The Great Grid Upgrade

Sea Link

Sea Link

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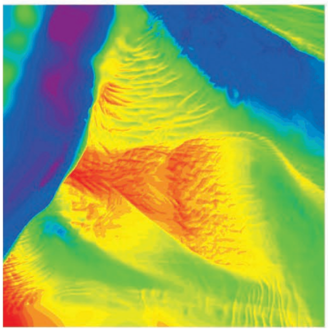
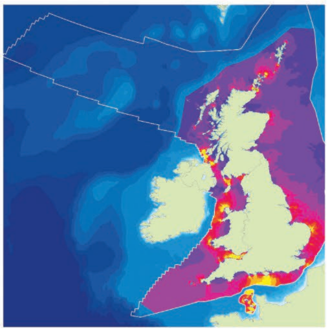
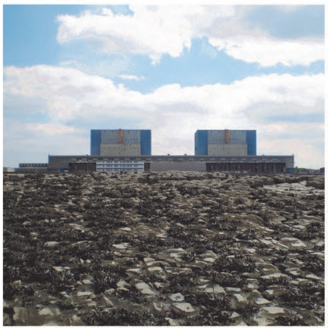
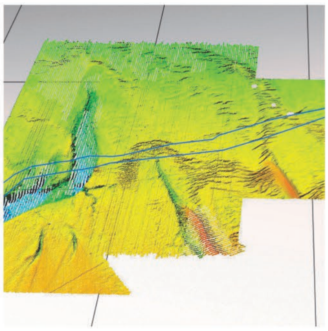
NGET

Landfall Assessment at Pegwell Bay

Sea Link Project

December 2024

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Landfall Assessment at Pegwell Bay

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December 2024

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1 Introduction

1.1 Overview

The Sea Link Project is a proposed network reinforcement link by National Grid Electricity Transmission Plc (NGET) to reinforce the transmission network in the southeast of England and East Anglia. The network reinforcement link makes landfall at Aldeburgh in East Suffolk, and at Pegwell Bay, Kent. The installation methodology at the landfalls are trenchless solution exit points for the HVDC (high-voltage direct current) cable.

The risk for cable landfalls can be summarised as:

- Short to medium term nearshore/beach variance: the risk can be assessed by comparing historical topographic profiles or maps, to determine the range of short to medium term variance in beach level, including daily, seasonal and interannual timescales if possible;
- Long term nearshore/beach level variance: the risk is assessed by comparing historical topographic profiles or maps, identifying if long term patterns are accretionary, stable or erosional; and
- Shoreline stability: whether the frontage is advancing or retreating. This will be primarily dependent upon whether the frontage is protected by coastal defences and if the short, medium and long-term Shoreline Management Plan (SMP) policies are to maintain these defences. Where there are no defences, data is gathered on the long-term stability of the natural shoreline and if other shoreline management measures are in place.

The project deliverable is this factual report which includes:

- Description of data utilised, models implemented and methodology;
- Description of the hydrodynamic flow and sediment circulation at each landfall;
- Presentation of the results of the modelling on the beach profiles and strandlines development, for the different storm return periods and the effects of eustatic and climatic change during the planned lifetime of the asset;
- Assess the impacts of the different storm events at each landfall during the planned lifetime of the asset;
- North-up charts of the modelled bathymetric changes at the landfalls and trenchless solution exit points; and
- Profiles along line of the proposed cable route for Pegwell Bay to MLWS boundary.

1.2 Construction methodology

The cable route and location of the horizontal directional drilling (HDD) exit points are shown in Figure 1 below. This shows the HDD exit at around KP120.5 at a depth of 0.2 mODN (Ordnance Datum Newlyn)/ 2.42 mLAT (Lowest Astronomical Tide) (see more on Datum conversions in Section 2.1).

The current plan is to use three ducts, two for HVDC cables and one for an Optical cable, with one spare. After exiting the HDDs the cables converge and are bundled into a single trench. The route from the HDD entry to the exit (in thick orange line in the profile view) is 939 m long with a maximum depth of -20.62 mODN. Throughout this report, any references to profile lengths are based on the orange line in the profile view.

The year of construction (baseline year) used for this assessment has been 2027 with the period of operation considered to be 50 years.

Source: NGET

Figure 1 Landfall Concept Drawing Pegwell Bay.

PLAN VIEW

SECTION VIEW

NOTES

1. ALL DIMENSIONS, LEVELS AND CHAINAGES ARE IN METRES UNLESS OTHERWISE STATED. PROPOSED BOREHOLES ARE INDICATED BY YELLOW MARKERS.
2. LAND ELEVATIONS FROM 2023 SURVEY.
3. LAT CORRELATION TO OD NEWLYN PROVISIONAL - TO BE CONFIRMED
4. GEOLOGY IS BASED ON INTERPRETATION OF AVAILABLE BOREHOLE LOGS, BGS MAPPING, AND GEOPHYSICAL SURVEYS.

DO NOT SCALE

Rev	Date	Description	By
D	25/04/2024	Site amended to avoid potential flooding area	TR
C	23/04/2024	Expanded Site Layout	TR
B	14/03/2024	Updated Site Layout	TR
A	01/03/2024	Draft for discussion	TR

Client: RED PENGUIN / NATIONAL GRID

Scale	Drawn by	Date Drawn	Sheet Size
AS SHOWN	TR	25/04/2024	A1
Designed by	Checked by	Approved by	Date approved
TR			

Drawing Number: 20220105RA-C/03

Issue: A

Project Title: SEALINK HVDC CONNECTOR HDD FEASIBILITY STUDY

Drawing Title: CONCEPTUAL HDD DESIGN 1 PEGWELL BAY

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2 Methodology and Data Sources

2.1 Units and Datums

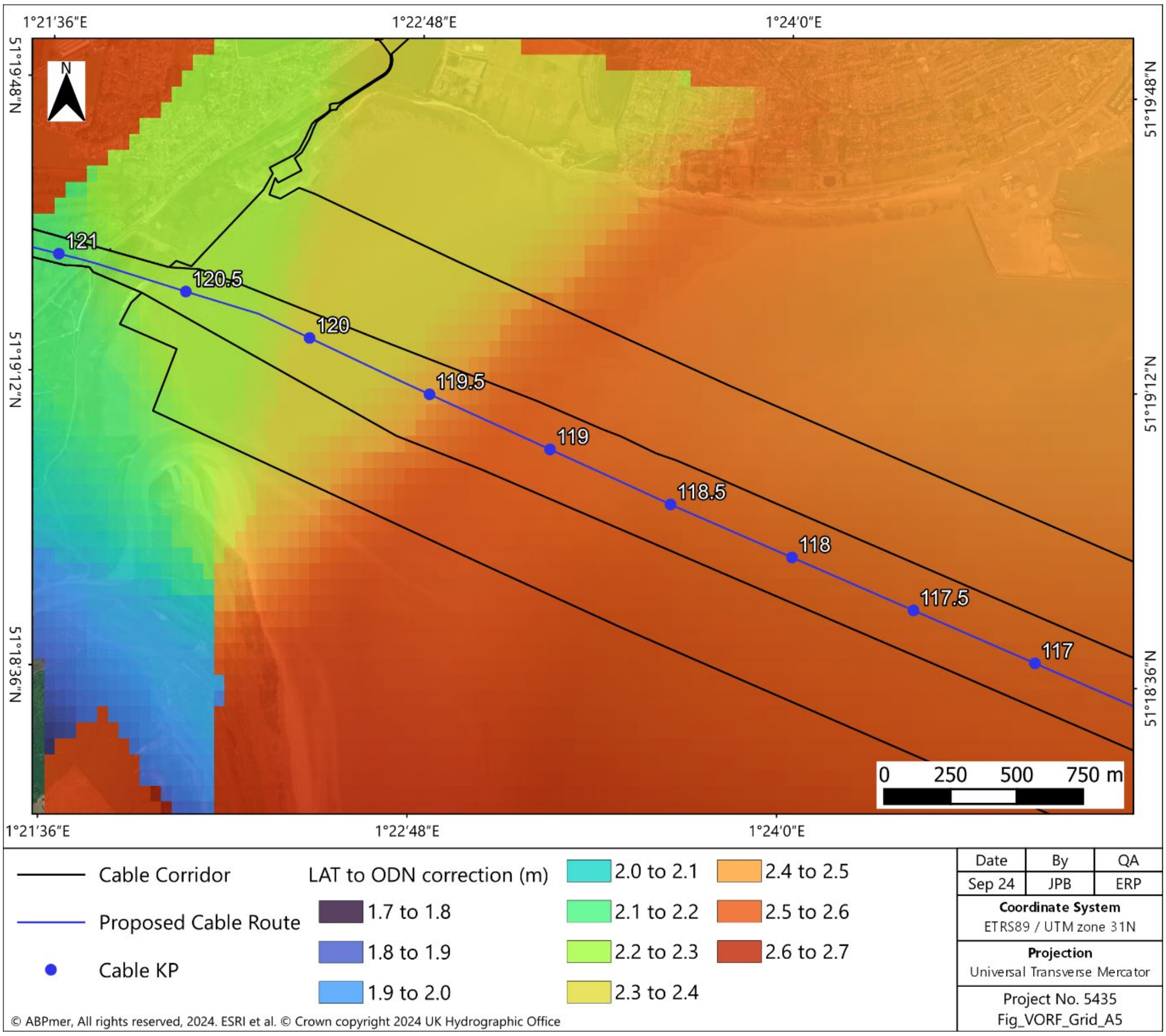
The following units and vertical datum details are used for all submitted datasets:

- Horizontal positions are provided as UTM Zone 31, WGS84;
- Bathymetric information is given as metres above LAT; subtidal bathymetry has a negative value; and
- Data sets obtained with positive depth values have been inverted as needed.

Where needed, the vertical datum of historical data has been adjusted from ODN to LAT using the UK Vertical Offshore Reference Frames (VORF) rev2 method of reduction using the UK VORF rev2 data layers from UK Hydrographic Office (UKHO). The VORF model / app is available via: https://datahub.admiralty.co.uk/portal/apps/sites/#/marine-data-portal/apps/2d71688069744cc6873768d39e0c2f2e/explore

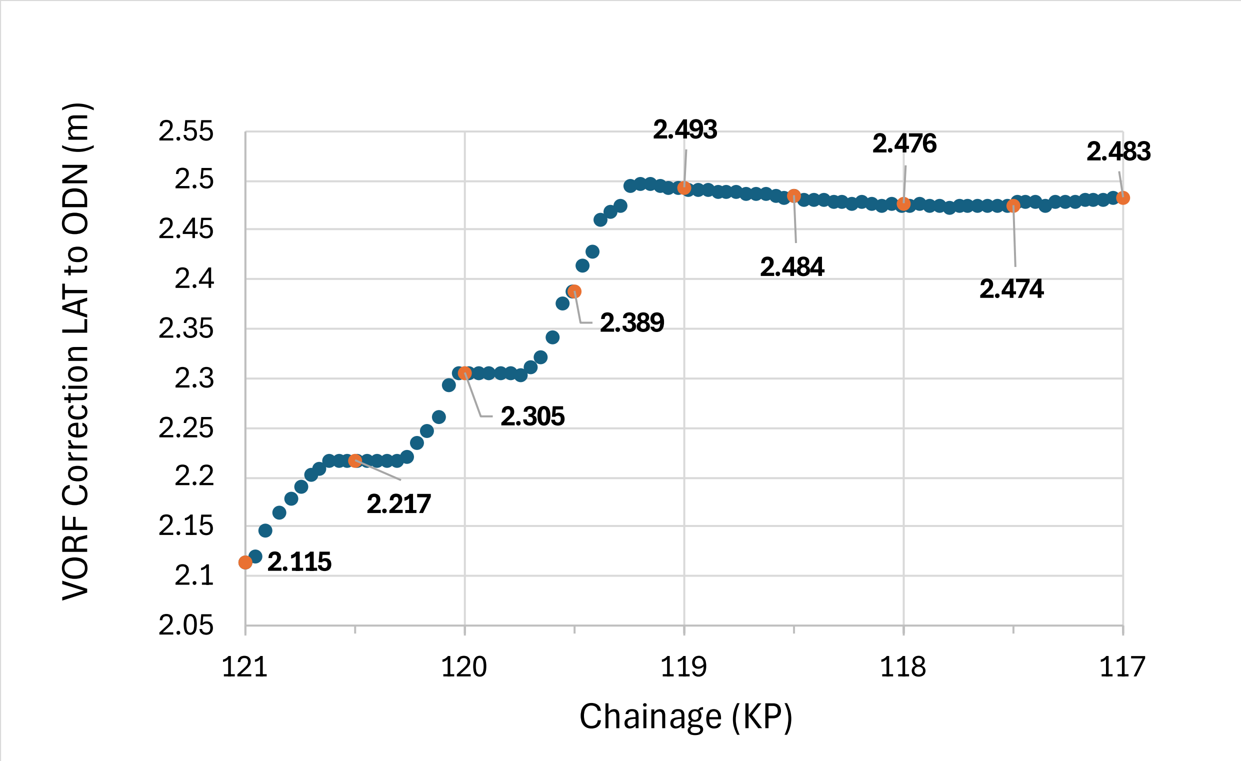
A range of values have been used for the conversion from ODN to LAT throughout the study to account for spatial variability as shown in Figure 2 for the landfall and Figure 3 shows the values for the conversion along the cable route from KP121 to KP117.

Throughout the report, both values (with respect to ODN and with respect to LAT) will be mentioned if the original data was in ODN and we have applied the variable conversion from one to the other.



Source: UK Hydrografic Office VORF rev2 data layers

Figure 2 VORF LAT to ODN correction values for the area of Pegwell Bay.



Note: Dots in orange show conversion values every 0.5 KP

Figure 3 **VORF LAT to ODN correction values along the cable route.**

2.2 Direction conventions

During this study, the following conventions are used when describing directions:

- Waves – wave directions are FROM, so that for example a northerly wave comes from the north and a 90° wave direction represents a wave coming from the east
- Currents – currents are TO, so that for example a northerly current goes towards the north and a 90° current direction represents a current going to the east

2.3 Data Sources

The study has used a combination of project specific and publicly available data, studies and reports to inform the investigation. The following data sources have been used in the analysis.
Data has been obtained from:

- Channel coastal observatory (CCO): https://coastalmonitoring.org/
- UKHO https://seabed.admiralty.co.uk/
- SEASTATES North Atlantic wave hindcast and SEASTATES North West European Shelf Tide and Surge hindcast https://www.seastates.net/

Reports and other literature are referenced throughout the document and provided in the reference list.

Table 1. Data sources

Data	Data Type	Year Collected	Description	Comment	Source
Metocean Data					
ABPmer SEASTATES Tide and Surge Model	Tide and water level	1979-2023	Tide surge hindcast model providing flow parameters for a >40 year period		ABPmer SEASTATES hindcast database
ABPmer SEASTATES Wave Model	Wave data	1979-2023	Spectral wave hindcast model providing wind and wave parameters for a >40 year period		ABPmer SEASTATES hindcast database
Topographic Data					
LiDAR	Topography	2023	ETRS89 mLAT	20cm grid Extent smaller than the rest	Client
LiDAR	Topography	2018, 2020, 2022	OSGB36 mODN	1m grid	CCO
LiDAR	Topography	2007, 2008, 2010, 2011, 2013	OSGB36 mODN	1m grid	EA
Full topographic profiles	Topography	2014-2022	OSGB36 mODN	2-3m	CCO
Topographic profiles	Topography	2003-2023	South of river (4bUnit8C) OSGB36 mODN	4-5m	CCO
Bathymetric data					
Bathymetry	Bathymetry	2021	ETRS89/UTM31N mLAT	20cm, converted to 1m for analysis. Only along cable corridor	NGET
Bathymetry	Bathymetry	1994 2010	OSGB36 mCD	1994-30m 2010 (same dataset as CCO one)	UKHO

Data	Data Type	Year Collected	Description	Comment	Source
Bathymetry	Bathymetry	2003 2006 2010	OSGB36 mODN	2003- 4m (single beam) 2006- 0.8m (single beam) 2010- 2m	CCO
Other Data					
Cable corridor	Shapefile	2022	Cable corridor for the entirety of the project EPSG:25831		NGET

2.4 Historical morphological analysis

Arguably the most robust means by which to understand the potential for future variability at the landfall is through detailed consideration of the observed longer term morphological behaviour which has taken place. This assessment approach is followed here and has been described below.

2.5 Historical morphological analysis of the River Stour

A number of historical satellite and aerial images covering the period 1940 to 2022 are available from Google Earth. These have been analysed and some selected to create a compendium of the most relevant one throughout the years. Conclusions of the changes observed have then been drawn out.

2.6 Seabed mobility

This section encompasses both seabed mobility (from the bathymetric data) and intertidal mobility (from the topographic lidar data), as the methodology employed for both is the same.

To allow for the morphological assessment a continuous high-resolution bathymetry surface within the wider area was required. The data used for these have been:

- UKHO bathymetric data (1994, 2010);
- Client provided bathymetric data (2021);
- CCO data (2003, 2006, 2010);
- EA Lidar data (2007 to 2013, yearly or every two years);
- CCO Lidar data (2018, 2020, 2022); and
- Client Lidar data (2023).

The following process was used:

- The bathymetry data sources are added in the order that they appear in Table 1;
- Some data sources use spatial coordinates other than UTM31 (e.g. Latitude/Longitude or Ordnance Survey Eastings/Northings), which have been converted accordingly; and
- The vertical datum of all surveys is quoted as either LAT or 'Chart Datum[1]' (CD). There is generally insufficient information more precisely define or differentiate between these similar vertical datum specifications in the offshore environment (difference typically in the order of a few centimetres). It is therefore assumed that all data sets are representative of levels to the same vertical datum (LAT). The VORF correction values (see Section 2.1) were used for the conversions.

Relevant results from the analysis are provided in the report discussion.

1 Chart Datum is the plane below which all depths are published on a navigational chart. In the United Kingdom, this level is normally approximately the level of Lowest Astronomical Tide. Table III in Admiralty Tide Table Volumes 1A (NP201A) and 1B (NP201B) gives the connection between Chart Datum and Ordnance Datum (Newlyn or Local) for all Standard Ports and many Secondary Ports in the UK

2.7 Morphological changes of nearby beaches

Historical morphological analysis of the beach to the East of the River Stour has been undertaken using Coastal Channel Observatory topographic surveys between 2003 and 2023. An assessment of the changes of these profiles has been included in Appendix A and relevant results of the analysis provided in the report discussion.

2.8 Intertidal gradient analysis

To determine the stability and possible future evolution of the intertidal mudflat/sandflat, LiDAR data for the years 2018, 2020 and 2022 were used generate streamlines to simulate downhill flow. For each year, a 40 m sub-sampled grid was produced for calculating the gradient at each grid point. Streamlines were then generated using a predefined set of starting points located within a polygon boundary, with the gradients derived from the subsampled data (Figure B1). The full analysis of this data is provided in Appendix B and relevant results of the analysis provided in the report discussion.

2.9 Metocean Analysis

ABPmer are currently undertaking a metocean study for NGET, where metocean conditions are being derived for a number of points along the cable route and weather downtime analysis then carried out.

For the metocean study, two models have been used:

- A high resolution hydrodynamic (HD), tide only, model covering the cable corridor at 200 m resolution. Given the variation in flow conditions along the route it is felt appropriate that the main tidal components of flow are extracted from this model to gain the most accurate representation of tidal currents across the route. This model has been run for 1 year, the baseline year of 2027.
  - The tide only timeseries for locations along the route were then subject to harmonic analysis. Tidal constituents from each location then used to generate a 40+ year timeseries of tidal currents and water levels.
  - Location specific residual components of flow and water level have been extracted from the ABPmer SEASTATES HD tide surge model and combined with the harmonically predicted high-resolution HD model tidal data to produce total current and water level data for each location.
  - Tidal currents from this model have been extracted for the sediment transport analysis.

- The ABPmer SEASTATES spectral wave (SW) hindcast model from which wind and wave parameters will be assessed from the for a >40 year period: 1979 to near present. The spatial resolution of this model is approximately 5 km near the cost increasing to approximately 10km in the offshore parts of the route.

  - Univariate analysis of the combined tide/surge timeseries along the route has been carried out to calculate the still water level return period of 1:1, 1:10 and 1:100 conditions. For the landfalls and inshore, the Environment Agency's (EA) Coastal Design Sea Levels (Coastal Flood Boundary Dataset CFBD) has been used.
  - Univariate analysis of the wave timeseries along the route has also been carried out to calculate wave return period of 1:1, 1:10 and 1:100 conditions.
  - Extreme water levels from the EA's CFBD have been used for the landfall and extreme wave conditions from the univariate analysis of the wave parameters for this study.

2.10 Assumptions and uncertainty in morphodynamics

Uncertainty can arise when measuring trends of long-term bed level change by the direct comparison of absolute levels in repeat survey data. Uncertainty (differences) in the vertical datum of measurements introduced during data collection and processing can erroneously introduce apparent differences in levels. Such uncertainty is mainly mitigated through consistent and robust methodologies for survey data collection and processing.

The quoted vertical uncertainty for bathymetry collected by a modern high-resolution multibeam system is typically in the order of ±0.30 cm; this is the uncertainty in the absolute level of the surface as a whole, e.g. relative to a geoid or tidal level, and does not imply random uncertainty or ‘noise' of this magnitude in every individual data point (uncertainty of ‘relative measurements’ is discussed below).

Larger uncertainties in absolute levels may occur when comparing datasets with different horizontal spatial resolutions. For example, individual data points from the lower resolution EMODnet data (100 m resolution) are likely to be an integrated or averaged value representing a larger area of seabed. In practice, this footprint may potentially include a range of elevations about the average value due to smaller bedforms and parts of larger bedforms, that may have been originally very accurately measured. In comparison, individual data points from higher resolution multi-beam bathymetry (1 to 4 m resolution) retain the detail of individual bedforms at this finer scale, and therefore might be considered ‘more accurate’ over smaller horizontal distances.

Residual uncertainty in absolute levels is accounted for by applying additional caution when the magnitude of a measured trend or difference in levels is less than the combined residual uncertainty of the two data sets being compared.

Uncertainty in relative measurements (i.e. between adjacent bathymetric data points in the spatial grid) is much smaller (likely in the order of <0.1 m). Measurements of the height of bedforms based on the difference in levels from trough to crest, or length based on the distance from crest to crest, will likely be much more accurate.

Uncertainty is inherent in the assumption that present-day conditions and trends will persist into the future. This uncertainty is mitigated through a robust understanding of regional as well as local scale processes and systems, which should ideally explain both historical and present-day observations, and support any assumptions being made about the future. Uncertainty becomes greater as trends identified over a relatively short term are applied further into the future.

Short term beach levels will vary in response to the local wave climate and storm events but long-term patterns are heavily influenced by beach and coastal defence management within the wider coastal Sediment Cell. The shoreline recession score is based upon the SMP policy, but these are subject to regular review and funds being available and long-term sediment availability may be affected by human activities both updrift and downdrift.

3 Baseline Understanding

3.1 Overview of study area

The export cable will make landfall in the southwest of Pegwell Bay, just to the west of the mouth of the River Stour (Figure 4). The location is characterised by the presence of saltmarsh across the upper intertidal, with muddy / sandy sediments present in the lower intertidal/ shallow subtidal.

The south-western corner of Pegwell Bay is predominantly low-lying intertidal saltmarsh flanked by mud/sand flats (which are designated features within the Sandwich Bay Special Area of Conservation, SAC). A key feature is the River Stour, which meanders and exits into the Bay to the north of Shell Ness, see Figure 4.

Shell Ness at the mouth of the River Stour on the western margin of Pegwell Bay is an important feature as it partially controls the position of the channel of the River Stour, which has historically meandered both behind the spit and also across the intertidal areas. Future evolution of the spit (including ongoing northward progradation or a significant erosion or breach event) could alter the course of the river channel across the intertidal area.

In the vicinity of the cable landfall to the southwest, an embankment of height 4.5-5.5 mODN (7.38 to 8.38 m above LAT) runs from the central Bay in a southerly direction for approximately 1 km. This protects parts of the frontage which are exposed to wave action and inundation during extreme events and is the boundary of the Pegwell Bay Country Park.

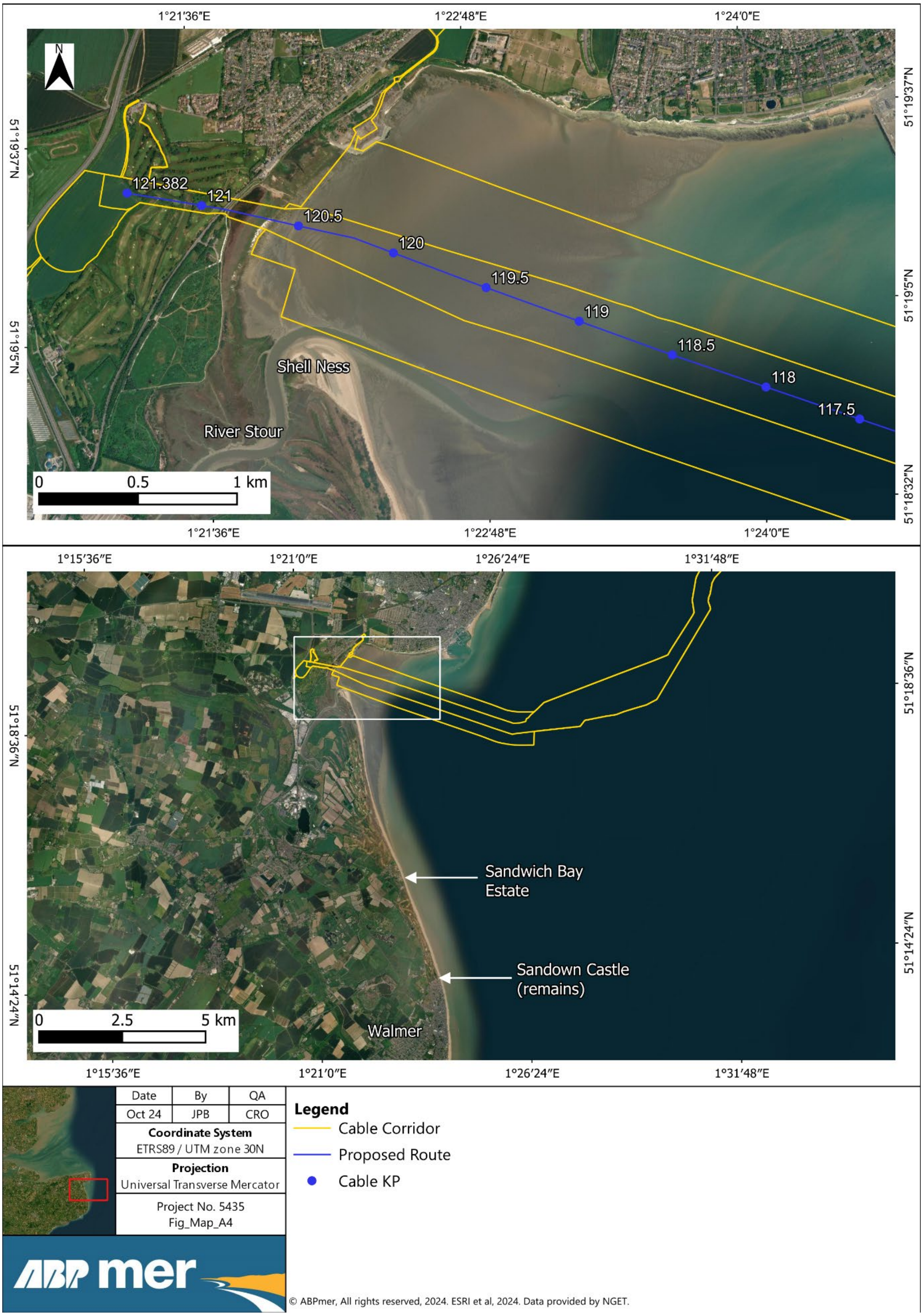


Figure 4 Location map

3.2 Flood and coastal erosion risk

3.2.1 Shoreline Management Plan Policy

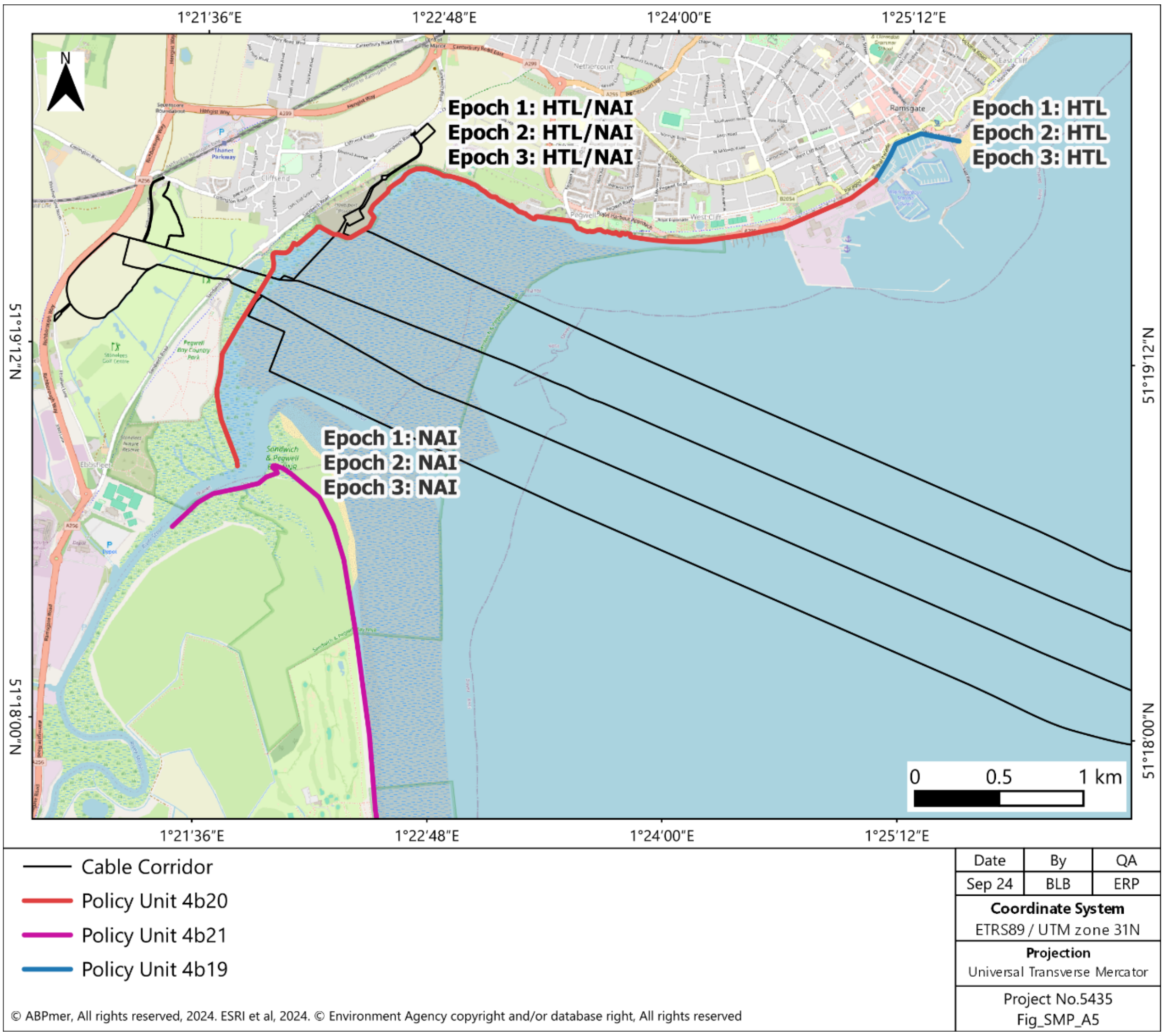
The proposed landfall at Pegwell Bay lies within SMP10 'Isle of Grain to South Foreland', unit 4b20: 'Ramsgate Harbour (west) to north of the River Stour' (Halcrow, 2010). The Policy Units for the area are shown in Figure 5, together with their policy (Environment Agency, 2024).

