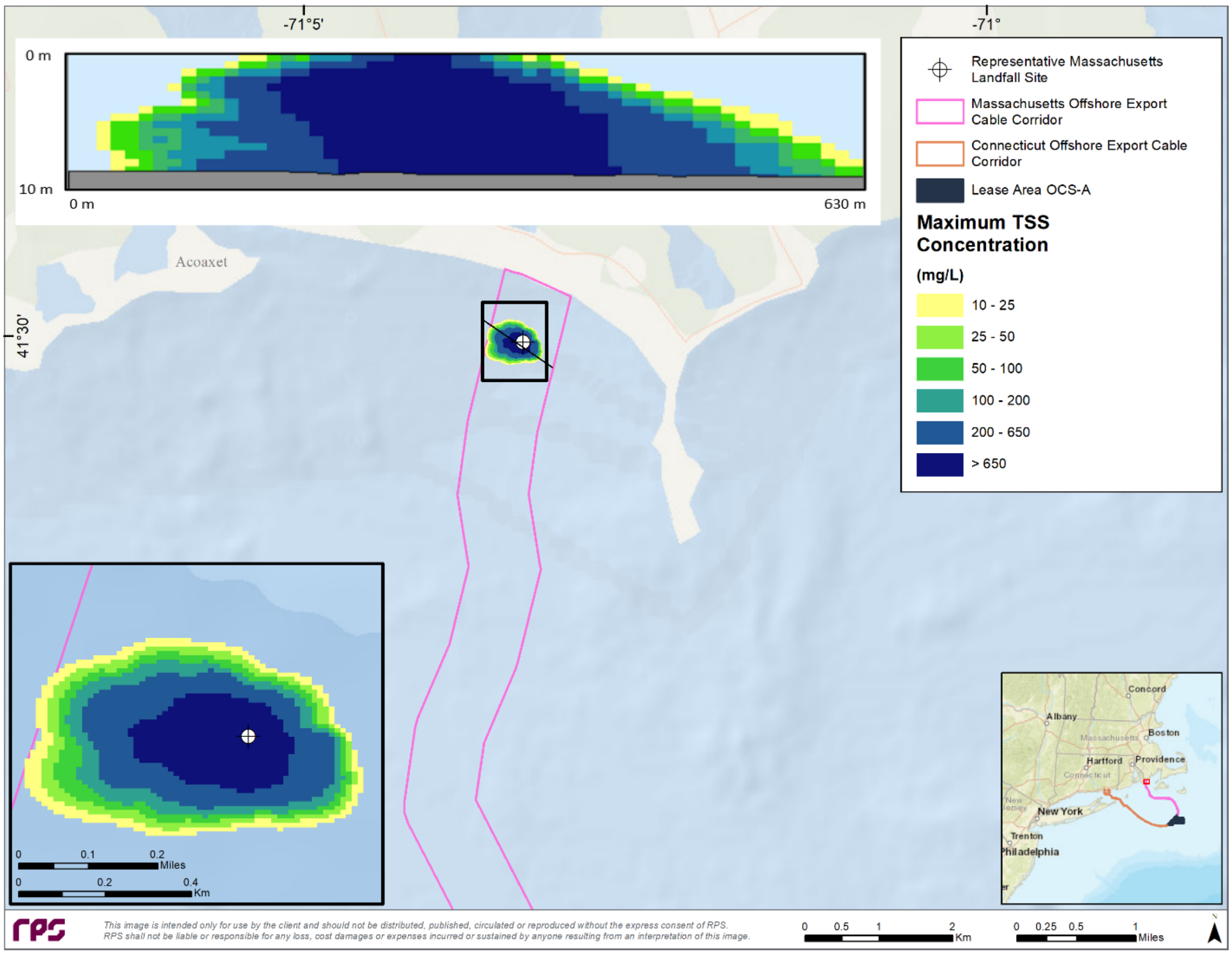

Figure 3-45: Map of time-integrated maximum concentrations associated with the Representative Massachusetts Landfall Site HDD Exit Pit Construction simulation.

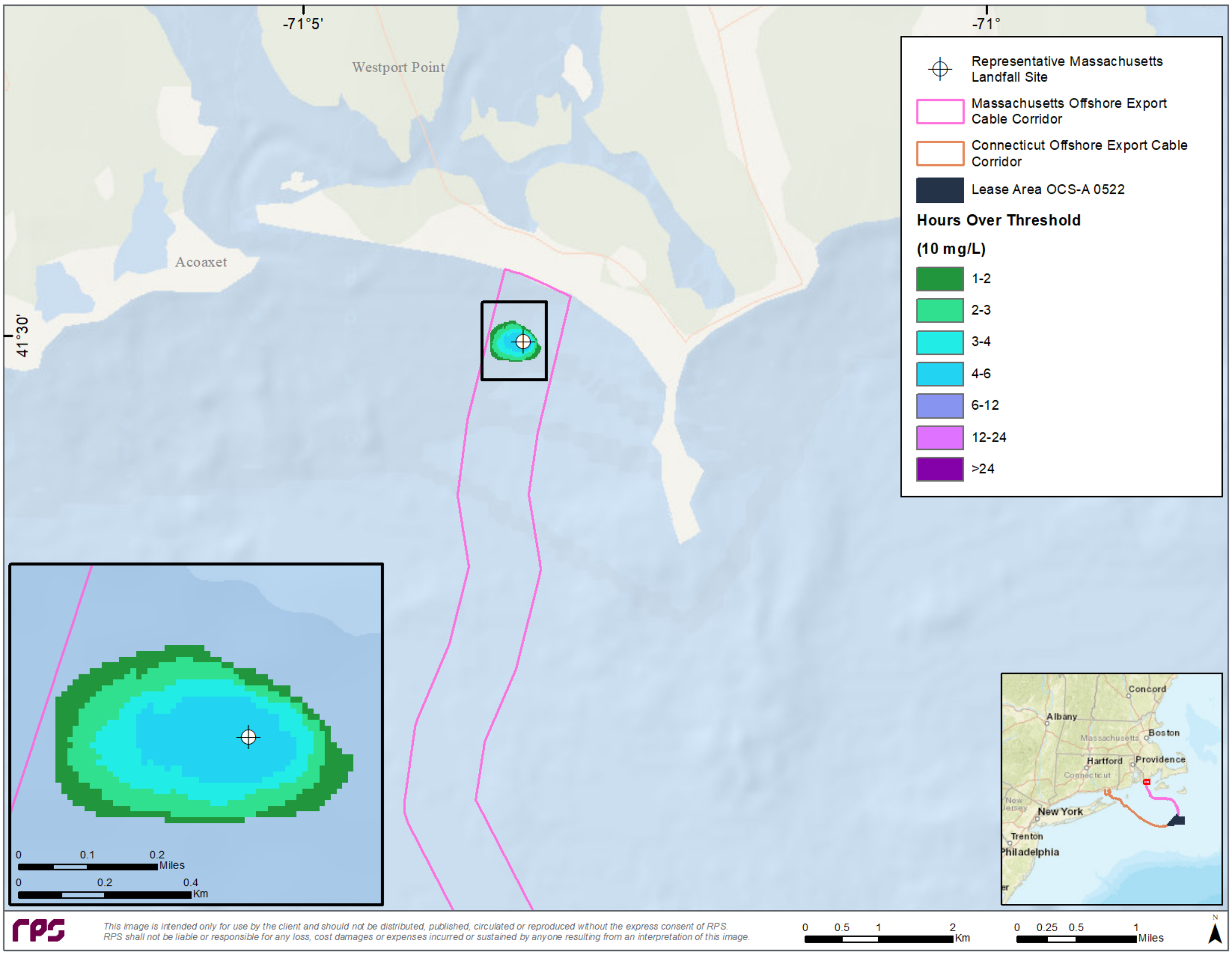

Figure 3-46: Map of duration of TSS ≥ 10 mg/L associated with the Representative Massachusetts Landfall Site HDD Exit Pit Construction simulation.

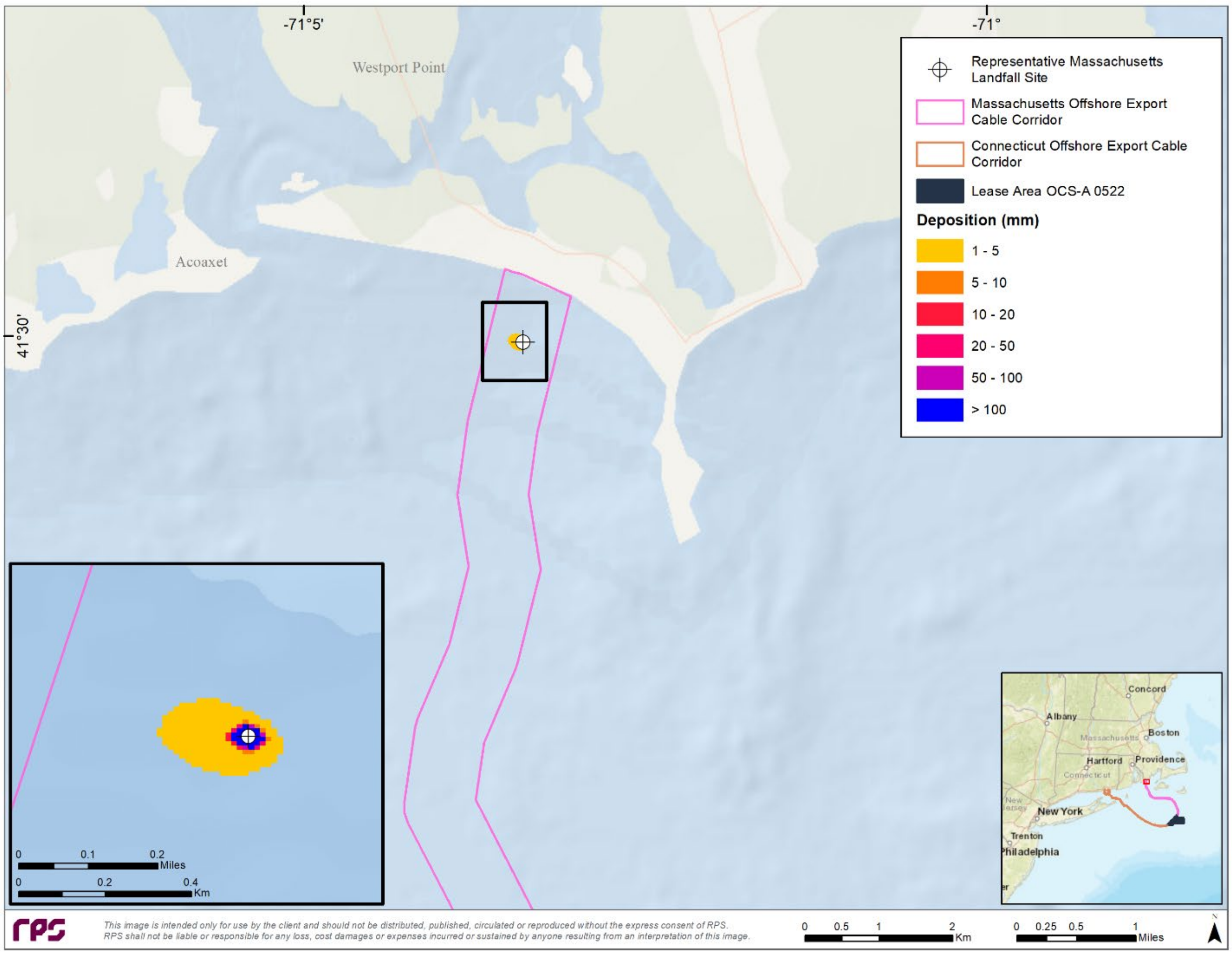

Figure 3-47: Map of deposition thickness associated with the Representative Massachusetts Landfall Site HDD Exit Pit Construction simulation.

Representative Massachusetts OECC Cable Installation — Jetting

A snapshot of the instantaneous concentrations from the representative Massachusetts OECC cable installation using typical jetting parameters shows the plume remains localized near the seabed and is transient in time and space depending on the local currents (Figure 3-48). This snapshot was taken within an area of relatively high fractions of fine material and was subjected to swift currents. The time-integrated maximum water column concentration map (Figure 3-49 to Figure 3-51) contains an inset that shows the cross-sectional view of the plume throughout the entire length (from the landfall site to the Lease Area) of the Massachusetts OECC.

TSS concentrations tended to remain along the route centerline, especially in regions that consisted of primarily sand substrate. As the route approached the Lease Area, the sediment type changed slightly to contain more fine sand and coarse silt resulting in the plume being transported away from the route centerline. The elevated TSS concentrations rapidly dissipated or settled and concentrations ≥10 mg/L are not predicted to persist for more than four hours (Figure 3-52 to Figure 3-54), and areas reported to have TSS concentrations ≥50 mg/L were predicted to dissipate within two hours.

Seabed deposition for this scenario ranged between 1 mm and 5 mm for the majority of the cable route, with isolated patches of deposition between 5 mm and 10 mm (Figure 3-55 to Figure 3-57). The maximum distance to the 1 mm contour is predicted to extend approximately 0.14 km (Table 3-16). In general, the depositional footprint is uniform along the route, with a large portion of the route not exceeding depositional thicknesses of 1 mm.

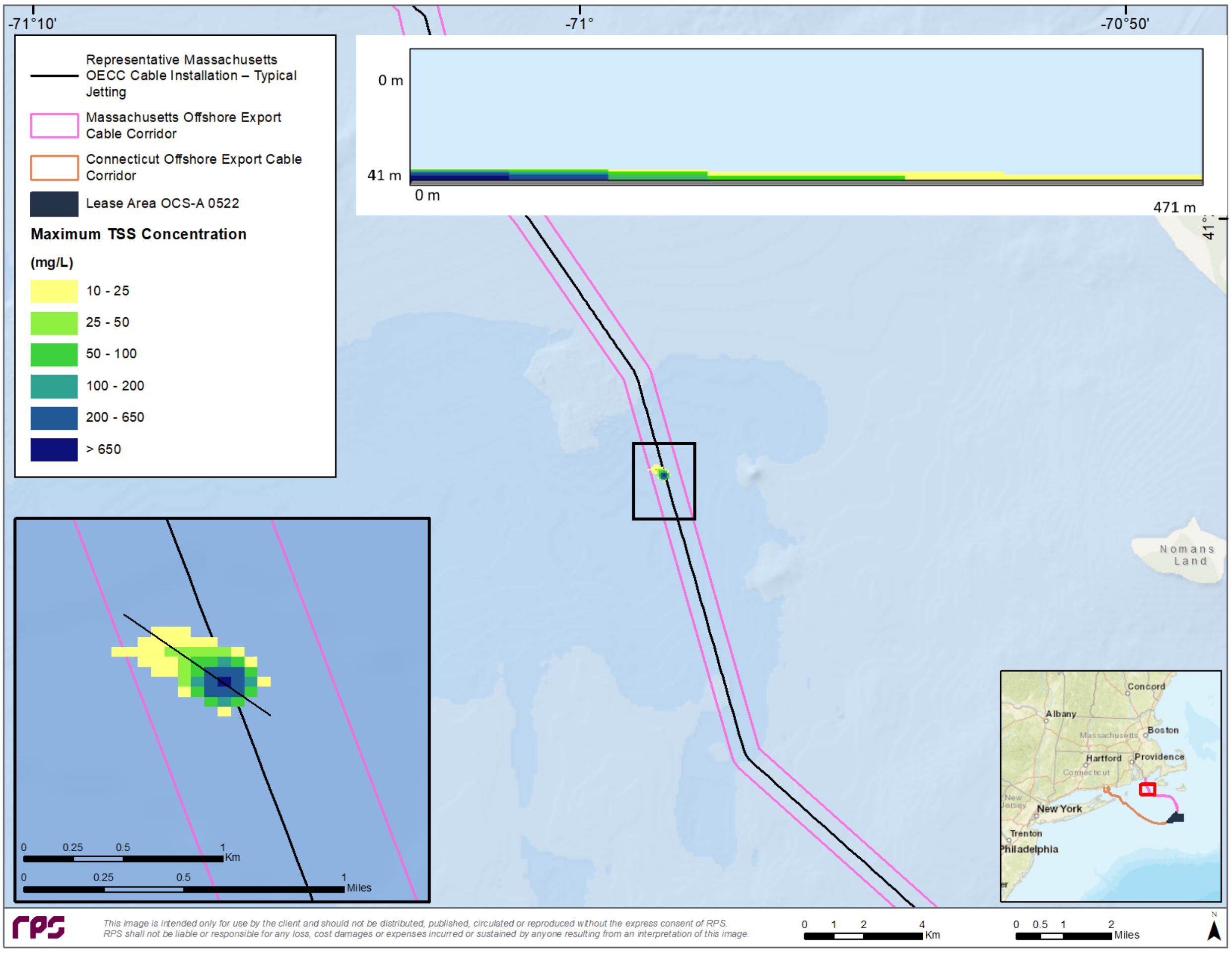

Figure 3-48: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Massachusetts OECC Cable Installation — Jetting simulation.

