The Great Grid Upgrade

Sea Link

Sea Link

Volume 6: Environmental Statement

Document: 6.3.4.1.A
Part 4 Marine
Chapter 1 Appendix 4.1.A
Suspended Sediment Modelling

Planning Inspectorate Reference: EN020026

Version: A
March 2025

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 Regulation 5(2)(a)

nationalgrid

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1. Introduction

1.1 Background

1.1.1 This note describes the modelling of sediment dispersion processes resulting from burial operations along cable corridor between the Suffolk and Kent landfalls during the construction phase of the development. A description is provided of how discrete locations have been selected for the modelling of sediment dispersion processes and how the sediment inputs to the modelling were estimated using information available at the time.

1.1.2 Results from the modelling exercise are presented which will be used by other disciplines for the interpretation of impacts on key receptors in the marine environment.

1.1.3 Details of each stage of the modelling process and the definition of key model input parameters are provided in the following section.

2. Modelling Approach

2.1 Model Set-up

2.1.1 The first stage in the model set-up requires a description of tidal conditions from a hydrodynamic model the English Channel - North Sea (ECNS) region. The result file contains water levels and currents throughout the model domain at half-hourly intervals from a 15-day simulation of hydrodynamic conditions.

2.1.2 The hydrodynamic model was updated involving re-setting of the boundary conditions for the year 2024 and validating the resulting tidal conditions against predicted tides (water levels) and currents (tidal streams). Details of the model validation process are reported separately[1].

2.1.3 For the simulation of sediment dispersion processes, the following inputs are also required:

- Sediment properties (i.e. fall velocity and critical erosion threshold)
- Sediment release points;
- Sediment release rate (kg/s dry mass);

2.1.4 The following sections describe how these model inputs were established.

2.2 Sediment Properties

2.2.1 Key sediment properties required as inputs to the modelling exercise include the particle fall velocity and the critical erosion threshold which controls the re-erosion of particles deposited on the seabed. The distribution of particles sizes from seabed sediment samples obtained along the route of the cable corridor is given in Table 1.

Table 1 Particle size distribution for sediment grab samples

Sample ID	Release Location	% mud <0.063 mm	% sand 0.063 mm-2 mm	% gravel >2 mm
S008	R1	19	29	52
S013	R2	38	45	17
S015	R3	16	53	31
S018	R4	17	43	40

[1] AECOM (2024). Sea Link Marine EIA, Technical Note 1 – Validation of Tidal Model. July 2024.

Sample ID	Release Location	% mud <0.063 mm	% sand 0.063 mm-2 mm	% gravel >2 mm
S020	R5	9	90	1
SO27	R6	14	84	2

2.2.2 Coarse, non-cohesive sediment fractions (gravel and coarser sand fractions) will not remain in suspension for extended periods but instead rapidly settle to the seabed. With a typical fall velocity of 0.009 m/s for fine sand, these particles will settle to the seabed from a height of 2 m in approximately 4 minutes whilst coarse sand fractions falling with a velocity of 5 mm/s will settle the same vertical distance in less than 1 minute. Gravel-type material will reach the seabed in even shorter timescales. A summary of fall velocities and indicative travel distances are provided in Table 2 for a range of particle types.

Table 2 Characteristics of different particle types

Sediment Characteristics	Mud	Fine Sand	Medium Sand	Coarse Sand	Gravel
Particle size (mm)	0.03	0.125	0.35	1	5
Fall velocity (m/s)	0.0005	0.009	0.045	0.114	0.282
Travel distance (m)	1930	115	22	9	3.5

2.2.3 The distance travelled by gravel and coarse sand particles during their time in suspension is shown to be less than 10 m whilst subject to a constant near-bed current speed of the order 0.5 m/s but fine sands travel more than 100 m and mud fractions much further.

2.2.4 Fine sand and mud (silt and clay) particles will remain in suspension for extended periods and travel distances larger than the resolution of the model mesh. On this basis the dispersion modelling will be undertaken for these fractions only. Since the gravel and coarser sand fractions will remain close to the source location, these are not included in the numerical modelling exercise.

2.2.5 Analysis of sediment properties along a previously proposed alignment of the cable route was undertaken using particle size analysis results from 37 sediment grab samples. Plate 1 shows how sediment properties vary from north to south with gravel being the dominant fraction off the Suffolk Coast to the south of the landfall and sand being the dominant fractions off the Kent Coast. The proportion of silt and clay fractions is shown to be variable along the route. Samples which were found to have higher silt/clay content were therefore selected as ‘release points’ for the subsequent simulation of sediment dispersion. These locations are identified by the red circles around the sample locations, as shown on Plate 1. The easting coordinate of the sample location was however adjusted to be centralised within the currently proposed alignment of the cable corridor as defined by the scoping boundary

2.2.6 Beneath the surface layers of bed sediment, the material is expected to be predominantly of a clayey nature. This material will be relatively well consolidated therefore the release of particulate matter will be limited, regardless of the cable installation method used. It is assumed that the release of sediment from these lower depths of the zone of disturbance will be the same as the surface layers providing a conservative assessment of the amount of sediment released into the water column.

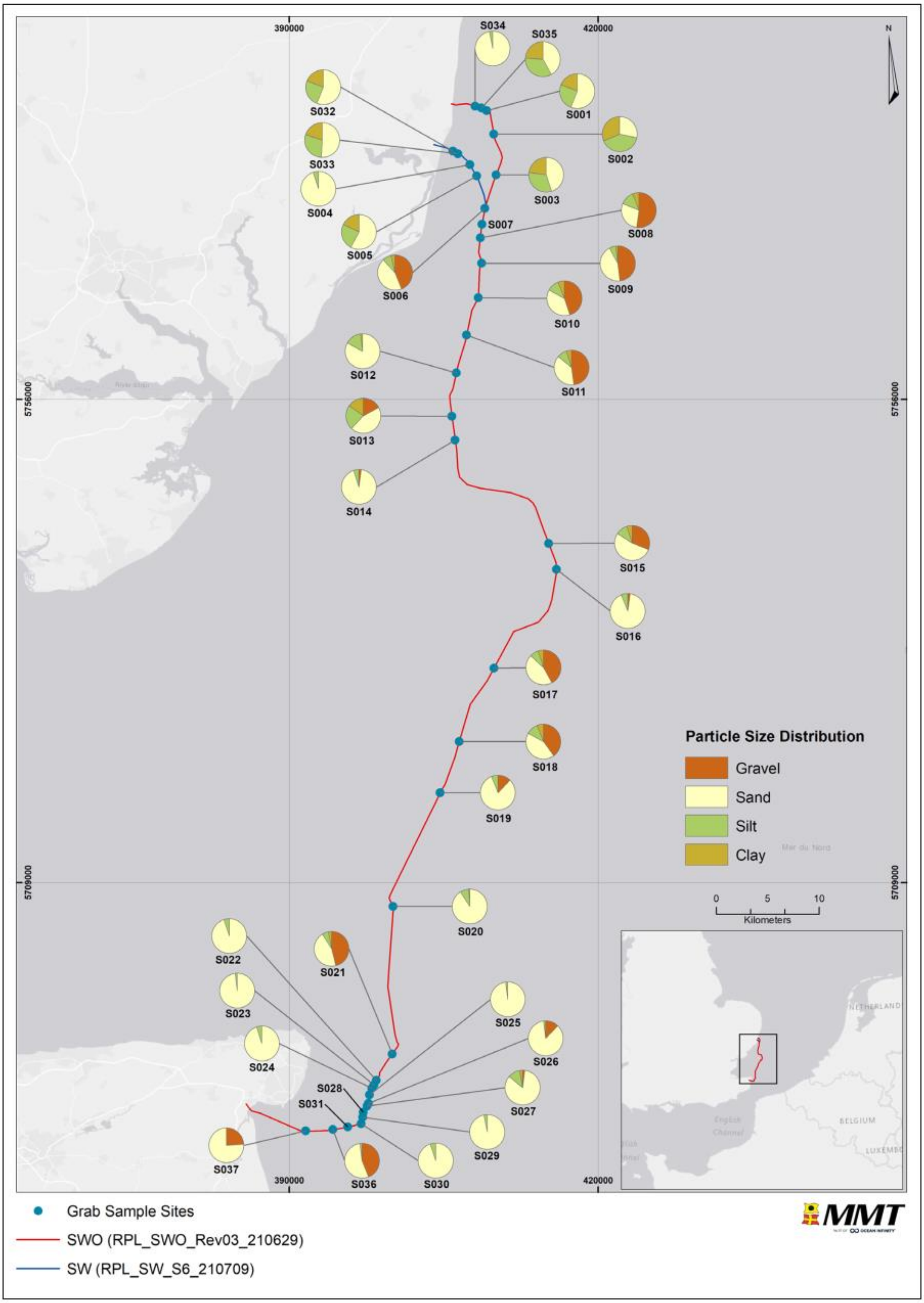


Plate 1 Variation in particle size distribution along previous cable route alignment (MMT, 2022)

2.2.7 Key input parameters to the particle-tracking model include the particle fall velocity and the critical erosion threshold defining conditions for the onset of re-erosion of any sediment deposited on the seabed. The fall velocity was calculated for a fine sand with a representative median diameter, d50, of 0.125 mm and 0.030 mm for the mud fractions.

2.2.8 Two different methods were used to calculate the critical shear stress for erosion for the non-cohesive and cohesive fractions. For fine sand, the method used is based on equations developed by Soulsby (Soulsby, 1998). For mud, calculation of the critical erosion parameter was based on an assumed bulk density of 1100 kg/m^3 which is representative of the 'gel point' for North Sea mud (Winterwerp & van Kesteren, 2004). A summary of key model input parameters is provided in Table 3.

Table 3 Sediment related model input parameters

Sediment type	Fall velocity (m/s)	Critical erosion threshold (N/m^2)
Mud	0.0005	0.038
Fine Sand	0.0087	0.143

2.3 Sediment Release Location

2.3.1 The sediment release location describes the positions within the model domain where sediment disturbed during the cable burial process is introduced into the model. A moving source was used to closely simulate this process.

2.3.2 Plate 2 shows the bathymetry for part of the ECNS model together with the scoping boundary for the marine cable corridor. Six locations have been chosen to allow the influence of varying hydrodynamic conditions to be accounted for in the sediment dispersion modelling exercise as well as variations in seabed sediment. As shown, these are evenly distributed along the cable corridor and will be used to interpret effects at intermediate locations along the route.

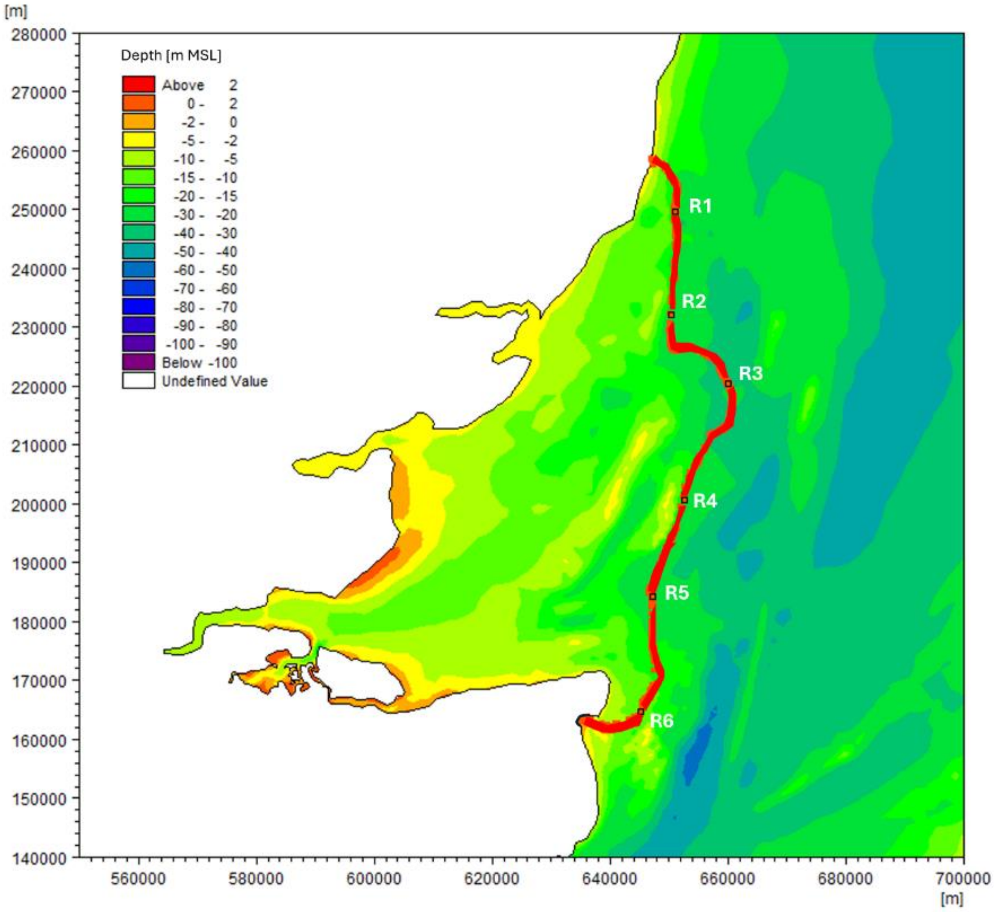


Plate 2 Hydrodynamic model bathymetry with marine cable corridor (red line) and sediment release locations

2.3.3 The six locations identified on Plate 2 (R1 to R6) were selected as release locations for the sediment dispersion modelling. These were selected due to having the largest silt and clay content when compared to adjacent sample locations, as shown in Plate 1. This approach will provide an overestimate of the amount of fine sediment released into the water column giving a conservative assessment of potential effects on the marine environment.

2.3.4 The coordinates of the grab samples collected during surveys carried out in 2021 are provided in Table 4. The table includes a modified easting coordinate for a sediment release point located centrally within the scoping boundary. The offset in the easting coordinate for the sample is also provided which shows that the offset from the grab sample location is largest for locations S013 and S027. The differences for the other 4 locations are less than 100 m and the sediment samples can therefore be considered as representative of the conditions within the scoping boundary.

2.3.5 Sediment properties for locations corresponding to S013 and S027 will be checked against the latest sediment sample data, when this information becomes available, to assess the validity of results presented for sediment releases from these locations.

Table 4 Coordinates of sediment grab samples and release locations

Sample ID	Easting (m)	Northing (m)	Easting (m)	Difference in Easting (m)
R1 (S008)	651197	249671	651150	47
R2 (S013)	649633	232153	650479	846
R3 (S015)	659862	220446	659931	69
R4 (S018)	652510	200613	652520	10
R5 (S020)	647201	184164	647260	59
R6 (S027)a	646011	164630	645288	723

2.3.6 The modelling of sediment dispersion processes uses a particle-tracking approach which follows the path of sediment 'particles' in three dimensions. Coordinates for moving source points were specified together with a vertical position in the water column or height above the seabed. There is considerable uncertainty associated with the vertical release position which will be highly dependent on the degree of local turbulence near the seabed during installation at the point where the sediment is entrained into the water column which can be directly related to the installation method. The following release heights have been assumed in the modelling:

- bed +1 m for installation using a plough
- bed + 2 m for installation using jetting techniques

2.4 Sediment Release Rates

2.4.1 Sediment release rates are a key input to the dispersion modelling which describe the rate at which disturbed sediment is introduced into the water column during the installation process and has been estimated using the following details:

- Cross-sectional area of seabed normal to the cable route disturbed during installation: 1.5 m wide x 2.5 m deep
- Operational workplan: 24hrs/day, continuous
- Installation rate: 7,000 m/day (maximum estimate)
- Installation method: Ploughing or Jetting

2.4.2 The actual installation rate is expected to vary between 0 to 7,000 m/day. The upper estimate of 7,000 m/day has been applied over a 24-hour period allowing the simulated sediment plume to develop in the model. A lower installation rate of 1,000 m/day was considered as a sensitivity test which was found to result in lower suspended sediment concentrations (SSC). The upper rate of 7,000 m/day was therefore used to provide a worst-case representation of elevated SSC levels.

2.4.3 Based on previous cable burial experience[2], it has been estimated that between 10-35% of the material within the trench is brought into suspension with 25% considered as a conservative estimate when using jetting techniques[3]. If a plough is used without jetting, then a 10% loss can be assumed as a conservative estimate. Different values are therefore used to represent the alternative installation methods as provided in Table 5 for both mud and fine sand fractions.

Table 5 Release rates for alternative methods of cable installation

Release Location	Jetting release rate (kg/s)		Ploughing release rate (kg/s)	
	Mud	Fine sand	Mud	Fine sand
R1	20.2	17.6	8.1	7.0
R2	40.4	27.3	16.2	10.9
R3	17.0	32.2	6.8	12.9
R4	18.1	26.1	7.2	10.4
R5	9.6	54.7	3.8	21.9
R6	25.5	51.0	10.2	20.4

2.4.4 Separate simulations were carried out to consider the release during spring and neap tides. Spring tides can be expected to provide the largest plume extent whilst neap tides will result in a smaller plume but with potentially higher suspended sediment concentrations.