The Shore Management Plan (SMP) was superseded by SMP2 (Halcrow, 2010) and can be accessed through the South East Coastal Group (https://environment.data.gov.uk/shoreline-planning/shoreline-management-plan/SMP10). The policy for Pegwell is Hold The Line (HTL) for all epochs (see Table 2) if there are defences and No Active Intervention (NAI) where there are no defences. No defences are present to the east of the landfall, around Shell Ness (SMP policy unit 4b21), where the policy is for No Active Intervention (NAI) for all epochs.

Table 2. Shoreline Management Plan Policies

Policy Unit	2025	2055	2105
PU4b19	Hold the line (HTL)	Hold the line (HTL)	Hold the line (HTL)
PU4b20	**Hold the line (HTL) (No active intervention (NAI) where no defences)**	**Hold the line (HTL) (No active intervention (NAI) where no defences)**	**Hold the line (HTL) (No active intervention (NAI) where no defences)**
PU4b21	No active intervention (NAI)	No active intervention (NAI)	No active intervention (NAI)

Source: SMP2 (Halcrow, 2010)



Source: SMP2 (Halcrow, 2010)

Figure 5 Shoreline Management Plan policy units and policies (short term, medium term and long term in rows under the policy unit)

3.2.2 Coastal Erosion Risk

With regards to the predicted changes in the area in the different epochs, the SMP2 predict significant changes (from their baseline of 2005), especially in the epochs to 2055 and to 2105, see Table 3, for a summary of their predicted changes. When the situation predicted at the time seems unlikely now with present day evidence, a note has been included in italics on the table.

The potential baseline erosion rates for the frontage from the SMP2 are provided in Table 4. Base rates were assessed from monitoring and historical data so that the range of potential erosion was assessed in terms of variation from the base rate and sensitivity in potential sea level rise.

Table 3. General change predicted from the SMP2 (Halcrow, 2010)

Epoch	General change predicted
Years 0-20 (2005 to 2025)	Extensive tidal mudflats in the north of Pegwell Bay, give way to saltmarsh, tidal mudflats and the mouth of the River Stour in the centre of the Bay. South of the River Stour the wide sandy foreshore is backed by an extensive (relict) dune system. It is predicted that the low-lying relict dune ridge system, will continue to experience 'ponding' in places, due to a lack of contemporary material supply. Further inland (i.e. landwards of the toll road) the relict sand dunes increase in height and are regarded as stable (which may be related to their age, being vegetated or being previously managed), either way it is envisaged that little change will take place to the relict dunes during this epoch. Sediment movement for this unit is complicated and in parts poorly understood. It is known that several sediment transport pathways converge at Pegwell Bay: from the east, predominantly fine sediment (sand and silt) due to cliff recession; from the south (alongshore transport); from the River Stour; and from the nearby offshore sand banks of the Goodwin Sands.
Years 20-50 (2055)	In the northern section of this frontage, erosion and flooding is expected in the vicinity of Cliffs End. Continual weakening of the revetted embankment in front of Pegwell Bay Nature Reserve, will result in its demise. As the embankment fails, the backing hinterland will be subjected to flooding. There is potential that the dynamics of the River Stour could significantly change if the river breaks through the tight meander around Richborough. The impact of this on the coast would be a realignment of the river's mouth (to a location south of its current outlet). *(ABPmer note: based on present day (2024) evidence, this seems less likely)* Sediment stored within the dunes, which "decorate" the shingle ridge between Shell Ness and Sandwich Flats, would be affected in two ways: 1) by the potential relocation of the Stour's mouth; and, 2) not having a sufficient volume of sediment to resist erosion. As a result, the dune-topped ridge will be at risk of breaching. The timing of the breach is uncertain, although it is anticipated that it could take place following a major storm surge, especially if accompanied by swell wave activity. If this breach is not repaired (by natural processes) then a permanent hiatus will form. *(ABPmer note: the hiatus might not be the only possible scenario, as there could be a different exit on the back or a whole new outlet through the spit).*
Years 50-100 (2055 to 2105)	During this epoch further changes in the dynamics are predicted, as the system adjusts to changes from the previous epoch and responds to continued sea level rise (6mm/year). As a result, more extensive and/or locally deeper flooding of the low-lying backing hinterland is predicted. It is likely that the relict channel and subsequent tributaries of the Wantsum Channel (see Section 3.5 of this report) will be adopted, as a new estuary at both the north and east develops. *(ABPmer note: Although a possibility, this scenario seems very unlikely)* Depending on the dynamics of the River Stour and the tidal currents there is the potential for either an ebb tidal delta or flood tidal channel to form. There is also the potential for change in wave attenuation (height, direction) to affect patterns of coastal processes (i.e. local drift reversals, interruption of alongshore transport). *(ABPmer note: No basis or explanation was provided for this, so difficult to comment on).*

Note: Sea Level Rise assumed rates: 0.04m to year 2025; 0.85m to year 2055; 1.2m to year 2085 and 1.5 to year 2115

Source: Halcrow, 2010

Table 4. Potential baseline erosion rates from the SMP2

Location	Years 0-20 (2005-2025)	Years 20-50 (2025-2055)	Years 50-100 (2055-2105)
Between the western end of Western Undercliff and Pegwell	**Along non-defended sections:** 2-5m by yr. 20. (mean 3.5m) **Along defended sections:** No change predicted.	**Along non-defended sections:** 4-10m by yr. 50. (mean 7m) **Along defended sections:** defences are assumed to fail in year 35. <1.5<3.75m (mean<2.63m)	**Along non-defended sections:** 2-5m by yr. 100. (mean 3.5m) **Along defended sections:** defences are assumed to fail in year 35. <6.5<16.25m (mean<11.4m)
Between Pegwell village and Cliffsend Tunnel	2-7m by yr. 20. (mean 4.5m) **Along defended sections:** No change predicted.	5-15m by yr. 50. (mean 10m) **Along defended sections:** defences are assumed to fail in year 35. 1.5-3.75m (mean 2.63m)	2-7m by yr. 100. (mean 4.5m) **Along defended sections:** defences are assumed to fail in year 35. 6.5-16.25m (mean 11.4m)
Between Cliffsend Tunnel and the Old Hoverport.	<1m by yr. 20. **Along defended sections:** No change predicted.	1-3m by yr. 50. (mean 2m) **Along defended sections:** defences are assumed to fail in year 35. 0.3-0.9m (mean 0.6m)	<1m by yr. 100. **Along defended sections:** defences are assumed to fail in year 35. 1.3-3.9m (mean 2.6m)
From Cliffs End to Sandwich Bay State	Erosion of the shingle / sand topped ridge: 0.25-1.0 m / year	Large scale flooding is predicted, with the exception of the area north of Sandwich Bay Estate (which would experience erosion). New shoreline alignment (Wantsum Channel) with estuarine processes developing	Large scale flooding is predicted New shoreline alignment (Wantsum Channel) and extended estuarine conditions.

Note: Sea Level Rise assumed rates: 0.04m to year 2025; 0.85m to year 2055; 1.2m to year 2085 and 1.5 to year 2115
Source: Halcrow, 2010

This section abuts the Stour Catchment Flood Management Plan at the Stour Estuary mouth near Sandwich (see more in Section 3.7.6) and is also a section of coastline that has been addressed in more detail within the Pegwell to Kingsdown Coastal Management Strategy, where the preferred policy for 'Reach 1: Cliffs End to Stonar Cut' is to 'sustain', which concurs with the hold the line policy in the SMP2 (Halcrow, 2010).

The National Coastal Erosion Risk shows the coastal baseline (https://www.data.gov.uk/dataset/7564fcf7-2dd2-4878-bfb9-11c5cf971cf9/national-coastal-erosion-risk-mapping-ncerm-national-2018-2021).

This baseline is split to 'frontages' or 'features', which are defined as lengths of coast with consistent characteristics based on the cliff behaviour characteristics and the defence characteristics. This database is intended as an up-to-date and reliable benchmark dataset showing erosion extents and rates for three periods:

- Short Term (0 – 20yr);
- Medium Term (20 – 50yr); and
- Long Term (50 – 100yr).

These erosion extents are provided for the 5th, 50th and 95th percentile confidence levels for two different scenarios (all distances are cumulative over time and given in metres):

- No Active Intervention Policy Scenario; and
- With the implementation of Shoreline Management Plan 2 Policies. Defence type and SMP policies for each of the three periods described above are included.

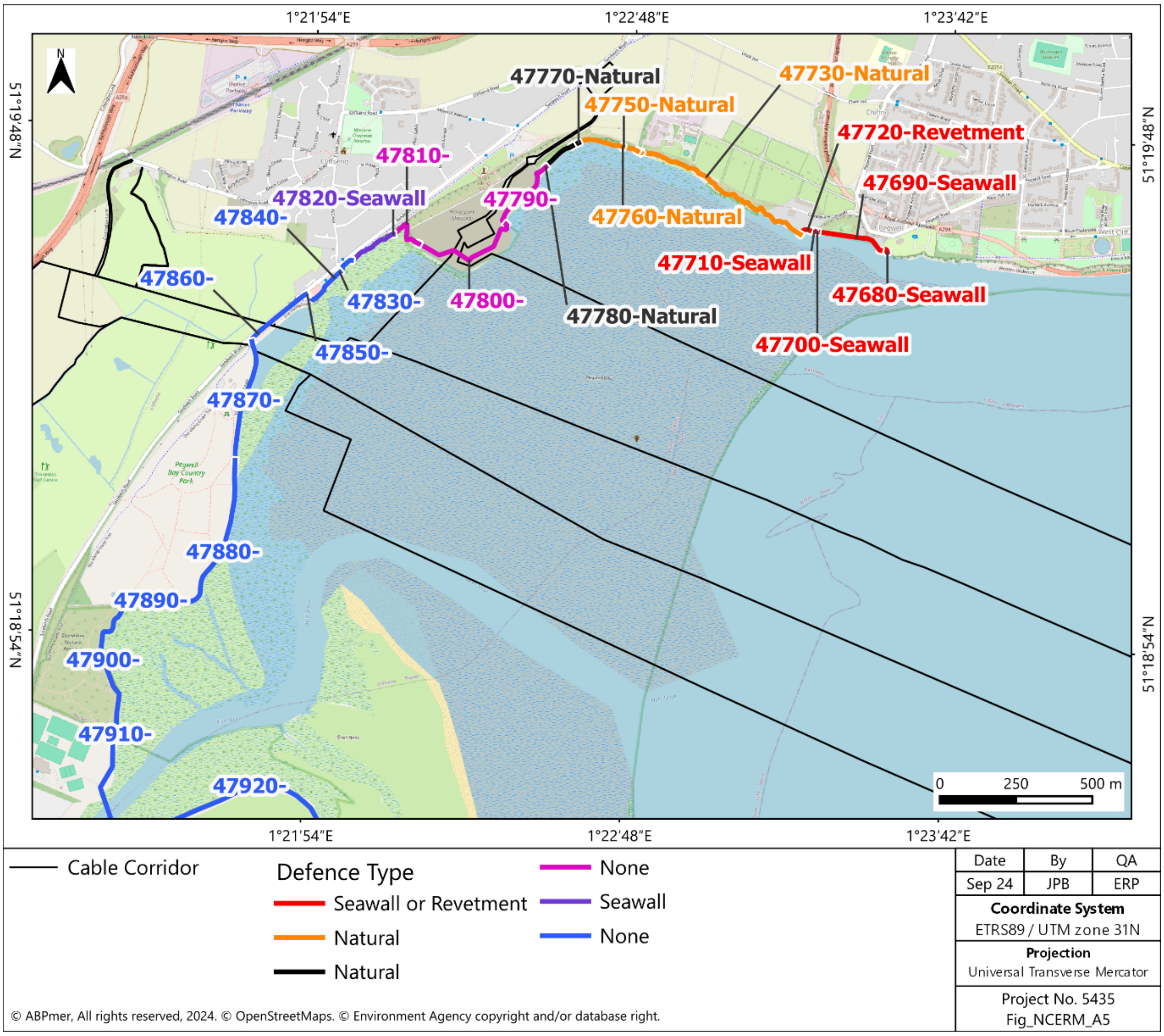
The NCERM information considers the predominant risk at the coast, although flooding and erosion processes are often linked, and data on erosion of foreshore features are, in general, not included.

Figure 6 shows the defence types of the features along the coast where similar type of defences that are close to each other have been coloured the same and Figure 7 shows the predominant risk at the coast per feature; both figures show the feature number.

The NCERM data in terms of erosion rates for the two scenarios (NAI and SMP policy) for the three different periods and for the three confidence level intervals (5th, 50th and 95th percentile) is provided in Table 5 and Table 6 for NAI and SMP policy respectively. The Representative Concentration Pathway or RCP is not mentioned but believed to be 8.5.

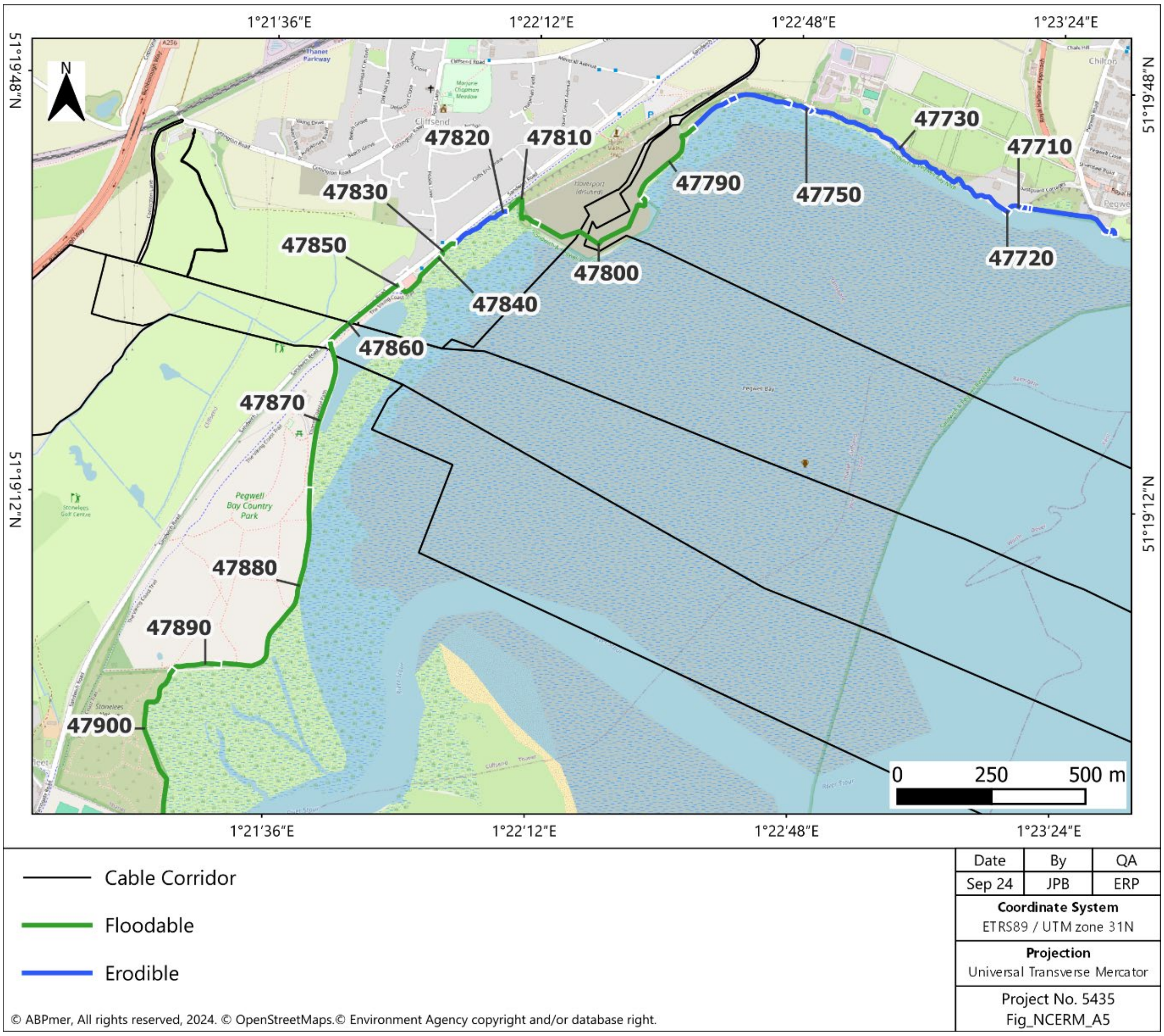
The data describes the upper and lower estimates of erosion risk at a particular location, within which the actual location of the coastline is expected to lie. The data does not estimate the absolute location of the future coastline. Details of geologically complex areas, known as "complex cliffs" are, in general, not included within the dataset due to the inherent uncertainties associated with predicting the timing and extent of erosion at these locations.

The area of the cable corridor does not contain information on the defence type and it is classified as floodable as the predominant risk to the coast. However, to the north of it the area is classified as erodible. The area of the cable corridor at the coastline will be at risk of both erosion and floods, the latter being of greater importance to the former.



Source: NCERM (https://www.data.gov.uk/dataset/7564fcf7-2dd2-4878-bfb9-11c5cf971cf9/national-coastal-erosion-risk-mapping-ncerm-national-2018-2021)

Figure 6 NCERM information: feature number and defence type



Source: NCERM (https://www.data.gov.uk/dataset/7564fcf7-2dd2-4878-bfb9-11c5cf971cf9/national-coastal-erosion-risk-mapping-ncerm-national-2018-2021)

Figure 7 NCERM information: feature number predominant risk at the coast

As the area of the cable corridor at the coastline is classified as Floodable, the erosion rates shown in these figures is 0 m/yr for both scenarios, the three periods and the three confidence intervals. It is important however to consider that to the north of our area, the coastline is prone to erosion.

Table 5 Erosion rates for No active intervention policy

Period	Short Term Erosion Rate (m/yr)			Medium Term Erosion Rate (m/yr)			Long Term Erosion Rate (m/yr)		
Confidence level interval	5th percentile	50th percentile	95th percentile	5th percentile	50th percentile	95th percentile	5th percentile	50th percentile	95th percentile
Feature number (colour refers to defence type in Figure 6)									
47680 to 47720 (red)	0	0	0	3.3	2.5	1.40	6.6	5	3.4
47730 to 47760 (orange)	8	6	4	20	15	10	40	30	20
47770 to 47780 (black)	1.32	1	0.68	3.3	2.5	1.7	6.6	5	3.4
47790 to 47810 (green)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
47820 (purple)	0.99	0	0	3.3	2.5	1.7	6.6	5	3.4
47830 to 47920 (blue)	0	0	0	0	0	0	0	0	0

Table 6 Erosion rates for No active intervention policy

Period	Short Term Erosion Rate (m/yr)			Medium Term Erosion Rate (m/yr)			Long Term Erosion Rate (m/yr)		
Confidence level interval	5th percentile	50th percentile	95th percentile	5th percentile	50th percentile	95th percentile	5th percentile	50th percentile	95th percentile
Feature number (colour refers to defence type in Figure 6)									
47680 to 47720 (red)	0	0	0	0	0	0	0	0	0
47730 to 47760 (orange)	8	6	4	20	15	10	40	30	20
47770 to 47780 (black)	1.32	1	0.68	3.3	2.5	1.7	6.6	5	3.4
47790 to 47810 (green)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
47820 (purple)	0	0	0	0	0	0	0	0	0
47830 to 47920 (blue)	0	0	0	0	0	0	0	0	0

3.2.3 Flooding risk

According to the SMP2 (Halcrow, 2010) in the northern section of this frontage, erosion and flooding is expected in the vicinity of Cliffs End. Similarly, sediment stored within the dunes, which "decorate" the shingle ridge between Shell Ness and Sandwich Flats will also be prone to breach. Once a significant breach occurs, the new opening is likely to be inundated on normal tides, resulting in flooding of the low-lying hinterland. There is also the potential that the dynamics of the River Stour could change, if the river broke through the tight meander around Richborough; the impact of this would be a realignment of the river's mouth, but based on present evidence this scenario seems less likely.

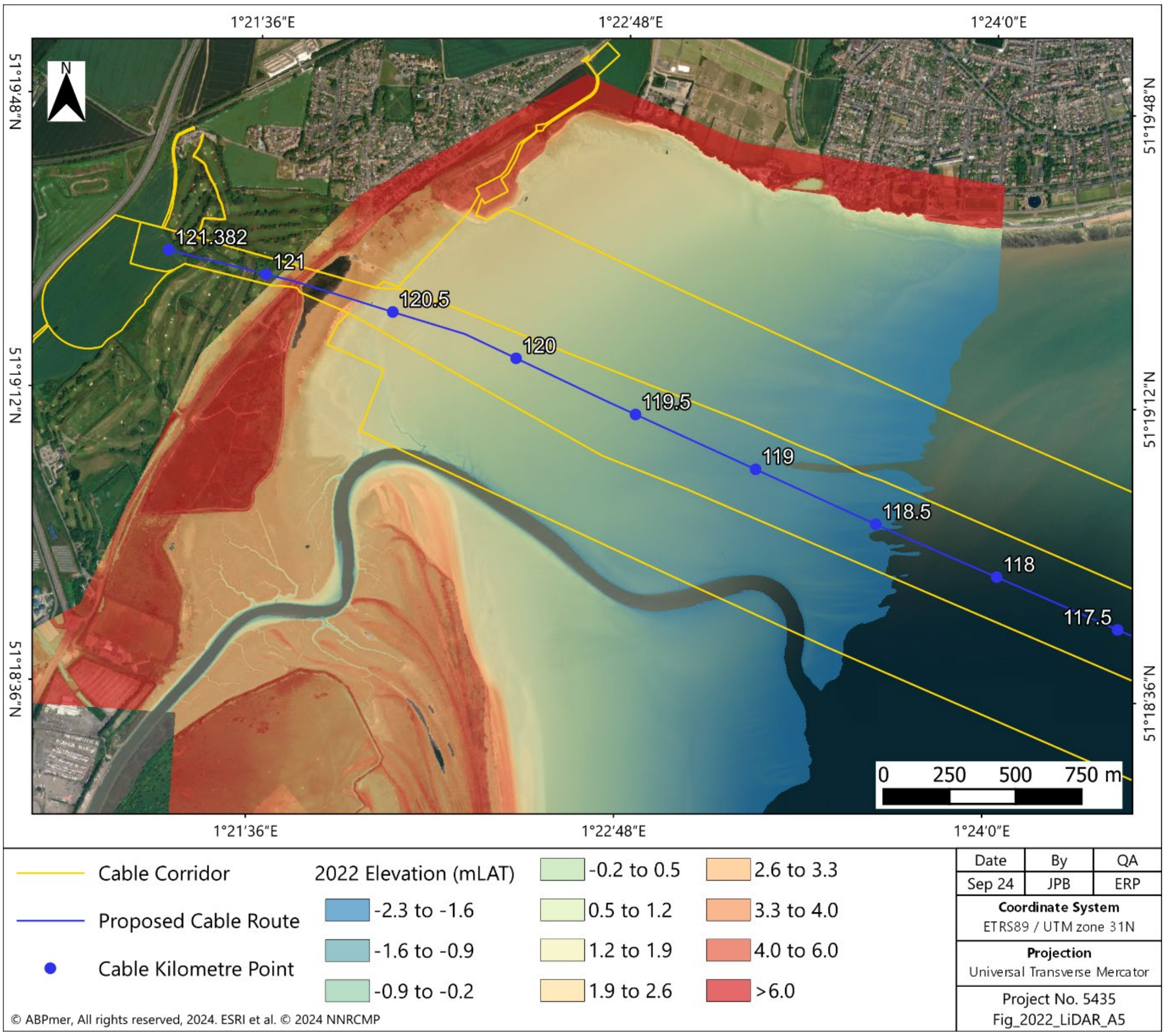
It is predicted (Halcrow, 2010) this flooding in the north could combine with flooding from the south (Sandwich Bay Estate (south) to Sandown Castle (remains of)), which in turn could combine with inundation from the north Kent coast, from the Reculver to Minnis Bay frontage. Should this occur then the former tidal channel, the Wantsum Channel, between north and east Kent would be re-activated. In the long term (beyond the scope of the SMP) there is the potential for either an ebb tidal delta or flood tidal channel to form, depending on the dynamics of the River Stour, sea level and the tidal currents (Futurecoast, 2002).

The construction of flood embankments along the low-lying coast i.e. between Pegwell Bay and Walmer, provide a secondary defence to marine inundation. As the low-lying hinterland is a single flood cell, the embankments provide the backing assets with fundamental protection.

The latest topographic data from 2024 is shown in Figure 8. It illustrates, along with the profile of the cable route (Figure 1) how the hinterland is higher (for example where the road is) before it reaches the area at around KP121 where there is a small dip (shown as drain in the profile). Then, the elevation of the golf course and proposed Construction Compound / Transition Joint Bay behind is higher, the latter being at 7 mODN (9.1 mLAT).

The 1:200 return period extreme water level for 2018 (provided in Table 9) is 6.81 mLAT[2], lower than the Construction Compound / Transition Joint Bay, which therefore should not be flooded. The hinterland north of KP 120.5 is between 4-6 mLAT and could therefore be flooded very often (note that HAT is 6 m above LAT). In the future, with sea level rise (see Section 3.3.2), the risk of flooding will increase. A major flooding event in the area is both possible and unpredictable.

[2] Note that this is the level for 2018 and sea level rise should be applied to take this value to 2027. However, the difference in levels (from 2018 to 2027) will be of the order of 5 to 6 cm and therefore considered insignificant for this high-level assessment.



Source: EA, 2024

Figure 8 Topography of the study area

The Stour Catchment Flood management plan (EA, 2019) describes the policies in the Stour catchment. Sandwich Bay is under Policy 3, which is for areas of low to moderate flood risk where the existing flood risk is being managed effectively.

The Stour Catchment Flood management plan (EA, 2019) also mention the risk of flooding from the impacts of tide-locking is likely to increase as sea levels increase under the impacts of climate change. They also mention that some of these will be mitigated with sea defence improvements expected in other plans[3], as well as upstream policies, such as increasing flood storage within the Lower Stour.

[3] Some of the proposed actions are:

- tidal flood risk will be addressed through the Sandwich Tidal Scheme.
- water on the marshes upstream of Sandwich marsh should be moved around and managed
- address issues of surface water flooding and drainage

3.2.4 Defences

The SMP2 (Halcrow, 2010) describes the defences in the area as per the different stretches:

- Pegwell to Cliffs End: undefended chalk cliffs
- Cliffs end to river Stour: Along the low-lying section where the road is at its closest to the MHW line there are no formal defences. Further south, within the boundaries of the nature reserve, there is an embankment which is revetted with rock along the sections exposed to wave action.
- River Stour to Sandwich Bay Estate: no formal defences. The only protection against flooding and erosion are the extensive sand dunes.

