Ormonde Project

Scoping study for coastal and seabed processes

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Summary

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This study has been commissioned by Rudall Blanchard Associates Ltd (RBA) to support the Environmental Impact Assessment being prepared for Eclipse Energy with regard to the Ormonde Project. RBA are preparing a Scoping Study leading to the Environmental Statement for development Consent.

The proposed Ormonde Project will combine the electricity generating capacity of natural gas and wind, centred on two small, undeveloped gas fields and an offshore wind farm in the Irish Sea, approximately 10km off Walney Island. The development will include up to thirty wind turbines with inter-connecting cables, a Gas Turbine Platform (GTP), a Sub Station Platform (SSP) and export cables. The development site lies to the northwest of the already Consented Barrow OWF. Three alternative export cable routes are considered, with the landfall within Half Moon Bay north of Heysham Harbour.

HR Wallingford has undertaken a desk study of the coastal and seabed processes to set out the existing state of knowledge and to assess the potential impact of the development in accordance with the CEFAS Guidance Notes 2004. The assessment takes account of any cumulative impacts arising from the nearby Consented Barrow Offshore Windfarm and from the potential Shell Flats, West of Duddon and Walney Offshore Windfarms. No new modelling has been undertaken to support this work, but geophysical and geotechnical survey information has been derived from the recent work undertaken by Gardline Geosurvey Ltd.

It is considered that the proposed scheme is likely to have some localised impact on the waves, currents and corresponding sediment transport regime in the immediate vicinity of the development and cabling, but is unlikely to have any significant or measurable far field impacts. The proximity to the adjacent proposed and potential windfarm sites will not result in any cumulative impacts with regard to foundations or cabling.

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1. Introduction

1.1 BACKGROUND

This study has been commissioned by Rudall Blanchard Associates Ltd (RBA) to support the Environmental Impact Assessment being prepared for Eclipse Energy with regard to the Ormonde Project. RBA are preparing a Scoping Study leading to the Environmental Statement for development Consent.

HR Wallingford has undertaken a desk study of the coastal and seabed processes to set out the existing state of knowledge and to assess the potential impact of the development in accordance with the CEFAS Guidance Notes 2004 (Reference 1). The assessment takes account of any cumulative impacts arising from the proposed Barrow Offshore Windfarm and the potential Shell Flats, West of Duddon and Walney Windfarms, sited nearby. The study also provides preliminary information to support outline engineering design with regard to hydraulic and sedimentary conditions. No new modelling have been undertaken to support this work, but geophysical and geotechnical survey information has been derived from the recent work undertaken by Gardline Geosurvey Ltd (Reference 2).

The report sets out a review of the existing coastal, seabed and hydrodynamic conditions (Chapter 2), and then considers the potential impacts of the development (Chapter 3). Conclusions and recommendations are set out in Chapter 4.

1.2 PROJECT UNDERSTANDING

The proposed Ormonde Project will combine the electricity generating capacity of natural gas and wind, centred on two small, undeveloped gas fields and an offshore wind farm in the Irish Sea, approximately 10km off Walney Island (Figure 1). The development will include up to thirty wind turbines with inter-connecting cables, a Gas Turbine Platform (GTP), a Sub Station Platform (SSP) and export cables (Reference 3). The development site lies to the northwest of the already Consented Barrow OWF (Reference 4). Several alternative export cable routes are under consideration (Figure 1), with a landfall in Half Moon Bay just north of Heysham Harbour. The site also lies in the area of several other potential developments (Shell Flats (Scottish Power) Round 1 site, 20km to the SSE; Walney (DONG) Round 2 site, 5km to the west; and West of Duddon (Elsam/Scottish Power) Round 2 site, 10km to the SSW). At this time the Round 2 sites are not known to have progressed towards Consent, and the Shell Flats site is on hold due to environmental concerns; however they are of potential concern for cumulative impact considerations.

The main site lies in water depths of 17m to 21m below Chart Datum (CD) and is exposed to severe wave conditions generated within the Irish Sea. The predominant southwesterly winds have an effective fetch length of over 200km and waves are enhanced by swell entering from St George's Channel. Exposure to other wave directions is less severe due to the protection offered by the mainland and the Isle of Man. The tidal range is over 8m on Spring tides and the area is subject to tidal currents of under 0.6m/s offshore, rising to over 2m/s along the proposed cable route within Morecambe Bay. The seabed at the site mainly comprises fine sands and silt or soft clays overlying dense sands, with the bedrock or boulder clay interface at least 20m below the surface (Reference 2, Volume 1). The seabed at the southeastern corner of the site has compacted clean sand with scattered patches of gravel/shells. There are no apparent bedforms, indicating an area of slow deposition, consistent with the Eastern Irish Sea Mudbelt identified by BGS.

The assumed cable route runs southeast approximately along the 15mCD contour for about 5km towards the Barrow OWF site. From there, three alternative routes are under consideration, all leading to the landfall within Half Moon Bay, north of Heysham Harbour (Figure 1 and Plate 1):

- Option 1 turns westward to track inshore of the Barrow OWF site, and then runs parallel to the Consented Barrow OWF cable but offset to the north by about 1000m. The route traverses Morecambe Flats to the upper reach of Lune Channel, then crosses Heysham Lake towards the Clarke Wharf sand bank, turns west to cross the deep channel above Heysham Harbour and finally crossing Heysham Sands to the landfall in the centre of Half Moon Bay.
- Option 2 runs south around the seaward side of the Barrow OWF site, then turns west to cross Morecambe Flats (and the Barrow export cable), meeting up with Option 1 to cross Heysham Lake on route for the same landfall.
- Option 3 also passes seaward of the Barrow OWF, but continues southwest to Lune Deep, which it follows towards Heysham Lake where it joins the other two routes towards the landfall.

These routes encounter thick beds of fine sand over the deeper section leading towards the Barrow OWF. As the water shallows to about the 10m contour, the sands thin to a surficial layer, and then exposed tillite and boulder clays with thin patches of surficial sands across the Morecambe Flats. Within the Lune Channel and Heysham Lake there are deep surface sands with significant bedforms, including large sand waves. Heysham Sands comprise relatively stable muddy sands assumed to overly tillite, giving way to coarser sediment and rock outcrops at the shore. Option 3 follows the Lune Deep, with its very steep side slopes dropping down to over 60m depth, where muddy sands/sandy muds predominate.

The coast adjacent to the site includes Walney Island, the Duddon Estuary and the area around Haverigg Point, Cumbria. The shoreline along much of Walney Island and north of Haverigg Point comprises low, eroding cliffs of glacial till and alluvium. Other areas comprise sand dunes and accreting sand/shingle spits. Duddon Estuary largely comprises expanses of shifting intertidal sandbanks, cut by the Scarth and Duddon Channels, with some areas of salt marsh along sheltered shores. Some of the backshore is low lying, with areas at risk from flooding. There are some flood defences or erosion protection structures, including banks, walls, groynes and breakwaters. Several areas are designated for environmental protection including possible SAC/SPA sites and SSSI, as well as National and Local Reserves.

This study assumes that the thirty wind turbines and the export hub will be founded on 5m diameter (approximately) driven or drilled/grouted monopiles. An alternative foundation design may comprise tripods or quadrapods, anchored with driven or drilled piles. The turbines will be set out in three rows, oriented in a northwest to southeast direction, with spacings of at least 425m along the rows and 950m between rows. The export hub will be offset to the east of the turbines by approximately 1000m. The cables will be buried throughout, including the landfall. The final methods of cable laying to the landfall has not been defined at this time, but may included jetting or ploughing with trenching or directional drilling through the harder strata at the landfall.

No specific proposals have been set out for the decommissioning of the turbine foundations or cables at the end of their design life of 25 years. It is assumed that buried cables would be left in place, and that foundations would be removed at the seabed surface. Any sediment disturbance would be short term during actual site operations.

The gas platform foundation design and construction are uncertain but believed to be a small-scale, multi-leg layout, with construction being undertaken independent of the turbines. The legs may be anchored by driven or drilled piles, or by suction caissons. It is anticipated that the gas platform will be relocated after depletion of the first (southern) gas field, and will be removed on depletion of the second (northern) field. No pipelines are anticipated for the first phase, but a sub-sea tieback to one wellhead may be included for the second phase.

1.3 AVAILABLE DATA

The following table summarises the available data provided by RBA as input to the study. In addition the study has reviewed the extensive archive of past projects and public information held by HR Wallingford.

Item	**Source**	**Reference No.**
Geo-surveys: windfarm site, cable route and pipeline route	Gardline, provided by RBA	2
FEED Basis of Design Report	ODE, provided by RBA	3
Proposed layouts	ODE, provided by RBA	
Soil samples for site and cable route	ODE, provided by RBA	
Barrow Offshoe Wind Farm EIS	RSK Environmental, provided by RBA	4

2. Physical environment

2.1 COASTAL MORPHOLOGY AND PROCESSES

The proposed offshore development has the potential to influence the coastal processes along the shore of Walney Island, the Duddon Estuary and the Cumbrian coast around Haverigg Point. The export cable also has the potential to influence processes at the landfall near Heysham in Morecambe Bay. To assess this potential there must be a clear understanding of the existing processes, and the likely future evolution of the coast, including an understanding of the temporal and spatial variability, and the level of uncertainty.

The area has been studied within the Shoreline Management Plan process during the past decade, and much of the available information has been collated and summarised with the Future Coast 2002 document. Parts of the area have been previously studied by HR Wallingford for the proposed Barrow offshore wind farm, and earlier in relation to the Heysham power station, the Morecambe Barrage and Barrow port, plus other regional studies and reviews (References 5 - 19).

The seabed and coastline around the proposed Ormonde Project have been strongly influenced by the last Ice Age and the post-glacial period. Large quantities of sediment were laid down across the area by retreating glaciers and associated rivers. The material has been reworked by waves and currents during the post-glacial period up to the present day, with general onshore movement of sediment into the large estuaries of Morecambe Bay, Duddon and the Solway Firth, as well as the Ribble, Mersey and Dee further south. Littoral drift of sediment along the coast is strongly affected by the estuaries, with each estuary forming a partial or complete barrier to drift north or south.

Apart from the landfall area near Heysham, the potentially influenced coastal area is largely undeveloped, but includes valuable farmland, recreational areas and environmentally designated sites.

Walney Island

The shoreline of Walney Island consists of unconsolidated sands, gravels and glacial tills laid down under various glacial and post-glacial conditions. Analysis of historic Ordnance Survey Maps indicated that the west shore of the island has been eroding for at least the past 150 years, most notably towards the south. The north and south ends of the island have undergone periods of accretion or stability over the same time period. The foreshore is characterised by “scars”, composed of coarse gravels and cobbles, that provide some protection to the low, eroding coastal cliffs.

