5 The existing physical environment

This chapter of the Environmental Statement describes the existing physical environment, considering both the far-field environment of the Irish Sea and Liverpool Bay and the near-field environment in the vicinity of the Gwynt y Môr project area. This provides the baseline information for both the definition and evaluation of the proposed Gwynt y Môr Offshore Wind Farm in the context of the wider environment. Specifically, this chapter describes the baseline situation with regard to:

- oceanography
- sediment transport
- sediment quality
- surface and sub-surface geology
- water quality

The need to describe the physical environment is drawn from guidance provided in relation to offshore wind farm development (e.g. CEFAS, 2004) and in response to the extensive and detailed scoping process completed for the Gwynt y Môr project.

5.1 Oceanography of the Irish Sea

Principally, water is moved by the action of tides, winds and differences in density between adjacent water masses (Bowden, 1980). The twice daily flooding and ebbing of the tides provides the most obvious movement of water. However, the strength of the tidal currents varies across the region and this determines many of the processes and distributions within the sea (mixing, fronts, sediment transport, sediment distribution and indirectly, elements of the long period density-driven circulation) (Defra, 2000).

In general terms the overall water movement within the Irish Sea is from south to north. Oceanic water from the north Atlantic enters from the south and west of the region and moves northwards through the area, to exit into Arctic waters to the north or, after flowing around the north of Scotland, to enter the Greater North Sea. There are however, complex intermediate water movements, particularly within the Irish Sea (OSPAR, 2003).

A large number of studies were undertaken between 1950 and 1980 to look at circulation within Liverpool Bay and the Irish Sea. The use of seabed drifters showed easterly to south-easterly movement onto the coasts of Lancashire, Cheshire and North Wales. The movement has been shown to be due to an onshore density flow brought about by horizontal gradients of salinity and temperature normal to the coast. For Liverpool Bay this characteristic density distribution gives rise to horizontal currents directed across the density gradient towards the coast at the seabed, turning to the left as their height above the bed increases. Therefore, rotation through depth and currents at the surface are inclined at an obtuse angle to those at the bottom (Heaps, 1972).

5.1.1 Frontal systems in the Irish Sea

An oceanographic front is the area bounding two distinct water masses with different densities. The density differences may result due to changes in either salinity or temperature. A characteristic feature of Regions of Freshwater Influence (ROFI) systems is the occurrence of a marked semi-diurnal oscillation in stability of the water column. The amplitude of these oscillations in some cases is comparable to the mean stability so that the water column approaches, or even attains, complete vertical homogeneity once during each tidal cycle.

