Modeling of Sediment Dispersion during Installation of the Submarine Cable for the Poseidon Project

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Project No. P298-001

September 18, 2013

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EXECUTIVE SUMMARY

The Poseidon Project includes approximately 39.2 miles (mi) (63 kilometer [km]) of high voltage direct current (HVDC) Submarine Cable bundled with a fiber optic cable (Submarine Cable) to be buried in the seafloor of Raritan Bay and the New York Bight with landfalls at Union Beach, in Monmouth County, New Jersey and Jones Beach on Long Island in Suffolk County, New York. The Submarine Cable will be buried to specific target depths below the seafloor of Raritan Bay and the New York Bight in New Jersey and New York state-owned submerged lands below the High Water Mark utilizing jet plow embedment.

ESS Group, Incorporated (ESS) has conducted an analysis of how sediment suspended during jet plow embedment of the cable may be transported away from the jet plow due to the currents in the vicinity of the jet plowing activity. The analysis includes a determination of suspended sediment concentrations in the water column and the eventual deposition thickness on the seafloor. In order to complete this analysis, ESS developed a hydrodynamic model of the Project Area using the Advanced Circulation Model (ADCIRC). ESS used the results from the hydrodynamic model as a current field for the execution of a sediment dispersion model using the Particle Tracking Model (PTM).

The hydrodynamic model predicted water levels for the period from October 2, 2012 through October 26, 2012 and the results compare well to measured water levels at the National Oceanic and Atmospheric Agency (NOAA) monitoring Station at Sandy Hook, New Jersey (Station 8531680). The hydrodynamic model current speeds also compare well to modeled current speeds from the New York New Jersey Operational Forecast System (NYOFS) model. There were no publically available current measurements within the hydrodynamic model domain; therefore, ESS could not fully calibrate the model, but the high degree of matching with the NOAA water level monitoring station and NYOFS model led ESS to conclude that the hydrodynamic model was appropriate for use as a part of the analysis of sediment dispersion.

The sediment dispersion model used the currents from the hydrodynamic model to predict sediment transport taking into account variable trenching depth, variable jet plow speed, and variable sediment composition. The results from the sediment dispersion model indicate that the suspension of fine sediments present in Raritan Bay will result in small increases (less than 50 milligrams per Liter [mg/L]) in suspended sediment concentrations at distances greater than 1,000 feet (ft) (305 meters [m]) from the Cable Route. Large increases in suspended sediment concentrations (greater than 200 mg/L) will be limited to areas less than 500 ft (152 m) from the Cable Route for short periods of time (less than four hours). Increases in suspended sediment in the water column will have a short duration with concentrations typically returning to ambient conditions in one to four hours and in all cases in less than 24 hours after the passage of the jet plow. East of the Ambrose Channel, increases in suspended sediment concentrations will be limited to a zone within 500 feet of the Cable Route due to the combination of predominantly sandy sediments and lower current speeds.

Sediment deposition is thickest at the channel crossings where increased trenching depths result in increased rates of sediment suspension. The maximum predicted deposition thickness is approximately 5 millimeters (mm) while typical deposition thickness in the immediate vicinity of the Cable Route will be between 1 mm and 3 mm. Deposition thickness in excess of 0.2 mm is typically limited to areas within 500 ft (152 m) of the Cable Route. The only exception to this is an area between Sandy Hook, New Jersey and the Ambrose Channel. High ebb and flood current speeds in this zone result in the transport of sediments away from the Cable Route prior to their settling out of the water column. This process results in areas with depositional thicknesses greater than 1 mm. These occurrences are limited in areal extent.

The findings of the sediment dispersion analysis indicate that, in general, large increases in suspended sediment concentration are limited to a zone within 500 ft (152 m) of the Cable Route and deposition thicknesses greater than 1 mm are also limited to this area. Deposition and elevated suspended sediment concentrations outside of this zone occur on a limited basis. In all cases and all locations in the model, suspended sediment concentrations return to background conditions within 24 hours of the passage of the jet plow.

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1.0 INTRODUCTION

The Poseidon Project includes approximately 39.2 miles (63 kilometers [km]) of high voltage direct current (HVDC) Submarine Cable bundled with a fiber optic cable (Submarine Cable) to be buried in the seafloor of Raritan Bay and the New York Bight with landfalls at Union Beach, in Monmouth County, New Jersey and Jones Beach on Long Island in Suffolk County, New York. The Submarine Cable will be buried to specific target depths below the seafloor of Raritan Bay and the New York Bight in New Jersey and New York state-owned submerged lands below the High Water Mark utilizing jet plow embedment. Figure 1 shows the site location and the Cable Route.

The Submarine Cable will be buried to specific target depths below the seafloor of Raritan Bay and the New York Bight in New Jersey and New York state-owned submerged lands below the High Water Mark utilizing jet plow embedment. Jet plow operation typically releases suspended sediments into the water column. ESS Group, Incorporated (ESS) has conducted an analysis of how the suspended sediment may be transported away from the jet plow due to the currents in the vicinity of active cable laying. The analysis includes a determination of suspended sediment concentrations in the water column and the eventual deposition thickness on the seafloor.

In order to complete this analysis, ESS developed a hydrodynamic model of the Project Area and a sediment dispersion model which simulates predicted transport and deposition of sediment disturbed during jet plowing. This report describes both the hydrodynamic model and the sediment dispersion model including the development and application of the models. This report also provides an assessment of the extent of impacts on suspended sediment concentrations and sediment deposition thicknesses.

The Project will include construction activities in New York Harbor (Raritan Bay and Lower Bay) as well as the coastal zone of the New York Bight along the Rockaways, Long Beach, and Jones Beach Island. The New York Harbor is a system of bays, tidal straits, coastal inlets, and rivers that surround New York City and the northern border of New Jersey. The Lower Bay is approximately 25 feet (ft) (7.6 meters [m]) deep at its deepest locations and also includes shallower areas and dredged navigation channels (NOAA, 2012). Raritan Bay is shallower than the Lower Bay with a maximum depth of approximately 18 ft (5.5 m) (NOAA, 2012). The mean tidal range for Lower Bay and Raritan Bay is approximately 4.7 ft (1.4 m) as measured at the Sandy Hook tide gage (mean high water minus mean low water) (NOAA, 2013a). Currents in the Lower Bay and Raritan Bay are influenced by tidal cycles, inflow from rivers (primarily the Raritan River and the Hudson River), and the interaction of other parts of the New York Harbor through tidal straits like Arthur Kill. As a result, current speeds and directions vary in space and time.

The New York Bight is an open coastal zone in the Atlantic Ocean that begins at the limit of the New York Harbor and extends east along Long Island and south along the coast of New Jersey. The New York Bight also extends out into open water. Water depths vary in the New York Bight, but generally increase with distance from the shoreline. In the vicinity of the Cable Route, water depths are between 13 ft (4.0 m) and 50 ft (15.2 m) (ESS 2013). The mean tidal range in the New York Bight near the shoreline is similar to the range observed in the Lower Harbor. Currents in the New York Bight are driven by two large circulation patterns, the Gulf Stream (which flows towards the northeast) and an extension of the Labrador Current (flowing towards the southwest). These currents interact well off-shore from the Project Area and currents in the Project Area are controlled primarily by the tides.

Sediments in the Lower Bay are heterogeneous with the majority of the bay being sandy while some areas have sediments that are primarily composed of fine sediments (Adams and Benyi 2003) and sediments in Raritan Bay are predominantly sandy with some areas of sand that are overlain by fine sediment material (silts and clays) (USFWS 1997). Sediments in the New York Bight are primarily sandy (Liberty 2012). A site-specific geophysical survey was conducted for the Project between June and July 2013 demonstrating that sediments in the immediate vicinity of the Cable Route are consistent with regional sediment characteristics (OSI 2013).

2.0 MODEL DESCRIPTION

The installation of the Submarine Cable will involve jet plowing the majority of the Cable Route. When sediment is suspended by the jet plow it may be transported away from the trench by advective transport. In order to understand the transport, it is necessary to understand the current patterns in the Project Area. In order to be able to evaluate current speeds and directions, ESS developed a hydrodynamic model of the Project Area using the Advanced Circulation Model (ADCIRC).

2.1 ADCIRC

ADCIRC is a hydrodynamic circulation model that simulates water levels and currents over a finite element grid. The model can be used to evaluate both two and three dimensional models. ADCIRC was developed by Rick Luettich and Joannes Westerink (2004) in conjunction with the United States Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC) and has been certified by the Federal Emergency Management Agency (FEMA) for evaluating storm surge (USACE 2013a). ADCIRC has also been historically used for modeling tides and wind driven circulation, dredging feasibility and material disposal studies, as well as nearshore marine operations (USACE 2013b)).

ESS selected ADCIRC for use in this analysis because of the various boundary conditions that can be assigned in ADCIRC. The Cable Route extends into the New York Bight and therefore part of the hydrodynamic model must be an open-water boundary condition. ADCIRC can simulate open-water boundaries based on tidal constituents, and ADCIRC can incorporate reversing flow as a specified normal flow boundary condition. ADCIRC meets the technical requirements to develop a representative hydrodynamic model of the Project Area because of these boundary condition options.

2.2 Particle Tracking Model (PTM)

In addition to being appropriate for use in evaluating the hydrodynamics, ADCIRC is also readily linked to the Particle Tracking Model (PTM). PTM is a Lagrangian particle tracker developed to simulate particle (i.e. sediment) transport processes. The model was developed by ERDC as a part of the Coastal Inlets Research Program and the Dredging Operations and Environmental Research Program (MacDonald et al. 2006). Suspended sediment in PTM is modeled as a discretized finite number of particles that are transported by flow. These particles are representative of all particles coming from a source. Each particle is assigned a mass of sediment to represent and each particle has individual characteristics including mean grain size, grain size distribution, and density. The transport and eventual deposition of these representative particles can then be used to determine suspended sediment concentrations and deposition thicknesses.

3.0 HYDRODYNAMIC MODEL APPLICATION

3.1 Model Setup

Figure 2 shows the limits of the model domain as well as each boundary condition applied to the hydrodynamic model. The model domain includes all of Raritan Bay, all of Lower Bay, and extends approximately 30 mi (48.3 km) out into the New York Bight. There is one tidal boundary in the New York Bight which is driven by tidal constituents K1, M2, N2, O1, and S2. ESS used the Atlantic Ocean ADCIRC tidal constituent database (ADCIRC 2013) to determine the amplitude and phase for each constituent. Table A summarizes the tidal constituents that were applied at the open boundary. The open boundary is approximately 55 mi (88.5 km) long. The representative tidal constituents change over this distance. In the model the tidal constituents were assigned every 3.5 mi (5.6 km) along the open boundary. The amplitudes and phases shown in Table A indicate the range of values for each assignment along the open boundary.

Table A Open Boundary Tidal Constituents

Tidal Constituent	Amplitude ft	Amplitude m	Phase degrees
K1	0.246 – 0.466	0.075 – 0.142	169.3 – 170.3
M2	1.978 – 2.080	0.603 – 0.634	347.3 – 351.9
N2	0.459 – 0.479	0.140 – 0.146	333.1 – 337.1
O1	0.174 – 0.177	0.053 – 0.054	183.4 – 184.9
S2	0.289 – 0.371	0.088 – 0.113	15.6 – 19.7

The hydrodynamic model also includes three normal flow boundaries. These flow boundaries represent the mouth of the Raritan River, mouth of the Hudson River, and mouth of the Arthur Kill. The Arthur Kill is a tidal strait connecting Newark Bay to Raritan Bay. The model domain excludes the Raritan River and truncates the Hudson River downstream of where the Hudson River is joined by the Kill Van Kull and the East River (both tidal straits). The Raritan River is tidally influenced miles upstream of its mouth and flow at the mouth may reverse based on the interaction of freshwater flow and water levels. The effective flow rate and direction of flow at the boundary depends on the complex interaction between the various bays in the New York Harbor system. In order to appropriately simulate flow at each of the flow boundaries, it would be necessary to develop a circulation model of the entire New York Harbor.

The National Oceanic and Atmospheric Agency (NOAA) has developed and maintains the New York and New Jersey Operational Forecast System (NYOFS) model as a part of the Center for Operation Oceanographic Products and Services (CO-OPS). The NYOFS model simulates currents and water levels throughout the New York Harbor (NOAA 2013) and results from this model take into account the complex interaction between the various bays in the New York Harbor as well as tidal reversing in rivers. ESS assigned historical model results from the NYOFS model to the reversing flow boundaries (Raritan River, Arthur Kill, and Hudson River) in the hydrodynamic model.

Figure 2 also shows the hydrodynamic model grid. The grid is an unstructured grid. Near the open tidal boundary grid cells are approximately 3 mi (4.8 km) on a side whereas near the Cable Route they are approximately 4,000 ft (1220 m) on a side. The hydrodynamic model resolution is appropriately scaled to simulate circulation patterns in the model domain and provide the necessary current speed information for the sediment dispersion model.

ESS assigned the hydrodynamic model bathymetry based on a series of National Ocean Service (NOS) hydrographic surveys for New York Harbor and the New York Bight (NOAA 2013b). ESS collected the bathymetric data from the NOAA National Geophysical Data Center, and processed and interpolated bottom elevations to the model grid. ESS checked model bathymetry elevations against bathymetry survey results from the Project specific hydrographic survey (OSI 2013). There were some discrepancies between the NOS surveys and the Poseidon survey, but ESS concluded that the discrepancies were not significant and the NOS survey data was acceptable for use in the hydrodynamic model.

ESS also incorporated wind data recorded at the NOAA meteorological buoy near Sandy Hook, New Jersey (Station SDHN4) into the model and applied the time varying wind uniformly across the entire model domain.

3.2 Model Results/Comparison

In order to evaluate the performance of the hydrodynamic model, ESS ran the model simulating a four-week period between October 1, 2012 and October 27, 2012, simulating the time of year and length of time associated with jet plow embedment activities. Model results show that the tidal boundary and reversing flows at the inland flow boundaries are syncopated; meaning, as the tide rises in the New York Bight, water flows into Lower Bay and Raritan Bay between Sandy Hook and Breezy Point. The direction of flow at each flow boundary reverses and water leaves the model domain during flood tides. During ebb tides, the direction of flow reverses again and water enters the model domain at these boundaries. Figure 3 shows a time series of predicted water levels and current speeds from the hydrodynamic model at a location north of Sandy Hook. Figure 3 demonstrates how peak current speeds occur during flood and ebb tides when the water levels in the model domain are changing most rapidly. Current speeds are lowest during slack tides when the hydraulic gradient between Lower Bay and the New York Bight is minimal. Peak current velocities occur during flood and ebb tides with the highest velocities occurring during ebb tides.

ESS used model results from October 2, 2012 through October 26, 2012 to compare predicted water levels to observed water levels at the NOAA tide gage at Sandy Hook, New Jersey (Station 8531680). Figure 4 shows a time series of predicted water levels and observed water levels. The predicted water level matches the observed water level well. The mean residual (the average difference between the predicted and observed data) is 0.22 ft (0.07 m) with a standard deviation of 0.59 ft (0.18 m). Figure 5 shows a graph of predicted water levels versus observed water levels. The Square of the Pearson Correlation Coefficient (R^2) is 0.93 which indicates a strong correlation between predicted and observed water levels. This high correlation demonstrates that the hydrodynamic model appropriately simulates changing water levels in the model domain.

ESS also evaluated how well the predicted currents in the hydrodynamic model matched the predicted currents in the NYOFS model. ESS did not have access to any observed currents data near the Project Area. In the absence of such data, an evaluation of how the hydrodynamic model compares to a previously calibrated model of the same area is the next best option. ESS selected a location equidistant between the tip of Sandy Hook, New Jersey and Breezy Point, New York. The location is in the immediate vicinity of the Cable Route and correlates to the NYOFS model cell identified as 13, 61. Figure 6 shows a time series graph of current speeds (where positive is flowing towards the New York Bight and negative is flowing towards New York Harbor) from the hydrodynamic model and the NYOFS model for the same location. The two models are almost perfectly in phase. The mean residual is -0.04 feet per second (fps) (0.01 meters per second [m/s]) with a standard deviation of 0.76 fps (0.23 m/s). Figure 7 shows a graph of the hydrodynamic model predicted current velocity versus the predicted NYOFS current velocity. The R^2 is 0.79 which indicates reasonable correlation between the two models.

3.3 Model Acceptance

The preceding discussion and Figures 4 through 7 demonstrate that the hydrodynamic model appropriately simulates water levels and currents in the model domain. The hydrodynamic model does slightly over predict current velocities which results in a slightly conservative model. The planned construction window for the project involves jet plowing between October 1, 2014 and November 14, 2014. The conditions that will be present at this time are unknown. In order to account for seasonal variability in boundary conditions, ESS ran the hydrodynamic model for the same time period in 2012. ESS assumed that once jet plowing begins it will be conducted continuously until all jet plowing is completed. The estimated total jet plowing time is nine days. ESS chose to run the hydrodynamic model from October 1, 2012 through October 20, 2012 and the hydrodynamic model results were used as the current field for the subsequent sediment dispersion model.

4.0 SEDIMENT DISPERSION MODEL APPLICATION

4.1 Model Setup

The sediment dispersion model used the same model boundaries and bathymetry as the hydrodynamic model. Setting up the PTM model consists of defining how the operation of the jet plow is simulated and characterizing the sediment that is suspended by the jet plow.

The jet plow operation is simulated in the sediment dispersion model beginning at the western end of the Submarine Cable off-shore near Union Beach, New Jersey. The simulated jet plow then advances along the Cable Route moving north and then east towards the landfall location at Jones Beach, New York. The rate of progress and suspended sediment production varies based on planned plow speed and planned trenching depth. Table B summarizes the anticipated trenching depth and plow speed for the Cable Route.

Table B Cable Route Segment Characterization

Segment Start		Segment End		Trench Depth		Plow Speed	
cable mi	cable km	cable mi	cable km	ft	m	ft/hr	m/hr
0.0	0.0	6.6	10.6	5.5	1.7	650	198
6.6	10.6	6.7	10.8	13.5	4.1	150	45.7
6.7	10.8	7.9	12.7	5.5	1.7	650	198
7.9	12.7	8.1	13.0	13.5	4.1	150	45.7
8.1	13.0	10.4	16.7	5.5	1.7	650	198
10.4	16.7	10.9	17.5	13.5	4.1	150	45.7
10.9	17.5	39.0	62.8	5.5	1.7	1,650	503

The trench depth shown in Table B assumes that the trench depth is 1.5 ft (0.46 m) below the planned cable laying depth. As the jet plow advances it will fluidize the sediment creating a trench with a constant width of two feet. The majority of the sediment that is fluidized will be re-deposited on top of the Cable. ESS conservatively assumed a constant sediment loss rate of 25%. The rate of suspended sediment generation (on a volume basis) is the product of trench width, trench depth, plow speed, and the sediment loss rate. In order to calculate the rate of suspended sediment production on a mass basis it is necessary to have an understanding of the sediments that will be disturbed and makeup the suspended sediment.

ESS collected a total of 47 vibracore samples along the Cable Route. Figure 8 shows the locations of each vibracore sample location. ESS completed a comprehensive sediment characterization for each sample. Table C provides a summary of this characterization including the specific gravity, sediment type (gravel, sand, fines) and median grain size (D50).

Table C Vibracore Sample Sediment Characterization

Sample ID	Specific Gravity	Gravel %	Sand %	Fines %	D50 mm
VC-10	2.75	3.01	36.22	60.78	0.07
VC-11	2.80	1.76	20.62	77.61	0.06
VC-12	2.75	1.13	12.96	85.91	0.04
VC-13	2.76	0.69	9.82	89.49	0.03
VC-14	2.76	0.00	40.38	59.62	0.14
VC-15	2.71	0.00	50.09	49.91	0.12
VC-16	2.69	0.28	61.33	38.39	0.11
VC-17	2.71	6.91	83.20	9.89	0.31
VC-18	2.68	4.60	71.91	23.49	0.26
VC-19	2.69	2.94	81.06	16.00	0.52
VC-20	2.70	2.01	89.86	8.13	0.48
VC-22	2.68	5.60	80.76	13.64	0.40
VC-23	2.68	5.71	88.33	5.96	0.40
VC-24	2.71	1.58	96.46	1.96	0.34

Sample ID	Specific Gravity	Gravel %	Sand %	Fines %	D50 mm
VC-25	2.71	2.75	92.87	4.37	0.35
VC-26	2.73	3.01	91.23	5.77	0.33
VC-27	2.70	5.47	91.17	3.36	0.50
VC-28	2.72	3.75	88.02	8.22	0.17
VC-29	2.70	7.78	89.89	2.33	0.25
VC-30	2.65	0.40	95.16	4.45	0.25
VC-31	2.71	0.00	96.48	3.52	0.33
VC-32	2.69	0.15	94.79	5.06	0.23
VC-33	2.69	0.13	94.35	5.52	0.32
VC-34	2.74	0.41	93.99	5.60	0.28
VC-35	2.72	0.36	95.94	3.70	0.34
VC-36	2.66	0.32	94.72	4.96	0.28
VC-37	2.68	1.97	83.13	14.90	0.17
VC-38	2.71	1.25	82.89	15.87	0.14
VC-39	2.66	7.23	87.33	5.45	0.23
VC-40	2.72	5.53	92.57	1.90	0.22
VC-41	2.69	0.76	89.94	9.29	0.13
VC-42	2.64	0.25	89.25	10.51	0.24
VC-43	2.69	0.07	84.07	15.87	0.21
VC-44	2.68	4.71	86.41	8.88	0.22
VC-45	2.69	3.38	80.59	16.03	0.18
VC-46	--	0.13	88.04	11.84	0.17
VC-58	2.70	2.36	95.06	2.59	0.18
VC-59	2.67	1.61	92.73	5.66	0.18
VC-61	--	--	46.93	53.07	0.11
VC-62	--	--	59.15	40.85	0.19
VC-63	2.66	2.87	90.70	6.43	0.33
VC-D1	--	2.70	75.51	21.79	0.20
VC-D2	--	0.50	80.16	19.34	0.22
VC-D3	--	--	62.64	37.36	0.16
VC-E1	2.69	7.64	68.90	23.46	0.74
VC-E2	2.69	5.36	94.38	0.25	0.67
VC-E3	2.69	0.59	98.50	0.91	0.45

The average specific gravity for the vibracore samples shown in Table C is 2.7 with individual cores ranging from 2.6 to 2.8. This means that the density of the samples is relatively consistent across the entire Cable Route, but the median grain size varies by an order of magnitude. Figure 9 arranges the vibracore samples by location from west to east. Figure 9 demonstrates that there are four distinct regions along the Cable Route. In the most western portion of the Cable Route the sediment is approximately equal parts sands and fines (VC-62 to VC-10). Sample results indicate that sediments from VC-11 to VC-13 are predominantly fines while sediment from VC-14 to VC-16 are approximately equal parts sands and fines. The fourth region extends from VC-17 and extends all the way to the landfall location at Jones Beach, New York. Sediments in this region are predominantly sands. Based on the information provided in Table B, Table C, and Figure 9, ESS identified 10 distinct types of sediment production. These distinct regions are shown in Figure 10 with a summary of the characteristics that serve as inputs to the sediment dispersion model including sediment production rate, median grain size, and density.

4.2 Model Results

The total estimated jet plowing time is nine days. ESS ran the sediment dispersion model for a total of 20 days (October 1, 2012 through October 20, 2012) with jet plowing beginning on October 1, 2012 off-shore of Union Beach, New Jersey. In the model, jet plowing stops on October 9, 2012 near Jones Beach, but the model runs for an additional 10 days to ensure that all suspended sediments settle prior to the end of the model run. The sediment dispersion model simulates suspended sediment concentrations and the total deposition thickness (based on initial deposition and assuming no re-suspension) for the entire model domain show in Figure 2. In order to show these model results at a scale that is useful for analysis, ESS divided the Cable Route into 17 segments. Figure 11 provides a key indicating the location of each segment relative to the overall model domain. Figure 12 shows the maximum predicted suspended sediment concentration for each segment.

The sediments in Raritan Bay are composed of between 40% and 90% fines. In the model, fine sediments are represented with a median grain size of 0.04 mm. These small particles are easily transported away from the jet plow once they are suspended. The smaller particles also readily disperse laterally. Low elevated suspended sediment concentrations are predicted to occur at distances in excess of 1,000 ft (304 m) from the jet plow during peak ebb and peak flood tides. Suspended sediment is transported the furthest from the Cable Route for the portions of the jet plowing that are oriented perpendicular to the dominant current directions. This includes the first 2.5 mi (4.0 km) of the Cable Route in Raritan Bay and the area north of Sandy Hook, New Jersey.

Suspended sediment concentrations away from the Cable Route are typically low and limited to less than 50 mg/L. High suspended sediment concentrations only occur in the immediate vicinity of the Cable Route. Suspended sediment concentrations in excess of 200 mg/L are limited to a distance of 500 ft (152 m) from the Cable Route. These high concentrations are predicted to only occur at two locations, off-shore of Union Beach, New Jersey (segment A) and off-shore of Sandy Hook, New Jersey (segment D).

North and northeast of Sandy Hook, New Jersey, there are high current speeds during ebb and flood tides. This means that even though the sediments in this region are predominantly sandy they are still transported away from the Cable Route. Segments E and F in Figure 12 show the influence of reversing tides as suspended sediments from jet plowing are transported first to the west with a flood tide and then to the east with an ebb tide. This pattern is repeated until the jet plowing moves east of Breezy Point, New York and current speeds in the vicinity of jet plowing decrease. The last 25 mi (40.2 km) of jet plowing generate very limited suspended sediment transport. The combination of lower current speeds and larger particle size results in elevated suspended sediment concentrations being limited to less than 100 mg/L and the typical distance from the Cable Route for any influence from jet plowing limited to less than 500 ft (152 m). This pattern is consistent all the way to the termination of jet plowing off-shore of Jones Beach, New York.