Eroded material is transported by waves and tidal currents north towards the Duddon Estuary and south to Walney Channel at the entrance to Morecambe Bay. The direction and rate of drift is variable, but along much of the shoreline it is considered to have a nett southerly path along the upper beach. Sand and shingle may be transported at different rates and sometimes in different directions due to the relative influence of waves and currents. There is thought to be some tidal re-circulation of sand between the Duddon Estuary and the north of the island.

The shoreline has been influenced by various small scale coastal defences built to reduce erosion, longshore drift or flooding. These defences include groynes and revetments of rock or building rubble. The effects are localised and limited.

In the absence of further interventions or the impacts of offshore developments, the Walney Island shoreline will gradually erode along the exposed west coast, with continued development of the south spit and the sand deposits to the north. Erosion rates will be influenced by the frequency of storms and surges, and there is uncertainty regarding future rates of change. It is considered unlikely that the island will be permanently breached at any point over the next 50 years, but occasional overwashing has occurred in the past and may become more frequent as sea levels rise.

Duddon Estuary
The estuary is characterised by continually changing banks and channels. The exposed shorelines comprise shingle ridges and sand dunes with several areas of limestone outcrops. The estuary is considered to be generally accreting, with feed of sand and shingle from the north and south. The shoreline is generally not protected by built defences, although there are areas of reclamation protected by seawalls and embankments. The inner estuary has areas of salt marsh.

The future evolution of the shoreline depends on the maintenance of defence walls around reclamations and the continual, but unpredictable, changes to the intertidal banks and channels.

Haverigg Point
The shoreline comprises occasionally eroding glacial till cliffs, providing sand and gravel to feed the shingle ridges and dune systems. Drift is complex, with sand and shingle moving at different rates and directions due to the variable wave climate and local tidal residual flow directions. The coast is orientated with the predominant wave direction, so nett drift rates are low. Upper beach drift is southward towards the point and into the estuary, forming a series of accreting spit ridges. Processes are not expected to change in the future, although rising sea levels may result in increasing rates of storm induced erosion.

Morecambe Bay
The only other shoreline location that may be influenced is the Heysham frontage north of the harbour where the proposed cable route comes ashore across Heysham Sands, between the Near Naze headland and the low cliffs along the Lower Heysham foreshore leading to Throbshaw Point. The wide intertidal beach comprises muddy fine sands, with low, shifting banks and ground water drainage channels. There are exposures of cobble beds close to the shore, and a gravel/cobble upper storm beach fronting the low cliff shoreline of glacial till over sandstone. The south shore of the Bay was formed as part of the Heysham Harbour reclamation in the early 1900s, with a rock faced embankment connecting the natural rock outcrops of Near Naze and Far Naze.

Previous studies (References 9-11) indicate that sediment transport within the Bay is dominated by tidal flows. The nett drift along the Heysham shore is towards the northeast, resulting from the flood tide dominated currents combined with waves from the exposed west-southwest direction.

Analysis of historical maps (five Ordnance Survey editions between 1847 and 1980), recent aerial photographs and previous studies indicate that the lower beaches along Heysham Lake channel and immediately north of the harbour have remained relatively stable, despite construction of the Heysham Harbour in 1904 and progressive changes to the channel and banks further offshore. The high water line has also remained stable, due to the presence of reclamation embankments and the rock outcrops of sandstone at the Near Naze and Throbshaw Point that provide natural hard points. Assuming that there are no major changes to Heysham Harbour then there is no reason to expect this nearshore area to change significantly over the next few decades. The buried export cable will not be expected to cause any significant impacts during construction or subsequently, either across the intertidal area or at the landfall.

2.2 SEABED GEOMORPHOLOGY AND SURFACE SEDIMENTS

The bed sediments at and around the offshore site have been extensively sampled for the Ormonde Project, and a full geophysical/geotechnical survey has been completed (Reference 2). Information has also been derived from Admiralty Charts, BGS publications and previous studies. The assumed cable routes approximately follow the proposed routes for the Barrow OWF, which has been fully surveyed: outline information is set out in the EIA Statement (Reference 4), while detailed data are held by the developers. Although these data do not provide information on the exact cable routes proposed for the Ormonde Project, they do provide clear evidence of the geophysical environment anticipated.

The seabed at the proposed wind farm site slopes gently from east to west, with depths from 17mCD to 21mCD. The surface sediments vary from muddy very fine SAND in the west to fine SAND with patches of gravel/shells in the east. The surface sediment has a depth of around 0.5m-1.0m and overlies dense sands to a depth of 20m-30m where the interface with bedrock or boulder clay is expected. There are no apparent bed features across the main site, suggesting a stable or gently accreting environment.

Review of historic chart information suggests that the bed depths have increased since 1842 by about 1m, but this is likely to be largely the result of past surveying and reduction methods rather than a significant change. There is no other evidence to suggest that the area has been subject to any significant long term change.

A comparison of recent changes to the bathymetry along the assumed cable routes has been undertaken using Admiralty chart information (Admiralty Chart 2010), Ordnance survey maps and recent aerial photography (2004). The chart information includes surveys from the periods 1961-69 (1:37,500 scale) and 1989-91 (1:50,000 scale). OS maps reviewed include the series from 1847-51, 1913-19, 1930-33, 1955-58 and 1970-80. The high and low water marks from each series were overlaid and analysed for the SMP studies.

Along the assumed cable corridor inshore from the proposed Barrow OWF there is substantial variation in the surface sediment. Much of the corridors of Options 1 and 2 include very similar sediment regimes as the Barrow route. The shallows of Morecambe Flats comprise tillite and clays with superficial sand. East of the Fisher Bank Patches the bed drops to a depth of 25m CD within the upper reach of Lune Deep and is covered by bedded sands with a surface layer of mobile sand including mega-ripples and large sand waves. The surface layer thickens to as much as 5m across Heysham Lake.

Inshore from Heysham Lake, the Ormonde cable route diverges from the geophysical surveys of the proposed Barrow route. Analysis of all available map, photographic, published and anecdotal data clearly indicates that the bedforms of Heysham Lake, Clarke Wharf Bank and the banks off the entrance to Heysham Harbour are highly mobile at timescales from days to decades, with bed levels potentially changing by as much as 10m where steep sided channel undergo changes of alignment.

The corridor for Option 3 also includes the muddy sands / sandy muds of the outer Lune Deep, which are assumed to be stable or accreting. This area includes the Spoil Ground off the River Wyre channel, where sandy / muddy dredge spoil from Heysham Harbour and the Wyre is dumped.

The solid geology underlying the offshore site is the Manx Furness Basin of mainly Triassic sandstones and mudstones. The thick overlying deposits are tillite, dense sands and the unconsolidated muds and muddy fine sands of the East Irish Sea Mudbelt.

2.3 WATER LEVELS

Table 1 sets out the tidal ranges for adjacent coastal sites based on Admiralty Tide Table information, with conversions to Ordnance Datum for convenience. It has been assumed that Chart Datum (CD) is 4.7m below Ordnance Datum (OD) around Morecambe Bay, and 4.2m below further to the north (this latter OD adjustment for Tarn and Duddon Bar is assumed from Admiralty information, but may need to be revised if better local data are available).

Extreme water levels, due to combined surges and high tide levels, have been assessed through investigation of previous work (References 20 and 21). The results from these studies are set out in Table 2. These studies were based on coastal points rather than offshore sites such as the wind farm, but they provide useful estimates of extremes and indicate that the 100 year extreme level is about 6.8mOD (11.5mCD). Figure 2 presents the best estimate curve for a range of return periods. Adjustment for offshore water levels is likely to reduce high water levels at the site by about 0.3m for MHWS conditions and about 0.4m for less frequent surge related conditions.

Table 1 Tidal ranges for adjacent coastal sites from Admiralty Tide Tables

	Tarn		Duddon Bar		Barrow		Haws Point		Heysham		Fleetwood	
	mCD	mOD	mCD	mOD	mCD	mOD	mCD	mOD	mCD	mOD	mCD	mOD
HAT					10.3	5.5	-	-	-	-	-	-
MHWS	8.3	4.1	8.5	4.3	9.3	4.5	9.4	4.7	9.4	4.5	9.2	4.3
MHWN	6.4	2.2	6.6	2.2	7.1	2.3	7.1	2.4	7.4	2.5	7.3	2.4
MSL					5.0	0.2	4.9	0.2	5.1	0.2	5.0	0.1
MLWN	2.5	-1.7	2.6	-1.6	3.0	-1.8	3.0	-1.7	2.9	-2.0	3.0	-1.9
MLWS	0.9	-3.3	0.9	-3.3	1.1	-3.7	1.1	-3.6	1.1	-3.8	1.2	-3.7
LAT					0.1	-4.7	-	-	-	-	-	-

Table 2 Extreme water levels

Return period (years)	Extreme elevations (mOD)			
	Graff, 1981 (Ref. 20) Heysham	Coles & Tawn, 1990	Dixon & Tawn, 1995	Dixon & Tawn, 1997 (Ref. 21)
1	5.8			5.7
10	6.1	6.1	6.1	6.3
100	6.5	6.9	6.8	6.8

2.4 WAVE REGIME

Field monitoring and modelling work has been completed for other sites in the area in the past (References 4, 12-15). This work was reviewed to provide information for use in this study. Table 3 sets out extreme offshore conditions based on these earlier studies (both modelling and monitoring), indicating a 100 year significant wave height of about 7.5m (Reference 13) and therefore a maximum individual wave height of about 14m. Along the proposed cable route wave conditions are affected by the reduced water depths, causing larger waves to break thus reducing the extreme values. Waves are also influenced by the currents, particularly within deeper channels where the interactions can be complex.

Table 3 Predicted extreme offshore wave conditions (H_s m)

Return period (years)	Reference 11	Reference 12	Reference 13
0.2	3.8		4.0
1	4.8		5.1
10	6.2	6.4	6.3
100	7.4	8.3	7.5

2.5 TIDES AND CURRENTS

Tidal currents in the area around Morecambe Bay have been measured and modelled for a number of studies by HR Wallingford and others (References 4, 9 and 22). Currents for specific sites to the north and south are also defined on the Admiralty Charts. Admiralty information and numerical model results (Figures 3 and 4, Reference 4) indicate that currents across the offshore site set in a generally easterly direction on the flood and west-northwesterly on the ebb. Depth averaged peak currents are slightly stronger on the ebb, but are no more than 0.6m/s under normal tidal conditions. Residual currents set to the southwest, but are slight at only about 0.05m/s averaged over a tidal cycle. Assuming a normal vertical distribution of current speed it is considered that currents alone will give rise to very limited nett southwesterly transport of surface sand and silt within the proposed windfarm site.