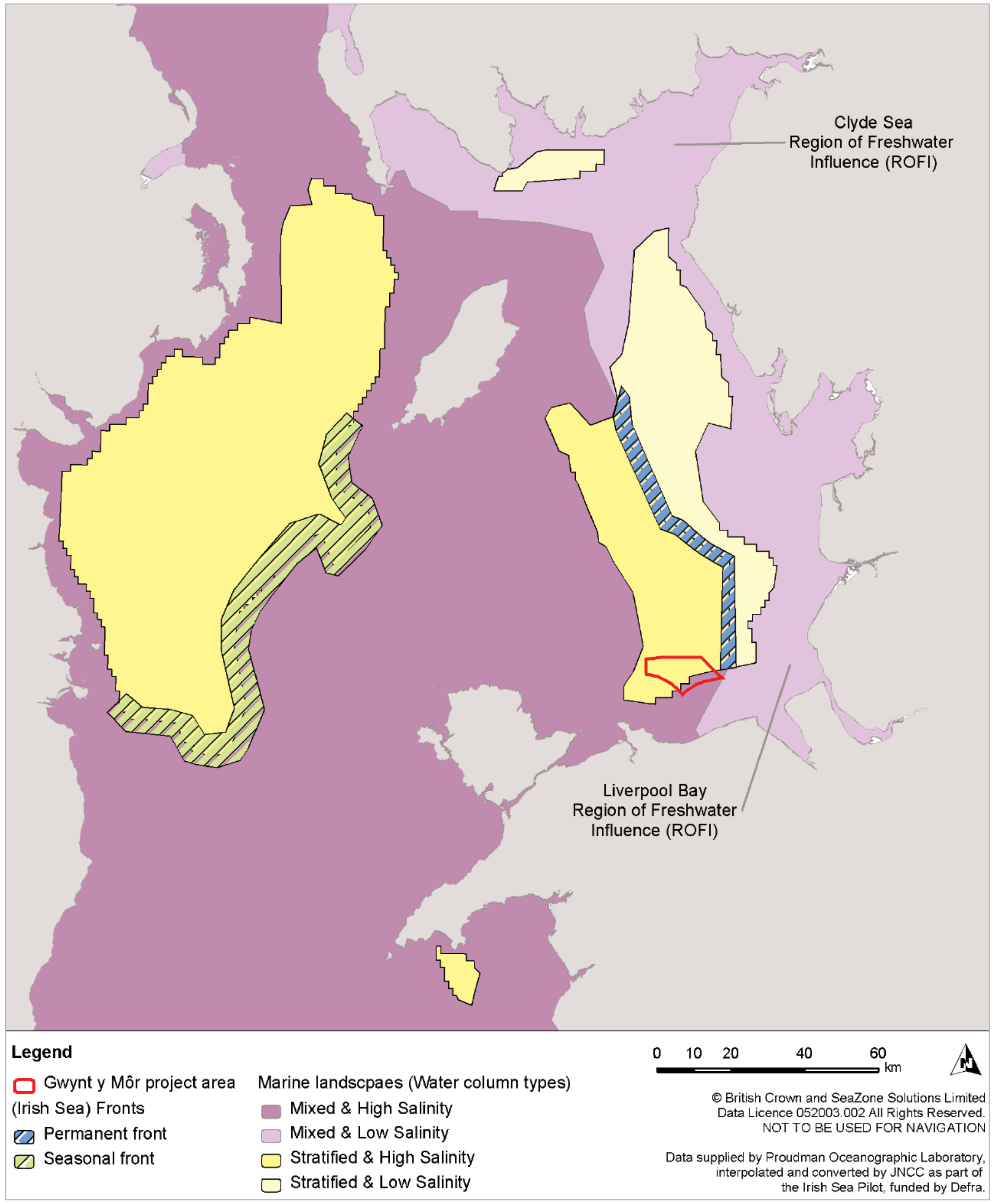

Figure 5.1 Water column marine landscapes and Irish Sea fronts (Source: JNCC (2003))

The Irish Sea is a semi-enclosed sea opening to the Celtic Sea at St. Georges Channel, and connected to the Malin shelf through the narrow North Channel. It receives freshwater run-off from a large area of land compared to the relatively small sea area and is generally shallow, apart from the North Channel.

The strong influence of tidal flows, with correspondingly intense tidally generated turbulence and mixing, results in a partitioning of the Celtic Sea environment as a function of water depth and tidal current amplitude. Away from sources of freshwater, the seasonal behaviour of water column structure is controlled by a simple competition between the rate of surface heating/cooling and the strength of the tidal currents. The relatively deep, lower tidal energy environment of the south west Celtic Sea becomes thermally stratified during summer, while the shallower, tidally-energetic region of the Irish Sea remains vertically mixed throughout the year. These permanently-mixed and seasonally-stratified regimes are separated by the shelf sea tidal mixing fronts, which vary in structure and position on both seasonal and spring-neap timescales. Water column structure at the Malin and Celtic Sea shelf edges is significantly affected by strong mixing associated with internal tidal wave dissipation.

The influence of freshwater input on circulation in the Irish Sea is relatively small and is limited to two areas with significant coastal currents and haline stratification; Liverpool Bay and the Clyde Sea. The Clyde Sea Region of Freshwater Influence (ROFI) is more likely to retain its stratification throughout the year than the Liverpool Bay ROFI although stable stratification can occur in Liverpool Bay in the winter months (POL, 2005). This phenomenon is shown in Figure 5.1.