Figure 12 shows maximum suspended sediment concentrations. The maximum suspended sediment concentration occurs at different depths within the water column at different locations in the model. In order to understand the duration of elevated suspended sediment concentrations in the water column, ESS selected 10 locations along the Cable Route and evaluated the suspended sediment concentration throughout the water column over time. The various combinations of trench depth, suspended sediment production rate and sediment composition (shown in Figure 10) are all represented in these 10 locations. Figure 13 shows the locations where ESS evaluated suspended sediment throughout the water column over time.

Figure 14 shows a series of graphs with time on the x-axis and the distance above the seafloor on the y-axis. The color at each location indicates the suspended sediment concentration at that height above the floor. The graphs in Figure 14 generally show that the duration of increased suspended sediment concentrations at any location is short with a sediment plume present for between one hour and four hours. In all cases, suspended sediment concentrations in the water column return to background conditions within 24 hours. Elevated suspended sediment concentrations have the longest duration in Raritan Bay where finer particles tend to stay suspended longer than the larger sand particles present in the New York Bight.

The sediment transport model does not take into account near-field effects. Near-field effects occur within a range of approximately 80 ft (24 m) and it is common professional practice to exclude near-field behavior from sediment dispersion models as the scale of the near-field is insignificant relative to the scale of the model. Consequently, the highest concentrations at a given location may not necessarily occur immediately behind the jet plow. One result of this approach is that the suspended sediment concentration immediately behind the plow may be lower than the suspended sediment concentration in front of the jet plow when currents are advecting a sediment plume in front of the jet plow. The maximum planned speed of the jet plow is 1,650 ft/hr (503 m/hr) which is equivalent to 0.46 fps (0.14 meters/second [m/s]) while typical peak ebb and peak flood current speeds are expected to be in excess of 1 fps (0.30 m/s). One example of the plume leading the jet plow occurs at Location 6 in Figure 13. Appendix A of this report includes a set of snapshots from the model that demonstrate the movement of the plume and the movement of the plow. In the first snapshot the plume is ahead of the jet plow. By the last snapshot, the plume is trailing the jet plow. This back and forth process is present throughout the model period and is a result of tidal current patterns.

The combination of the advection of suspended sediment by the current and the vertical diffusion of suspended sediments can also result in situations where the peak suspended sediment concentration at a location does not occur at the bottom of the water column either. Depending on current patterns and particle size, the maximum concentrations may occur near the water surface. This result is clearly present at Location 1, Location 2, and Location 3 (all in Raritan Bay) where high current speeds keep fine sediment suspended. As the plume is advected by the water, the finer particles become concentrated near the surface. When current speeds drop during slack tide, these particles settle out of the water column and onto the seafloor.

As was previously mentioned, within 24 hours, suspended sediment concentrations return to background conditions and the sediment that was introduced into the water column by jet plowing settles onto the seafloor. Figure 15 shows the total deposition of sediment on the floor and is consistent with the suspended sediment pattern. Maximum deposition occurs in the three channel crossings (Raritan Bay East, Chapel Hill, and Ambrose) where the excavation depth is greatest. In these regions, the jet plow is trenching a substantially deeper depth resulting in an increase in the total sediment that is suspended into the water column. Consequently, the deposition of sediments in these areas is elevated. Outside of channel crossings, maximum deposition depths are in the range of 1 mm to 3 mm and maximum depths typically occur in the immediate vicinity of the Cable Route. Deposition depths greater than 0.2 mm are typically limited to a distance less than 500 ft (152 m) from the Cable Route. Exceptions to this general rule occur in Raritan Bay (segments A, B, and C in Figure 15) and north and northeast of Sandy Hook, New Jersey (segments D, E, and F in Figure 15). The fine particles in Raritan Bay and the high current speeds north and northeast of Sandy Hook, New Jersey result in greater transport of suspended sediments prior to deposition.

Significant deposition depths (greater than 1 mm of sediment) are limited to a distance of less than 200 ft (61 m) from the Cable Route. The only exception to this pattern occurs in the stretch between Sandy Hook, New Jersey and the Ambrose Channel crossing. Peak ebb and peak flood current speeds in this stretch result in depositional areas that exceed 1 mm (segments E and F in Figure 15) occurring more than 1,000 ft (305 m) from the Cable Route. These incidences are limited in frequency and areal extent.

5.0 CONCLUSION

The Poseidon Project includes the jet plow embedment of a submarine 500 MW electric transmission cable coupled with a fiber optic cable between Union Beach, New Jersey and Jones Beach, New York. The Cable Route passes through Raritan Bay and east into the New York Bight, crossing three channels (Raritan Bay East, Chapel Hill, and Ambrose) along the Route. ESS conducted an analysis of the transport and deposition of the sediment that will be disturbed during jet plow embedment of the Cable. ESS developed a hydrodynamic model using ADCIRC and then developed a sediment dispersion model using PTM.

The modeling simulates the suspension of sediments along the 39.2 mi (63 km) Cable Route and takes into account variable trenching depth, variable jet plow speed, and variable sediment composition. The model simulated jet plow operation between October 1, 2012 and October 9, 2012 and transport was simulated through October 20, 2012. The results of the sediment dispersion model indicate that small increases in suspended sediment concentrations above background levels will be present in Raritan Bay at distances in excess of 1,000 ft (305 m) from the Cable Route. Large increases in suspended sediment concentrations (greater than 200 mg/L) will be isolated and limited to a distance of 500 ft (152 m) or less from the Cable Route. Table D demonstrates these facts by providing mean and maximum distances for a given maximum concentration contour.

Table D Mean and Maximum Suspended Sediment Excursions from Cable Route

Susp. Sed. Concentration (mg/L)	Mean Distance ft	Mean Distance m	Maximum Distance ft	Maximum Distance m
25	505	153.9	4,935	1,504
50	545	166.0	3,499	1,066
100	253	80.2	1,079	329
200	98	30.0	232	70.8
300	29	9.0	51	15.7

Figure 16 provides a graph comparing excursion from the Cable Route and maximum predicted suspended sediment concentration. Beyond 500 ft (152 m) suspended sediment concentrations will not exceed 200 mg/L. Table D and Figure 16 support the same finding that small increases in suspended sediment concentrations will be observed well away from the Cable Route, but large increases in suspended sediment concentrations will be limited to the area within 500 ft (152 m) of the Cable Route. The elevated suspended sediment concentrations will be limited in time. In most cases suspended sediment concentrations will return to ambient conditions within one to four hours and in all cases within 24 hours after the passage of the jet plow.

Sediment deposition occurs predominantly within 500 ft (152 m) of the Cable Route. Any measurable deposition beyond that distance is typically 0.2 mm or less. Figure 17 provides two histograms of the area covered by different levels of deposition. Figure 17 demonstrates how the overwhelming majority of significant deposition occurs near the Cable Route. One exception to this pattern is areas of deposition in excess of 1 mm between Sandy Hook, New Jersey and the Ambrose Channel. These areas are limited in extent and deposition thickness. The model predicts that deposition will be generally limited to a narrow band near the Cable Route especially in the last 25 mi (40.2 km) of jet plowing where lower current speeds and larger grain sizes limit sediment transport prior to deposition.

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Figures

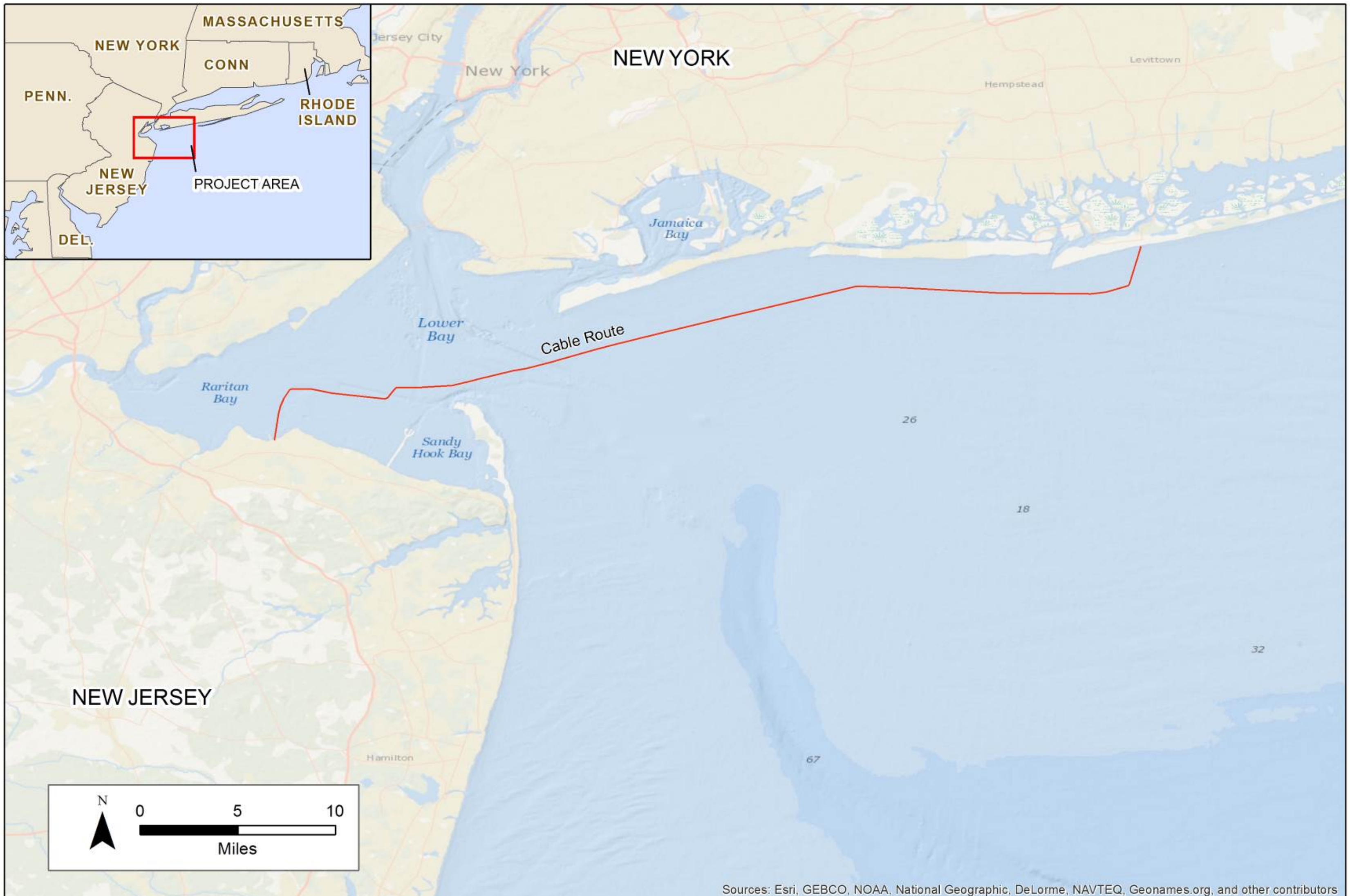

Figure 1 Locus Map

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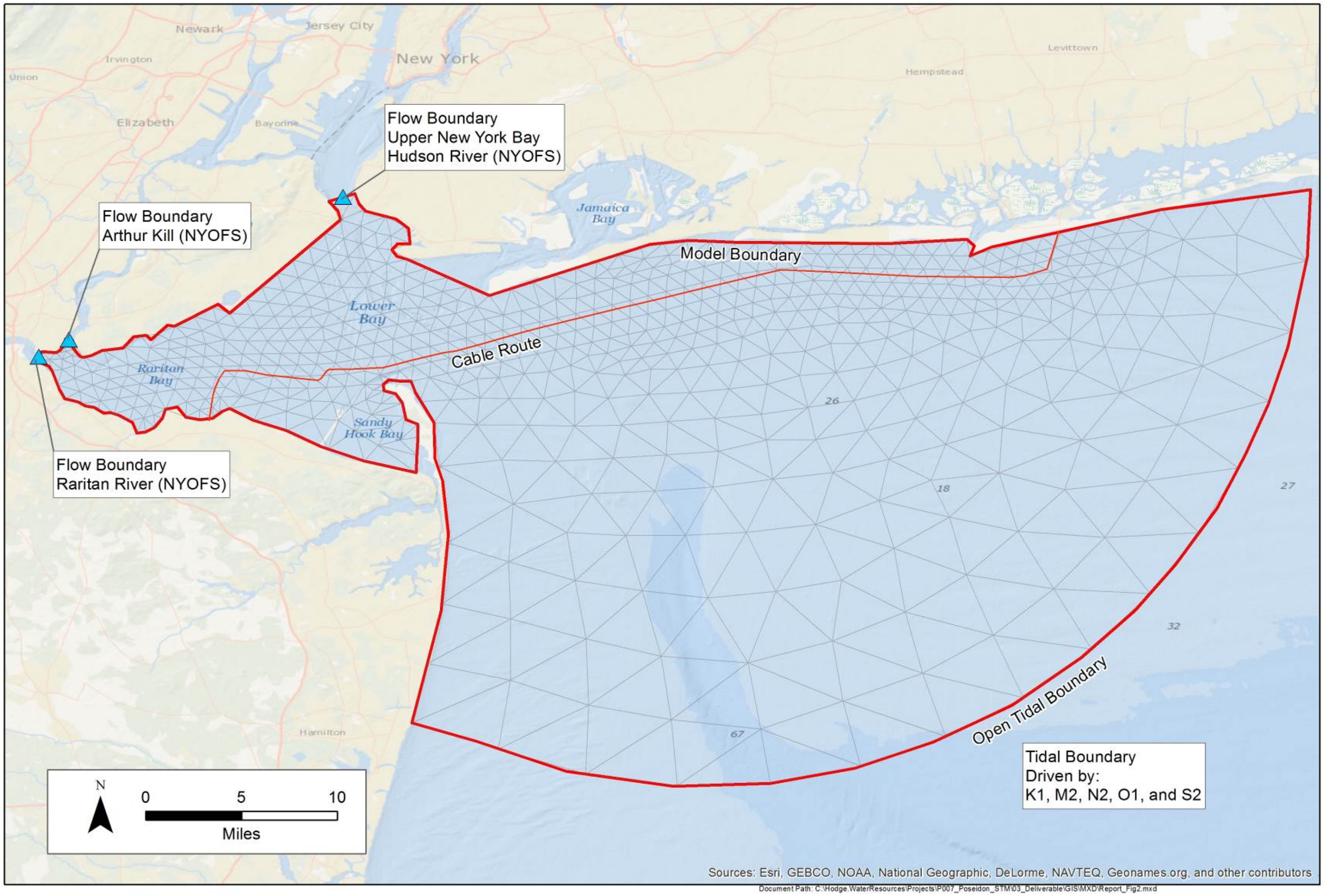