2.4.5 The combinations of sediment type, installation method with consideration of spring and neap tides provides the set of results which have been used to determine the extent and magnitude of changes in SSC levels and depths of sediment accumulation on the seabed as a result of the cable installation process.

[2] *Foreman (2002). Resuspension of sediment by the jet plow during submarine cable installation, Engineering Technology Applications. May 2002.*

[3] *RPS (2015). Modelling Sediment Dispersion from Cable Burial for Seacoast Reliability Project, Little Bay, New Hampshire. December 2015.*

3. Model Results

3.1 Scenario Tests

3.1.1 The software used for the modelling of sediment dispersion was MIKE (officially 'MIKE Powered by DHI'). This software is the most widely used coastal/marine modelling software globally. This modelling considers the two main cable installation methods (jetting and ploughing) along the Offshore Scheme.

3.1.2 The modelling of sediment dispersion was carried out for discrete locations along the cable route at intervals of approximately 15 km allowing changes in sediment properties and local dispersion characteristics along the cable route to be accounted for.

3.1.3 Within the model, a constant release rate was applied as a point source which was varied to simulate alternative installation techniques. Separate simulations were carried out to consider the release during a 1-day period commencing on spring and also neap tides with the model runs carried out for a further 13 days without any additional sediment input. Typically, spring tides can be expected to provide the largest plume extent with neap tides resulting in a more smaller plume extent but with potentially higher suspended sediment concentrations. Results are presented for the case involving installation commencing on spring tides with selected results at the end of the 14-day period for installation commencing on neap tides provided in Appendix A. Overall the results in terms of SSC and deposition are found to be very similar at the end of the 14-day simulation period.

3.2 Installation by Plough

Suspended Sediment Concentrations

3.2.1 Results of SSC levels resulting from the alternative cable installation methods are in all cases presented for a 4 m high layer above the seabed. This bottom layer is where concentrations will be highest and using this approach avoids presenting artificially diluted SSC values that would be the case if the full height of the water column were used in the calculation.

3.2.2 Plate 3 shows the initial development of sediment plumes for the mud fraction on flood and ebb tides after a 24-hour period of installation covering a distance of 7 km along the cable route centred on the six release locations, as given in Table 4. A very low minimum concentration value of 0.1 mg/l has been applied to the plot which allows each of the individual plumes to be visualised. The plots for the flood and ebb phases of the tide indicate the orientation of the major axis of the tidal ellipse which is clearly defined for locations R1 to R4. However, flows in the vicinity of locations R7 and R8 approaching the Kent landfall are more complex involving circulatory flow patterns which help increase the dilution of suspended sediments.

3.2.3 Plots of SSC levels for the mud fraction at 7 and 14 days from the start of cable installation are provided in Plate 4 which are plotted with a minimum concentration value of 1 mg/l. The plots show that these have returned close to background levels with low levels of persistent SSC (1-5 mg/l) associated with locations R1 and R2 only.

At each of the other locations SSC levels are shown to have returned to background levels.

3.2.4 A similar set of plots are provided for the fine sand fraction with the initial flood/ebb plumes provided in Plate 5. The fine sand SSC levels associated with the resulting plumes are generally higher than mud values mainly as a result the higher release rates. Other differences can be explained by the different settling velocities for the different particle types and re-erosion thresholds which are both lower for the finer mud material. As a result, the mud fractions remain in the water column for longer periods and naturally disperse. In contrast the fine sand tends to deposit on the seabed during the slack tide period before being re-eroded as the tidal currents increase on the subsequent phase of the tide.

3.2.5 After 7 days, Plate 6 shows there are only isolated points where concentrations are above 5 mg/l and even fewer after 14 days. The largest area where SSC levels are in the range 1-5 mg/l is found near location R6, closest to the Kent landfall.

3.2.6 Time-series plots of variations in SSC at each of the central release locations are provided in Plate 7 and Plate 8 for mud and sand fractions, respectively, to provide a indication of the persistence of elevated SSC levels. These both show that after an initial ‘spike’ in SSC, after less than two days levels are significantly reduced to less than 5 mg/l. Elevated levels of SSC for the fine sand, although low, are shown to persist for longer as a result of deposition and re-erosion rather than progressive dispersion, as found for the suspended mud fraction.

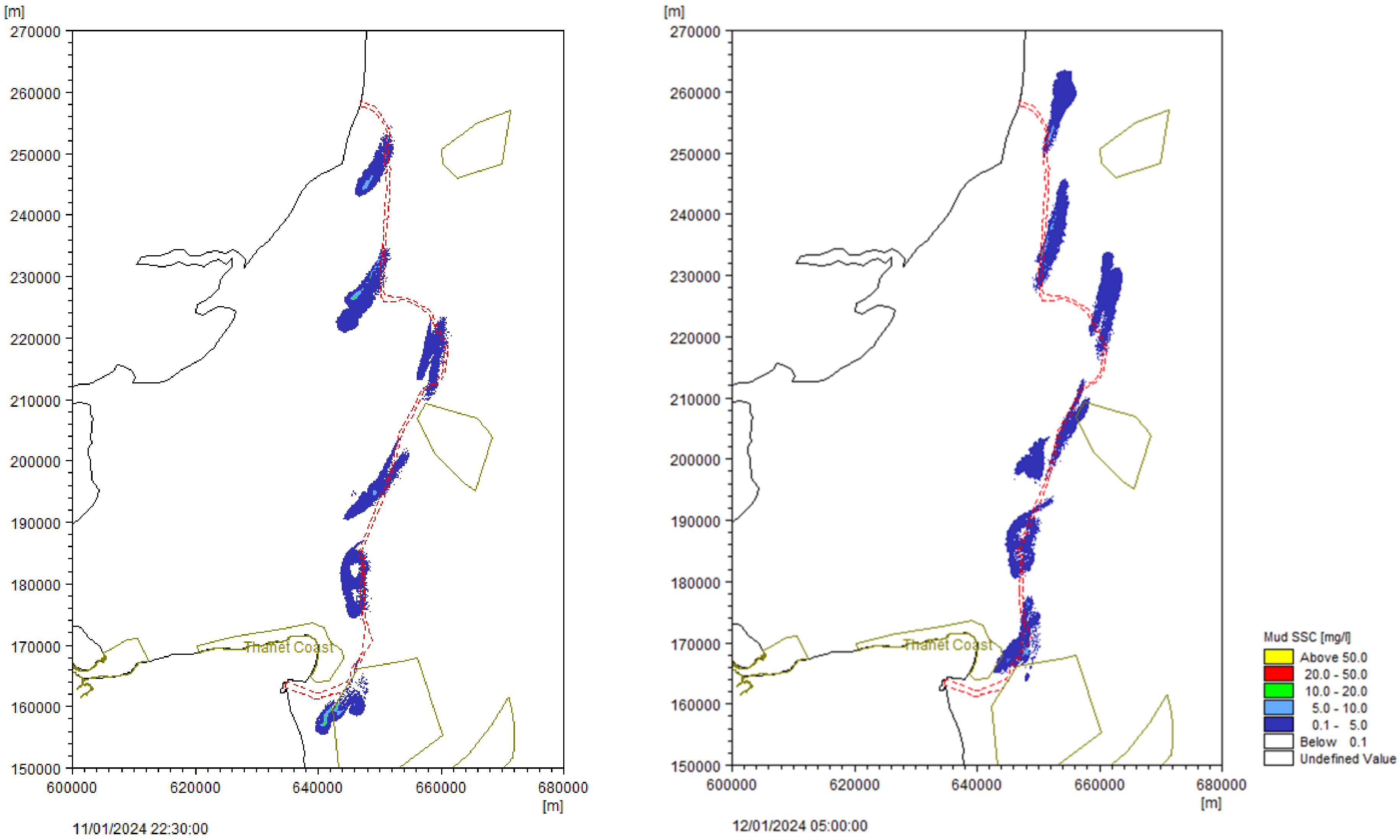


Plate 3 Mud SSC levels for plough installation commencing on spring tides with output on flood (left) and ebb (right) tide after first 24 hours of activity

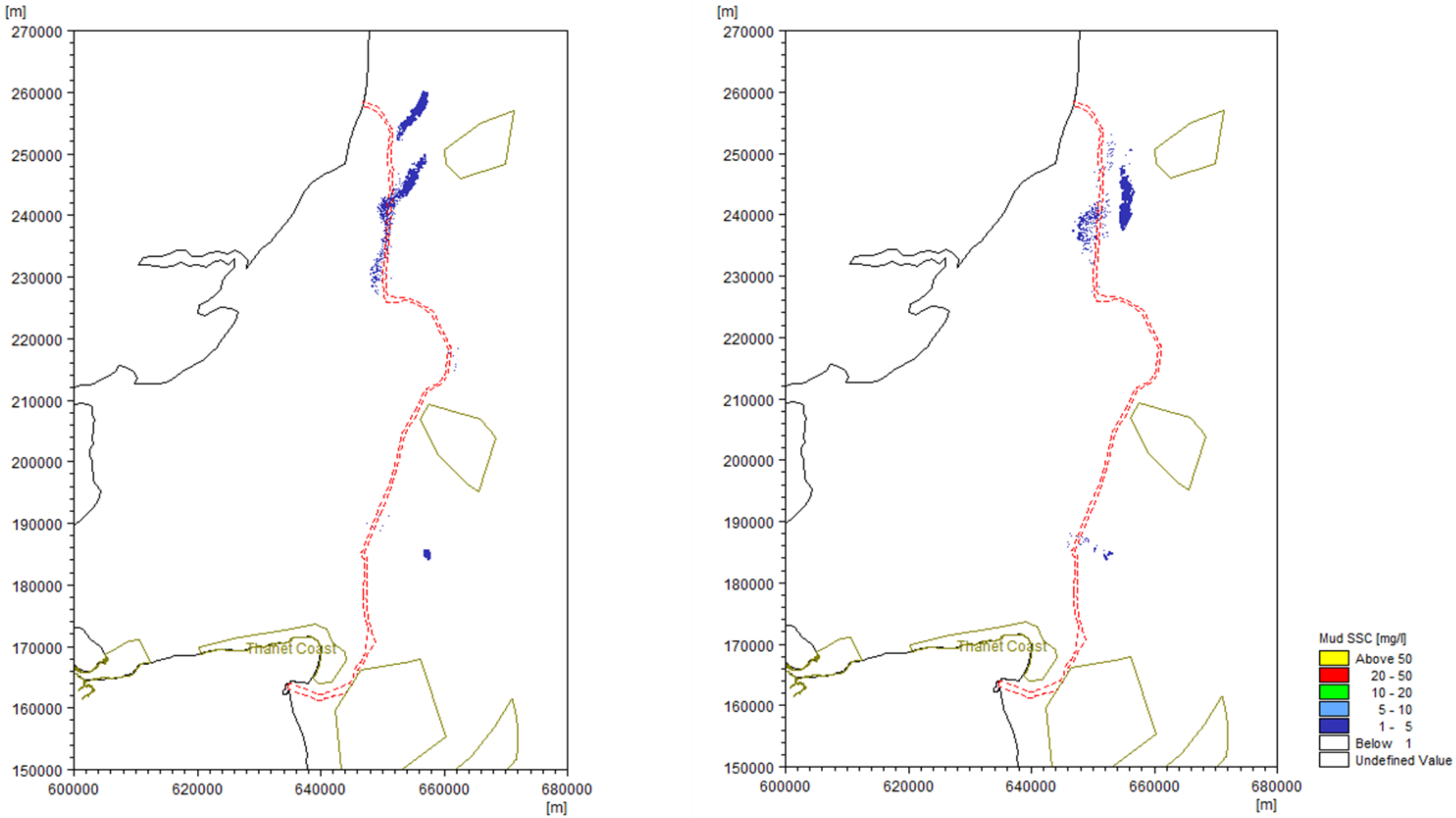


Plate 4 Mud SSC levels for plough installation commencing on spring tides with output at +7 days (left) and +14 days (right) after start of activity

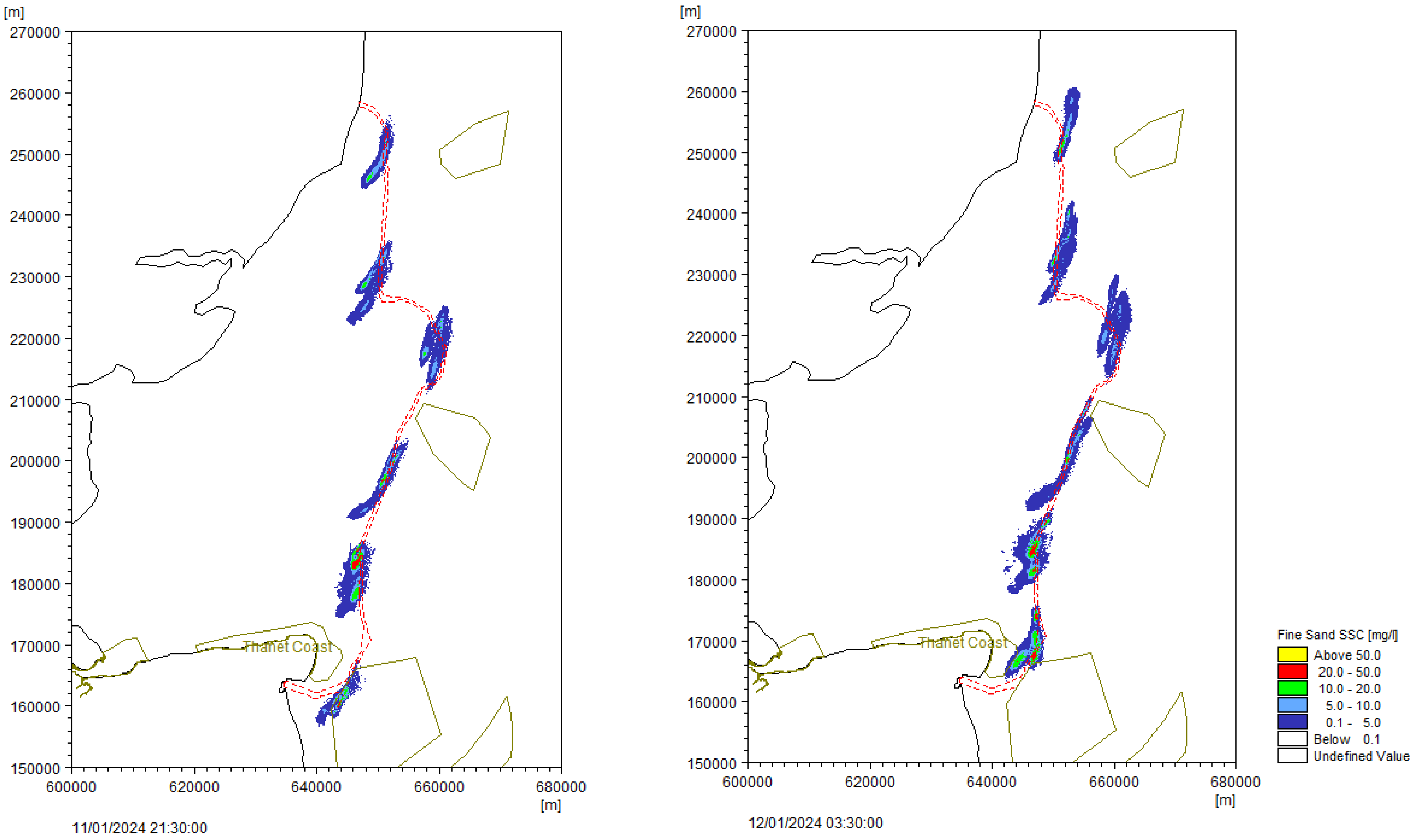


Plate 5 Fine sand SSC levels for plough installation commencing on spring tides with output on flood (left) and ebb (right) tide after first 24 hours of activity