Along the cable route flows are more complex, with speeds published on the Admiralty Charts reaching up to about 1.1m/s on the ebb and 1.3m/s on the flood near Heysham, with stronger flows up to 1.8m/s within the deep Lune channel. Recent modelling suggests that peak currents could be in excess of 2m/s along the inner lengths of the proposed cable routes. In conjunction with wave conditions in this area, these currents are sufficient to transport sediment, create mobile bed forms and cause long term changes to the bed.

2.6 JOINT PROBABILITY EVENTS

There is a strong correlation between tidal surges and large wind waves within the eastern Irish Sea as they are generated by similar conditions (Reference 23). The coincident occurrence of a surge, causing water levels to be higher than the predicted tidal condition, and severe wave conditions can give rise to conditions that may influence structural design or sediment transport. For a given probability of joint occurrence, expressed in terms of return periods, the conditions may range from very high water levels with a modest wave condition to very severe waves with a modest water level.

In relation to the environmental impacts, events with severe wave conditions and high water levels can cause short term disturbance and may be important during construction or cable laying. They may also give rise to coastal erosion and flooding. However, they are infrequent and are therefore not significant to the longer term condition of the physical environment at the windfarm site or along the cable route, except at the landfall.

2.7 FUTURE CONDITIONS

The proposed wind farm is assumed to have a design life of 25 years, during which time it is anticipated that the site conditions may vary due to the effects of global climate change. The important parameters will be increasing sea level and changes to the frequency and direction of strong winds.

Global sea levels have been rising over the past century, and rates are predicted to increase. Changes to sea levels must be considered relative to changing ground levels to give relative water level change. At present there is an assumption by DEFRA and the Environment Agency that relative sea level change along the UK northwest coast will be 4mm/year over the next 50 years, giving 100mm over the design life of the wind farm. Ongoing work by several institutions will provide refinements to this accepted standard in the future.

The impacts of climate change on winds and waves have not reached a similar state of agreement. It is generally accepted that the design of coastal structures should consider the potential for increased storminess and changes to the dominant directions. Due to the configuration of the Irish Sea, the proposed wind farm site is predominantly exposed to severe waves from the southwest and there is no reason to suppose that future extreme waves will arrive from a changed direction. However, the frequency of strong winds may increase, affecting both extreme wave heights and surge levels. In the absence of any certainty it would be prudent to take a conservative approach and allow for design conditions at a higher level of predicted return period than would be the case if present conditions were assumed to continue.

2.8 SEDIMENT TRANSPORT

Sediment transport is driven by tidal currents combined with waves, and is a function of the type and availability of bed sediment. The relative importance of waves and tidal currents varies depending on local conditions, with the effects of waves dependent on the wave height and period relative to the depth of water.

The existing sediment transport regimes for the Barrow OWF and cable route were simulated using the HR Wallingford TELEMAC, SANDFLOW and COSMOS models, in order to assess the potential impact of the development (Reference 4). The results of that work provide an indication of the situation for the Ormonde Project, including the assumed cable route and landfall.

Over most of the wind farm area the dominant driver for sediment transport is tidal current. The effects of unbroken waves in the relatively deep water of the site are limited mainly to a stirring effect whereby the entrainment process is enhanced, particularly during periods of higher wave activity. By this process, wave action can increase the magnitude of the suspended sediment concentration, but the transport pathways are unaltered. Given that currents are relatively weak and approximately rectilinear, the nett sediment flux is low (Figure 5, Reference 4).

Large waves in relatively shallow water cause wave breaking that generates an additional driving force, and this process does alter the direction of sediment transport. However, for the proposed wind farm location, the seabed levels are greater than 17mCD in all areas with mobile surface sediment. The onset of wave breaking due to depth limitation occurs when the wave height exceeds a factor of the water depth of between 0.55 and 0.8. This range criterion indicates that only the most extreme individual waves of over 9m would break over the wind farm at lowest tide levels, while at mid-tide levels only waves above about 12m would be likely to break. These are conditions that would only occur during very severe wind conditions with an occurrence probability of no more than 1:1 year. Consequently it is appropriate to focus attention on the potential impact of the turbine foundations on the sand transport patterns due to tidal currents alone.

At the wind farm site, tidal currents are just sufficient to transport fine sand, but significant transport will only occur during strong onshore winds when waves are sufficiently large to disturb the seabed. Along much of the cable route there are moderate to strong tidal currents sufficient to transport sand and pebbles even in the absence of waves.

Within Morecambe Bay all levels of wave energy will enhance tidal current effects by lifting sand into temporary suspension and thereby making it available for transport by the currents. Moderate waves may break across shallower areas affecting the direction of transport. Nett sediment transport rates will depend on the surface sediment characteristics, the direction / strength of the tidal currents, water depths and wave conditions. Along much of the cable route the conditions are sufficient to have swept the seabed of any surface deposits, leaving only clay/tillite exposures. Further inshore there are deposits of potentially mobile surface sediment within the main channels and along the intertidal margins of the estuary. Currents in the channels can be strong enough to create both small scale, mobile bed forms (sand waves, mega-ripples) and large migrating banks.

The migration of the Clarke Wharf Bank along the northwest margin of the Heysham Channel has caused concern for navigation into Heysham Harbour (References 10 and 18). The bank moved eastwards across the channel through the last century up to 1968 causing the channel to shallow by 5m. Since then it is believed that the channel has become deeper and wider again (Reference 6). The future of the channel is uncertain, but can be assumed to be subject to continuous and significant change. In the past there has been no navigation dredging of the main channel, apart from the harbour entrance, but future changes to the bed or the traffic into the harbour may necessitate dredging to maintain navigable depths, with potential impacts on the cable route.

Potential levels of suspended sediment concentration at peak flood and ebb were also considered in earlier studies. Figure 6 (Reference 4) shows the distribution of potential suspended sediments across the site and cable route. Over much of the cable route the concentrations of suspended sediment are considered to be typically up to 0.3kg/m^3. There are some areas where the strong currents race across shallow areas and give rise to higher potential levels. Wave effects will increase these levels. HR Wallingford fieldwork, presented in 1970 (Reference 10), indicated background suspension levels of up to 0.3kg/m^3 within Heysham Lake and peak values of nearly 0.5kg/m^3 across parts of

Middleton Sands. It is assumed that levels across Heysham Sands will be similar. Plumes of sediment arising from the cabling process should be assessed within the context of the potentially high background suspended sediment concentration levels.

Although not modelled for this study, previous work has shown that monopiles may cause a reduction in current speed over a short distance downstream. Evidence from various studies indicates different distances over which effects are discernible, but in all cases it is agreed that the impact of 5m diameter monopiles on the bed level will be localised and that there are will be no discernible far-field impacts on the sediment transport patterns. The impacts of multi-leg structures have not been investigated to the same level, but it is also assumed that impacts will be local to each structure, with the extent of scour or accretion depending on the dimensions of the legs, the proximity of any cross-bracing to the seabed and the orientation of the legs in relation to the tidal currents. There may be minor post construction accretion downstream of the foundations as a consequence of the reduced currents speeds, assuming that mobile sediment is available from scour. A further impact of the reduced current speed will be a reduction in the potential for suspended sediment concentrations. These impacts are considered to be insignificant in relation to the general sediment transport regime and will have no far-field impacts.

3. Potential impacts

The potential impact of the development on coastal and seabed processes are assessed in terms of localised effects, as a consequence of the direct impact of the structures, and far-field effects due to the interactions between the various processes over a wider area. The impacts are also considered over a range of timescales:

- Existing baseline conditions (extreme and normal)
- Construction period
- Post-construction recovery
- Design lifetime
- Decommissioning

Assessment takes account of uncertainty and temporal spatial variability against a background of natural change. Impacts are designated from negligible / un-measureable up to unacceptable. Appropriate mitigation measures are suggested to reduce significant impacts. Consideration is given to recently completed work for the DTI and DEFRA relating to generic impacts of turbines on waves, currents and sediment transport (Reference 24), seabed / foundation interactions (unpublished DTI research on suction caissons) and site specific measurements at the Scroby Sands site by CEFAS (in preparation).

3.1 LOCALISED IMPACTS

3.1.1 Waves

Waves will be modified in the immediate vicinity of the turbine monopiles due to sheltering and also wave diffraction and reflections. The monopiles are considerably narrower than the typical wavelength of most waves affecting the study area, and therefore it is considered that the direct impact on waves will be small, other than immediately around each structure, and there will be no discernible interaction between the piles. The reasons for these conclusions are set out below.

Waves are disturbed by the presence of monopiles when the diameter, D, becomes large relative to the wavelength, L. A value of $D/L \geq 0.2$ is generally taken as the regime in which wave scattering becomes important. A reflected wave is generated when it hits a large cylinder and moves outwards from it. On the sheltered side of the cylinder there will be a shadow zone where wave fronts are bent around the cylinder. These waves are the diffracted waves and, combined with the reflected waves, they are referred to as the scattered waves.

The wave climate for the area around the proposed windfarm site is considered to include short period waves likely to be influenced by the monopiles for about 60% of the time. However, these short period waves have low heights and therefore the resulting scattered and diffracted waves will be small. Monopiles may be considered to act independently if the scattered waves have decayed to an insignificant wave height when they reach the nearest adjacent monopiles.

Several approaches to simulating wave diffraction and scattering are available. Recent published research from Oxford University (Reference 25) clearly supports the view that the scattered waves created by interactions with any one monopile will be negligible before reaching the nearest adjacent monopile assuming the range of configurations likely for an offshore windfarm. Even under likely worst case conditions as simulated using a simplified numerical model for a shallow sand bank under an ongoing CEFAS/DEFRA research project (Reference 26), the cumulative impact of closely spaced turbines has been shown to reduce incident wave heights by no more than 5%, with no influence on wave period. More realistic non-linear, random wave modelling using the turbine spacings proposed for the Ormonde Project would show that the cumulative impact of a windfarm on the wave conditions would be negligible.

Multi-leg foundations may be proposed for the wind turbines and for the gas turbine platform due to the large water depth. There are no standard methods to assess the impact of complex, braced structures on wave conditions, but it is assumed that they will have only slightly more impact on wave energy scattering or dissipation than the monopiles, and that the overall effect would still be negligible. The limited research work that has been completed indicates that impacts on sediment transport will be local to each structure, with the extent of scour or accretion depending on the dimensions of the legs, the proximity of any cross-bracing to the seabed and the orientation of the legs in relation to the tidal currents.