Figure 2 Hydrodynamic Model Domain

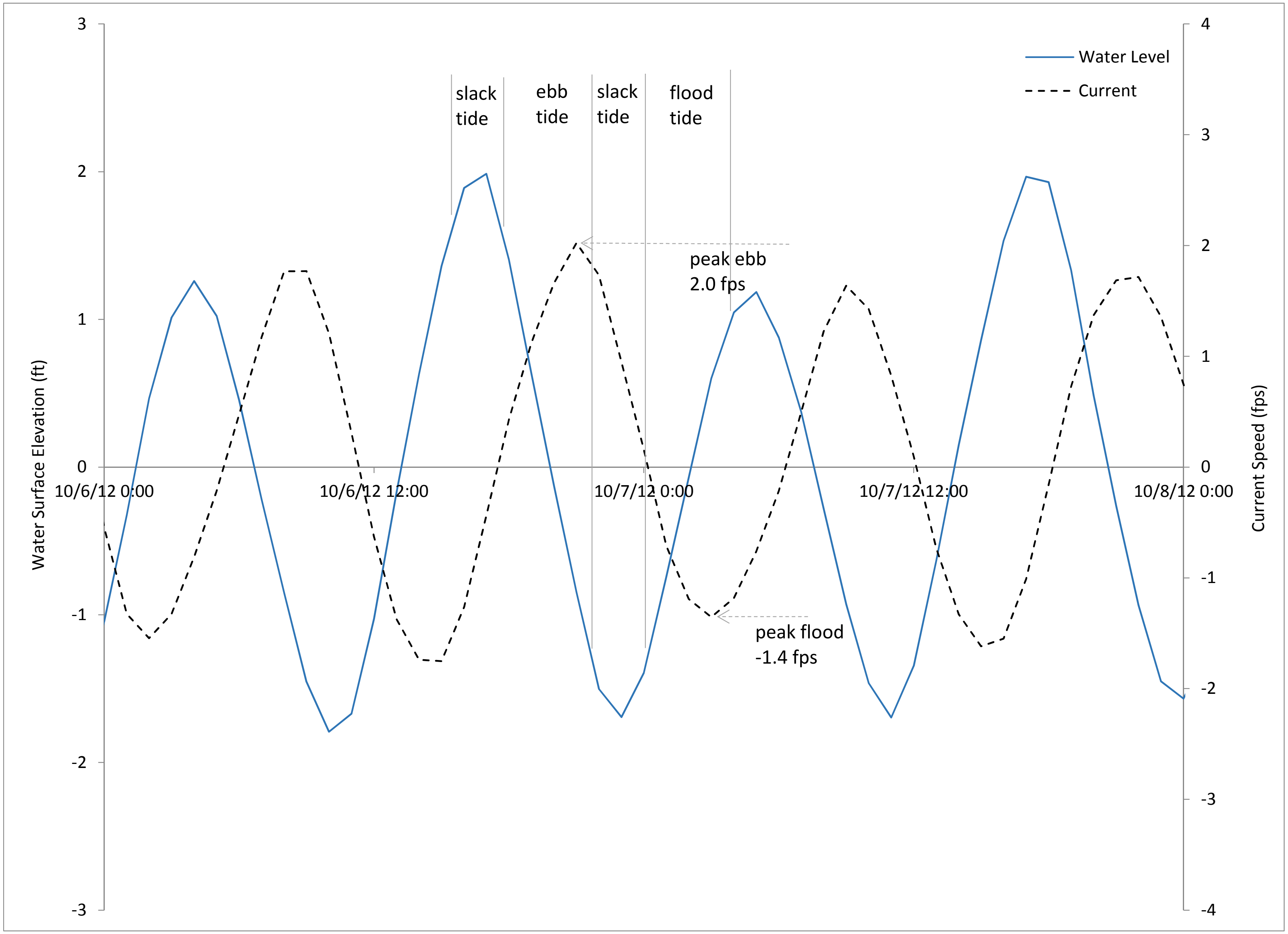

Figure 3 Typical Hydrodynamic Model Tide and Current Cycles

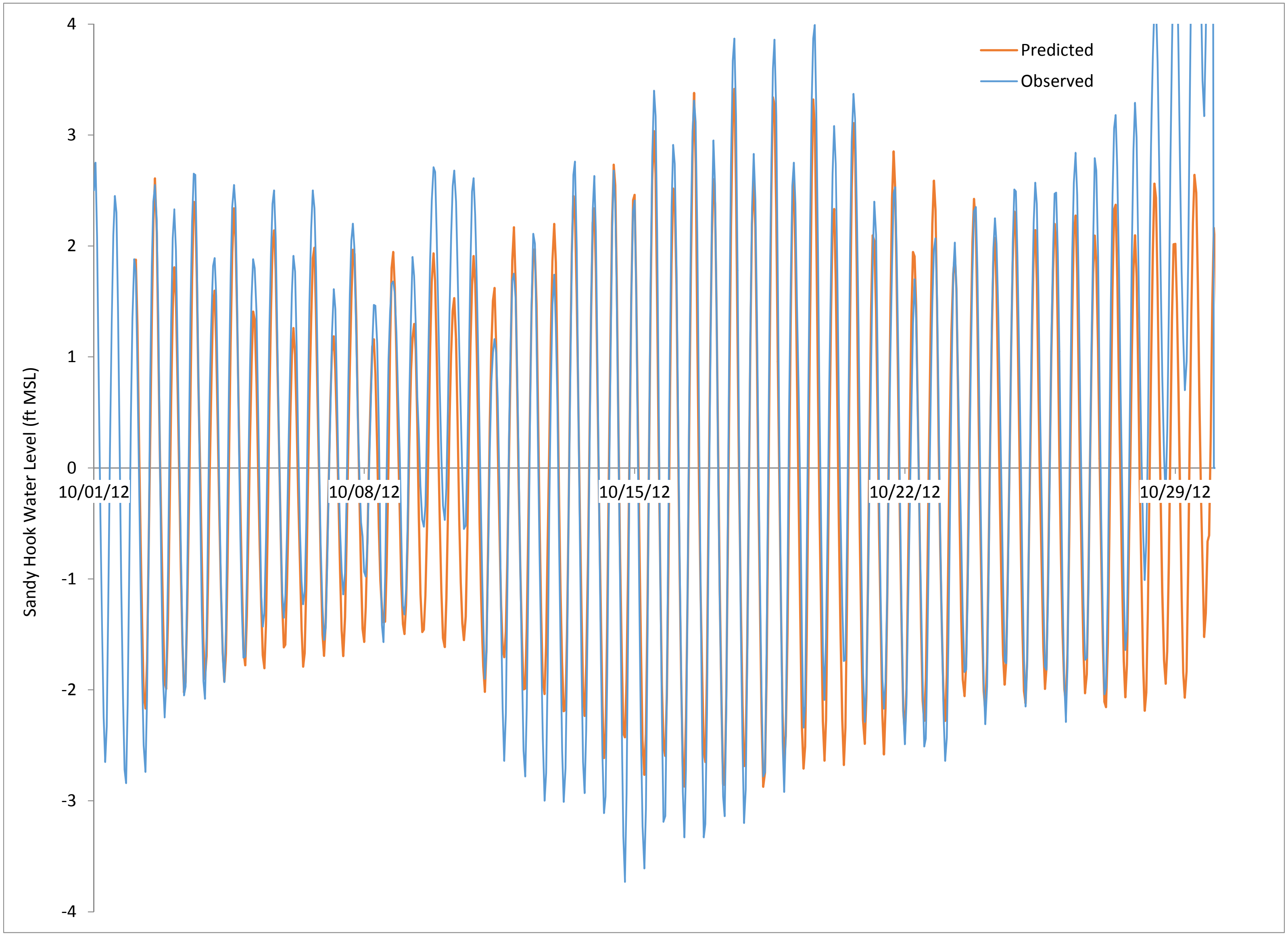

Figure 4 Observed and Predicted Water Level Time Series

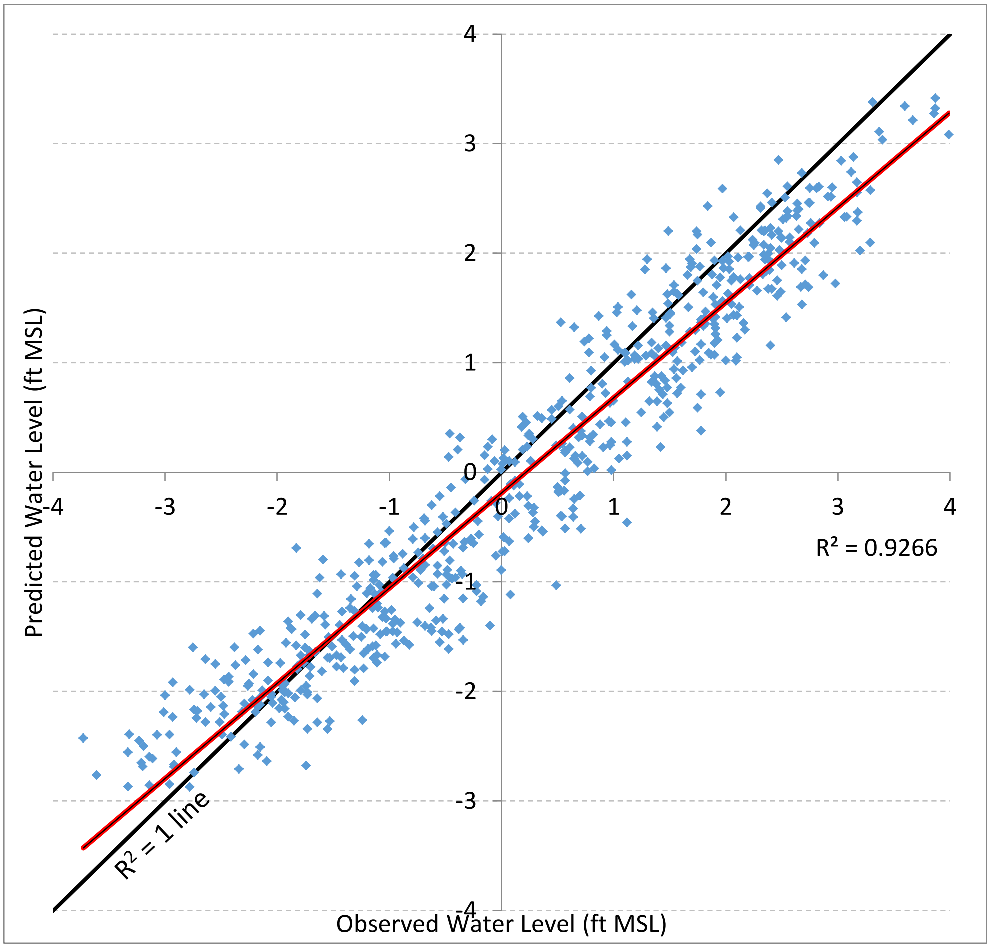

Figure 5 Direct Comparison Observed and Predicted Water Levels

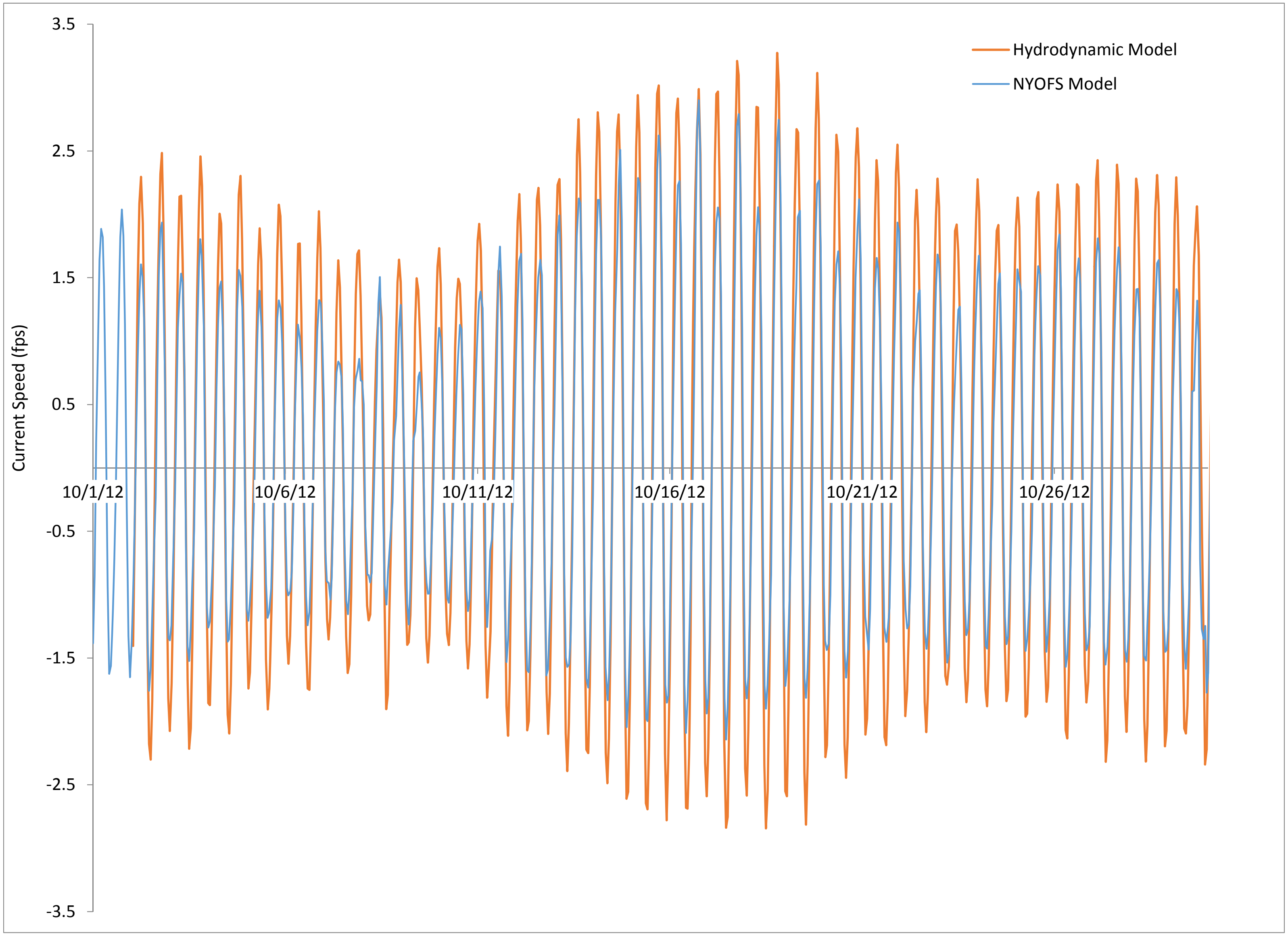

Figure 6 Hydrodynamic Model and NYOFS Model Current Speeds

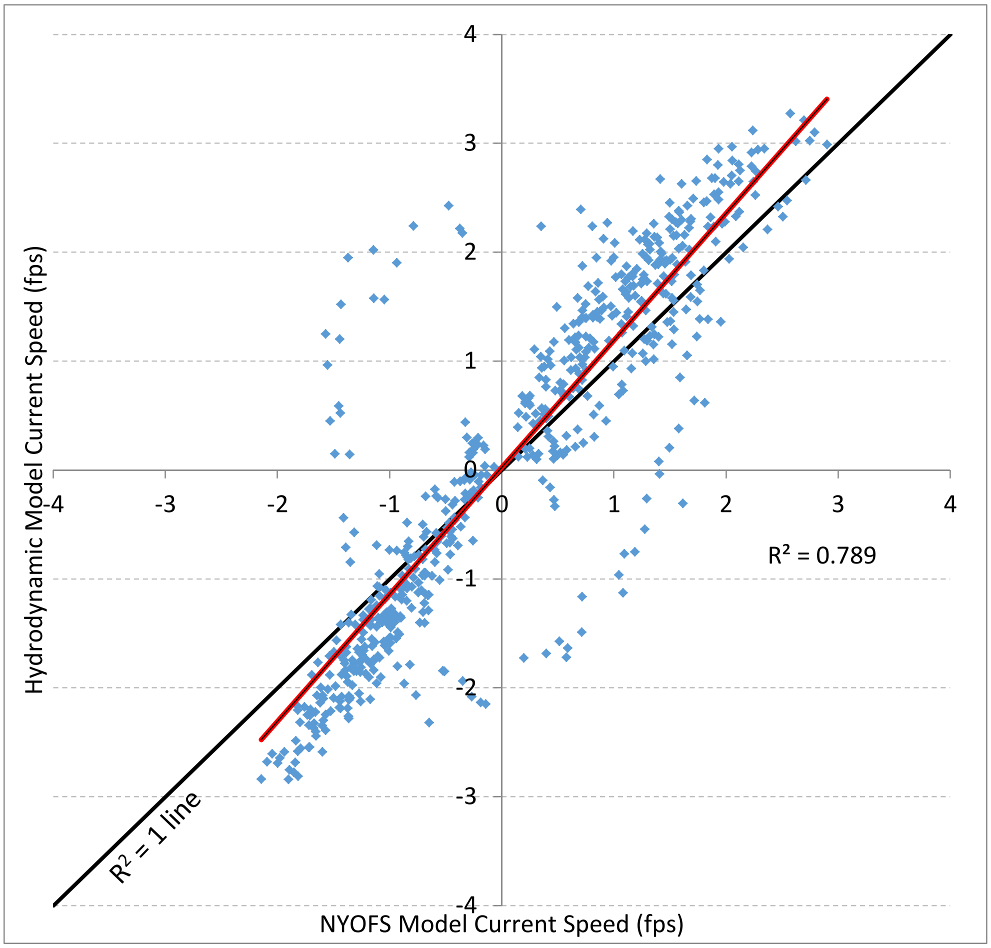

Figure 7 Direct Comparison Hydrodynamic Mode and NYOFS Model Current Speeds

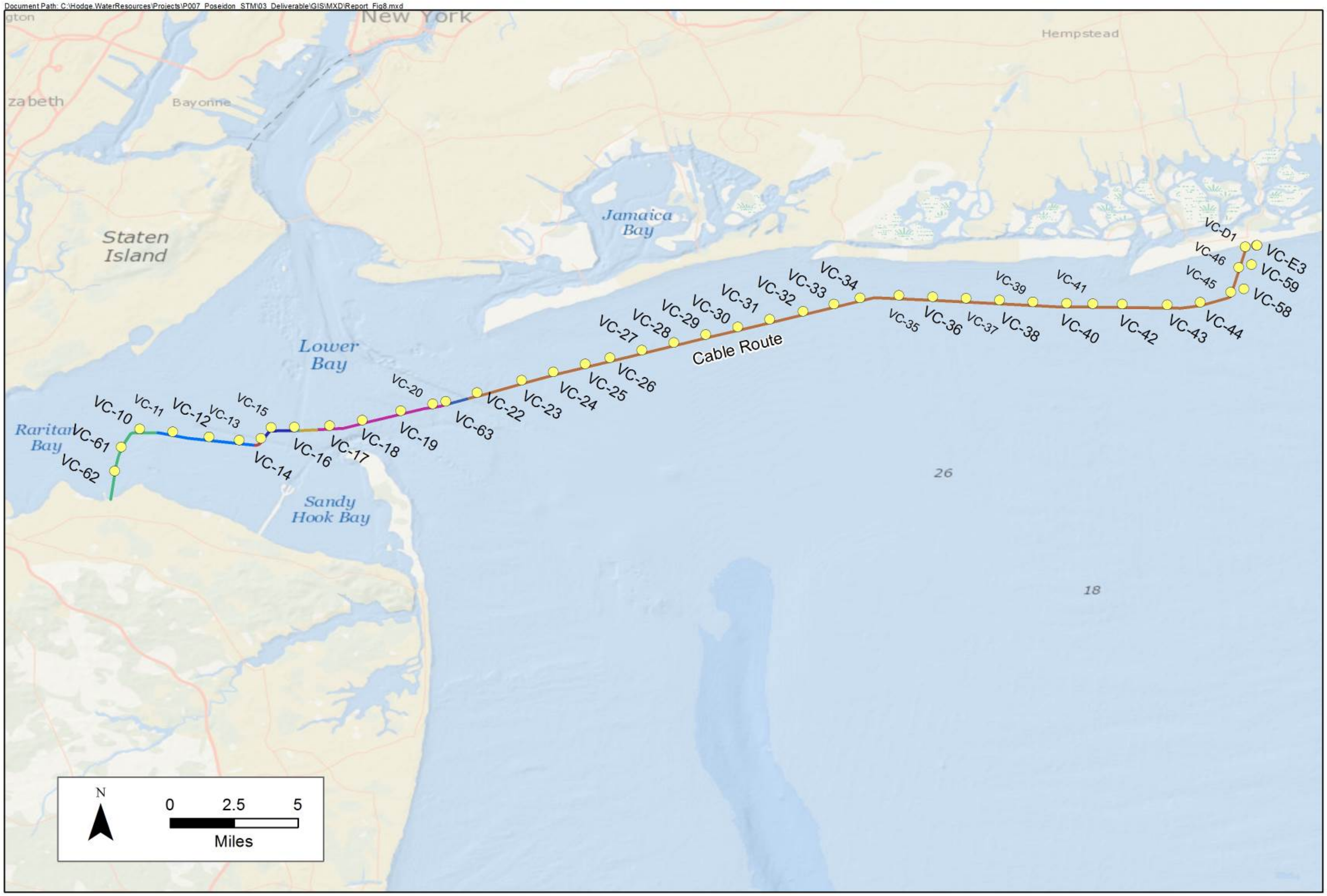

Figure 8 Vibracore Sample Locations

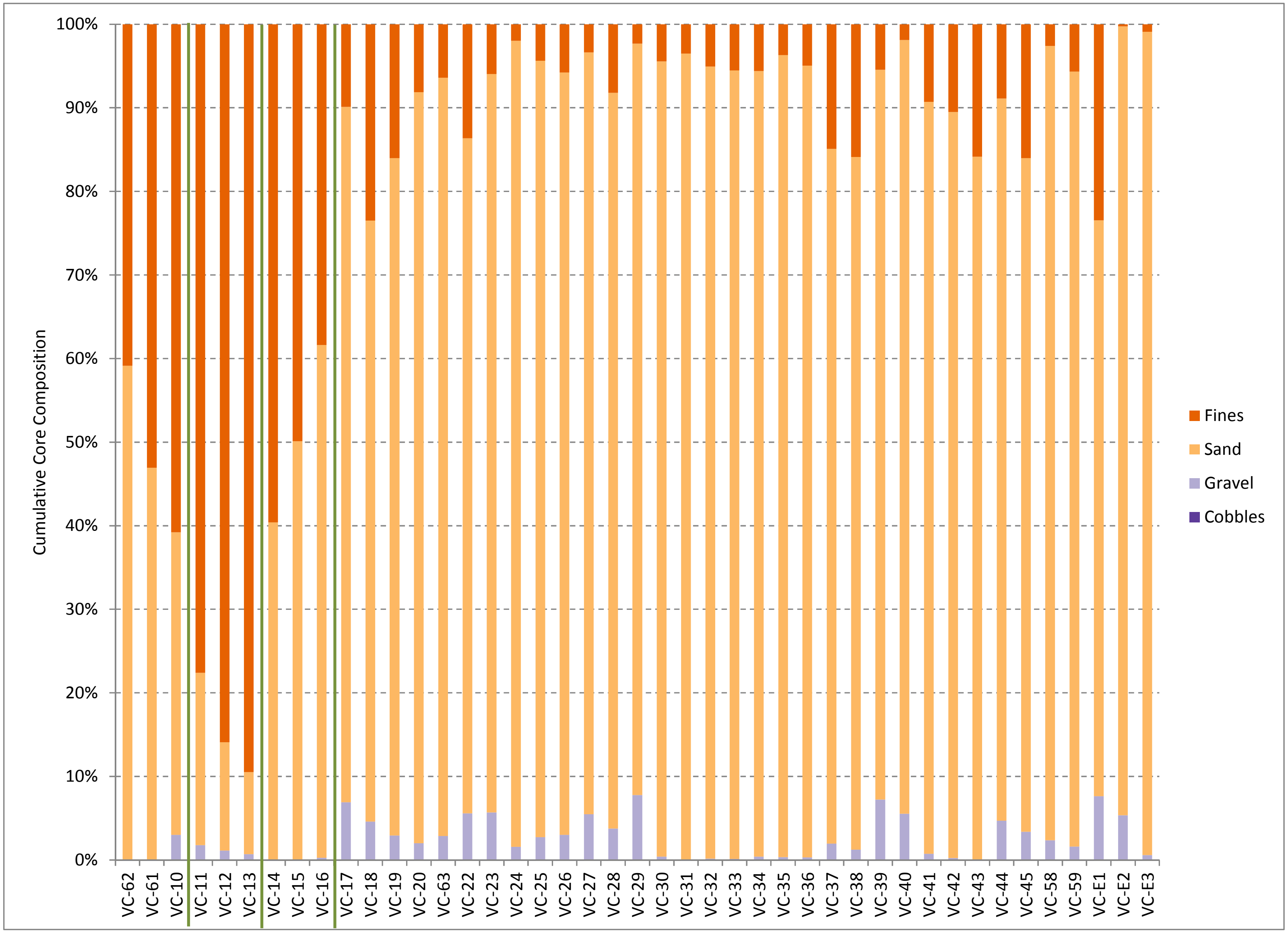

Figure 9 Vibracore Sample Sediment Type Characterization

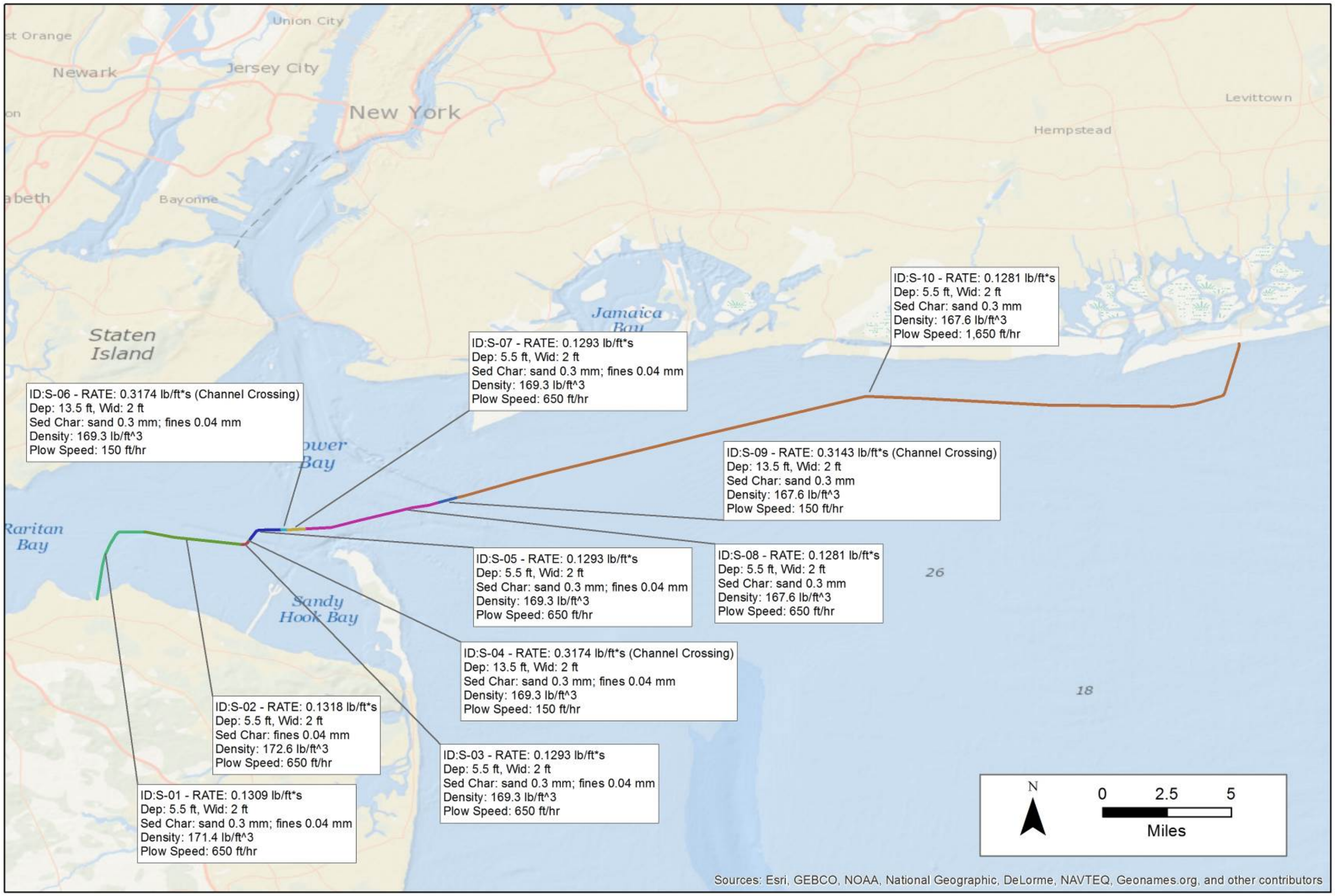

Figure 10 Sediment Dispersion Model Input Segments

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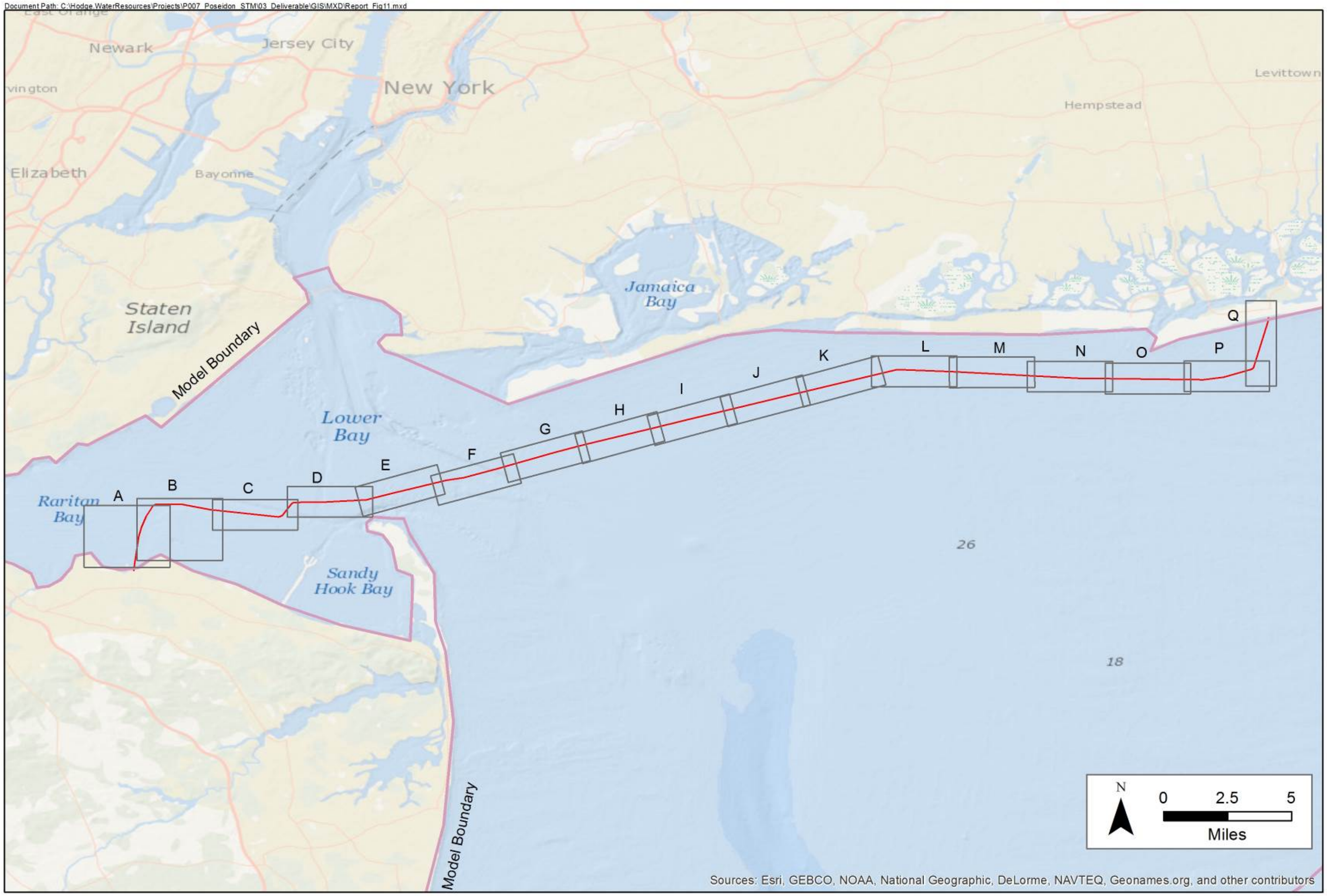


Figure 11 Sediment Dispersion Model Result Segments

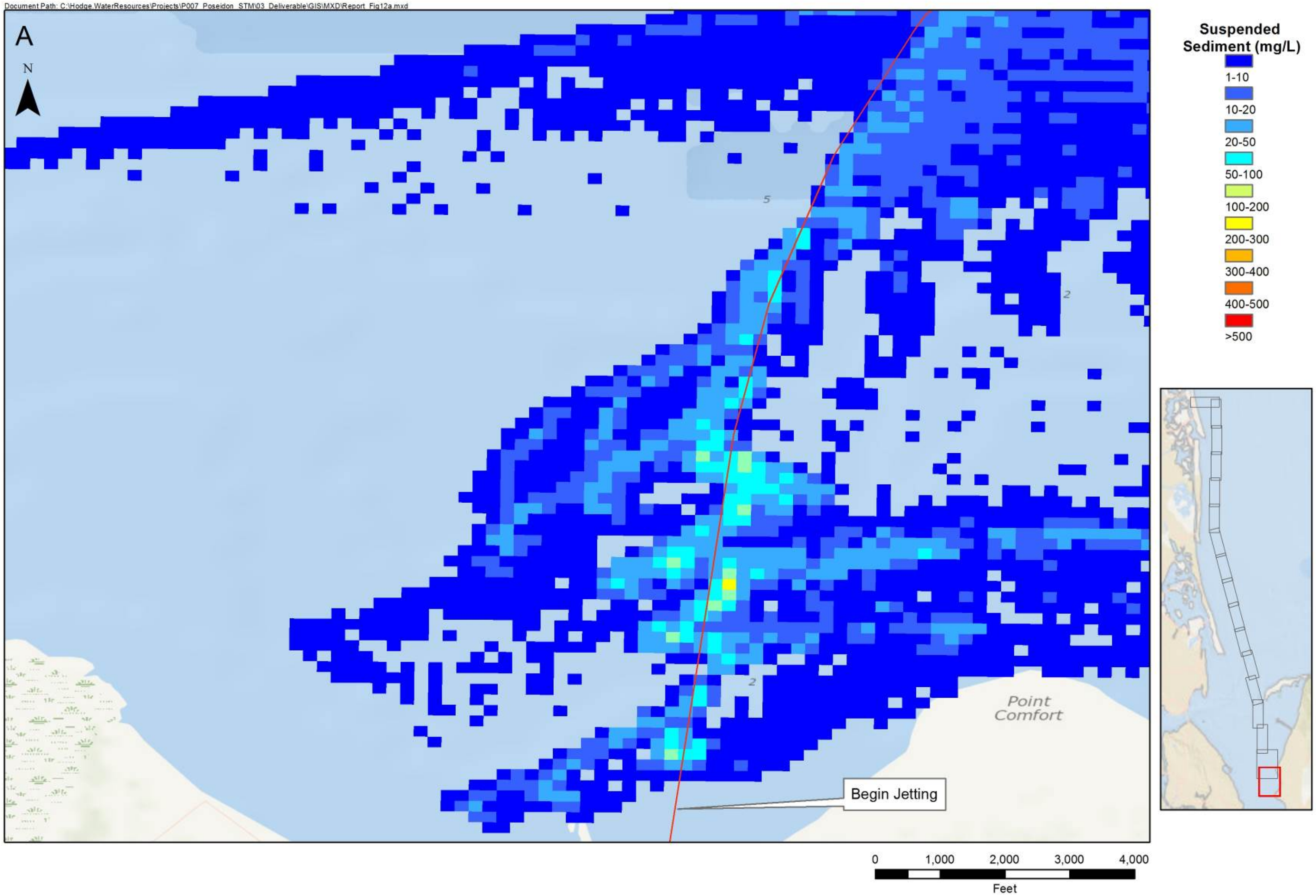
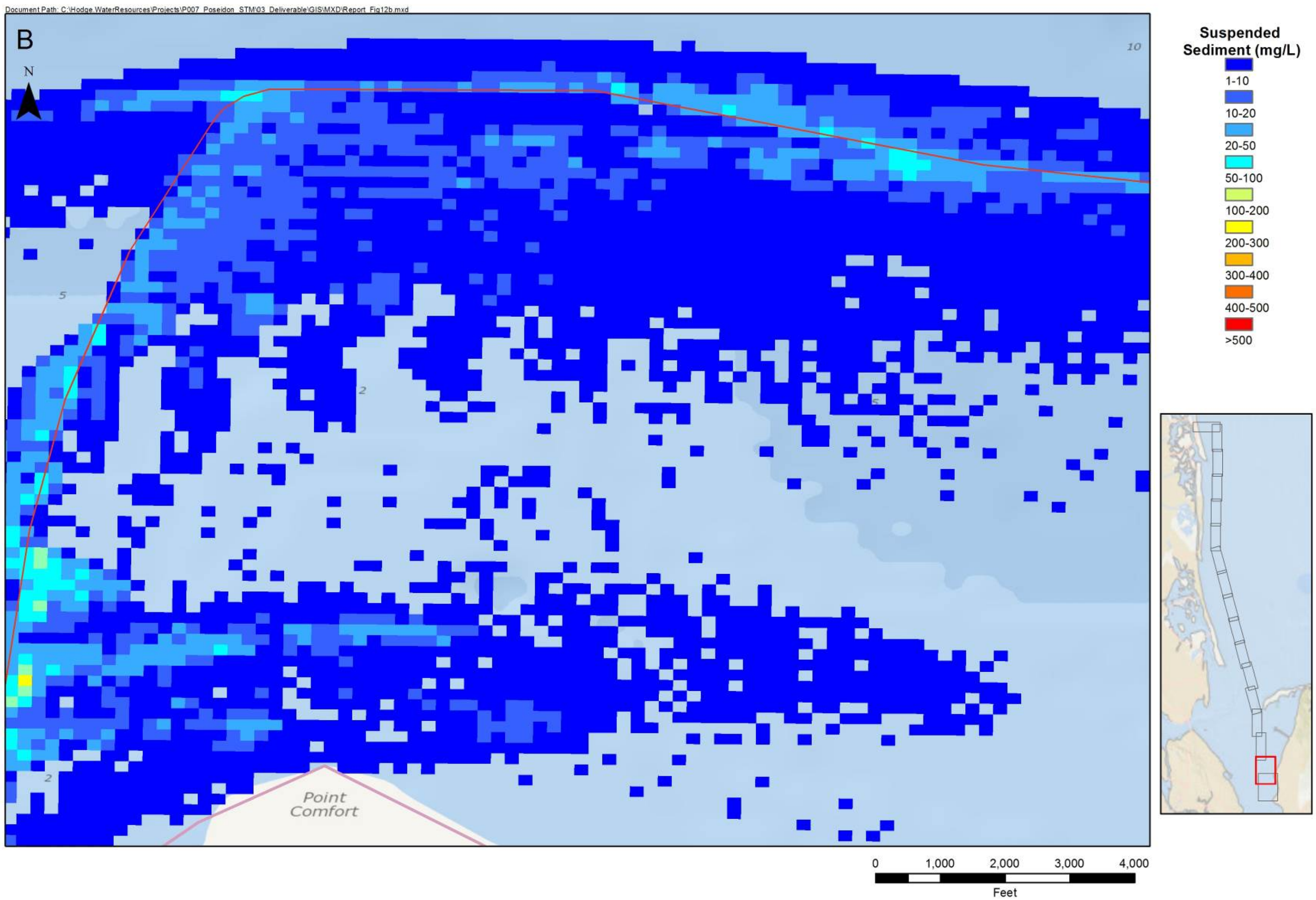