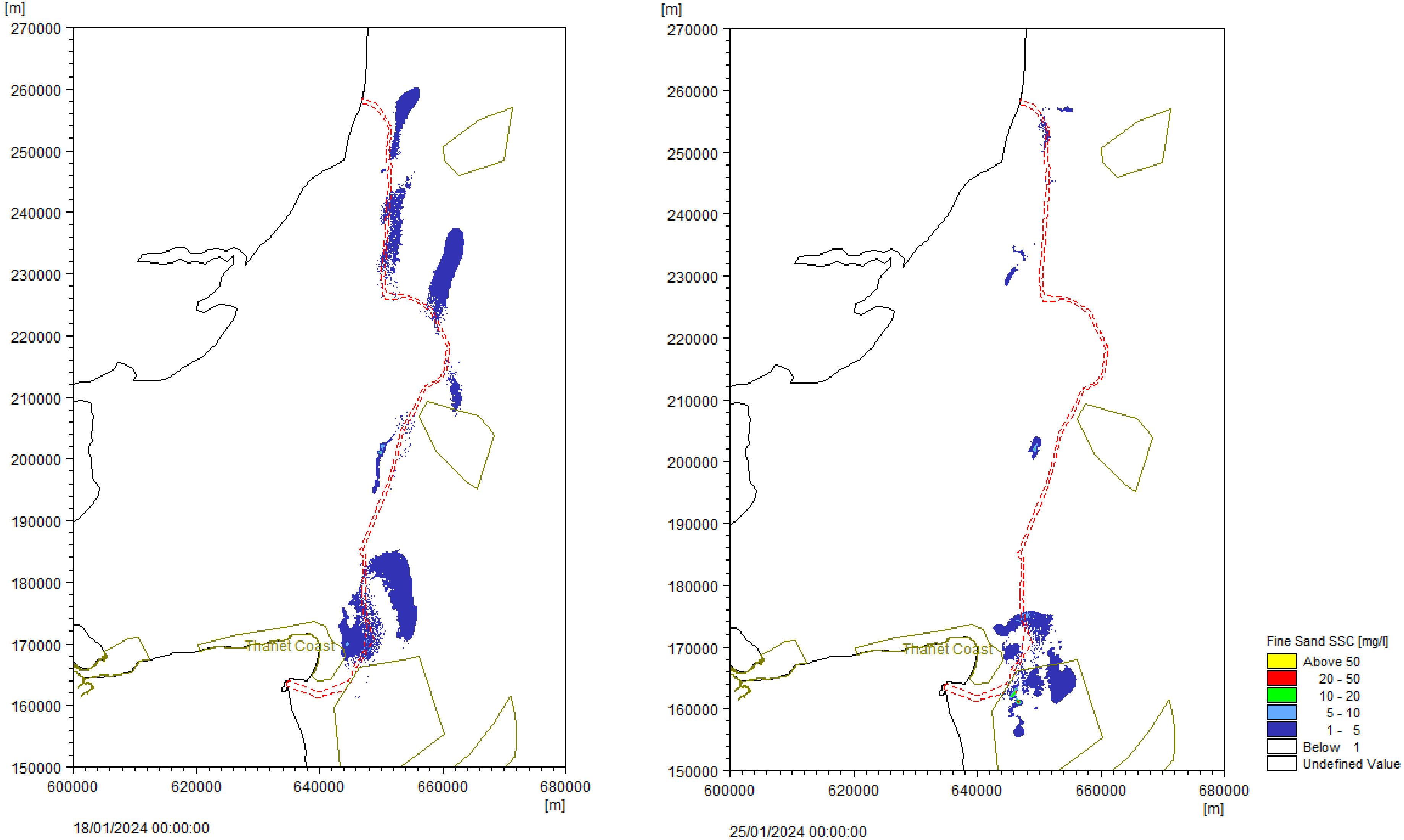


Plate 6 Fine sand SSC levels for plough installation commencing on spring tides with output at +7 days (left) and +14 days (right) after start of activity

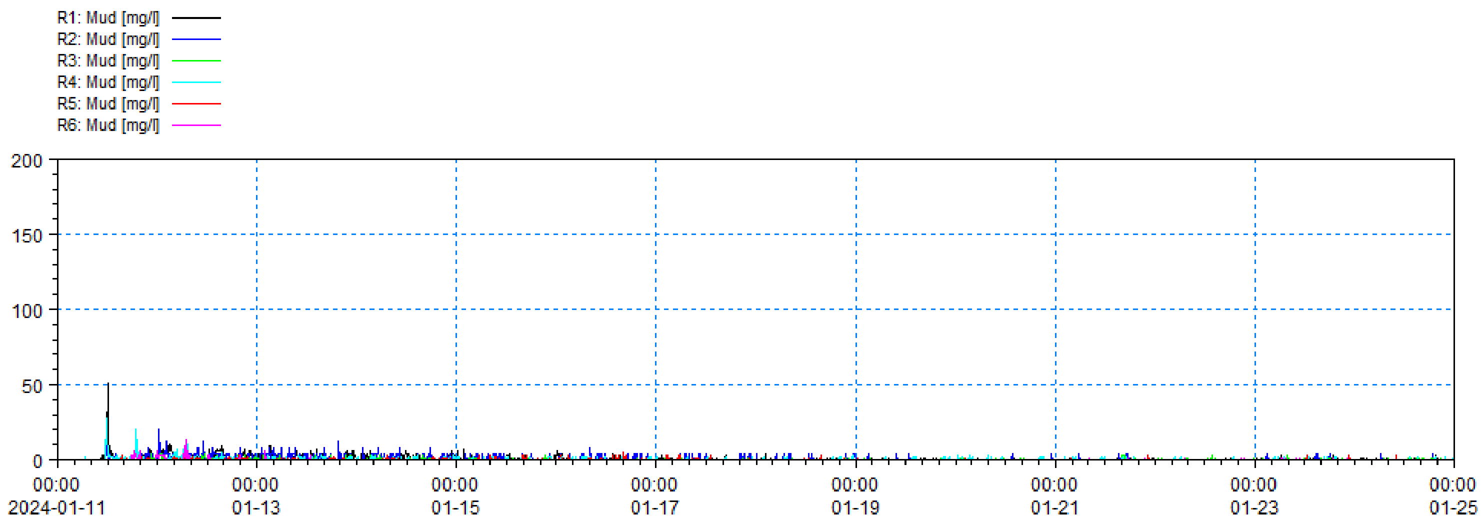


Plate 8 Time-series of mud SSC levels for plough installation at central sediment release locations over 14-day period

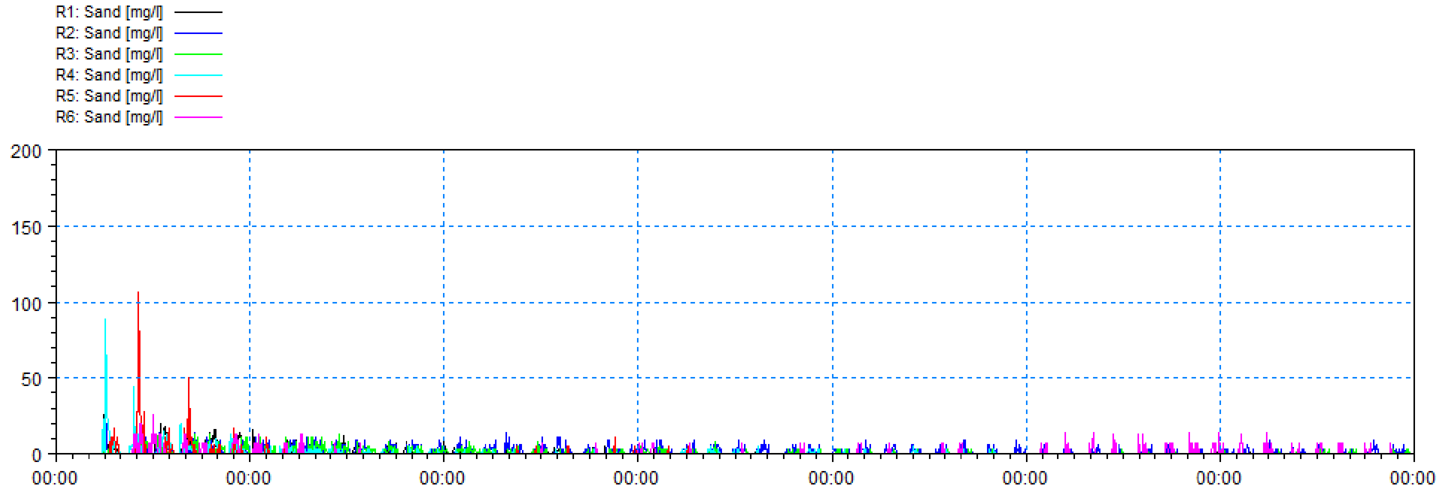
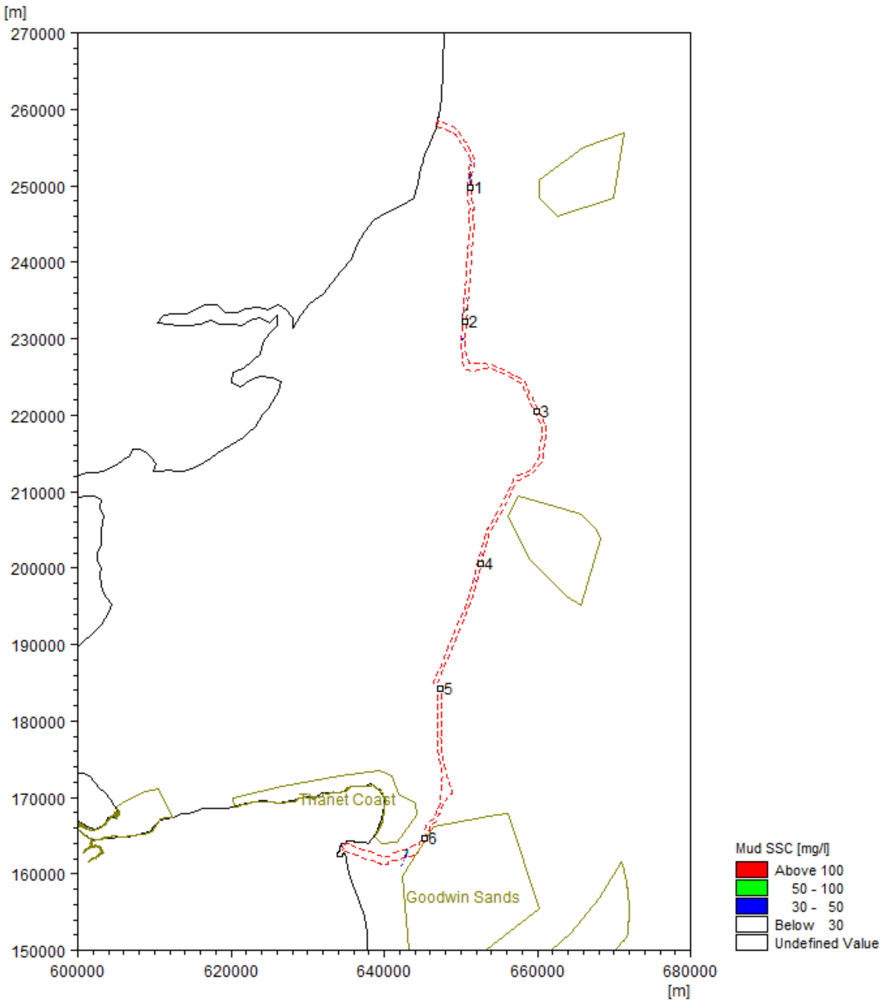


Plate 7 Time-series of fine sand SSC levels for plough installation at central sediment release locations over 14-day period



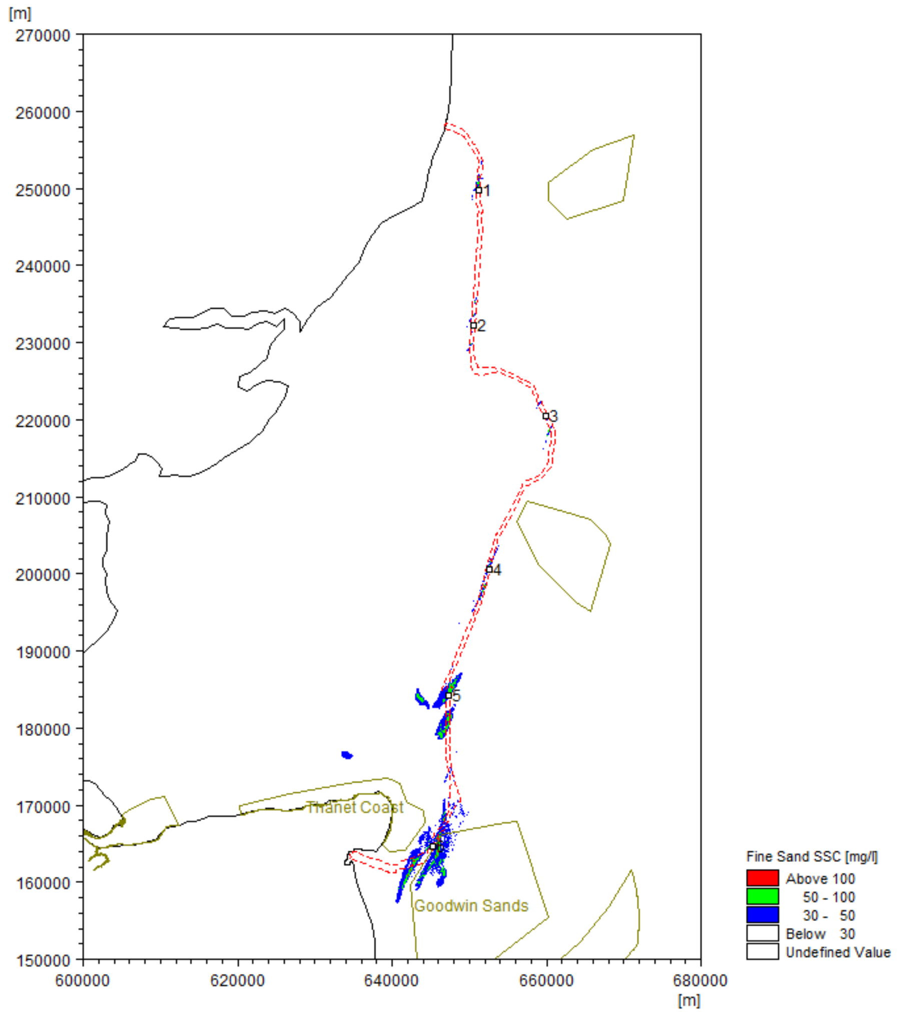


Plate 9 Maximum SSC levels over 14-day period for mud (left) and fine sand (right) for installation by plough

SSC and Zone of Influence

3.2.7 Plate 9 shows the maximum SSC concentration reached at any location over the 14-day model simulation period for both mud and fine sand. The distances provided are typically aligned with the axis of the dominant flood and ebb currents with the footprint of an elongated ellipse rather than a circle. Table 6 provides the Zone of Influence (ZOI) based on modelling results for the finer sediment fractions for each release location for installation by plough and assumed threshold SSC levels of 30 mg/l and 100 mg/l. These thresholds represent levels that, if exceeded, may affect different receptors.

Table 6 Modelled SSC ZoI for fine sediment fractions with installation by plough

Location	Approximate distance (km) from cable trench	
	Mud [30 mg/l / 100 mg/l]	Fine Sand [30 mg/l / 100 mg/l]
R1	2/0	4/0
R2	3/2	4/0
R3	0/0	4/0
R4	2/0	6/0
R5	1/0	6/0
R6	5/0	10/5

Note:
Values estimated from dispersion modelling results for a threshold level of 30 mg/l and 100 mg/l.

3.2.8 Table 7 provides estimates of the SSC ZOI distance for coarser sediment fractions, as derived through consideration of the particle fall velocity and ambient currents.

Table 7 Estimated SSC ZOI for coarse sediment fractions with installation by plough

Location	Approximate distance (km)[1] from cable trench		
	Medium Sand	Coarse Sand	Gravel
R1	10	5	2.5

Location	Approximate distance (km)[1] from cable trench		
	Medium Sand	Coarse Sand	Gravel
R2	10	5	2.5
R3	10	5	2.5
R4	10	5	2.5
R5	10	5	2.5
R6	10	5	2.5

Note: 1. Values estimated from calculation of fall velocity and assumed height above bed (+1 m for installation by plough). The values provided do not account for potential re-erosion of the deposited sediment.

3.2.9 The ZOI distances vary with location due to spatial variations in hydrodynamic conditions and the different proportion of sediment types. The largest ZOIs for both mud and fine sand were found for location R6 off the Kent coast extending a distance of 5 km and 10 km, respectively, from the release point. These relatively large distances result from the complex nature of currents in this area.

Deposition and Zone of Influence

3.2.10 Whilst a significant proportion of the disturbed seabed material will remain in suspension, some sediment particles will have the opportunity to settle onto the seabed where it will either remain or be subject re-erosion, depending on the strength of the ambient flow conditions.

3.2.11 Plate 10 shows that due to the very low threshold shear stress for re-erosion of the mud particles, they are unable to settle and accumulate on the seabed. The situation is similar for the fine sand particles with deposition limited to very localised, small magnitude accumulations of less than 0.1 mm in isolated areas. Further detail of deposition trends are provided in the time-series plots for fine sand (Plate 11) and mud (Plate 12) Further analysis was undertaken to determine the maximum depth of deposition over a 14-day period, as shown in Plate 13, which can be used to provides a conservative estimate for the ZOI related to sediment deposition in which a thickness of 0.5 mm was used to define the extent of the deposition ZOI, as given in Table 8.

Table 8. Modelled deposition ZOI for fine sediment fractions with installation by plough

Location	Approximate distance (km)[1] from cable trench	
	Mud	Fine Sand
R1	2	3
R2	2	4
R3	0	3
R4	2	8
R5	0	6
R6	0	10

Note:
1. Values estimated from dispersion modelling results for a threshold deposition depth of 0.5 mm.

Table 9 provides estimates of the deposition ZOI distance for coarser sediment fractions, as derived through consideration of the particle fall velocity and ambient currents.

Table 9. Estimated deposition ZOI for coarse sediment fractions with installation by plough

Location	Approximate distance (km)[1] from cable trench		
	Medium Sand	Coarse Sand	Gravel
R1	10	5	2.5
R2	10	5	2.5
R3	10	5	2.5
R4	10	5	2.5
R5	10	5	2.5
R6	10	5	2.5

Note:
1. Values estimated from calculation of fall velocity and assumed height above bed (+1 m for installation by plough). The values provided do not account for potential re-erosion of the deposited sediment.

