EGL 3 Sediment Dispersion Assessment, Scottish MEA

PU061_TN03v1 Spreadsheet-Based Modelling Tool

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1. Introduction

The Eastern Green Link (EGL) 3 is a proposed high voltage direct current link between Peterhead in Scotland and Anderby Creek in England.

Sediment suspended during installation of the submarine cables could result in temporary increases in suspended sediment concentrations (SSC) which could have an adverse effect on water quality. Subsequent deposition once material re-settles to the bed could also result in smothering.

To inform the Marine Environmental Appraisal for the Scottish Offshore Scheme, a spreadsheet based model which was previously developed for assessing impacts associated with the English Offshore Scheme, has been applied to assess the potential adverse effects on water quality and smothering from construction related activities, including sandwave clearance, excavation of HDD exit pits and cable trenching operations.

This technical note is structured as follows:

- details on the baseline characteristics (including sediment properties and flow field) are provided in Section 2.
- details on the methodology are provided in Section 3;
- results are presented in Section 4; and
- a summary is provided in Section 5.

1.1. The Study Area

The Study Area includes the proposed submarine cable corridor for EGL 3 within Scottish waters (seaward of mean high water springs) plus the Red Line Boundary (which are nominally 500 m wide, widening in areas where there are seabed features such as sandwaves, challenging seabed conditions or sensitive habitats to allow for micro-routing) and a 15 km buffer either side. This buffer is informed by the tidal excursion, which varies along the proposed submarine cable corridor. Regional scale modelling tools indicate that the largest tidal excursions occur close to the proposed landfall where they are 10 km on a mean tide (equivalent to around 14 km on a spring tide). In other areas of the proposed submarine cable corridor tidal excursions are much shorter, being around 4 km on a mean tide. The adoption of a 15 km buffer throughout provides a precautionary approach.

Kilometre Points (KPs) are used throughout this Chapter to provide context as to where within the Scottish Offshore Scheme a feature lies. The KP's are referenced as KP436 at the Scottish/English EEZ to KP580.6 at landfall at Peterhead (with KP0 to KP435 within the English Offshore Scheme).