3.2.5 Nature conservation

The south-western corner of Pegwell Bay is predominantly low-lying intertidal saltmarsh flanked by mud/sand flats (which are designated features within the Sandwich Bay SAC (Special Areas of Conservation). The Thanet Coast consist of many nature conservation designations:

- Two Special Areas of Conservation: Thanet Coast SAC & Sandwich Bay SAC.
- A Special Protection Area: Thanet Coast & Sandwich Bay Special Protection Area (SPA).
- A Wetland of International Importance: Thanet Coast & Sandwich Bay Ramsar site.
- Site of Special Scientific Interest (SSSI): all Thanet Coast Sites of Special Scientific Interest and part of the Sandwich Bay to Hacklinge Marshes.
- Kent's largest National Nature Reserve: the 'Sandwich and Pegwell Bay National Nature Reserve (NNR)'
- A Marine Conservation Zone (MCZ): Thanet Coast MCZ

In 2013, the Thanet Coast MCZ (Marine Conservation Zone) was added, as part of progress towards a network of marine protected areas (Marine and Coastal Access Act 2009) – and all the designations are now collectively known as the "North East Kent Marine Protected Area" (NEKMPA). Previously the international designations were collectively known as the 'North East Kent European marine site'.

The NEKMPA is legally protected and the shore and sea has a management scheme which ensures that they are managed in a way that conserves their importance for wildlife.

3.3 Wave conditions

The offshore wave climate for the Pegwell Bay frontage is illustrated as Figure 9 below. The dominant offshore wave directions come from the northeast and the south. A range of nearshore bathymetric features are present which locally modify the waves approaching Pegwell Bay from offshore. Notable features include several sandbanks, such as the Goodwin Sands (between 4 and 12 km offshore of Deal), Goodwin Knoll, Gull Stream, and also deep water channels such as the Ramsgate channel (shown in Figure 10).

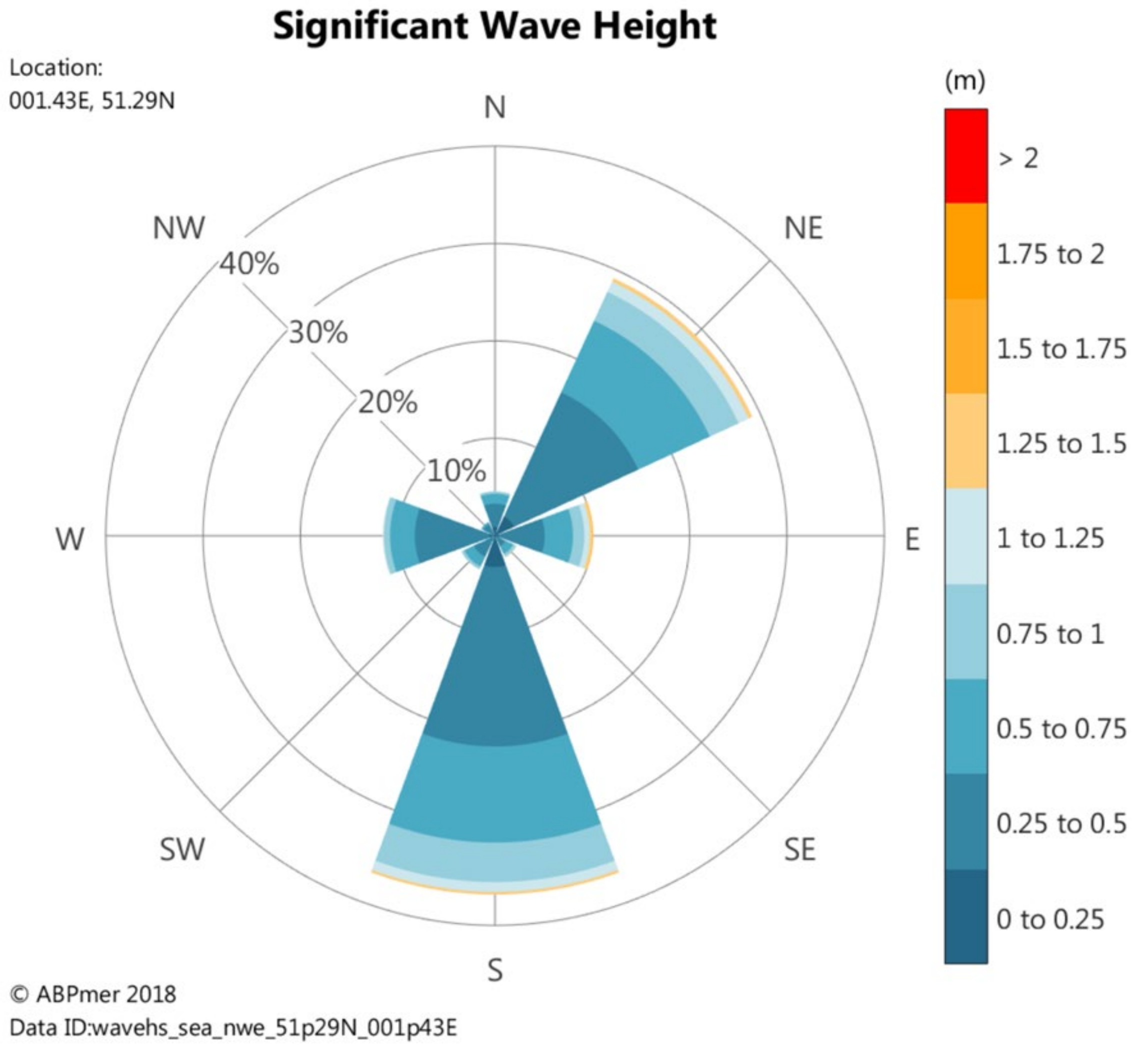
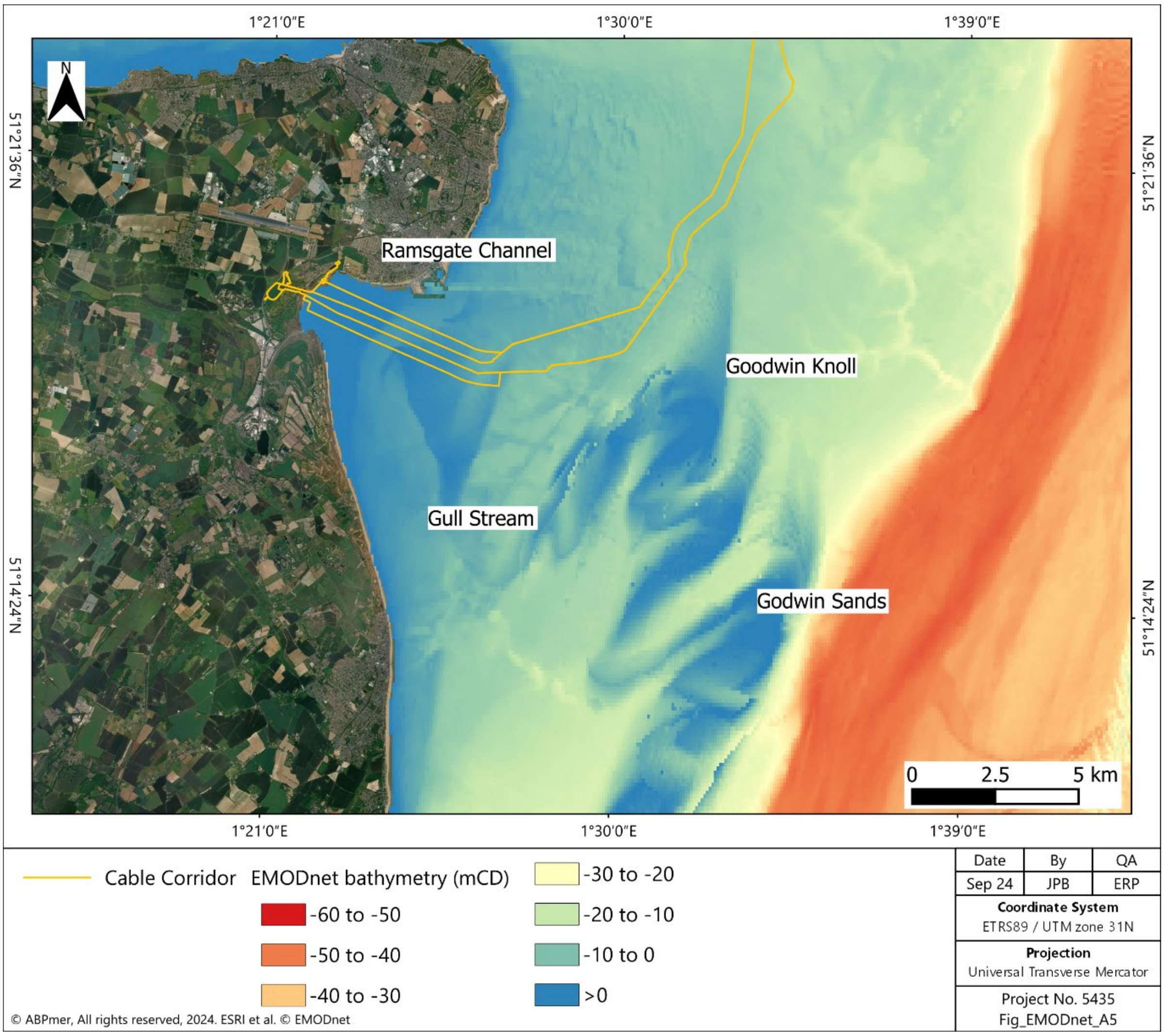


Figure 9 **Wave climate offshore of Pegwell Bay (source ABPmer's SEASTATES[4] 40 year wave hindcast)**

4 www.seastates.net



Bathymetric data source: Emodnet, 2022

Figure 10 **Bathymetry of the wider area, showing larger nearby sandbanks and other features potentially affecting wave climate**

3.3.1 Extreme wave conditions

Univariate analysis from the SEASTATES wave data has been carried out for the metocean study for NGET at different locations along the cable rote.

Values at KP115 (see location in Figure 11) for five different return periods from the analysis are given here in Table 7 for all directions. An example of the directionality of this data is provided in Figure 12, where the directional extreme wave heights for a 1:50 year return period have been plotted. The relative directional distribution of all (45 years of) available wave data are shown by the underlying scatter points where colour indicates the relative density of the data (relative frequency of occurrence of joint wave height/direction occurring) the resulting 1:50 year return period extreme wave height estimate for each directional sector is overlaid as a black solid line shape and value. In this case, for the 1:50 return period, the most extreme wave height is from the east at 1.8 m, followed by northeasterly and south at 1.7 m. These wave heights are representative of nearshore approaches to the landfall, however, very local modification of waves might be expected at and around the exact landfall position.

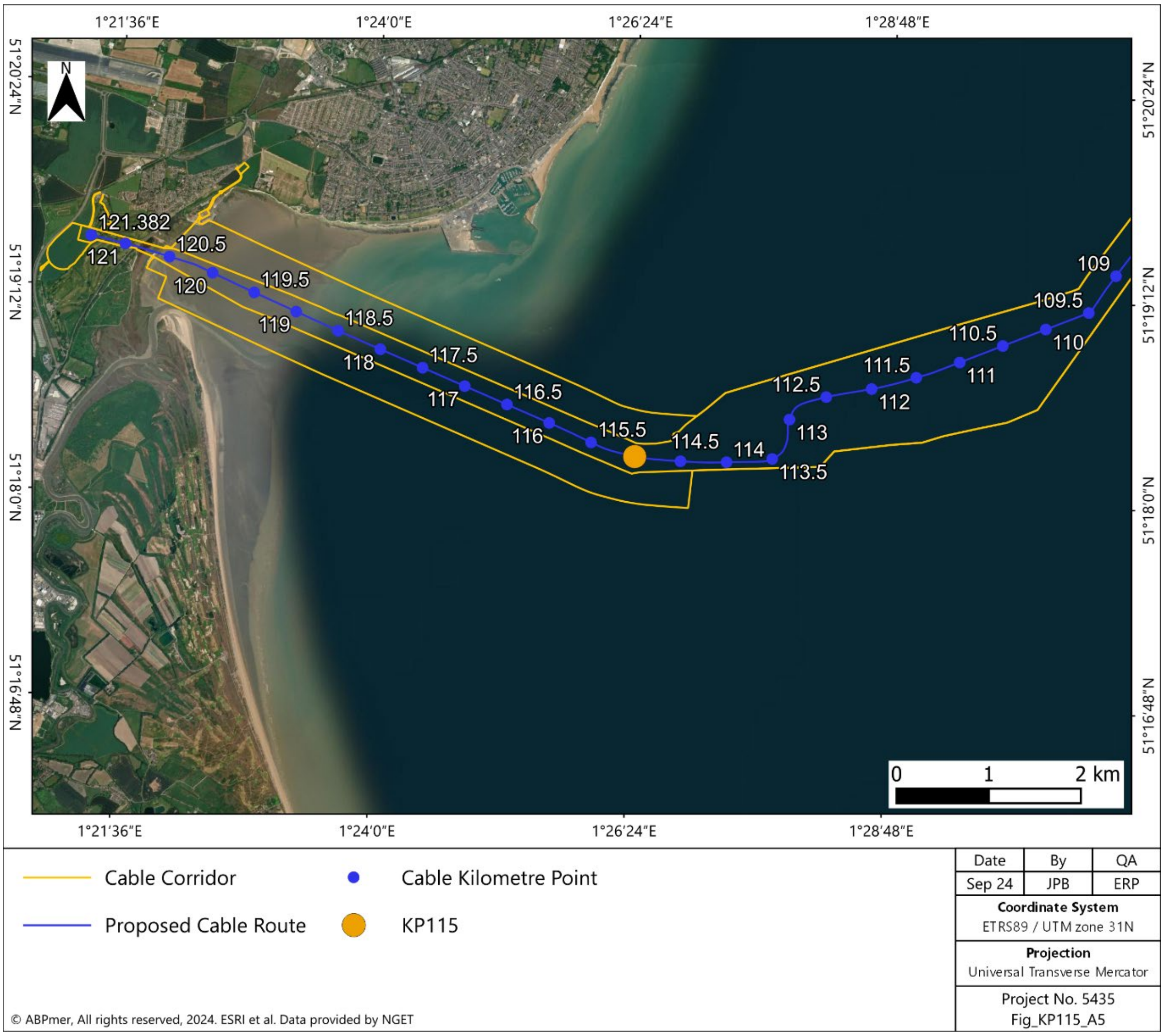


Figure 11. Position of KP115

Table 7. Omnidirectional extreme wave results at KP115 for five different return periods

Wave parameter	Return period (years)				
	1:1	1:5	1:10	1:50	1:100
Hs (m)	1.6	1.7	1.8	1.8	1.8
Tp (s)	6.9	7.2	7.3	7.4	7.4

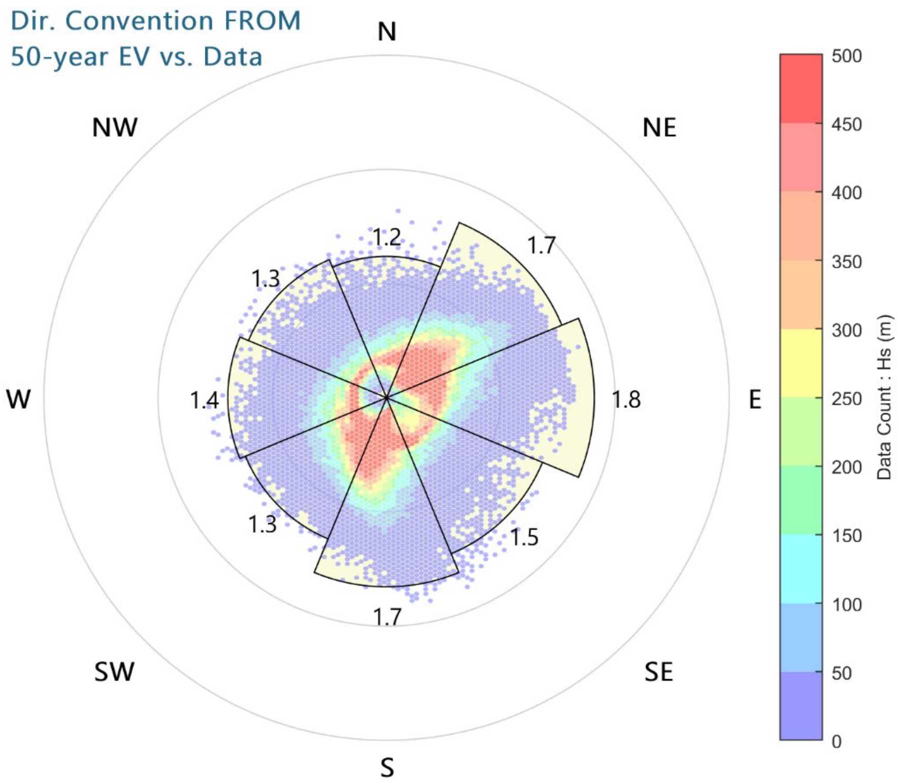
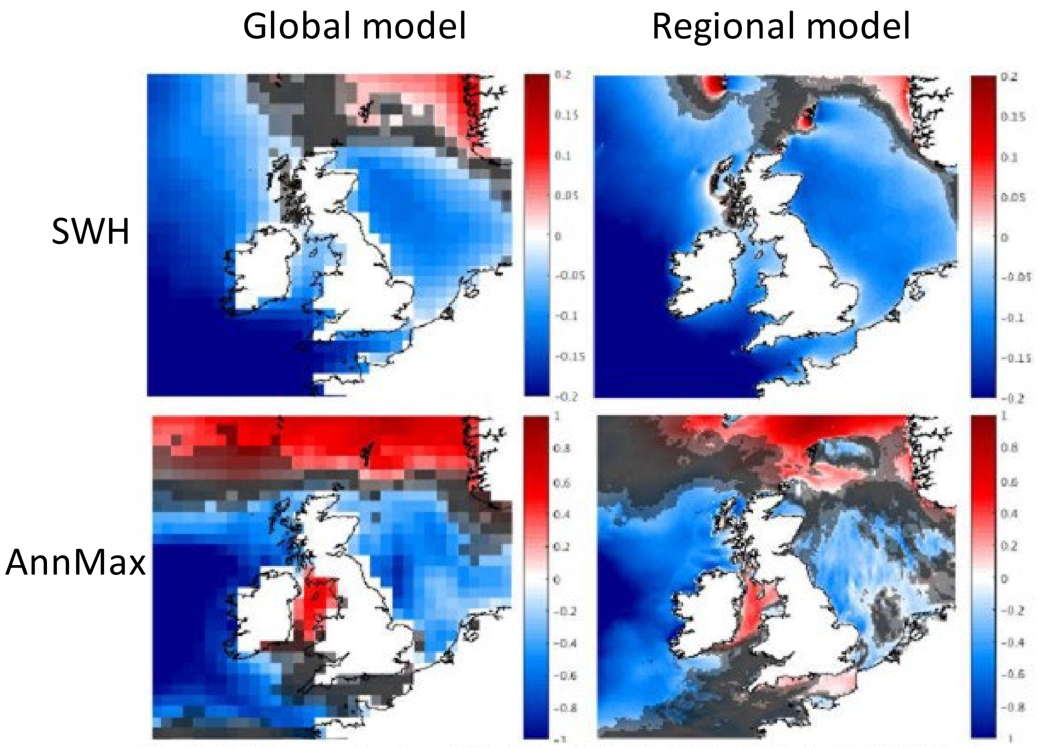


Figure 12 **Wave rose of extreme wave heights at 1:50 return period for KP115, showing the amount of wave height data per sector and in black the exteme wave height per direction sector.**

3.3.2 Climate change

The UKCP18 Marine Projections report (MetOffice, 2018) provides with regional wave model projections where significant wave heights (SWH) and mean annual maximum (AnnMax) are provided for the UK for the end-21st century period 2081-2100. Their results are reproduced here in Figure 13 as maps of change in SWH between the end-21st century RCP8.5 projection, and the present-day conditions. The area of the proposed landfall shows an absolute change in significant wave height of maximum 0.1 m. As for the mean annual maximum, the area is within that where the changes are hidden by the natural variability.



Source: MetOffice, 2018

All plots show an absolute change, in metres. Grey masking indicates where natural variability is high. Where there is no masking, there is higher than a 75% chance that the future wave conditions are different to the historical conditions, rather than masked by natural variability

Figure 13 **RCP8.5 end century change in mean SWH (top) and mean AnnMax (below). Global model (left) and regional (right).**

Storm surges

UKCP18 found no evidence for significant changes in future storm surges.

3.4 Tides and Water Levels

Predicted tide levels for the primary port of Ramsgate are presented in Table 8 which have been taken from Admiralty Total Tide data (2024). The conversion from mCD to mODN is -2.58 m. Tides are semi-diurnal with approximately two tides a day.

Table 8. **Predicted tidal levels at Pegwell**

Level	Tide Level (mODN)	Tide Level (mCD)
HAT	3.12	5.7
MHWS	2.62	5.2
MHWN	1.42	4
MSL	0.15	2.73
MLWN	-1.18	1.4
MLWS	-1.98	0.6
LAT	-2.88	-0.3
Mean neap tide range (m)	2.6 m	
Mean spring tide range (m)	4.6 m	

Note the datum conversions are done as per spatially changing VORF reference levels, as explained in Section 2.1.

3.4.1 Extreme Water Levels

Estimated, present day extreme water levels from Coastal Flood Boundaries Dataset (CFBD) 2018 are presented in Table 9 (Environment Agency, 2019). Location of points of this dataset is given in Figure 14. In the table, t1 for example refers to the 1 in 1 return period, where return period provides an estimate of the probability of exceedance of a given level in this case. For example, t100, a 100-year return period corresponds to a level that has an exceedance probability of 0.010 or a 1% chance that the level will be exceeded in one year[5].

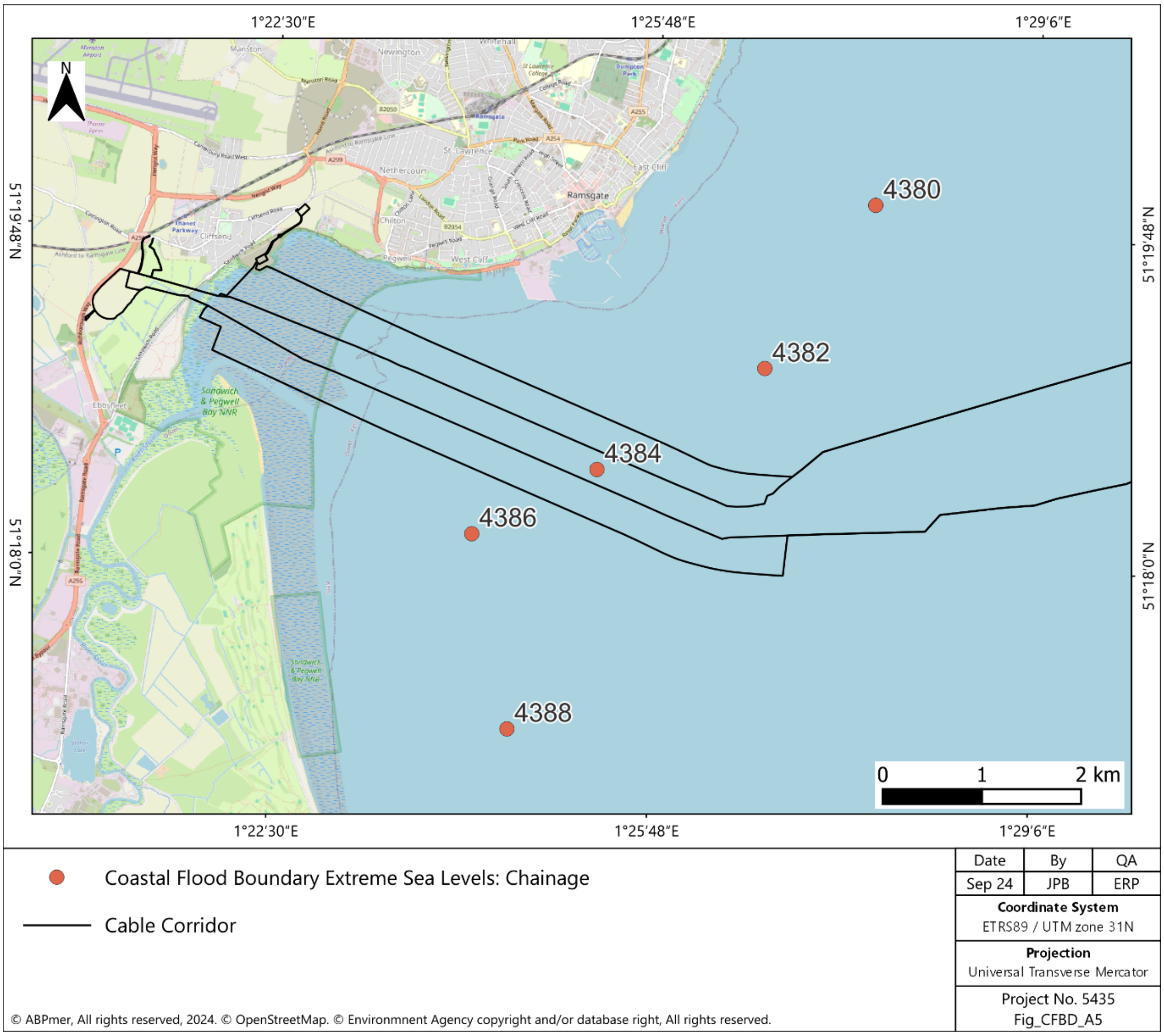
Table 9. Extreme water levels for 2018 (Chainage 4386)

Return Period	Level (mODN)	Level (mLAT)[6]
HAT	2.93	5.12
t1:	3.72	5.91
t2:	3.83	6.02
t5:	3.97	6.16
t10:	4.08	6.27
t20:	4.21	6.4
t25:	4.25	6.44
t50:	4.36	6.55
t75:	4.44	6.63
t100:	4.49	6.68
t150:	4.57	6.76
t200:	4.62	6.81
t250:	4.67	6.86
t300:	4.70	6.89
t500:	4.81	7
t1000:	4.96	7.15
t10000:	5.46	7.65
Note: Some return periods have been highlighted for ease of reading the table		

Source: Environment Agency, 2019

5 The most common misconception about return periods, for example, the 100-year return period is that the extreme water level will only occur once in 100 years. It is essential to understand that if an extreme water level with a 100-year return period occurs now, it does not mean that another extreme water level of this magnitude will not occur in the next 100 years.

6 The conversion from ODN to LAT has been done using a value of 2.19, which corresponds to the value at midpoint between the KP121 (2.11 m) and KP120 (2.22 m), see Figure 2 and Figure 3



Source: Environment Agency, 2019

Figure 14 Location of the Coastal Flood Boundary Extreme Sea Levels points

3.4.2 Climate Change

The Environment Agency provide climate change guidance in their website (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#offshore-wind-speed-and-extreme-wave-height-allowance).

The sea level allowances provided by the EA for the South East region are provided in Table 10. They are provided based on two percentiles (a percentile describes the proportion of possible scenarios that fall below an allowance level). These are:

- Higher central allowance is based on the 70th percentile: an allowance based on the 70th percentile is exceeded by 30% of the projections in the range.
- Upper end allowance is based on the 95th percentile: an allowance based on the 95th percentile it is exceeded by 5% of the projections in the range.

This data has been plotted for both the higher central and the upper end allowances, from the baseline year of 2027, for 50 years. It can be inferred from the table or the graph that, for our site, the following sea level rise should be considered:

- For 40 years from 2027: a sea level rise of 0.35 to 0.45 m needs to be considered.
- For 50 years from 2027: a sea level rise of 0.45 to 0.58 m needs to be considered.

The EA does not mention the RCP considered in these allowances, although it is believed to be RCP 8.5.