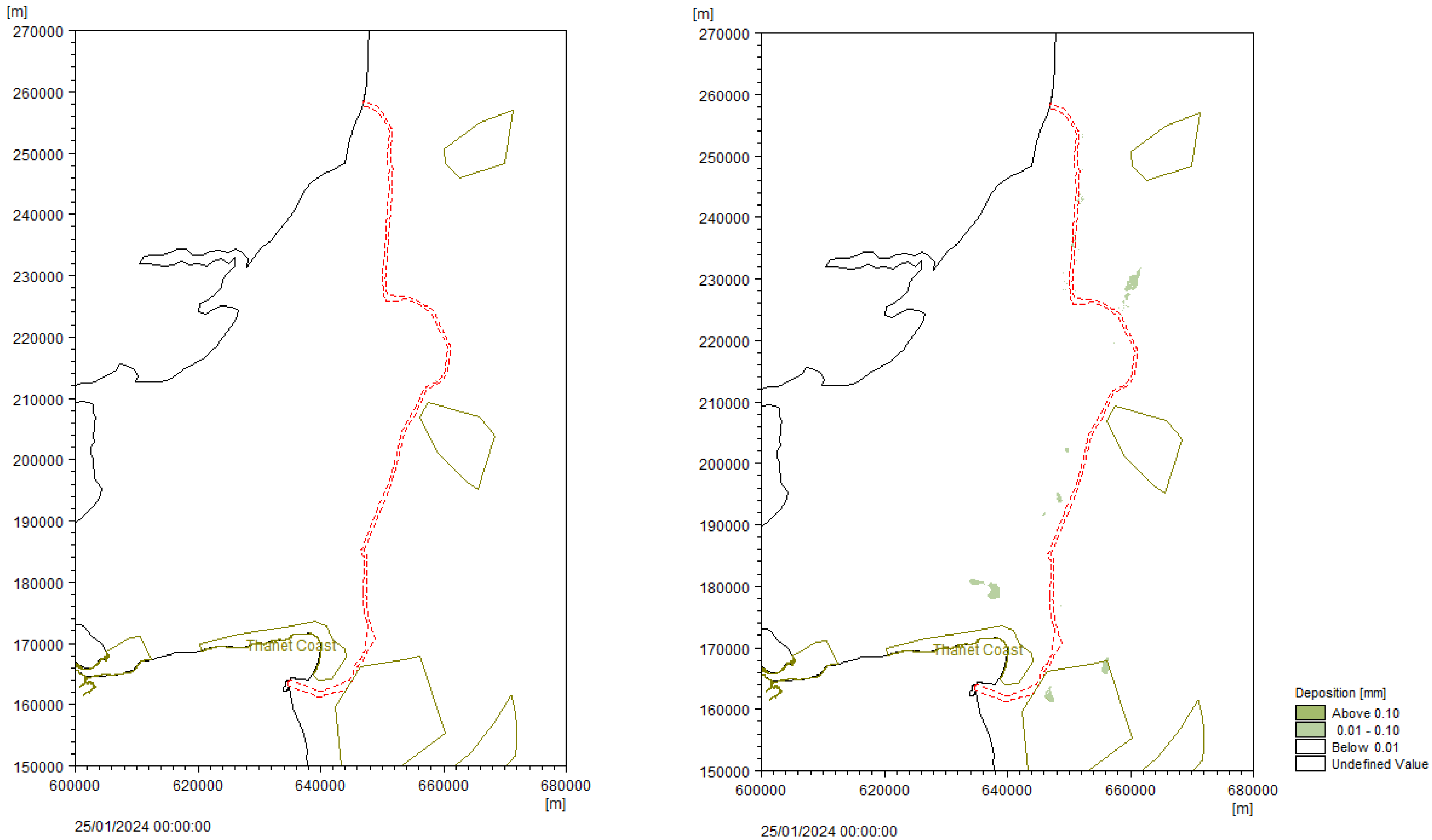


Plate 10 Depth of deposition with plough installation for mud (left) and fine sand (right) at end of 14-day period

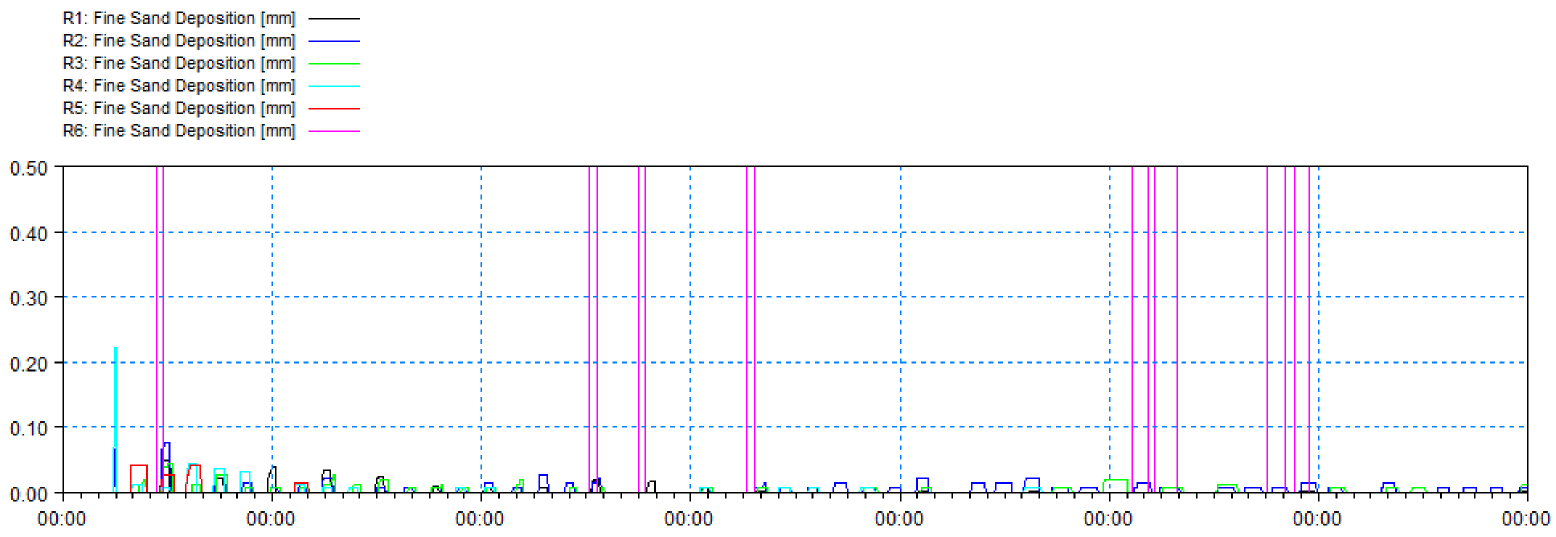


Plate 12 Time-series of fine sand deposition for plough installation at central sediment release locations over 14-day period

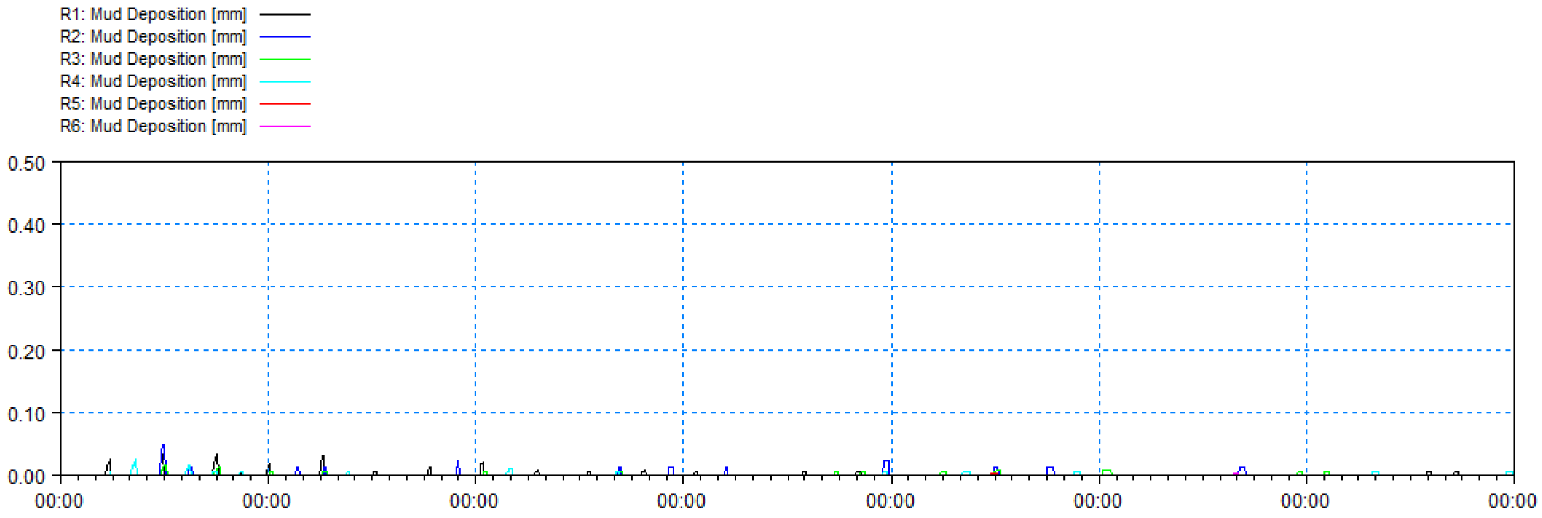


Plate 11 Time-series of mud deposition for plough installation at central sediment release locations over 14-day period

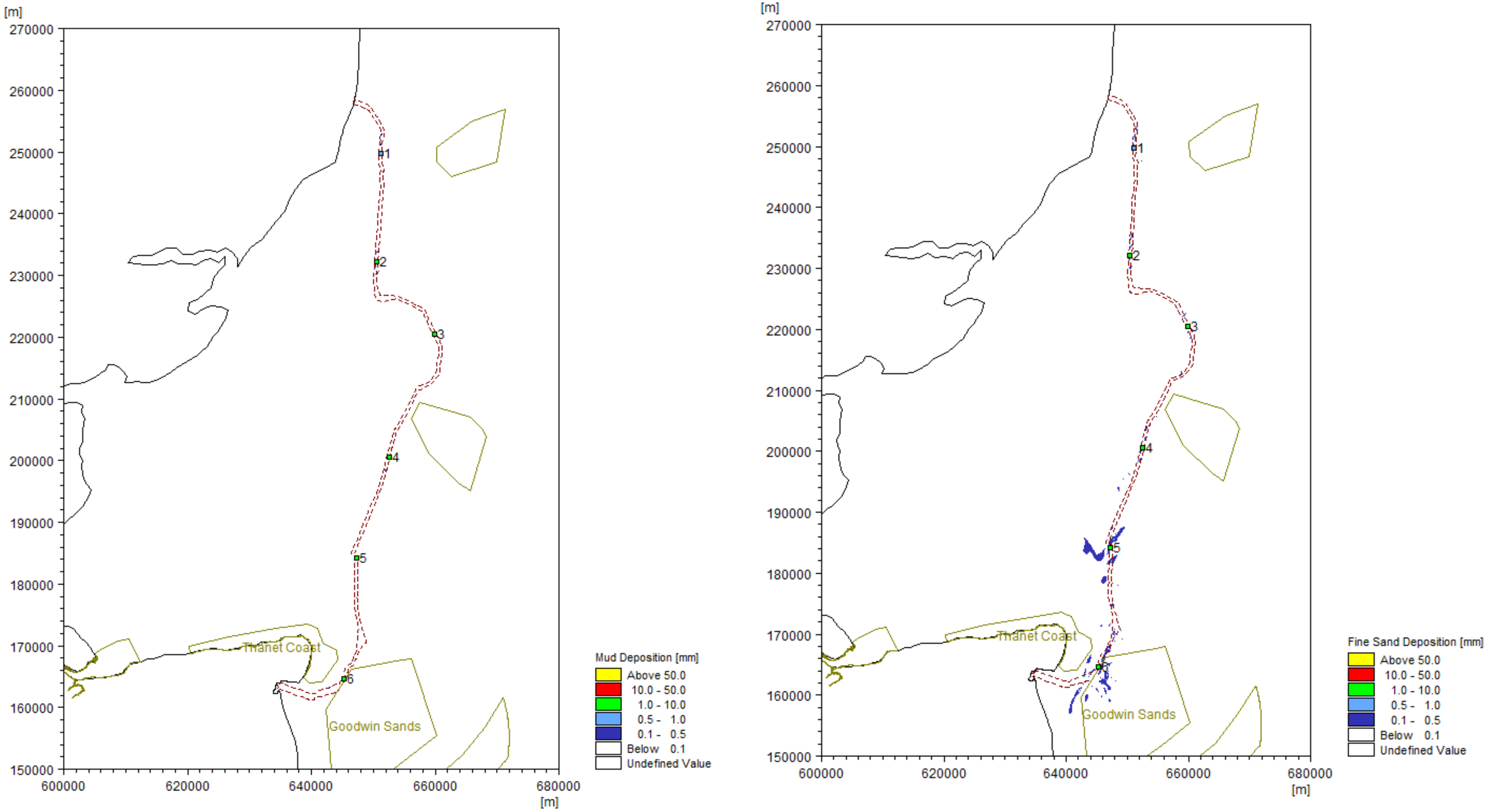


Plate 13 Maximum deposition over 14-day period for mud (left) and fine sand (right) for installation by ploughing

3.3 Installation by Jetting

Suspended Sediment Concentrations

3.3.1 As for the SSC results presented previously for cable installation by plough, these are also presented in this section calculated for a 4 m high layer above the seabed. This extends above the assumed release point at 2 m above the bed to allow for sediment transported vertically by dispersion processes and provides a consistent approach allowing direct comparisons to be made between the alternative methods.

3.3.2 Plate 14 shows the initial development of sediment plumes for the mud fraction on flood and ebb tides after a 24-hour period of installation covering a distance of 7 km along the cable route centred on the six release locations. A low minimum concentration value of 0.1 mg/l has been applied to allow the individual plumes to be visualised. The resulting plumes show relatively high peak SSC values (>20 mg/l) during the flood phase for sediment release from location R2 and R6 which reduce to less than 20 mg/l during the subsequent ebb tide. Peak concentrations are shown to be lower at the intermediate release locations (R3 to R5), presumably due to the lower release rates for these locations, as given in Table 5.

3.3.3 Plots of SSC levels for the mud fraction at 7 and 14 days from the start of cable installation are provided in Plate 15 which are plotted with a minimum concentration value of 1 mg/l. The plots show that whilst SSC levels have generally returned to background levels, there are areas where SSC remain in the range 1-5 mg/l associated with locations R1, R2 and R5.

3.3.4 Plots for the fine sand fraction with the initial flood/ebb plumes are provided in Plate 16. The fine sand SSC levels are typically higher than mud values, partly as a result of the higher release rates but also the lower level of dispersion associated with the sand material, as previously explained.

3.3.5 Plate 17 shows how the SSC levels for fine sand continue to reduce over time for releases from locations R1 to R5. The exception to this is location R6 off the Kent coast where elevated SSC levels (>20 mg/l) are shown to persist locally at the end of the 14-day period.

3.3.6 Time-series plots of variations in SSC at each of the central release locations are provided in Plate 18 and Plate 19 for mud and sand fractions, respectively. The mud SSC levels are shown to consistently reduce over the initial 7-day period after which there are only short duration ‘spikes’ in SSC over the subsequent 7 days. As seen with the plough installation method, elevated levels of SSC for fine sand are shown to persist for longer, particularly at location R6, as is also evident in the corresponding spatial plots.