5.1.2 Bathymetry

Analysis of Admiralty Chart 1953, Approaches to the River Dee, shows that water depths (below Chart Datum) in the outer part of Liverpool Bay can exceed 40 m. Around the Gwynt y Môr project area, water depths range from approximately 15 m to 35 m below Chart Datum, with a mean of 26 m.

The site specific bathymetric surveys undertaken for Gwynt y Môr are consistent with the broad patterns described by the Admiralty data (allowing for small local variations) and confirm the minimum depth of approximately 15 m (below Chart Datum) observed in the south east and east of the area, deepening towards the west and north west to a maximum depth of approximately 35 m (below Chart Datum).

Based on the nearest available site for predictions (Hilbre Island), mean water level is defined by the mean tide level applying (0.22 m above Ordnance Datum), with an Ordnance Datum to Chart Datum conversion of +4.93 m.

A qualitative review of historical charts across Liverpool Bay together with the recent results of the geophysical survey (Osiris, 2004) indicated that there have been no significant changes in bathymetry within the Gwynt y Môr project area between 1873 and 2004. During that period of time it is concluded that the area has been stable.

5.1.3 Water elevations in Liverpool Bay

The pattern of tidal elevations across Liverpool Bay amplifies in range from east to west. Over the scale of the Gwynt y Môr project area the range in water levels needs to be considered as a variable. Hilbre Island is sufficient to provide characterisation of the eastern limit of the project whilst Llandudno provides data more representative of the western limit, as summarised in Table 5.1.