Figure 12.1 Model Maximum Suspended Sediment Concentrations



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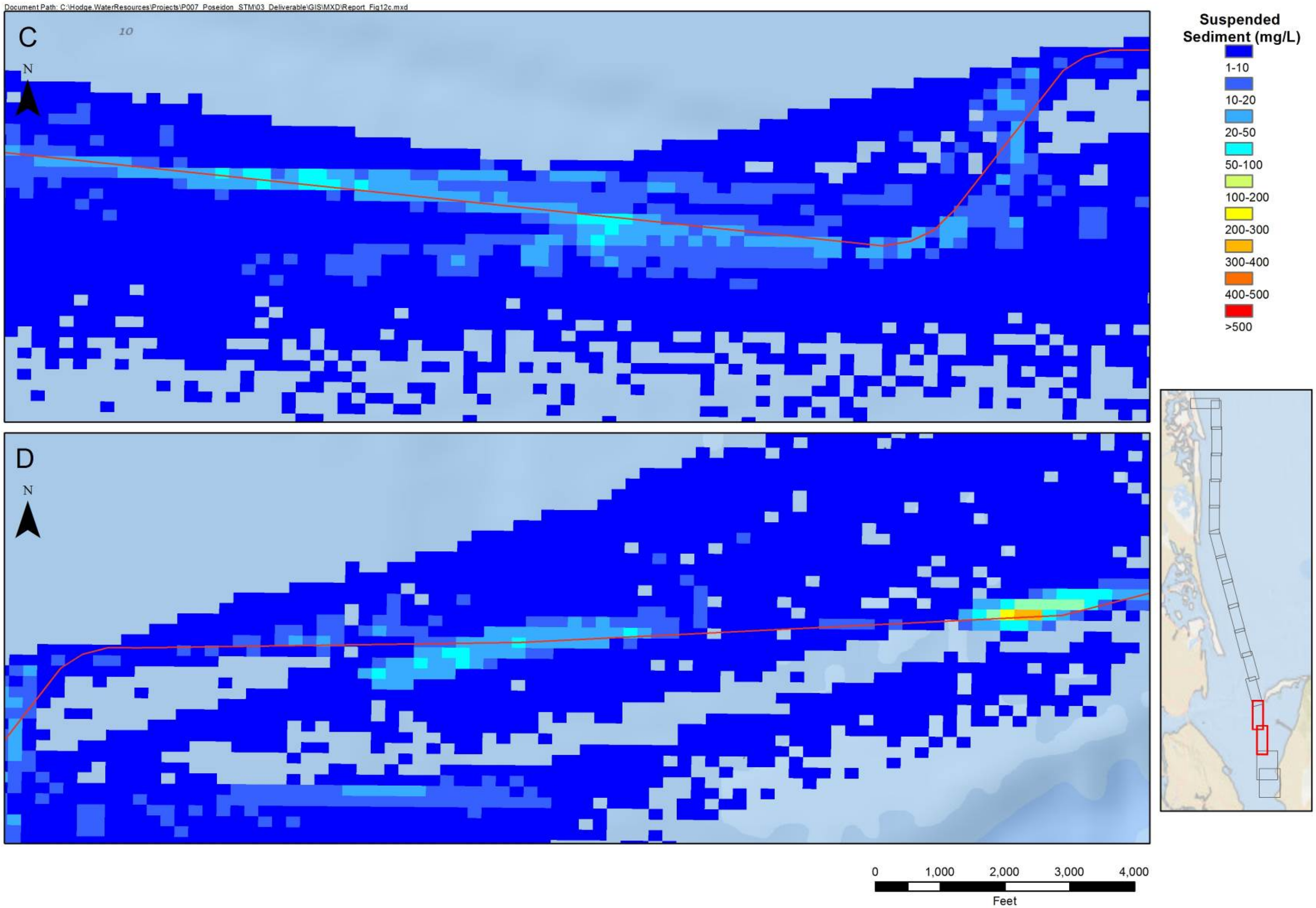

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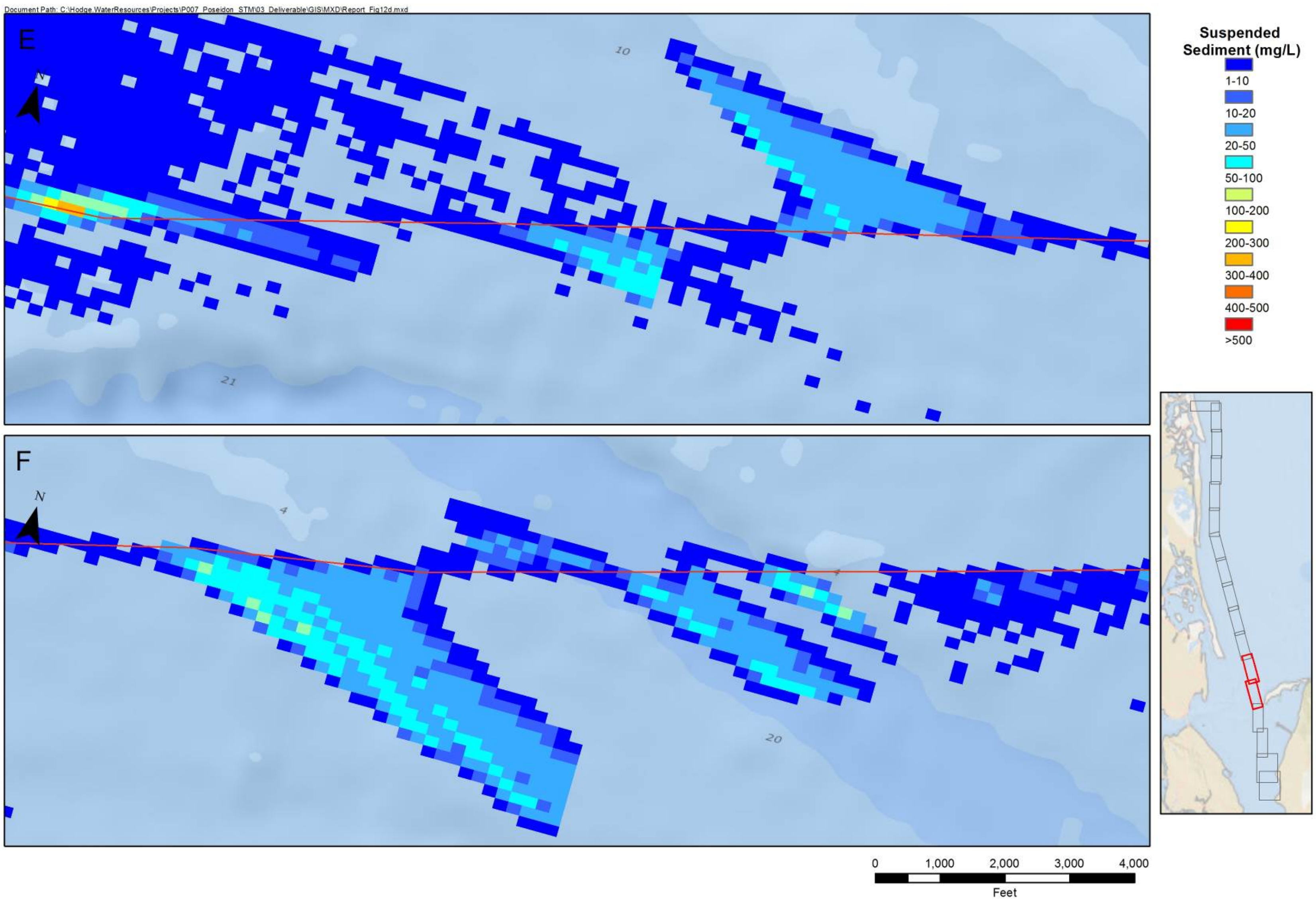

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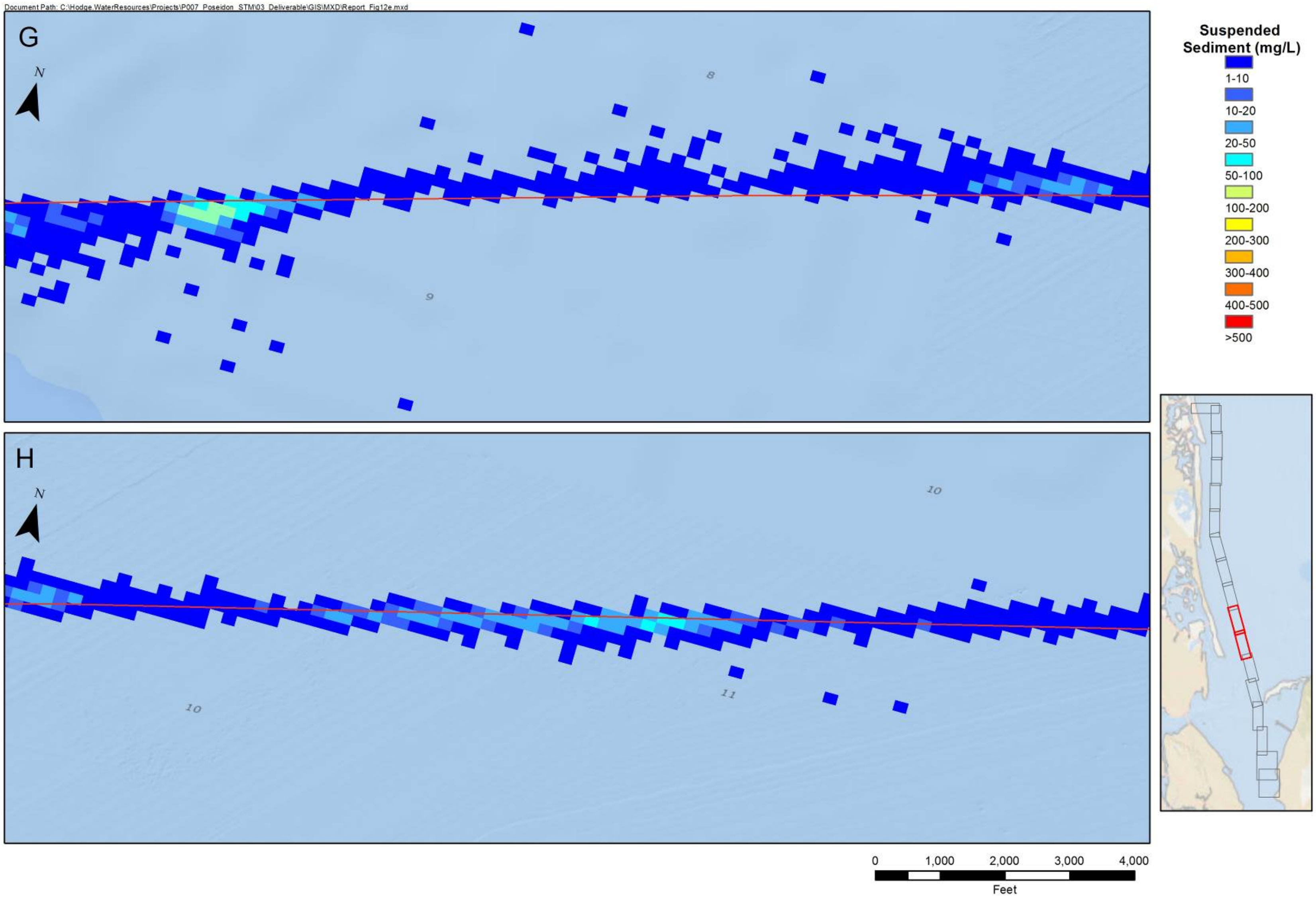

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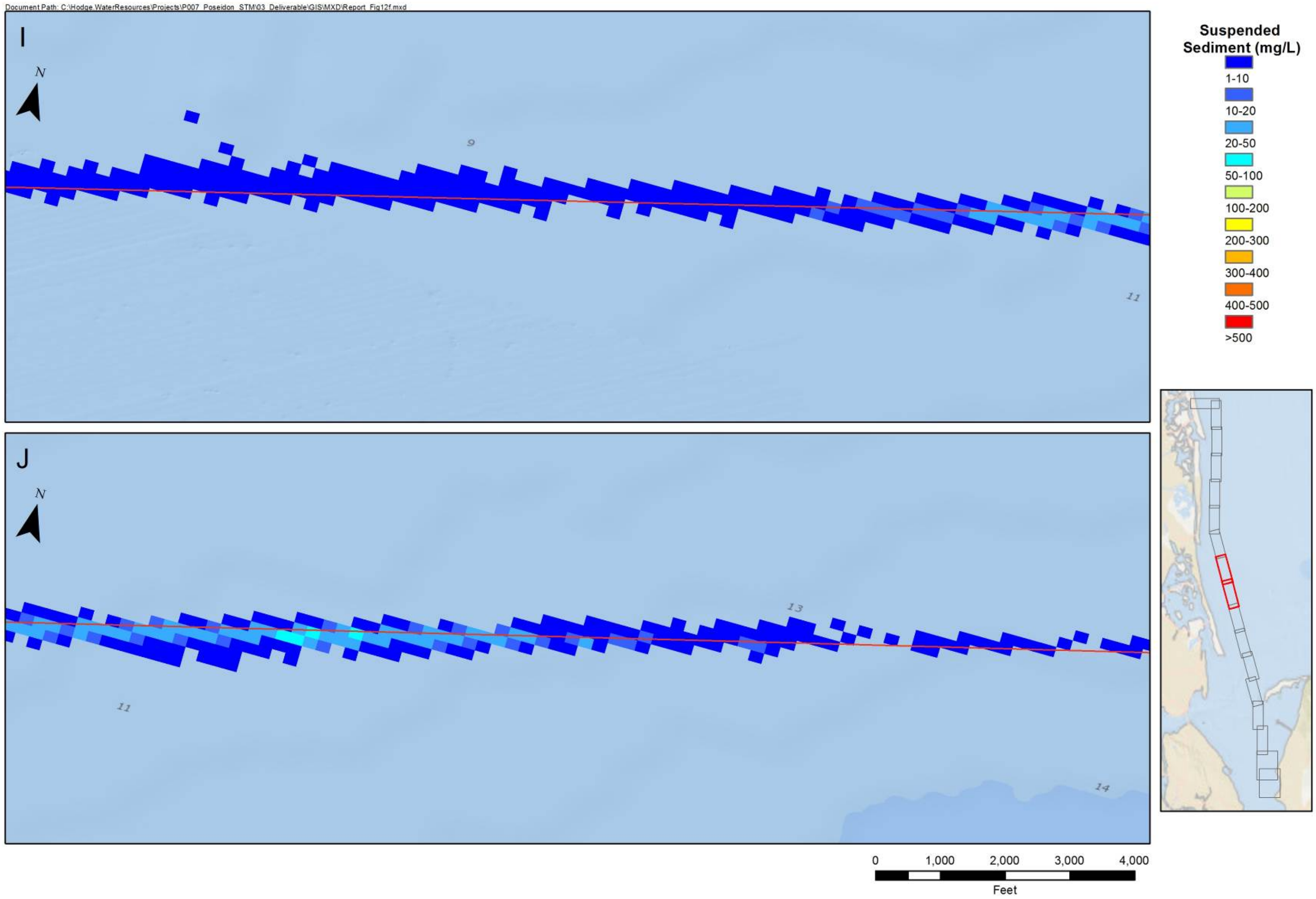

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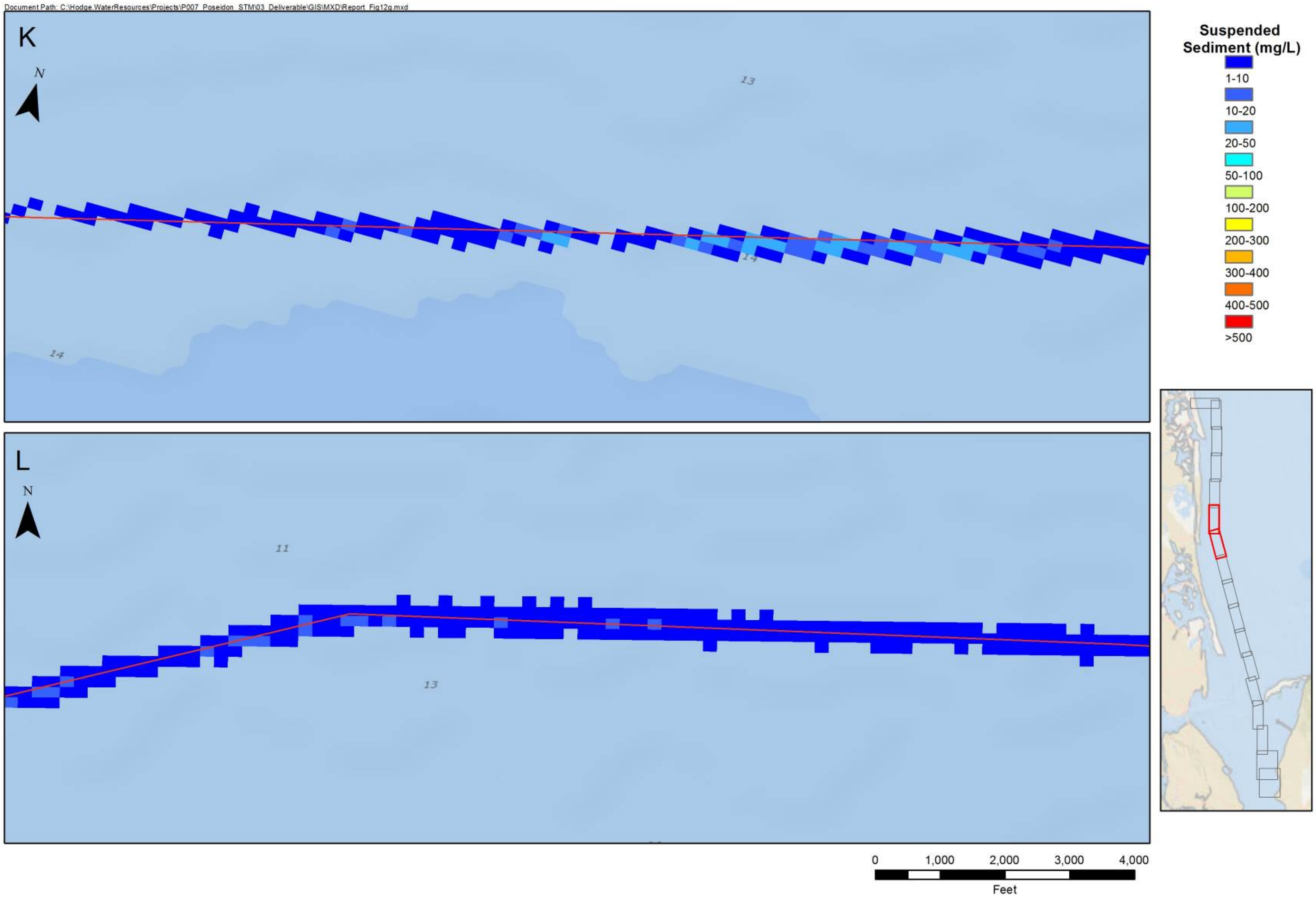