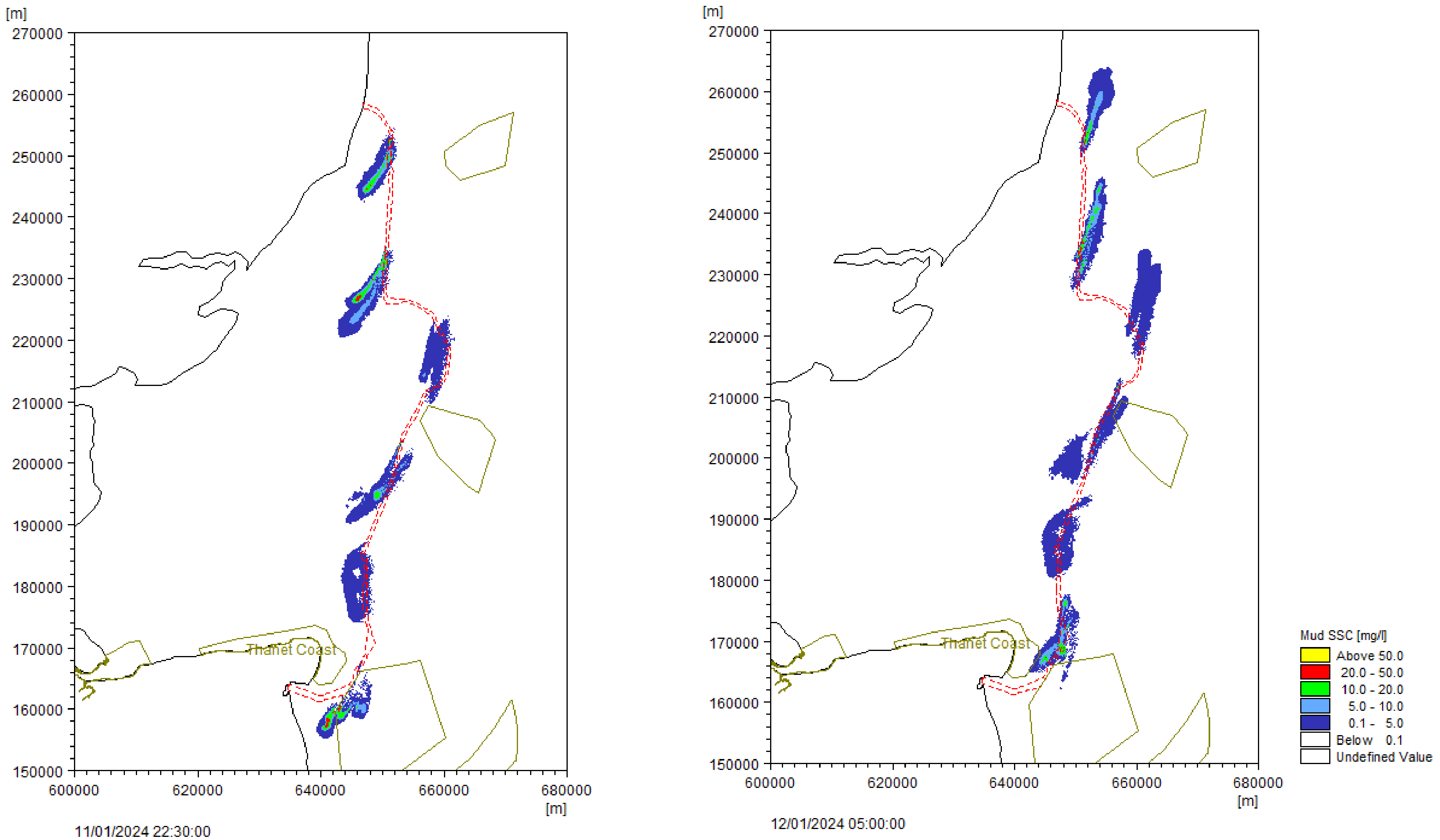


Plate 14 Mud SSC levels for jetting installation commencing on spring tides with output on flood (left) and ebb (right) tide after first 24 hours of activity

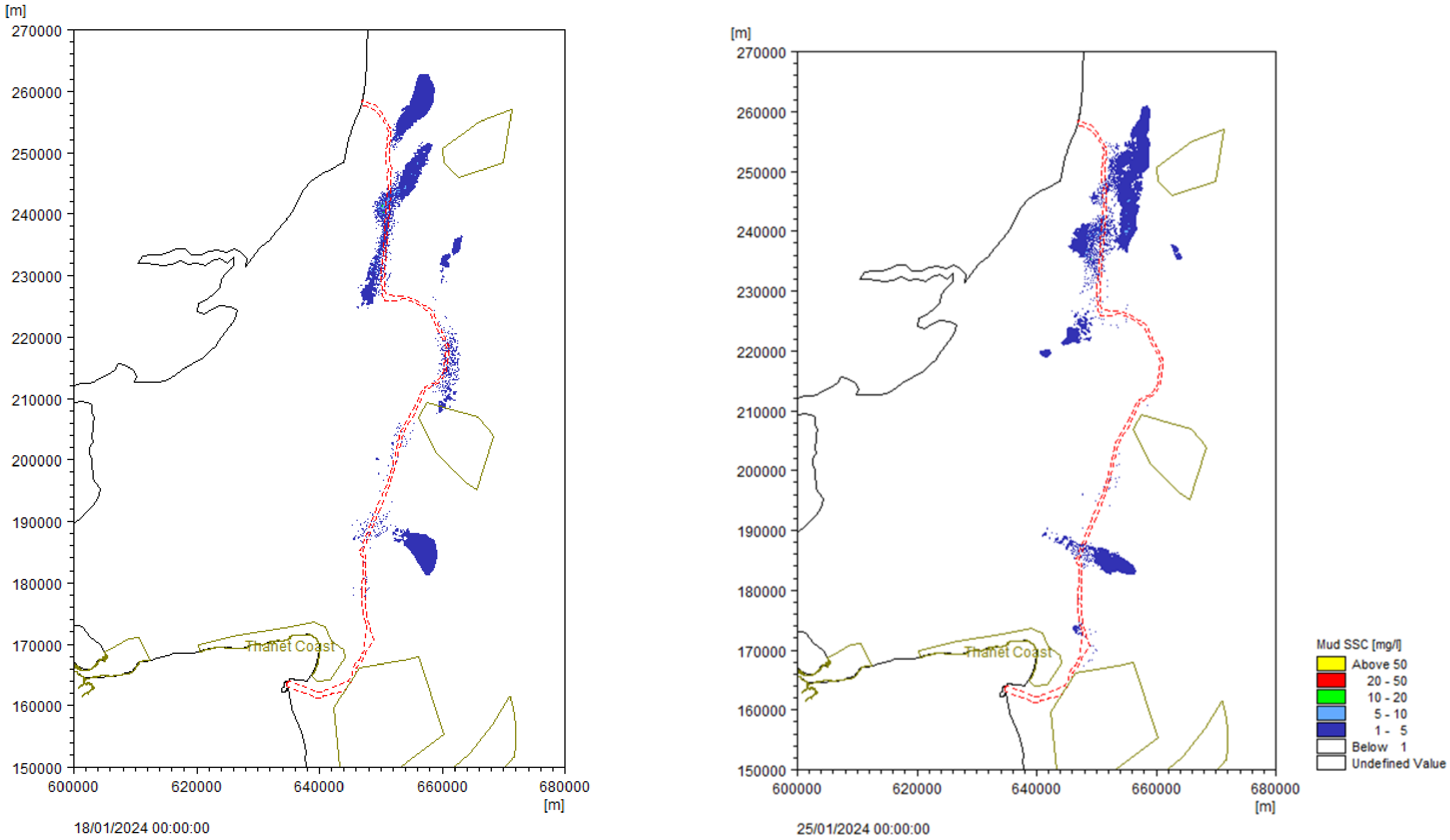


Plate 15 Mud SSC levels for jetting installation commencing on spring tides with output at +7 days (left) and +14 days (right) after start of activity

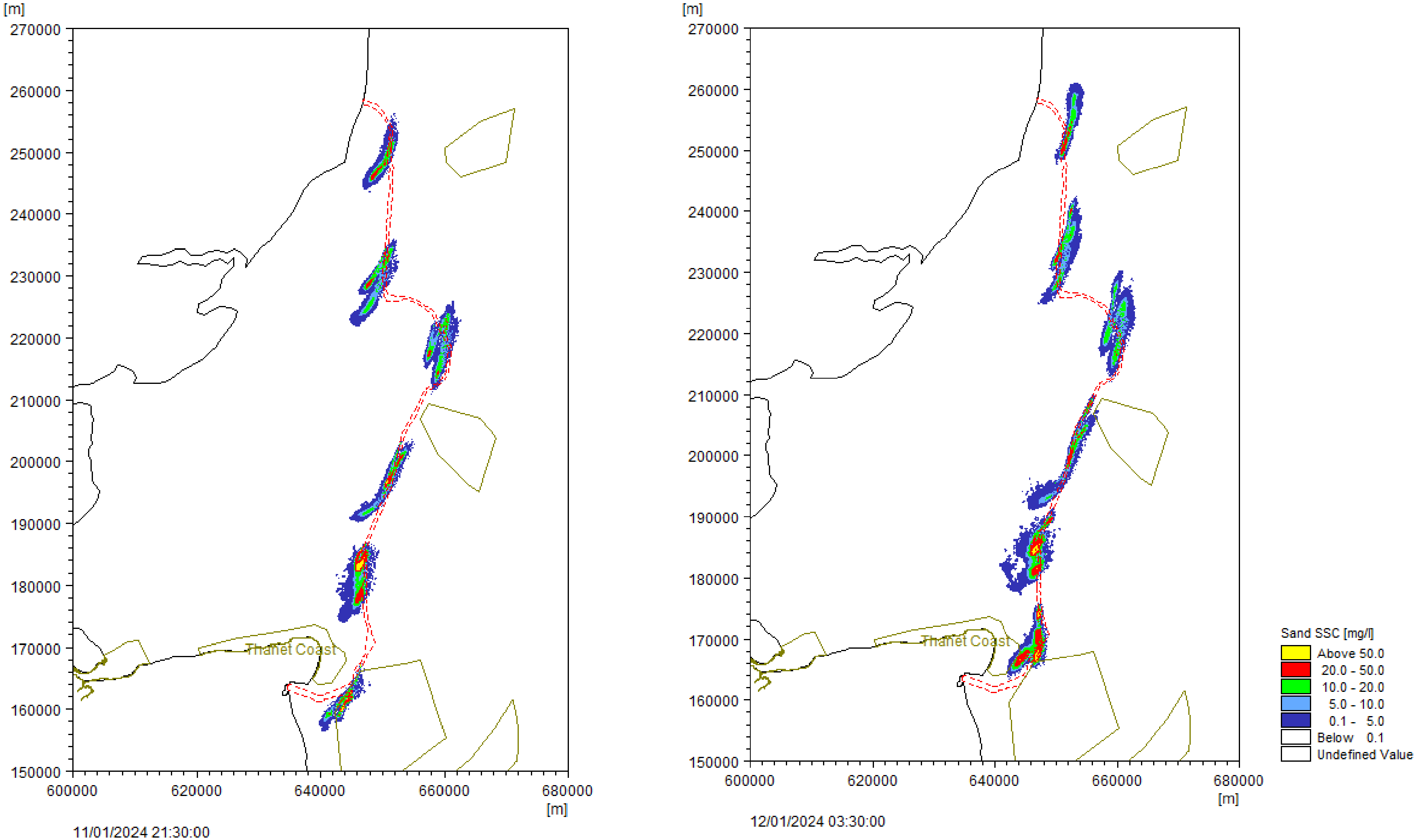


Plate 16 Fine sand SSC levels for jetting installation commencing on spring tides with output on flood (left) and ebb (right) tide after first 24 hours of activity

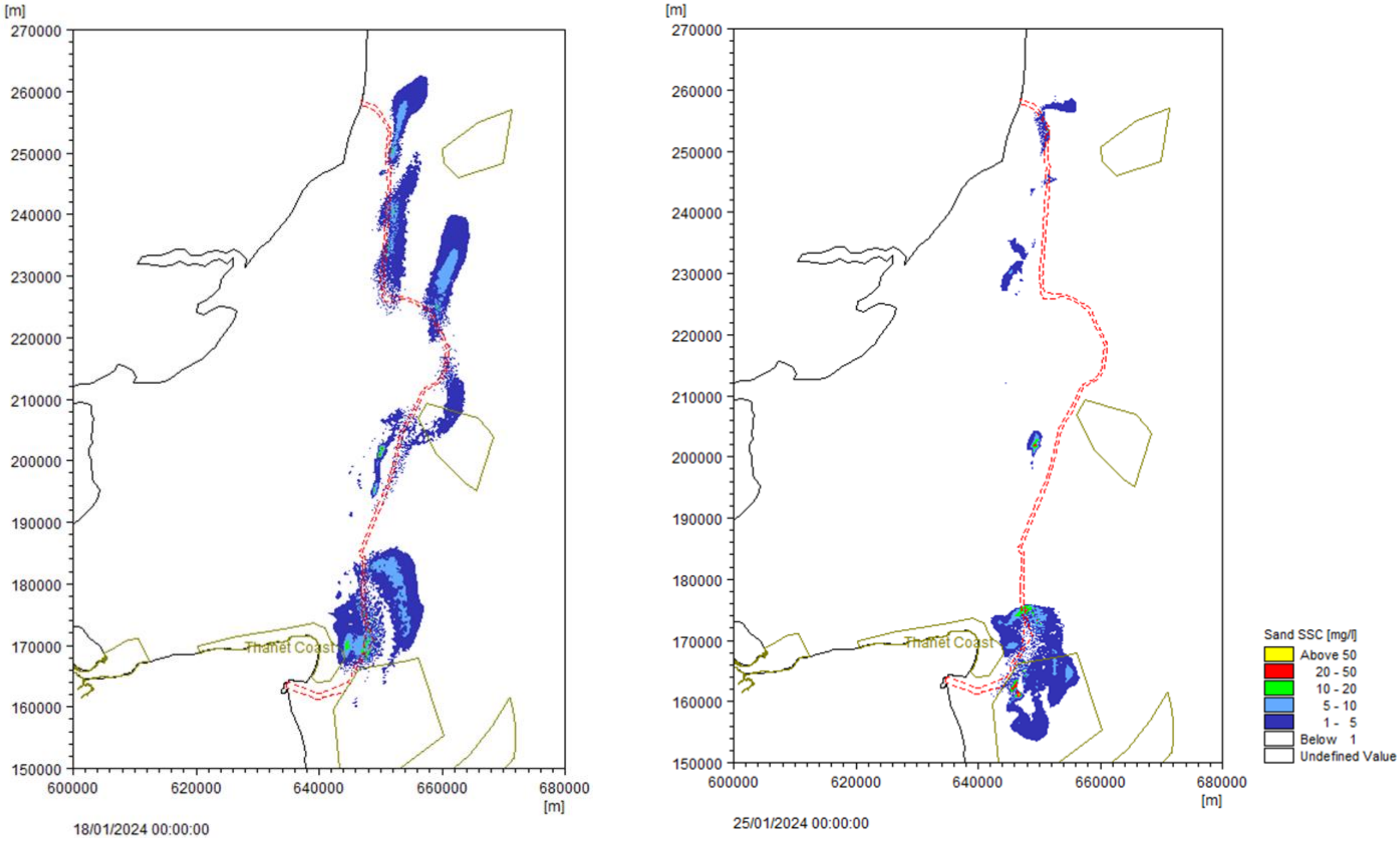


Plate 17 Fine sand SSC levels for jetting installation commencing on spring tides with output at +7 days (left) and +14 days (right) after start of activity

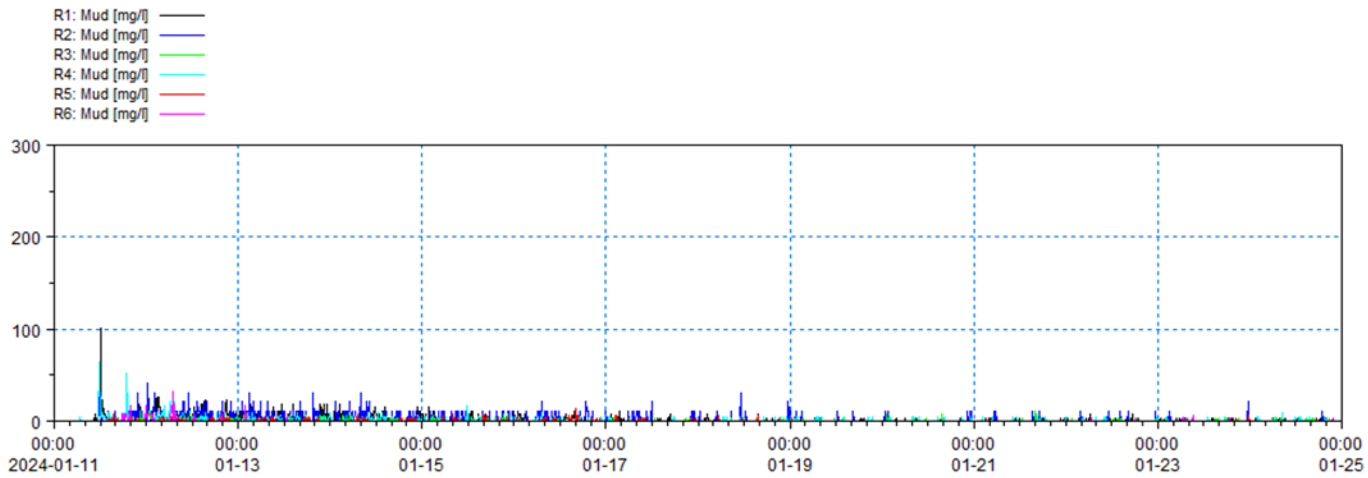


Plate 18 Time-series of mud SSC levels for jetting installation at central sediment release locations over 14-day period