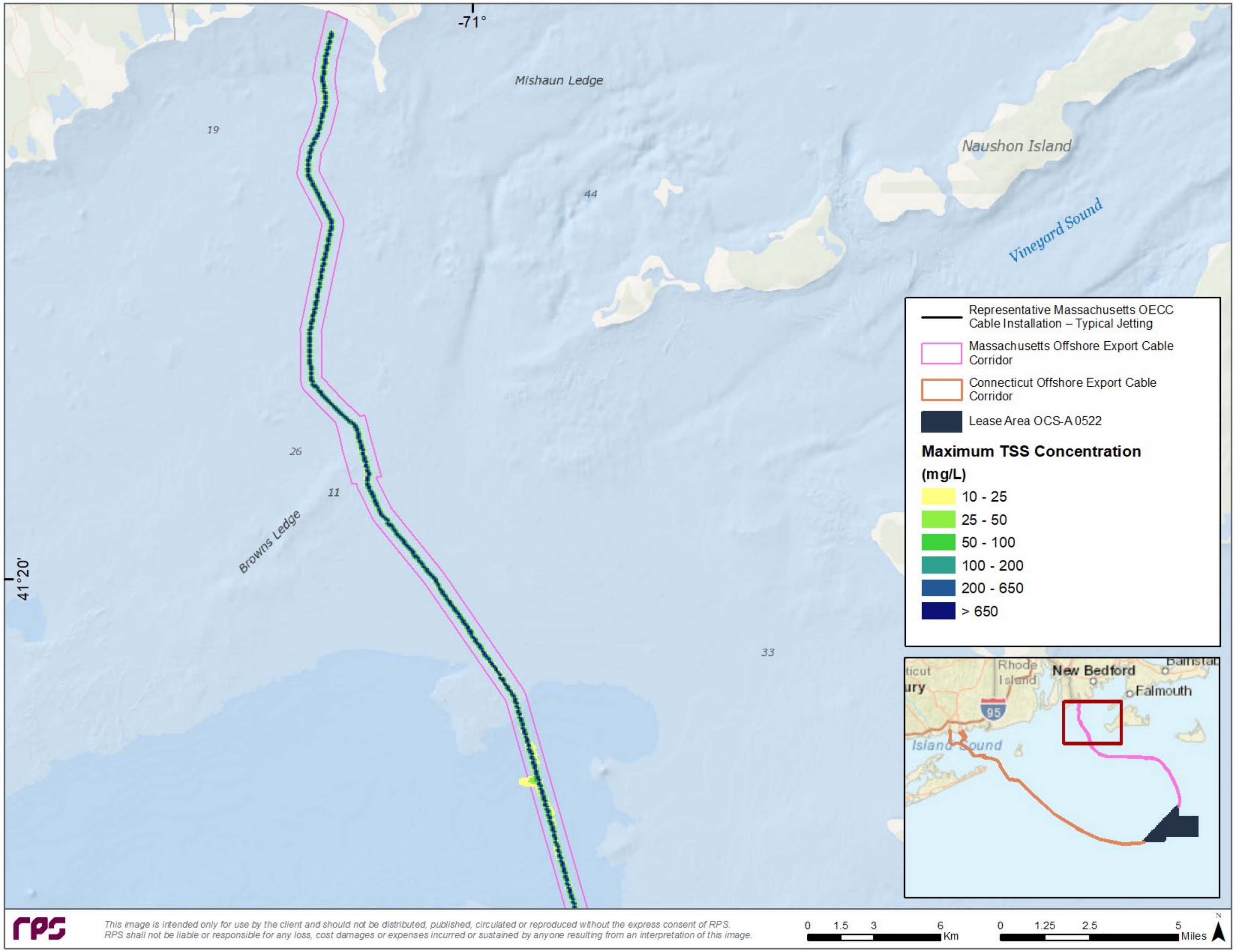

Figure 3-49: Map of time-integrated maximum concentrations associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 1 of 3).

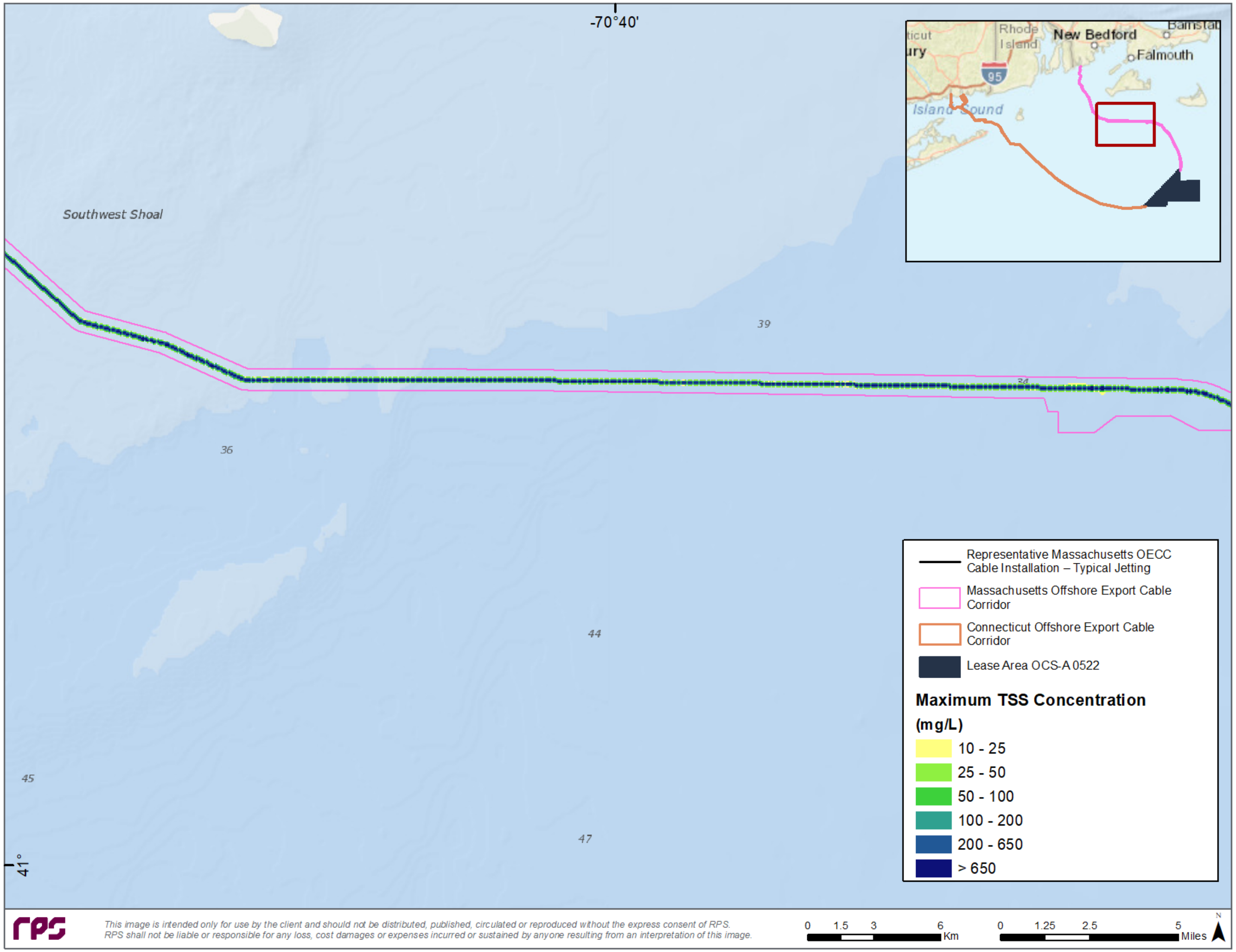

Figure 3-50: Map of time-integrated maximum concentrations associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 2 of 3).

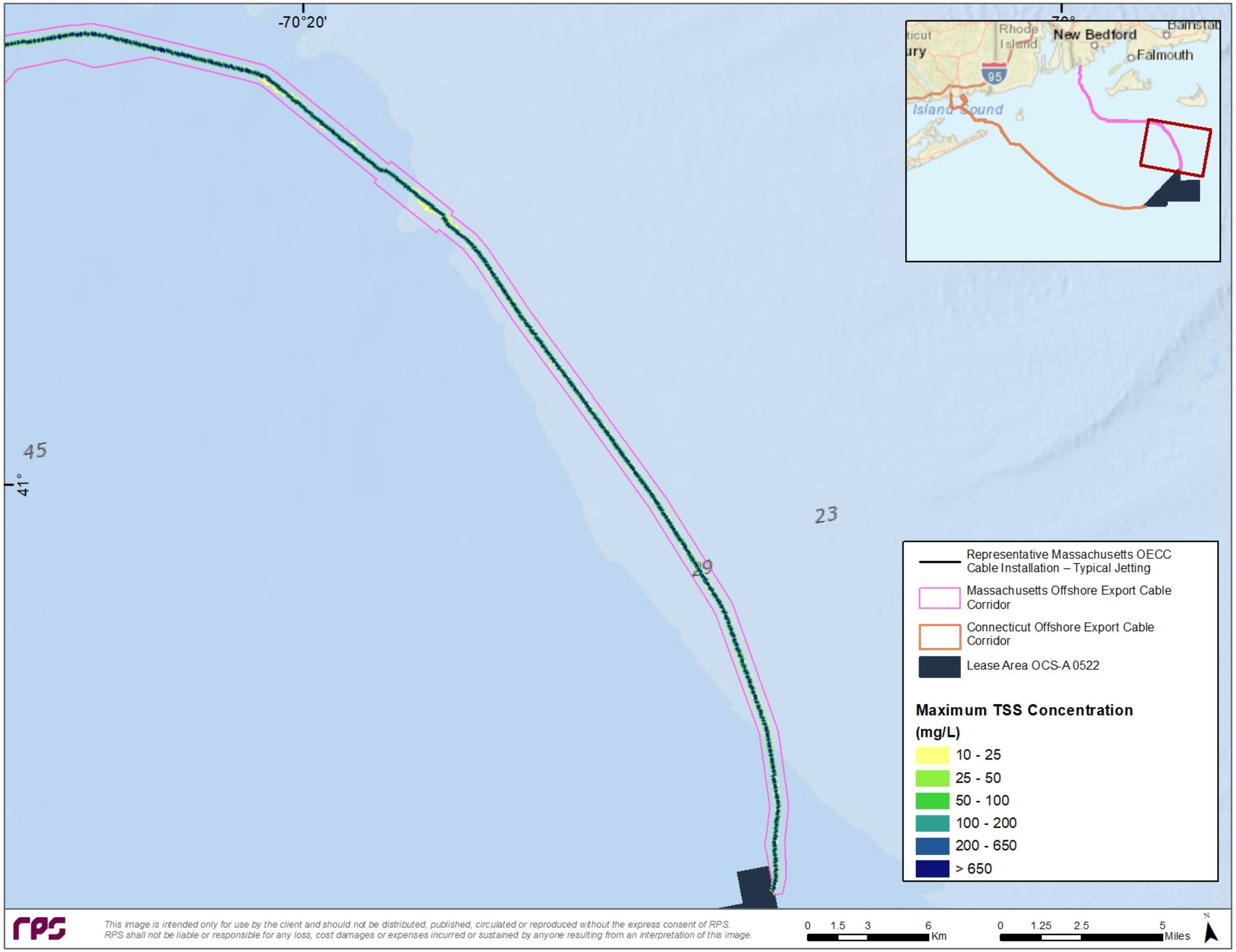

Figure 3-51: Map of time-integrated maximum concentrations associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 3 of 3).

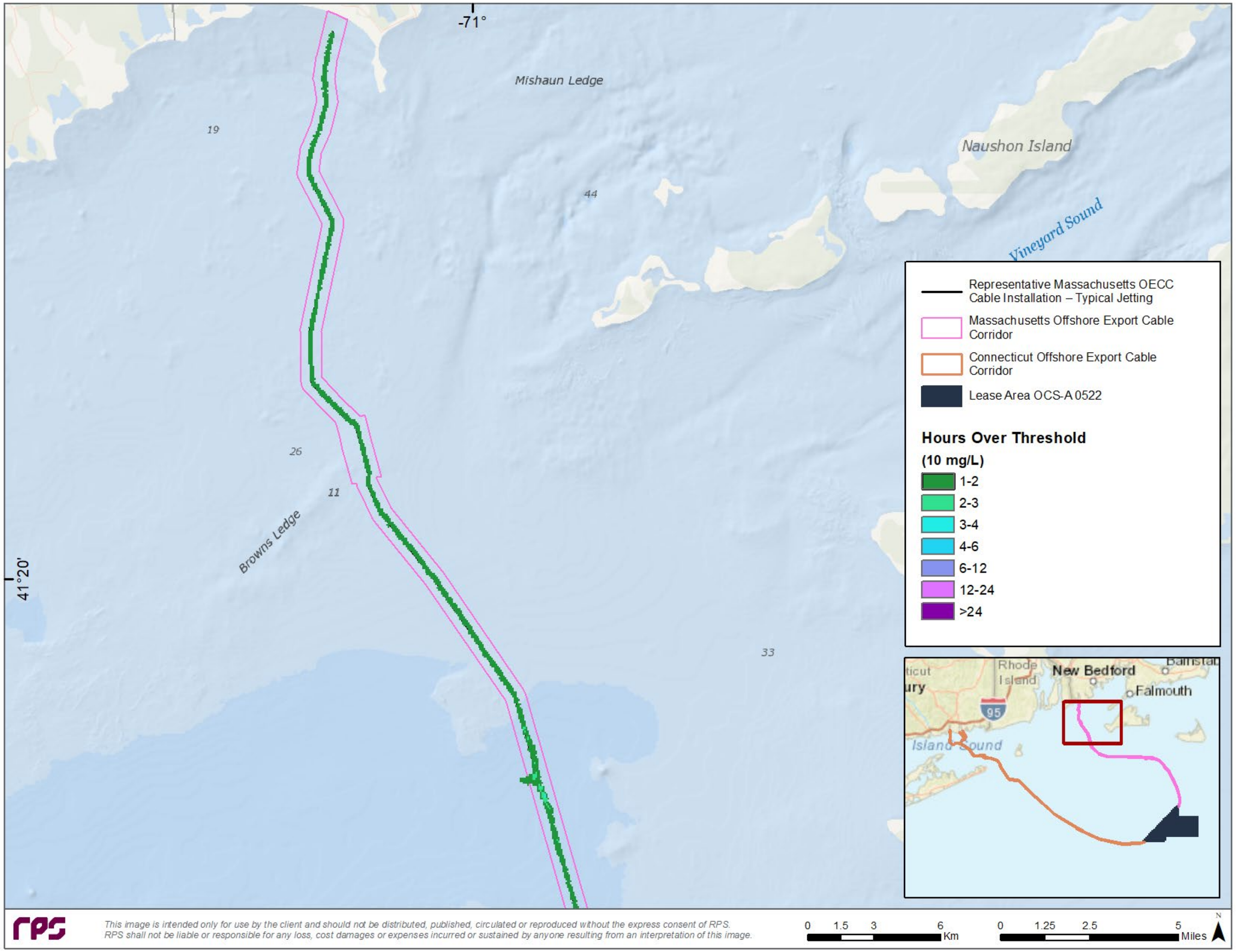

Figure 3-52: Map of duration of TSS ≥ 10 mg/L associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 1 of 3).