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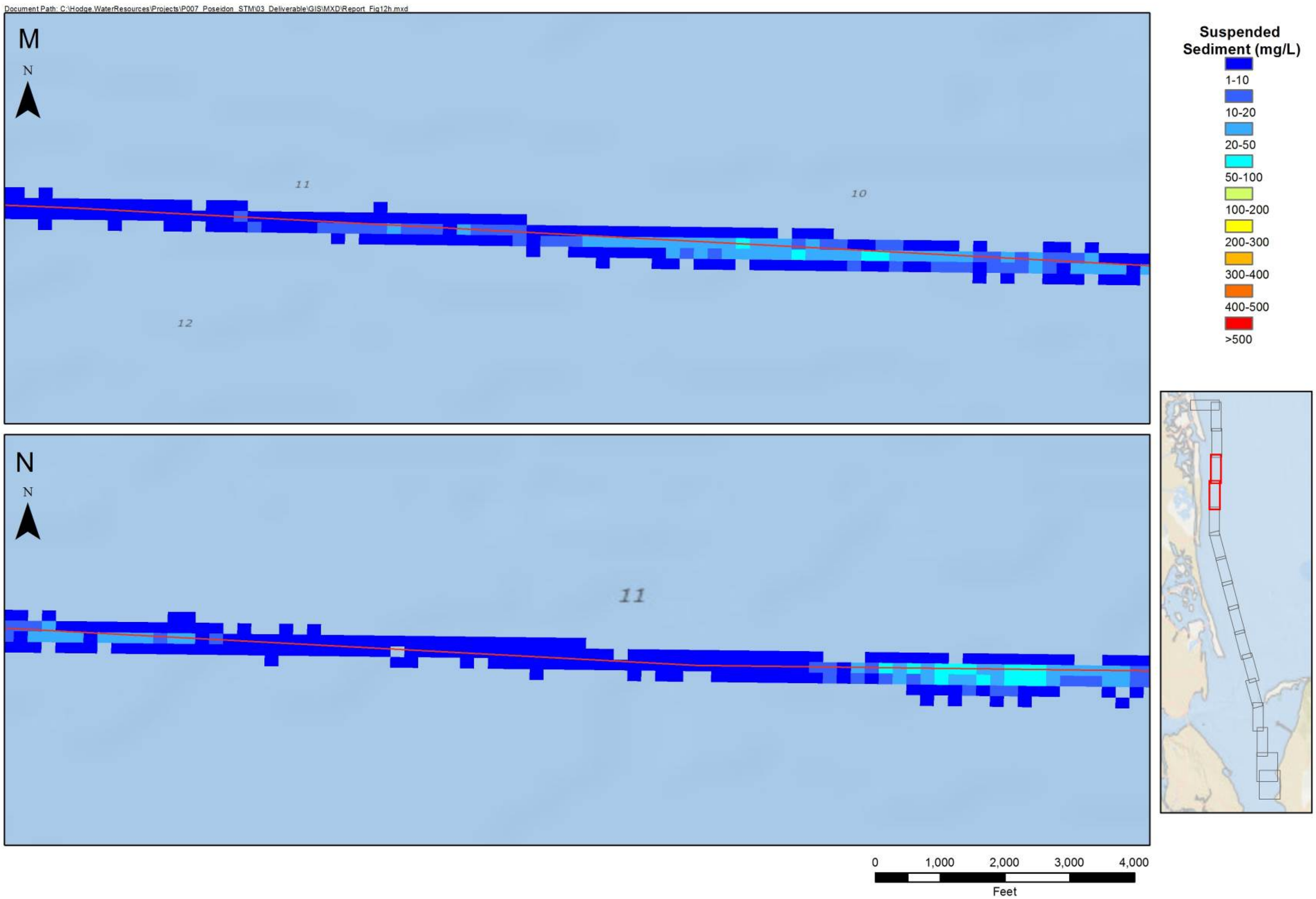
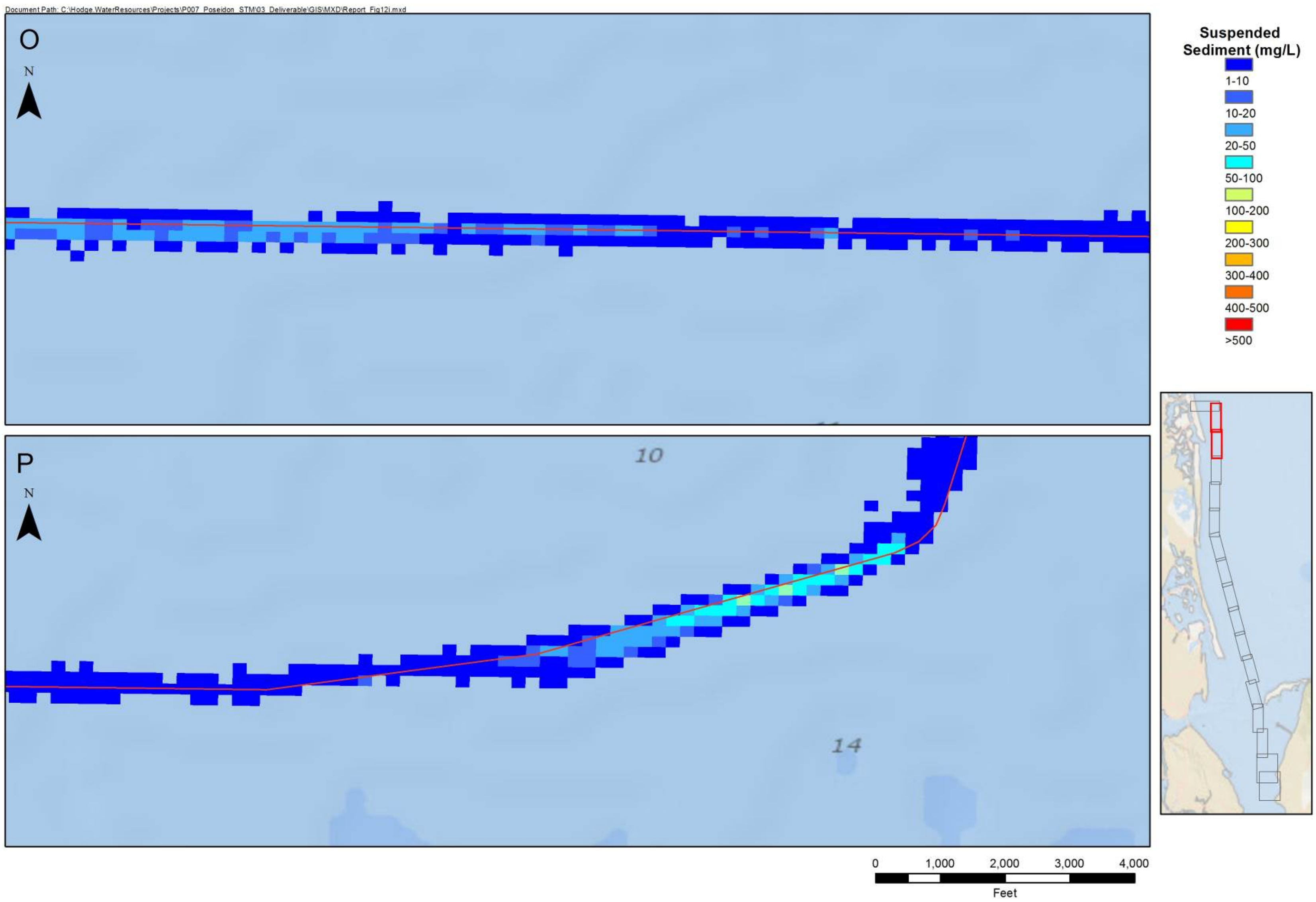


Figure 12.8 Model Maximum Suspended Sediment Concentrations



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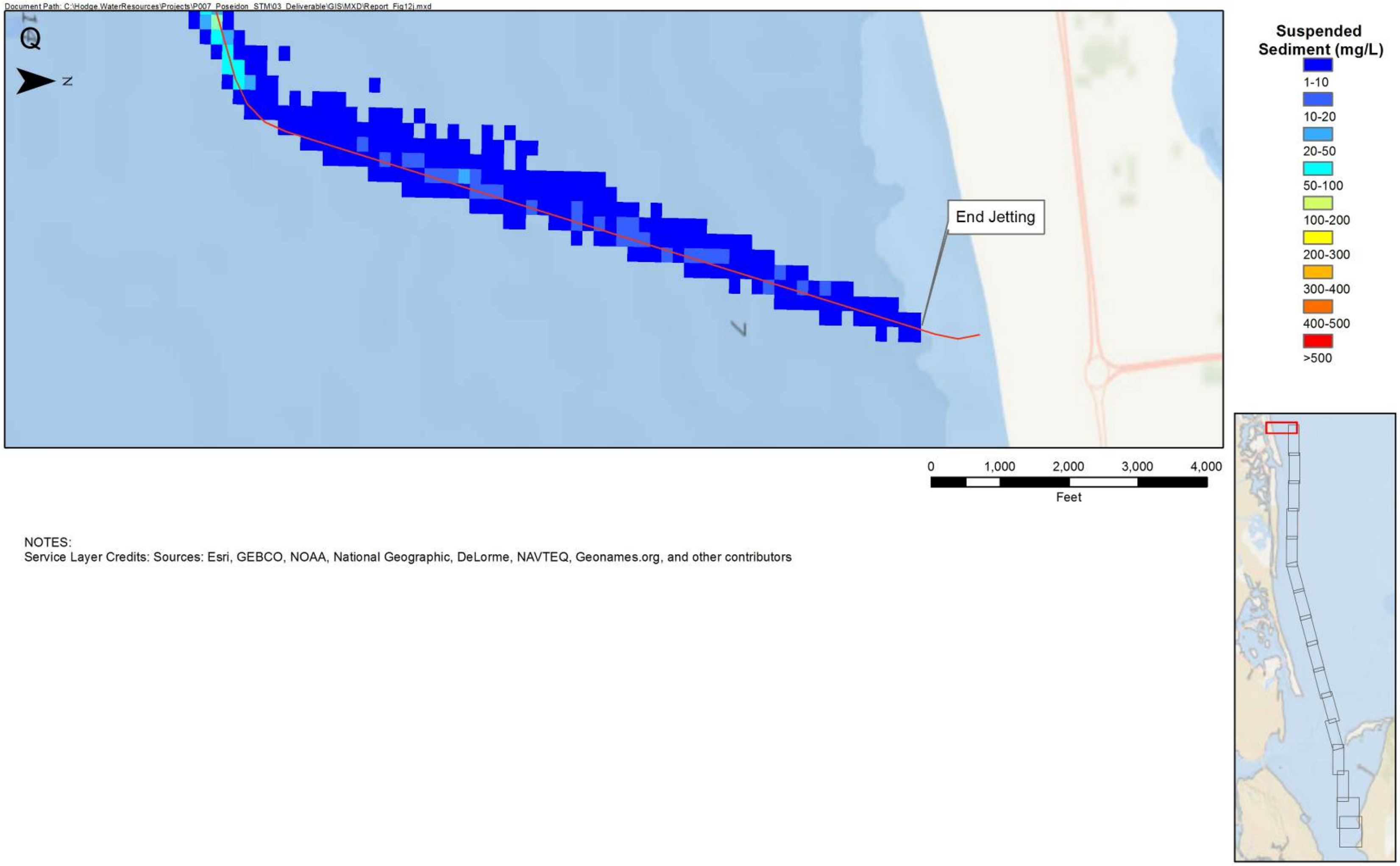

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Figure 12.10 Model Maximum Suspended Sediment Concentrations

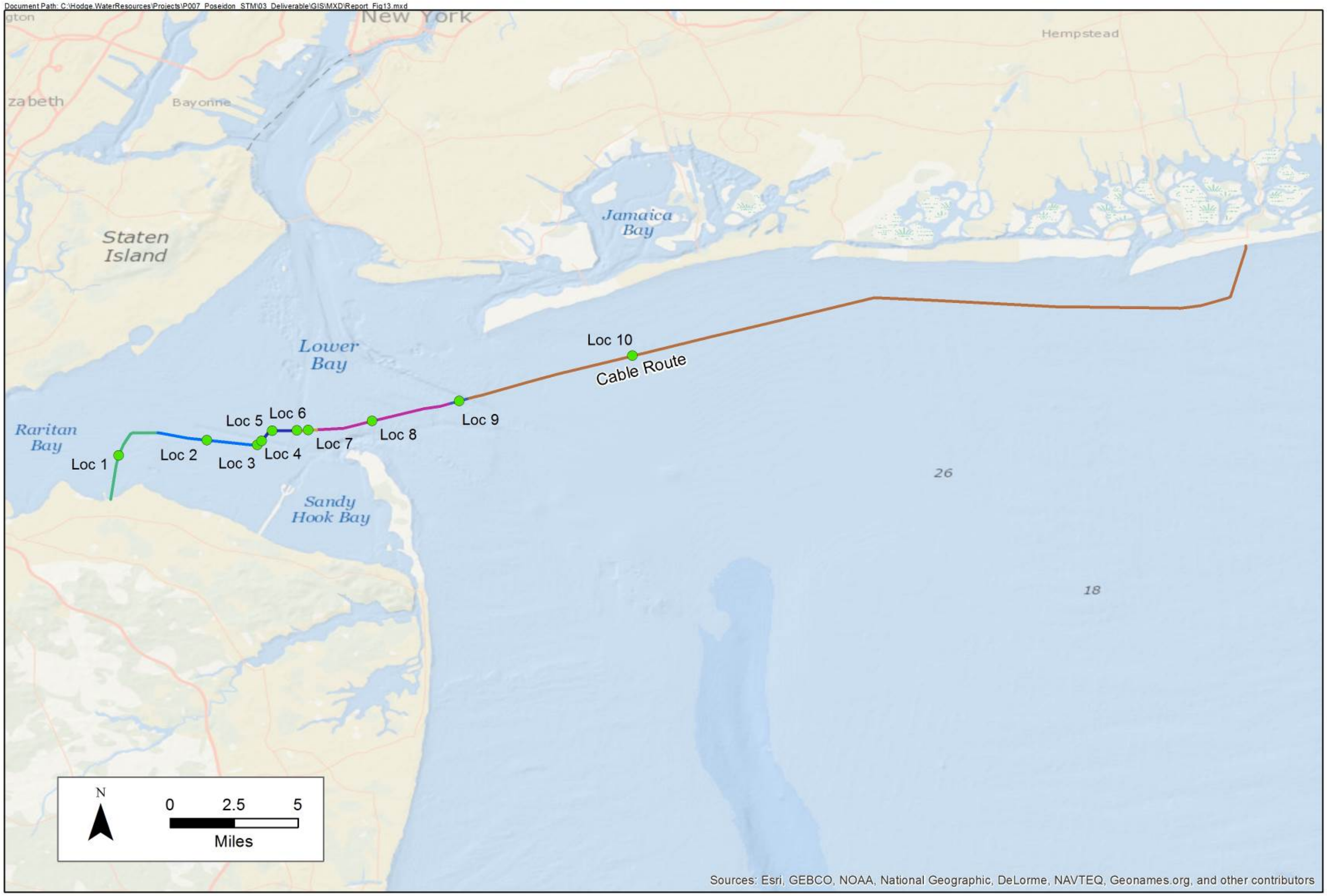
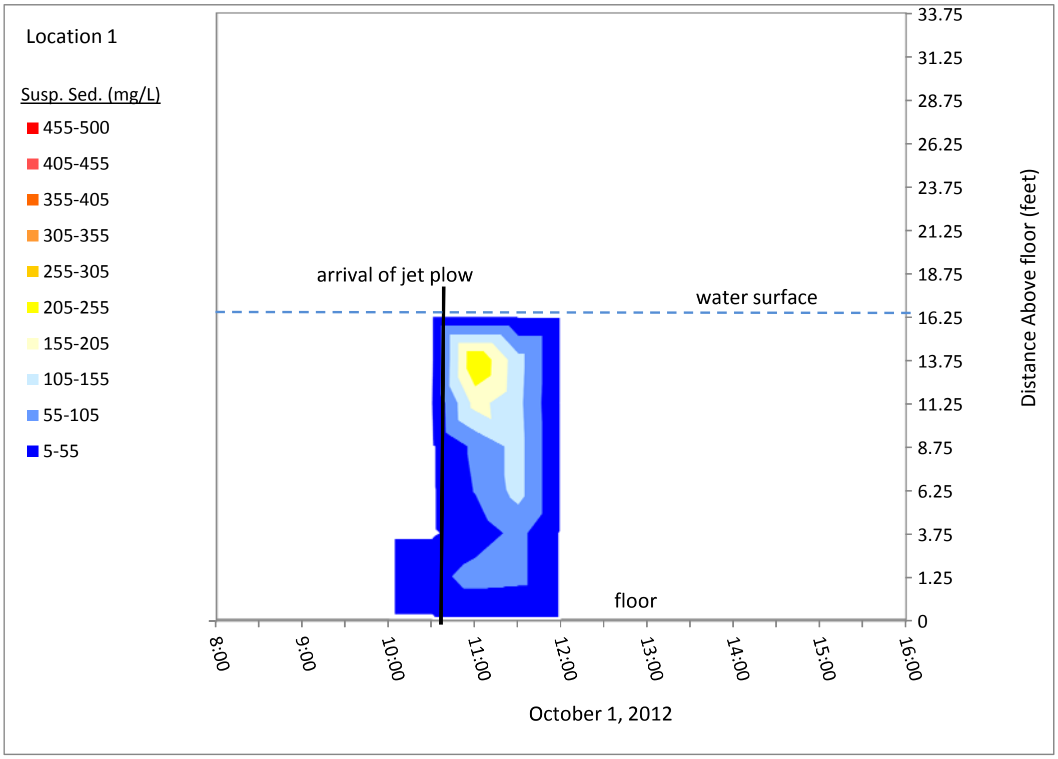


Figure 13 Model Water Column Observation Locations



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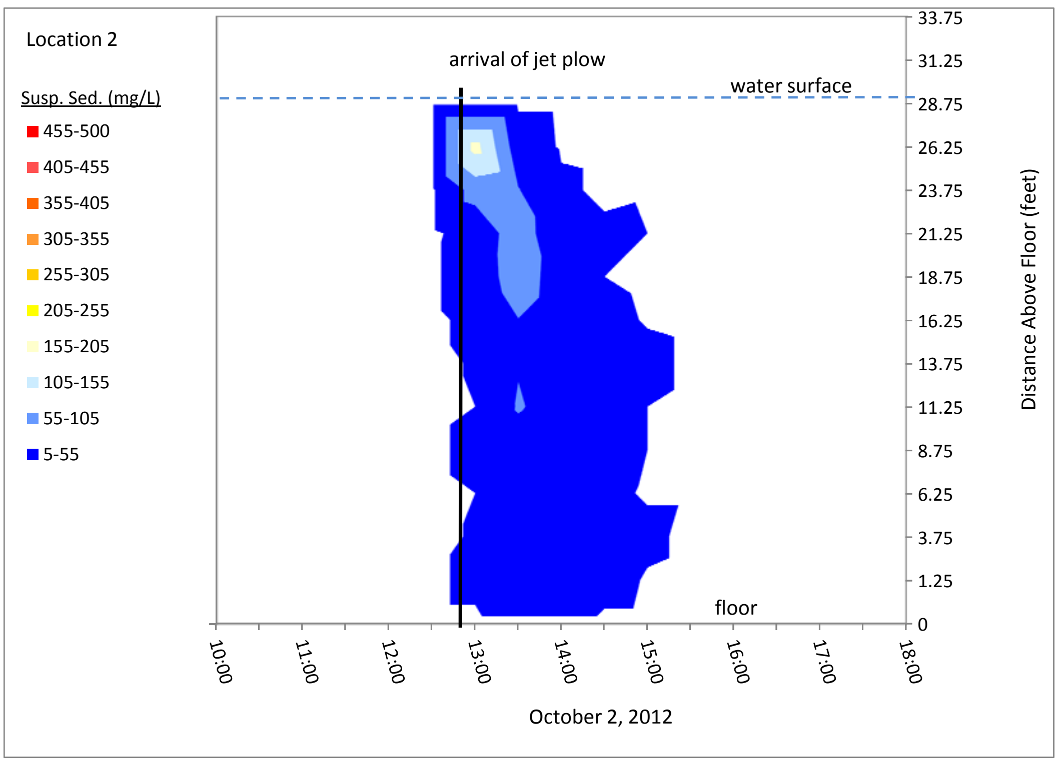

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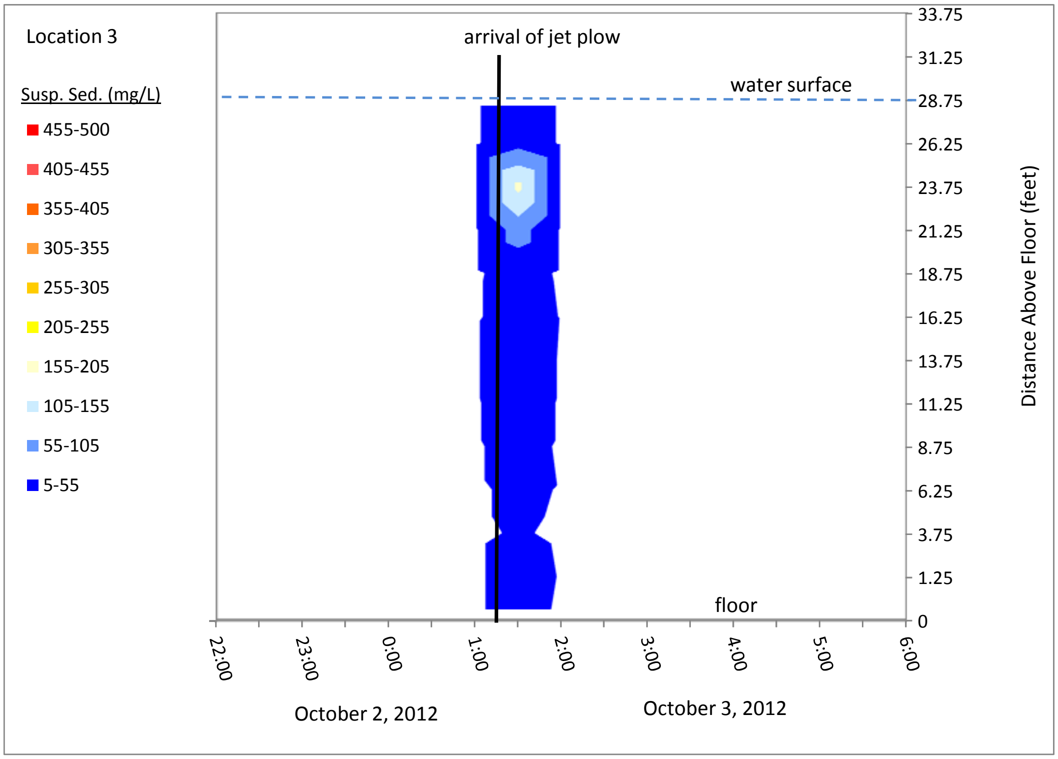

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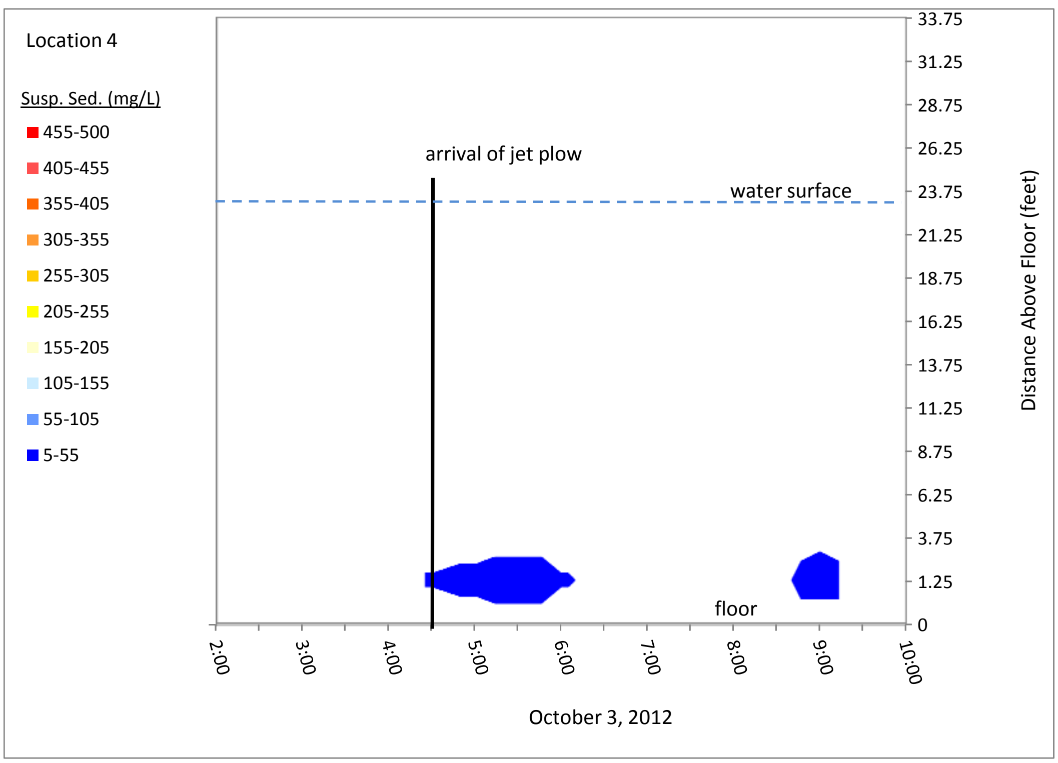

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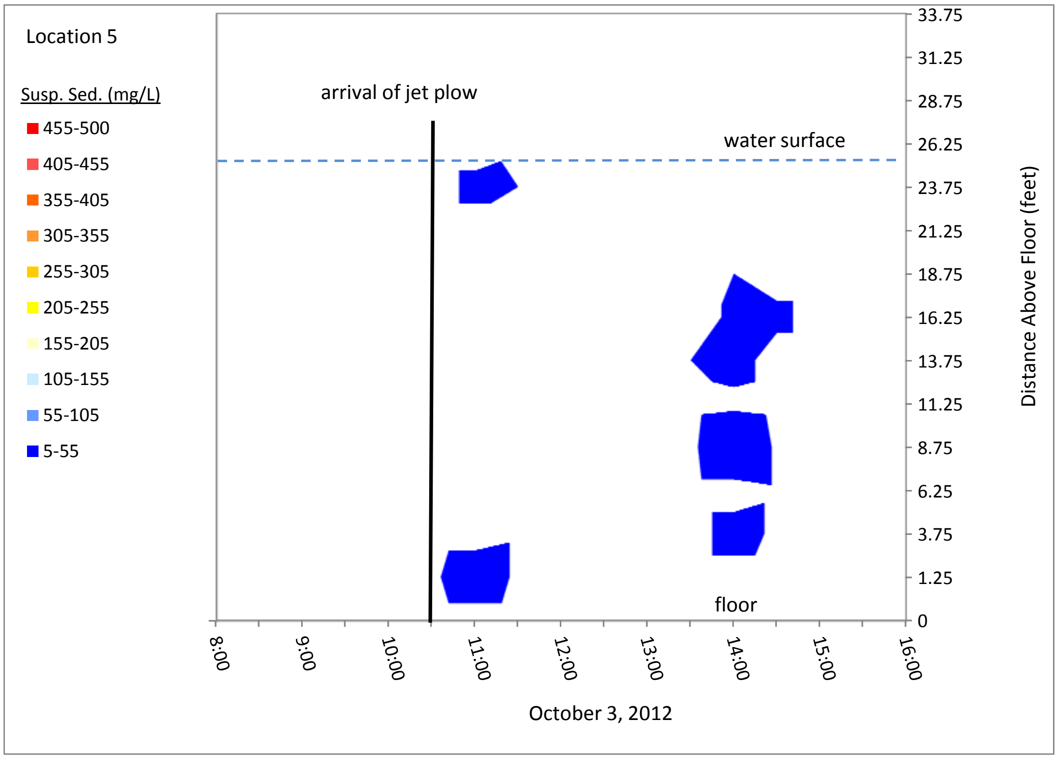

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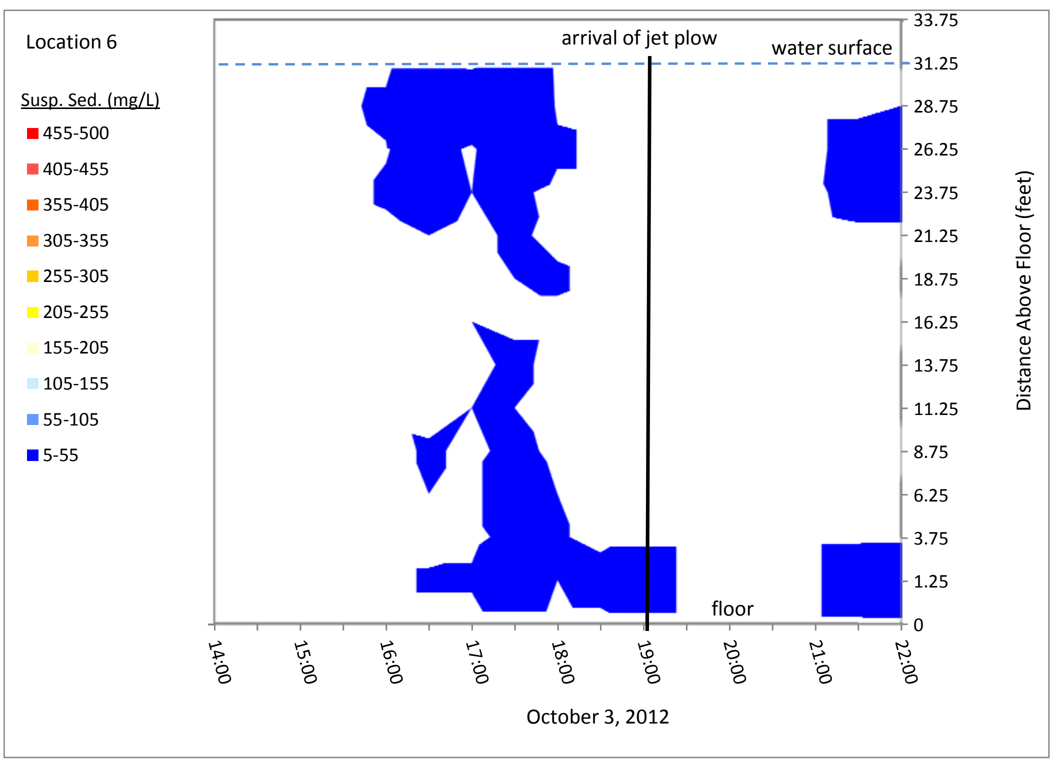