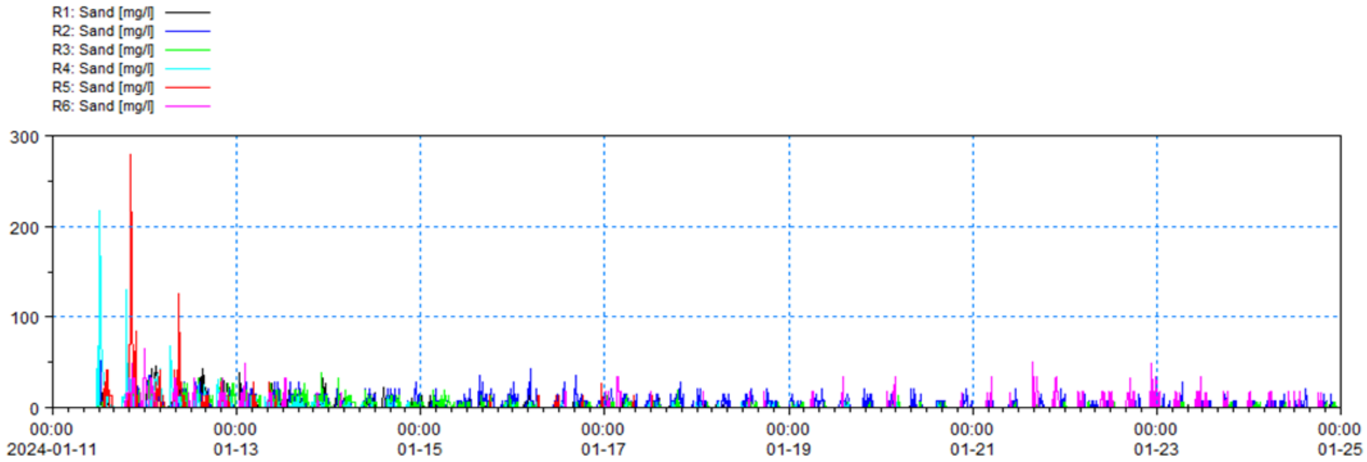


Plate 19 Time-series of fine sand SSC levels for jetting installation at central sediment release locations over 14-day period

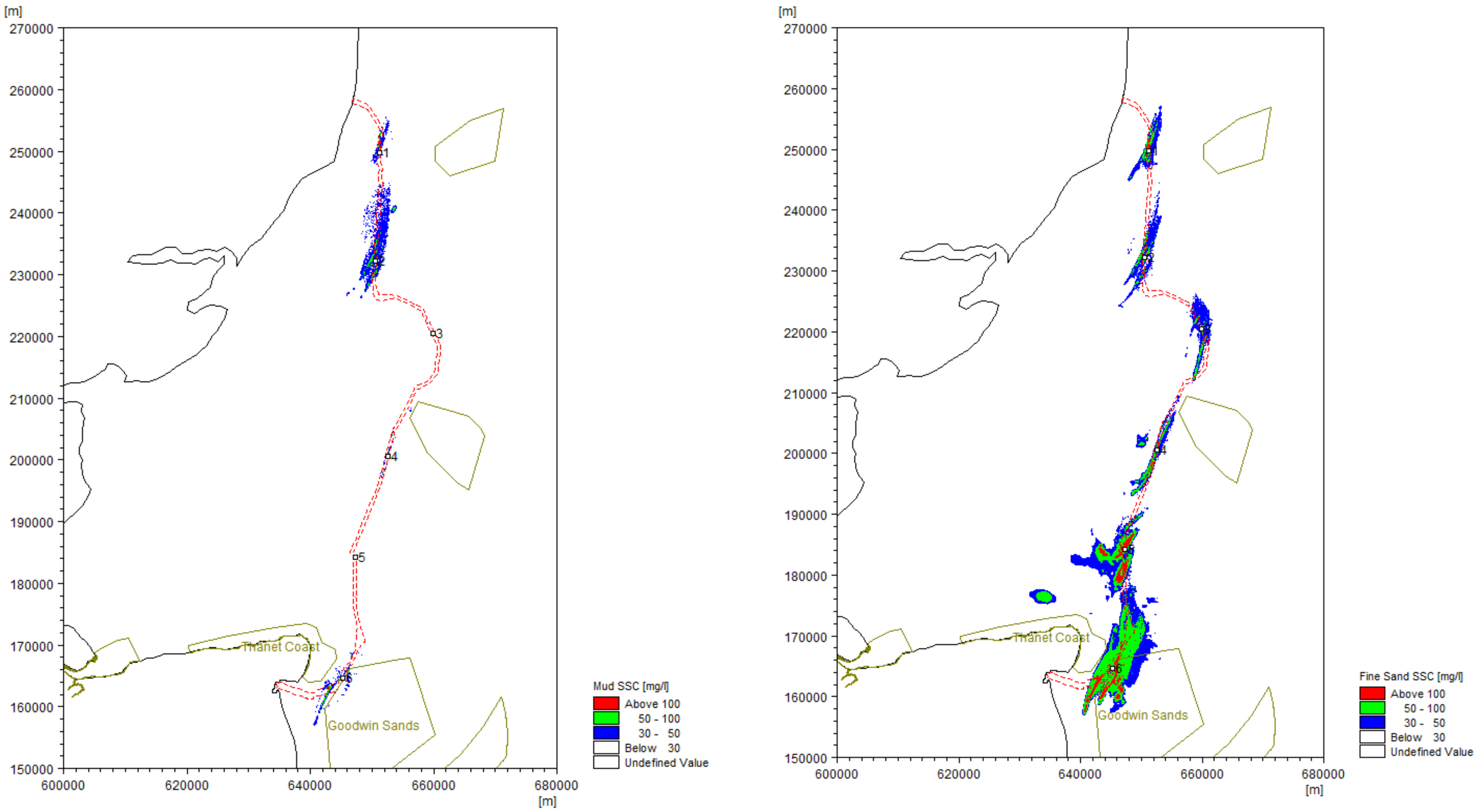


Plate 20 Maximum SSC levels over 14-day period for mud (left) and fine sand (right) for installation by jetting

SSC and Zone of Influence

3.3.7 ZOIs for SSC have been derived separately for the alternative cable installation methods with results from the modelling of finer sediment fraction involving the use of jetting techniques summarised in Table 10. Due to the enhanced dispersion with the use of jetting, the resulting sediment plumes show a degree of interaction making it more difficult to determine distances to the edges of the 30 mg/l and 100 mg/l SSC contours.

Table 10 Modelled SSC ZOI for fine sediment fractions with installation by jetting

Location	Approximate distance (km)[1] from cable trench	
	Mud [30 mg/l / 100 mg/l]	Fine Sand [30 mg/l / 100 mg/l]
R1	5 / 0	7 / 4
R2	12 / 3	12 / 4
R3	0 / 0	8 / 6
R4	4 / 1	9 / 8
R5	0 / 0	9 / 6
R6	9 / 0	14 / 11

Note:

1. Values estimated from dispersion modelling results for a threshold level of 30 mg/l and 100 mg/l.

3.3.8 Table 11 provides estimates of the SSC ZOI distance for coarser sediment fractions, as derived through consideration of the particle fall velocity and ambient currents.

Table 11 Estimated SSC ZOI for coarse sediment fractions with installation by jetting

Location	Approximate distance (m)[1] from cable trench		
	Medium Sand	Coarse Sand	Gravel
R1	20	10	5
R2	20	10	5
R3	20	10	5
R4	20	10	5

Location	Approximate distance (m)[1] from cable trench		
	Medium Sand	Coarse Sand	Gravel
R5	20	10	5
R6	20	10	5

Note:
Values estimated from calculation of fall velocity and assumed height above bed (+2 m for installation by jetting). The values provided do not account for potential re-erosion of the deposited sediment.

3.3.9 The distances provided to characterise the ZOIs are generally larger than found for installation by plough with the largest extent for the mud fractions found at location R2 off the Suffolk coast. The largest SSC ZOI for fine sand was found for sediment released from location R6 near the Kent coast where, as shown in Plate 20, a relatively large area of elevated SSC levels is shown as a result of the high proportion of sand at this location combined with complex flow patterns due to currents flowing eastwards from the Outer Thames interacting with currents flowing through the Straits of Dover.

Deposition and Zone of Influence

3.3.10 Plate 21 shows that due to the very low threshold shear stress for re-erosion for the mud particles, there are few areas where this material is able to settle on the seabed. The situation is similar for the fine sand particles with deposition limited to small magnitude accumulations of less than 0.1 mm in the areas shown on the plate although these areas are more widespread than predicted for the plough installation method. Due to the small magnitude of the deposition thickness, any accumulation of sediment on the seabed is unlikely to be detectable in the field.

3.3.11 Further detail of deposition trends are provided in the time-series plots for fine sand (Plate 22) and mud (Plate 23). Further analysis was undertaken to determine the maximum depth of deposition over a 14-day period, as shown in Plate 24. As before analysis of the maximum deposition over a 14-day period for a deposition thickness of 0.5 mm is used to define the extent of the ZOI, as given in Table 12.

Table 12 Estimated deposition ZOI for fine sediment fractions with installation by jetting

Location	Approximate distance (km)[1] from cable trench	
	Mud	Fine Sand
R1	7	8
R2	13	10
R3	3	10
R4	3	10

Location	Approximate distance (km)[1] from cable trench	
	Mud	Fine Sand
R5	0	17
R6	9	14

Note:

1. Values estimated from dispersion modelling results for a threshold deposition depth of 0.5 mm.

3.3.12 Table 13 provides estimates of the deposition ZOI distance for coarser sediment fractions, as derived through consideration of the particle fall velocity and ambient currents.

Table 13. Estimated SSC ZOI for coarse sediment fractions with installation by jetting

Location	Approximate distance (m)[1] from cable trench		
	Medium Sand	Coarse Sand	Gravel
R1	20	10	5
R2	20	10	5
R3	20	10	5
R4	20	10	5
R5	20	10	5
R6	20	10	5

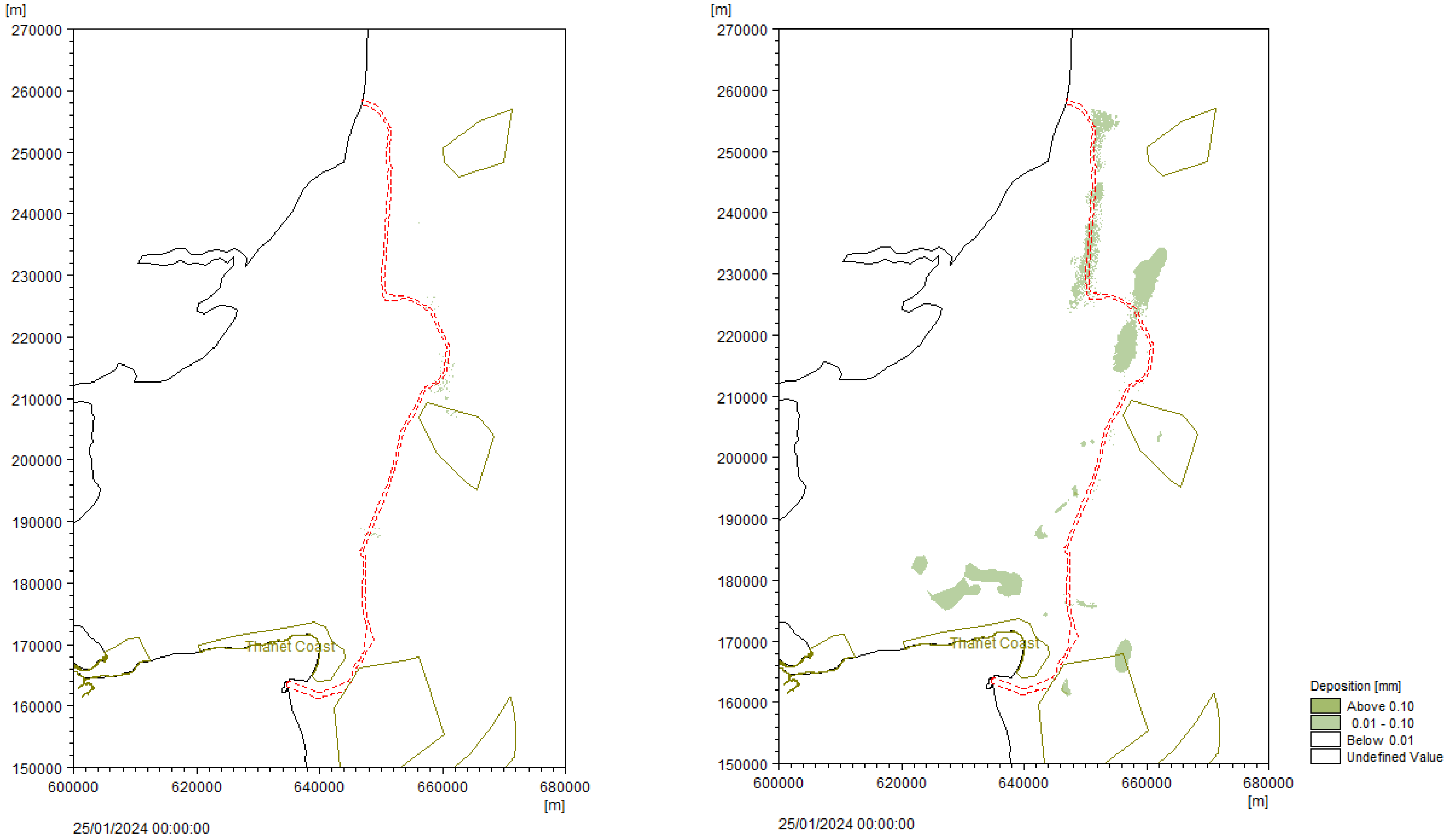


Plate 21 Instantaneous depth of deposition with jetting installation for mud (left) and fine sand (right) at end of 14-day period

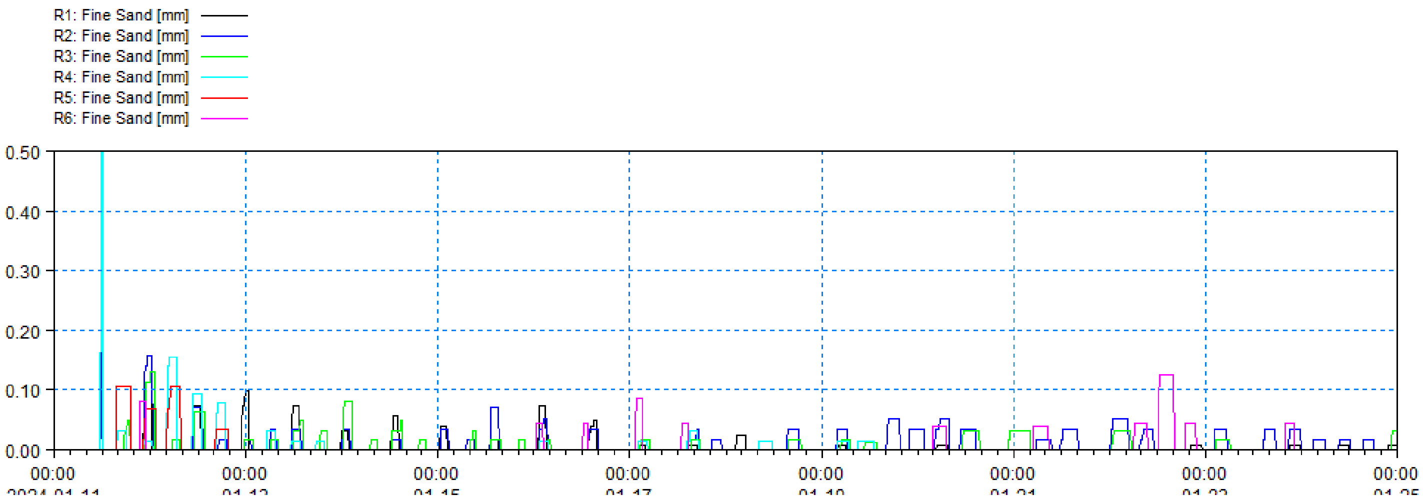


Plate 23 Time-series of fine sand deposition for jetting installation at central sediment release locations over 14-day period

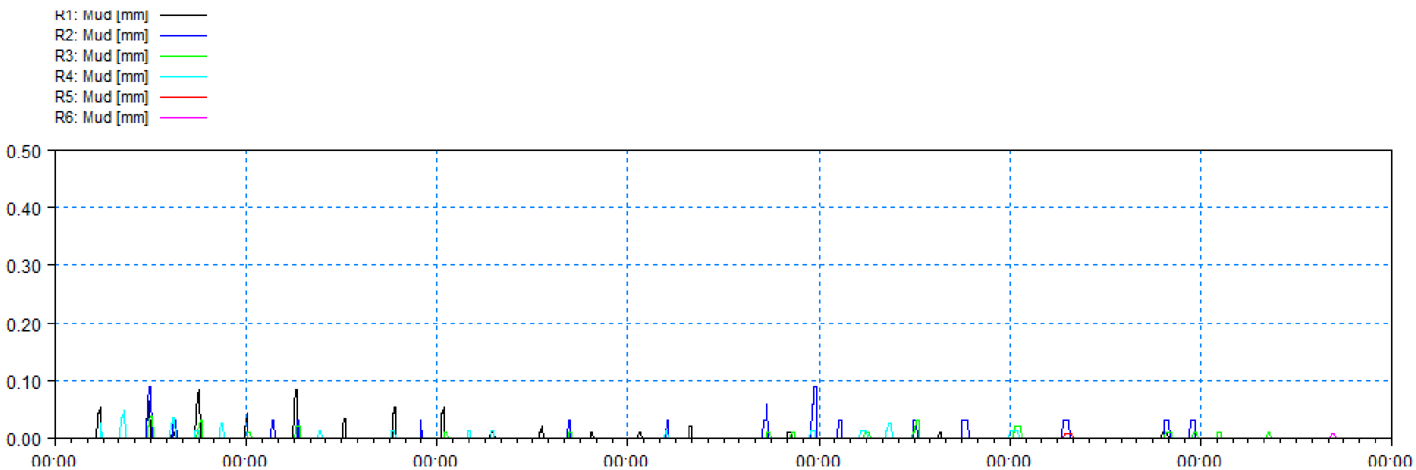


Plate 22 Time-series of mud deposition for jetting installation at central sediment release locations over 14-day period