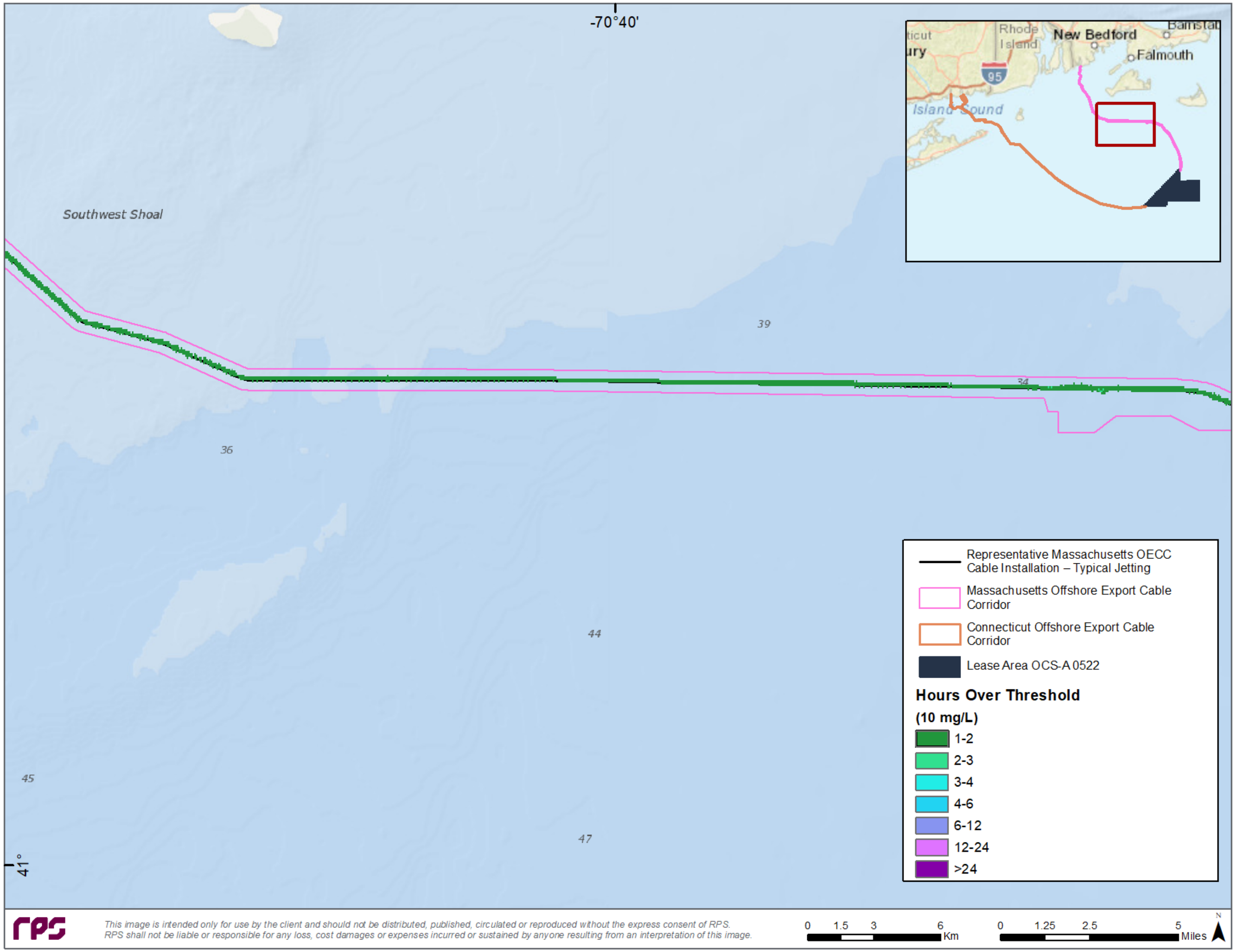

Figure 3-53: Map of duration of TSS ≥ 10 mg/L associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 2 of 3).

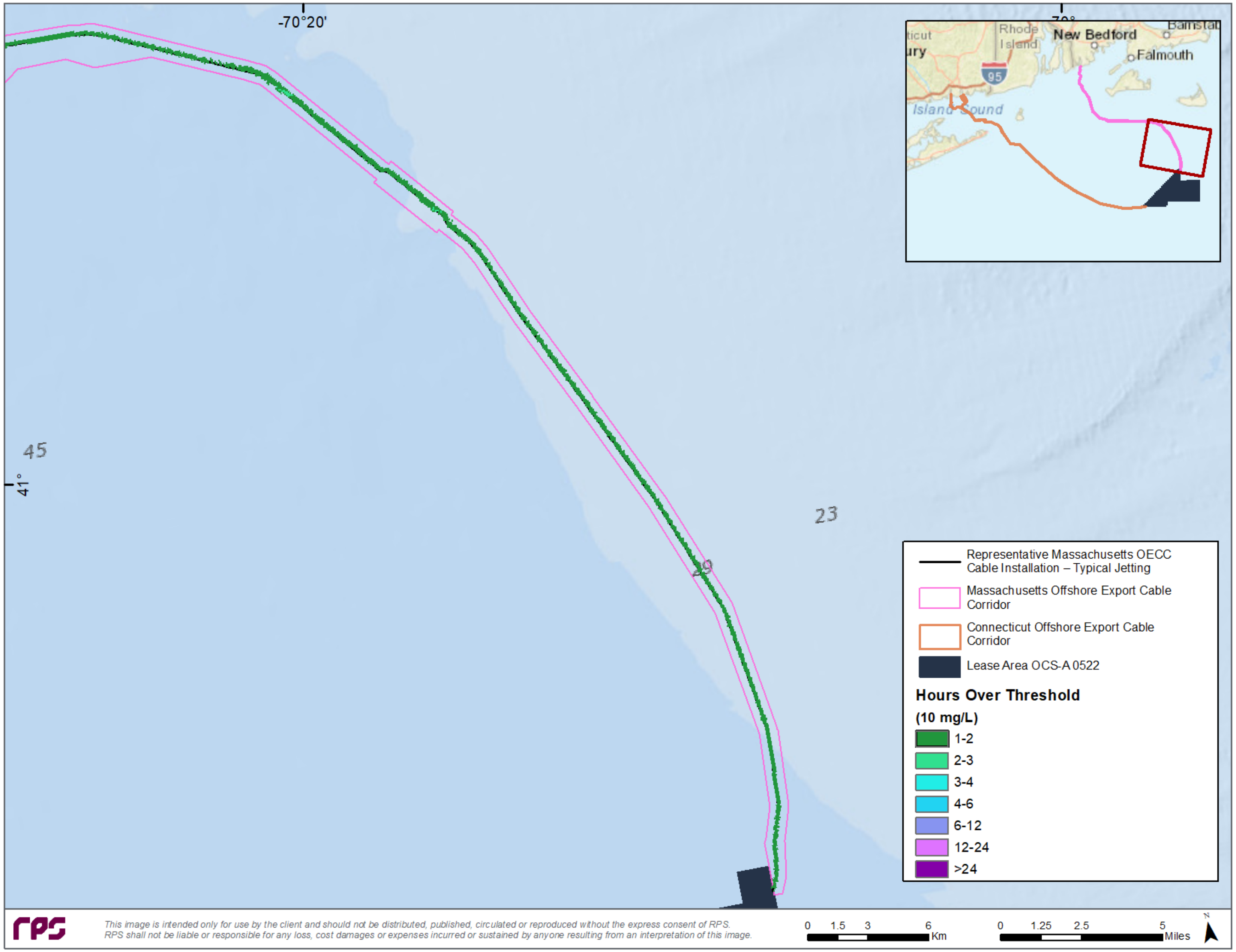

Figure 3-54: Map of duration of TSS ≥ 10 mg/L associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 3 of 3).

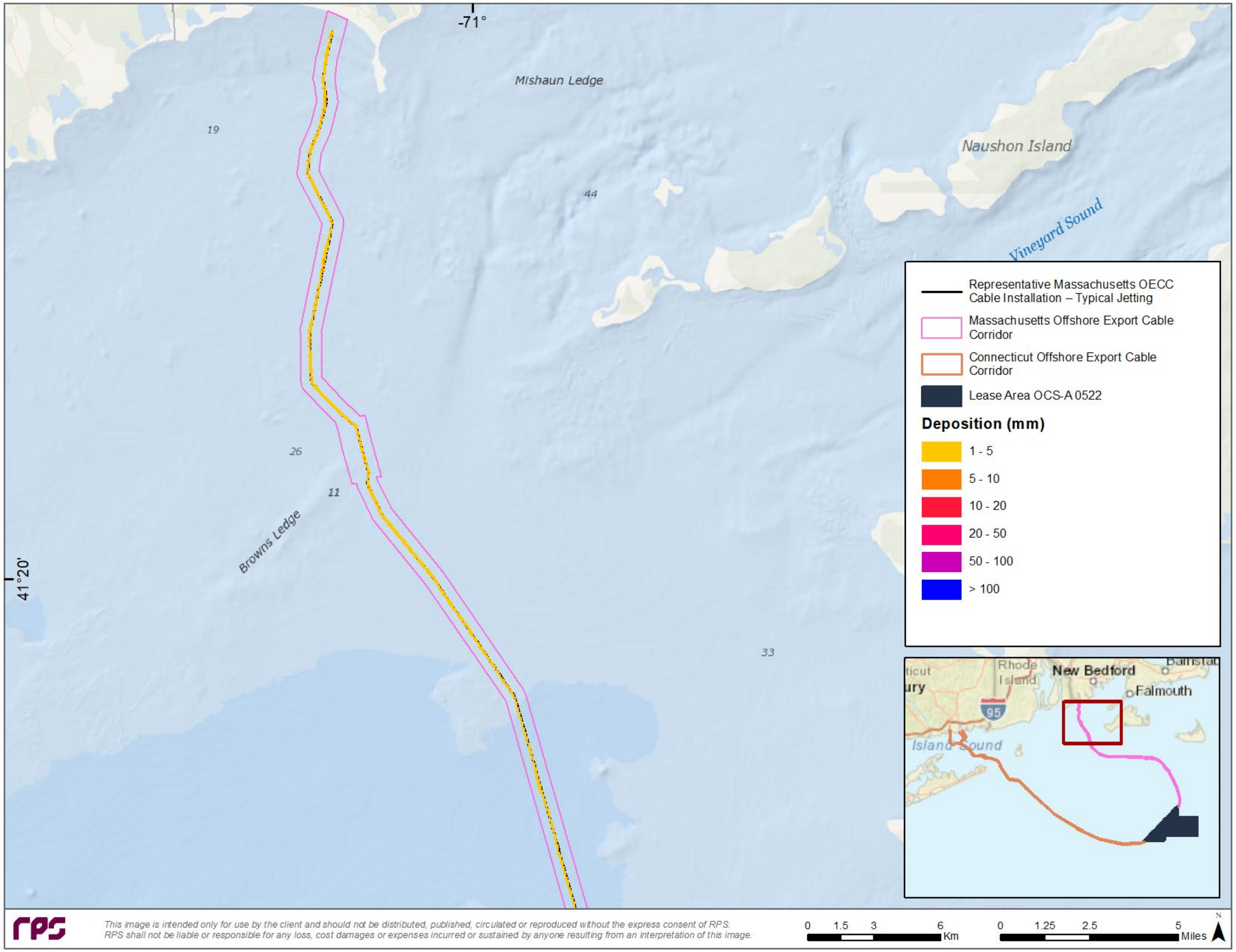

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Figure 3-55: Map of deposition thickness associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 1 of 3).

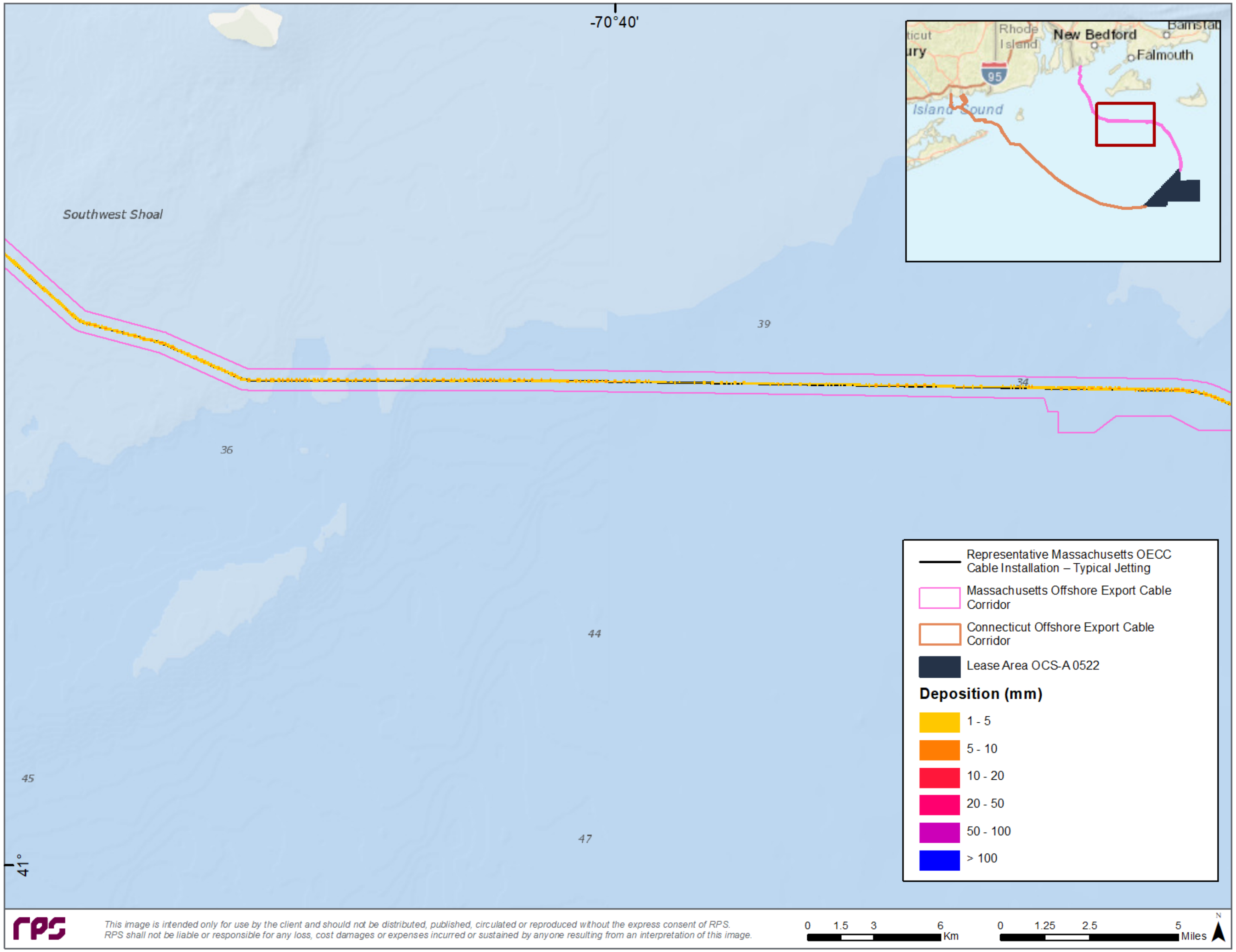

Figure 3-56: Map of deposition thickness associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 2 of 3).

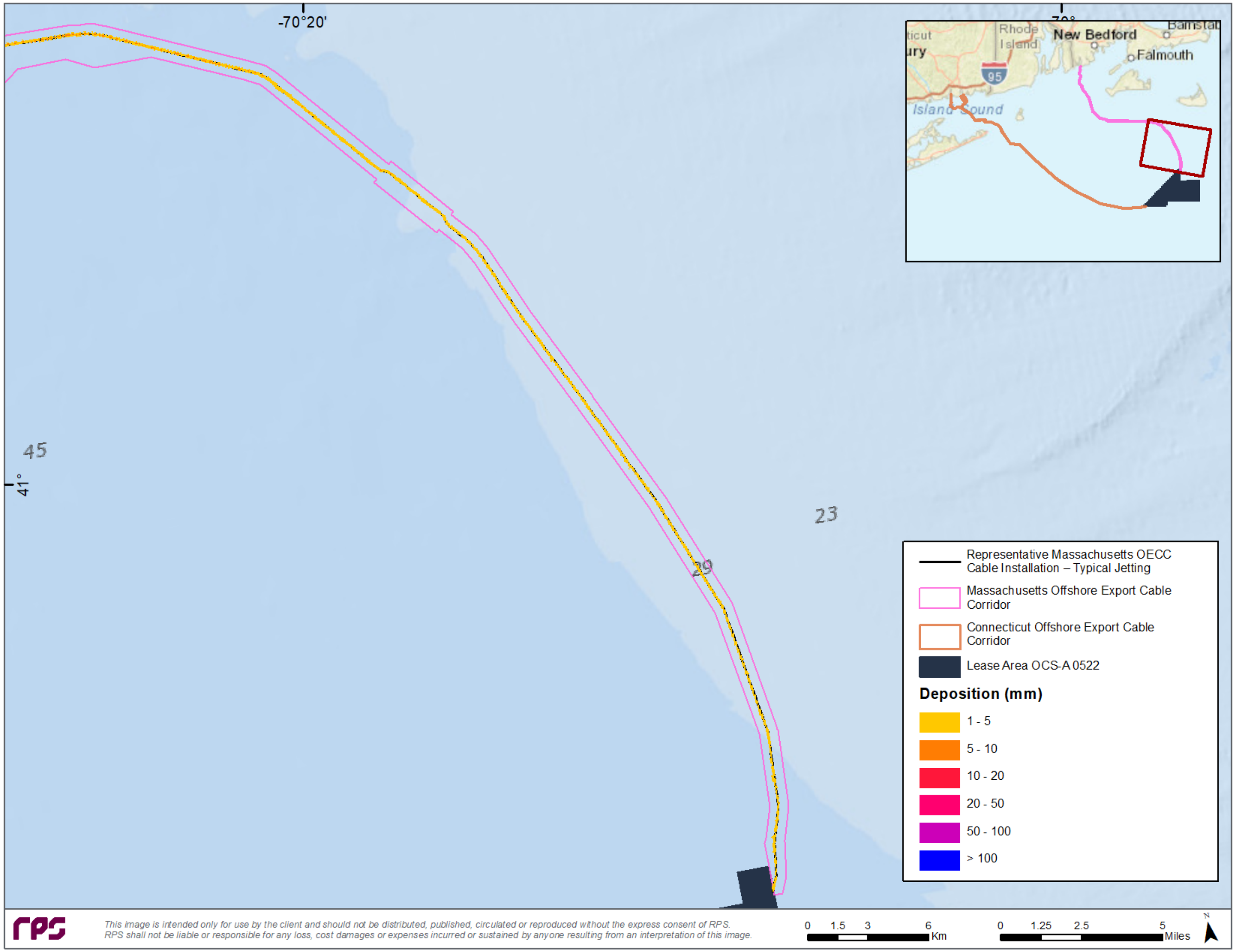

Figure 3-57: Map of deposition thickness associated with the Representative Massachusetts OECC Cable Installation — Jetting simulation (Panel 3 of 3).