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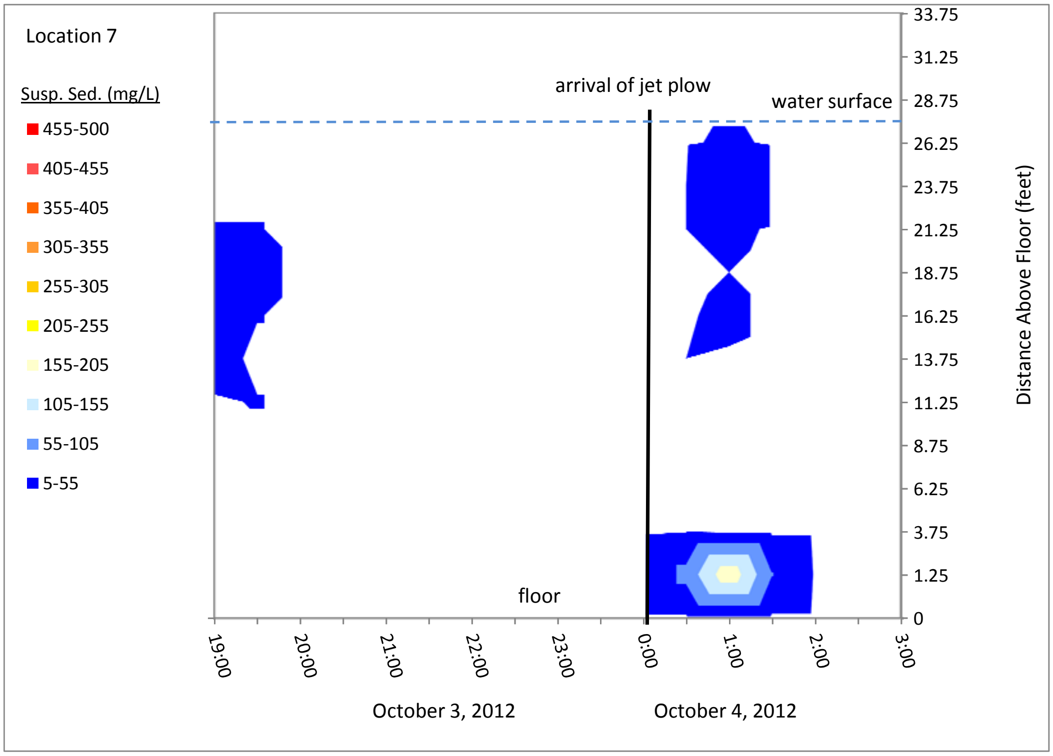

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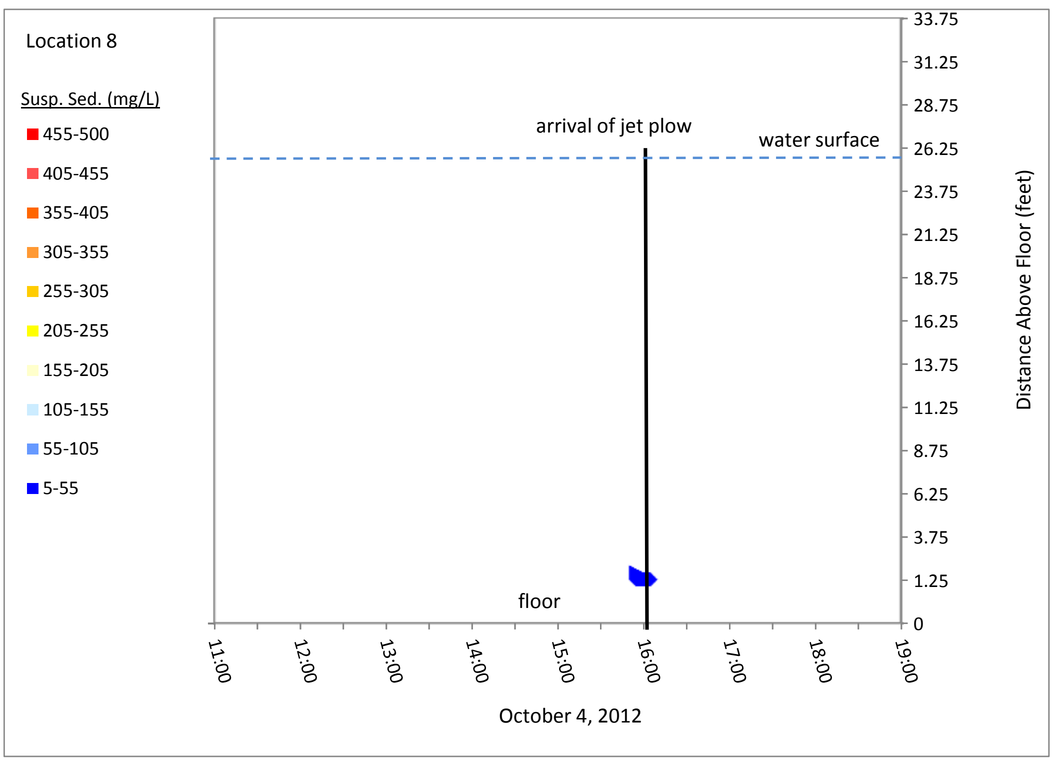

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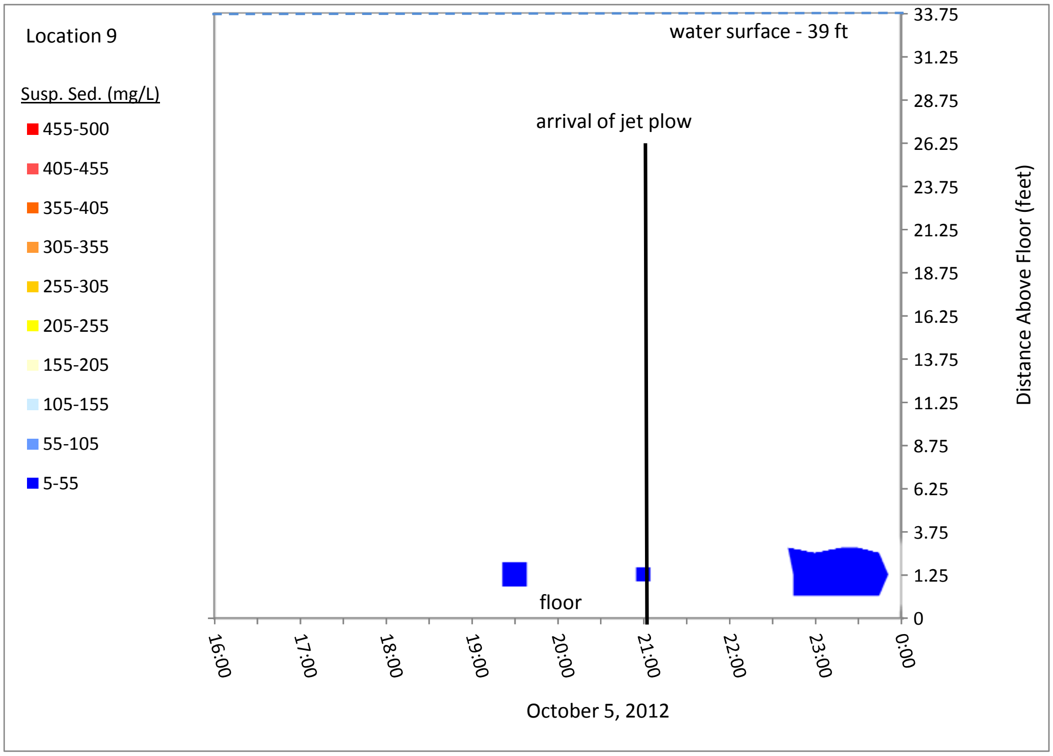

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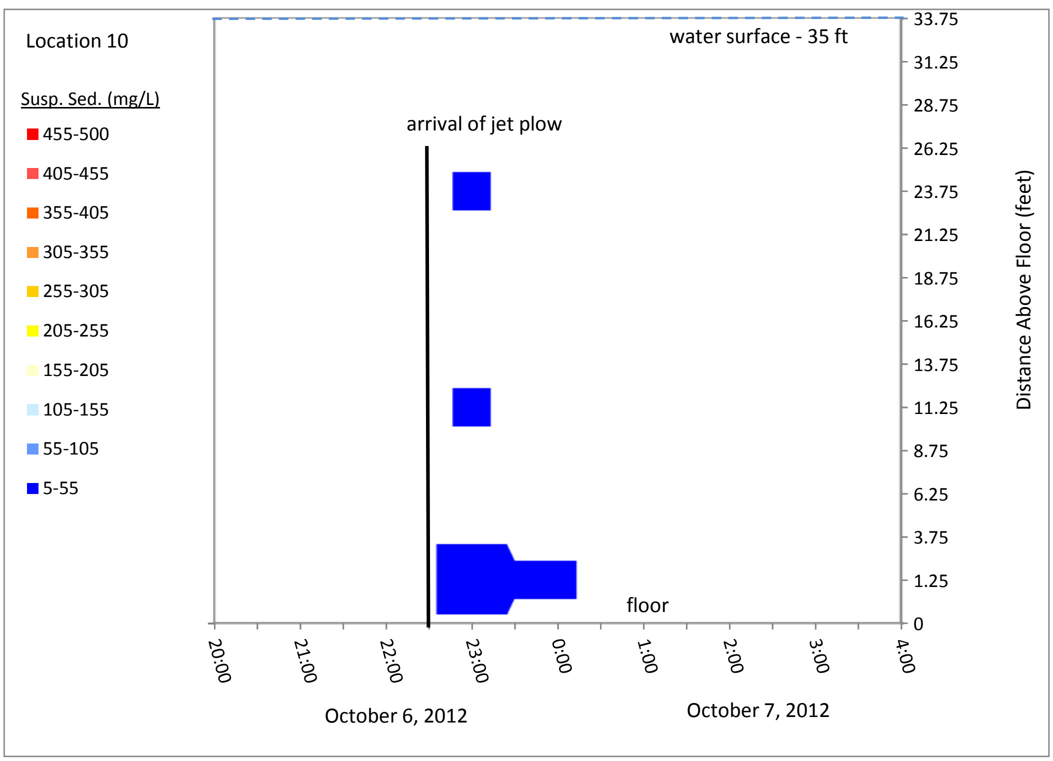

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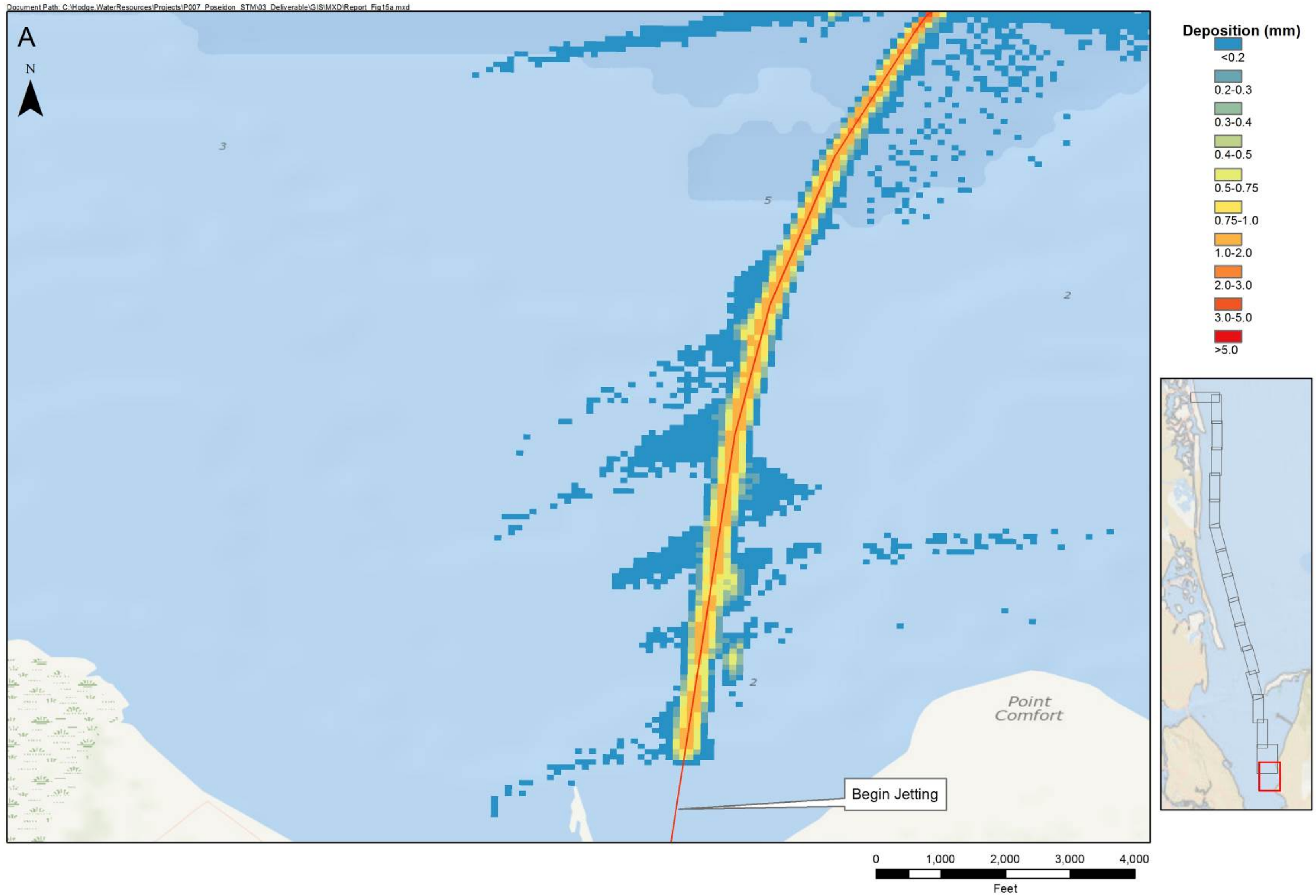

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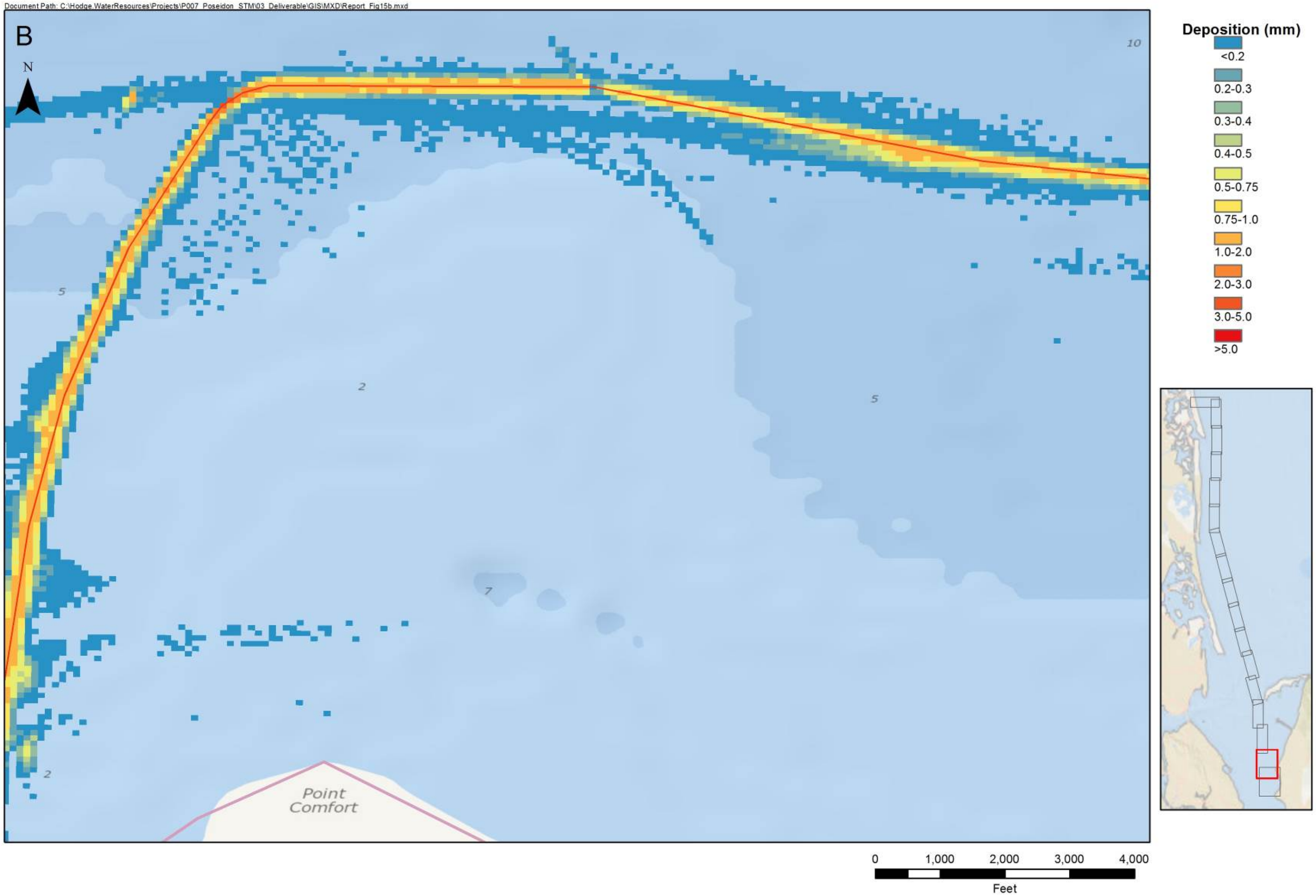

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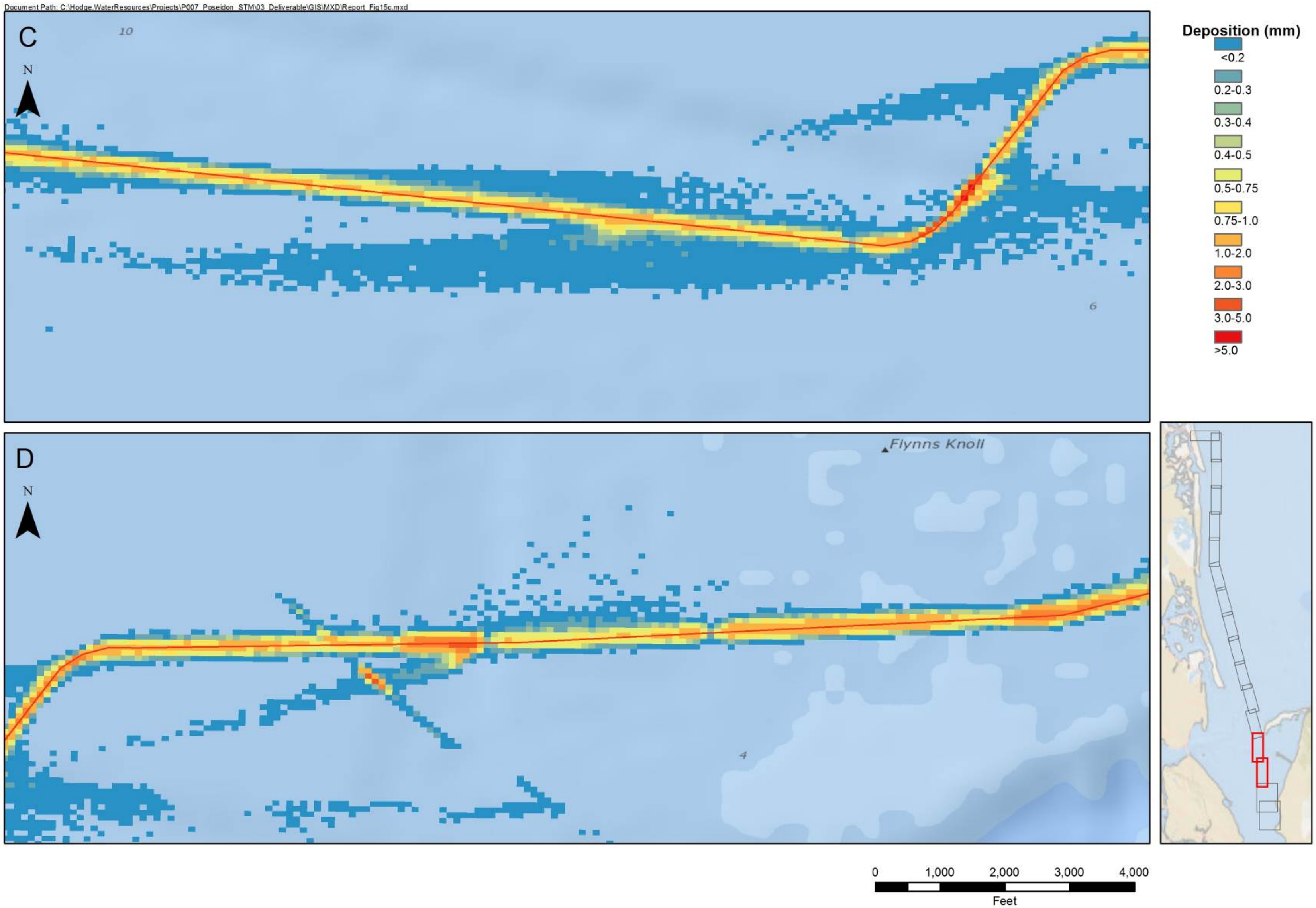

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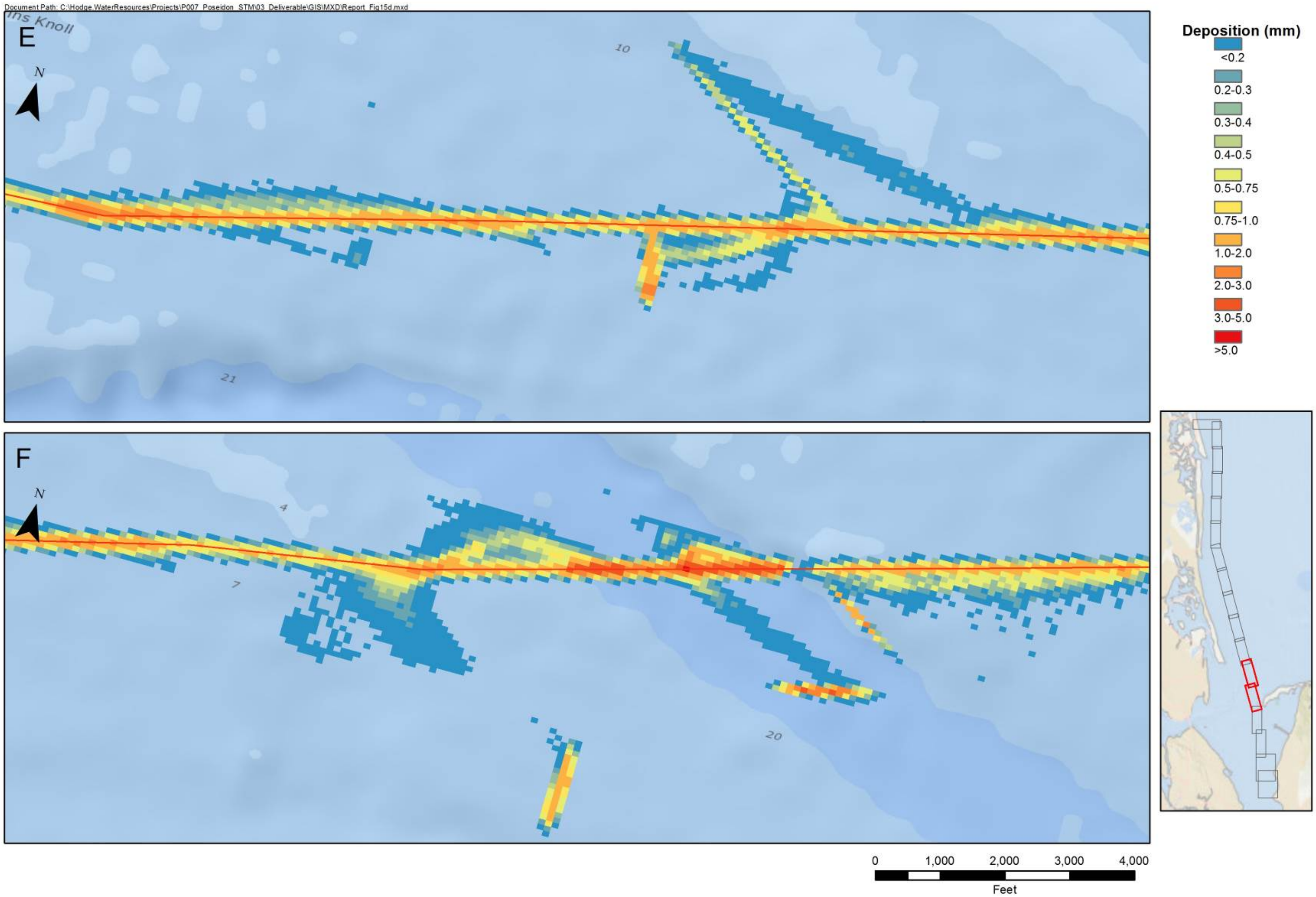