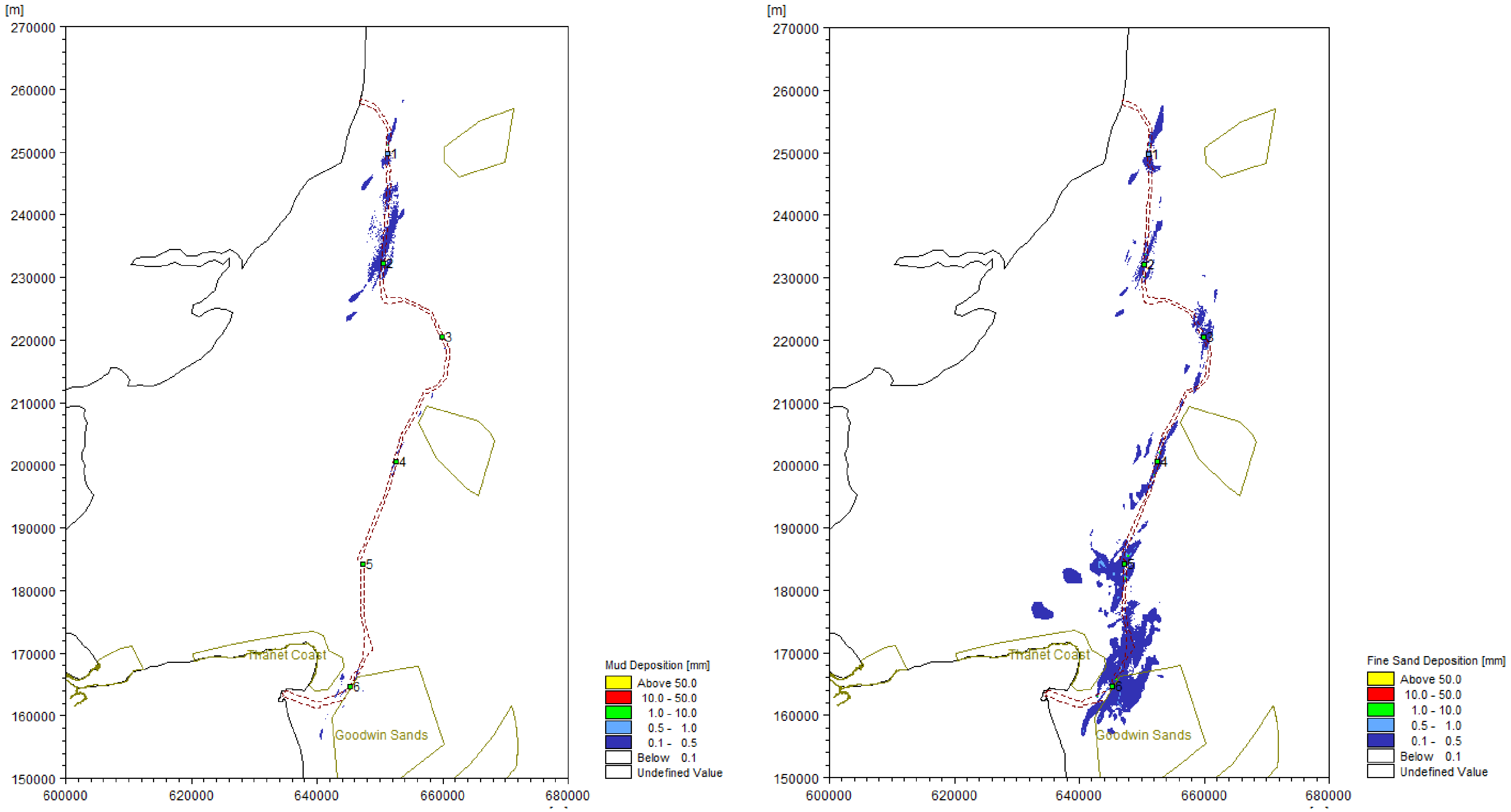


Plate 24 Maximum deposition over 14-day period for mud (left) and fine sand (right) for installation by jetting

4. Summary

4.1 Suspended sediment concentrations

4.1.1 Total SSC would result from a combination of fine sand and mud concentrations. Close to the release location there will be additional contributions from coarser sediment fractions although these will rapidly settle out of suspension (i.e. within a few minutes).

4.1.2 Both the mud and fine sand fractions are shown to develop plumes of suspended sediment which are transported by the ambient currents. The results presented show that with cable installation by plough, elevated SSC levels are relatively low and transitory with a short duration for any specific location. As expected, levels of elevated SSC are higher when using the jetting method of installation.

4.1.3 The circulatory currents immediately to the north of the Kent coastline provide more rapid dilution of sediment plumes relative to release locations further to the north where flow directions tend to be bi-directional rather than circulatory due to the enhanced degree of mixing.

4.1.4 If elevated SSC levels are considered to be unacceptably high, this could be mitigated to some extent by reducing the rate of cable installation. For particularly sensitive areas, further consideration could be given to the timing of installation relative to the phasing of the tide so that the initial, high concentration plume is carried away from the sensitive area while the tidal currents are flowing in the opposite direction.

4.1.5 The modelling undertaken has applied conservative assumptions at each stage and therefore provides an upper-bound estimate of elevated SSC levels as a result of cable installation processes.

4.2 Sediment deposition

4.2.1 Based on the results presented for two alternative installation methods and two sediment fractions, the associated deposition on the seabed is not expected to lead to any adverse effect since any accumulation is unlikely to be detectable. The potential risk of smothering of sensitive benthic habitats is therefore considered to be negligible.

5. References

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RPS. (2015). *Modelling Sediment Dispersion from Cable Burial for Seacoast Reliability Project, Little Bay, New Hampshire. .*

Soulsby, R. (1998). *Dynamics of Marine Sands .*

United Kingdom Hydrographic Office. (2024). *TotalTide.*

Winterwerp, J., & van Kesteren, W. (2004). *Introduction to the physics of cohesive sediment in the marine environment.*

6. Annex A

6.1 Introduction

Background

6.1.1 This annex provides details of the tidal model used to describe flow conditions within the North Sea and presents evidence confirming that the model remains suitably well calibrated following adaptations to the mesh implemented to provide enhanced resolution along the cable route between the Suffolk and Kent landfalls.

Model Set-up

6.1.2 This section provides details of the set-up of the numerical tidal model including the extent of the model domain, bathymetry data and boundary conditions. The model is configured using the MIKE21 software and therefore provides a 2-dimensional, depth-averaged representation of tidal currents.

Model Domain

6.1.3 The full extent of the English Channel/North Sea model domain is shown in Plate 25 together with the marine cable corridor.

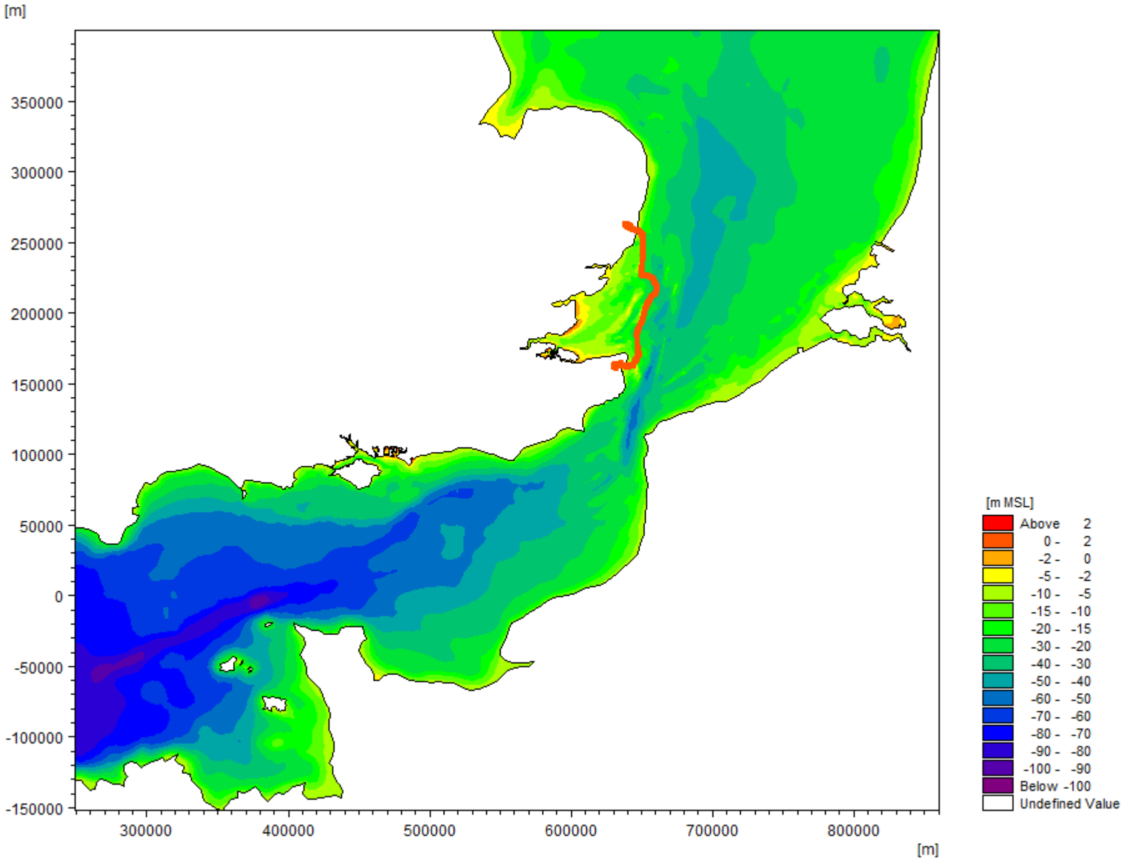

Plate 25. English Channel/North Sea model domain with marine cable corridor (red line)

6.1.4 The mesh resolution in offshore regions is typically 2000 m reducing to approximately 1000 m at the coastline. The model mesh was refined along the entire corridor route providing a typical resolution of 70 m, which is suitable for the modelling of sediment dispersion processes (Plate 26). The use of a coarser mesh would lead to excessive numerical dispersion and inaccuracies in the concentrations predicted by the model.

6.1.5 Due to the relatively coarse model mesh covering most of the model domain, bathymetry applied in the model was based on the GEBCO gridded bathymetric dataset having a 15-arc second resolution (i.e. approximately 450 m). This provides a seamless dataset which also allows large-scale bathymetric features within the model domain to be represented.

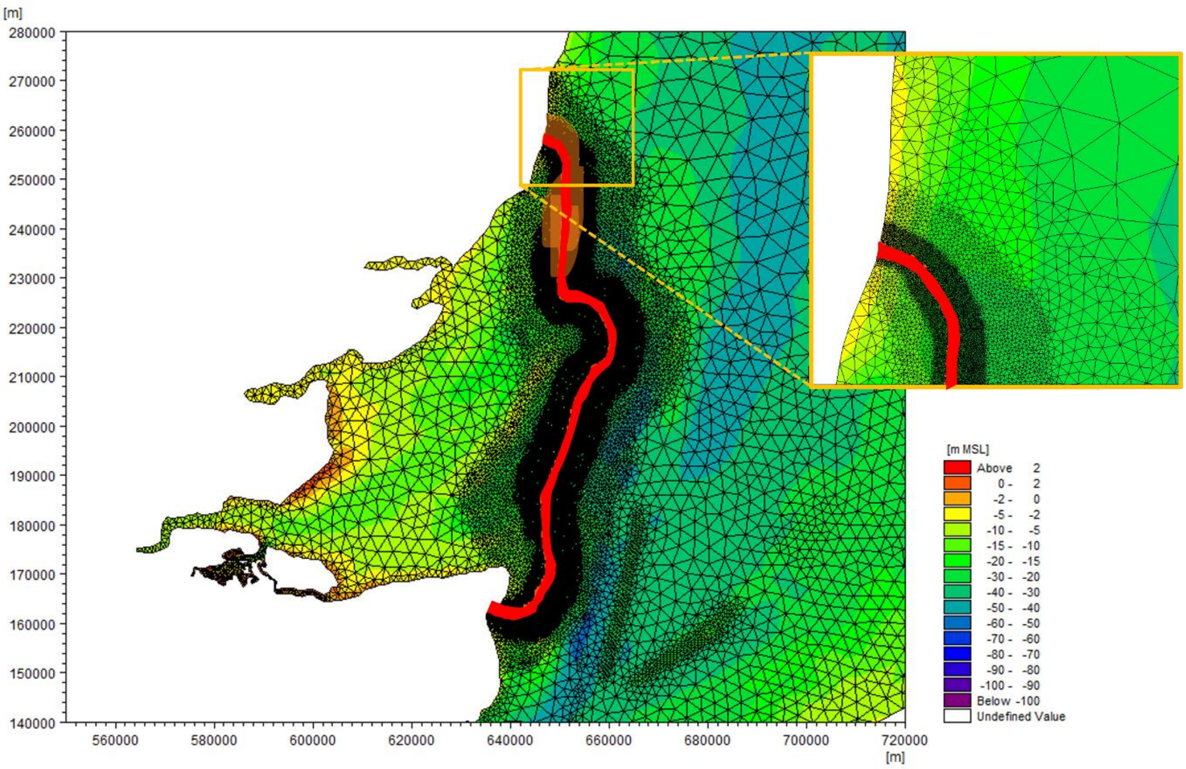

Plate 26 Model mesh and bathymetry along marine cable corridor (red line) with inset showing mesh detail at the Suffolk landfall

6.2 Boundary Conditions

6.2.1 Time-varying water level boundary conditions were applied along for the north and west open boundaries of the English Channel/North Sea model derived using harmonic tidal constituents from the Proudman Oceanographic Laboratory (POL) CS20 continental shelf model. Time-varying water levels were calculated for pre-defined locations along each boundary, with linear interpolation used to provide data for all intermediate model mesh points.

6.3 Model Validation

6.3.1 The original English Channel/North Sea model was calibrated using available data for a period in 2010. The boundary conditions of the model have since been updated to 2024 prior to undertaking the validation exercise. Also, the model mesh has been modified internally to provide enhanced resolution along the cable corridor. As a result of these changes, a model validation exercise has been undertaken to demonstrate that the level of calibration achieved using the original model set-up has not been affected. The approach used involves a qualitative assessment based on a visual inspection of the relevant datasets.

Validation Data

6.3.2 A 13-day model calibration period was selected covering both spring and neap tides from the start of January 2024. Predictions of tides and currents prepared using the UKHO TotalTide software were used as the reference dataset during the validation process. The currents, also referred to as tidal streams, are based on surface measurements which are generally slightly higher than the depth-averaged values calculated by the model due to the added influence of bottom friction.

6.3.3 The location of tide gauges and tidal stream data points used for validation of the model are shown in Plate 27. The tide gauge locations closest to the Suffolk and Kent cable landfalls were chosen for the comparison of water levels with the tidal stream locations selected for points distributed along the cable corridor.