Water depths at the wind farm are large relative to the typical waves at the site, with waves up to about 4m H_s relative to depths of 17m to 29m depending on location and tidal state. This relationship implies that any minor short or long term changes in bed level caused by the monopiles or cables (scour discussion – Section 3.1.3) will not significantly affect the wave conditions either locally or over a wider area.

3.1.2 Currents

Currents will also be modified in the immediate vicinity of the turbine monopiles. Tidal currents in the area are essentially rectilinear with normal velocities no greater than 0.6m/s. In the immediate lee of the proposed turbine monopiles there will a flow separation zone. Standard design guidance (Reference 27) suggests that this zone typically extends 6-10 monopile diameters (30m to 50m) downstream, and within this zone there is likely to be generation of turbulence that is greater than normal, especially during peak flood and ebb conditions. There may also be some shedding of turbulent vortices that extend beyond this main zone of influence. As the structures are separated by at least 425m, and by over 1000m in the direction of peak flows, then it can be assumed that there is no significant interaction between structures with respect to flows.

The use of multi-leg foundations would give rise to more complex interactions, and potentially a greater area of local disturbance. However, the limited research completed indicates no reason to believe that there will be any significant interaction between structures, nor any significant cumulative impacts.

As was noted for waves, if structures cause any changes to the seabed, the changes will be small relative to the depth of water and the influence on flows will be negligible.

3.1.3 Scour

The potential impact of the foundations and any exposed cable on the sediment transport will depend on the local modifications to the waves and currents, as described above, and the availability of potentially mobile sediment. The acceleration of the tidal current and generation of turbulence, together with wave activity, will tend to scour sediment from around the foundations and from beneath the cables on both the flood and ebb tide, and deposit it downstream.

A best estimate for the depth of scouring can be based on existing literature (Reference 28, recent unpublished research from the DTI Suction Caisson programme and recent commercial windfarm physical modelling contracts). The scour extent and depth around a cable or monopile is dictated by the hydraulic and sediment conditions. For the purposes of considering the worst case situation for the environmental impact assessment, it is assumed that the bed sediment is homogeneous and unlimited. In reality it is known that the fine surface sediment found across the offshore site is up to 1m in depth, and overlies denser sands that may be more resistant to scour.

At present there is no accepted method of assessing scour around multi-leg structures, apart from physical modelling, so estimates of scour are not quantified. For the purposes of this impact assessment it is assumed that the monopile situation will be representative.

If multi-leg structures are taken forward then further studies will be needed to consider wave and current interactions, and resultant potential scour. These studies may need to include the gas turbine platform. Existing limited research suggests that scour and accretion will be influenced by the dimensions of the legs at the seabed, the distance of separation, the presence of cross-bracing close to the seabed and the orientation of the legs in relation to the currents. The upstream leg(s) will suffer similar scour to a single monopile, while the downstream ones will be exposed to lower flow velocities and therefore will have less scour. However, as currents are approximately rectilinear at the site, the upstream and downstream legs are interchangeable, and the nett effect will be approximately equal scour at each leg, with the potential for cumulative scour if the legs are closer together than the diameters of each individual scour hole. In order to reduce concerns over stability and structural fatigue it is likely that scour protection will be specified for multi-leg foundations.

The results of the scour assessment under approximate worst case conditions for the wind farm site and cable corridor are as follows:

Case 1: Wind farm monopiles
Input parameters assumed:

Monopile:	*Diameter = 5m*
Water depth:	*h = 21 to 25m at mid-tide*
Waves:	H_s *= 5.3m* T_p *= 8.5s Direction = 260 deg.*
	U_{orb} *at bottom = 0.6m/s*
Current:	*U = 0.5m/s Direction = 90 or 290 deg.*
Sediment 1	d_{10} *= 0.010mm* d_{50} *= 0.220mm* d_{90} *= 0.450mm*
Sediment 2	d_{10} *= 0.004mm* d_{50} *= 0.08mm* d_{90} *= 0.30mm*
Threshold of motion:	U_{crit} *= 0.5m/s*

Conclusions:
The steady velocity required to initiate sediment transport is approximately 0.5m/s, while the minimum wave height needed to mobilise the sediment is approximately 0.9m (d50 = 0.22mm) and 0.6m (d50 = 0.08mm). This indicates that under peak flow conditions the tide alone is capable of moving sediment and causing scour around the structure, even in the absence of any waves. The scour hole due to tidal currents alone has the potential to extend about 3D horizontally from the pile and up to about 1.5D vertically, where D is the monopile diameter. Given D=5m, then scour may extend approximately 15m from the outside of the structure and about 8m in depth. The presence of waves will tend to speed up the rate at which the scour occurs, although the

presence of storm waves with Hs greater than 3m may inhibit the scour depth and extent.

Given the potential for scour and the possibility that alternative, multi-leg foundations may be used, it would be prudent to undertake further studies of potential scour and to allow for placement of a rock scour apron around the foundations. Experience from other windfarms has shown that scour can occur rapidly after foundation construction, potentially requiring unscheduled, unconsented and costly remedial work. Although scour may not constitute a significant structural or ecological risk, it may cause a problem for the cable connections. Monitoring of the seabed immediately after foundation construction will guide the need for rock placement. Materials and plant should be available should the problem be considered significant.

Rock aprons stabilise the local seabed, and would provide a new benthic habitat within an area characterised as a featureless, muddy fine sand bed. Removal of the rock during decommissioning could prove difficult, though possible if the impacts on habitat over the long term were considered unacceptable.

Case 2: Wind farm cables (assumed not to be buried)
Input parameters assumed:

Cable:	*Diameter = 0.25m*
Water depth:	*h = 21m to 25m at mid-tide*
Waves	*as Case 1*
Current:	*as Case 1*
Sediment:	*as Case 1*
Threshold of motion:	*as Case 1*

Conclusions:

For unburied cables within the windfarm site, the tide alone is capable of moving sediment and causing scour, even in the absence of any waves. After cable laying, a scour hole may quickly develop to a depth of approximately 0.15m underneath the cable and this may grow to around 0.70m after 10 to 15 tidal cycles. The scour may extend up to 20m either side of the cable. If the cable sags the depth of the hole may be as large as 1m underneath the initial cable position. This suggests that the cable should be buried in those areas of the site with a mobile sediment surface layer to avoid stresses on the cable as a result of spans over scour pits. Burial is likely to be required for protection of the cables from fishing gear and anchor damage.

Case 3: Heysham Lake cable corridor (assumed buried)
Input parameters:

Cable:	*Diameter = 0.25m*
Depth at mid-tide:	*h = 20m*
Waves:	$H_s = 4.3m$
	$T_p = 7.5s$
	Direction = 260 deg.
	U_{orb} *at bottom = 0.35m/s*
Current:	*U = 1.5m/s*
	Direction = 70 or 250 deg.
Sediment:	$d_{50} = 0.120mm$
Threshold of motion:	$U_{crit} = 0.5m/s$

Conclusions:
In this region the tide alone is capable of moving sediment and causing scour around exposed cable, even in the absence of any waves. If the cable is exposed following initial burial, due to large scale bed movements, a scour hole may quickly develop to a depth of approximately 0.15m underneath the cable and this may grow to around 0.70m after 5 to 10 tidal cycles. The scour hole may extend up to 20m either side of the cable. If the cable sags the depth of the hole may be as large as 1m underneath the cable. This assumes that the current is normal to the line of the cable, whereas the peak currents (and largest waves) along the cable route run at less than 30° to cable. Scour beneath exposed cables may therefore be less than predicted by this method.

To avoid scour the cable must always remain buried below the seabed. Consideration should be given to the sandwaves and channel/ bank migrations in the area. As the bed is mobile, the cable should be buried to such a depth that it is always below the troughs of the bed features. This should ensure that as the bed forms move over the cable, it would not become exposed. Where the cable route passes along the edge of Clark Wharf and the Heysham Harbour Channel, it may not be possible to achieve a sufficient depth of burial. The channel floor is up to 10m below the bank crest, and the channel has the potential to shift laterally by hundreds of meters giving rise to bed elevation changes of the full 10m. Ongoing monitoring will be required, along with a commitment to rebury the cables as the need arises.

3.1.4 Sediment transport

Assuming a final spacing between turbines of at least 425m, and up to 1000m in the dominant east-west tidal flow direction, it is considered unlikely that there will be any overall sheltering effect that could give rise to broad scale accretion or erosion over the area of the wind farm. A generic industry modelling project undertaken for the DTI (Reference 24) supports the view that broad scale effects are unlikely for a situation with similar characteristics to the study site. This has not been proven for multi-leg structures, but it is considered a reasonable assumption.

Sediment brought into suspension due to scour around the foundations will be transported downstream a short distance. An increase in the level of suspended sediments during and after construction above background levels may be an issue with regard to potential smothering of benthic communities. The increase will depend on the construction method and the significance of the impact will depend on the sensitivity of the benthos during the construction period. Assessment of ecological impacts should take account of the high background levels of suspended sediment throughout the region. Driving monopiles will cause considerably less suspended sediment than drilling, as the spoil from drilling operations will remain on the seabed for a sufficient time to allow tidal currents to transport fine particles away from the site.

Sediment transport will also be influenced by the cabling. It is assumed that the cables will be buried within the fine sediments of the site, along the landfall route across the tillite beds of Morcambe Flats and across the mobile sand beds to the landfall site. Regardless of burial method, the bed sediment will be disturbed causing increased suspended loads during laying operations and increased potential for subsequent re-suspension. The impacts will depend on the construction method employed, the amount of disturbance, composition of the bed and the sensitivity of the benthos during the construction period.

Ploughing is considered to cause the least disturbance as excavated bed material is largely returned as the cable is laid. Jetting and sub-sea trenching depend on natural processes to backfill, and the results depend on the local currents, bed type and availability of suitable sediment. It is possible that imported backfill material may be required across the exposed clay beds of Morecambe Flats as the trench is unlikely to refill naturally. The backfill material should be specified to reduce the potential for future re-suspension or bedload transport.

3.2 FAR-FIELD AND COASTAL IMPACTS

3.2.1 *Waves*

As described above, wave effects are limited to the immediate vicinity of the monopiles, with no significant or measurable interactions between structures, and therefore no significant cumulative effect. Given the nature and depth of the seabed at the proposed wind farm site it is considered that the structures will not significantly modify the seabed in a more general sense, either by large scale erosion due to an increase in turbulence, or large scale accretion due to sheltering. In the absence of any general bed level changes there will be no significant impacts on areas outside the wind farm site, including the shoreline at Walney Island or within the Duddon Estuary or Morecambe Bay. This conclusion is in line with industry research (Reference 24) that concludes far-field impacts due to turbine influence on the wave climate will be negligible for situations with similar characteristics to the Ormonde site.