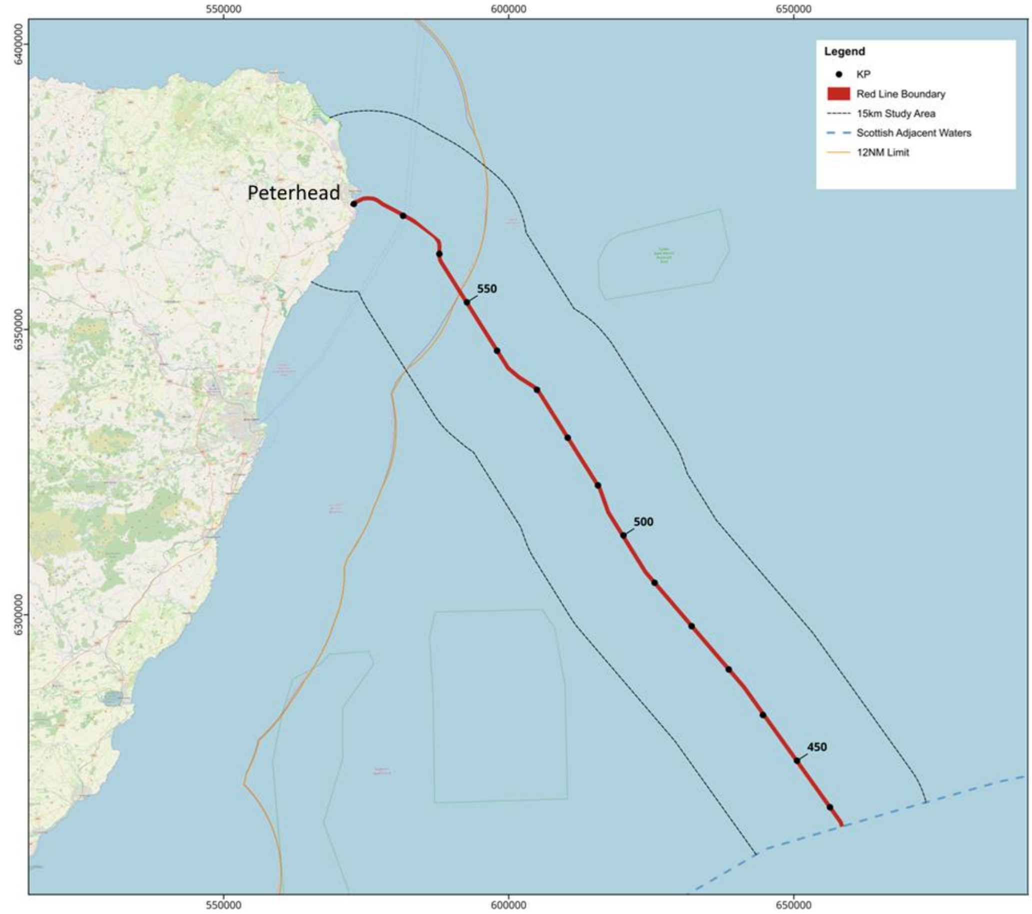

Figure 1. The EGL 3 proposed submarine cable corridor and Study Area.

2. Baseline Characterisation

A characterisation of the baseline conditions was undertaken to determine the sediment properties (particle size distribution (PSD) and dry sediment density) and hydrodynamic flow conditions along the proposed submarine cable route. Results on sediment properties are presented at a number of KPs in

Table 1.

The PSD varies between samples, the samples were selected to include those with the highest percentages of fines (at KP470) to provide a conservative assessment of the potential area of impact. This is because fine sediment will remain in suspension and disperse, while coarser grain fractions will settle to the bed close to the location of disturbance. Other selected KP's coincide with the area of fastest tidal flow (KP575), proximity to protected sites (KP564), proximity to sandwave areas (KP548) and proximity to horizontal directional drilling (HDD) exit pit locations (KP579).

The dry sediment density was derived from the percentage of fines based on the work of Allersma (1988) as presented in Van Rijn (1993).

Table 1. PSD at locations along the proposed submarine cable corridor.

Location	Clay to medium silt 2 to 47µm	Coarse silt 47 to 63 µm	Very Fine Sand 63 to125 µm	Fine Sand 125 to 250 µm	Medium Sand 250 to 500 µm	Coarse sand and above (>500 µm) >	% age of fines
KP470	14	0	12	57	16	1	14
KP548	7	1	4	26	44	18	8
KP564	1	1	1	7	18	72	2
KP575	1	0	1	8	24	66	1
KP579	1	1	7	31	51	9	2

Tidal currents in the Study Area are generally orientated southwards on the flood tide and northwards on the ebb tide. The currents close to the proposed landfall in the Study Area are bi-directional in nature, aligned with the coast, while currents become slightly more orbital in nature offshore. Fastest currents occur close to the landfall site at around KP575 (with spring tide flows peaking around 1.05 m/s), while slower flows occur close to the English/Scottish border around KP470 where peak spring flows are approximately 0.5 m/s. Peak neap current speeds are just over half the quoted peak spring tide current speeds.

There is a slight dominance in the northward flowing ebb currents. Superimposed on the regional scale flow pattern, local flow variations can be expected to occur in response to bathymetric features (for example to realign with channel features, or around banks).

The North Sea is particularly prone to surge-driven flows during winter months, when intense low-pressure systems, particularly from the North Atlantic, dominate the region. These systems can generate strong easterly and / or northerly winds and heightened sea levels, driving elevated surge flows into the North Sea. These flows are accentuated by strong surface winds, occurring at high tide (particularly during a spring tide), topography that funnels flows into narrow channels, and shallow regions of seabed including coastlines. Elevated surge flows can temporarily lead to an increase in sediment resuspension and transport, particularly in shallow regions and along coastlines (Spencer et al., 2015).

Table 2. Peak spring flow speeds at locations along the proposed submarine cable corridor (ABPmer, 2017).

Location	Peak flow speed (m/s)
KP470	0.50
KP548	0.76
KP564	0.90
KP575	1.05
KP579	0.91

3. Method

The key inputs into the model include:

- ambient flow speed;
- sediment release height (which will depend on the construction method);
- sediment fall velocity (which will depend on the sediment properties); and
- sediment release rate (which will depend on the construction method and sediment properties).