Table 10. Sea level allowances for South East region for each epoch in mm for each year (based on a 1981 to 2000 baseline) – the total sea level rise for each epoch is in brackets

Allowance	2000 to 2035 (mm)	2036 to 2065 (mm)	2066 to 2095 (mm)	2096 to 2125 (mm)
Higher central	5.7 (200)	8.7 (261)	11.6 (348)	13.1 (394)
Upper end	6.9 (242)	11.3 (339)	15.8 (474)	18.2 (546)

Source: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#offshore-wind-speed-and-extreme-wave-height-allowance

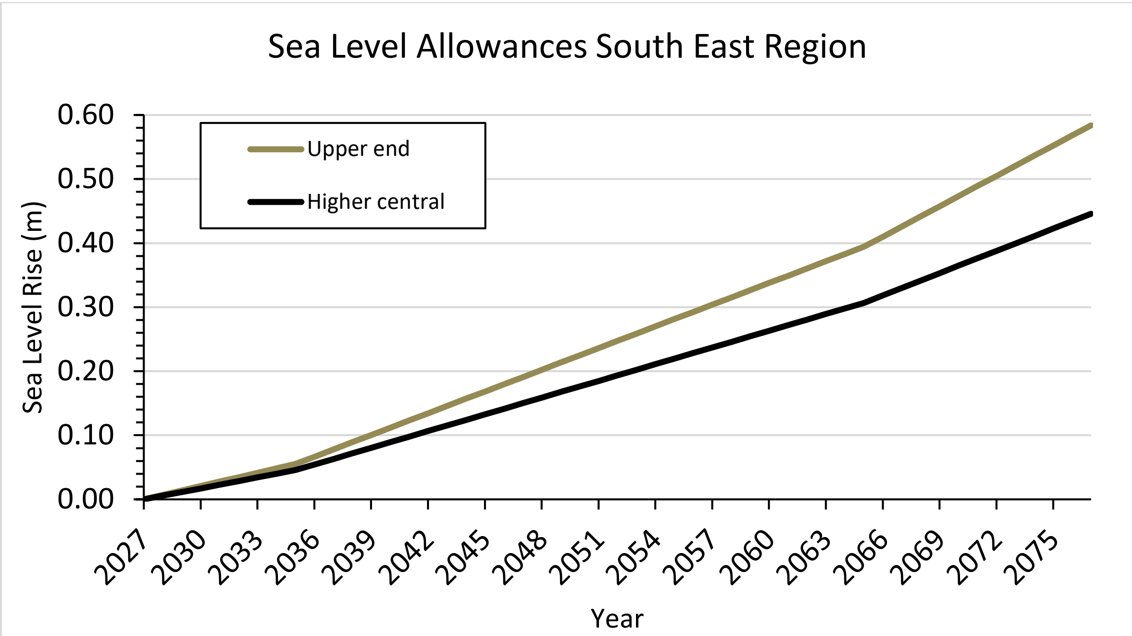


Figure 15 **Sea Level allowances for the South East region from baseline year of 2027 for 50 years.**

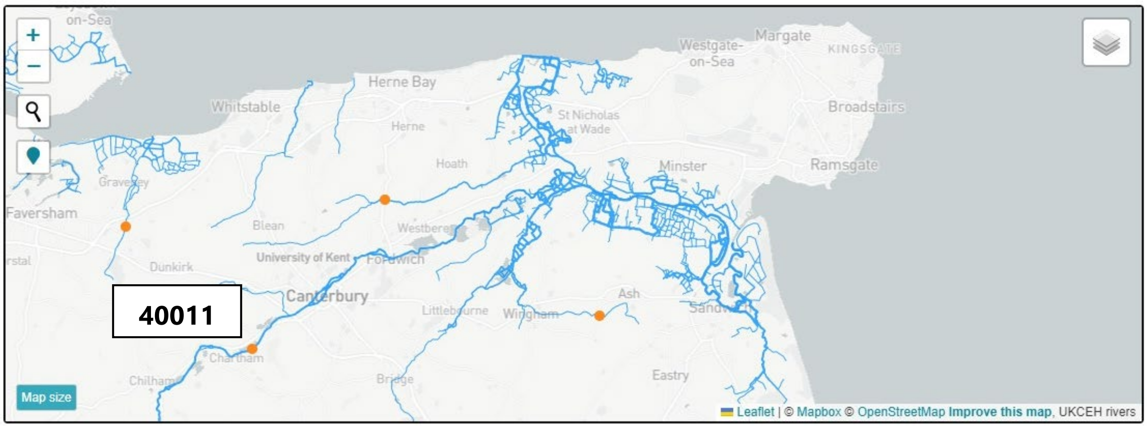
3.5 River Flow

The Stour catchment, see Figure 16, comprises the Great Stour, East Stour, Little Stour and The Stour as well as many other tributaries. When the Great Stour leaves Canterbury, the river flows on to Fordwick, where it becomes tidal. It then enters the Lower Stour. At Pluck's Gutter, the Great Stour is joined by the Little Stour, and becomes The Stour. From here it flows across a landscape that was once the sea – the Wantsum Channel separated Kent from the Isle of Thanet during the Roman and Early Medieval period. The Stour flows on through Sandwich onto Pegwell Bay.

Source: EA, 2009

Figure 16 The Stour Catchment

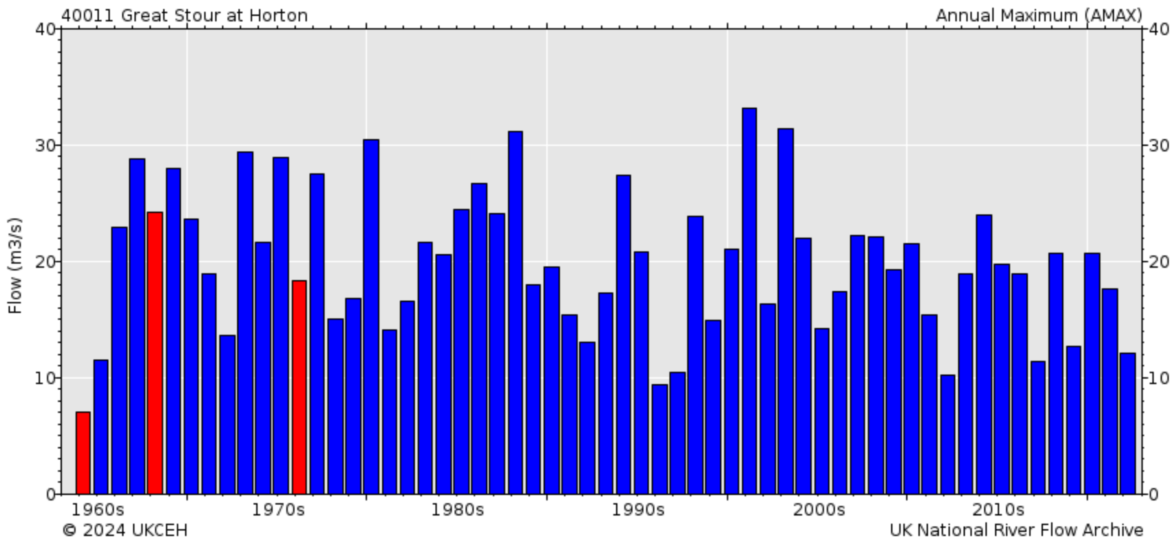
The National River Flow Archive (NRFA), based at the UK Centre for Ecology & Hydrology, is the UK's official record of river flow data (https://nrfa.ceh.ac.uk/). They hold information for all the gauging stations around the UK. The gauging stations for the River Stour are shown in Figure 17. Of these stations the most relevant for the study is station 40011 for the Great Stour at Horton, as it captures the flow before it splits into two. The data at this gauging station is an overestimation of the river flow at Pegwell Bay but the trends in the data should be similar.



Source: https://nrfa.ceh.ac.uk/

Figure 17 Gauging stations River Stour

The annual maximum river flow (or maximum instantaneous peak flows) in m^3/s measured at station 40011 is provided in Figure 18 from the 60's to date (red bars contain rejected annual maximum values). Both the trends for this maximum river flow and for the daily flows are for a slight reduction over the years, although what is clear is that the natural variability of the annual maximum flow is very high.



Source: https://nrfa.ceh.ac.uk/

Figure 18 Annual maximum river flow at Station 40011 Great Stour at Horton.

3.5.1 Climate change

The environment Agency provides peak river flow allowances within their climate change allowances (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances).
Peak river flow allowances show the anticipated changes to peak flow by management catchment.

The range of allowances is based on percentiles. A percentile describes the proportion of possible scenarios that fall below an allowance level. The 50th percentile is the point at which half of the possible scenarios for peak flow fall below it, and half fall above it.

The allowances provided are:

- Central allowance is based on the 50th percentile: this allowance is exceeded by 50% of the projections in the range
- Higher central allowance is based on the 70th percentile: this allowance is exceeded by 30% of the projections in the range
- Upper end allowance is based on the 95th percentile: this allowance is exceeded by 5% of the projections in the range

For the River Stour Management catchment, the river flow allowances are provided in Table 11. These allowances range from 18% to 101% of possible changes to the peak flow; given the high variability of these peak flows (see Figure 18) these seem quite reasonable.

Table 11 River Stour catchment river flow allowances

	Central	Higher	Upper
2020s	18%	25%	40%
2050s	20%	30%	55%
2080s	38%	55%	101%

Source: https://environment.data.gov.uk/hydrology/climate-change-allowances/river-flow?mgmtcatid=3087

3.6 Geology and geomorphology

The main foreshore features in the area of study are the saltmarsh and extensive tidal mudflats of Pegwell Bay. Cliffs composed of resistant Upper Cretaceous Chalk (99-65 million years ago) extend south from North Foreland to Ramsgate (West Cliff). West of Ramsgate (West Cliff) the Chalk cliffs give way to low-lying hinterland composed predominantly of superficial Pleistocene deposits (i.e. gravel and sand). This stretches down through Pegwell Bay, Sandwich, Deal and Kingsdown (Halcrow, 2010). Offshore banks, see Figure 10, also believed to be a relict feature of the Holocene Marine Transgression (10,000 years BP) along this section of the coast, are believed to exert a key control.

3.6.1 Seabed sediment composition

The seabed over the study area contains a mix of sandy gravel, slightly gravelly sand and sand as shown in Figure 19. Closer inshore, in the bay, sediments comprise of medium to silty sands overlying chalk (Rees Jones, 1998; Dussart and Rodgers, 2002; Thanet Offshore Wind Limited, 2005).

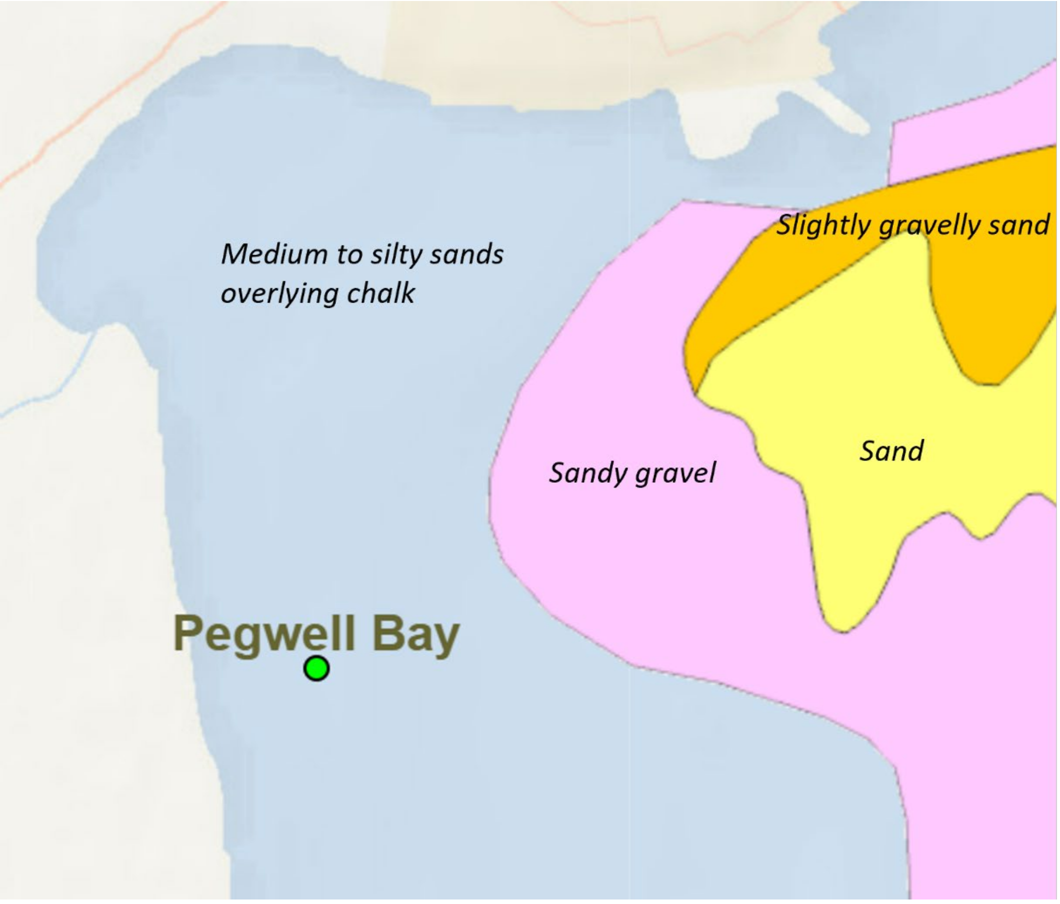


Figure 19. Offshore seabed sediments. Derived from (1:250,000) scale BGS Digital Data under License (2007/017) British Geological Survey. ©NERC.

3.7 Sediment transport regime

3.7.1 Introduction

SMP2 (Halcrow, 2010) state that various studies acknowledge that there is a general lack of contemporary sediment entering the system (Atkins, 2001; Futurecoast, 2002). The headland at North Foreland acts as a natural boundary thus little to no sediment is known to enter from the north. Between Ramsgate (West Cliff) and Cliffs End there is a small amount of contemporary sediment being added to the system and this is derived from two sources: from alongshore and from the River Stour (which exits into Pegwell Bay).

As such, the present functionality of Goodwin Sands exerts a large-scale control on the development of Sandwich and Pegwell Bay. Nominally Goodwin Sands supplying fine material (sand) to the foreshore as well as protecting the shoreline against direct incident wave attack.

Anthropogenic constraints according to the SMP2 (Halcrow, 2010) have greatly influenced the morphology and coastal processes of the study frontage. The most notable example of intervention is at Sandwich Bay. The inter-tidal areas were constrained via reclamation, in the twelfth and thirteenth century. This, along with the northward migration 'Stonar Neach' caused gradual silting up / closure of the Wantsum Channel; a tidal waterway that once extended from north Kent to Sandwich Bay and separated the Isle of Thanet from the mainland.

There are several forcings to the sediment transport in this area:

- Offshore the sediment transport is dominated by the action and asymmetry of tidal currents
- Inshore, there is a combination of:
  - Tidal currents that will cause longshore transport along the coast
  - Oblique waves that cause longshore drift along the coast
  - Storm events that will mostly work in the cross-shore dimension moving sediment at shorter time-scales

All of these are influenced by the bathymetry of the area, and in particular to the complex banks present, shown in Figure 10.

These forcings are all detailed below, together with a summary of the banks movement.

3.7.2 Longshore drift due to oblique waves

According to the SMP2 (Halcrow, 2010) the section of the frontage from North Foreland to Deal is exposed to coastal processes operating both within the southern North Sea and the English Channel. The Deal to Kingsdown Strategy Study (Atkins, 2001) and Futurecoast (2002) assert that the predominant wave direction is from the north-east (inshore wave direction) and the south-west (offshore wave direction); as such alongshore sediment transport is both north and southwards. Between North Foreland and Cliffs End the net littoral drift is south whereas between Cliffs End and South Foreland the net littoral drift is north; as such a drift convergence exists at Pegwell Bay. As the sediment moves alongshore, the transport rates reduce, so that fine sediments collect at Sandwich Flats and Pegwell Bay.

However, under storm conditions, which are mainly south-easterly events, then sediment transport is unidirectional i.e. towards the south.

3.7.3 Tidal Currents

Tidal currents bring in sand and silt as suspended load into Pegwell Bay (Motyka and Brampton, 1993).

ABPmer has extended the grid of their high-resolution hydrodynamics model and run it for the whole year of 2027 to extract high resolution tidal currents along the cable route. The model grid near the Pegwell Bay landfall is shown in Figure 20 in two images, one of the outer area and one zoomed on the bay. The bathymetry is shown with the mesh, so in the outer area image one can see that the channel bathymetry is well resolved in the model. In the detailed image of the bay, the shoals offshore of Ramsgate channel outside of the bay can also be observed.

Figure 21 shows the tidal currents in the area of the larger area of interest, at four states of the tide; Low Water (LW), nearly Mid Flood (MF), High Water (HW), and nearly Mid Ebb (ME) during a large spring tide in March 2027 (the KP points along the cable route shown are at 0.5 km intervals). Each sub-plot shows in a small insert the surface elevation at KP115.0 (location in Figure 11) at the time of the snapshot. The results are for the largest tidal range typically experienced in a year and illustrates a potential annual maximum flow regime; lower flow speeds will be experienced over a typical tide.

In all four cases, the tidal currents inside the bay are very small. At the positions of KP120.5 and 120.0, the tidal current speeds are always less than 0.1 m/s during all stages of the tide. Outside of the bay, the tidal currents are towards the South in low water and mid flow, splitting when reaching Goodwin so that inshore of it the tidal currents are running towards the southwest and offshore of it they continue southwards until they meet again south of Goodwin. Across the Ramsgate channel, the tidal currents follow its path during the low water and mid-flow travelling southwest and then south southeast. In high water and mid ebb, the currents are tidal currents offshore of the bay also follow Ramsgate channel alienation close to the bay and offshore they split either side of Goodwin in a similar (but opposite directions) as they did during the floods.

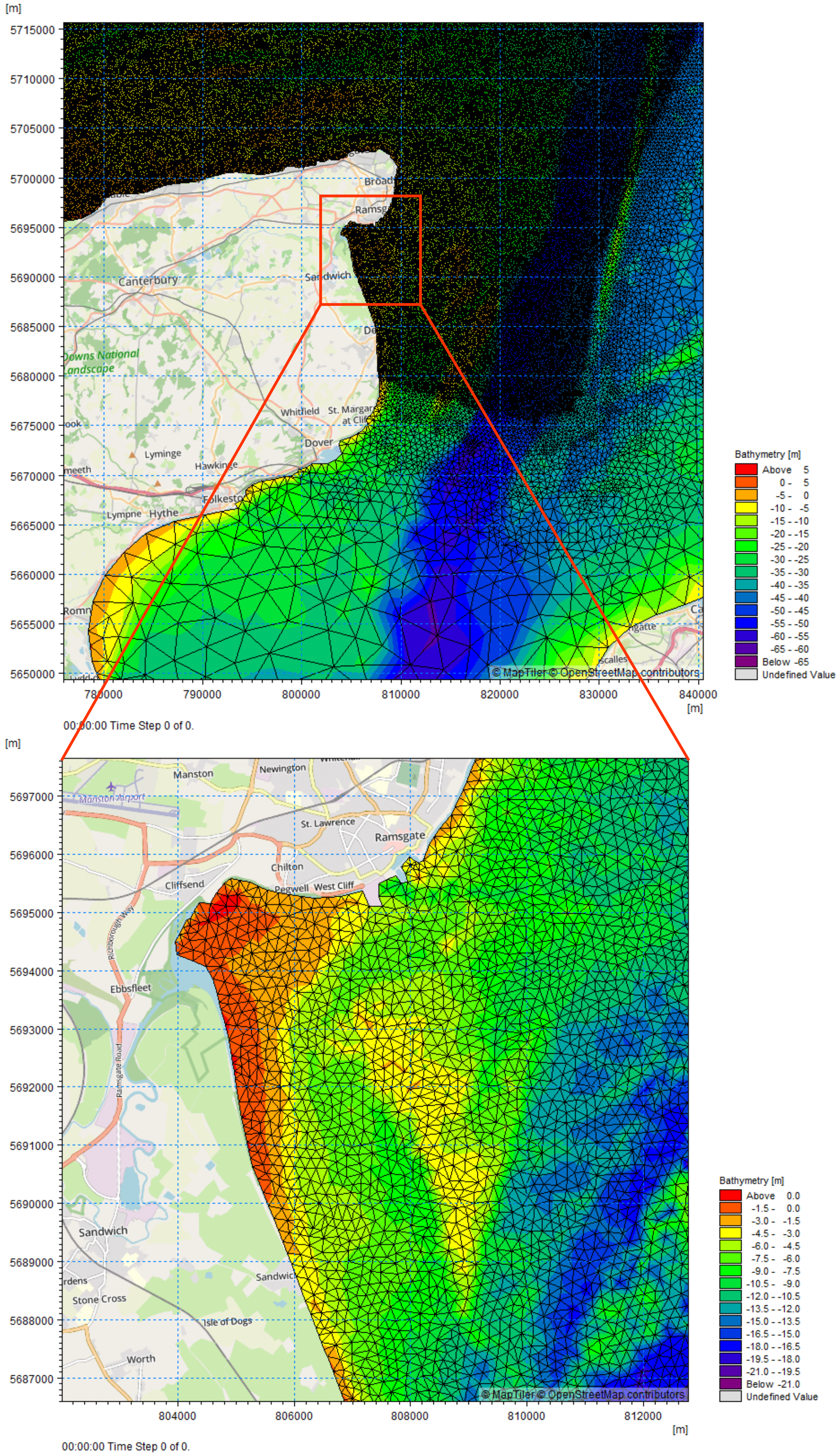


Figure 20 Mesh and bathymetry for hydrodynamic high resolution model

Tidal ellipses

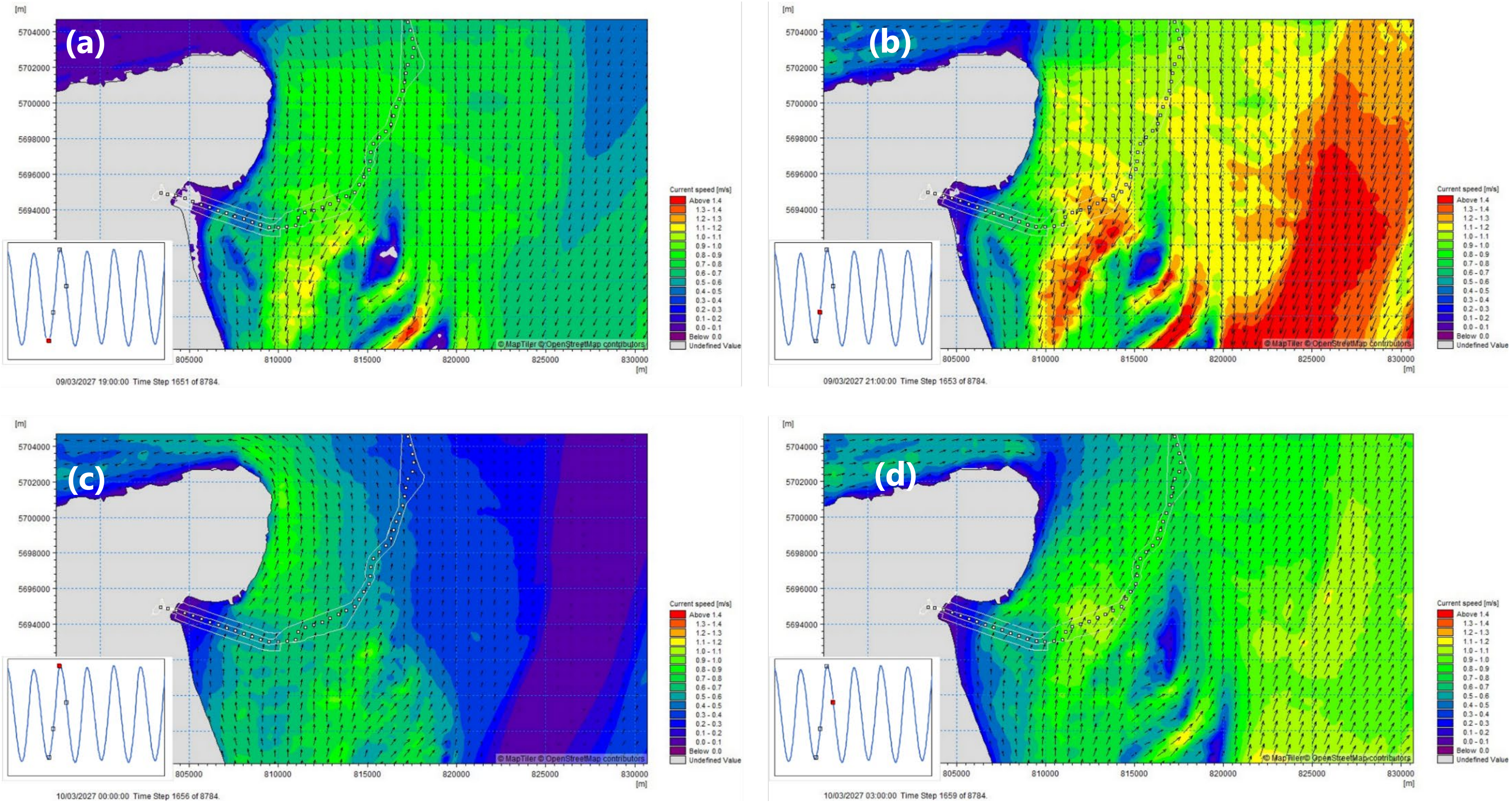
ABPmer (2018) carried out harmonic analysis of the current velocity in the wider area of study and produced a map of tidal ellipses, reproduced here in Figure 22. These tidal ellipses show:

- the maximum current velocity within one period of the tidal constituent with the semi-major axis of the ellipse;
- the minimum current velocity within one period of the tidal constituent with the semi-minor axis of the ellipse;
- the orientation of the maximum current induced by the tidal constituent with the direction of the semi-major axis of the ellipse; and
- the orientation of the minimum current induced by the tidal constituent with the direction of the semi-major axis of the ellipse.

From these results, one can observe the following:

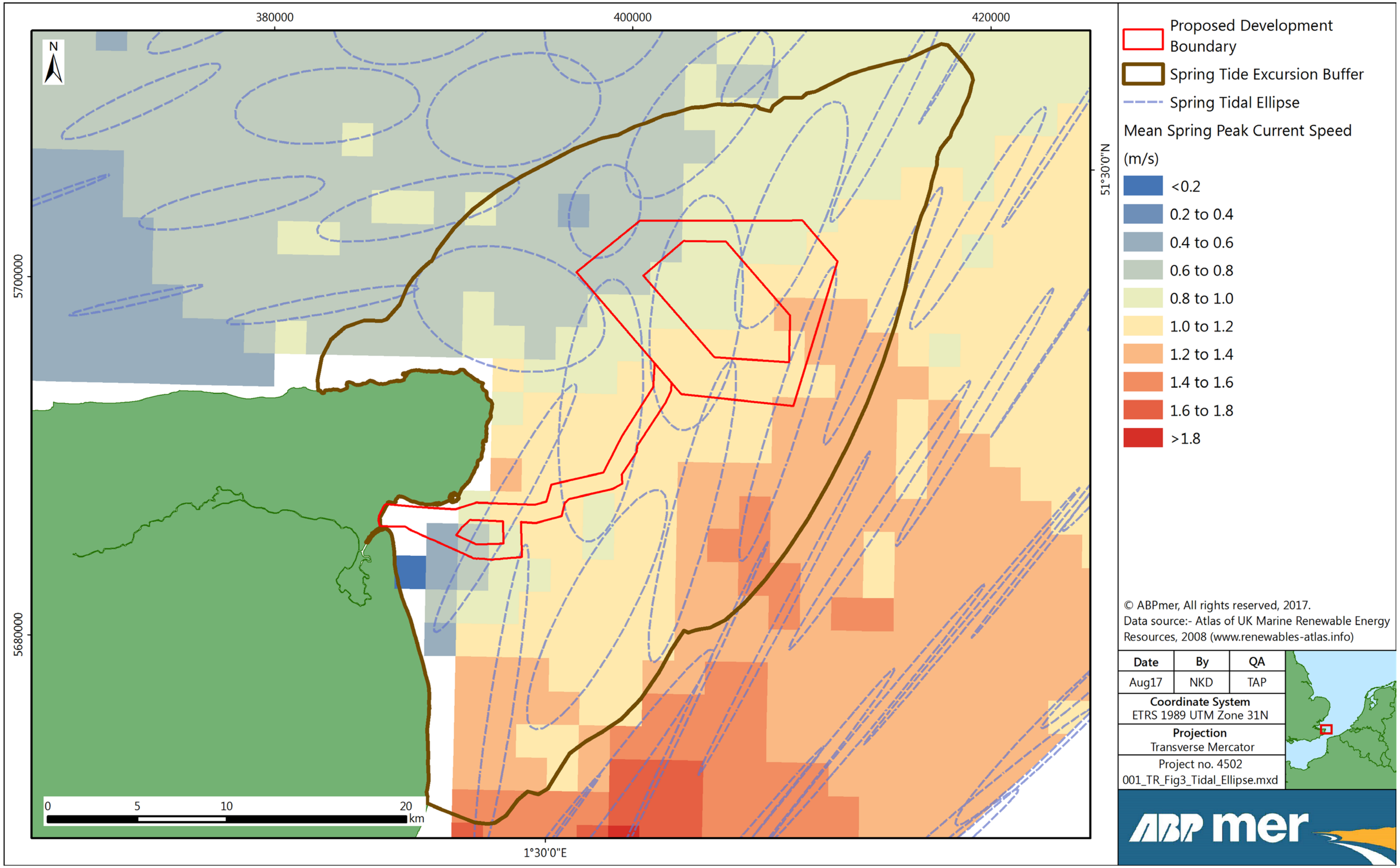
- The tidal excursion ellipse closer to the Bay is up to ~17 km in overall length on spring tides and 9 km on neap tides; the tidal axis is aligned northeast – southwest and the flow pattern is relatively rectilinear (with a well-defined flood and ebb direction, characteristic of tidal flow constrained by bathymetry in an estuary (Prosser *et al*., 2015)).

- Within the spring tidal excursion ellipse buffer around the Thanet Extension array area (in brown in Figure 22), and beyond the two closest inshore, the ellipses are less rectilinear and move clockwise as you move offshore. To the south of this buffer, the ellipses are very rectilinear.



The inset figures show water elevation at KP115 and are used as a general reference to the state of the tide with respect to water level. The red dot on the insets indicate the state of the tidal cycle displayed in the image.

Figure 21. Tidal currents at four at four states of the tide: (a) Low Water, (b) Mid Flood, (c) High Water and (d) Mid Ebb.



Source: ABPmer, 2018

Figure 22 **Spatial extent of spring tidal excursion ellipses around the Thanet Extension array area and export cable corridor. (Figure reproduced from Thanet Extension Offshore Wind Farm, ABPmer (2018))**

3.7.4 Response to storms

The topographic profiles of Shell Ness showed significant volume of sediment movement throughout periods of known storm activity. An example of this is shown in Figure 23 with profile 4b00133, the location of which can be inferred from Figure 31. This figure shows two consecutively following profiles, in summer of 2017 and winter of 2018, which encapsulate the typical winter storm period in the UK. Between “summer” and “winter” profile, there was erosion of the berm by 0.3 to 0.5 m at around 2 to 3 m above LAT, and a raising of the lower profile of up to 0.5 m at around 1.5 m above LAT.