Representative Massachusetts OECC Cable Installation — Vertical Injector

As within the Connecticut OECC, a representative simulation was performed to simulate cable installation within the Massachusetts OECC using a vertical injector. The simulation was performed within an area containing high fractions of fine material to evaluate a potential worst-case scenario when predicting water column concentrations. In addition, the conservative nature of the sediment characteristics, the representative vertical injector simulation was modeled in an area exposed to fast currents. The combination between the fine material and fast currents resulted in a plume that was transported away from the source and sediment that remained suspended for a longer time when compared to the typical jetting parameters. Additionally, the vertical injector simulation assumed a slower installation speed and a deeper target trench depth. The instantaneous snapshot illustrates the influence of the currents on the suspended plume as it is transported away from the source at the time and the cross-sectional view (inset map) shows the plume was localized to the seabed (Figure 3-58).

The time-integrated maximum water column concentration map captures the influence of the currents and the resulting sweeping motion of the tail of the plume as the tide stages changed (Figure 3-59). The plume was compounded on itself due to the perpendicular nature of the currents to the route; thus, causing higher concentrations that required more time to settle. TSS concentrations ≥50 mg/L persisted up to four hours while TSS concentrations ≥10 mg/L were predicted after six hours and estimated to dissipate within 12 hours (Figure 3-60). Due to the nature of the fine material and the dissipation of the plume because of subsurface currents, seabed deposition was not predicted to exceed 5 mm (Figure 3-61). The depositional footprint fell along the route centerline and the distance to the 1 mm contour is predicted to extend approximately 0.15 km (Table 3-16).

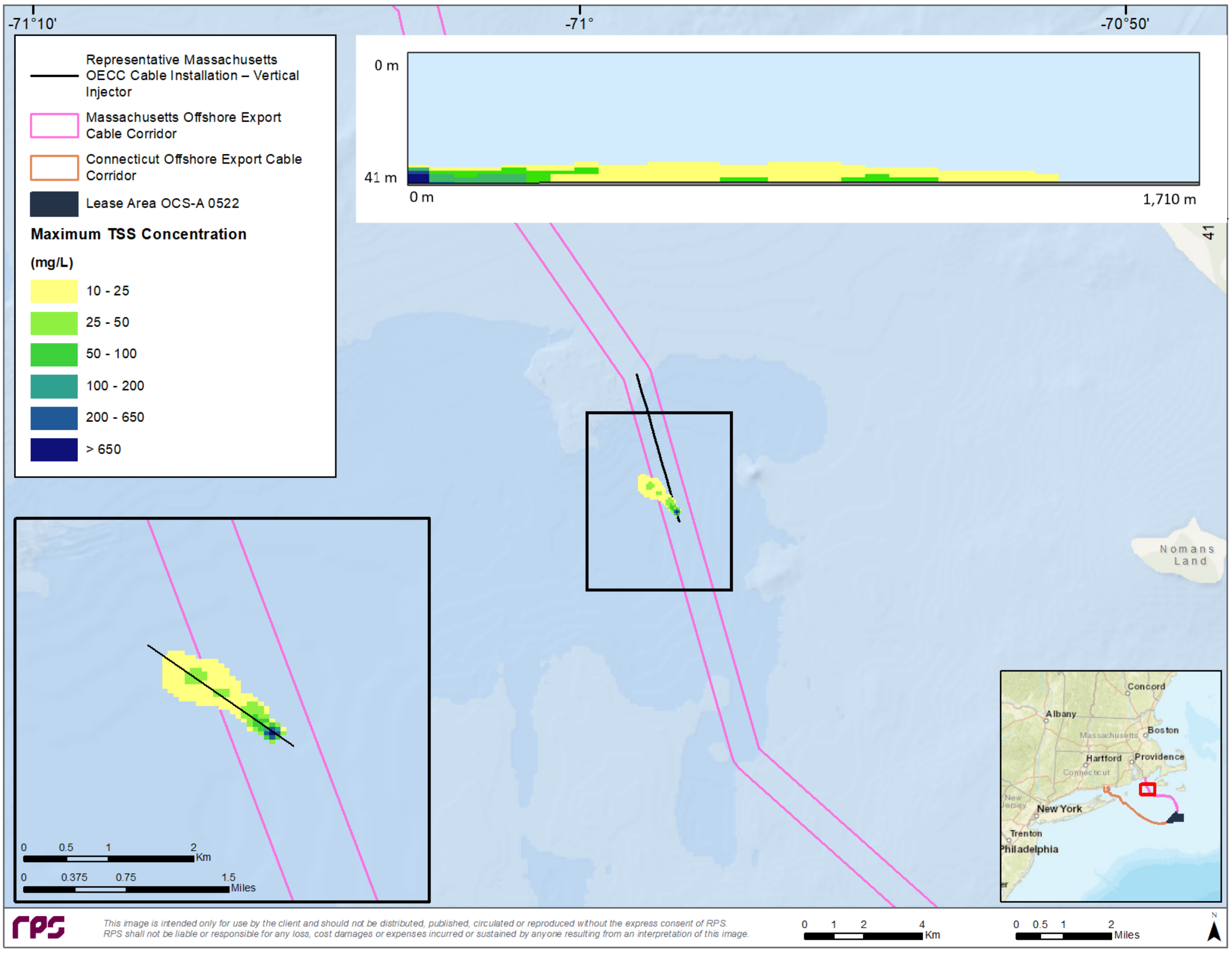

Figure 3-: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Massachusetts OECC Cable Installation — Vertical Injector simulation.

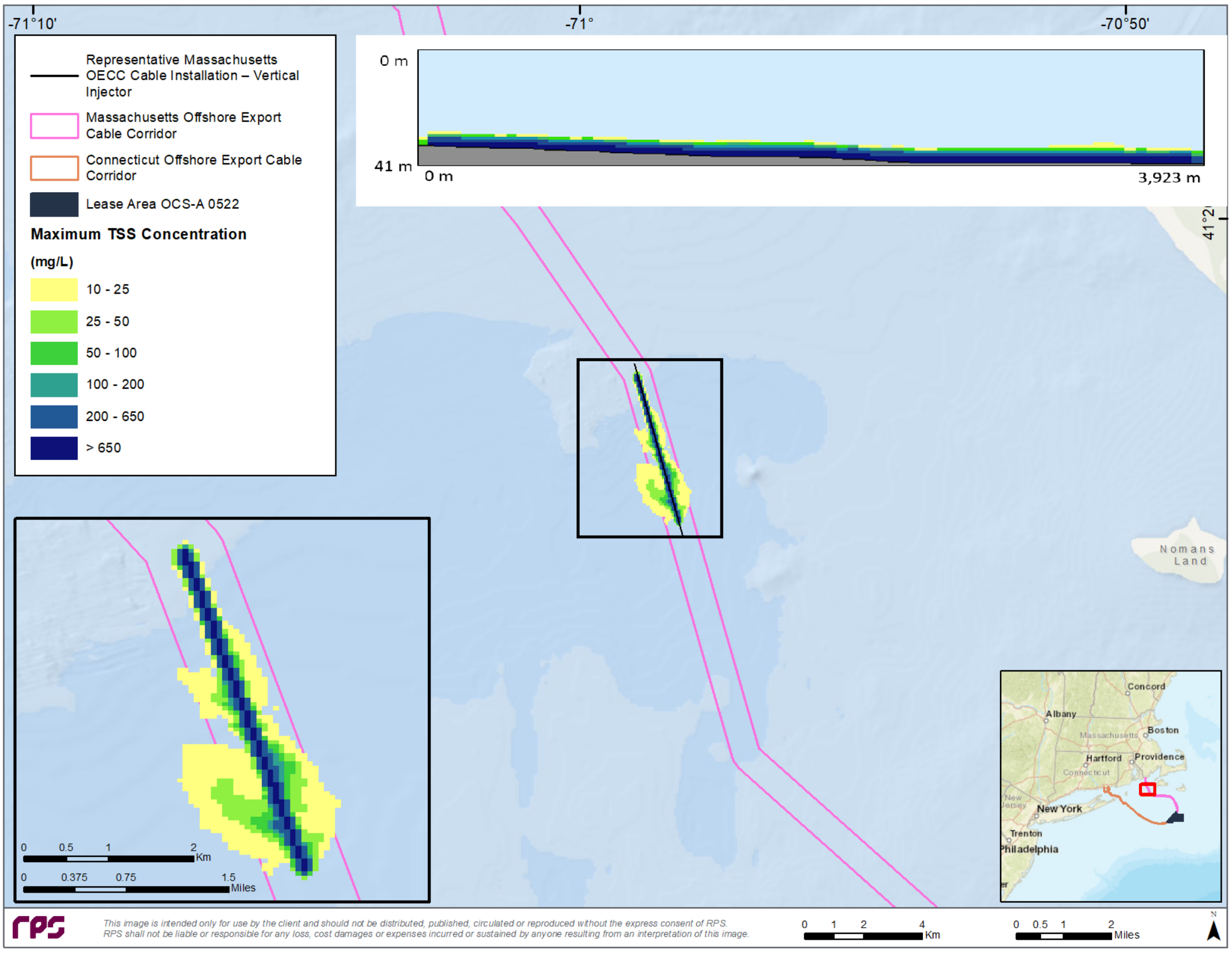

Figure 3-58: Map of time-integrated maximum concentrations associated with the Representative Massachusetts OECC Cable Installation — Vertical Injector simulation.

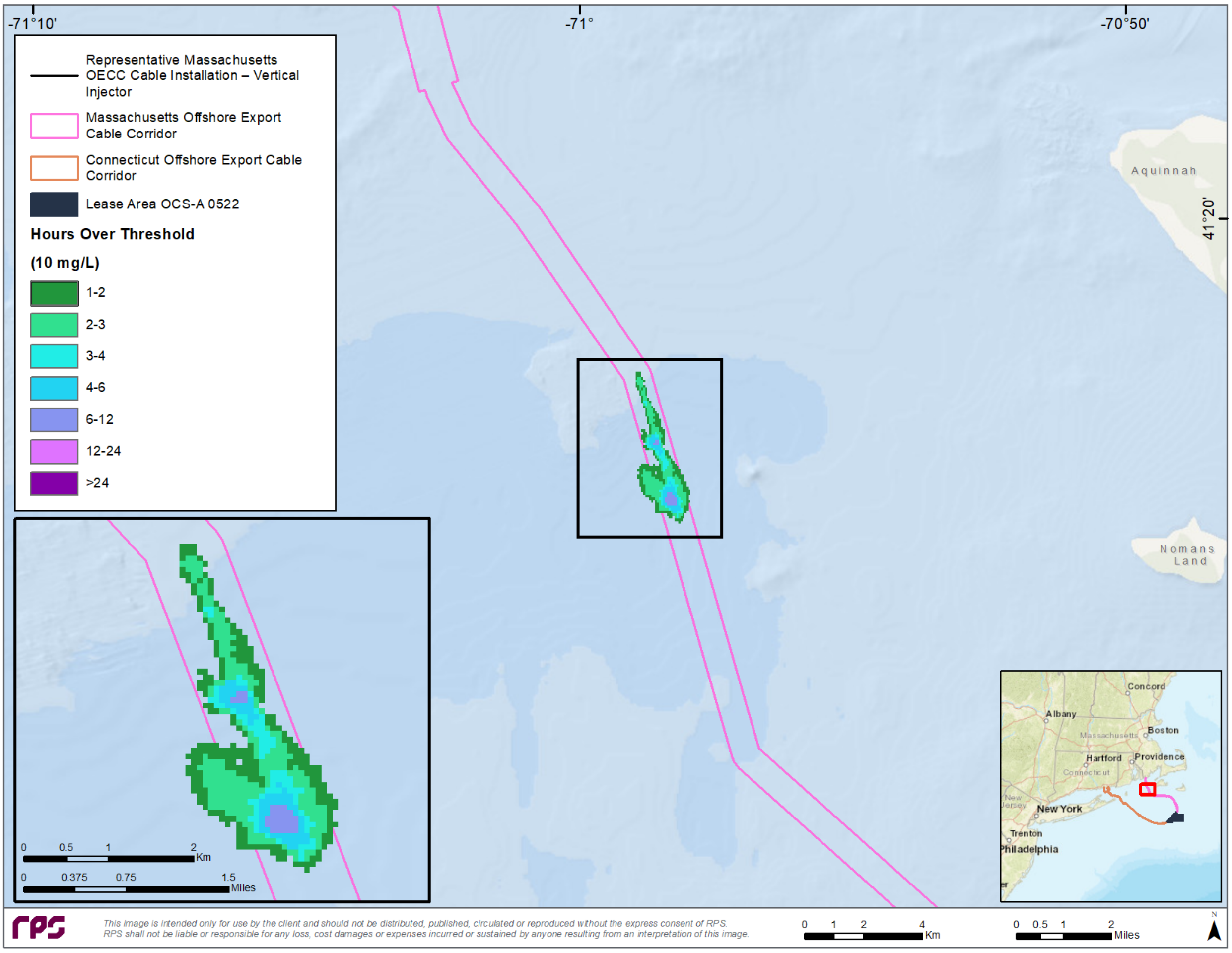

Figure 3-59: Map of duration of TSS ≥ 10 mg/L associated with the Representative Massachusetts OECC Cable Installation — Vertical Injector simulation.

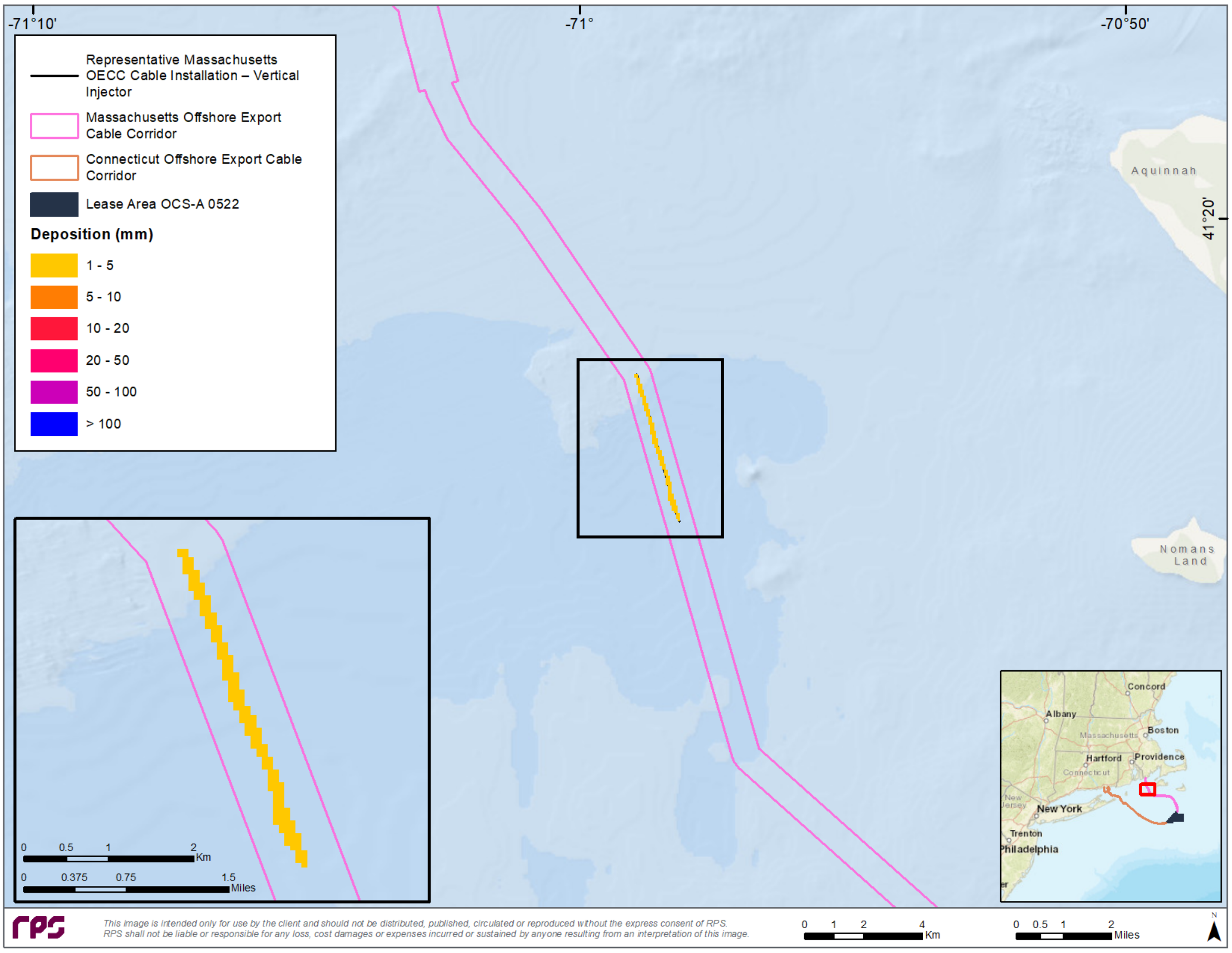

Figure 3-60: Map of deposition thickness associated with the Representative Massachusetts OECC Cable Installation — Vertical Injector simulation.