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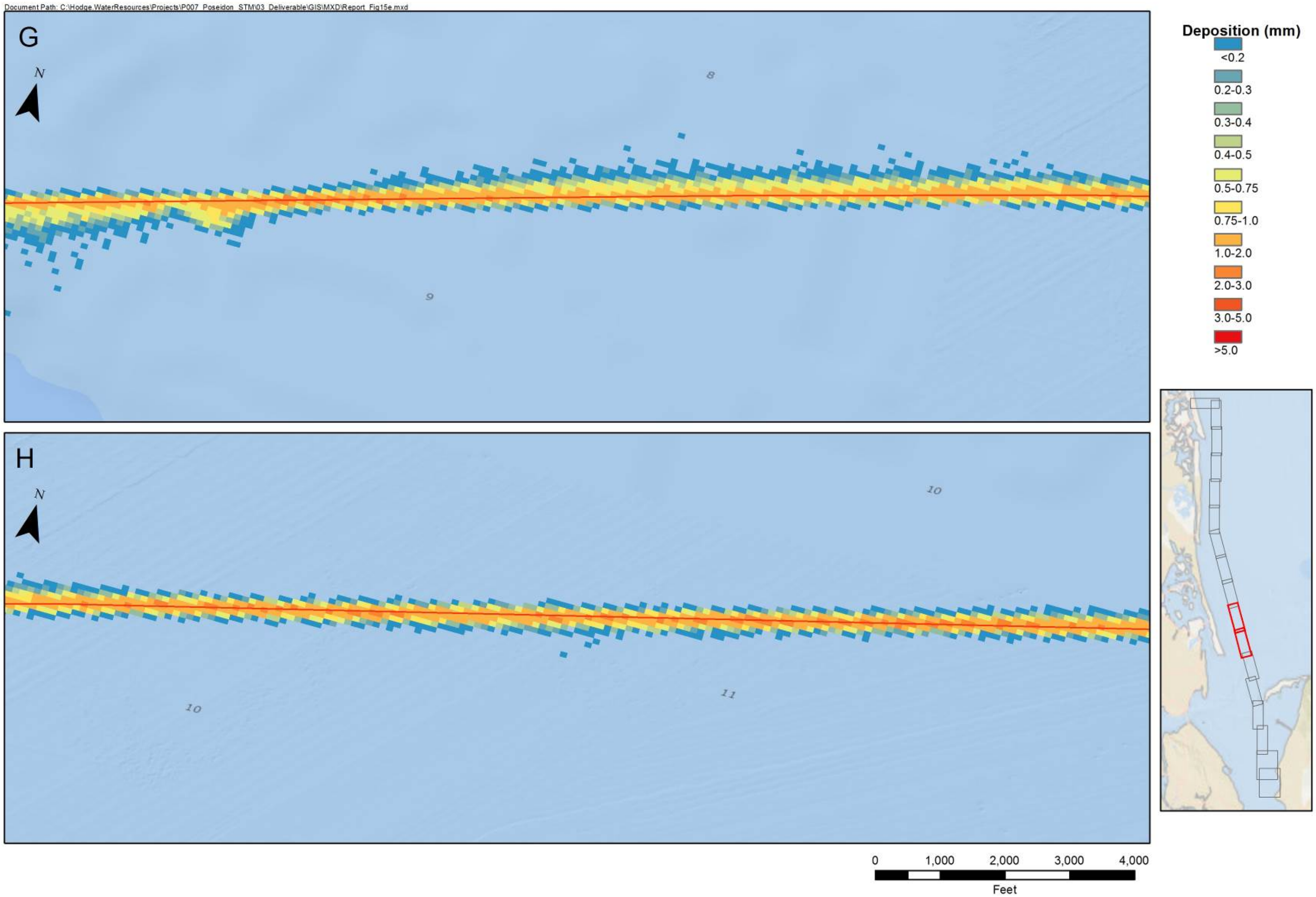

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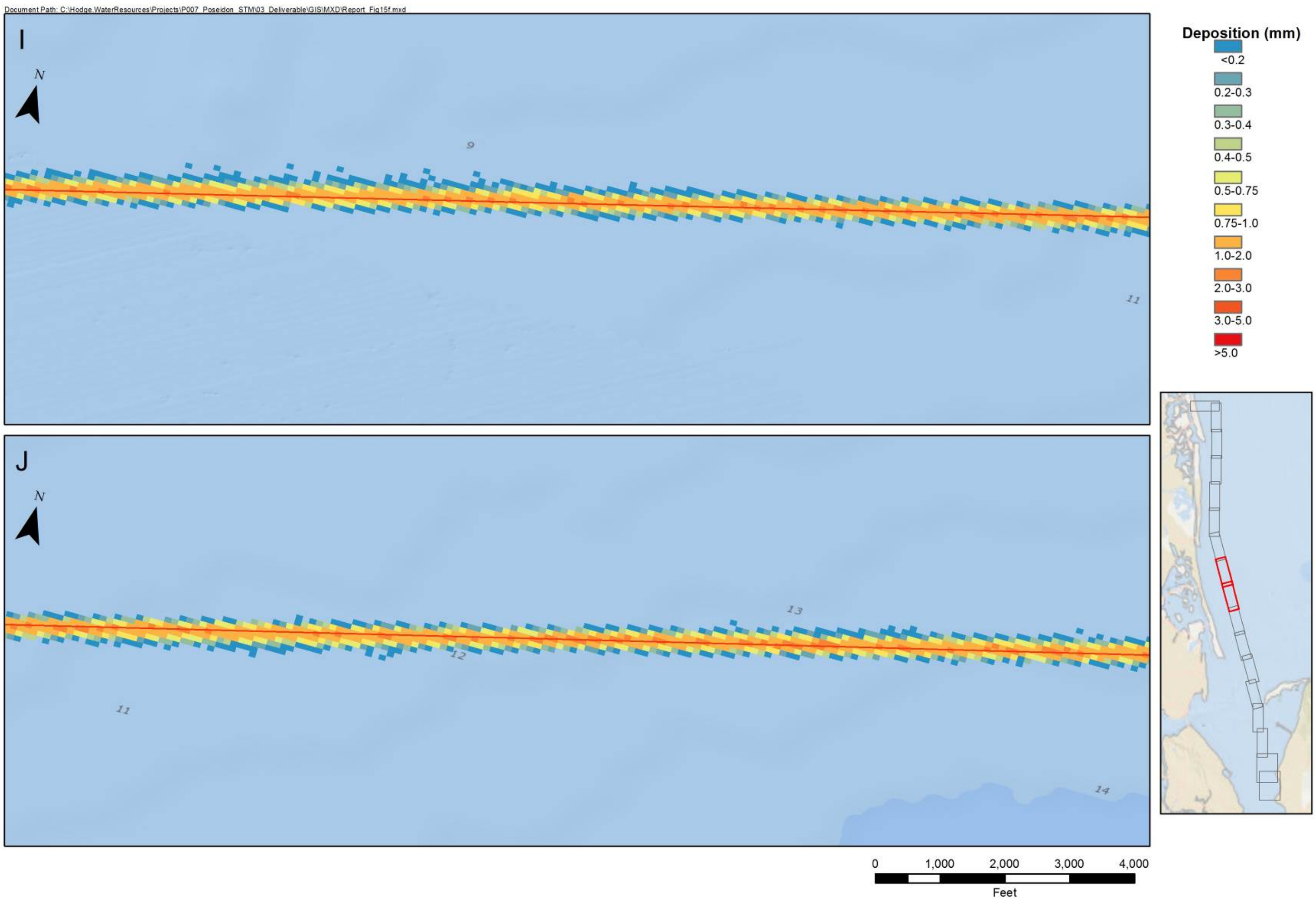

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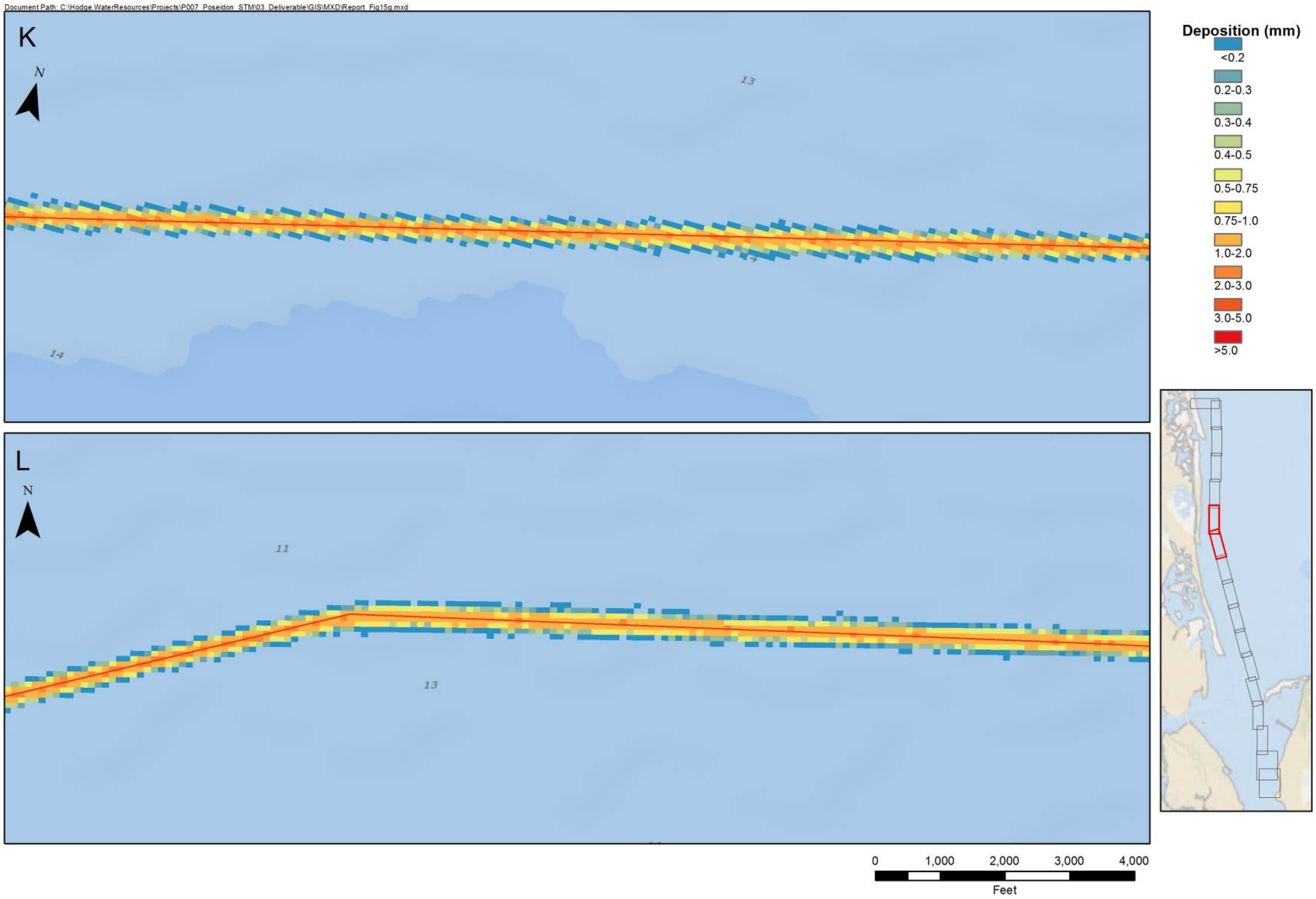

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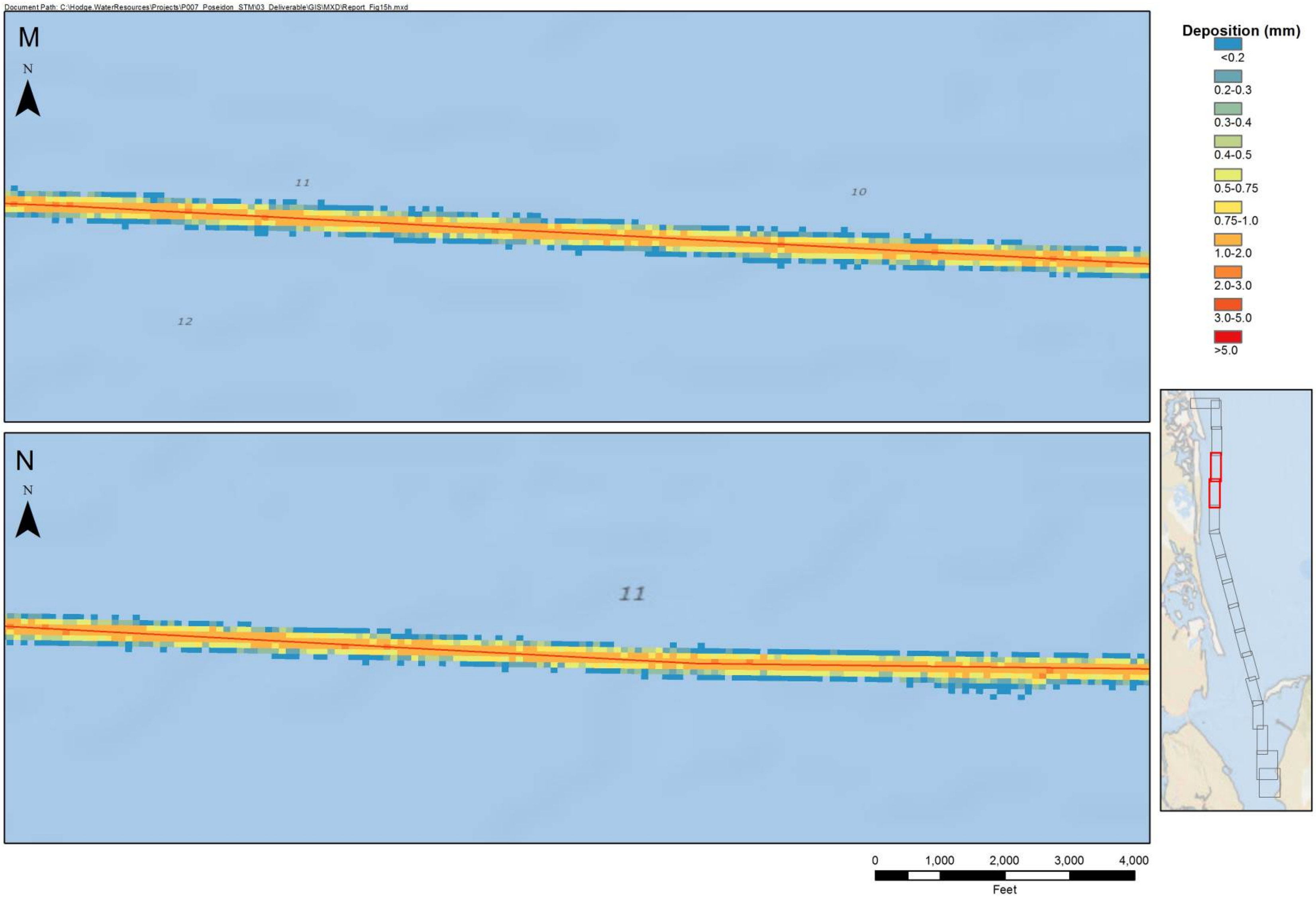

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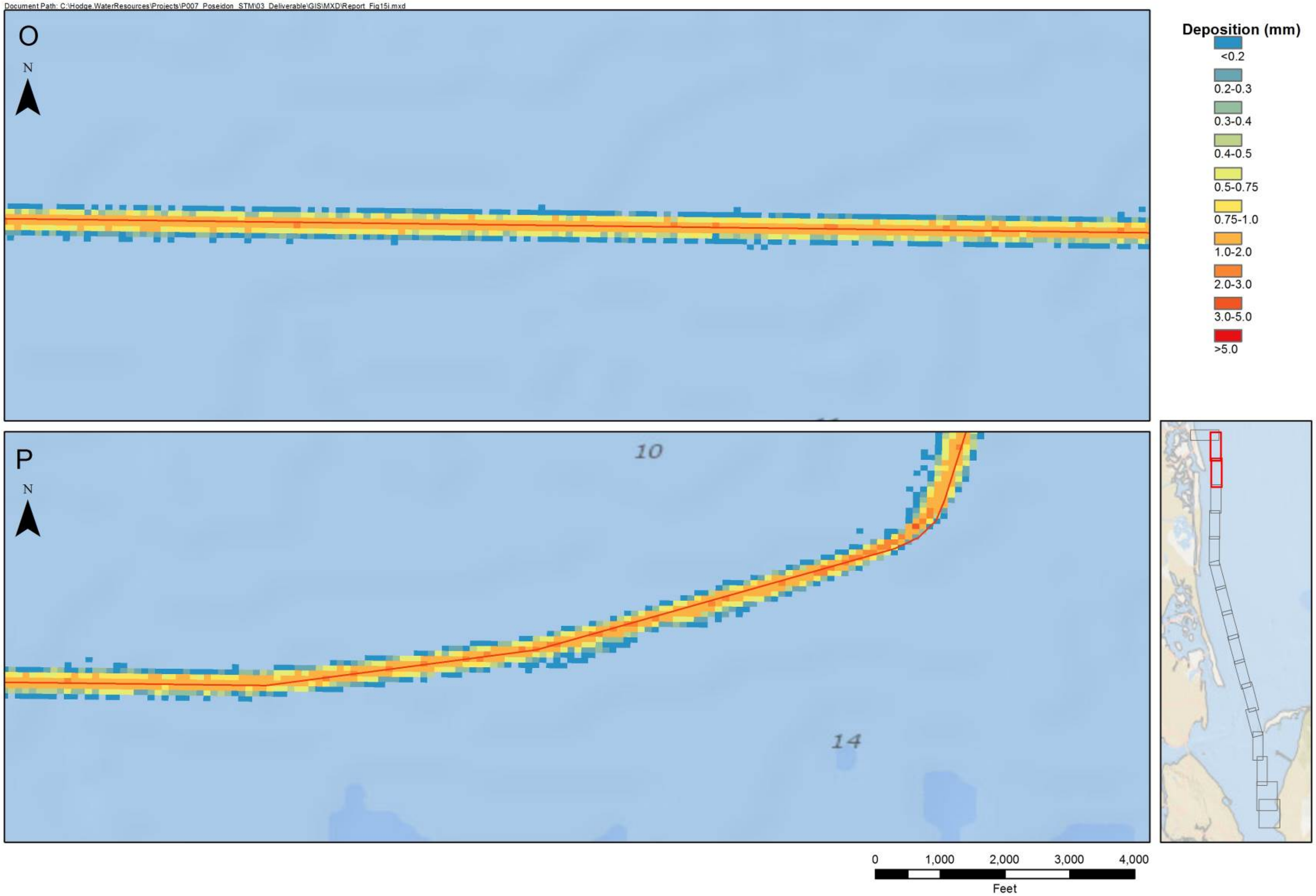

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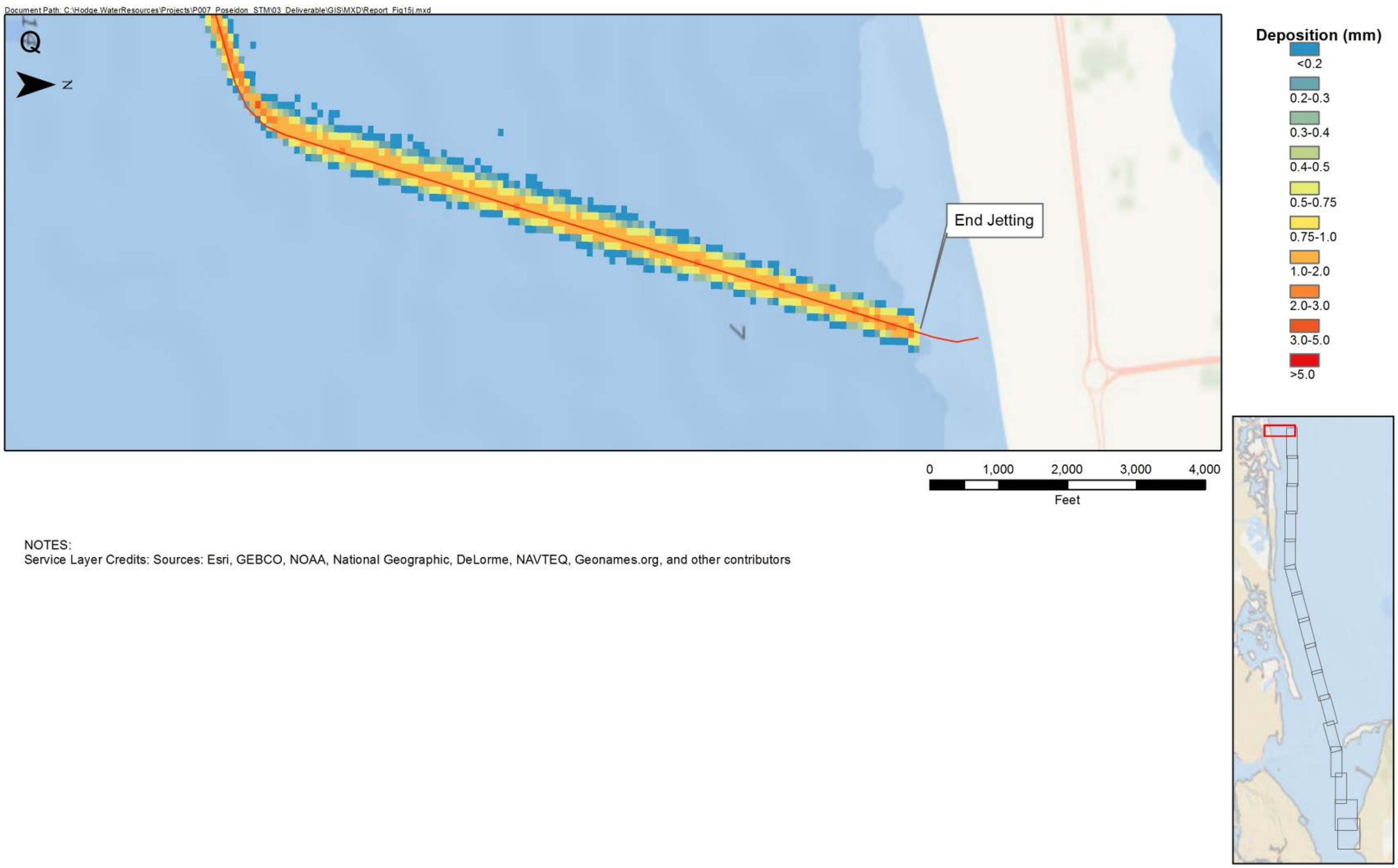

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Figure 15.10 ModelTotal Sediment Deposition Thickness