These “summer” and “winter” profiles allow some insight into how Shell Ness responds to storms, but with only 1 to 3 surveys conducted per year, the dataset lacks the temporal resolution necessary to capture the immediate impact of individual storm events. Appendix A contains details for the topographic/profile analysis.

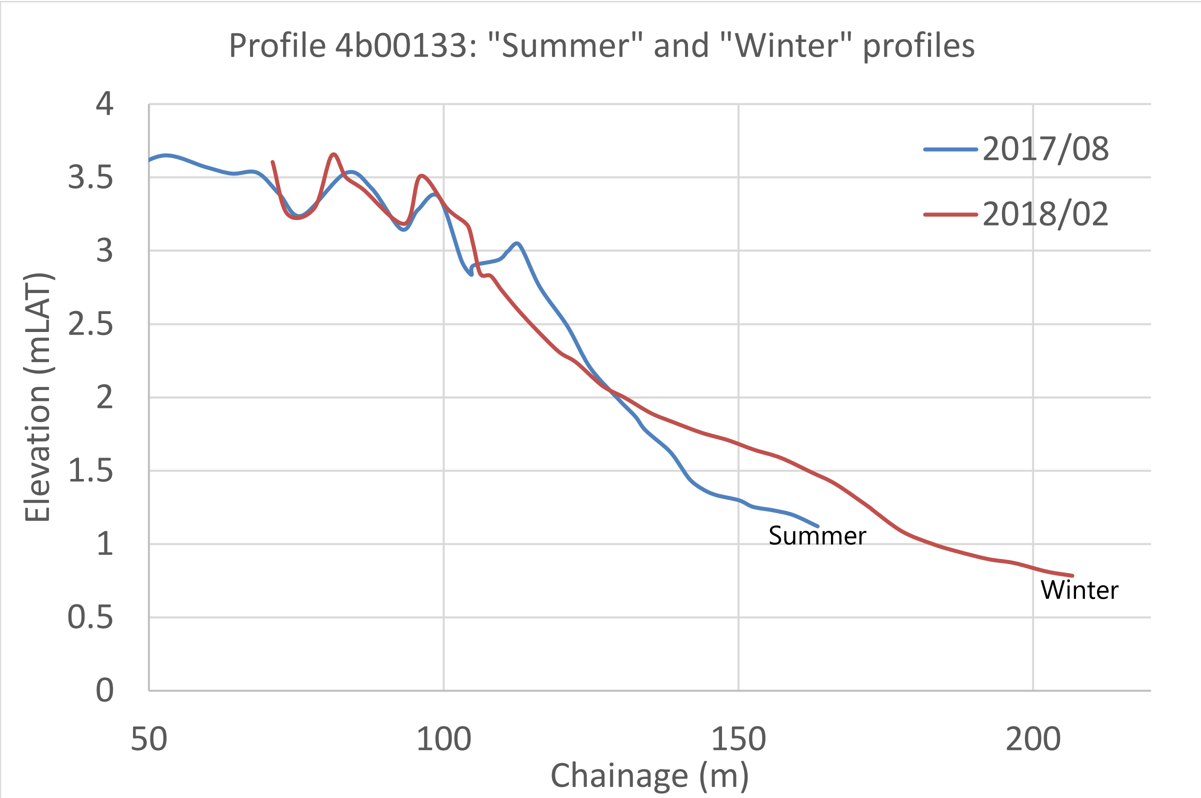


Figure 23 **Differences between a “summer” profile from August 2017 and the following “winter” profile in February 2018.**

Although there is no actual data to compare the morphology before and after storms in the mud/sand flats in the area of the cable landfall, the available topographic data (Section 4.2) and bathymetric data (Section 4.4) shows that the gross morphology is roughly stable over time with no great changes in between surveys.

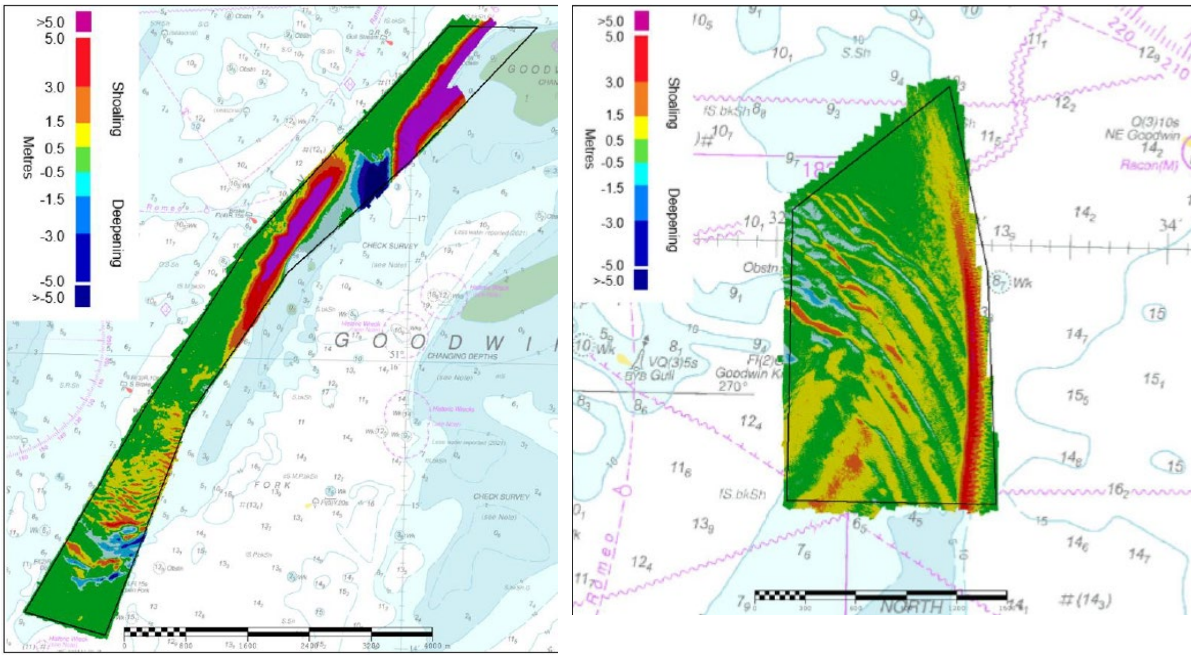
3.7.5 Offshore banks

According to the SMP2 (Halcrow, 2010) offshore banks are believed to be relict features of the Holocene Marine Transgression (10,000 years BP). Sandbanks located off the north Kent coast are believed to influence coastal processes and sediment transport patterns. Sand from these banks feed onshore, naturally replenishing the sand beaches on the Thanet coast. On the east coast they are believed to exert a key control on the wave climate and sediment supply. Goodwin Sands, located between 4 and 12 km offshore of Deal, is the most notable. Forming a series of natural shallow sandbanks, which are maintained by the tidal currents of the area (Atkins, 2001); Goodwin Sands buffers the offshore wave climate and as such alters the inshore wave climate, as well as supplying fine material (sand) to the foreshore.

Futurecoast (2002) stated that Goodwin Sands is a remnant of a former tidal delta, which was present during the early stages of the Holocene (10,000 years/BP) and attributed to tidal flows from the Dover Straits and southern North Sea. However as sea levels rose, under the Holocene Marine Transgression (10,000 years/BP to the present), tidal flows sweeping around from North Foreland modified the form and functionality of the original delta; reducing its dimensions considerably.

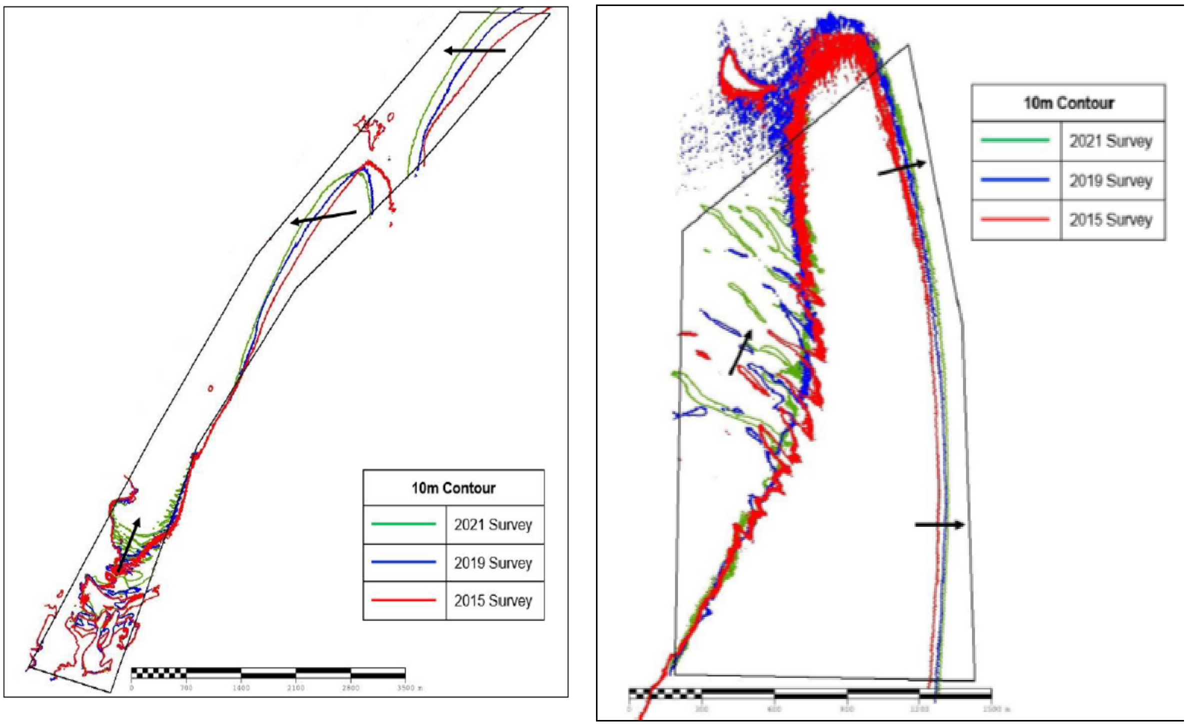
The UKHO carried out an assessment (UKHO, 2021) of the area around Goodwin Sands (GS) to monitor recent seabed movement. The main conclusions were:

- Significant shoaling in the central and northern parts of the GS2A area along the eastern edge of the channel, restricting the width of the Gull Stream passage, see Figure 25, where the 10 m contour had migrated approximately 300 to 600 m between 2015 and 2021 (50 to 100 m/yr respectively).
- In the east of GS2B, see Figure 25, sediment has migrated eastwards (which is consistent with historic trends), where the 10 m contour has migrated approximately 150 to 250 m between 2015 and 2021 (25 to 42 m/yr).
- There is also migration of sandwaves and scour in the north west of the survey area in an east-north-easterly direction, Figure 25. The sand ridges have also slightly shoaled between 2019 and 2019.
- They recommend continuing surveying the area in 3 years and 6 years interval (focused survey and full survey respectively).



Source: UKHO, 2021

Figure 24 **Difference surface showing bathymetric changes bewteen the 2021 and 2015 in GS2A surveys (left) and GS2B surveys (right)**



Source: UKHO, 2021

Figure 25 **Contour plot showing changes in the 10m contours for survey area between 2021 (green), 2019 (blue) and 2015 (red) GS2A surveys (left) and GS2B surveys (right). Black arrow represents the sandwave migration**

3.7.6 River Stour

According to the SMP2 (Halcrow, 2010), this section of the coast has experienced a significant amount of change. The depression that is Pegwell Bay may, Futurecoast (2002) speculates, have been initiated by drainage from the Thames Estuary into the English Channel, during a period of lower sea levels in the early Holocene (10,000 – 5,000 yrs/B.P.). However, as sea levels rose and prior to Sandwich becoming a 'Cinque Port', the ancient Saxon town of Stonar, located on the opposite bank of the Wantsum Estuary, at the mouth of the River Stour, was well established and remained a place of considerable importance until it disappeared almost without trace in the 14th century. Reclamation at Sandwich, which extended approximately 250 years, between the 14^{th} Century and mid-16^{th} Century; significantly altered the regions coastal processes. Reclamation, for example, reduced the tidal flow of the River Stour, increased sediment deposition and initiated the Wantsum Channel, which used to separate the Isle of Thanet from mainland England, to close. Amalgamated with the mixed gravel and sand spit, which had lengthened and migrated north, since the 9^{th} Century, it forced the mouth of the River Stour to exit further north and left Sandwich two miles inland of its original coastal position. Today the spit extends from Deal in the south to the northern bank of Pegwell Bay. Alluvium and fine-grained marine sediment have been deposited in its lee, which has resulted in the formation of tidal flats and marshes.

Futurecoast (2002) stated that Goodwin Sands, a sand bank system located offshore of the east-facing Kent coast, is a remnant of a former tidal delta, which was present during the early stages of the Holocene (10,000 years/BP) and attributed to tidal flows from the Dover Straits and southern North Sea. However, as sea levels rose, under the Holocene Marine Transgression (10,000 years/BP to the present), tidal flows sweeping around from North Foreland modified the form and functionality of the original delta. As such, the present functionality of Goodwin Sands exerts a large-scale control on the development of Sandwich and Pegwell Bay.

Flowing into Pegwell Bay, the River Stour is a navigable channel, with red and green lateral marks for navigation. The channel is routinely dredged to maintain a safe depth. This dredging is carried out within the current position of the channel – there is no scheme to stop any migration. It might be possible that the dredging of the channel slightly encourages the migration of the river, as they dredge towards where the river is migrating. In the future, it could be decided that the dredging of the river is done in such a way that might partially counterbalance the migration of the river.

There is a potential future scenario in which a river flow increase would cut through the present river channel. It is impossible to predict such scenario and there is a high level of uncertainty associated with it, but potentially plausible.

Some of the available data shows an old river channel north of the present one and within the proposed cable route (see the difference plot of the last two LiDAR surveys in Figure 29 where a meandering channel of blue colour is observed north of the present channel going across KP119).

3.7.7 Conclusion on the sediment transport regime

The sediment transport in the area is a combination of several forcings, such as the northward longshore drift at Shell Ness and the southerly longshore drift between North Foreland and Cliffs end. The effect of the asymmetry of the tidal currents is more prominent offshore and the migration of the River Stour contributes to the building of the spit at Shell Ness. On top of this, the changes of the offshore banks will modify the incoming waves. All of these are medium to long term mechanisms, on top of which, there are short-term response to storms, more visible on the beach to the South of the landfall.

Notwithstanding all these sediment transport mechanisms, the transport on the mud and sand flat is quite limited.

All of these make this area very difficult to be modelled successfully in a sediment transport numerical model and therefore the morphological changes in the future will be better implied by the assessment of the historical data of morphological changes instead. This is what has been carried out in this study, presented in the next section.

4 Morphological changes near the landfall area

The morphological changes near the landfall area have been separated into three regions: river, intertidal and sub-tidal, which are specified below.

Historical morphological analysis of Pegwell Bay has been undertaken using:

- Google Earth historical satellite and aerial imagery;
- Environment Agency LiDAR topographic surveys; and
- Coastal Channel Observatory bathymetric surveys.

4.1 Historical morphological analysis of the River Stour

A number of historical satellite and aerial images covering the period 1940 to 2022 are available from Google Earth (shown in Figure 26). The images show that:

- Historically, the area in the vicinity of the landfall has experienced notable change throughout the period 1940 to present, associated with anthropogenic modification of the coast, movement in the position of the River Stour channel and migration of Shell Ness;
- Whilst overall the saltmarsh and adjacent mud/sand flat has been relatively stable over the past decade or so, the eastern margin has been greatly eroded by westerly migration of the Stour river channel.
- Shell Ness is experiencing consistent progradation towards the north. From the 1940's to present, the spit has prograded north at an average rate of approximately 4 m per year, increasing to approximately 7 m per year between 2007 to present. This indicates a surplus of sediment supply to the spit from marine or fluvial sources and a net northerly transport of sediment along the western margin of the bay.

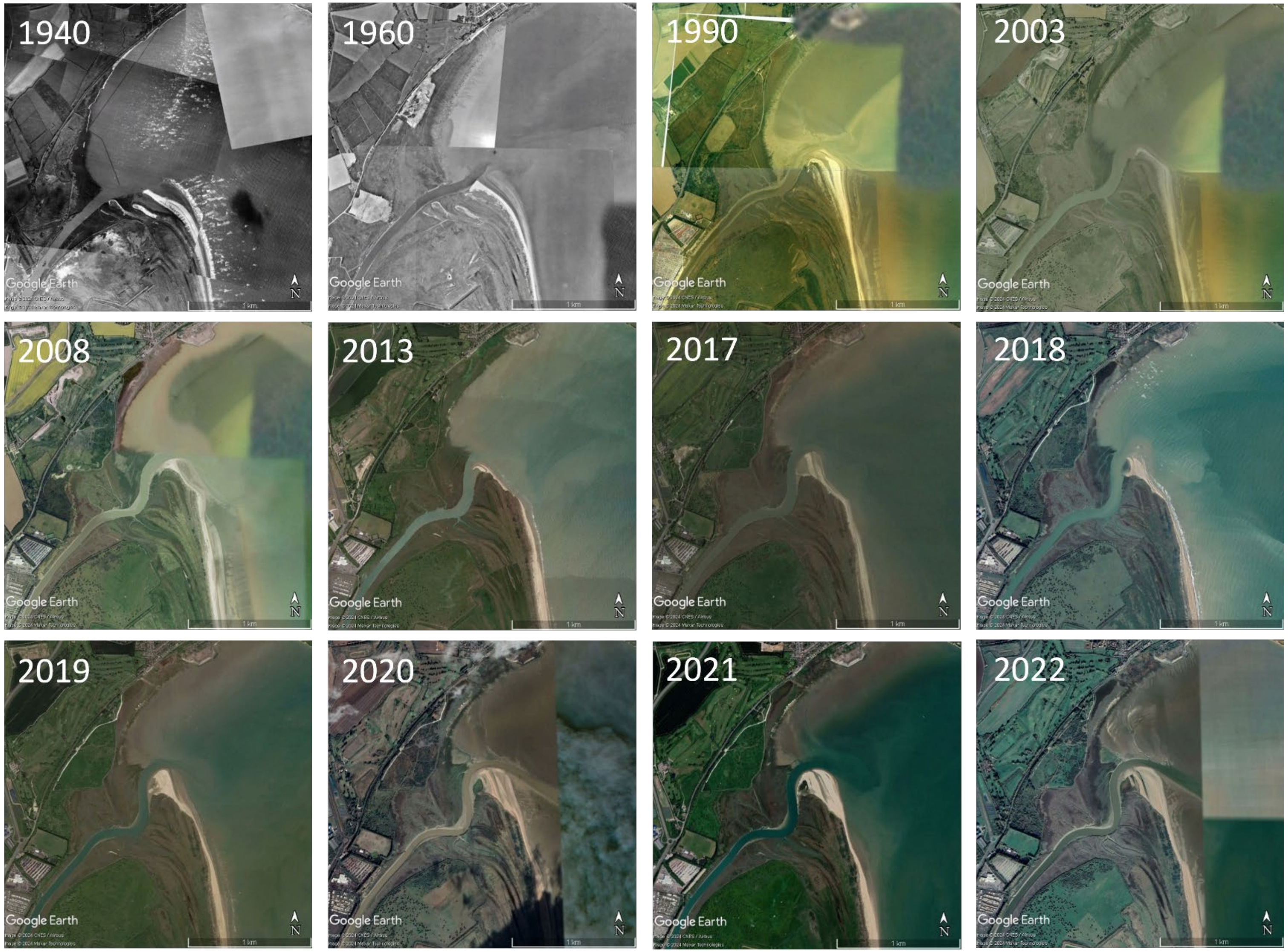


Figure 26. Satellite and aerial images of Pegwell Bay covering the period 1940 to 2022.

4.2 Morphological changes of the intertidal

4.2.1 Historic trend

A number of aerial LiDAR topographic surveys of the intertidal above a relatively low water level at 1 to 2 year intervals between 2007 and 2022 were obtained from the Environment Agency, CCO and the client, see Table 1 for all data sources. A map of the envelope of changes in intertidal elevation within surveys from 2007 to 2022 is presented in Figure 27, covering the wider area. The envelope of changes for the area covered by the 2023 survey of the cable corridor is shown in Figure 28 for the surveys from 2007 to 2023. The changes within the last two surveys of the wider area (2022 and 2020) are presented in Figure 29. Together, the data show that in the period 2007 to 2023 (16 years):

- Elevation changes across the main mid to upper intertidal areas are typically small (< ±0.25 m);
- Shell Ness at the mouth of the River Stour has migrated north-westward by ~110 m, giving an average migration rate of 7.8 m/yr;
- The River Stour channel bends have migrated across the intertidal, with channel migration of several tens of metres having occurred in places. The relative depth of the channel below the surrounding intertidal level in this area varies from approximately 3.5 to 0.7 m;
- Some of the available data shows an old river channel north of the present one and within the proposed cable route (see the difference plot of the last two LiDAR surveys in Figure 29 where a meandering channel of blue colour is observed north of the present channel going across KP119). This figure also shows the migration north and south of some parallel features towards the seaward boundary of the data (red and blue parallel lines). These features seem to be groundwater drainage channels which seem to move separately. Their migration results in elevation changes of up to 0.5 m (both positive and negative), which should not affect the cable;
- A surface water drainage channel is sometimes present at the back of the beach and intersecting the HDD cable conduit ~50 m landward of the HDD exit point (Figure 27 and Figure 28). Historical aerial imagery and recent LiDAR surveys show it is shallow (0.3 to 0.4 m deep) and its position is not fixed, with later variation of tens of meters in some cases, and entirely absent (fully infilled) in other cases. This feature is therefore likely to be ephemeral – in a cycle of (re)formation by surface drainage at sufficiently low water state, and infill, migration or flattening by wave action on a sufficiently high water state. The gradient between where the channel meets the River Stour and the intersection between the channel and cable, is unlikely to increase significantly as the spit progrades, therefore the migration of the river appears unlikely to cause a measurable change in the gradient in the channel in the future and the depth of the channel is not expected to change significantly as a result. Whether this channel will tend to relatively deepen and/or widen and potentially impact the cable if/as the River Stour migrates northward in the future cannot be determined with confidence. This highlights the importance of continued monitoring of the intertidal area; and
- The greatest elevation changes observed in the area covered by the 2023 survey of the cable corridor (shown in Figure 28 for the surveys from 2007 to 2023) is in the area of the cable corridor between KP119 and 119.5. These changes are of 0.4 m and above and it is observed how these are in an area where there seems to be a feature that could be a groundwater drainage channel or a remnant of an old river channel. In each case, the elevation changes are not that high and limited to that area, so it is not expected that this would pose a problem to the cable.

4.2.2 Storm events

There is insufficient data to draw any conclusions on the morphological changes of the intertidal caused by storm events.

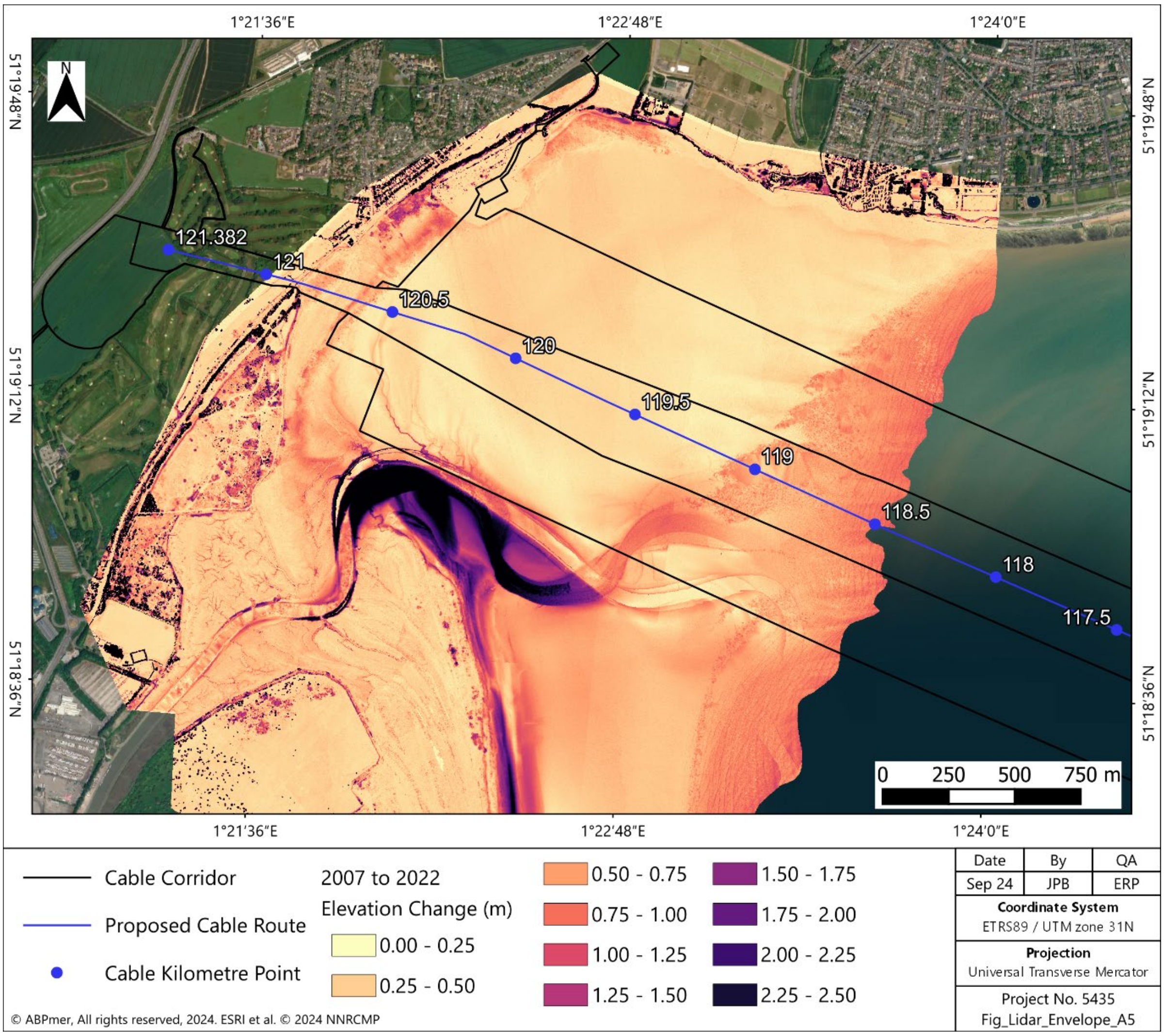


Figure 27 **Envelope of change from LiDAR data (2007-2022)**

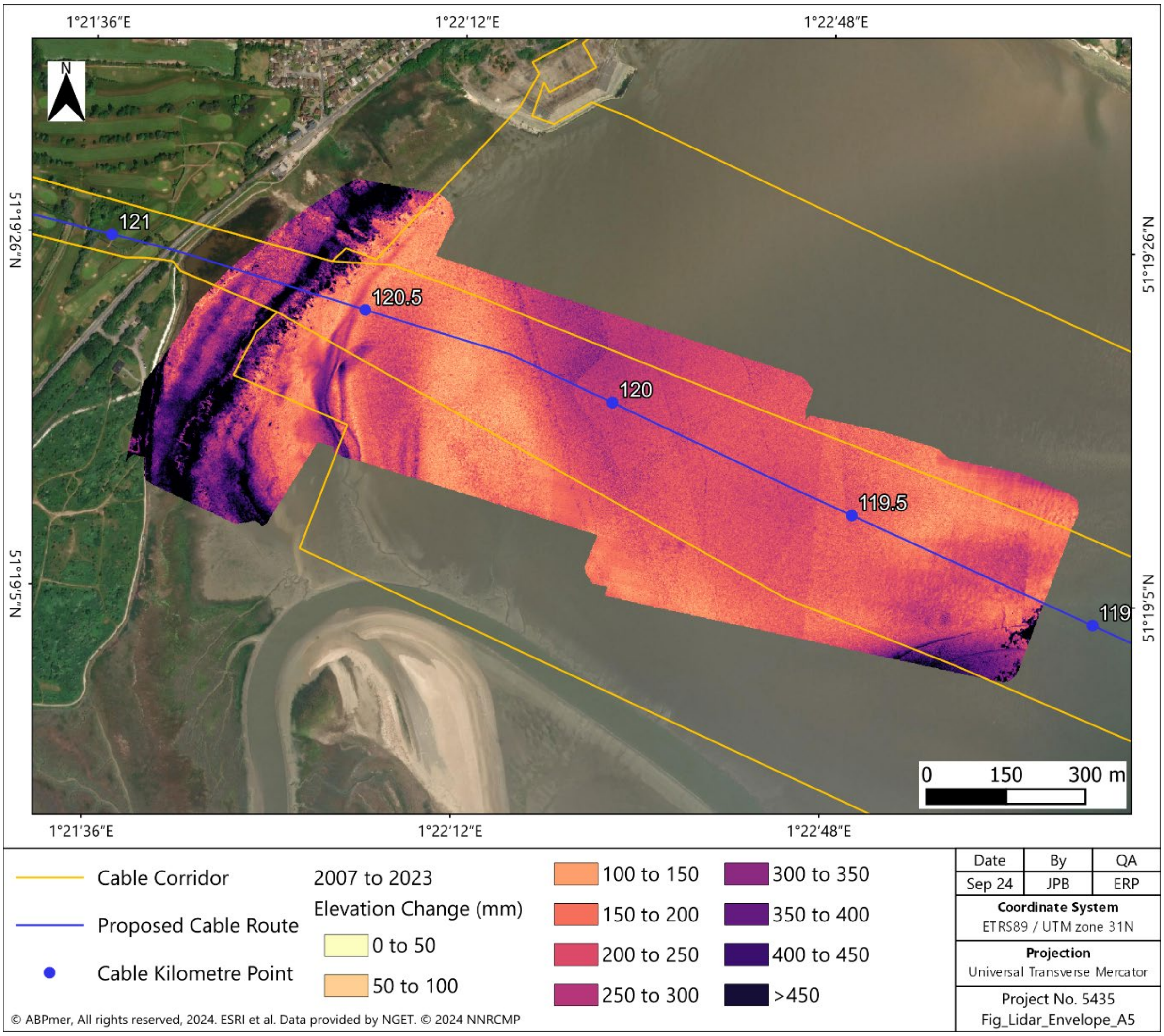


Figure 28 Envelope of change from LiDAR data for a slighly reduced area (2007-2023)