Details on the flow speeds in the Study Area were provided in Section 2. Details on the other model inputs are provided in the Sections 3.1 to 3.3.

The plume concentration was calculated at incremental distances from the source of the sediment release and tracked until the SSC dropped below 5 mg/l (which is unlikely to be discernible from background SSC and SSC variability in the Study Area based on information in Cefas (2016)). Only a single flow speed was applied, irrespective of time or distance from release. In reality flows would vary both spatially and temporally, however the application of the peak spring flow speed and given the fact that the proposed submarine cable corridor passes through the area of highest flows, this assumption will provide a conservative assessment with respect to plume spread. The plume spread was accounted for by the application of a low dispersion (0.2 m^2/s) applied in perpendicular to the direction of travel.

Estimates of sediment thickness of deposited material were calculated from the SSC at the time at which the sediment settled to the bed (based on a single sediment release height and settling velocity per representative grain size) to determine a sediment mass and associated deposit thickness. This approach will provide a conservative assessment of sediment thickness on the bed, since in reality sediment will be released at a range of heights and particles will therefore settle to the bed gradually over the settling period, spreading the sediment more thinly over a wider area up to the maximum distance reported.

For fines (<63 µm) the sediment mass was converted to deposit thickness using an *in situ* density of 135 kg/m^3. This is a low density, representative of freshly deposited sediment with a high *in situ* water content and overtime it is likely that sediment would settle and compact, increasing the *in situ* density and reducing the thickness of the deposit. For sands and coarser sediment fractions an *in situ* density of 1,250 kg/m^3 was applied to convert sediment mass to deposit thickness. This is because sandy sediment is non-cohesive and tends to hold less water than fines and will therefore have a much higher dry sediment density. The application of the faster peak spring tide flows and higher release heights were applied to provide an indication of the maximum distance from the sediment release location that impacts could occur, while application of slower neap tide flows and lower release heights were applied to provide an indication of the maximum thickness of deposits associated with each representative grain size. Sediment thicknesses are therefore quoted as a range.

3.1. Sediment Release Height

The height of release of sediment disturbed was assumed to be 5 m above the bed for cable trenching with a controlled flow excavator (CFE). In reality, the actual height of sediment release for trenching by CFE will be at a range of heights above the bed (from anywhere just above the seabed to several metres above the bed).

The release height adopted therefore provides a conservative assessment with respect to the impact distance.

3.2. Sediment Fall Velocity

The spreadsheet model calculates the settling times and distances for different grain sizes based on grain size settling velocities of individual grains using the equation from Van Rijn (1984) and a water temperature of 10 °C. The settling distances are calculated by applying the peak flow speed over the settling time. To account for variations in flow speed which would occur over the tide during the period during which fine sediment settles back to the bed, a maximum distance equal to the tidal excursion was applied. The tidal excursion was estimated assuming a sinusoidal flow distribution with a 6 hour cycle (representative of a flood or ebb phase).

Non tidal flow (wind driven and surge driven flow) could result in faster flow speeds and/or the persistence of flows in the same direction for longer than a 6 hour period. However, due to operability constraints, construction would be unlikely to occur during such conditions. In addition, the results (Section 4.1) show that plume concentrations are unlikely to have an impact on water quality at distances of more than approximately half of the spring tidal excursion and therefore the inclusion of non-tidal flows would not be expected to change the results presented.

Typically, it is accepted that the settling velocities are applicable to grains larger than 63 µm. At grain sizes smaller than this, the particles tend to have a more plate-like rather than spherical shape and this affects the settling velocity. In addition, cohesive processes (particularly in the marine environment) result in the formation of flocs (aggregates of smaller particles), further altering the settling velocity. In general, flocs will increase the settling velocity of fine grained sediment and the use of the settling velocity for individual grains will therefore tend to provide a conservative assessment of settling times.

The settling time to the bed for releases at 5 m above the bed are provided in Table 3, along with the indicative travel distance for a range of peak spring flow speeds and representative grain sizes.

Table 3. Settling times and distances for different sediment grain sizes.