3.2.2 *Currents*

Currents are dominated by tidal processes at the wind farm site and along the cable route, with enhanced currents due to wave breaking under high wave conditions along the cable route and near the landfall. Other than in the immediate vicinity of the foundations, currents are considered unlikely to be modified to a discernible extent by the scheme, and therefore there will be no significant impact on adjacent areas. This conclusion is also supported by industry research (Reference 24).

3.2.3 *Nearshore sediment transport*

The analysis described in Section 3.1 anticipates that the impact of the structures on sediment transport is likely to be restricted to localised areas around the structures and along the cable route during burial and the immediate post-burial recovery period. It is considered that the proposed development will have no significant or measurable impact on the general sediment transport regime or morphology of the area.

3.2.4 *Coastal processes*

There is the potential for littoral drift to be affected across the low tide beach near the cable landfall at Heysham, depending on the design and construction approach. Due to the orientation of the upper beach within Half Moon Bay (Plate 1), there is no significant drift to cause concern. At present, it is assumed that the landfall will be achieved by trenching or ploughing across the foreshore and trenching or drilling through the rocky outcrops at the shore line. If this is the case then there will be no significant impact on the shoreline, apart from short term impacts during construction, provided that the depth of installation is sufficient to minimise any future risk of exposure due to short term beach draw-down or long term erosion. Impacts during construction will be negligible provided that the foreshore levels are reinstated using the trenched material immediately following cable laying.

The open coast of Walney Island, the area around Haverigg Point and the intervening Duddon Estuary are in the lee of the windfarm during the dominant westerly and southwesterly wave conditions. It is considered that the impact of the proposed windfarm on wave and current regimes, and therefore nearshore transport, will be negligible and unmeasurable away from the immediate vicinity of the turbines. The short period waves incident on the foundations will mainly be scattered, rather than dissipated, although some energy will be lost when waves break onto the structures. At longer wavelengths, the waves will exert a force on the foundations, thus absorbing a very small amount of energy from the waves and reducing the height of the transmitted wave.

In order to assess the impact of the turbine foundations on the coastal processes without attempting to undertake a detailed calculation of wave energy loss, it has been assumed that the entire wave energy incident on the individual monopiles will be lost; this assumption allows a simple and conservative assessment of the effect at the coast. If the 30 monopiles remove energy in direct proportion to the sum of their diameters, and this is related to the overall length of the site, then a maximum of 150m/4000m or about 4% of the total wave energy from the southwest may be lost. The total proportion of time that waves at a given point on the coast arrive from the direction bisected by the monopile group is estimated from regional wave climates to be about 25%. Given these figures, 4% of the wave energy that occur for 25% of the time would be blocked, resulting in a conservatively approximated 1% reduction in the incident wave energy at the coast.

This calculation assumes that all wave energy incident on the monopiles is lost, when in reality much will be scattered (at least in the diffraction regime). Therefore the potential reduction of 1% is a significant over-estimation of the energy loss in waves reaching the coastline. In any event, it is clear that within the context of natural variability in the wave climate at the coast and the uncertainty as to the nature of the existing coastal processes on the lee shores, the potential magnitude of reduction is very small. The impact on coastal processes will be negligible and not measurable.

The impacts of multi-leg structures on the wave conditions will be more complex and have only been subject to very limited applicable research. However, the ratio of solid structure to the effective overall length of the wind farm will still be small. Even allowing for a conservative doubling of the effect in relation to monopiles, the impact at the coast would still be negligible and not measureable.

The Duddon Estuary is largely dominated by the tidal currents rather than waves, and is therefore even less susceptible to potential small changes in the wave climate.

3.3 CUMULATIVE IMPACTS

The Ormonde Project is located close to the Consented Barrow Offshore Windfarm (assumed construction in 2005), as well as several cables and pipelines. It is also close to several possible Round 2 windfarm sites and the unconsented Shell Flats Round 1 site. In combination there are potentially a large number of turbines within an area of about 1000km^2.

The existing pipelines connect the North and South Morecambe Gas Fields to Walney Island. They lie to the south of the windfarm site and will be crossed during cable construction. There is no evidence to suggest that they have any impact on seabed processes beyond their immediate vicinity. There will be a need to consider the crossing method in detail during design.

The existing cable route connecting the Isle of Man to the Cumbrian coast runs well to the north of the windfarm site, and will not be affected.

The discussions in Sections 3.1 and 3.2 above have asserted that monopile foundations spaced at distances of between 425m and over 1000m have no significant or measurable cumulative impact on waves, currents or sediment transport, either within the windfarm site or over a wider area. If individual monopiles do not have an influence on adjacent monopiles, then there is no potential for one windfarm having a cumulative impact with a neighbouring windfarm at several kilometres distance.

There is however some concern over the potential localised interactions between export cables from the various developments. It is likely that the various cables will need to cross and may run parallel over parts of their routes. The extent and significance of potential cumulative impacts will depend on the methods of crossing, distance of separation and the schedule of cable laying operations. Particular consideration will need to be directed towards the corridors within the mobile beds of the upper Lune Deep and Heysham Lake. These issues will need to be revisited during engineering design to ensure that due consideration is given to the potential interactions, ensuring that the cables remain buried.

4. Conclusions and recommendations

4.1 CONCLUSIONS

HR Wallingford has undertaken a desk study of existing reports, data, charts, bathymetric/geophysical/geotechnical surveys, model output, published papers, etc to provide preliminary hydraulic and sedimentary information in accordance with the requirements of the CEFAS Guidance Notes (Reference 1). Much of this information is held by HR Wallingford following our work for other wind farm sites in the area. Other information has been collated from sources such as the Future Coast study, related SMP and coastal strategy studies.

This work includes the wind farm area, giving consideration to the turbine foundations, the inter-connecting cables and the potential export cable routes up to the landfall. The work also considers potential cumulative impacts resulting from the Consented and potential nearby Offshore Windfarm sites and other seabed infrastructure.

The impacts of the development are assessed in relation to the waves, currents, sediment distribution, sediment transport regime (bedload and suspended load) and bedforms. The assessment considers impacts at each structure and along the cables, within the boundaries of the wind farm and further afield (specifically including the coastline of Walney Island, the southwest Cumbrian coast and the Duddon Estuary). Consideration is given to the natural variability of the coastal and nearshore system and inherent uncertainty within a dynamic environment.

Impacts have been assigned a level of likely significance (from high to negligible / non-measurable). The impacts are described quantitatively where possible. Potential mitigation measures are noted.

Gaps in existing knowledge are highlighted, with further work recommended only where it will provide a significant improvement in the understanding of potential impacts or mitigation measures.

It is considered that the proposed scheme is likely to have some localised impact on the waves, currents and corresponding sediment transport regime in the immediate vicinity of the development and cabling, but is unlikely to have any significant or measurable far-field impacts. This general conclusion concurs with the findings for the already Consented Round 1 wind farms set within similar nearshore situations and with recently published generic research (Reference 24).

The sediment transport rate is low at the wind farm site, and it is unlikely that foundations will have a significant impact on the transport regime, other than through localised scour around the base of each structure. Some scour around the structures should be anticipated due to peak currents up to about 0.6m/s, combined with a moderately high energy wave regime; the extent of scouring of the fine surface sediment may be limited by the presence of a dense sand sub-layer.

The potential for broad scale changes to the seabed as a result of the combined effect of all the turbines depends on the dimensions and spacing of the foundations, plus the seabed stability and the wave/current conditions. The proposed wind farm is anticipated to have 30 monopiles, with diameters up to 5m, and spacing of 425m to 1000m (depending on direction). A rough rule of thumb for the extent of disturbance to the current field of up to 10 length-scales suggests that the current will be affected for a distance of only 50m leeward of each monopile, although turbulent vortices may be apparent over a greater distance. This indicates that the monopiles can be considered as independent of each other in respect of the impact on the currents. Wave effects are considered to be similarly restricted in the spatial extent of their impact. This conclusion also indicates that there will be no cumulative impacts arising from the adjacent windfarms. Alternative multi-leg foundations are less well understood, and may have an impact on flows over a greater distance. However, it is considered reasonable to assume that the foundations will still act independently with no cumulative impact within the site or in combination with adjacent sites.

The potential sediment transport patterns along the assumed route of the cable have been assessed. It is concluded that the cable will pass through active areas requiring that the cable should be buried sufficiently deep to prevent its future uncovering, and routine monitoring should be undertaken to assess this issue in the future. The cable corridor passes through an area of large scale mobility in the area of Heysham Harbour, where it may not be possible to ensure long term burial. The cable should be designed in such a way that possible future uncovering and subsequent exposure to the strong tidal currents does not compromise its integrity, and a long term monitoring and management programme should be developed as part of the design process.

From an environmental impact perspective the existing natural mobility of the sediment indicates that the development is unlikely to have a significant impact following construction or over the design life. Changes due to the structures are likely to be less than those experienced due to natural variation. This is likely to be true for both the seabed and the shoreline.

It has been demonstrated that the background levels of suspended sediment concentration at the wind farm, and particularly along the cable route, are naturally high, so that the transient impact of plumes arising from the trenching process or later resuspension of the disturbed sediment are unlikely to be significant. If the monopiles require drilling and grouting then there will be locally high, but short term, suspended sediment loads. Any potential environmental impacts from drilling will depend on the season and the likely sensitivity of the benthic ecosystem, but are unlikely to be significant against the natural background of suspended sediment concentrations.

The shoreline at Heysham is subject to a relatively weak potential drift rate and the Heysham Sands foreshore is relatively stable, so there is no cause for concern regarding the landfall. It is assumed that trenching and/or drilling through the existing upper beach and low cliff will be undertaken with reasonable care to avoid unnecessary disturbance, and that the condition of the foreshore and cliff-face will be reinstated on completion to ensure minimal environmental impacts.

4.2 RECOMMENDATIONS

The work undertaken within this study should be considered together with the results of other environmental studies from the wind farm project team, allowing full consideration of engineering and environmental implications to ensure that all impacts are assessed, mitigation measures are proposed and design is optimised.

Induced sediment transport is likely to be highest during the winter months due to the enhancement of tidal current activity by large waves. Any potential impacts on the transport regime will be minimised by undertaking drilling or trenching activities in the summer months. This recommendation must be balanced against other considerations.