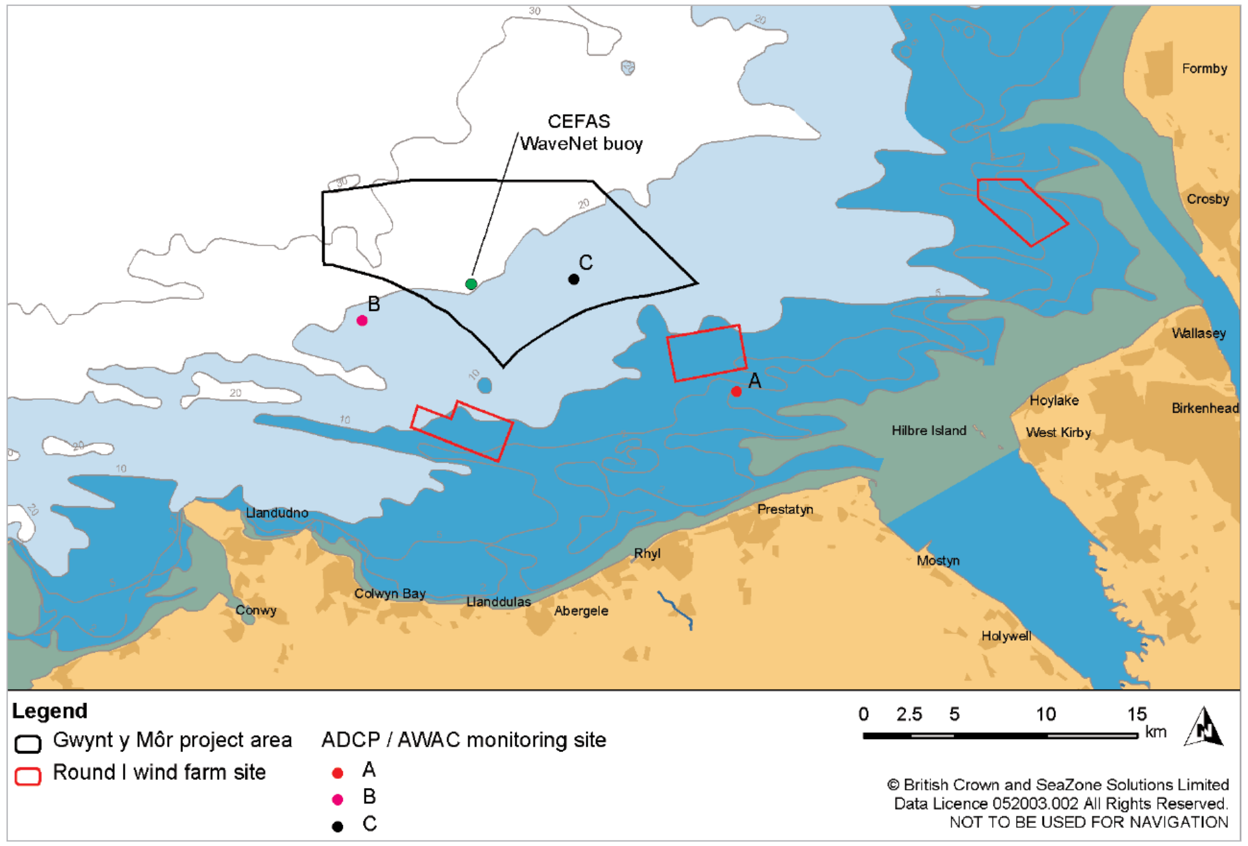

Figure 5.2 Nearshore ADCP/AWAC monitoring sites

Tidal level	Hilbre Island (53° 20'N, 3°50'W)	Llandudno (53° 23'N, 3°13'W)
Mean high water spring	9.0 m	7.6 m
Mean high water neap	7.2 m	6.0 m
Mean tide level	5.15 m	4.10 m
Mean low water neap	3.1 m	2.2 m
Mean low water spring	1.3 m	0.6 m
(Predicted heights are in metres above Chart Datum, 4.93 m)		

Table 5.1 Summary tidal data for Hilbre Island and Llandudno (Source: UKHO, 2004)

Given the absence of definitive water elevation data between Hilbre Island and Llandudno (within the Gwynt y Môr project area co-range line values vary from 8 m at Liverpool to 6 m at Cemaes Bay (UKHO, 1971)), additional data, within and in the near vicinity of the Gwynt y Môr project area, have been collected. Three ADCP/AWAC (Acoustic Doppler Current Profiler/Acoustic Wave and Current) meters were deployed at the locations shown in Figure 5.2 over the period 4th February 2005 to 13th March 2005 to simultaneously collect water level, current speed and direction, and wave data. This data has enabled a more accurate representation of water elevations across the project area to be determined.