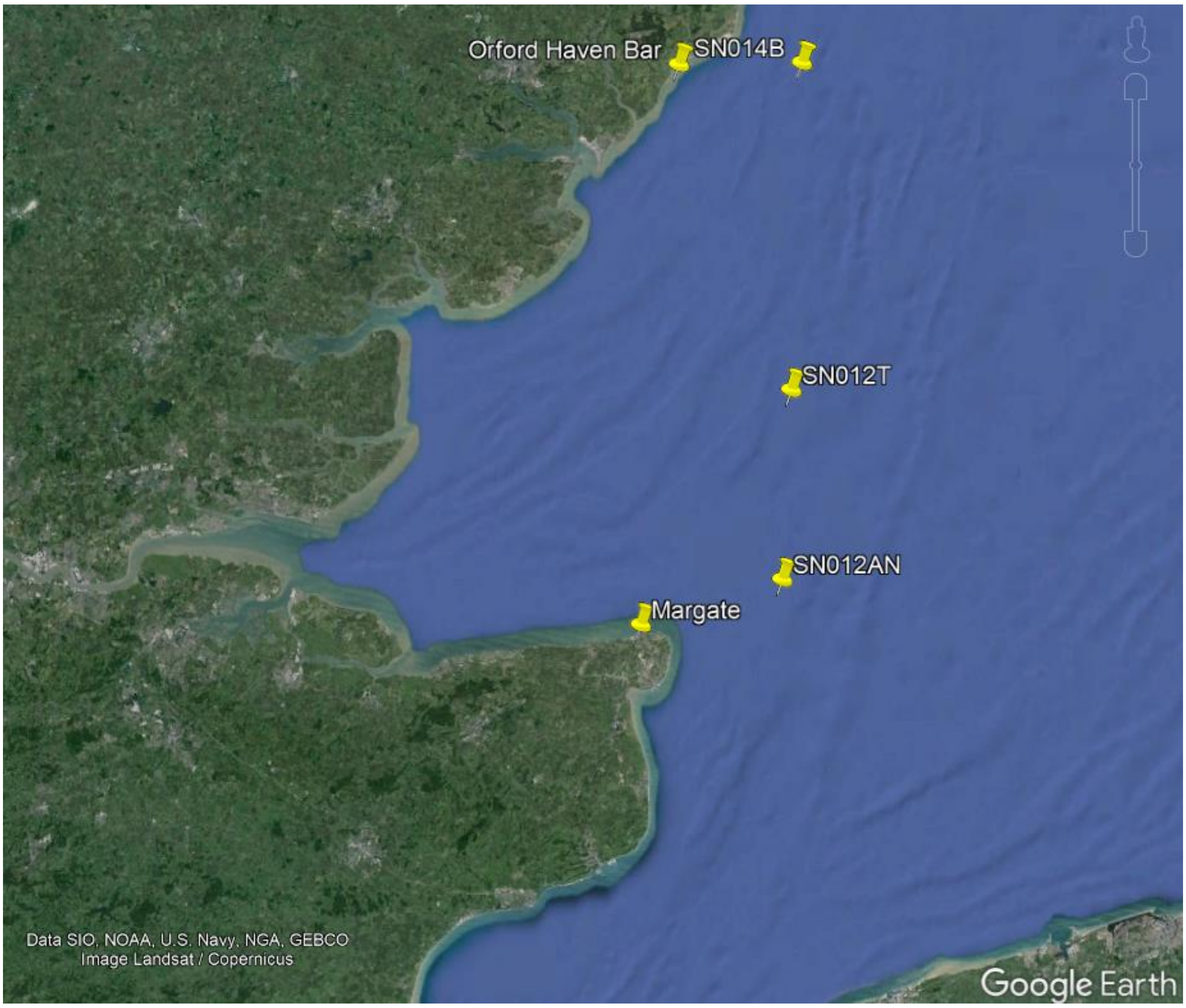

Plate 27 Tide gauge and tidal diamond locations used for model validation

Validation of Water Levels

6.3.4 Water levels have been validated for two locations corresponding to tide gauge locations closest to the Suffolk and Kent landfall sites at Orford and Margate, respectively. Plate 28 and Plate 29 show the comparison between predicted (TotalTide) and modelled water levels at the two locations.

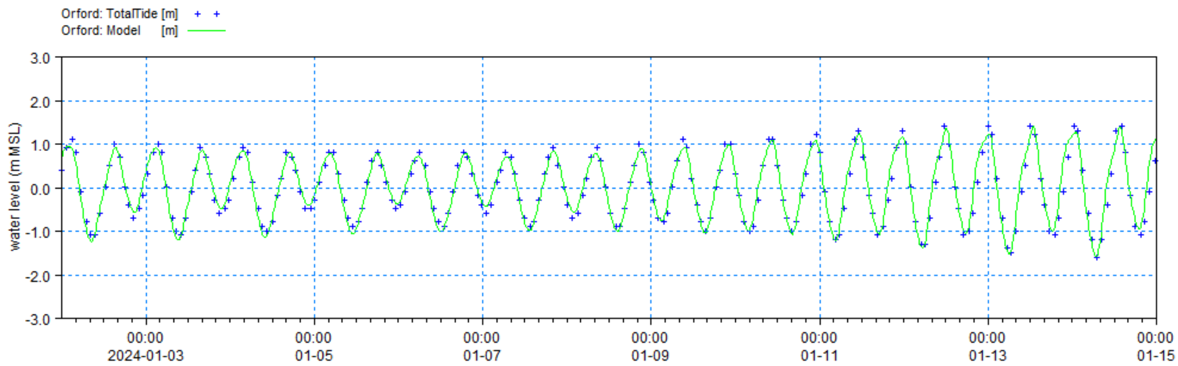

Plate 28 Comparison of model and predicted water levels at Orford

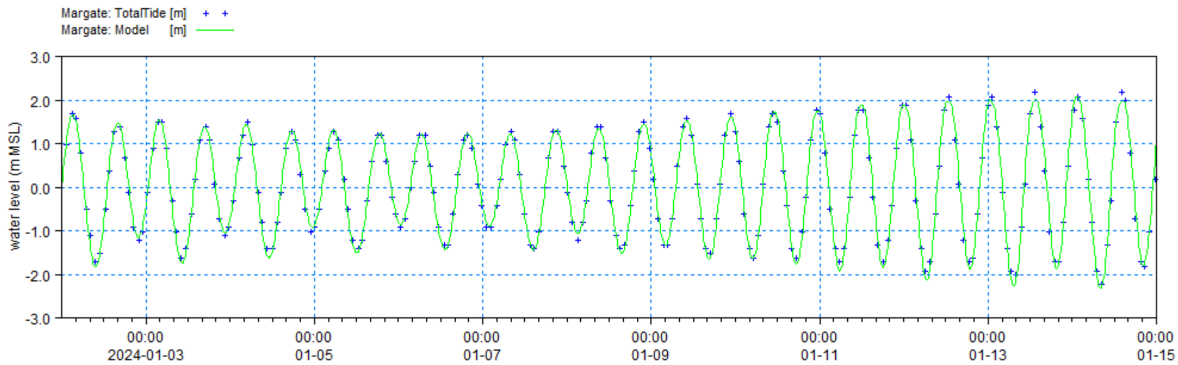

Plate 29 Comparison of model and predicted water levels at Margate

6.3.5 Tides at both Orford and Margate are shown to be accurately predicted by the refined model in terms of both phasing and water level over the full 13-day period of spring and neap tides.

Validation of Currents

6.3.6 Tidal currents predicted using the TotalTide software provide values at 30-minute intervals which are presented to the nearest 0.1 knot. These values were converted to metres/second to enable a direct comparison to be made with the model output. As a consequence of the limited precision of the predicted values from TotalTide, the curve showing the current values is sometimes truncated therefore providing an underestimate of the peak current value. This limitation should be taken into account when assessing the comparison of model and predicted values.

6.3.7 At location SN014B off the Suffolk coast, Plate 30 shows that the modelled current speeds closely match the TotalTide predicted values in terms of phase and magnitude. The model appears to overestimate peak current speeds slightly, partly due to the truncated peak values from the TotalTide predictions, as previously mentioned. Plate 31 shows that variations in current direction are accurately reproduced by the model, including detailed features around the turn of the tide.

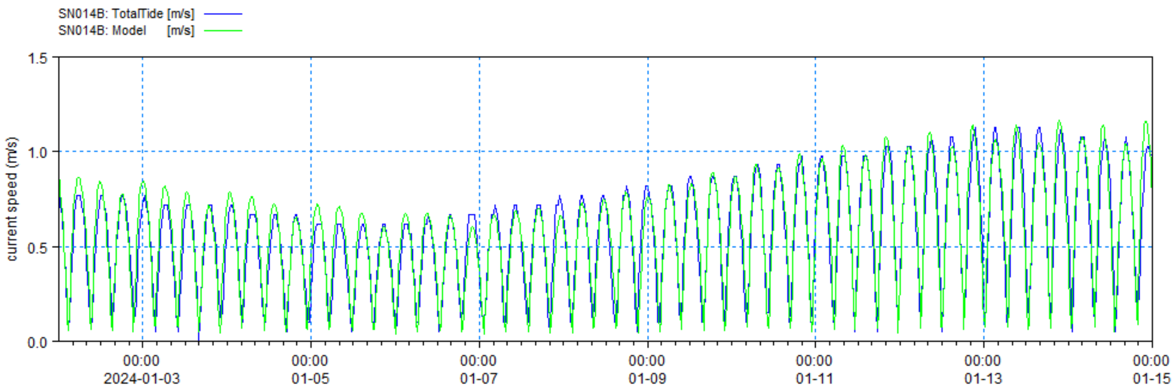

Plate 30 Comparison of model and predicted current speed at location SN014B

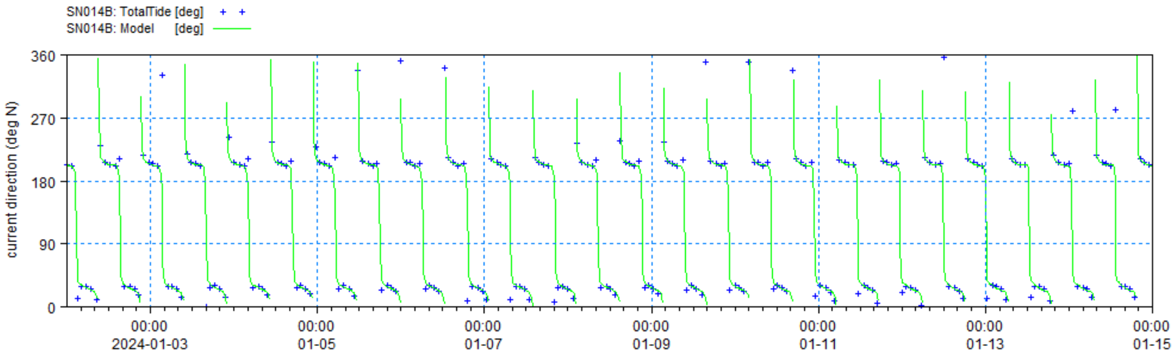

Plate 31 Comparison of model and predicted current direction at location SN014B

6.3.8 Location SN012T is in the Outer Thames Estuary near the mid-point along the cable corridor between the Suffolk and Kent landfalls. Plate 32 shows that the relative magnitudes of the peak ebb and flood currents are accurately reproduced by the model and likewise, subtle variations in the direction of flow are also well reproduced by the model at this location (Plate 33).

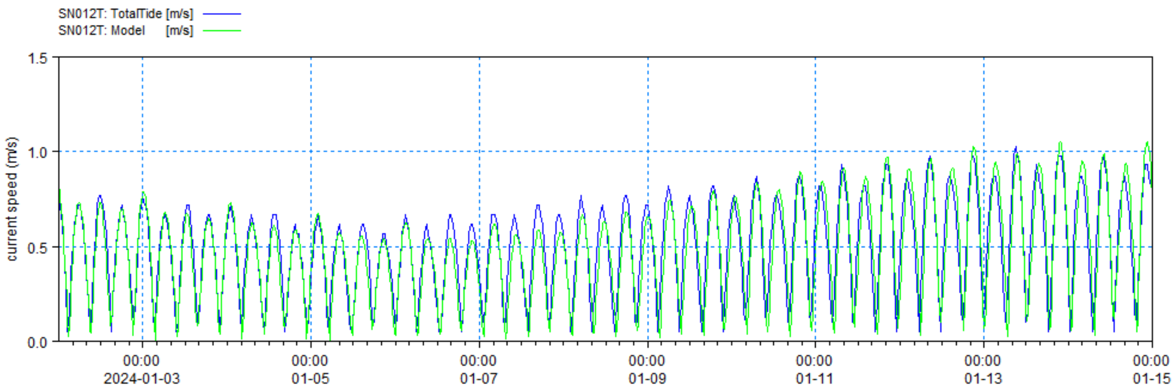

Plate 32 Comparison of model and predicted current speed at location SN012T

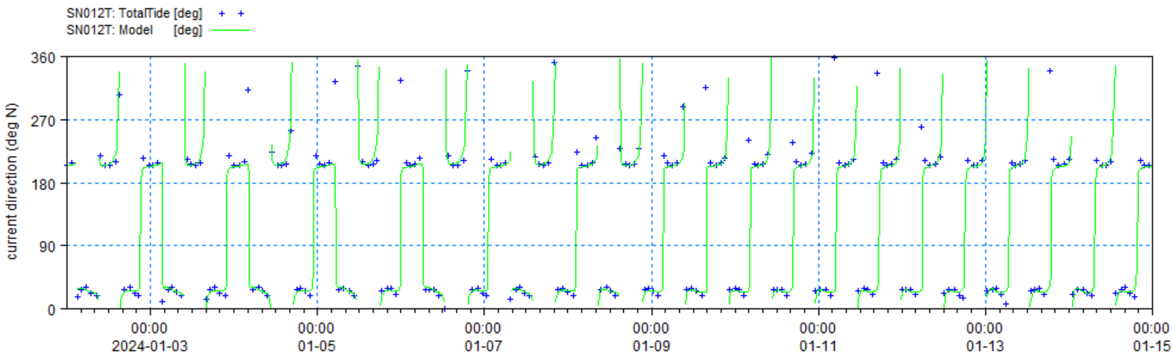

Plate 33 Comparison of model and predicted current direction at location SN012T

6.3.9 At location SN012AN off the Kent coast, currents are slightly weaker than at the two locations further north rarely exceeding 1 m/s, as shown in Plate 34 The currents are more rotational at this location as indicated by the current magnitude which remains above 0.1 m/s rather than reducing to zero. Current directions, as shown in Plate 35, show a gradual variation rather than a sudden switch in direction which is apparent in both predicted and measured datasets which is typical of a rotational flow pattern.

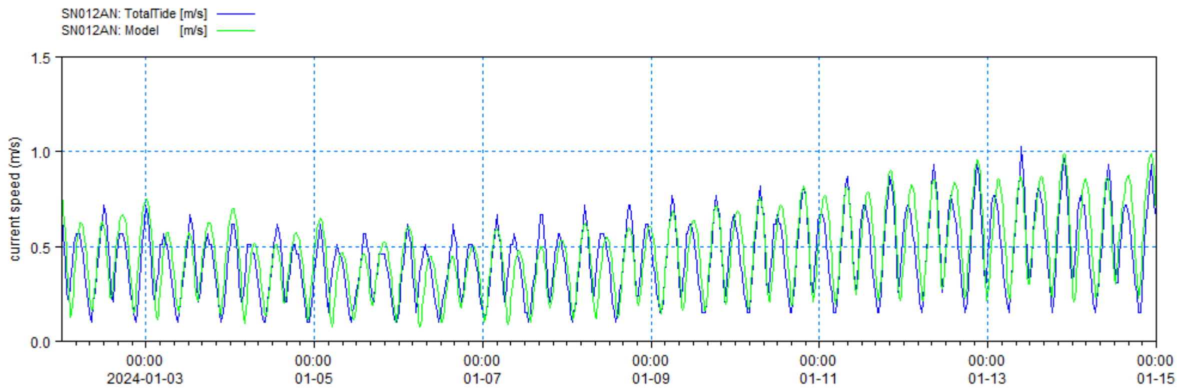

Plate 34 Comparison of model and predicted current speed at location SN012AN

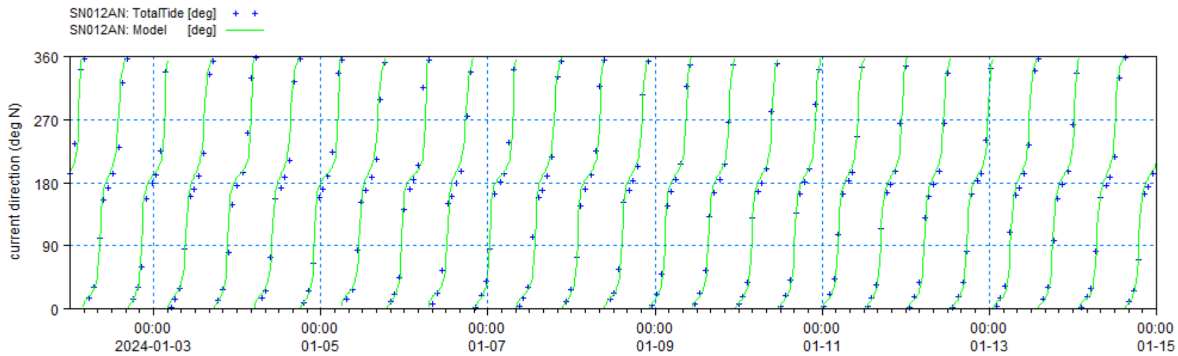

Plate 35 Comparison of model and predicted current direction at location SN012AN

6.4 Summary

Validation of Water Levels

6.4.1 Standards for the calibration of water levels[2] require model values to be within ±0.1 m or ±10% of the tidal range for spring tides, ±15% for neap tides. For both tide gauge locations on the Suffolk and Kent coastlines, a visual inspection of the water levels shows that they are consistently within these tolerances. The phasing of the model tide is also shown to be consistent with the reference dataset with an error estimated to be much less than the ±15-minute allowance suggested in the guidelines.

Validation of Currents

6.4.2 Standards for the calibration of current speeds recommend that model values are within ±0.1 m/s or ±10-20% of the reference values. Current directions should ideally be within an error band of ±10°and the phasing within ±15 minute. The current speeds and directions at locations SN014B and SN012T are accurately simulated by the model. Conditions are more complicated at location SN012AN where there is interaction between flows from the Outer Thames and Dover Straits, however, the model still provides a good representation of variations in current speed over the spring-neap cycle with directions shown to very closely match the reference dataset.

6.5 Conclusion

6.5.1 An assessment of model validation has been undertaken based on a visual inspection of model output compared to a reference dataset of predicted tides and currents, as calculated using the UKHO's TotalTide software.

6.5.2 Overall, the hydrodynamic model is demonstrated to provide an accurate representation of conditions along the length of the marine cable corridor and is therefore recommended for use in the further assessment of sediment dispersion processes.

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