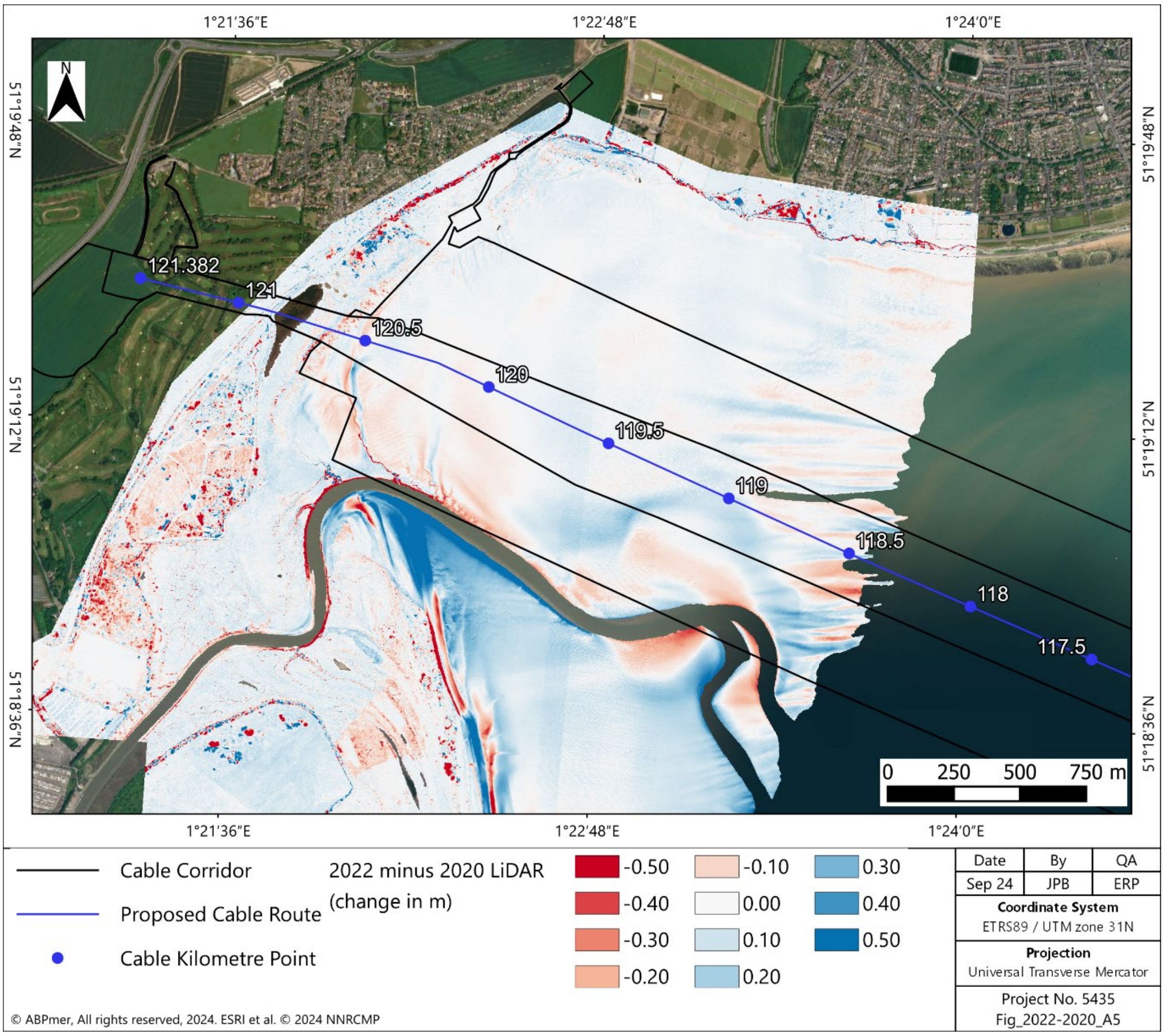


Figure 29 **Difference plot of the last two LiDAR surveys of the wider area (2022 and 2020)**

4.2.3 Intertidal surface gradient analysis

LiDAR data for the years 2018, 2020 and 2022 were used generate surface gradient streamlines to visualise patterns of surface drainage over the beach, see Appendix B for the analysis of this data. Figure 30 shows the comparison of the three sets of streamlines superimposed to the 2022 topography.

To the north of the river, drainage patterns have remined more or less stable over this 6 year period. Based on present day drainage patterns on the north side, the part of the river at the top end of the beach (onshore of KP119.5) is tending to be confined to an east-southeast or southeast trajectory, i.e. less likely to redirect northwards over the cable route without significant erosion of the body of the beach. Seawards of KP119.5, surface gradients are less well defined, suggesting that a redirection of the river northwards in this area lower on the beach (between KP119.5 and KP119) might move the whole lower beach river path closer to, or overlapping with the cable route in the area KP119 to KP118.5. This possibility is consistent with visual signatures in the historical LiDAR data of older river routes being further north on the lower part of the beach (e.g. Figure 27 and Figure 29).

On the south of the river, the orientation of the drainage streamlines has changed, especially after 2018, and rotated mostly clockwise, these changes associated to the northward migration of the river. This analysis indicates relative stability of the area to the north of the river where the cable route is.

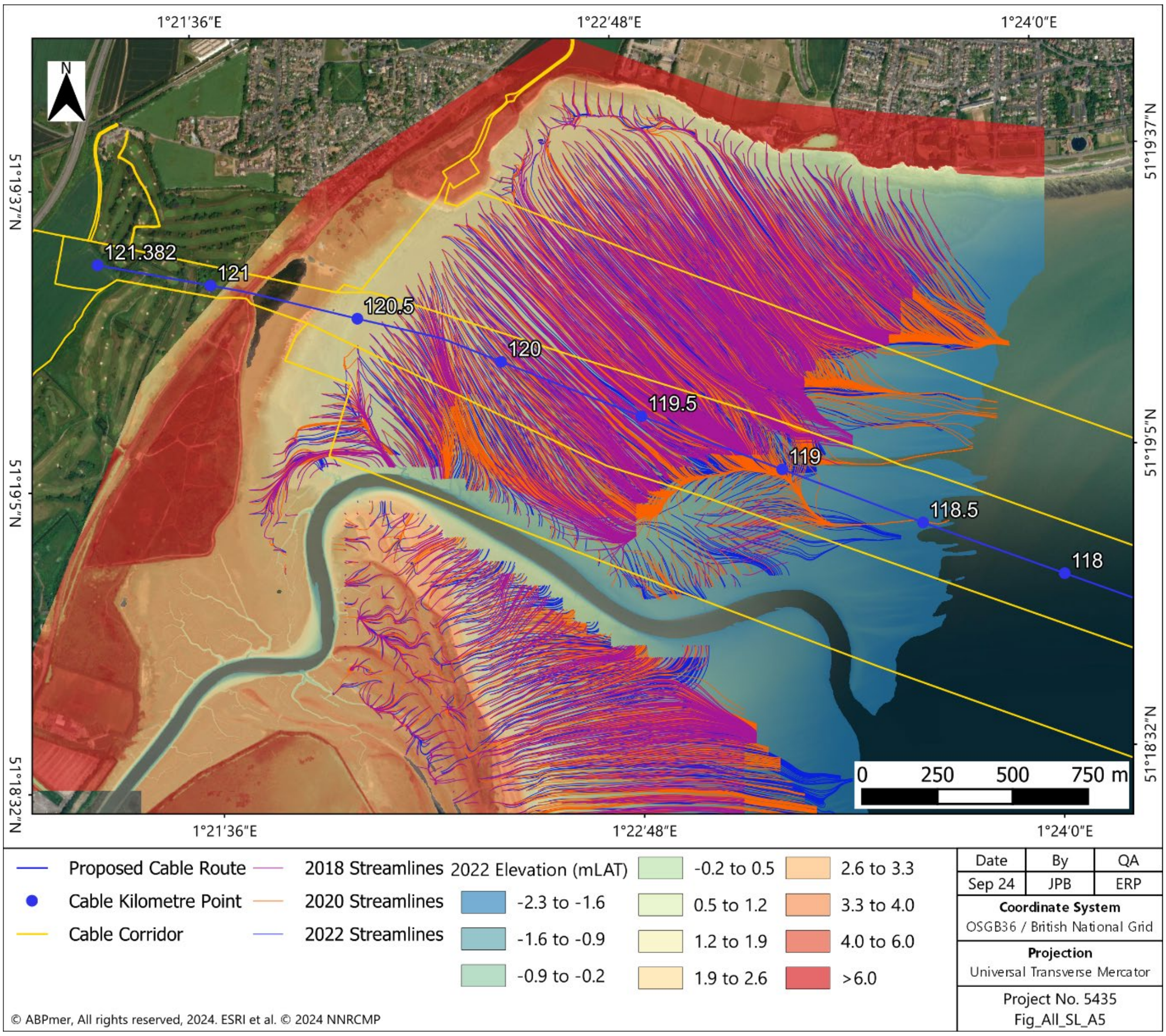


Figure 30 **Comparison of local gradient and surface drainage patterns on the beach in the 2018, 2020 and 2022 LiDAR data, superimposed onto the 2022 LiDAR topography**

4.3 Morphological changes of nearby beaches

4.3.1 Historic trend

A number of topographic profiles are available South of the River Stour (Unit 4b) between 2003 and 2023, see Figure 31. An assessment of the changes of these profiles has been included in Appendix A.

The four northern-most profiles show highly variable rates of morphological change as for example 4b00124, shown in Figure 32. In general, there is erosion and landward migration of the beach from 2003 to 2014, and from 2014 to present this part of the Ness has been accreting. Moving southward, the profiles show a much stronger trend of accretion and seaward movement.

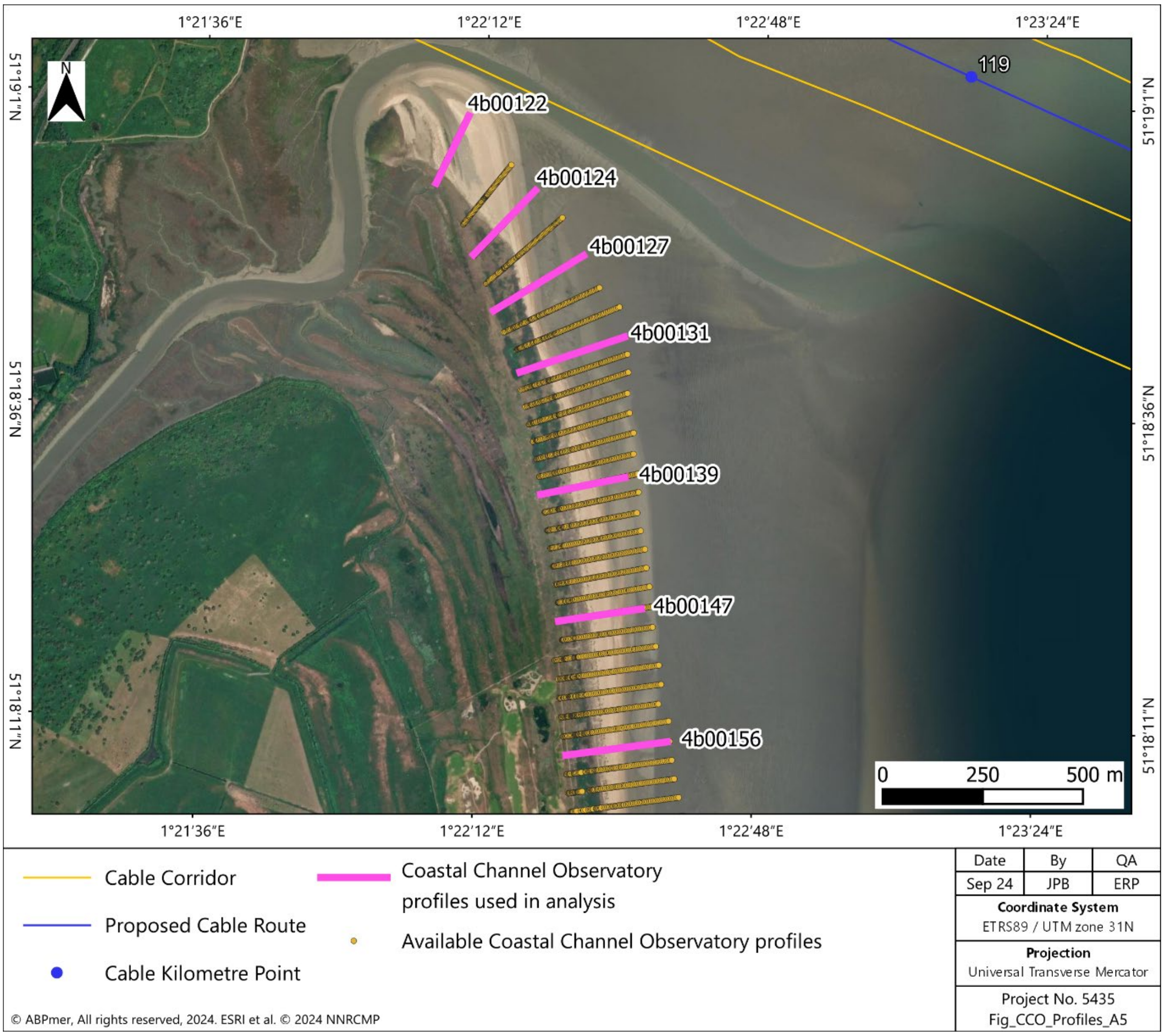


Figure 31 **Location of topographic profiles available (in yellow) and selected for analysis (in pink)**

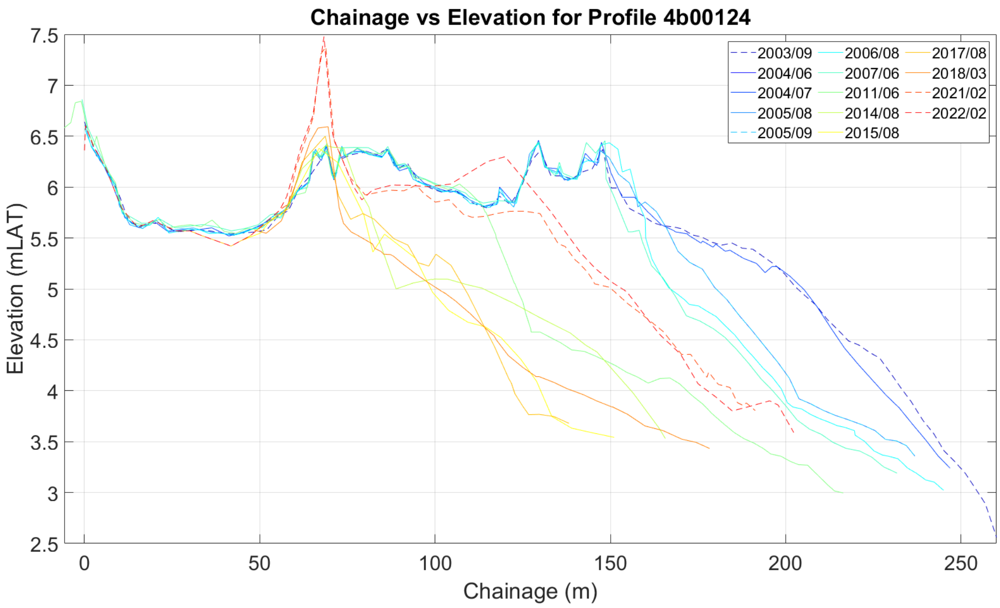


Figure 32 **Profile 4b000124 elevation change**

4.3.2 Storm events

Section 3.7.4 presented an example of “winter” and “summer” profiles at location 4b00133, see inferred position in Figure 31. This showed the erosion of the berm of the beach in the winter with the accompanying accretion of the lower foreshore. More detailed response to a given storm cannot be inferred from this data, as the surveys are once to three times a year. However, this is the response of the beach to the South of the landfall, on the other side of the river, not of the mud/sand flats in the area close to the landfall.

4.4 Morphological changes of the subtidal

4.4.1 Historic trend

A number of bathymetric surveys of the seabed/ intertidal area below approximately mean water level between 1994 and 2021 were obtained from the Channel Coastal Observatory (CCO), UKHO and the client (see Table 1 for data sources detail). The bathymetric sets available are shown in Figure 33 for the wider area and Figure 34 for the latest, which only covers the cable corridor. Unfortunately, the early bathymetric data are single beam surveys and have been removed from the analysis due to poor resolution. Only the 2010 and 2021 datasets are multibeam and therefore have enough resolution to extract meaningful conclusions from the comparison of their data.

A map of envelope of change in bathymetry between 2010 and 2021 is provided in Figure 35, which shows elevation changes across the mid to lower intertidal and shallow subtidal areas are typically in the range of < ±0.5 m, with a maximum change of ±0.7 m between KP118 and KP118.5.

The 1994 bathymetric data (Figure 33) covers the Ramsgate Channel, offshore of which, it gets shallower again; the channel and overall bathymetry of the wider area has been presented in Figure 10.

From this data and similar one from other studies, it can be deduced:

- ABPmer (2018) had access to an additional bathymetry from 2016 from the Thanet project and concluded that the River Stour channel exhibits significant migration across the intertidal. This was particularly notable between 2010 and 2016 where the channel has migrated several hundred metres to the north. The relative depth of the channel below the surrounding seabed level at this location is approximately 0.3 to 1.0 m, but is deeper (up to 1.6 m) higher up the intertidal and closer to the spit where the channel is above the tidal water level for more of the time;
- There has been notable erosion in the northeast of the bay, between 2010 and 2016, with erosion in excess of 1 m in places. This erosion is clear between the 2010 and 2016 surveys but is less apparent between 2003 and 2010; and
- Throughout the analysis period there is ongoing accumulation of material at/ just below the LAT mark, with approximately 1 m of material deposited during the 13-year analysis period. These sediments may be associated with deposition from the River Stour channel although could also reflect seasonal variations in wave conditions and the associated build-up (and removal) of offshore bars.

- Thanet Offshore Wind Limited (2005) showed a comparison between the water depths recorded in the 1955 UKHO Admiralty Chart for Pegwell Bay and those recorded during the Thanet Offshore Wind Limited export cable corridor survey (carried out in 2005). It was reported that the bathymetry had changed between the +1 m CD (1.3 m above LAT) and -1.5 m CD (-1.2 mLAT) contours in the Bay and in the area of the Port of Ramsgate extension. It was noted that the major areas of change, with accretion levels of up to 1.5 m, appeared to be associated with a southerly migration of the River Stour channel across the Bay (which was just about visible in the 1955 dataset. The channel is known to have shifted historically in response to changes to the Goodwin Sands, Brake Bank and Shell Ness and may also have been influenced by port extension at Ramsgate (Thanet Offshore Wind Limited, 2005). The observation from the bathymetric evidence that the River Stour channel is highly dynamic is entirely consistent with the available historic aerial imagery and more recent LiDAR data described above

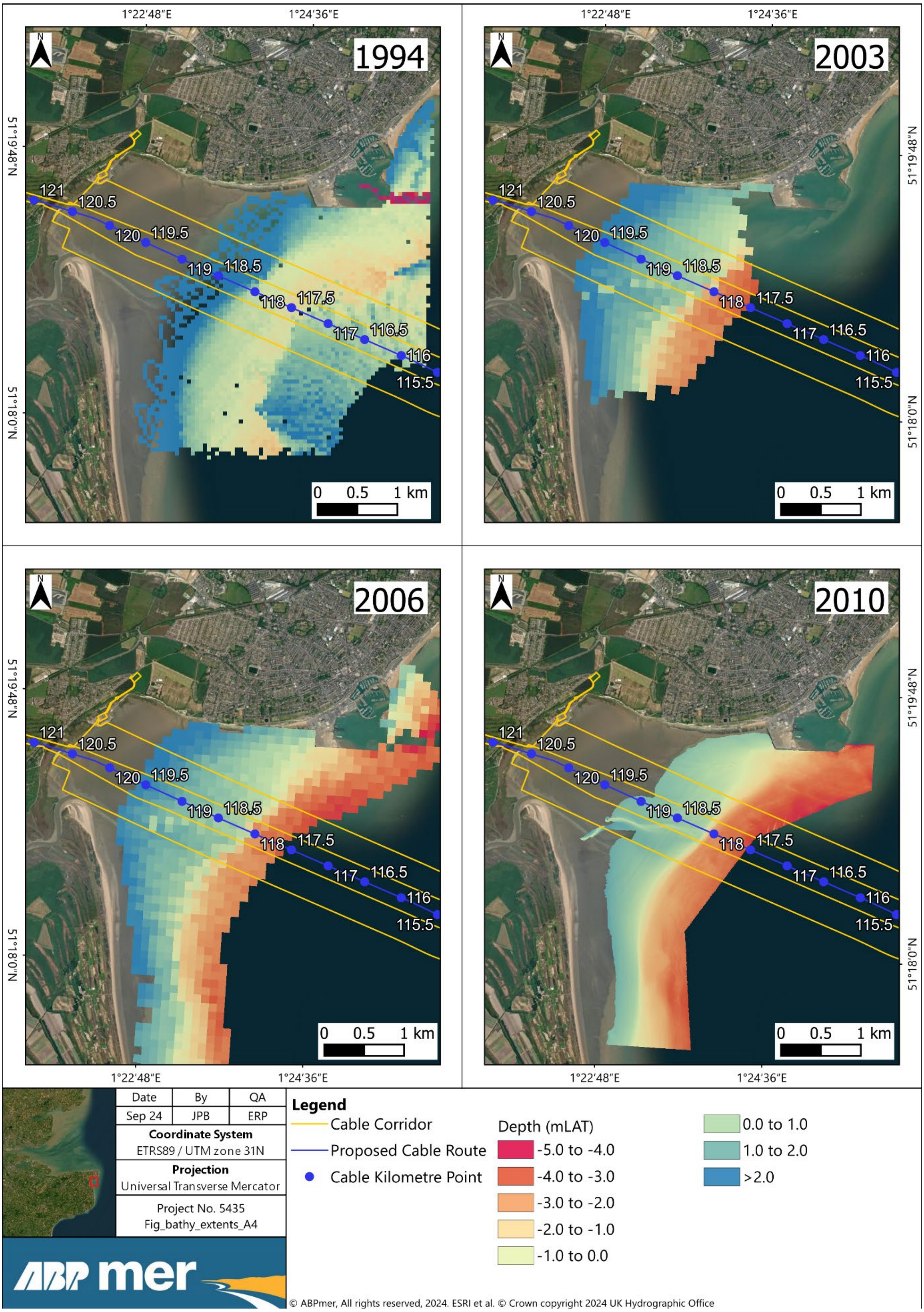
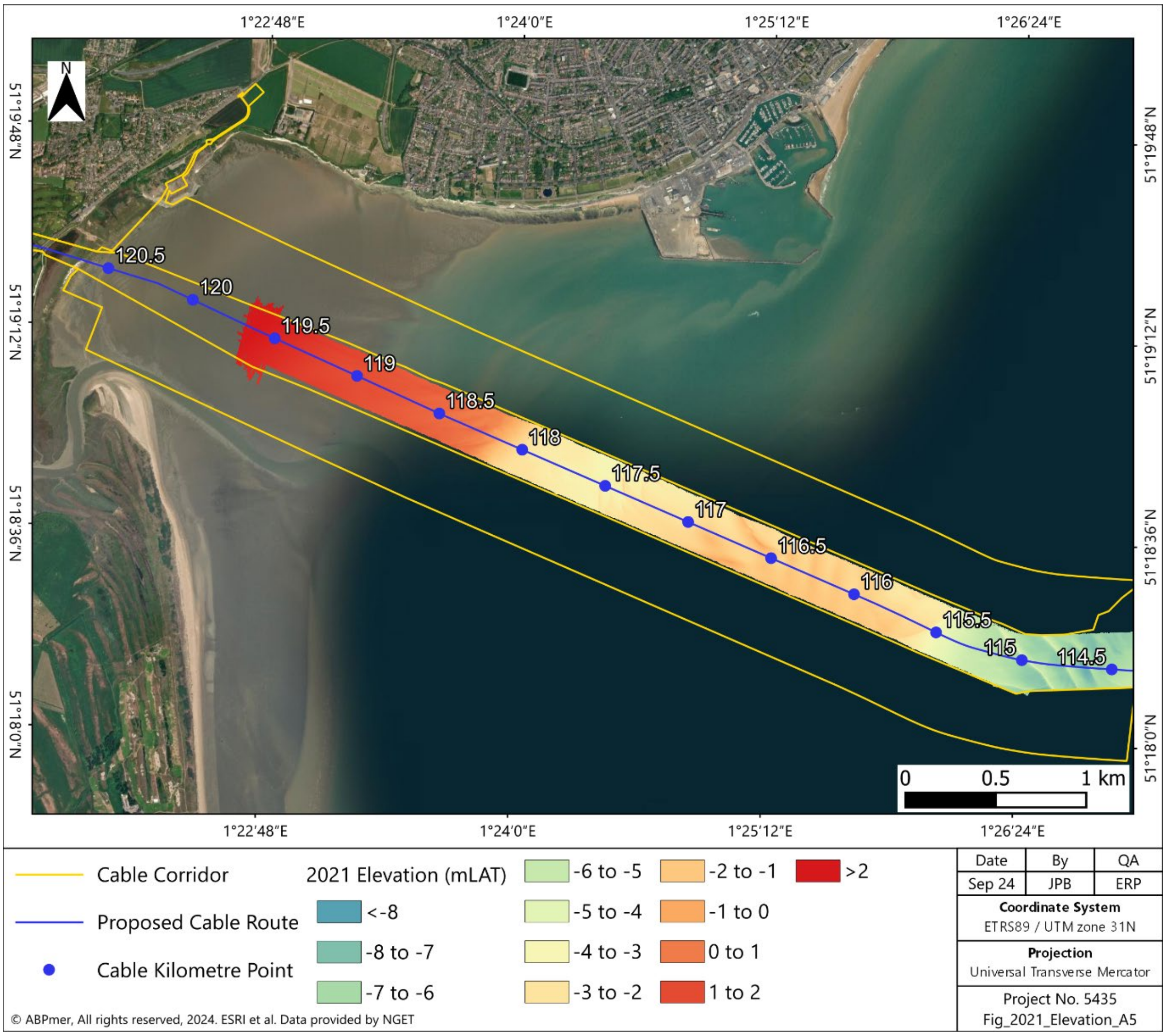


Figure 33 Available bathymetric data in the wider area from 1994 to 2010



Source: NGET supplied

Figure 34 Latest bathymetric data along the cable corridor

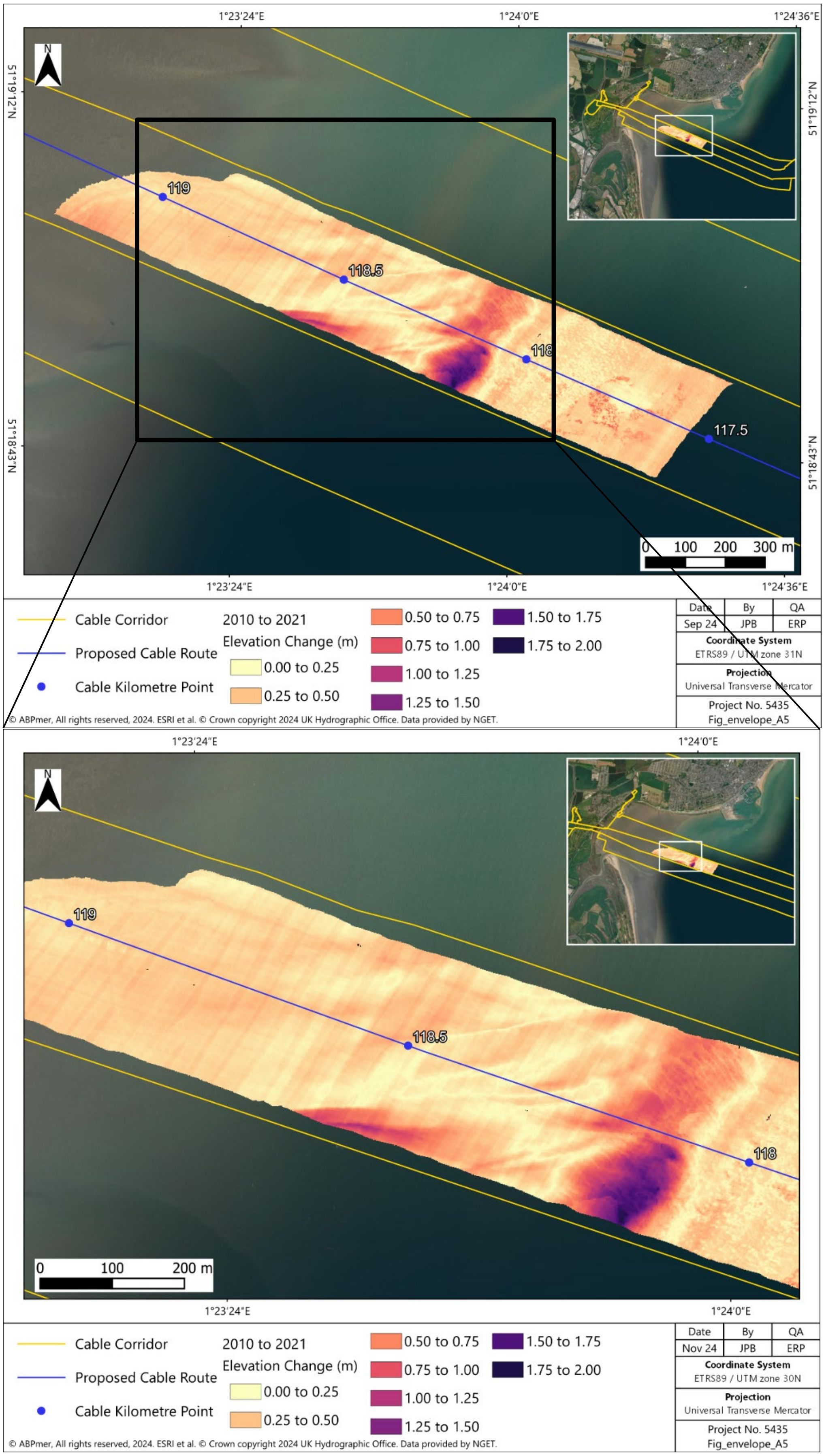


Figure 35 Envelope of bathymetric changes from 2010 to 2021

4.4.2 Storm events

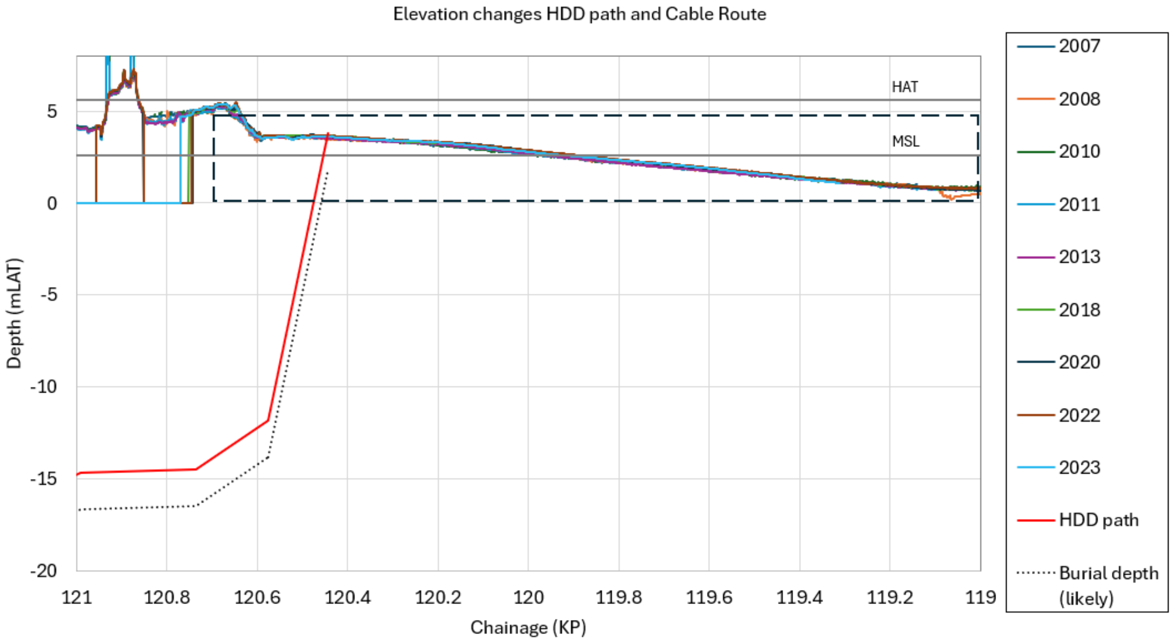
There is insufficient data to draw any conclusions on the morphological changes of the intertidal caused by storm events.