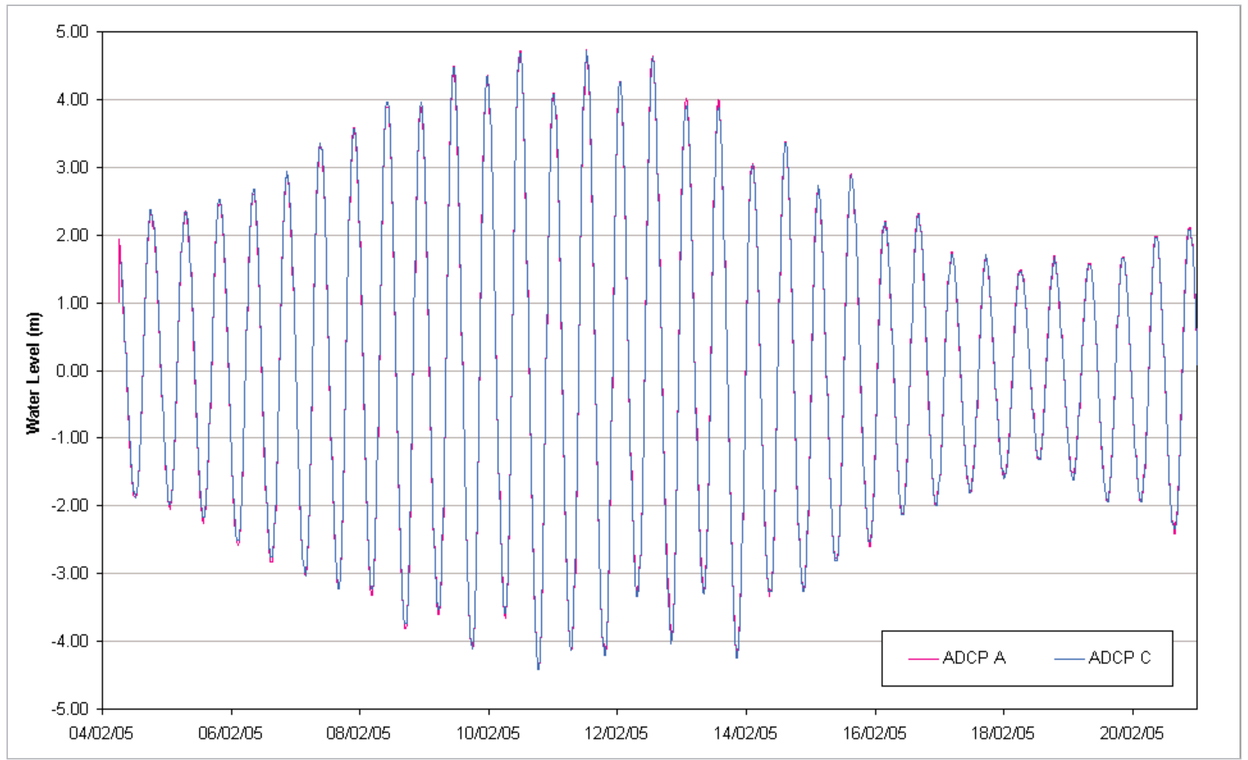

Figure 5.3 Variation in water level at ADCP sites A and C over a spring-neap cycle

Site observations illustrate the combined effect of tidal and non-tidal influences on water level variations (non-tidal influences may include, for example, storm surges or atmospheric pressure). The available data confirms that the project area is characterised by a strong semi-diurnal tide. Figure 5.3 presents an extract of water level observations taken at deployment sites A and C. The data indicates that within the project area (deployment site C) the maximum tidal range is of the order of 8.5 m, although water elevation in the area during the instrument deployments was as great as 9.1 m, which was taken to be the result of non-tidal influences.

5.1.4 Tidal currents

In Liverpool Bay the maximum tidal flows, both on the ebb and flood are on a west to east axis and currents are strongly rectilinear. The maximum flood currents are greater than the maximum ebb currents because the tidal rise time on the flood is shorter than the time of fall on the ebb. The inshore tidal streams are parallel to the north Wales coast with maximum current speeds ranging between 0.75 and 1.0 m/s on mean springs. Values on neap tides are typically 50% of those recorded during spring tides. For the majority of the flood tide, currents flow in a predominantly easterly direction, with peak current speeds on a mean spring tide of 0.7 m/s, and on a mean neap tide of 0.4 m/s. For the majority of the ebb tide, currents are predominantly westerly, with peak current speeds on a mean spring tide of 0.7 m/s, and on a mean neap tide of 0.4 m/s.

Figures 5.4 and 5.5 present details of the ADCP measurements at positions A and C. The flow results are presented as depth-averaged values and provide a measure of the variation in flow speeds across the study area. Figure 5.4 shows the flood dominance in the tidal signature, which is particularly noticeable over the spring tides. Figure 5.5 shows the same flood dominance as recorded at site A but also significantly higher flow rates.