3.3.3 Lease Area

The sediment composition within the Lease Area contains a mixture of sediment types, with higher proportions of coarse silt, fine silt, and clay scattered throughout the Lease Area. The southwest corner and along the southern boundary contain more fine material, while the northeast corner and within the central part of the Lease Area the primary composition consists of coarse sand and fine sand.

This section presents results from the simulations of seabed preparation and cable installation activities in the Lease Area. Results are presented separately for each of the model scenarios:

- Representative Lease Area Sand Bedform Dredging
- Representative Lease Area Cable Installation —Typical Jetting
- Representative Lease Area Cable Installation — Maximum Jetting

Representative Lease Area Sand Bedform Dredging

Intermittent dredging was simulated within the Lease Area along a representative inter-array cable route. Drag arm disturbances caused plumes localized to the seabed while overflow and dumping operations created plumes that extended the depth of the water column. Based on the total dredge volume, the hopper would reach capacity and require overflow and dumping to occur one time at the end of dredging operations. Overflow and dumping were modeled to occur at a representative location with existing bedforms. The portion of sediment associated with overflow was readily transported by the currents, based on the simulation timing, this resulted in the plume being transported in a cyclical pattern. Alternatively, coarse material released during dumping settled relatively quickly due around the dump site.

A snapshot of the instantaneous concentrations from the representative sand bedform dredging within the Lease Area shows the dump and overflow plume as patchy throughout the water column, with the highest concentrations near the seabed (Figure 3-62). This snapshot was taken within an area of relatively high fractions of fine material following overflow operations that was predicted to be the furthest from the route centerline. The time-integrated maximum water column concentration map (Figure 3-63) contains an inset that shows the cross-sectional view of the plume throughout the entire length of the representative dredging locations.

TSS concentrations tended to remain in close proximity to the route centerline and local to the seabed for the drag arm disturbances. Alternatively, the plume associated with dumping and overflow operations was spread throughout the water column and transported in a cyclical pattern due to the timing of the scenario with the changing of current direction. As with the maximum concentration maps, the maps of the duration of water column TSS concentrations ≥10 mg/L follow a similar pattern with the currents (Figure 3-64). TSS concentrations were predicted to exceed 650 mg/L and dissipate prior to three hours (Figure 3-64). TSS concentrations ≥10 mg/L are not predicted to persist for more than four hours (Figure 3-64). The results show, in any given location, the total exposure is typically one to three hours with some small, isolated patches of exposure between three to four hours.

Seabed deposition for this scenario exceeded 100 mm near the dump location, with thickness between 1 and 10 mm extending east/southeast from the dump site. Depositional thicknesses did not exceed 1 mm at the dredge locations in association with drag arm disturbances (Figure 3-65). The maximum distance to the 1 mm and 20 mm contour is predicted to extend approximately 0.96 km and 0.20 km, respectively (Table 3-16).

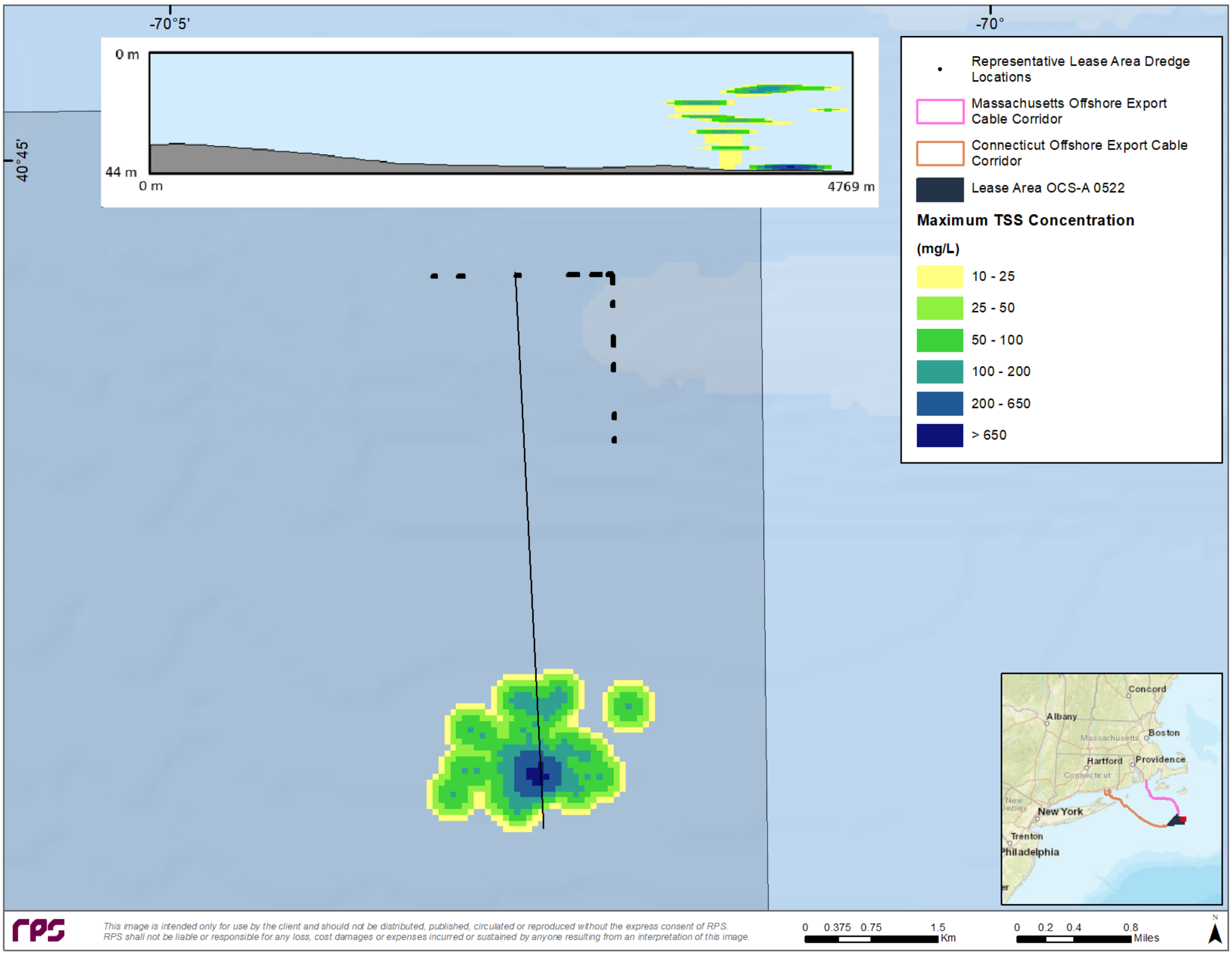

Figure 3-61: Snapshot of instantaneous TSS concentrations for a time step during the simulation for the Representative Lease Area Sand Bedform Dredging.

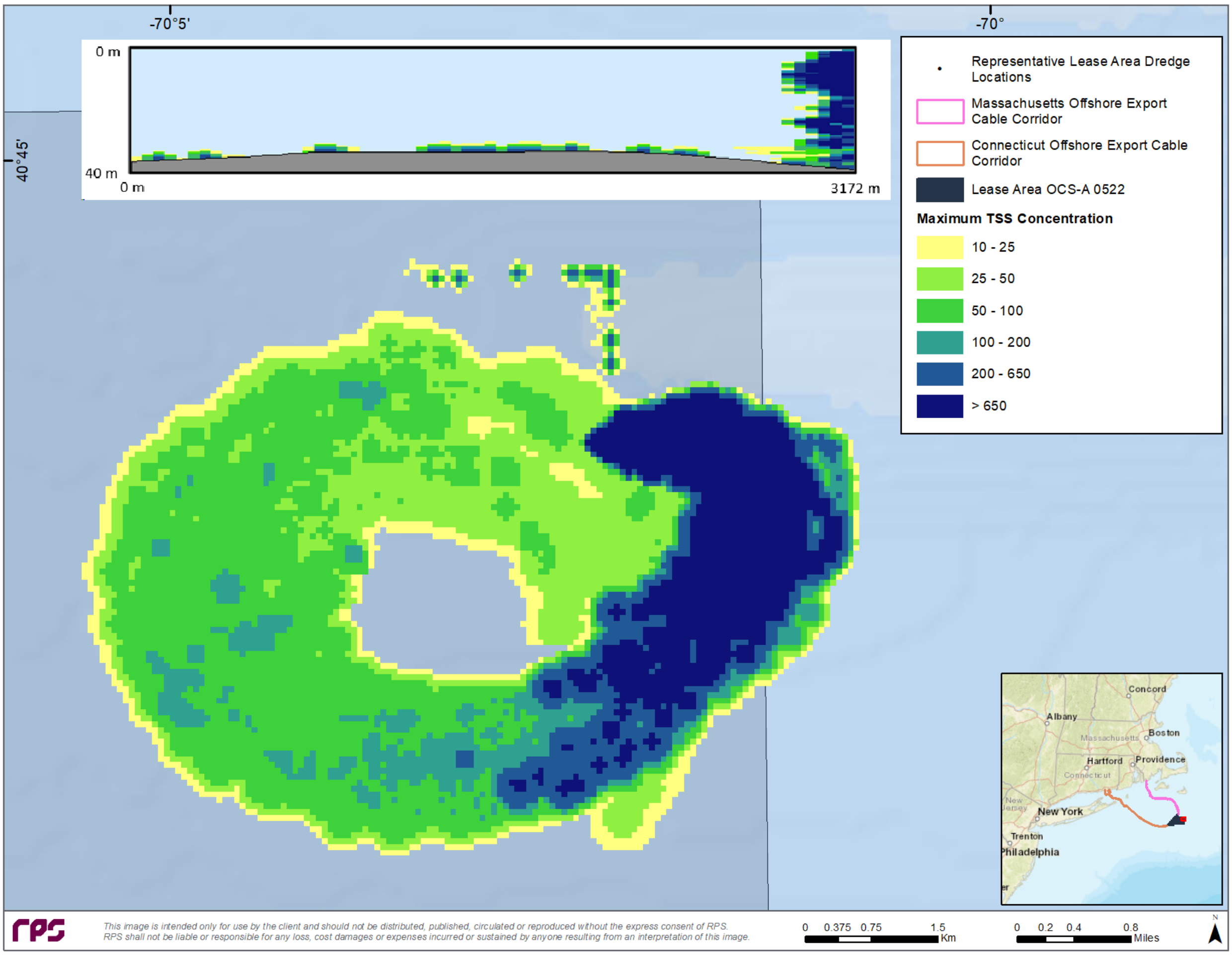

Figure 3-62: Map of time-integrated maximum concentrations associated with the Representative Lease Area Sand Bedform Dredging.

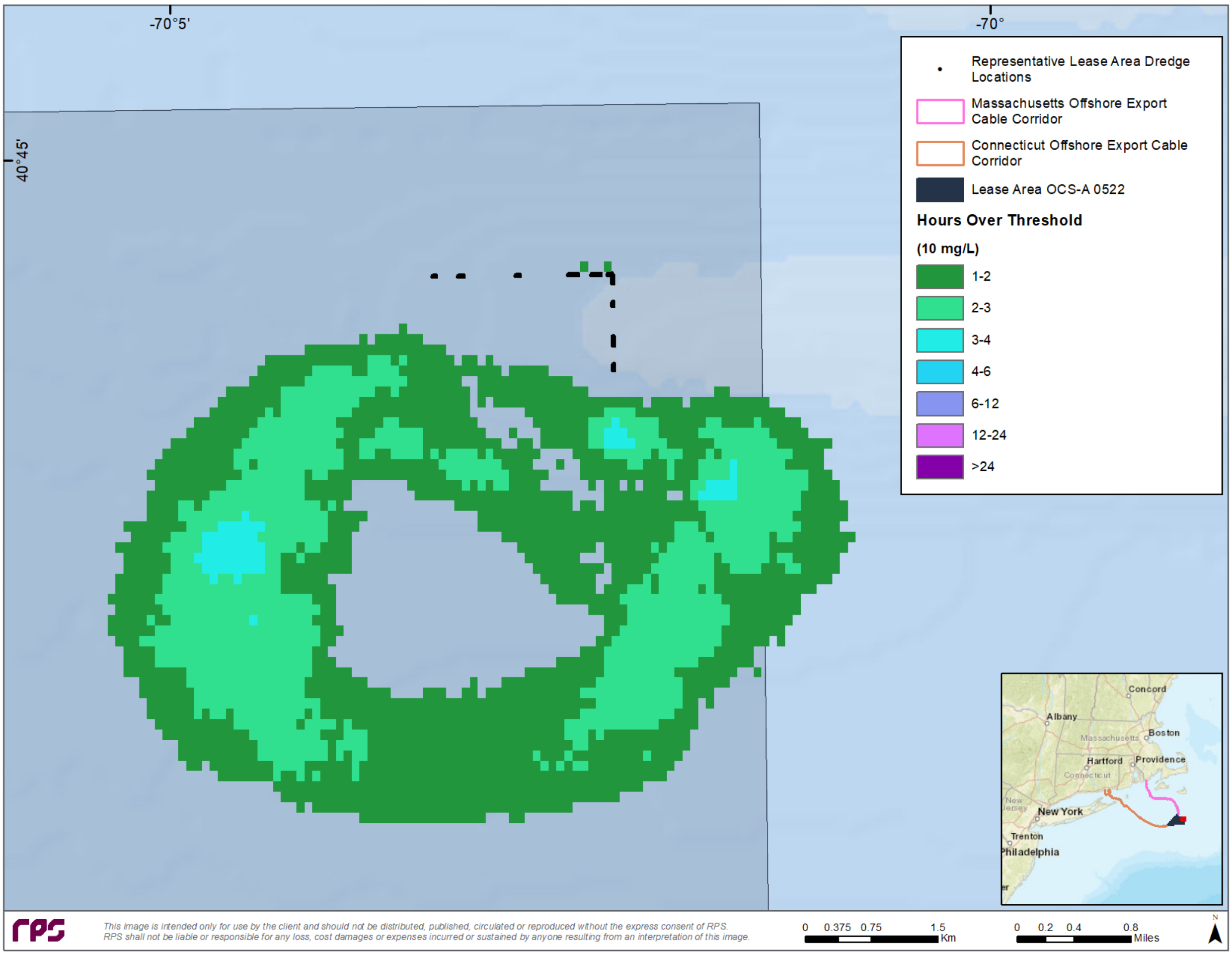

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Figure 3-63: Map of duration of TSS ≥ 10 mg/L associated with the Representative Lease Area Sand Bedform Dredging.