Peak flow (m/s)	Fines (<63 µm)		Very fine sand (125 µm)		Fine sand (250 µm)		Medium sand (500 µm)	
	Settling time (hours)	Settling distance (km)	Settling time (hours)	Settling distance (km)	Settling time (hours)	Settling distance (km)	Settling time (hours)	Settling distance (km)
1.05	0.5 to 400	1.8 to 13.6	0.1	0.5	<0.1	0.1	<0.01	<0.03
0.75		1.2 to 9.7		0.4		0.1		
0.5		0.8 to 6.5		0.3		0.01		

3.3. Sediment Release Rates

The rate of fine sediment disturbance was estimated for each activity based on information provided on the project design and results from the environmental surveys (as detailed in the baseline characterisation).

The following assumptions were applied when calculating the release rates for controlled flow excavator (which provides the maximum design scenario for sandwave clearance, HDD exit pit excavation and cable installation):

- rates are based on a productivity of 1,500 m^3 per hour,
- 30% of all sediment disturbed would be released at 5 m above the bed.

The sediment release rates are summarised in Table 4.

Table 4. Estimated rate of fine sediment release associated with different activities.

Location	Percentage Fines (%)	Dry sediment density (kg/m^3)	Release rate (kg/s)
Activity: Cable Burial			
KP470	14	1,400	24.5
KP564	2	1,520	3.8
KP575	1	1,520	1.9
Activity HDD exit pit excavation			
KP579	2	1,520	3.8
Activity: Sandwave clearance			
KP548	8	1,460	14.6

4. Results

Results of the predicted spread of sediment in suspension and the thickness of sediment on the bed are presented in Section 4.1 and Section 4.2, respectively.

4.1. SSC

Results of the predicted SSC from the spreadsheet model are plotted in Figure 2 to Figure 4, for cabling, HDD exit pit excavation and sandwave clearance. Based on the background SSC and natural temporal variability in SSC in the Study Area, increases in SSC of less than 5 mg/l are not expected to be detectable and impacts on receptors are therefore considered to be negligible.

In the near-field (within 5 to 10 m of the activity) sediment disturbed by construction activities will result in very high SSC (several orders of magnitude higher than shown in the plots). These very high SSC will only last while the activity resulting in the sediment disturbance is occurring. A large proportion of this sediment will settle back onto the seabed within the Red Line Boundary, with the actual amount depending on the grain size characteristics and the flow conditions (see Section 4.2 for additional information on sedimentation).

The distances at which elevated SSC is predicted to reduce to less than 5 mg/l (termed the ‘impact distance’) are summarised in Table 5. The greatest impact distance is associated with sandwave clearance which occurs in an area of relatively high fines and relatively fast flows with peak increases in SSC of more than 5 mg/l occurring up to 4.6 km from the point of release. Any exceedances of more than 5 mg/l will be of short duration (order of hours or less) beyond the Red Line Boundary, due to the variable nature of the flow field and the relatively fast installation speeds.

Table 5. Maximum distance where SSC is greater than 5 mg/l.

Location	Maximum distance where SSC >5 mg/l (km)
Activity: Cable Burial	
KP470	4.1
KP564	2.4
KP575	1.9
Activity: HDD exit pit excavation	
KP579	2.4
Activity: Sandwave clearance	
KP548	4.6

Based on the predicted impact distances, cable trenching and exit pit excavation have the potential to increase SSC by more than 5 mg/l at the Peterhead (Lido) bathing water and at the Buchan Ness to Collieston Coast Special Protection Area (SPA_ and the Southern Trench Marine Protected Area (MPA).

Although sandwave clearance at KP548 has the largest impact distance, there are no designated sites that could be impacted by increased SSC.