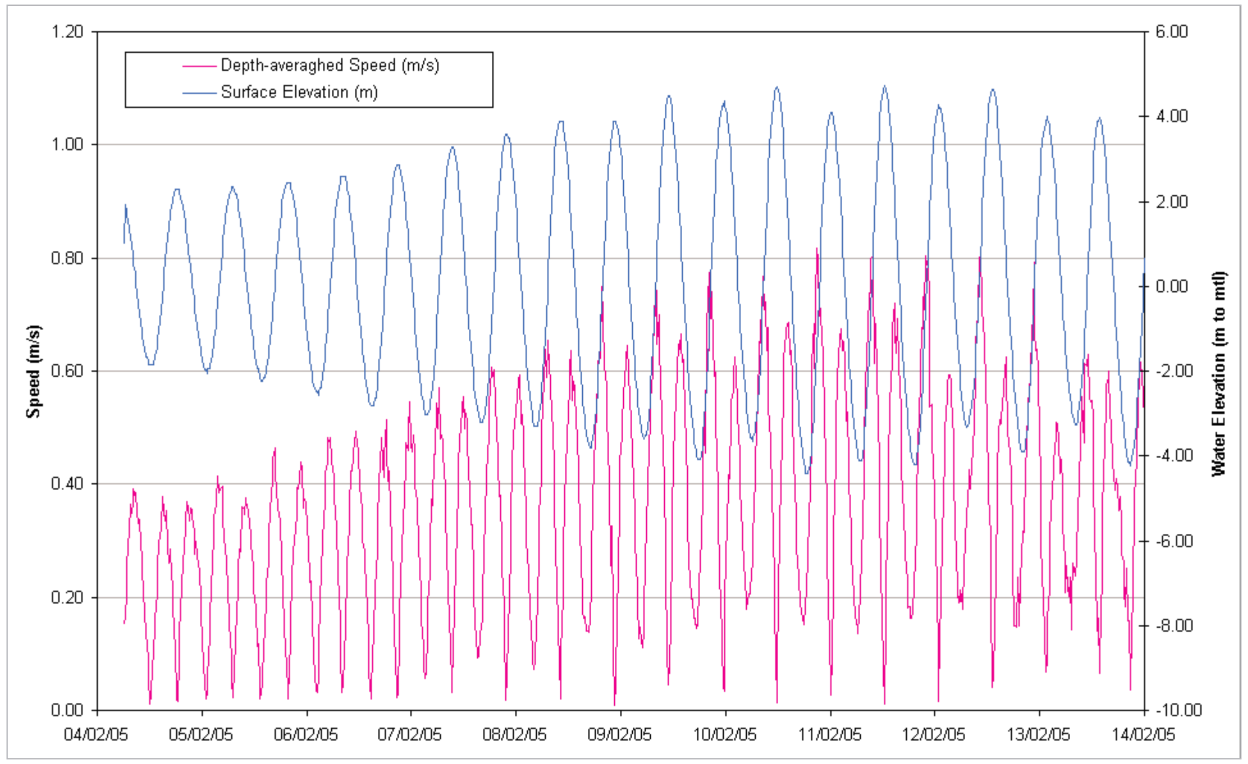

Figure 5.4 Current speed and water elevation at nearshore data site A

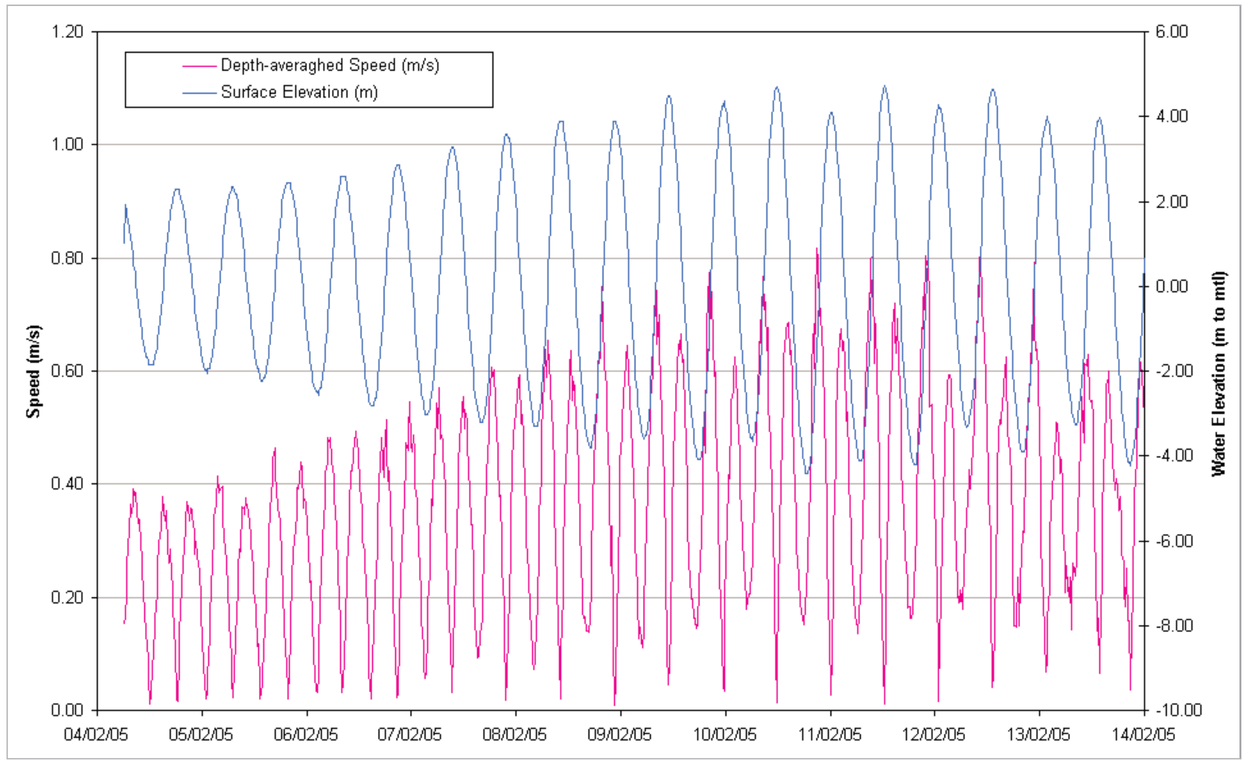

Figure 5.5 Current speed at nearshore data site C

5.1.5 The prevailing wind climate

Wind is the fundamental driving force for locally generated sea waves in Liverpool Bay. Significant changes in wind patterns within the Irish Sea affect the overall wave climate generated. The following data serve to summarise the wind climate in Liverpool Bay:

- the predominant wind direction is from the west, with approximately 70% of wind occurring from the SE to NW sectors
- the most frequent wind strength is 5–10 m/s (Beaufort Force 3 to 5)
- the most extreme wind conditions (wind speed greater than 20 m/s, Beaufort Force 8) are most frequent from the west. These high winds occur for some 0.75% of the time, typically about 65 hrs/year.

5.1.6 Wave climate

The wave climate is the result of the transfer of wind energy to the sea, creating sea-states and the propagation of that energy across the water surface by wave motion. The amount of wind energy transfer and wind-wave development is a function of the available fetch distance across which the wind blows, wind speed, wind duration and the original state of the sea. The longer the fetch distance, the greater the potential there is for the wind to interact with the water surface and generate waves. In shallower water, water depth is an additional limiting factor on the size of waves.

The wave regime in Liverpool Bay can be regarded as the combination of waves moving into the area (having been generated remotely from the area) and locally generated wind-waves. The Gwynt y Môr project area is open to north-westerly offshore waves that are generated within the Irish Sea. Locally generated waves related to the prevailing winds come from westerly, north-westerly and northern sectors.