Driving the monopiles will minimise the local increase in suspended sediment. Drilling and grouting will release sediment for transport as bedload and in suspension, but the volumes released will have a negligible impact on the general sediment regime. Consideration should be given to the phasing of this work to avoid severe wave conditions and any seasonal sensitivities of the benthic communities.

The turbine foundation may suffer some local scour of the mobile surface sediment. The maximum extent of scour is predicted to be up to 5m depth and up to 10m away from each monopile, with more complex responses around multi-leg structures. Sediment released by this scour is considered unlikely to have any significant effect on general sediment distribution or bed levels, and therefore scour aprons are not required to prevent transport. Aprons may, however, be desirable for structural stability, reduction of fatigue and to prevent damage at the cable / foundation interface. Further investigation of both scour and mitigation is recommended as part of engineering design.

A number of scour protection options can be considered:

- rock rip rap
- concrete unit mattresses
- sandbags, grout filled geotextile bags.

Regardless of method used, the protection layer must extend over the predicted scour area to provide adequate protection. A suitable filter layer (usually quarry run stone and/or geotextile layer) may be placed between the protection layer and the seabed material to prevent settlement. Scour can be expected within a few tides after installation of the monopile and it may be possible to utilise the initial scour hole within the scour mitigation design. Seabed levels adjacent to the turbine should be monitored before and after installation to determine the amount of scour.

Multi-leg foundations may be used for both the wind and gas turbines. There is no standard approach to assessing impacts of complex foundations on waves, currents or scour potential. Numerical models are not able to simulate the relevant processes, and therefore scaled physical modelling will be required in support of engineering design. A mobile bed model at suitable scale can be used to simulate waves currents and scour within known limits of certainty, and can support the design of any required mitigation. A limited amount of research has been undertaken using a physical model, indicating that scour will be influenced by the dimensions of the legs at the seabed, the distance of separation, the presence of cross-bracing close to the seabed and the orientation of the legs in relation to the currents. The upstream leg(s) will suffer similar scour to a single monopile of similar dimensions, while the downstream ones will be exposed to lower flow velocities and therefore will have less scour. However, as currents are approximately rectilinear at the site, the upstream and downstream legs are interchangeable, and the nett effect will be approximately equal scour at each leg, with the potential for cumulative scour if the legs are closer together than the diameters of each individual scour hole. In order to reduce concerns over stability and structural fatigue it is likely that scour protection will be specified for multi-leg foundations.

Scour under all cables should be anticipated during design. Burial will reduce any potential problems, with the added benefit of protection from anchors and fishing gear. The depth of burial required will vary, but should be sufficient to reduce the likelihood of future re-exposure. There is potential for interactions with cables from other sites, depending on the method of any crossings, separation distance and the length of time between cable lay operations. It is assumed that the Barrow cables will be laid in 2005, allowing an opportunity to review any issues arising and to route the Ormonde cable accordingly.

Cabling across Heysham Sands to the landfall at Heysham will require burial. As the area dries at low tide, and is open to the public, it is important that future cable exposure does not occur. The area is generally considered stable, but is subject to localised change due to the movement of intertidal drainage channels and potential erosion of the edge of Heysham channel during severe wave conditions. Disturbance of the foreshore during burial may result in drainage channels shifting to follow the cable route until the sediment cover stabilises. Given these factors a burial depth of at least 2m is recommended.

Across Heysham Lake and along Clark Wharf Bank, future exposure could result from large scale, long term, changes in the channel morphology as well as from smaller scale movement of sand waves or the effects of localised scour. A cable depth of at least 2.5m is recommended to minimise the risk of exposure within the troughs of sand waves. Backfilling should not be required as natural infill should occur rapidly. In the area of Clark Wharf Bank there is potential for depth changes of up to 10m if the steep sided Heysham Channel shifts laterally. Ongoing monitoring is recommended to ensure that the cable is not exposed, and a management programme needs to be in place to rebury the cable in the event of exposure.

Across Morecambe Flats the cable should be trenched to avoid exposure due to long term scour. It is assumed that a depth of 1m will be sufficient to avoid exposure within the design life of the wind farm. If backfilling is required across the firm tillite beds, this will require placement of imported coarse material as natural infill will be minimal.

Within the wind farm site scour should be expected. It is recommended that the cable be buried to a depth of about 1m. Backfilling should occur naturally except at the interface with the turbines where scour protection may be needed.

Following construction of the turbines and placement of the cables there will be a need for ongoing monitoring to ensure that scour depths or cable exposure do not exceed the design limits.