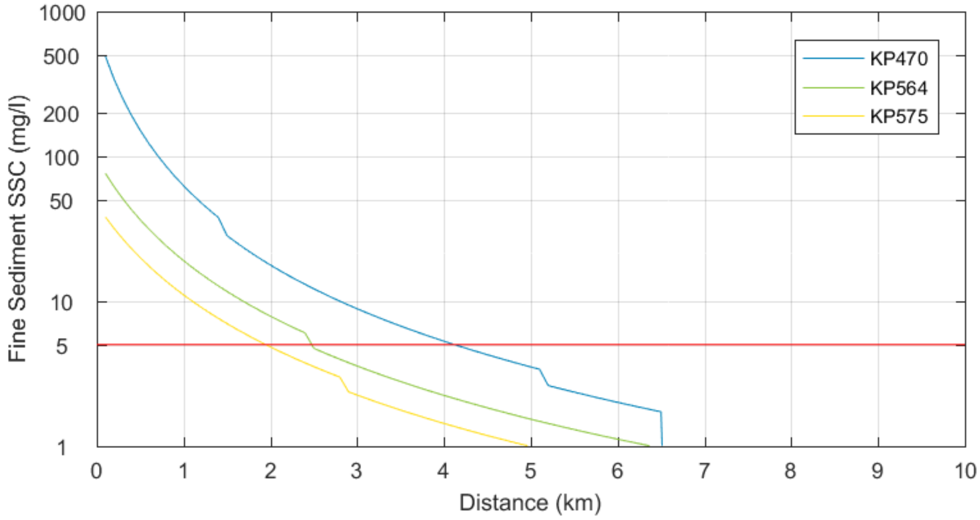

Figure 2. **Fine sediment SSC with distance from release during cable burial.**

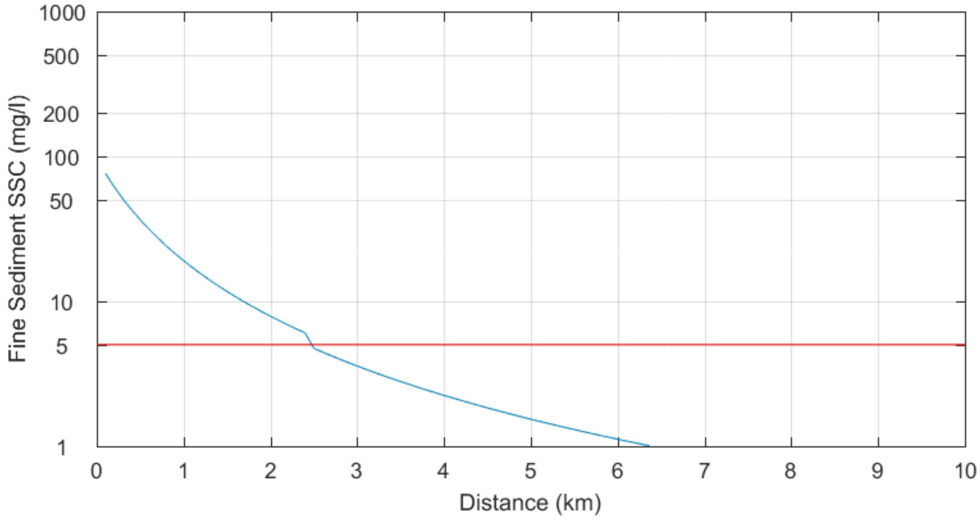

Figure 3. **Fine sediment SSC with distance from release during HDD exit pit excavation.**

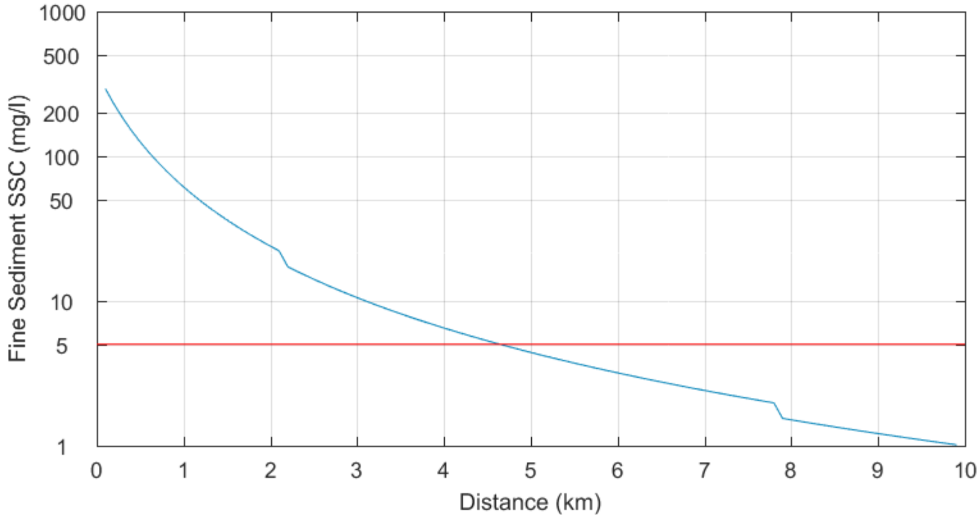

Figure 4. **Fine sediment SSC with distance from release during sandwave clearance.**