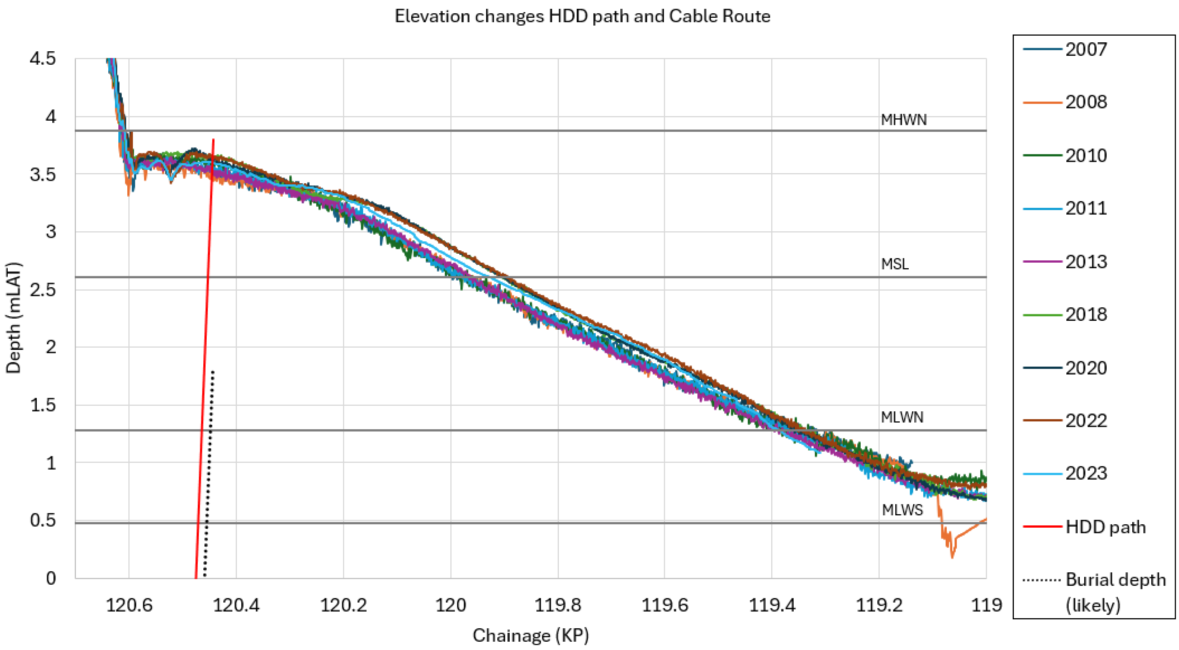
4.5 Variability along the cable route

The variability of the available sources of data along the cable route has been analysed with the topographic data available:

- LiDAR data from the Thanet extension cable landfall assessment (2007, 2008, 2010, 2011, 2013);
- LiDAR data from the CCO (2018, 2020, 2022); and
- Client provided LiDAR data (2023).

These are shown in Figure 36, where the approximate position of the proposed cable route has also been marked, together with an approximate burial depth of the cable of 2 m below.





Note: The cable route has been corrected from ODN to LAT using the 3.6 m value given in the cable profile route, Figure 1, and not the values given in Section 2.1

Figure 36 Elevation changes along the HDD path and cable route (top: from -20 m LAT to +7 m LAT, bottom: zoomed from 0 to 4.5 m LAT)

This figure shows how, despite the data containing spikes (due to the accuracy of the LiDAR data which is around 0.4 m for the older datasets and reduces to 0.15 m for the most recent ones), there is a high level of consistency of where the levels have been over the past 16 years. The differences in elevations are very small (less than 0.5 m). The cable burial is well below the natural variability of the data.

4.6 Prediction of future evolution

Future changes in the morphology of the mud/sand flat area up until the exit point are likely to be within the changes observed in the historical data:

- Changes of the order of 0.5 m are to be expected in the intertidal area, showing that the gross morphology is roughly stable over time with no great changes in between surveys.
- In the subtidal area, changes of up to 1 m in 13 years were observed, although it is believed that these were either to do with the deposition of the river channel or seasonal wave condition variations and the associated build-up or removal of offshore bars. It is not expected that greater changes than this will happen in the subtidal area close to the cable installation.
- There are, however, some future scenarios that need to be considered as they are plausible scenarios, albeit of very low probability of occurrence. There is also a high uncertainty associated to when and how these might occur. It is also believed that these will be dependent on anthropogenic actions and will not be allowed to happen or will be mitigated against. These future scenarios and the possible effect of these on the cable are:
  - The spit keeps on migrating Northwards at higher pace. This would migrate the channel northwards and there could be an impact as the cable could become exposed at the bottom of the river. There is currently uncertainty on whether the current river channel dredging strategy is contributing at some rate to the migration. Maybe a different dredging strategy, where dredging to the South of the channel is encouraged, might slow down the migration of the river.
  - Assuming the river continues its ~7m/yr northward migration, the channel may reach the cable alignment in approximately 60 years. In this case the river is most likely to affect the cable between KP 119.5 and 120.5 in the intertidal area, seaward of the HDD exit. However, due to the unknown future depth of the channel, there remains uncertainty regarding whether the channel would ultimately expose the cable, or whether the cable would remain exposed should the channel continue to migrate.
  - There is a potential future scenario in which a river flow increase would cut through the present river channel. It is impossible to predict such scenario and there is a high level of uncertainty associated with it, but potentially plausible. This scenario will move the actual river channel and there is a small risk that this would move towards the cable route, potentially exposing the cable.
  - Continued sea level rise and adjustments to previous changes in the system derive in flooding of the low-lying hinterland. This could derive into the river adopting the old Wantsun channel, creating a new estuary to the north. The implications on the landfall are more likely to be with the flooding of the Construction Compound / Transition Joint Bay and surrounding area, but should not affect the cable.
  - The SMP2 (Halcrow, 2010) stated the potential that the dynamics of the River Stour could change, if the river broke through the tight meander around Richborough. The impact of this on the coast would be a realignment of the river’s mouth (to a location south of its current outlet). The uncertainty of this future scenario and the even higher uncertainty of its consequences, depending on where the location of the new river’s mouth were to be located, make it less plausible than the previous ones.

5 Discussion and conclusions

The Sea Link Project is a network reinforcement link proposed by National Grid Electricity Transmission Plc (NGET) to reinforce the electrical transmission network in the South East of England and East Anglia. The network reinforcement link makes landfall at Aldeburgh in East Suffolk, and at Pegwell Bay, Kent.

This report describes the landfall at Pegwell Bay, Kent, An accompanying report, R4576 (ABPmer, 2024), describes the landfall at Aldeburgh in East Suffolk.

This report provides an assessment of the potential morphological changes around the cable corridor at the landfall position of Pegwell Bay. For this, an assessment of historical changes based on a number of datasets, together with a conceptual understanding of the coastal processes in the area have been used in order to estimate potential morphological changes in the future.

The study has used a combination of project specific and publicly available data, studies and reports to inform the investigation. The following data sources have been used in the analysis (more detail is provided in Table 1). The main data providers listed are:

- Channel coastal observatory (CCO): https://coastalmonitoring.org/
- UK Hydrographic Office (UKHO): https://seabed.admiralty.co.uk/
- SEASTATES North Atlantic wave hindcast (ABPmer 2013) and SEASTATES North West European Shelf Tide and Surge hindcast (ABPmer, 2017)

Key findings from the assessments presented in this report are summarised below:

- **Risk of flooding**: Part of the area of study is flooded for quite a lot of the time (area North of KP120.5, whereas the rest of the hinterland, included the Construction Compound / Transition Joint Bay, should be protected from flooding. However, in the future, with sea level rise, the risk of flooding will increase. A major flooding event in the area is both possible and unpredictable. The SMP2 (Halcrow, 2010) predicted that flooding in the vicinity of Cliffs End, is expected, due to the continual weakening of the revetted embankment, in front of Pegwell Bay Nature Reserve.

- **Sediment transport:** The sediment transport in the area is a combination of several forcings, such as the northward longshore drift at Shell Ness and the southerly longshore drift between North Foreland and Cliffs end. The effect of the asymmetry of the tidal currents is more prominent offshore and the migration of the River Stour contributes to the building of the spit at Shell Ness. In addition, the changes of the offshore banks will modify the incoming waves. All of these are medium to long term mechanisms, on top of which, there are short-term responses to storms, more visible on the beach to the South of the landfall.

  Moreover, the nearshore shoals and banks in the offshore region have been migrating and this in turn influences the forcings onto the beach, which in turn modifies the banks and shoals.

  All of these make this area very difficult to be modelled successfully in a sediment transport numerical model and therefore the morphological changes in the future will be better implied by the assessment of the historical data of morphological changes instead. This is what has been carried out in this study.

- **Morphological changes of the River Stour**: Historically, the area in the vicinity of the landfall has experienced notable change throughout the period 1940 to present, associated with anthropogenic modification of the coast, and movement in the position of the River Stour channel, and Shell Ness. From the 1940's to present, Shell Ness has experienced consistent progradation towards the north at an average rate of approximately 4 m per year, increasing to approximately 7 m per year between 2007 to present. The northern extent of the spit also influences the point of entry of the River Stour onto the beach, and so its route across the beach to the sea.

- **Morphological changes of the intertidal and subtidal**: overall the saltmarsh and adjacent mud/sand flat has been relatively stable over the past decade or so, with small and localised changes confined to immediately close to the river channel or other features such as groundwater drainage channels.

- **Morphological changes of the nearby beaches**: historical analysis of the available topographic profiles south of the River Stour show how the four northern most profiles show highly variable rates of morphological change. Moving south, the profiles show a much stronger trend of accretion and seaward movement. The effect of storms is also appreciated within the data. This area is morphologically different to that landfall location.

- **Variability along the cable route**: there is a high level of consistency of where the levels have been over the past 16 years. The differences in elevations are very small (less than 0.5 m). The cable burial is well below the natural variability of the data.

- **Future morphological evolution**: Changes of the order of 0.5 to 1 m are to be expected in the intertidal and subtidal area, showing that the gross morphology is roughly stable over time with no significant changes.

  There are, however, some future scenarios that need to be considered as they are plausible scenarios, albeit of very low probability of occurrence. There is also a high uncertainty associated to when and how these might occur. It is also believed that these will be dependent on anthropogenic actions and will not be allowed to happen or will be mitigated. These future scenarios and the possible effect on the cable are:

- **Spit migration**: The spit continues migrating Northwards at higher pace. This would migrate the channel northwards and there could be an impact as the cable could become exposed at the bottom of the river. There is currently uncertainty on whether the current river channel dredging strategy is contributing at some rate to the migration. Maybe a different dredging strategy, where dredging to the South of the channel is encouraged, might slow down the migration of the river.

- There is a potential future scenario in which a river flow increase would cut through the present river channel. It is impossible to predict such scenario and there is a high level of uncertainty associated with it, but potentially plausible. This scenario will move the actual river channel and there is a small risk that this would move towards the cable route, potentially exposing the cable.

- Continued sea level rise and adjustments to previous changes in the system derive in flooding of the low-lying hinterland. This could derive into the river adopting the old Wantsun channel, creating a new estuary to the north. The implications on the landfall are more likely to be with the flooding of the Construction Compound / Transition Joint Bay and surrounding area, but should not affect the cable.

The natural processes controlling morphological variability at the landfall described above will continue to act in the same way following installation of the cables and irrespective of any temporary local disturbance caused.

It is anticipated that the information on morphological variability will feed into a detailed engineering assessment of cable burial depth which will minimise the risk of exposure. Managing the risk of exposure relating to the ongoing migration of the River Stour channel will be particularly important here. Appropriate consideration will also need to be given to the potential effects of climate change which is expected to lead to mean sea level rise and potentially increased rates of erosion and shoreline retreat.

If the export cables are buried at a sufficient depth below the base of the mobile seabed material, the cables will have no potential to influence either hydrodynamics or seabed/ intertidal morphology. If a section of a cable does become exposed, it might locally influence coastal processes and morphology at a scale proportional to the diameter of the cable (order of a few tens of centimetres) and the length of the exposed section.

If the cable were to become exposed at any point during the operational lifetime of the Project, the exposed cable section may need to be reburied. This would be achieved using similar methods to that used for the initial installation, with similar potential impacts.

At the landfall, the potential for future coastal retreat should be limited due to the presence of coastal defences (embankment) and the (planned) 'Hold the Line' management policy. Following consent, a full cable landfall assessment will be undertaken to inform engineering design. This will take into consideration (*inter alia*), elevation, soil conditions and the latest available information regarding the future management policy at the exact location of the landfall. Due consideration will also be given to the potential influence of climate change (especially sea level rise) on coastal morphology.

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7 Abbreviations/Acronyms

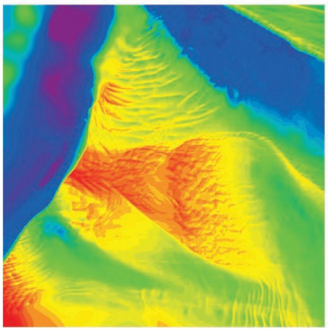
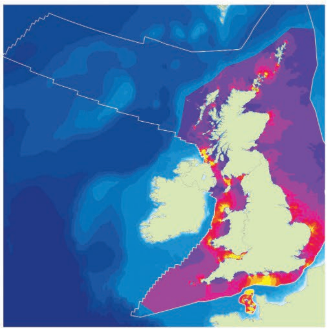
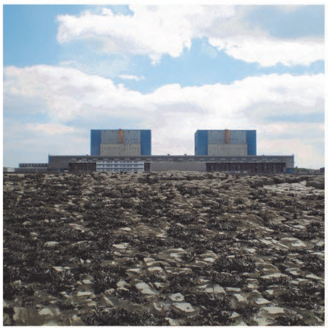
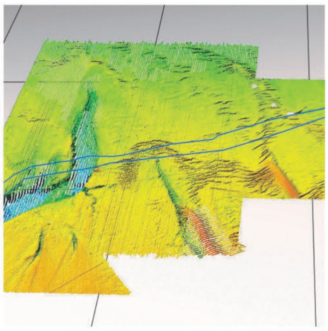
ABP	Associated British Ports
AnnMax	Mean annual maximum
BGS	British Geological Service
BP	Before Present
CCO	Channel coastal observatory
CD	Chart Datum
CFBD	Coastal Flood Boundary Dataset
EA	Environment Agency
EMODnet	European Marine Observation and Data Network
EV	Extreme value
GS	Goodwin Sands
HAT	Highest Astronomical Tide
HD	Hydrodynamic
HDD	Horizontal Directional Drilling
Hs	Significant Wave Height
HTL	Hold the line
HVDC	High-voltage direct current
HW	High Water
KP	Kilometre Point
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LW	Low Water
MCZ	Marine Conservation Zone
ME	Mid Ebb
MF	Mid Flood
MHW	Mean High Water
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MSL	Mean Sea Level
NAI	No active intervention
NCERM	National Coastal Erosion Risk Mapping
NEKMPA	North East Kent Marine Protected Area
NGET	National Grid Electricity Transmission Plc
NNR	National Nature Reserve
ODN	Ordinance Datum Newlyn
RCP	Representative Concentration Pathway
SAC	Special Area of Conservation
SMP	Shoreline Management Plan
SMP2	Shoreline Management Plan second generation
SPA	Special Protection Area

SSSI	Sites of Special Scientific Interest
SW	Spectral Wave
SWH	Significant Wave Height
UKCP18	UK Climate Projections 2018
UKHO	UK Hydrographic Office
UTM	Universal Transverse Mercator
VORF	Vertical Offshore Reference Frames
WGS84	World Geodetic System 1984

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices

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A Analysis of topographic profiles

A number of topographic profiles are available South of the River Stour (Unit 4b) between 2003 and 2023, see Figure 31. A total of seven profiles, highlighted in the figure have been selected for analysis. Figure A1 to Figure A8 show the available data for these profiles.

Profiles the north of Profile 4b00131 reveal high annual variability, making it difficult to determine long term trends. For example, Profile 4b00122 (Figure A2) has accreted between 2003 to 2007, when there was a period of significant erosion, causing the foredune to migrate landward by ~40 m. From 2007 to 2023, there is a period of accretion, with some interannual variability. Whereas Profile 4b00124 has been eroding from 2003 to 2017, where the foredune migrates landward by ~75 m. From 2017 to 2023, this profile shows a general pattern of accretion.

In general, the profiles south of Profile 4b00131, show evidence of consistent accretion of the foredunes throughout the survey period, with some periods of erosion seen on interannual time scales. The foredunes have increase by 2-3 m in height across these profiles between 2003 and 2023.

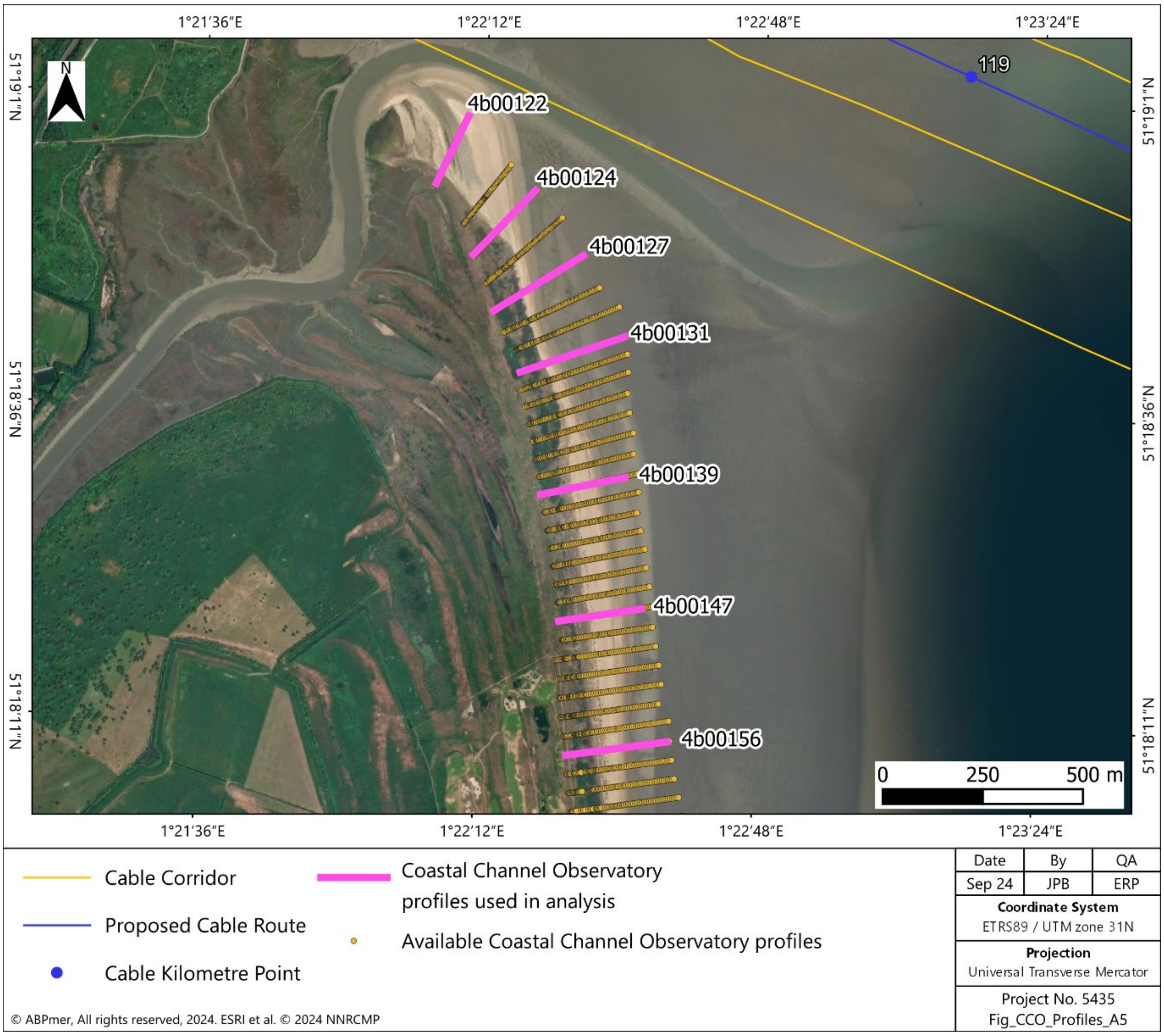

Figure A1 **Location of topographic profiles available (in yellow) and selected for analysis (in pink)**