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Figures

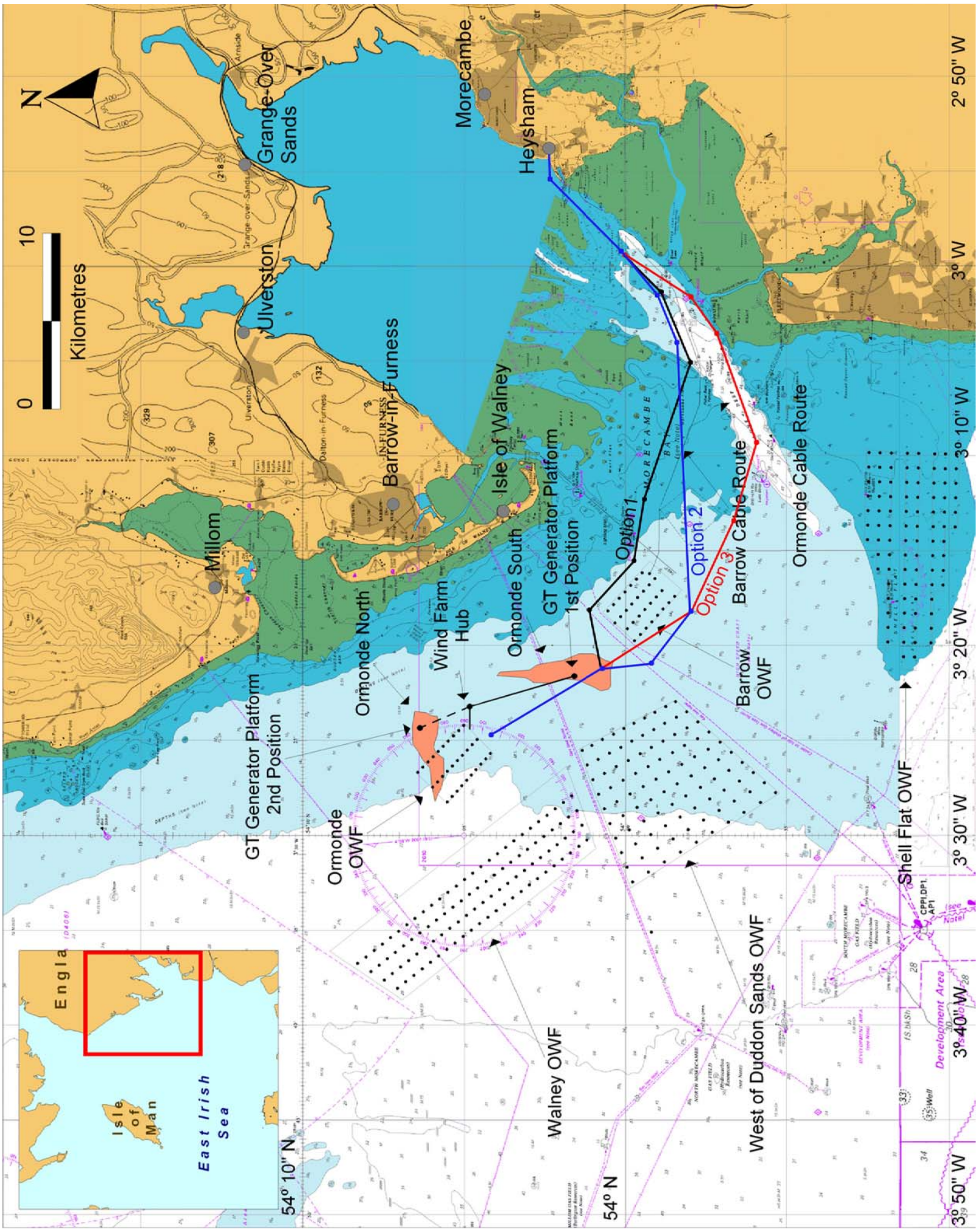

Figure 1 Location map

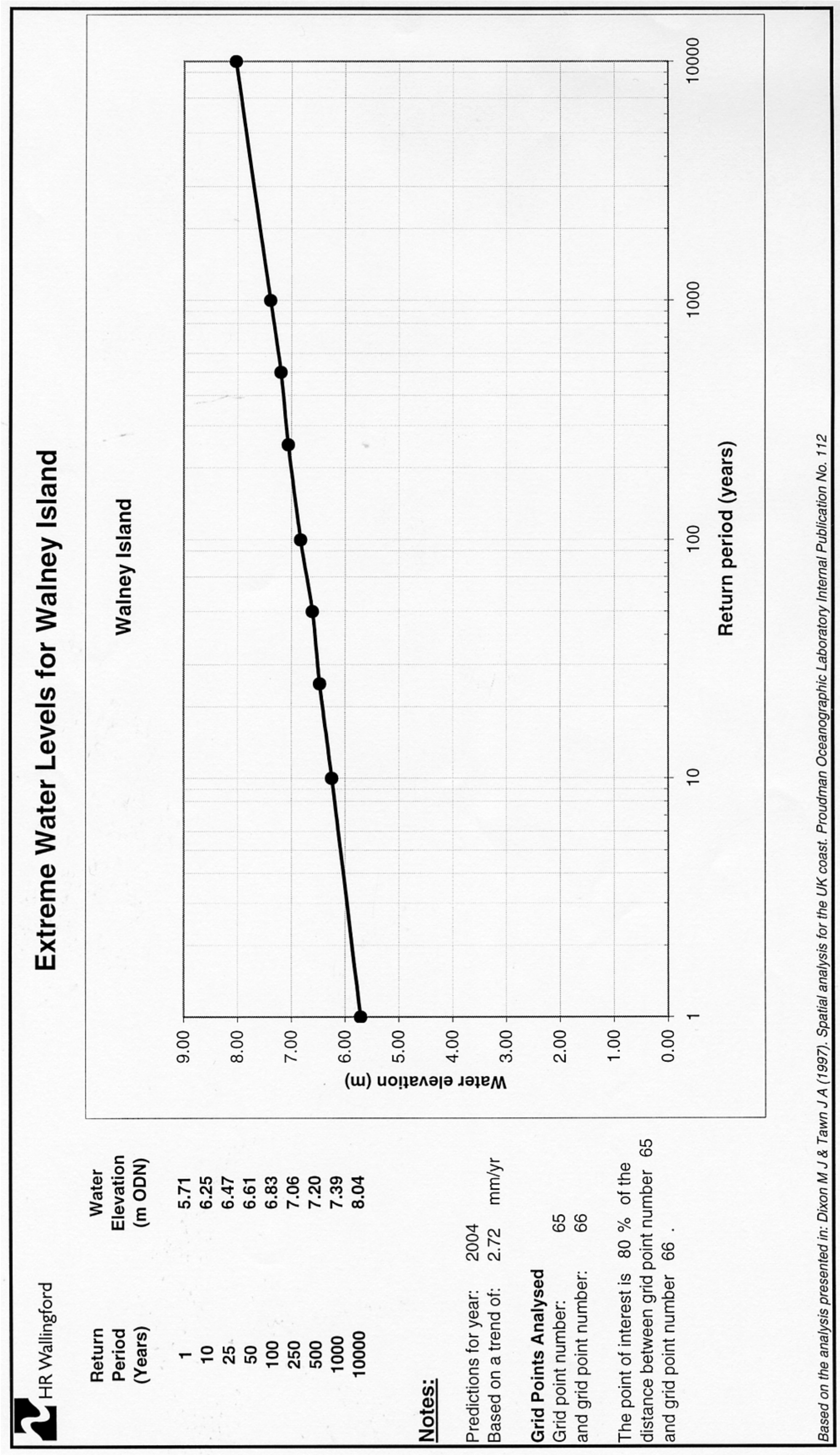

Figure 2 Extreme water levels for Walney Island

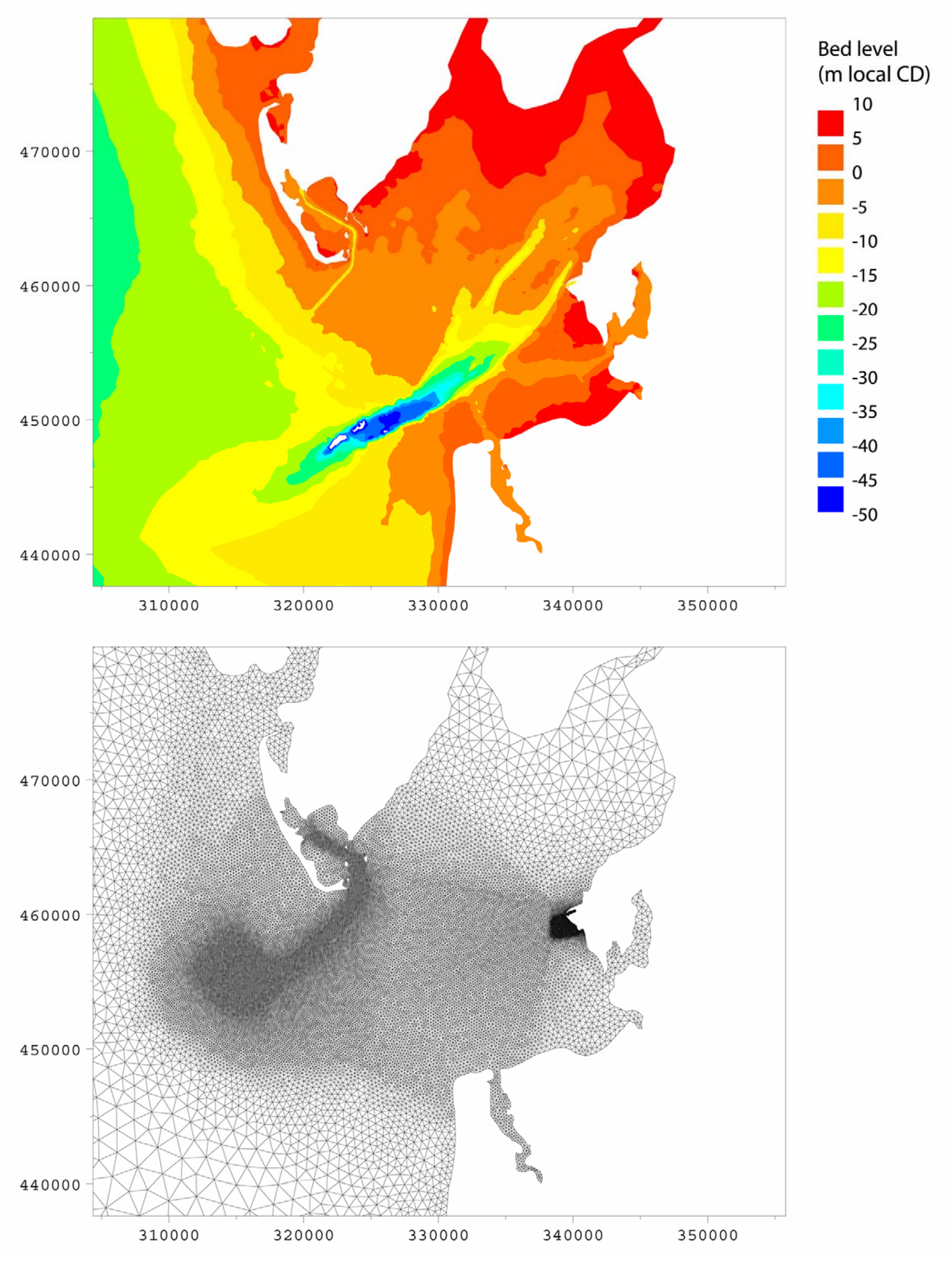

Figure 3 Flow model bathymetry and grid (Reference 4)

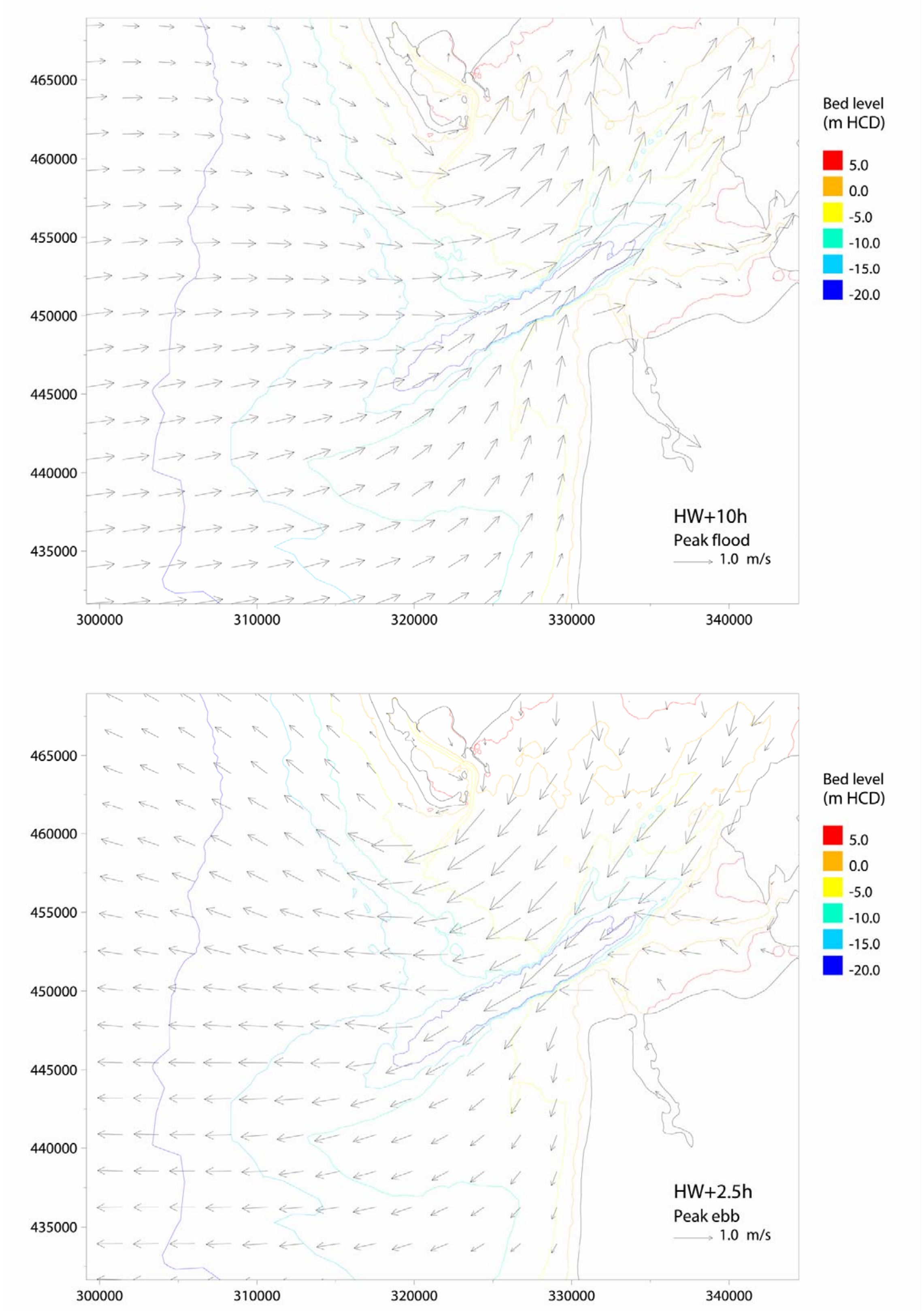

Figure 4 **Peak flood and ebb flow vectors under mean spring tide conditions (Reference 4)**