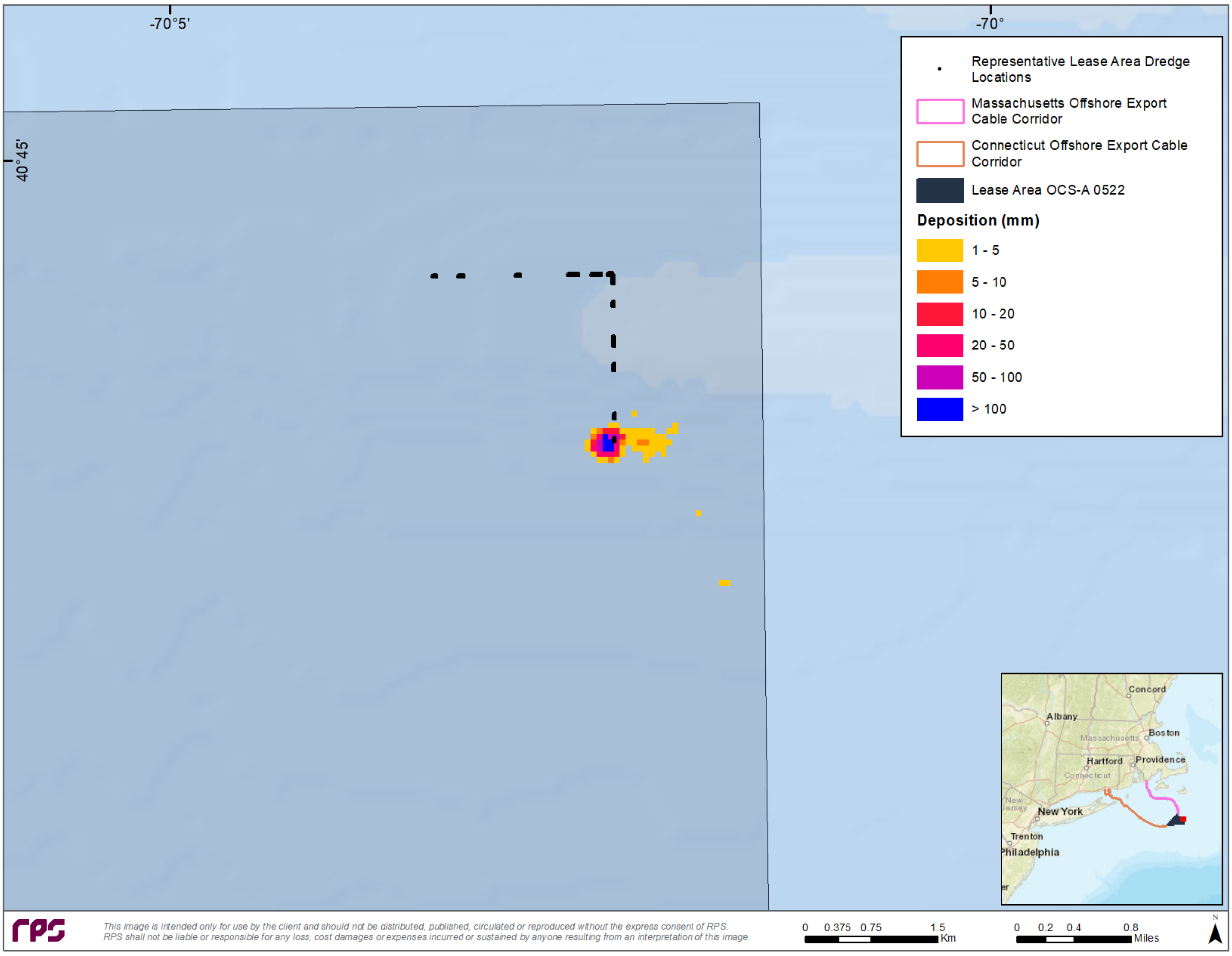


Figure 3-64: Map of deposition thickness associated with the Representative Lease Area Sand Bedform Dredging.

Representative Lease Area Cable Installation —Typical Jetting and Maximum Jetting

As indicated by both the instantaneous snapshot (Figure 3-66) and time-integrated maximum concentration maps (Figure 3-67), the cable installation using typical and maximum parameters illustrates that higher concentrations are contained around the centerline, and the cross-sectional view, presented as an inset, runs along the route centerline shows that the plume is localized to the bottom of the water column with the highest concentrations closest to the bottom (i.e., localized to the source). The discontinuous patches of the plume, furthest from the corridor, indicate rapid dispersion by currents and settling of suspended material (Figure 3-66). As anticipated, results from the maximum jetting parameter simulation show the faster installation rate and the deeper target trench depth cause more sediment being suspended over a similar timeframe and generating a larger plume footprint. For both cases, the overall footprint represents how the plume oscillates with the tides, which is reflective in the oscillatory pattern of the 10–25 mg/L (yellow) concentrations relative to the route centerline.

As with the maximum concentration maps, the maps of the duration of water column TSS concentrations ≥10 mg/L follow a similar pattern with the oscillating currents (Figure 3-68). The highest concentrations focused on the route centerline and last longest in the water column. When comparing these two simulations, the typical jetting parameters result in concentrations returning to ambient conditions within a similar timeframe as the maximum parameters; however, the area impacted above concentrations tended to be smaller (Figure 3-68). The results for both the typical and maximum impact parameters show, in any given location, the total exposure is typically one to two hours or two to three hours with some small, isolated patches of exposure between three to four hours for the maximum impact scenario. Most of the sediments settle out quickly (i.e., within three hours) and are not transported for long by the currents, but due to the currents moving perpendicular to the route centerline the plume is compounded on itself which causes elevated TSS concentrations that take longer to settle (i.e., between six and 12 hours).

It is important to note that this scenario was modeled in an area with high fractions of fine material that were easily transported with subsurface currents and inherently take longer to settle. Additionally, this was one of the longest inter-array cables within the Lease Area and so more sediment was suspended during the installation operations. In areas with less fine material, it would be anticipated that water column concentrations would return to ambient conditions within a shorter time period than those reported for these simulations.

The depositional footprint of the typical and maximum parameters scenarios falls along the route centerline (Figure 3-69). The typical parameters scenario did not predict deposition greater than 5 mm while the maximum parameters scenario predicted isolated patches of depositional thicknesses between 5 mm and 10 mm. Elevated TSS is confined to the bottom, within a few meters of the water column. Water quality impacts from these representative inter-array cable installation simulations predict that sediment-related impacts would be short-term (< 12 hours) and remain localized to the seabed.

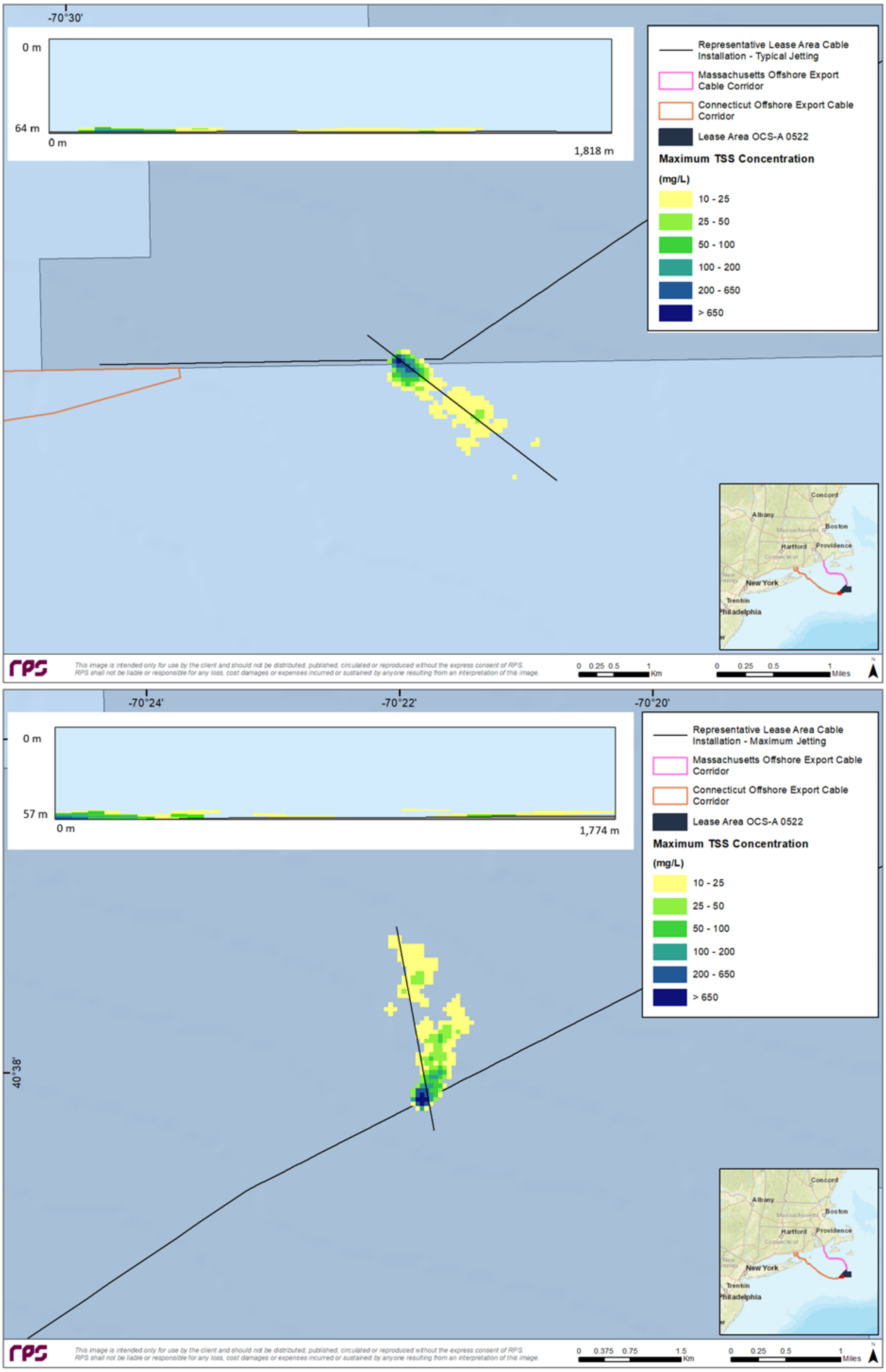


Figure 3-65: Snapshot of instantaneous TSS concentrations for a time step during simulation for the Representative Lease Area Cable Installation —Typical Jetting (top) and Maximum Jetting (bottom) simulations.

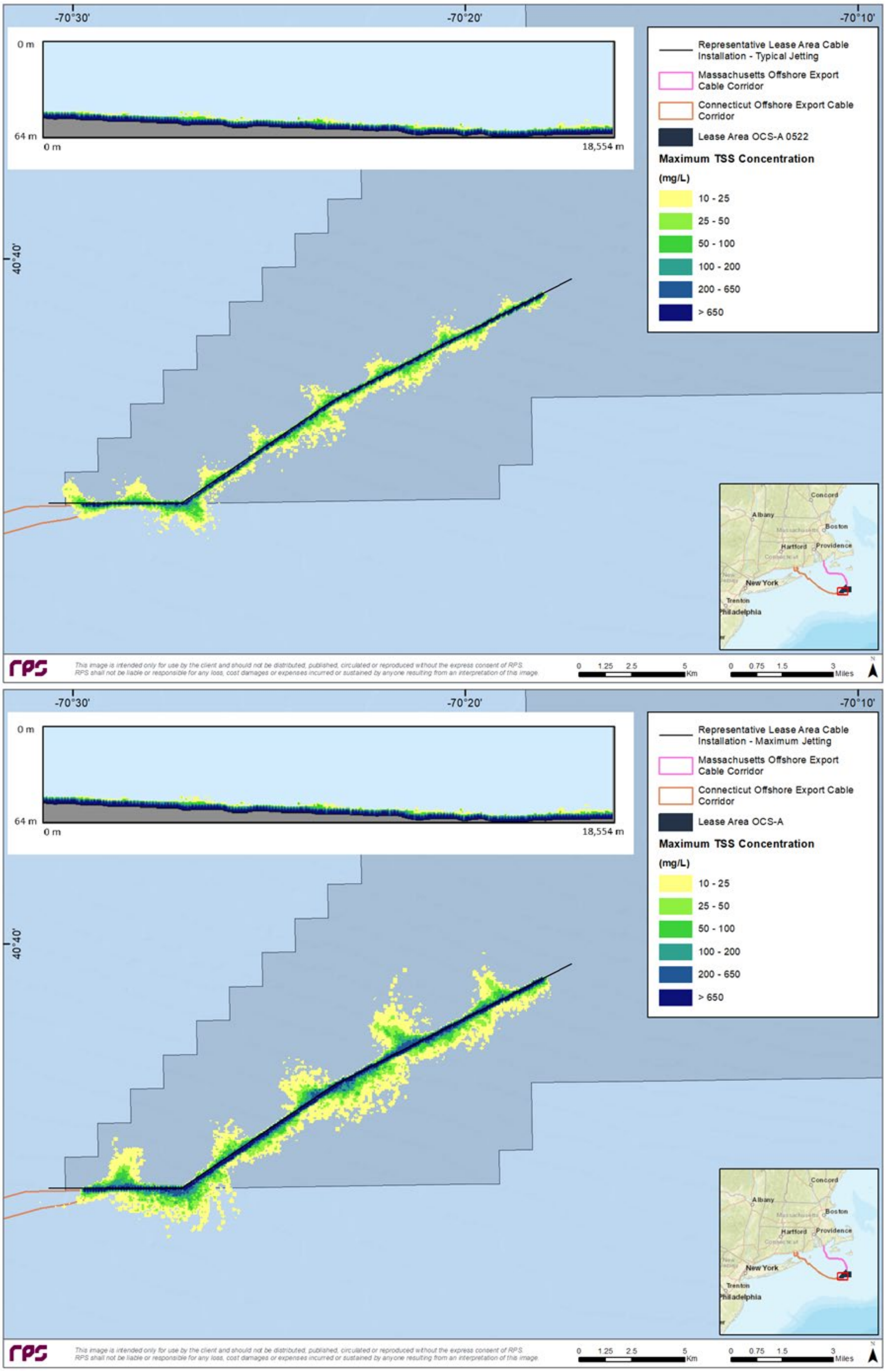


Figure 3-66: Map of time-integrated maximum concentrations associated with the Representative Lease Area Cable Installation —Typical Jetting (top) and Maximum Jetting (bottom) simulations.

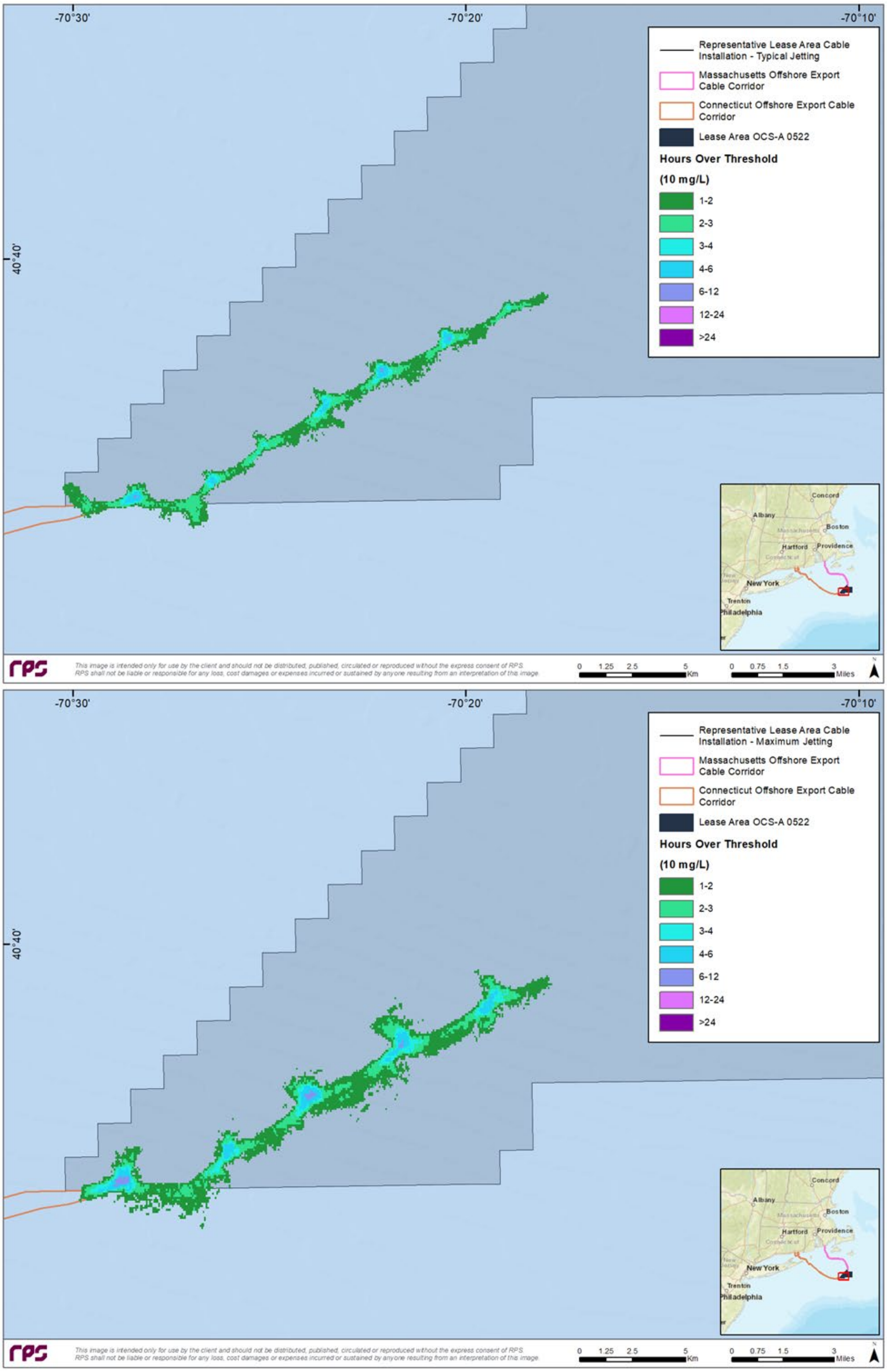
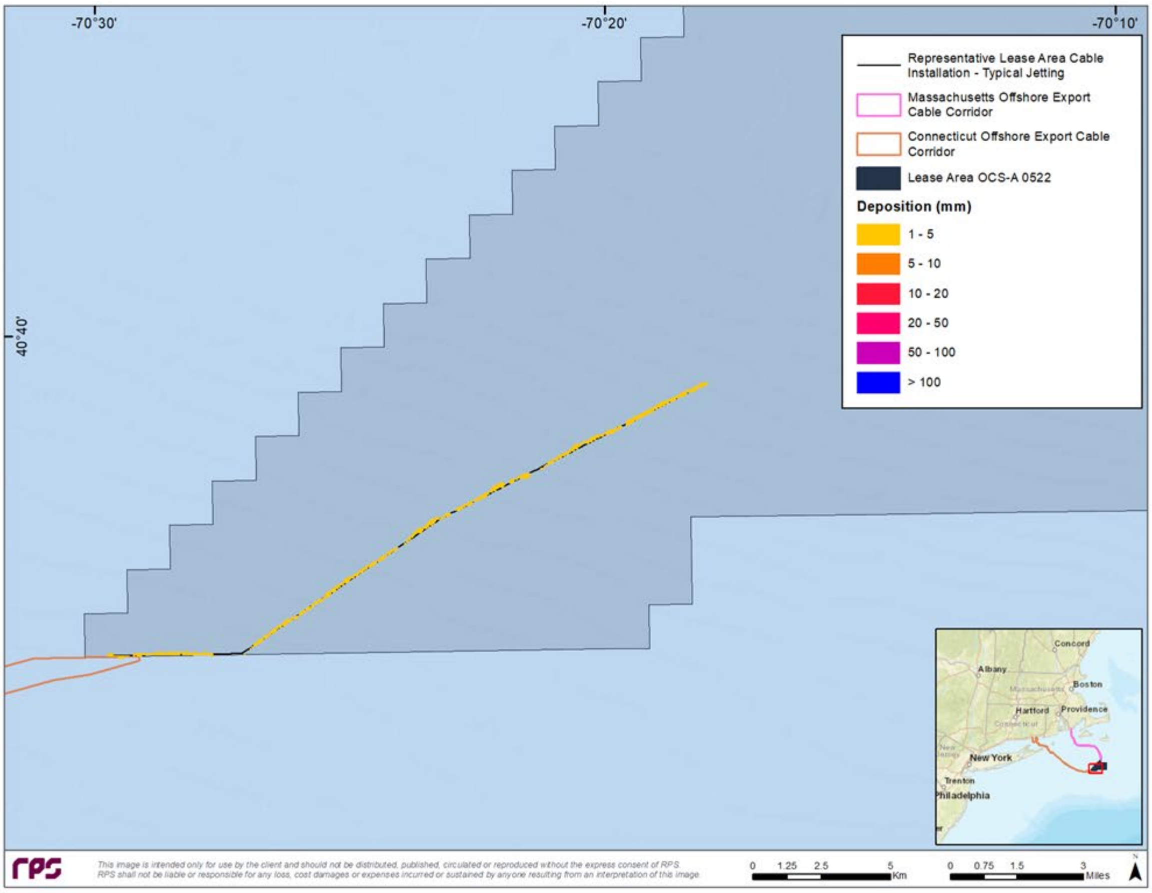