4.2. Sedimentation

Estimates of sediment thickness on the bed for different sediment fractions are provided for trenching at KP470, KP548 and KP575 in

Table 6 to

Table 8. Results are given for KP 470 which has a high percentage of fines and lower flow speeds, for KP548 which has a relatively high percentage of fines and moderately fast flow speed and for KP575 which has a low percentage of fines and fast flow speeds to give an indication of the range of sediment thicknesses and footprints.

At all three locations estimates of distance of impact and thickness of deposit were made for spring tide flow speeds with a release at 5 m above the bed and for neap tide flow speeds with a release at 2 m above the bed to provide a range of impact distances and sediment thicknesses. The upper distance is associated with the lower range of sediment thickness and the lower distance is associated with the upper range of sediment thickness.

In the near-field (within 5 to 10 m of the activity) sediment thicknesses on the bed will result in higher values than quoted, since the values are based averaging over a 100 m x 100 m area. Results show that within 0.1 km (i.e. within the Red Line Boundary) the sediment thickness can be several tens of mm's thick but that beyond the Red Line Boundary the sediment thickness is of the order of mm's or less.

It is important to note that the results only consider the 30% of sediment predicted to be ejected out of the trench. The other 70% will either fall back into the trench or be deposited within a couple of metres either side of the trench (as berms), resulting in much thicker deposits in these regions.

Depending where along the route trenching is occurring, the sediment deposited on the bed may or may not subsequently be transported from the bed by natural processes.

Table 6. Estimated sediment thickness from trenching activity at KP 470.

Fraction	Distance from release (km)	Max thickness (mm)
Medium silt to clay	0.3 to 6.5	0.18 to 1.02
Coarse silt	0.2 to 0.8	0.03 to 0.15
Very fine sand	0.1 to 0.3	0.92 to 3.7
Fine sand	<0.1	41.3 to 84.3
Medium Sand	<0.1	28.1 to 36.8
Coarse Sand and above	<0.1	3.6 to 3.9

Table 7. Estimated sediment thickness from trenching activity at KP 548

Fraction	Distance from release (km)	Max thickness (mm)
Medium silt to clay	0.4 to 9.8	0.07 to 0.4
Coarse silt	0.3	0.05 to 0.29
Very fine sand	0.1	0.35 to 1.41
Fine sand	<0.1 to 0.1	25.5 to 52.1
Medium Sand	<0.1	72.7 to 95.1
Coarse Sand and above	<0.1	31.3 to 33.8

Table 8. Estimated sediment thickness from trenching activity at KP 575

Fraction	Distance from release (km)	Max thickness (mm)
Medium silt to clay	0.6 to 13.6	<0.01 to 0.05
Coarse silt	0.4 to 1.8	0.03 to 0.18
Very fine sand	0.1 to 0.5	0.06 to 0.24
Fine sand	<0.1 to 0.1	6.0 to 12.2
Medium Sand	<0.1	44.0 to 57.6
Coarse Sand and above	<0.1	165.8 to 179.0

5. Summary

The greatest impact distance is predicted to be associated with sandwave clearance, with peak increases in SSC of more than 5 mg/l predicted to occur up to 4.6 km from the point of release. Baseline data indicate a relatedly high percentage of fines and moderately fast flow speeds in this region. More typically, impact distances are around half this value, reducing with both peak flow speed and percentage of fines. Any exceedances of more than 5 mg/l are predicted to be of short duration (order of hours or less) beyond the Red Line Boundary due to the relatively fast installation speeds.

A large proportion of sediment dispersed by construction activities are predicted to settle back onto the seabed within the Red Line Boundary, with the actual amount depending on the grain size characteristics and the flow conditions. Beyond the draft Order Red Line Boundary, sediment deposits are predicted to be very thin (mm's or less).

6. References

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