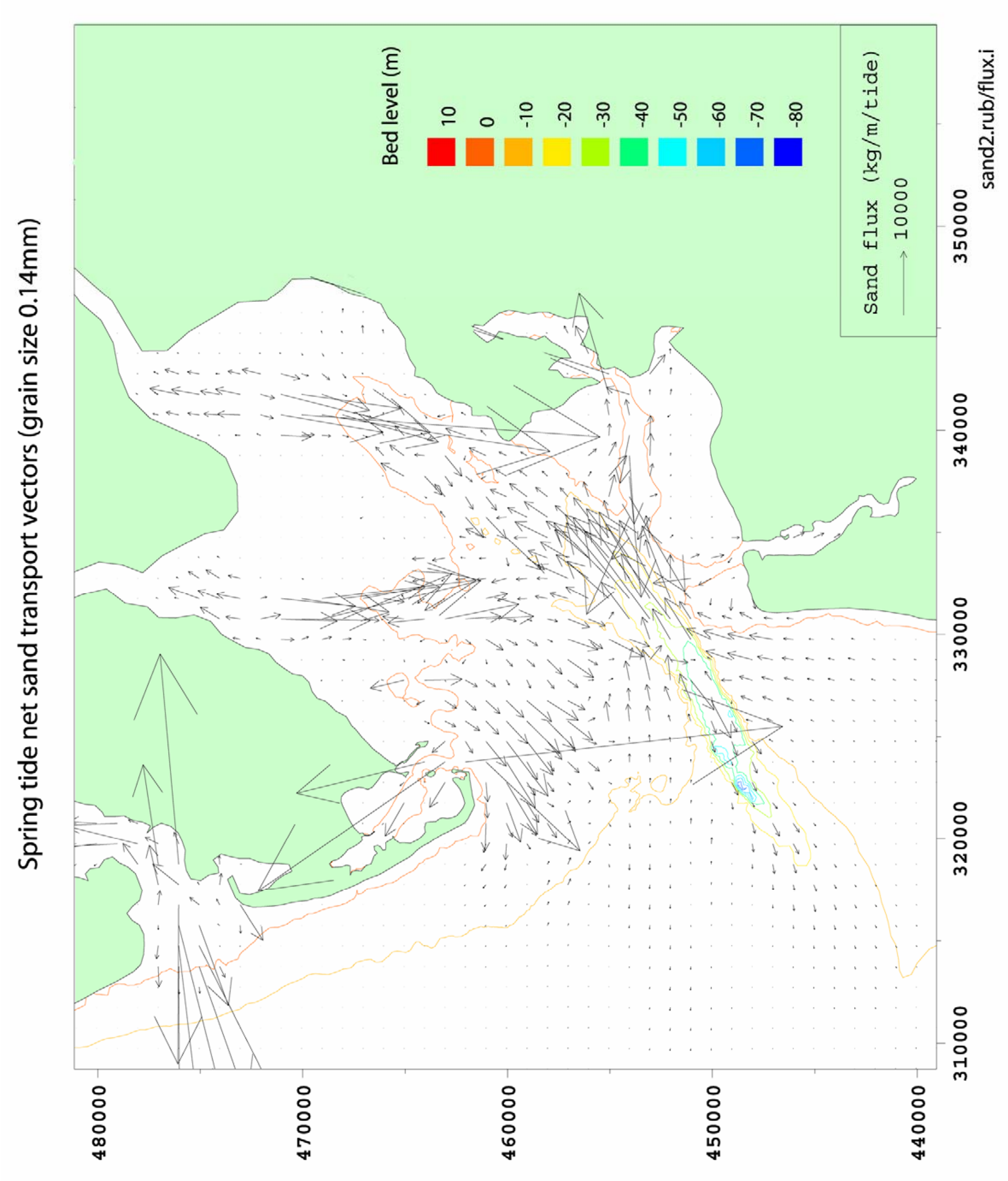

Figure 5 **Nett potential sediment flux for fine sand under mean spring tide conditions (Reference 4)**

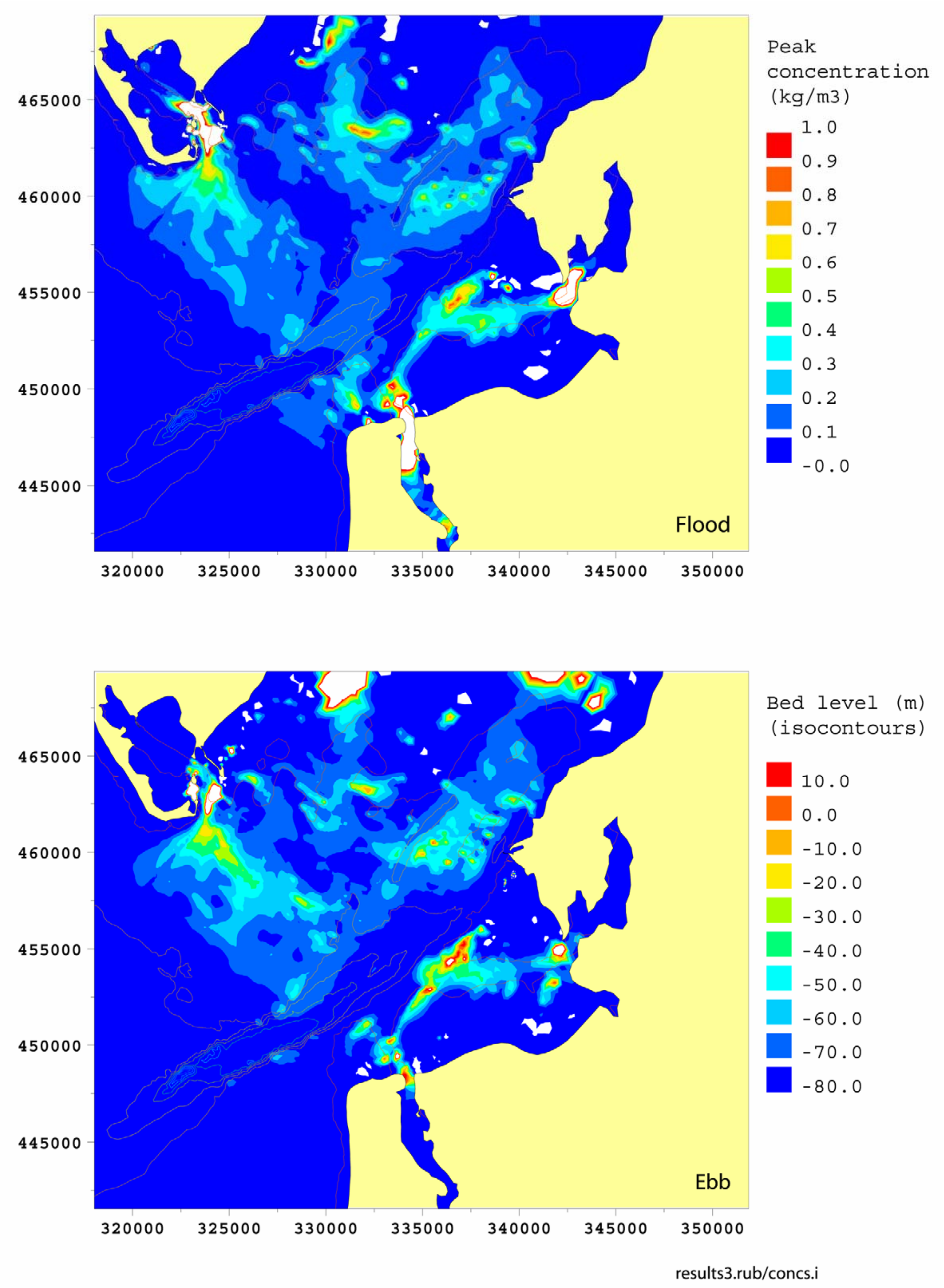

Figure 6 **Distribution of potential suspended sediment concentrations under peak flood and ebb tide conditions (Reference 4)**

Plates

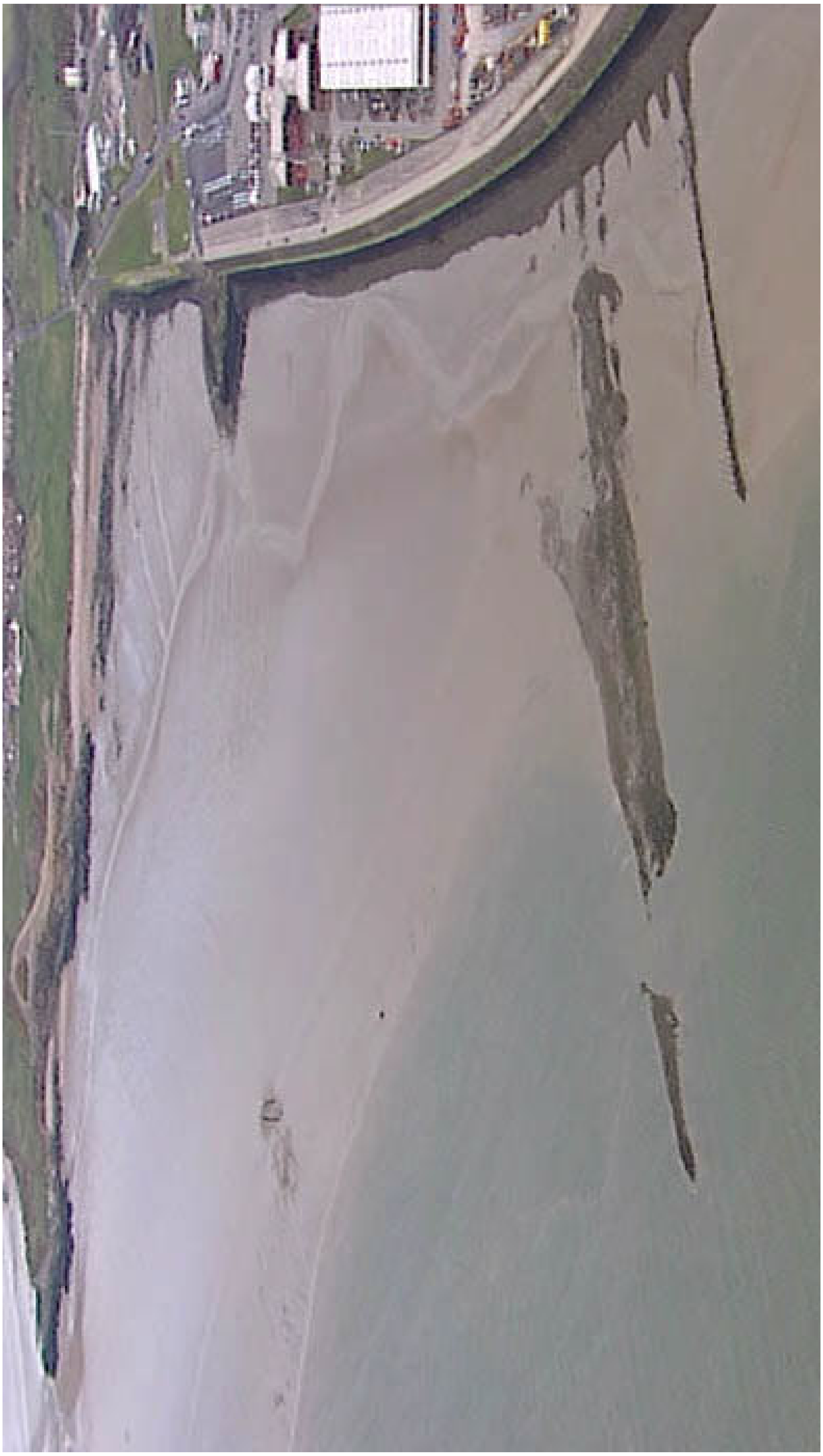

Plate 1 Cable landfall location: Half Moon Bay, Heysham