Figure 3-67: Map of duration of TSS ≥ 10 mg/L associated with the Representative Lease Area Cable Installation —Typical Jetting (top) and Maximum Jetting (bottom) simulations.



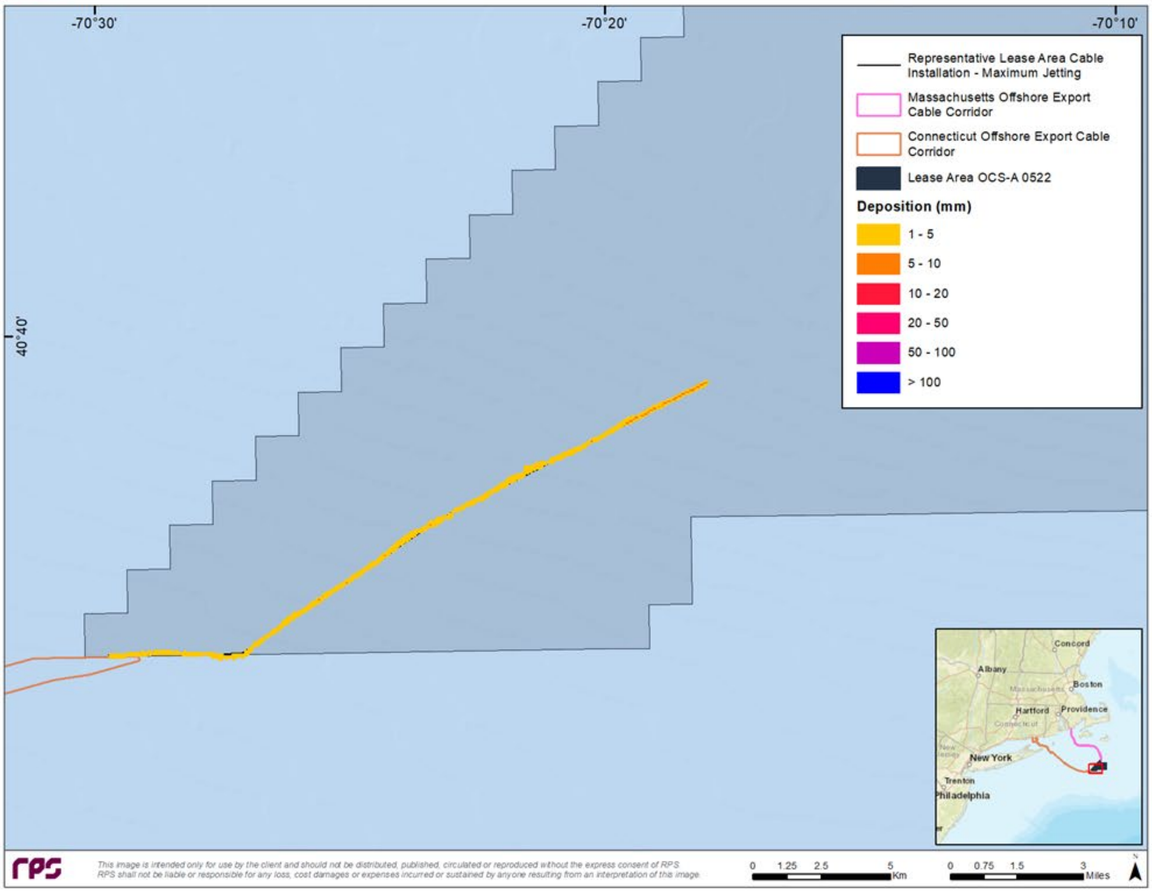


Figure 3-68: Map of deposition thickness associated with the Representative Lease Area Cable Installation —Typical Jetting (top) and Maximum Jetting (bottom) simulations.

3.3.4 Results Summary Tables: Suspended Sediment Concentrations

For each modeled scenario, the predicted mean and maximum distance to the 10 mg/L concentration contour was reported (Table 3-9). For the landfall scenarios, this distance was measured from the release location radially to the 10 mg/L contour, while the line source values were measured perpendicular to the route centerline to the 10 mg/L contour.

Based on the release conditions and the tidal stage, TSS concentrations ≥10 mg/L extended farther from the release location for the Representative Connecticut Landfall Site HDD Exit Pit Construction than was predicted for the Representative Massachusetts Landfall Site HDD Exit Pit Construction. The Representative Connecticut Landfall Site HDD Exit Pit Construction is more influenced to tidal and river forcing than the Massachusetts Landfall Site HDD Exit Pit Construction, which causes suspended sediment to travel farther from the source. TSS concentrations ≥10 mg/L also extended farther for the Representative Connecticut Landfall Site HDD Exit Pit Construction than any of the Connecticut OECC construction activities including cable installation within the entire OECC. This was likely due to the release of sediments at the surface rather than within the bottom few meters of the water column as was modeled for the cable installation simulations. When sediment is released near the surface, it is transported with the subsurface currents for a longer period; thus, causing the finer material to transport farther from the source. Additionally, sediments introduced much higher in the water column during backfill results in longer settling times; causing the 10 mg/L contour to extend farther from the activity.

Based on the release conditions and the tidal stage, TSS concentrations ≥10 mg/L extended similar distances from the release location for the representative sand bedform dredging within the Niantic Beach Approach and the main section of the Connecticut OECC. Alternatively, the mean and maximum extents to TSS concentration threshold of ≥10 mg/L was shorter for the Eastern Point Beach Approach when compared to the other two Connecticut OECC sections. TSS concentrations ≥10 mg/L extended the furthest for the representative sand bedform dredging within the Lease Area because it contained a much higher proportion of fine material compared to the OECCs simulations.

These maximum distances reflect the plume extent due to overflow and dumping operations as opposed to drag arm operations. This is because the sediment was released at or near the surface for overflow and dumping while drag arm resuspension was localized near the seabed. The mean extent was determined from drag arm, overflow, and dumping disturbances, the typical distance the plume would travel due to drag arm disturbances would likely be smaller than the estimated values because the mean value presented below are biased towards the large extent caused by the dump and overflow plumes.

The Representative Connecticut OECC Cable Installation using a mechanical trencher was predicted to have TSS concentrations ≥10 mg/L that remained relatively close to the route centerline as compared to the vertical injector and typical jetting simulations. Although the mechanical trenching scenario was modeled in an area with swift currents, the coarse material tended to remain close to the release location because it was released not only near the seabed, but in a relatively deeper area within the route. The maximum extent to the 10 mg/L TSS contour was comparable for the Niantic Beach Approach and Eastern Point Beach Approach, with the largest value reported along the Connecticut OECC after the intersection of the two landfall approaches.

The Representative Lease Area Cable Installation — Maximum Jetting simulation caused the farthest extent to the 10 mg/L TSS concentration contour because of the installation speed, the target trench depth, and because the simulation was performed in an area with high fractions of fine material.

Table 3-9: Summary of mean and maximum extent to the water column TSS concentration threshold.

Description		TSS Concentration Threshold 10 mg/L
		Mean [Maximum] Distance to Contour (km)
Representative Connecticut Landfall Site HDD Exit Pit Construction		0.76 [1.71]
Representative Connecticut OECC Cable Instillation — Jetting	Niantic Beach Approach	0.12 [0.49]
	Eastern Point Beach Approach	0.12 [0.51]
	Connecticut OECC	0.12 [1.33]
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	1.08 [6.48]
	Eastern Point Beach Approach	0.59 [5.05]
	Connecticut OECC	0.83 [5.20]
Representative Connecticut OECC Cable Installation — Mechanical Trenching		0.12 [0.18]
Representative Connecticut OECC Cable Installation — Vertical Injector		0.22 [0.44]
Representative Massachusetts Landfall Site HDD Exit Pit Construction		0.26 [0.40]
Representative Massachusetts OECC Cable Installation — Jetting		0.16 [0.90]
Representative Massachusetts OECC Cable Installation — Vertical Injector		0.31 [0.81]
Representative Sand Bedform Dredging – Massachusetts OECC		0.43 [1.58]
Representative Lease Area Cable Installation —Typical Jetting		0.33 [1.54]
Representative Lease Area Cable Installation — Maximum Jetting		0.72 [2.67]
Representative Lease Area Sand Bedform Dredging		2.16 [4.80]

Results from all modeled scenarios were analyzed to determine the spatial area exposed to above-ambient TSS concentrations exceeding specific thresholds for various concentration and duration thresholds. These areas are not always contiguous, but the results provide a sum of all individual concentration grid cells that exceeded a threshold anywhere in the water column for the duration of interest. Results provided in the following tables include areas greater than 0.01 km^2. Post-processing included calculations with respect to duration thresholds of one (Table 3-10), two (Table 3-11), three (Table 3-12), four (Table 3-13), six (Table 3-14), 12, 24, and 48 hours; however, not all scenarios exceeded the six hour threshold and only those which did were reported in the table. Additionally, there were no areas over thresholds for the 12-, 24- or 48-hour durations, so tables with those summaries were not included herein.

In reviewing these tables, it is helpful to keep in mind that the concentration grid resolution used in the modeling was 50 m in the horizontal plane. For a route 125 km long (e.g., Massachusetts OECC Cable Installation – Typical Jetting), the area covered by the grid cells along the route is therefore 6.25 km^2 (125,000 m x 50 m = 6.25 km^2). The dredge source is introduced in a smaller footprint since dredging is intermittent and dumping and overflow occur at designated locations (i.e., within presence of existing bedforms) and do not occur along the entire Connecticut OECC, Massachusetts OECC, or within the Lease Area. Similarly, the representative Lease Area cable installation simulations and the representative OECC sections (i.e., mechanical trencher, vertical injector) have a smaller direct footprint because their linear extents are smaller.

Areas exposed to above-ambient TSS concentrations are greatest when assessing concentrations above 10 mg/L, and those areas rapidly decrease in size with increasing concentration threshold and increasing duration. For example, as shown in Table 3-10 for the Representative Massachusetts OECC Cable Installation – Typical Jetting model scenario, 20.69 km^2 exceeded a TSS concentration of 10 mg/L for more than one hour, but only 0.14 km^2 of this area exceeded 650 mg/L for more than one hour. It is important to note that the listed areas are a summation of potential impacts throughout the entire OECC, such that all the listed areas are not impacted simultaneously. Above-ambient TSS concentrations similarly decrease quickly with time: for the same example scenario (Representative Massachusetts OECC Cable Installation – Typical Jetting) concentrations over 10 mg/L decrease from 20.69 km^2 for one hour (Table 3-10) to 0.31 km^2 for two hours (Table 3-11), to 0.18 km^2 for three hours (Table 3-12) to zero for four hours (Table 3-13). Additionally, for this route, TSS concentrations greater than 50 mg/L do not endure for periods of one hour or greater. Similar trends of rapid decrease in area with increasing time and/or increasing threshold are noted for all other routes presented.

Table 3-10: Summary of area over threshold concentrations for one hour or longer.

Description		Concentration Thresholds in mg/L					
		10	25	50	100	200	650
		Areas above Concentration Threshold (km^2)					
Representative Connecticut Landfall Site HDD Exit Pit Construction		0.83	0.75	0.66	0.57	0.44	0.14
Representative Connecticut OECC Cable Instillation — Jetting	Niantic Beach Approach	2.05	1.66	1.43	0.98	0.52	0.29
	Eastern Point Beach Approach	0.76	0.37	0.29	0.20	0.10	0.07
	Connecticut OECC	31.82	26.10	19.17	10.17	9.21	0.03
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	53.06	23.02	6.39	2.05	1.15	0.31
	Eastern Point Beach Approach	7.19	3.35	2.09	0.99	0.45	0.10
	Connecticut OECC	29.38	13.48	7.84	4.89	2.55	0.40
Representative Connecticut OECC Cable Installation — Mechanical Trenching		0.14	0.14	0.14	0.10	0.07	0.06
Representative Connecticut OECC Cable Installation — Vertical Injector		1.21	0.80	0.61	0.38	0.37	0.06
Representative Massachusetts Landfall Site HDD Exit Pit Construction		0.17	0.14	0.12	0.10	0.08	0.03
Representative Massachusetts OECC Cable Installation — Jetting		20.69	19.57	16.01	7.61	7.24	0.14
Representative Massachusetts OECC Cable Installation — Vertical Injector		2.18	1.05	0.69	0.47	0.39	0.05
Representative Sand Bedform Dredging – Massachusetts OECC		4.25	2.25	1.29	0.57	0.24	0.04
Representative Lease Area Cable Installation — Typical Jetting		10.5	5.7	3.9	2.4	1.3	0.31
Representative Lease Area Cable Installation — Maximum Jetting		18.21	9.13	5.81	3.89	2.31	0.36
Representative Lease Area Sand Bedform Dredging		16.61	12.91	7.28	3.34	2.54	1.36

Table 3-11: Summary of area over threshold concentrations for two hours or longer.