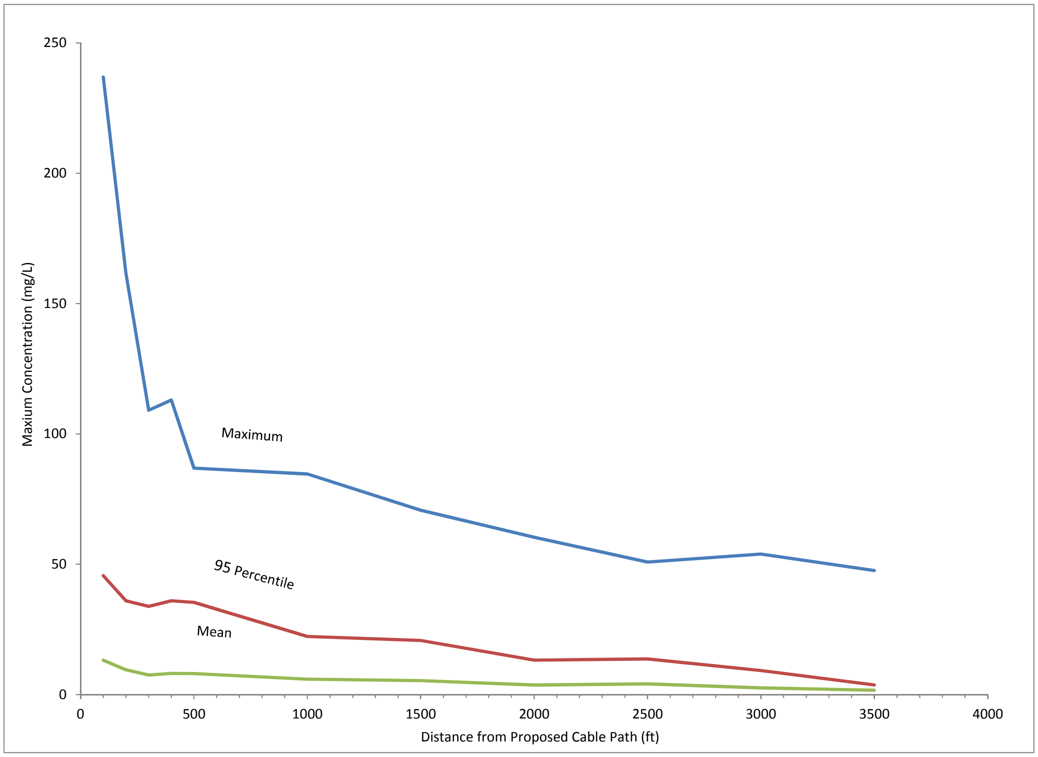


Figure 16 Suspended Sediment Concentration Excursions from Cable Route

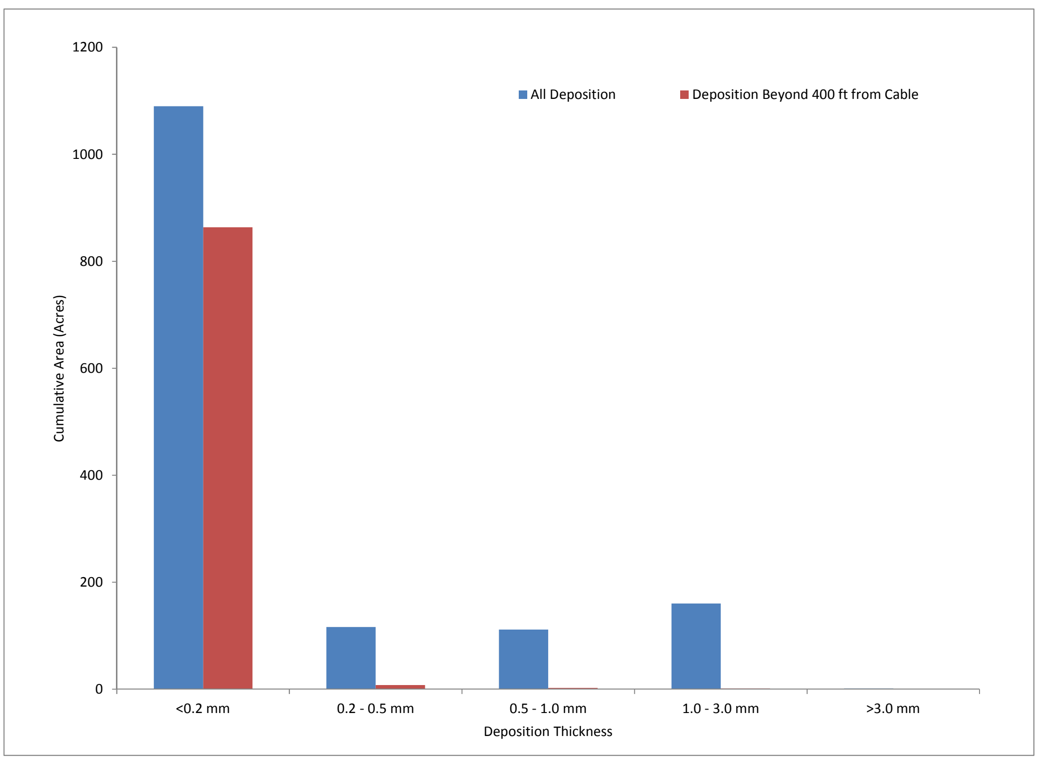
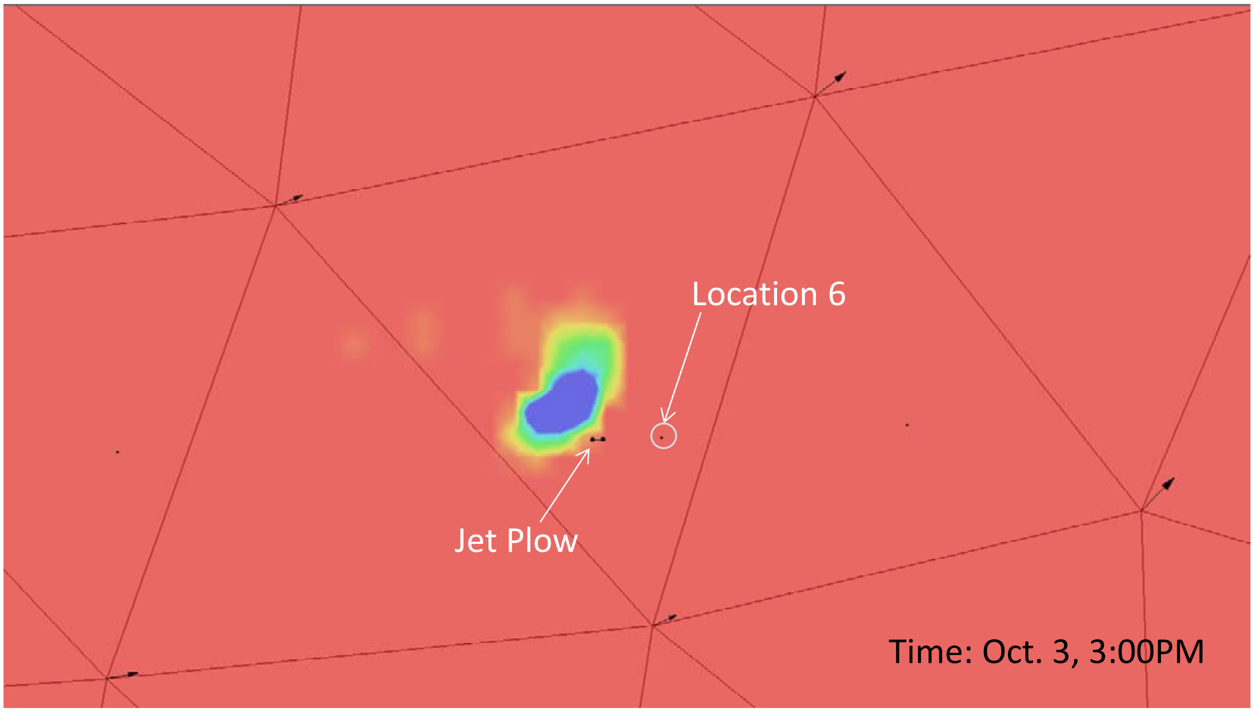


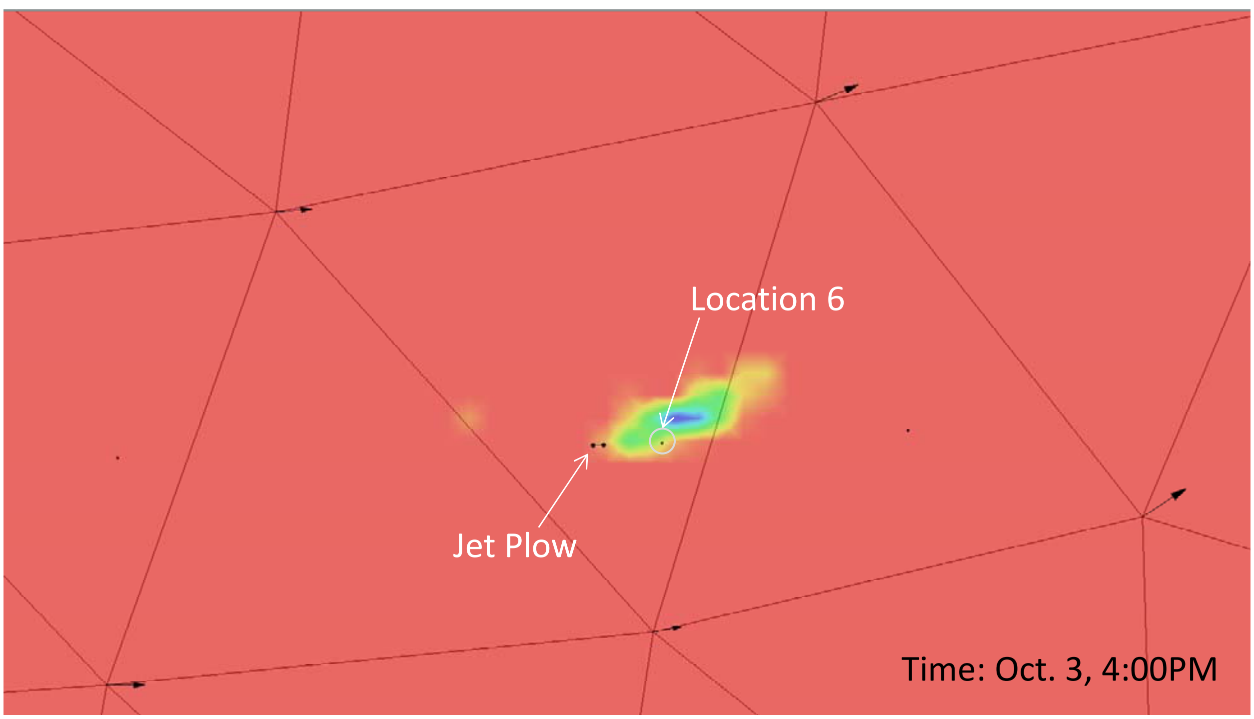
Figure 17 Sediment Deposition Thickness Histogram

Appendix A

Time Series of Suspended Sediment Plume Location 6



Location 6
Jet Plow
Time: Oct. 3, 3:00PM



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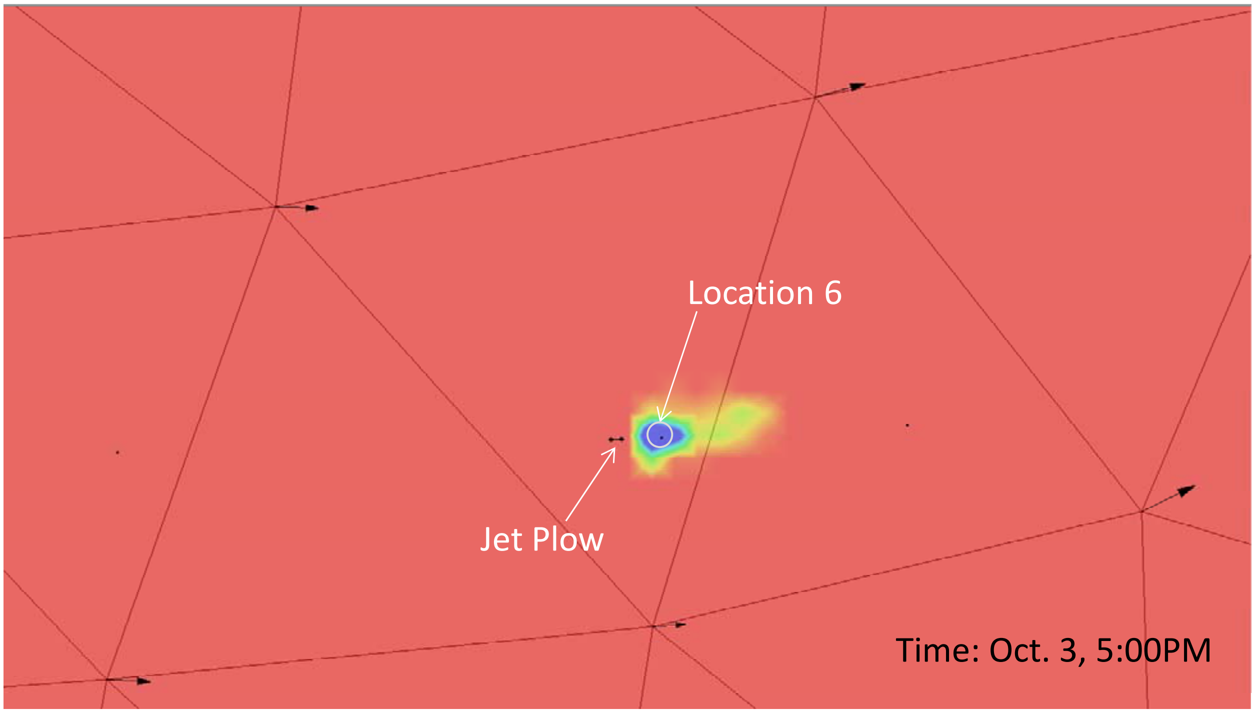
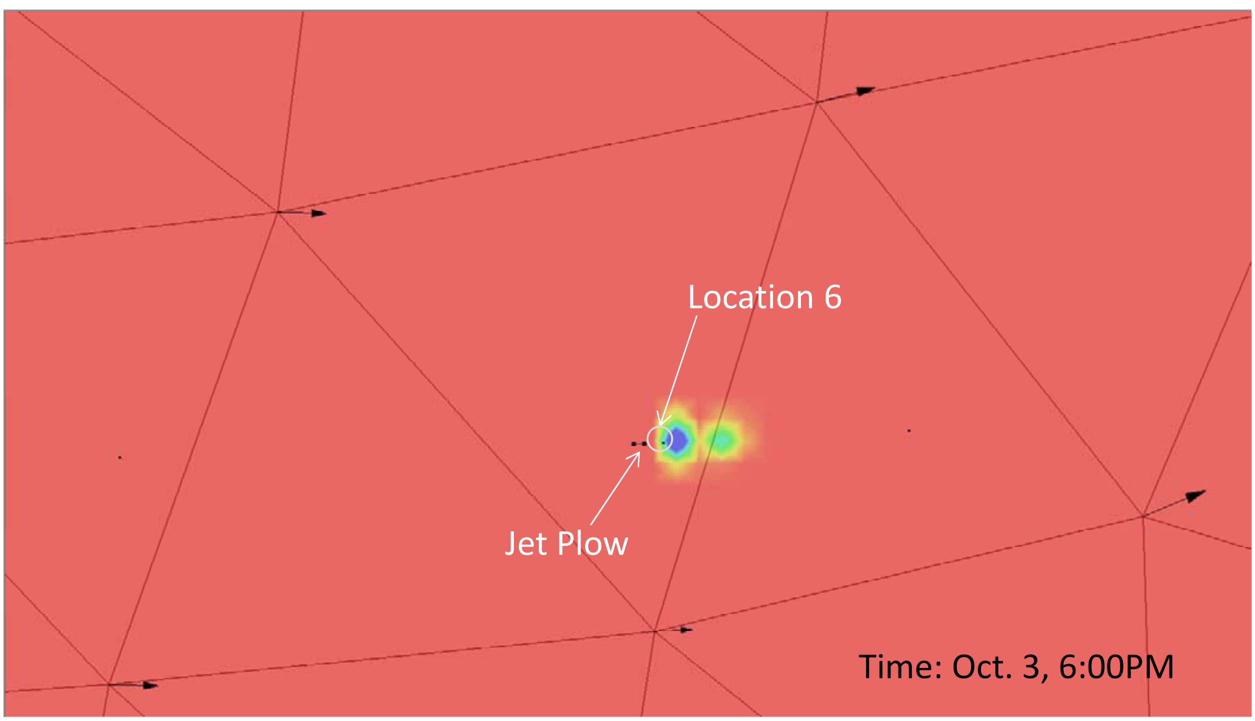
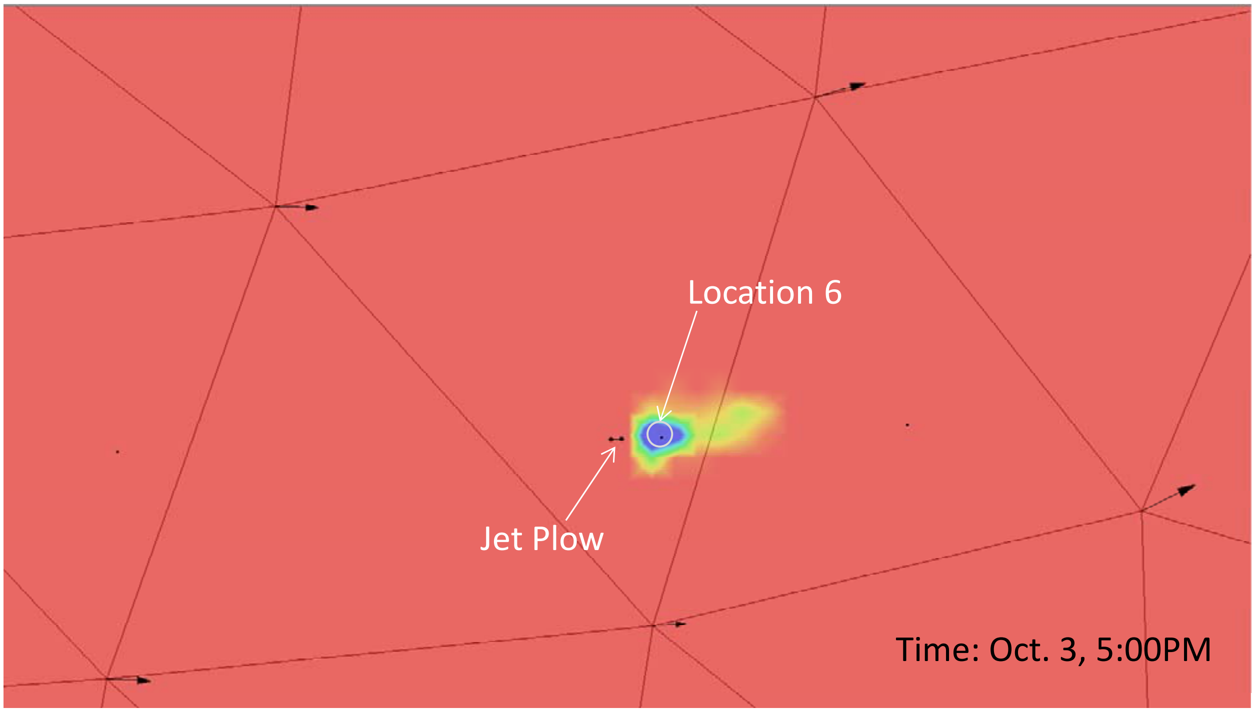
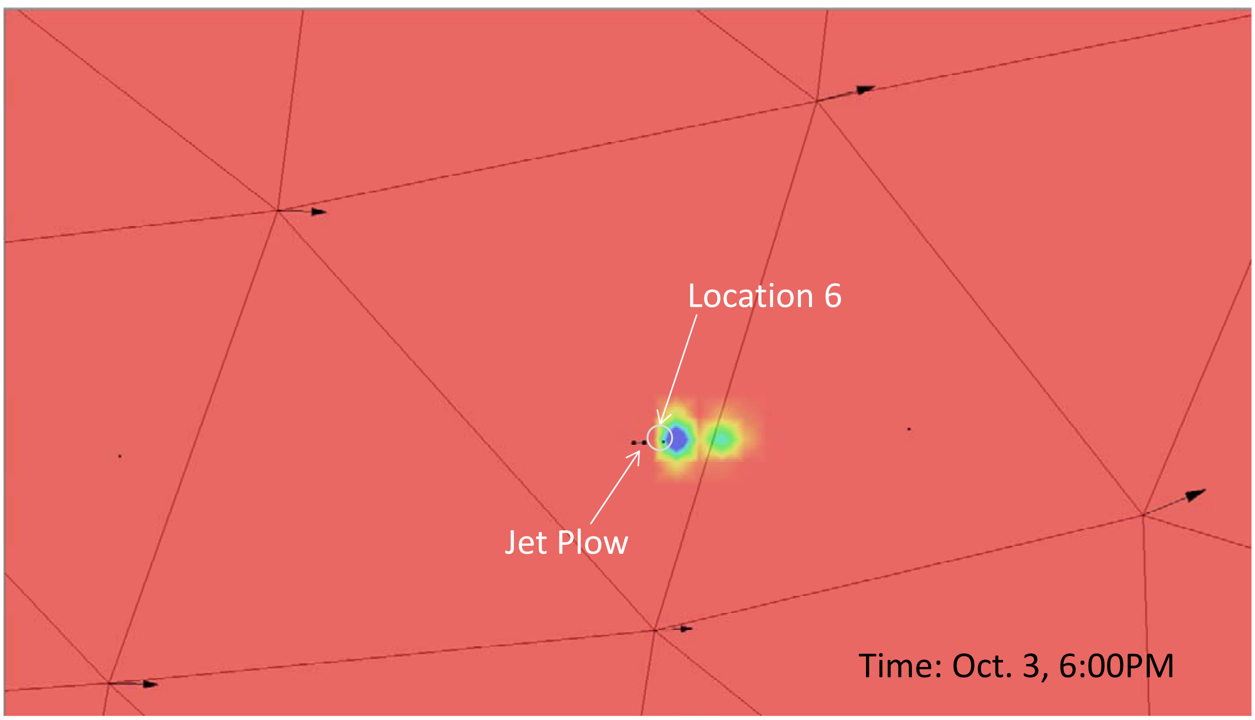
Jet Plow
Time: Oct. 3, 4:00PM


Location 6
Jet Plow
Time: Oct. 3, 5:00PM

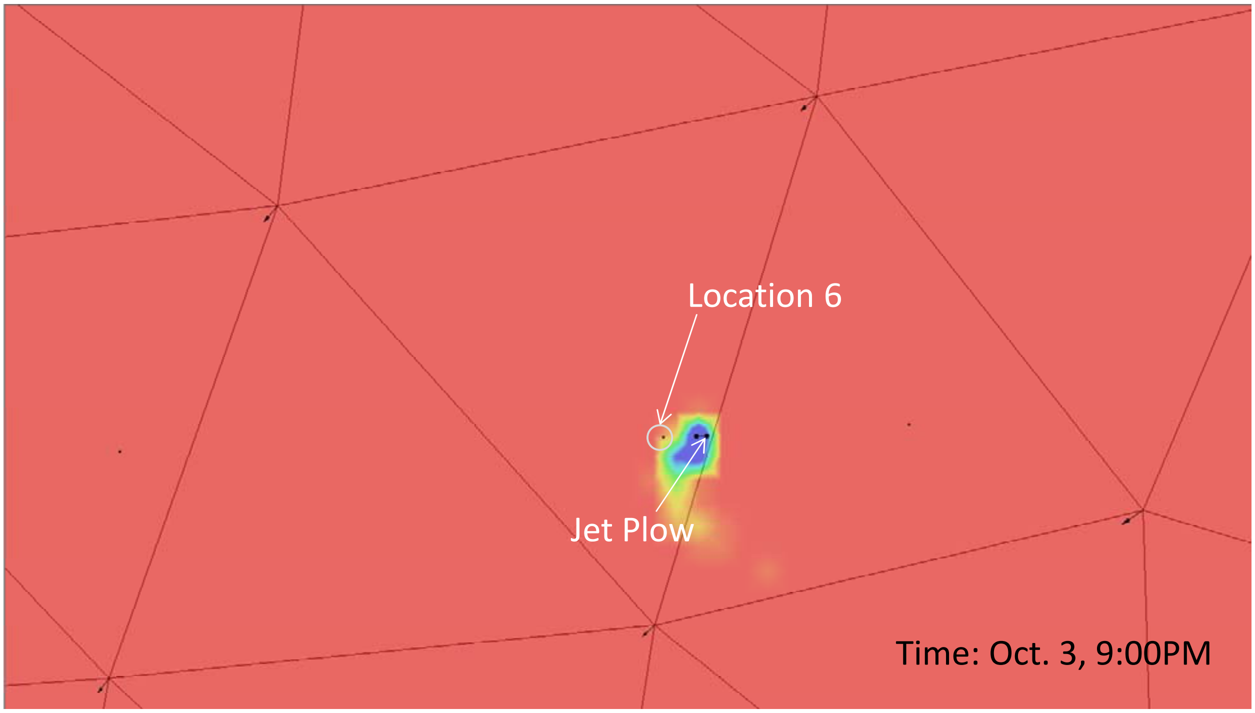

Location 6
Jet Plow
Time: Oct. 3, 6:00PM

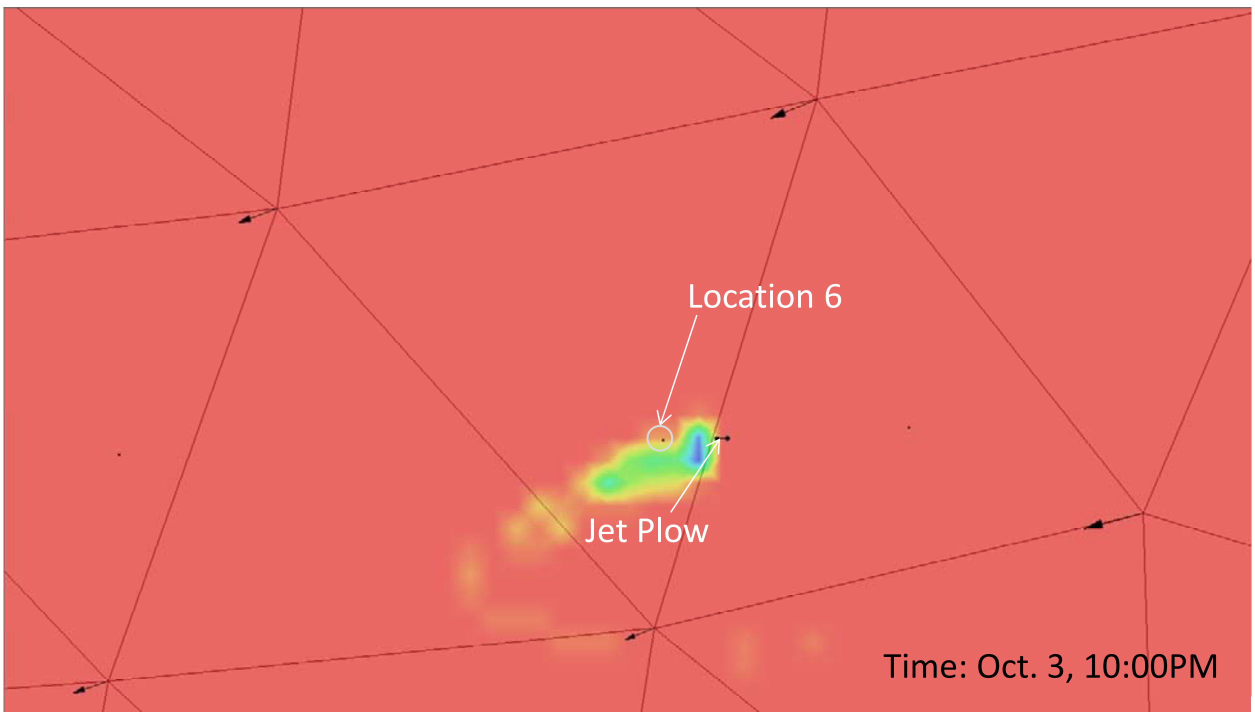

Location 6
Jet Plow
Time: Oct. 3, 5:00PM


Location 6
Jet Plow
Time: Oct. 3, 6:00PM


Location 6
Jet Plow
Time: Oct. 3, 7:00PM


Location 6
Jet Plow
Time: Oct. 3, 8:00PM


Location 6
Jet Plow
Time: Oct. 3, 9:00PM


Location 6
Jet Plow
Time: Oct. 3, 10:00PM