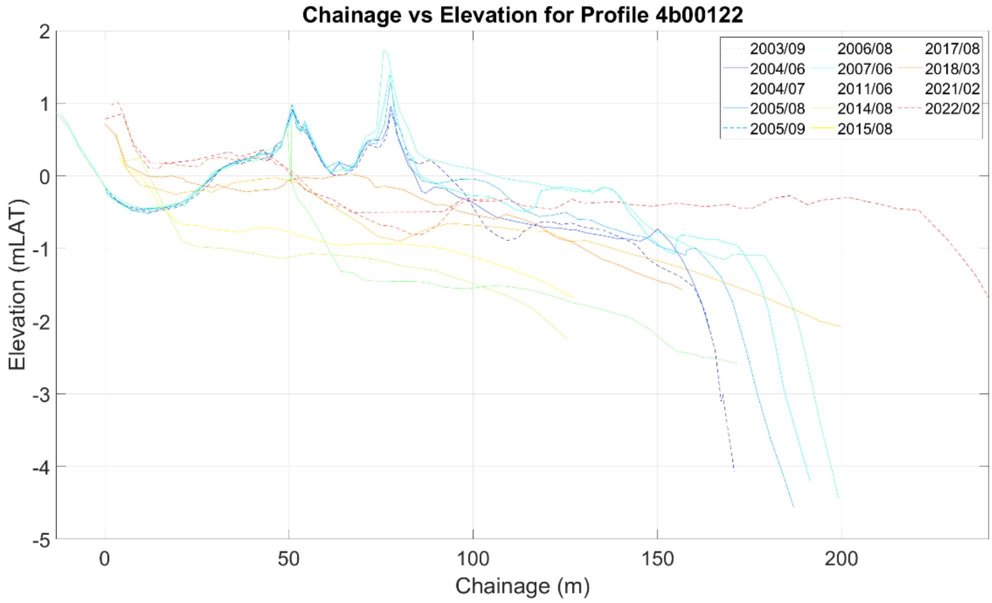

Figure A2 Profile 4b000122 elevation change

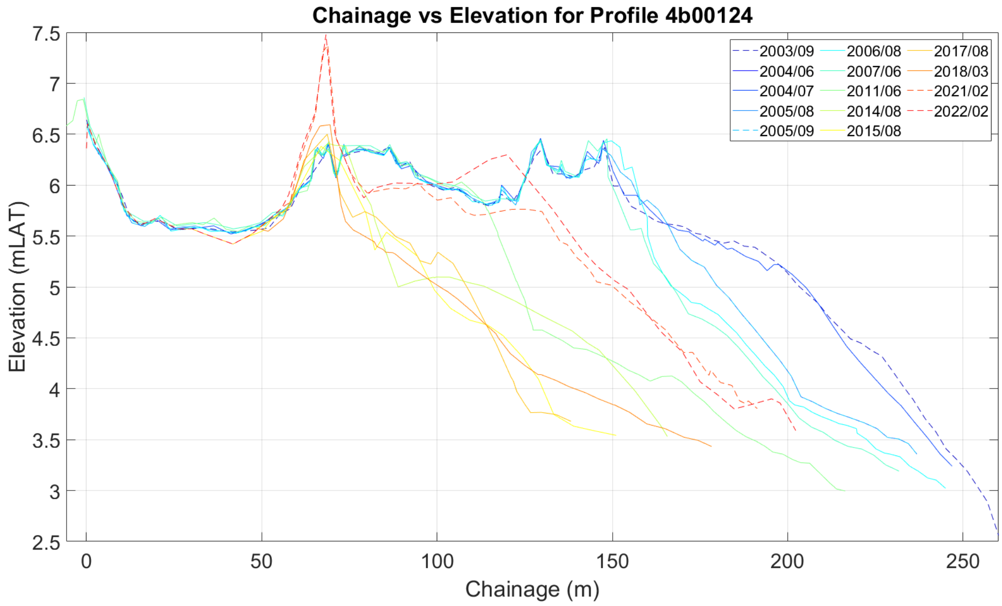

Figure A3 Profile 4b000124 elevation change

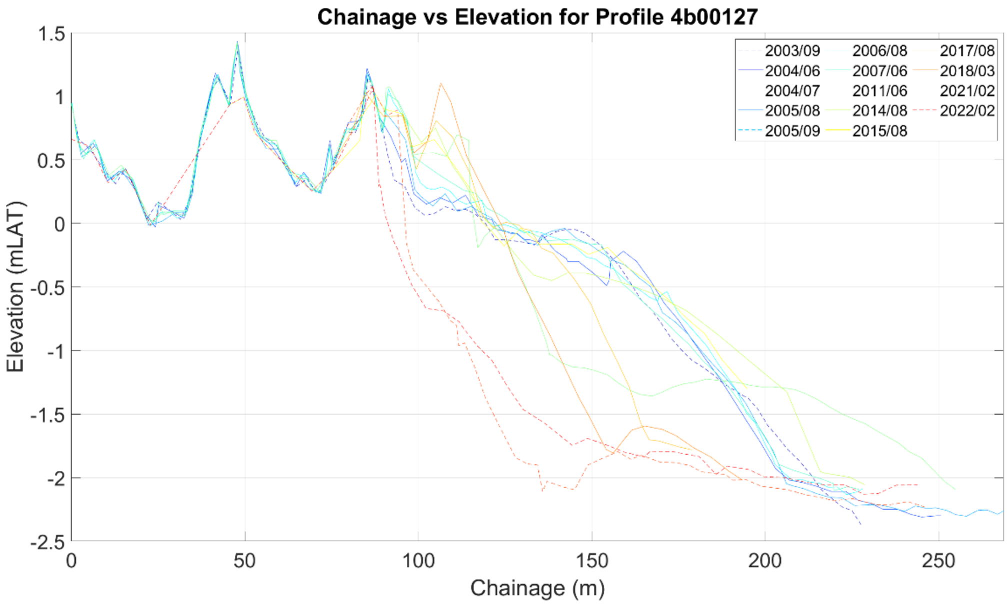

Figure A4 Profile 4b000127 elevation change

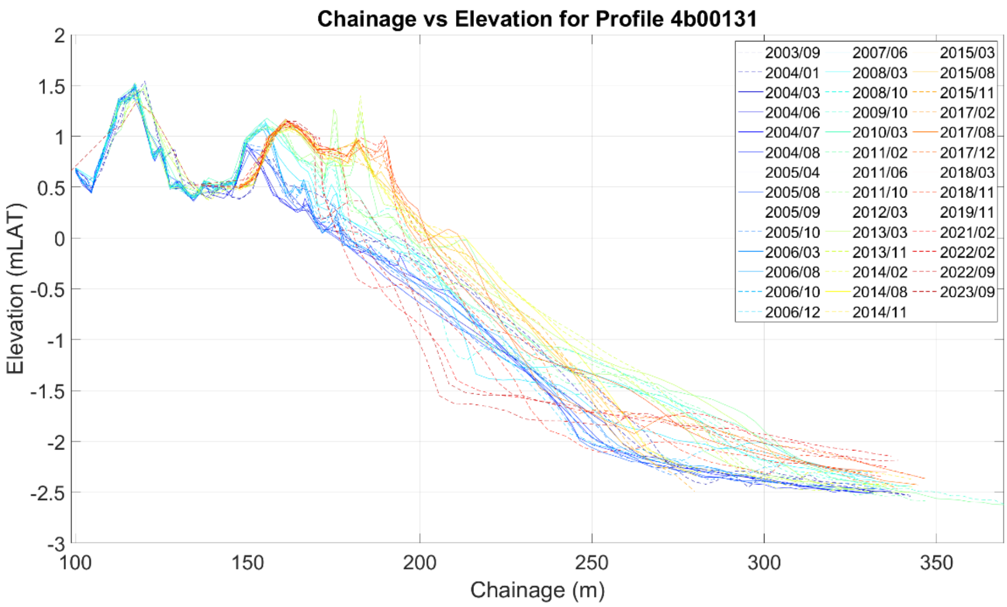

Figure A5 Profile 4b000131 elevation change

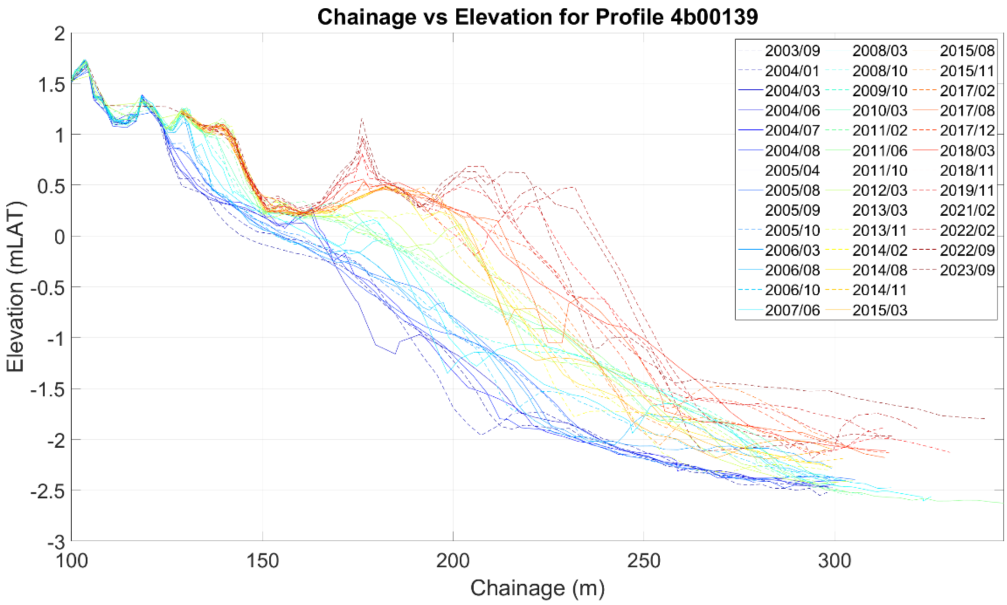

Figure A6 Profile 4b000139 elevation change

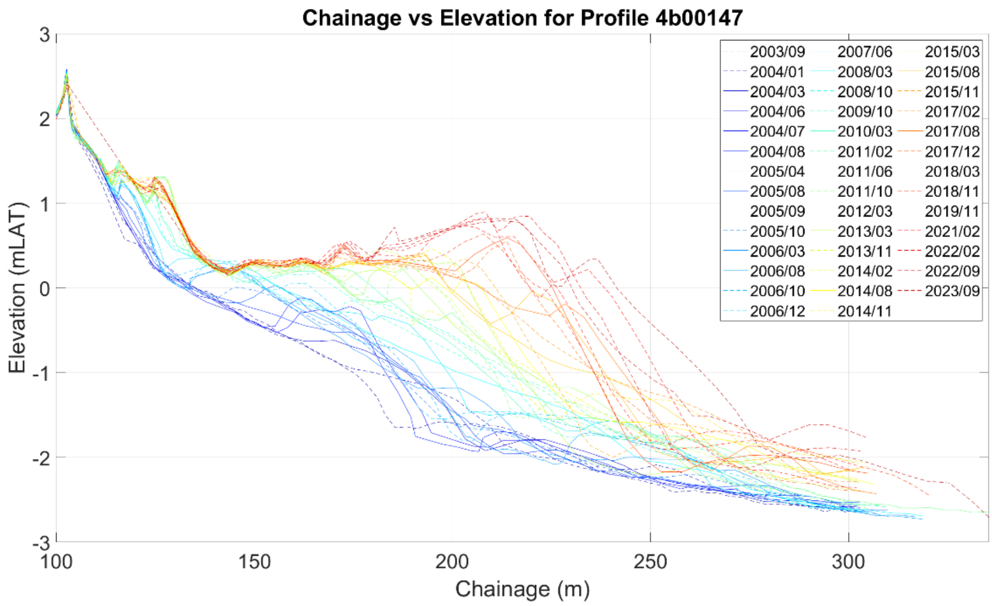

Figure A7 Profile 4b000147 elevation change

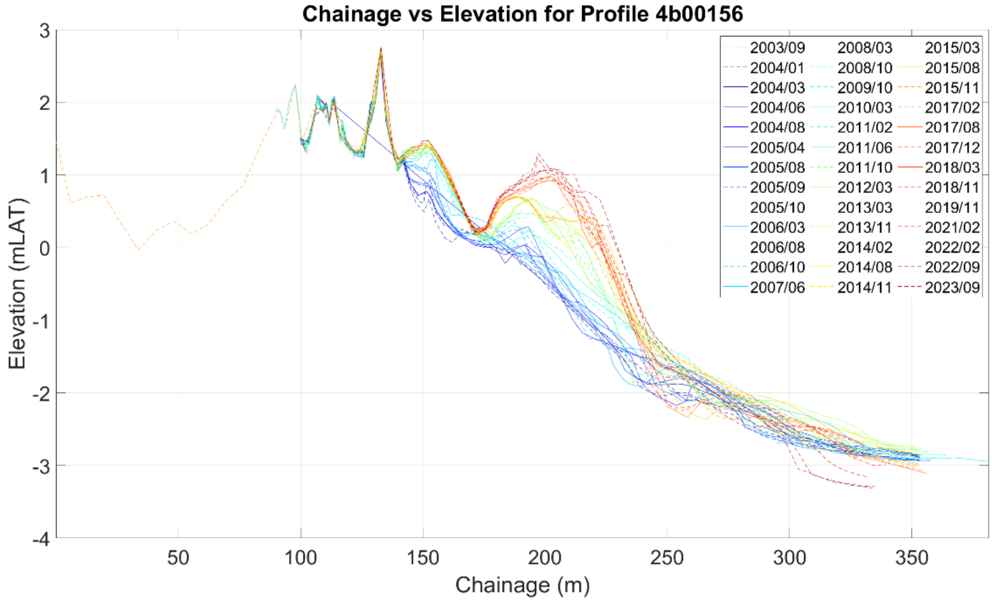

Figure A8 **Profile 4b000156 elevation change**

B Intertidal gradient analysis

LiDAR data for the years 2018, 2020 and 2022 were used generate surface bathymetry gradient streamlines. These lines help to visualise patterns of surface water drainage, and (present day) morphological controls and constraints on the route of the River Stour over the beach. The following analysis was undertaken as a bespoke data analysis using MATLAB software.

To remove the effect of micro-topographic features and noise in the LiDAR data, a 40 m sub-sampled grid was created within a polygon boundary encompassing the intertidal area and the northern section of Shell Ness. For each year of data, a map of local surface gradient vectors was calculated. The same sub-sampled grid points were used as starting locations for a set of continuous streamlines, which visualise the continuous 'downhill' path from any starting point, through the mapped gradient data (Figure B1).

The patterns of streamlines are shown overlying their respective LiDAR dataset in Figure B2 (2018), Figure B3 (2020), Figure B4 (2022). Figure B5 overlays and compares the streamlines from all three years, illustrating the similarity of patterns in the intertidal area between 2018 and 2022. This reinforces the findings of Section 4.2, where the intertidal area showed minimal elevation change between 2007 to 2022/23. Towards the lower intertidal area, the streamlines converge to follow the natural drainage channels. This is most clearly seen in Figure B4 and Figure B5. It is relevant to note that some present day drainage channels on the lower part of the beach might result in the path of the river coming close to, or overlapping the Sea Link cable route, most likely between KP118.5 and KP118.

The drainage channel seaward of KP119 is a previous river channel (Figure B2) and provides a potential new river channel location, should it migrate northward. Although the available LiDAR data shows accretion and northward migration of Shell Ness, there is no clear evidence of northward migration of the river channel on the beach as a result. However, future changes to the sediment transport regime from increased river discharge or continued accretion of the Ness, may cause a shift in the downstream river channel position, therefore, this poses a potential longer-term risk to the cable at KP119. Other predictions (e.g. future epochs in the SMP, Halcrow 2010, described in Section 3.2.2) suggest the possibility of a significant change in the river path as a result of a breach, but not necessarily a significant or persistent move to the north.

South of the river channel, the streamlines show slightly greater variability in their orientation, where the sediment is influenced by longshore drift along Shell Ness and the river, particularly between 2018 and 2020.

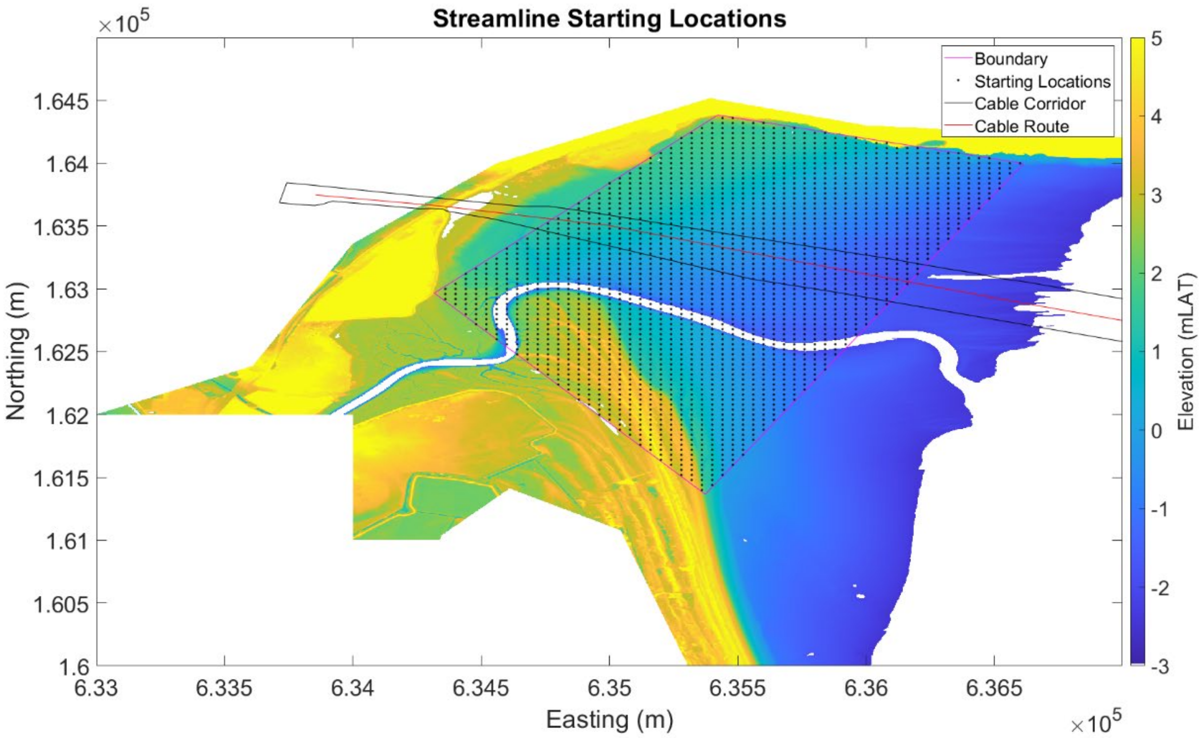

Figure B1 **Starting locations of the points to calculatate the intertidal gradients superimpoed to the LiDAR data of 2022**

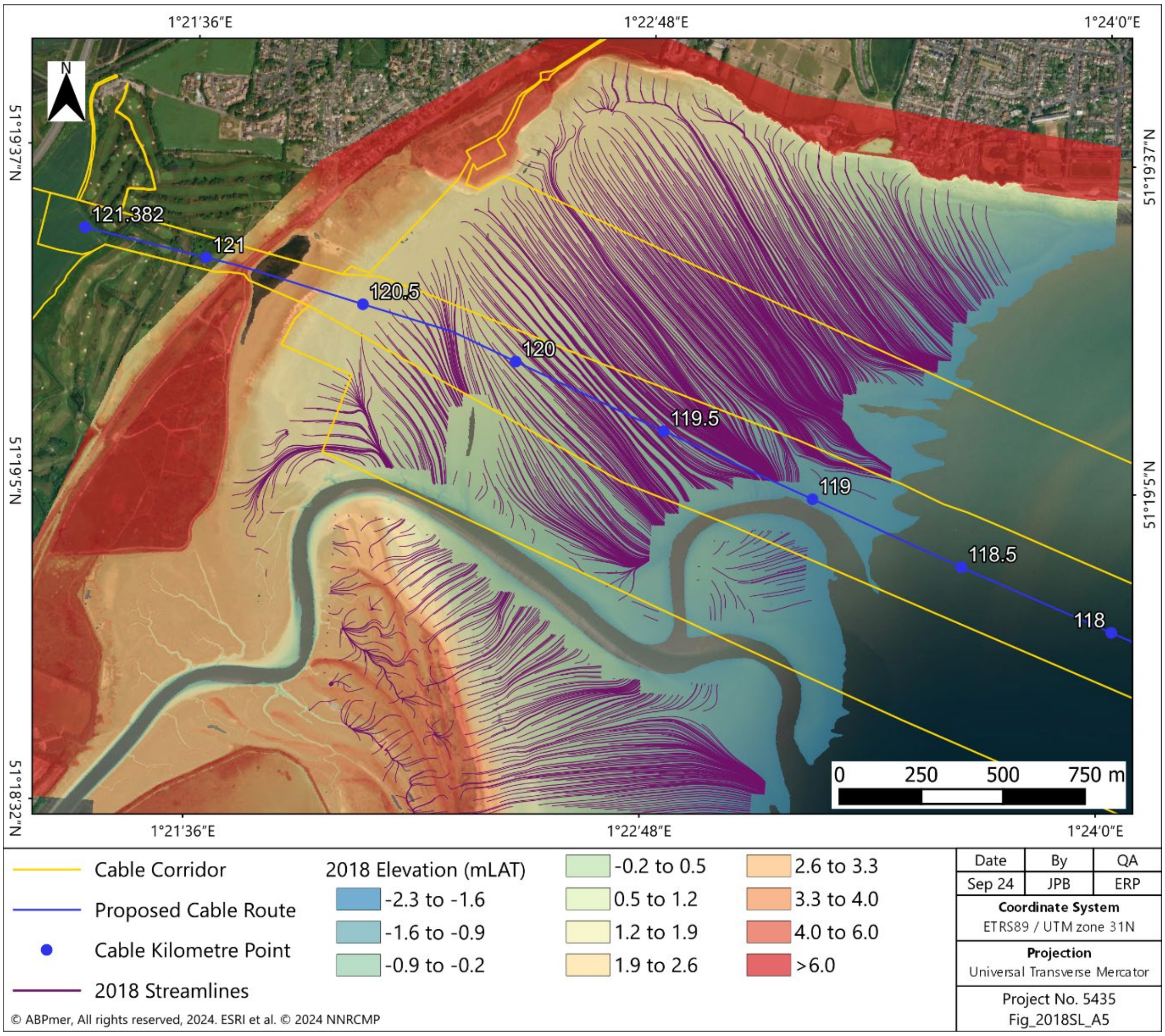

Figure B2 Streamlines from the 2018 LiDAR data superimposed to the 2018 LiDAR topography

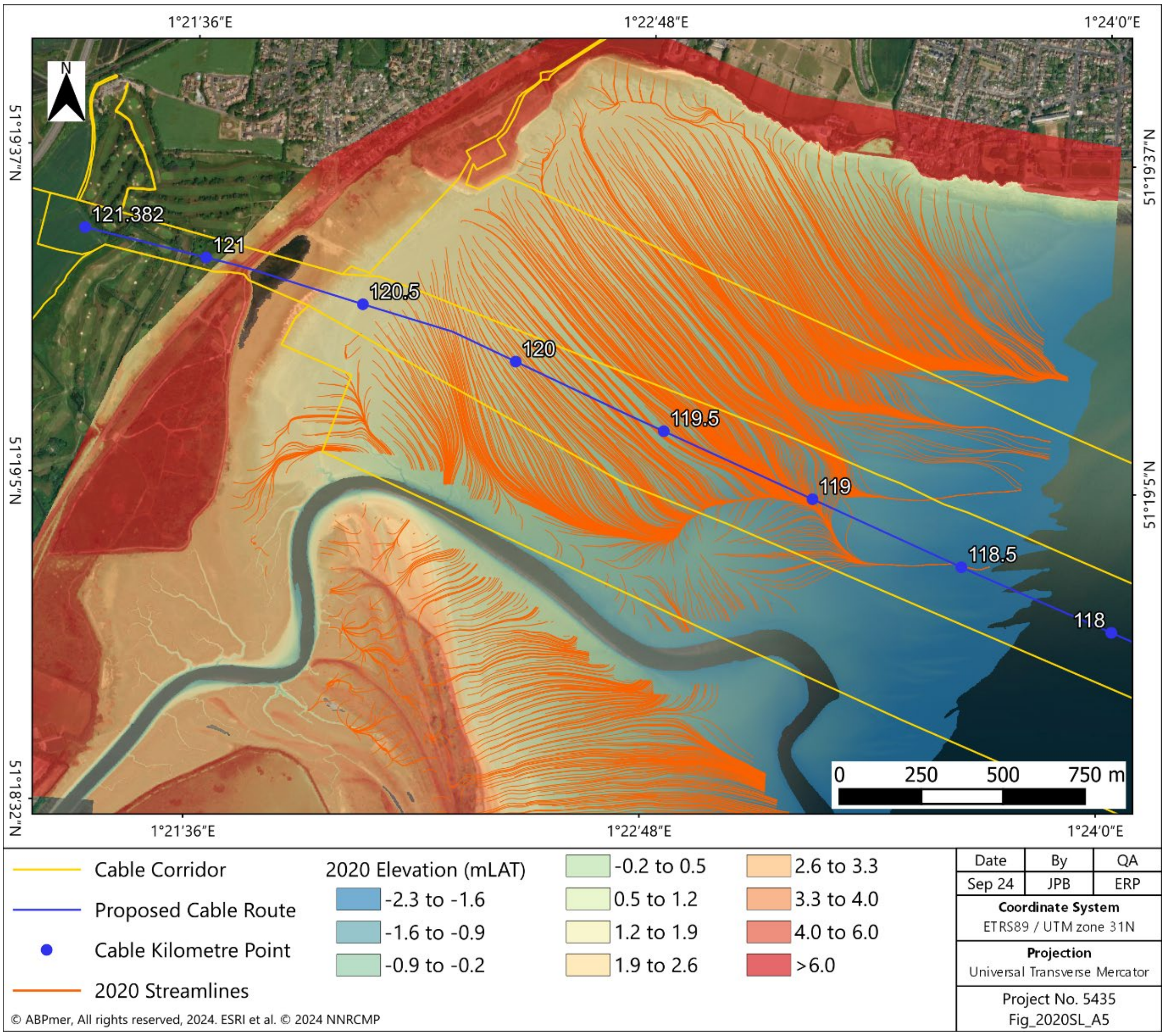

Figure B3 Streamlines from the 2020 LiDAR data superimposed to the 2020 LiDAR topography

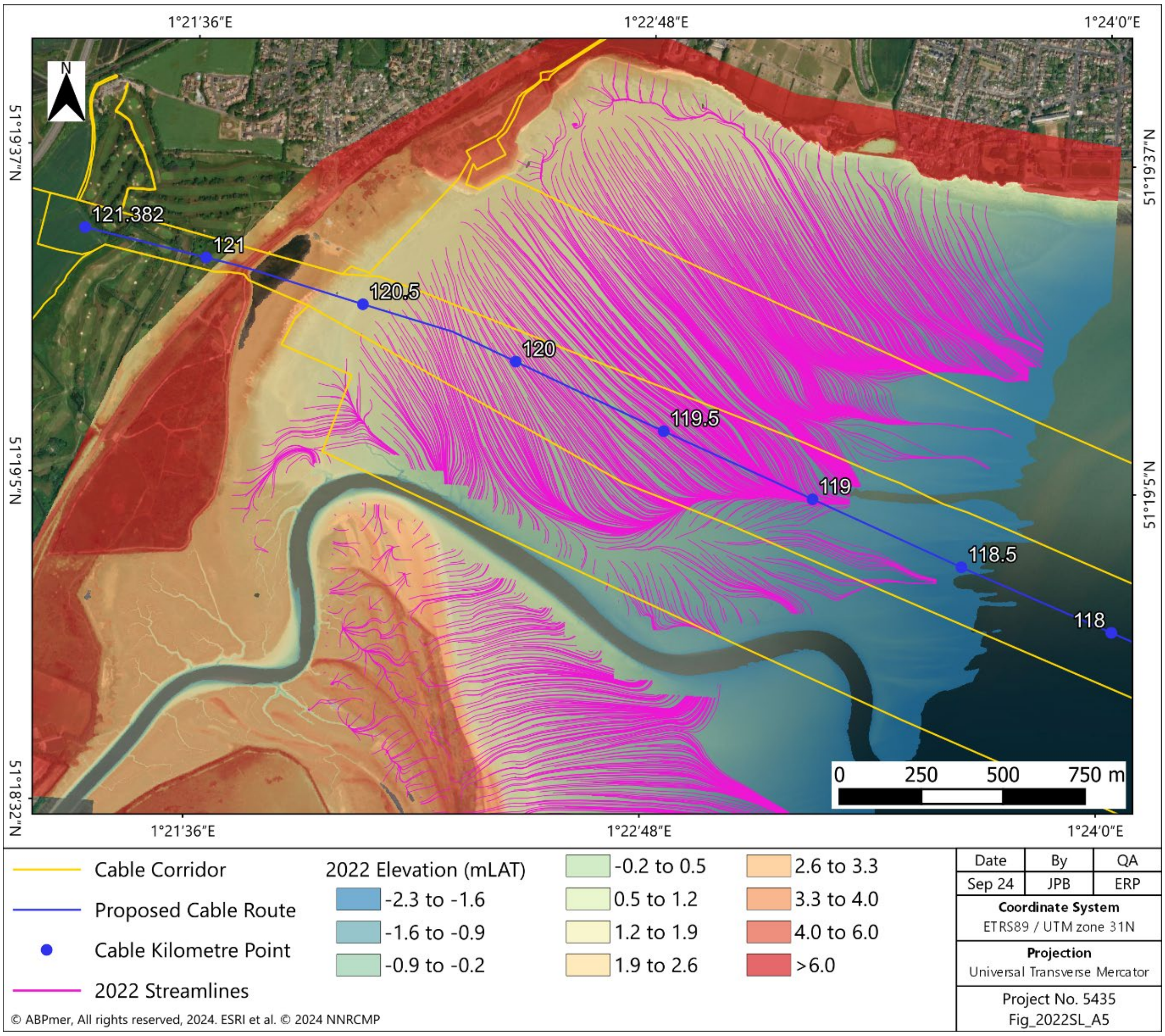

Figure B4 **Streamlines from the 2022 LiDAR data superimposed to the 2022 LiDAR topography**

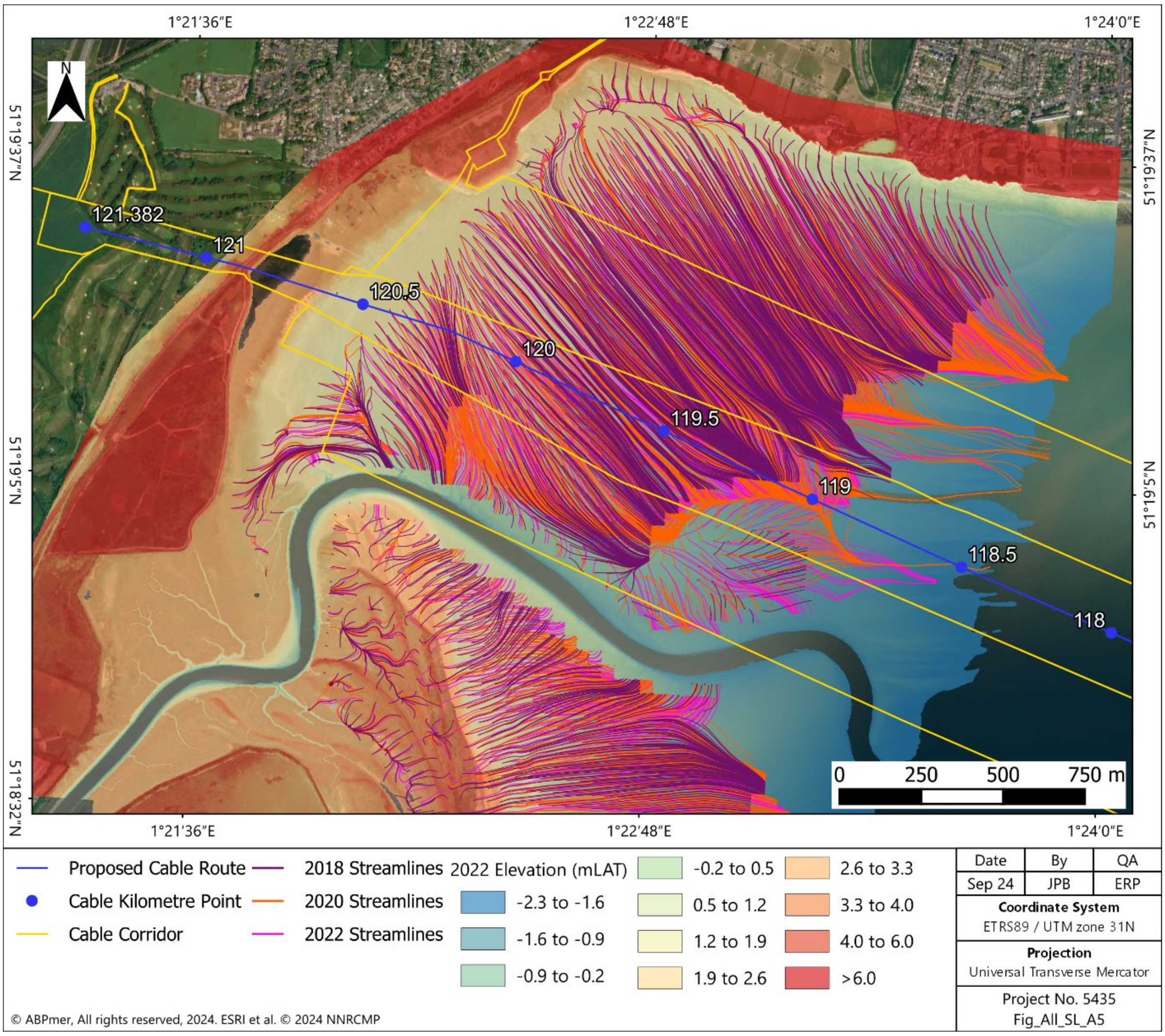

Figure B5 **Comparison between the 3 set of streamlines from the 2018, 2020 and 2022 LiDAR data superimposed to the 2022 LiDAR topograph**

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