Description		Concentration Thresholds in mg/L					
		10	25	50	100	200	650
		Areas above Concentration Threshold (km^2)					
Representative Connecticut Landfall Site HDD Exit Pit Construction		0.07	0.01	-	-	-	-
Representative Connecticut OECC Cable Instillation — Jetting	Niantic Beach Approach	0.05	-	-	-	-	-
	Eastern Point Beach Approach	0.01	-	-	-	-	-
	Connecticut OECC	3.15	-	-	-	-	-
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	29.53	6.13	1.32	0.21	0.05	0.04
	Eastern Point Beach Approach	2.24	0.53	0.32	0.16	0.11	0.06
	Connecticut OECC	11.31	1.96	0.82	0.43	0.25	0.09
Representative Connecticut OECC Cable Installation — Mechanical Trenching		0.03	0.03	0.02	-	-	-
Representative Connecticut OECC Cable Installation — Vertical Injector		0.75	0.35	0.05	-	-	-
Representative Massachusetts Landfall Site HDD Exit Pit Construction		0.13	0.11	0.09	0.07	0.06	0.02
Representative Massachusetts OECC Cable Installation — Jetting		0.31	0.02	-	-	-	-
Representative Massachusetts OECC Cable Installation — Vertical Injector		1.38	0.57	0.24	0.04	-	-
Representative Sand Bedform Dredging – Massachusetts OECC		2.28	0.52	0.28	0.12	-	-
Representative Lease Area Cable Installation — Typical Jetting		4.4	1.3	0.2	0.01	-	-
Representative Lease Area Cable Installation — Maximum Jetting		7.65	2.77	0.98	0.13	-	-
Representative Lease Area Sand Bedform Dredging		6.21	2.26	0.65	0.52	0.37	0.07

Table 3-12: Summary of area over threshold concentrations for three hours or longer.

Description		Concentration Thresholds in mg/L					
		10	25	50	100	200	650
		Areas above Concentration Threshold (km^2)					
Representative Connecticut Landfall Site HDD Exit Pit Construction		-	-	-	-	-	-
Representative Connecticut OECC Cable Instillation — Jetting	Niantic Beach Approach	-	-	-	-	-	-
	Eastern Point Beach Approach	-	-	-	-	-	-
	Connecticut OECC	0.16	-	-	-	-	-
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	17.50	1.50	0.17	-	-	-
	Eastern Point Beach Approach	0.29	0.13	0.11	0.07	0.06	0.05
	Connecticut OECC	3.04	0.20	0.02	-	-	-
Representative Connecticut OECC Cable Installation — Mechanical Trenching		-	-	-	-	-	-
Representative Connecticut OECC Cable Installation — Vertical Injector		0.24	0.02	-	-	-	-
Representative Massachusetts Landfall Site HDD Exit Pit Construction		0.08	0.07	0.06	0.04	0.03	0.01
Representative Massachusetts OECC Cable Installation — Jetting		0.18	-	-	-	-	-
Representative Massachusetts OECC Cable Installation — Vertical Injector		0.60	0.17	0.02	-	-	-
Representative Sand Bedform Dredging – Massachusetts OECC		0.44	0.05	0.01	-	-	-
Representative Lease Area Cable Installation — Typical Jetting		1.33	0.12	-	-	-	-
Representative Lease Area Cable Installation — Maximum Jetting		3.23	0.80	0.06	-	-	-
Representative Lease Area Sand Bedform Dredging		0.36	0.09	0.02	0.01	-	-

Table 3-13: Summary of area over threshold concentrations for four hours or longer.

Description		Concentration Thresholds in mg/L					
		10	25	50	100	200	650
		Areas above Concentration Threshold (km^2)					
Representative Connecticut Landfall Site HDD Exit Pit Construction		-	-	-	-	-	-
Representative Connecticut OECC Cable Instillation — Jetting	Niantic Beach Approach	-	-	-	-	-	-
	Eastern Point Beach Approach	-	-	-	-	-	-
	Connecticut OECC	0.15	-	-	-	-	-
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	9.03	0.05	-	-	-	-
	Eastern Point Beach Approach	0.10	0.08	0.07	0.06	0.05	0.01
	Connecticut OECC	1.09	-	-	-	-	-
Representative Connecticut OECC Cable Installation — Mechanical Trenching		-	-	-	-	-	-
Representative Connecticut OECC Cable Installation — Vertical Injector		0.21	-	-	-	-	-
Representative Massachusetts Landfall Site HDD Exit Pit Construction		0.04	0.03	0.02	0.01	-	-
Representative Massachusetts OECC Cable Installation — Jetting		-	-	-	-	-	-
Representative Massachusetts OECC Cable Installation — Vertical Injector		0.32	-	-	-	-	-
Representative Sand Bedform Dredging – Massachusetts OECC		0.03	-	-	-	-	-
Representative Lease Area Cable Installation — Typical Jetting		0.72	-	-	-	-	-
Representative Lease Area Cable Installation — Maximum Jetting		1.64	0.17	-	-	-	-
Representative Lease Area Sand Bedform Dredging		-	-	-	-	-	-

Table 3-14: Summary of area over threshold concentrations for six hours or longer.

Description		Concentration Thresholds in mg/L					
		10	25	50	100	200	650
		Areas above Concentration Threshold (km^2)					
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	1.00	0.05	-	-	-	-
	Connecticut OECC	0.01	-	-	-	-	-
Representative Massachusetts OECC Cable Installation — Vertical Injector		0.04	-	-	-	-	-
Representative Lease Area Cable Installation — Typical Jetting		0.03	-	-	-	-	-
Representative Lease Area Cable Installation — Maximum Jetting		0.25	-	-	-	-	-

3.3.5 Results Summary Tables: Sediment Deposition

Areas greater than 0.01 km^2 are reported herein based on depositional thickness thresholds for all scenarios (Table 3-15). The Representative Connecticut Landfall Site HDD Exit Pit Construction simulation caused the largest areas impacted by depositional thickness exceeding 20 mm and 50 mm. In general, most of the simulations resulted in depositional thickness between 1 mm and 5 mm. All of the Connecticut OECC cable installation using typical jetting techniques were predicted to exceed thicknesses of 5 mm, as was the case for the Massachusetts OECC cable installation with typical jetting simulation, and the Lease Area cable installation simulation using maximum jetting parameters. The Sand Bedform Dredging for the Representative Export Cable within the main section of the Connecticut OECC caused the largest areas impacted by depositional thickness exceeding all thresholds of interest because it was modeled with the largest dredge volume and consisted of multiple dump sites. All of the representative sand bedform dredging simulations are predicted to exceed thicknesses of 100 mm because of the r dredge volume and the cumulative impact associated with using the same dump location multiple times.

Additionally, the mean and maximum distance (measured perpendicular to the route centerline) is reported for all scenarios to the 1 mm and 20 mm thickness threshold (Table 3-16). The Representative Connecticut Landfall Site HDD Exit Pit Construction, Representative Massachusetts Landfall Site HDD Exit Pit Construction, and the Representative Connecticut OECC Cable Installation — Mechanical Trenching simulations resulted in maximum extents for the 20 mm thickness threshold. Of these three scenarios, the Representative Connecticut Landfall Site HDD Exit Pit Construction scenario was the only one to have an area greater than 0.01 km^2 impacted by depositional thicknesses exceeding 20 mm.

For the sand bedform dredging simulations, the maximum distances reflect the depositional extent due to dumping operations as opposed to overflow or drag arm operations. Sand bedform dredging within the Connecticut OECC – Niantic Beach Approach was estimated to have the longest extent to the 1 mm and 20 mm thickness thresholds compared with all other dredging simulations. The mean distance the depositional thickness to 1 and 20 mm extended would likely be smaller for drag arm impacts than the values provided below (Table 3-16). The mean value presented below are biased towards the large depositional footprint caused by dumping.

Table 3-15: Summary of area over threshold over depositions for all routes.

Description		Depositional Thresholds					
		1 mm	5 mm	10 mm	20 mm	50 mm	100 mm
		Areas above Depositional Threshold (km^2)					
Representative Connecticut Landfall Site HDD Exit Pit Construction		0.20	0.05	0.03	0.02	0.01	-
Representative Connecticut OECC Cable Instillation — Jetting	Niantic Beach Approach	1.48	0.14	-	-	-	-
	Eastern Point Beach Approach	0.89	0.11	-	-	-	-
	Connecticut OECC	14.93	0.45	-	-	-	-
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	1.02	0.46	0.40	0.36	0.26	0.17
	Eastern Point Beach Approach	0.56	0.33	0.29	0.24	0.18	0.12
	Connecticut OECC	1.86	0.79	0.68	0.56	0.36	0.25
Representative Connecticut OECC Cable Installation — Mechanical Trenching		0.15	-	-	-	-	-
Representative Connecticut OECC Cable Installation — Vertical Injector		0.50	-	-	-	-	-
Representative Massachusetts Landfall Site HDD Exit Pit Construction		0.03	-	-	-	-	-
Representative Massachusetts OECC Cable Installation — Jetting		12.42	0.71	-	-	-	-
Representative Massachusetts OECC Cable Installation — Vertical Injector		0.46	-	-	-	-	-
Representative Sand Bedform Dredging – Massachusetts OECC		0.19	0.07	0.05	0.04	0.03	0.02
Representative Lease Area Cable Installation — Typical Jetting		1.50	-	-	-	-	-
Representative Lease Area Cable Installation — Maximum Jetting		2.88	0.12	-	-	-	-
Representative Lease Area Sand Bedform Dredging		0.19	0.07	0.06	0.04	0.02	0.01

Table 3-16: Summary of mean and maximum extent to depositional thresholds for all routes.

Description		Depositional Thresholds	
		1 mm	20 mm
		Mean [Maximum] Distance to Contour (km)	
Representative Connecticut Landfall Site HDD Exit Pit Construction		0.28 [1.23]	0.09 [0.12]
Representative Connecticut OECC Cable Instillation — Jetting	Niantic Beach Approach	0.05 [0.13]	-
	Eastern Point Beach Approach	0.05 [0.19]	-
	Connecticut OECC	0.05 [0.43]	-
Representative Connecticut OECC Sand Bedform Dredging — TSHD	Niantic Beach Approach	0.34 [1.77]	0.27 [0.43]
	Eastern Point Beach Approach	0.11 [0.48]	0.18 [0.39]
	Connecticut OECC	0.23 [1.03]	0.16 [0.33]
Representative Connecticut OECC Cable Installation — Mechanical Trenching		0.1 [0.12]	<0.01 [0.04]
Representative Connecticut OECC Cable Installation — Vertical Injector		0.08 [0.14]	-
Representative Massachusetts Landfall Site HDD Exit Pit Construction		0.1 [0.16]	0.03 [0.04]
Representative Massachusetts OECC Cable Installation — Jetting		0.07 [0.14]	-
Representative Massachusetts OECC Cable Installation — Vertical Injector		0.08 [0.15]	-
Representative Sand Bedform Dredging – Massachusetts OECC		0.08 [1.27]	0.03 [0.10]
Representative Lease Area Cable Installation —Typical Jetting		0.05 [0.14]	-
Representative Lease Area Cable Installation — Maximum Jetting		0.13 [0.18]	-
Representative Lease Area Sand Bedform Dredging		0.10 [0.96]	0.02 [0.20]

3.3.6 Results Discussion

These analyses provide conservative predictions of suspended sediment concentrations above ambient conditions that could result from the HDD exit pit construction, sand bedform dredging, and cable installation activities associated with Vineyard Northeast. Results from the representative simulations of HDD exit pit construction, sand bedform dredging, and cable installation within the Connecticut OECC and Massachusetts OECC, and sand bedform dredging and cable installation within the Lease Area show that above-ambient TSS concentrations originating from the source are intermittent, depending on the *in-situ* sediment composition; the vertical distribution of the sediment in the water column; and the hydrodynamic forcing conditions. The models show the highest concentrations of induced suspended sediment occur in the vicinity of the activity (e.g., cable installation, dredging, dumping, HDD exit pit construction), as expected; however, these higher concentrations decrease rapidly with distance. All predicted above-ambient TSS concentrations are expected to settle out rapidly, with a maximum of four to 12 hours required to fully dissipate.

HDD Exit Pits

For the representative HDD exit pit construction at the landfall site simulations, the above-ambient TSS concentrations may be present throughout the entire water column because sediments were released at the water surface but are predicted to return to ambient conditions within six hours. The plumes of TSS concentrations greater than 10 mg/L were predicted to have longer extents in the Representative HDD Exit Pit Construction simulation than in the Representative Massachusetts HDD Exit Pit Construction scenario

(Table 3-9), because current speeds near the representative Connecticut landfall site are faster and more complex than at the Massachusetts landfall site. The model predicted that deposition may range from less than 5 mm for the Representative Massachusetts HDD Exit Pit Construction scenario to less than 100 mm for the Representative Connecticut Exit Pit Construction scenario.

Sand Bedform Dredging

The representative sand bedform dredging simulation along the Niantic Beach Approach were predicted to have the largest impact compared with the other sand bedform dredging simulations. This prediction is, in part, due to the *in-situ* sediment composition containing high proportions of fine material; the dredge volume; and the direction of the prevailing currents at the time of dumping and overflow activities. When compared to its counterpart (i.e., Eastern Point Beach Approach), there was a higher proportion of fine material along the Niantic Beach Approach and a larger dredge volume modeled. The higher fraction of fine material was, therefore, present in the water column longer and oscillated with the currents prior to settling or dissipating. Although the main section of the Connecticut OECC is anticipated to have a larger dredge volume, the dump sites were spread across multiple locations, so the plume had time to dissipate partially or fully prior to the occurrence of the next dump and overflow operation. Due to dispersion of the sediment plume by the currents, TSS concentrations were predicted to substantially dissipate within two to three hours and fully dissipate within four to six hours for most of the model scenarios, except for the Niantic Beach Approach and Connecticut OECC, which was predicted to require up to 12 hours to fully dissipate.

The model also predicts the cumulative sediment deposition from the representative sand bedform dredging simulations to remain close to the drag arm disturbances; within the OECC; and to be less than 5 mm. The deposition associated with overflow and dumping exceeded thickness of 100 mm in every scenario but was predicted to remain around the dump location with a thickness of 1 to 5 mm occurring in isolated and patchy locations depending on the location of the prevailing currents at the time of release. Deposition thicknesses over 1 mm are predicted to typically extend 0.11 km to 0.34 km depending on the *in-situ* conditions and the release conditions, with a maximum of 1.77 km (Table 3-16). TSS concentrations greater than 10 mg/L remained within 0.59 km and 1.08 km, on average, for the representative sand bedform dredging simulations within the Connecticut OECC, Massachusetts OECC, and Lease Area (Table 3-9).

Cable Installation

Simulations of several possible inter-array or offshore export cable installation methods using either typical installation parameters (for inter-array and offshore export cable installation) or maximum impact parameters (for inter-array cable installation only) predict a plume that is localized to the seabed. The model also predicts the cumulative sediment deposition from installation will generally occur along (i.e., back into the trench) and adjacent to the cable route. Deposition thicknesses over 1 mm stayed close to the cable alignment (≤0.43 km) for all cable installation simulations. The Representative Connecticut HDD Exit Pit Construction simulation was predicted to produce a larger footprint that extended further from the source because sediment was introduced at the surface.

When cable installation was modeled for typical jetting parameters, the TSS concentrations greater than 10 mg/L stayed within 0.12 km and 0.16 km, on average, for the representative Connecticut OECC and Massachusetts OECC simulations, respectively. For both the Connecticut and Massachusetts representative vertical injector scenarios, the mean TSS concentrations greater than 10 mg/L extended slightly farther away from the route centerline than the cable installation using typical jetting parameters. These predictions are anticipated because the vertical injector simulations were modeled in areas containing high fractions of fine material that transport readily with subsurface currents.

Cable installation scenarios within the Lease Area were predicted to elevate TSS concentrations greater than 10 mg/L around 0.33 km and 0.72 km for the typical and maximum jetting scenarios, respectively (Table 3-9). A maximum distance of approximately 2.67 km for maximum installation jetting parameters and up to 1.54 km for typical impact installation parameters for the representative inter-array cable installation in the Lease Area are predicted from this modeling assessment (Table 3-9). For all cable installation scenarios within the Connecticut OECC, Massachusetts OECC, and Lease area, above-ambient TSS concentrations substantially dissipate within one to two hours and fully dissipate in less than four to 12 hours.

Summary

Results from the representative simulations of sand bedform dredging within the Connecticut OECC, Massachusetts OECC, and Lease Area show above-ambient TSS concentrations originating from the source are intermittent along the route and coincide with the representative dredge locations due to drag arm disturbances and the representative dump locations. The *in-situ* sediment composition; the anticipated dredge volume and length of dredging; the vertical distribution of the sediment in the water column; the hydrodynamic forcing conditions; and the depth of the release also contribute to the variability in the extent of the plume, the duration of exposure to TSS concentrations, and pattern of the depositional footprint. For the disturbances associated with the drag arm, TSS concentrations remained localized to the seabed either dissipating quickly or depositing based on the *in-situ* sediment type. Alternatively, dumping and overflow operations created plumes that extended throughout the water column, and although patchy and discontinuous in nature, the plume was exposed to multiple tidal cycles causing it to be transported farther from the source before dissipating or settling. The model predicted above-ambient TSS concentrations induced from dredging and dumping substantially dissipated within two to three hours and fully dissipated within four to 12 hours.

For the cable installation and HDD Exit Pit Construction simulations, the modeling predicts suspended sediment concentrations induced by installation of the cables and excavation and backfill of the HDD exit pits will largely be of short duration, confined to the near-bottom portion of the water column (except if backfilling is used when constructing the HDD exit pits), and will return to ambient conditions within approximately 12 hours after the installation device has passed or backfilling has stopped.

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