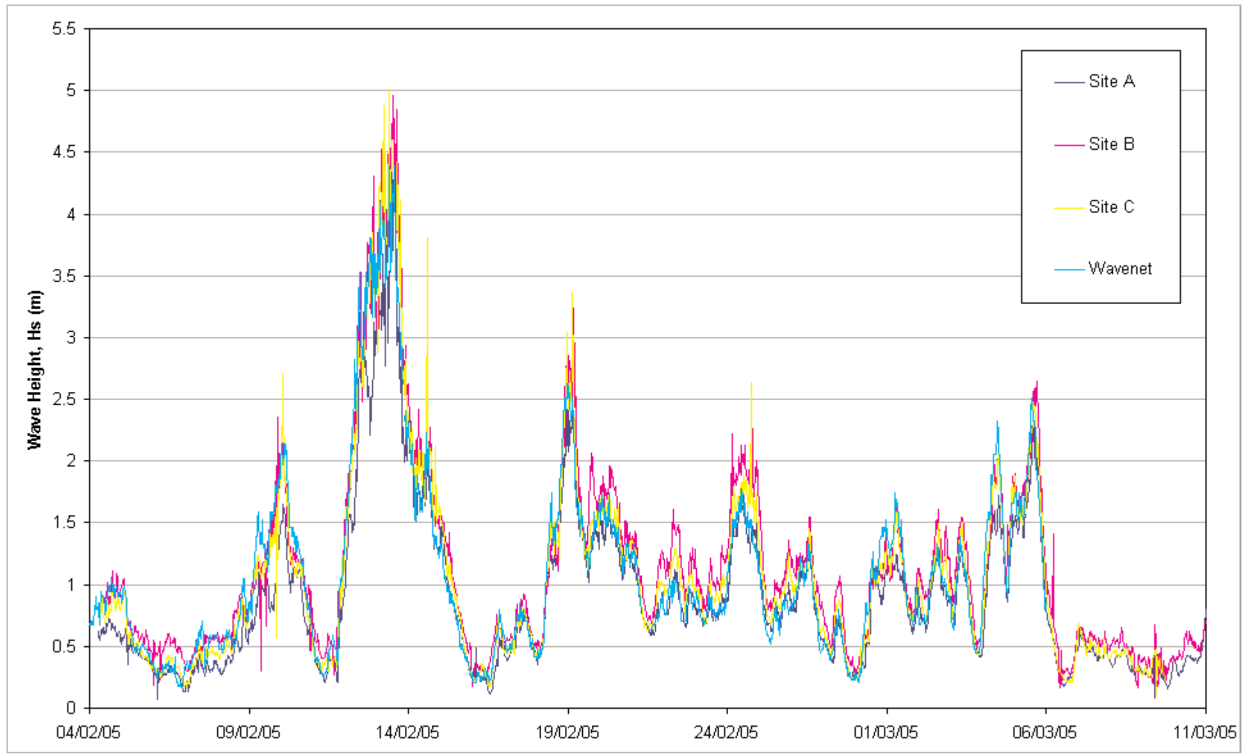

Figure 5.6 Time series of recorded wave heights at deployment sites A, B and C

Available wave information has been collated to characterise the local wave regime (both offshore and nearshore). The available data includes the key sources summarised in Table 5.2, below.

Variable	Key data source
Offshore waves	Liverpool Bay directional waverider buoy from the CEFAS WaveNet site for the period 13th November 2002 to date: 53° 32'.14N, 03° 21'.36W
Nearshore waves	Directional wave information from 3 AWAC devices located in proximity to the proposed Gwynt y Môr Offshore Wind Farm project area: 53°24.30'N, 03°25.30'W – Device A (4 February – 13 March 2005) 53°25.75'N, 03°43.41'W – Device B (4 February – 13 March 2005) 53°27.16'N, 03°33.39'W – Device C (4 February – 13 March 2005)
Local winds	Meteorological mast located on Hilbre Island 53° 23' N, 3° 14' W (11 December 2004–21 February 2005)

Table 5.2 Key date sources for wave regime characterisation

Figure 5.6 presents a time series of measured wave heights from the three deployment sites. It is evident that the peak wave activity occurred early in the record, with a peak significant wave height of 4.96 m reported at site A. The time series shows several significant events with wave heights exceeding 2.5 m.

A long-term wave measurement site is also available in Liverpool Bay as part of the WaveNet coastal monitoring network initiated by Defra. Data from this site is available from 13 November 2002 to present, although there are a number of data gaps during this period. The device is deployed around 15 km north east of Gwynt y Môr and in a water depth of around 22 m (Chart Datum).

Within the measurement period, which has been analysed from the WaveNet instrument (approximately 24 months of data returns over a 2.5 year period), a maximum local significant wave height of 5.43 m, and wave period (Tz) of 8.05 s was recorded on 8th February 2004, co-incident with the significant wave event recorded by the instruments deployed at the Gwynt y Môr monitoring sites and presented in Figure 5.6. Table 5.3 summarises the non-exceedance wave parameters for this dataset.

Non-exceedance (%)	Wave height (Hs, m)	Wave period (Tz, s)
99	3.40	6.2
95	2.51	5.5
90	2.05	4.5
75	1.33	3.6
50	0.76	3.3
25	0.45	2.8

Table 5.3 Summary of non-directional wave climate parameters from WaveNet

Within the limited data period it is suggested that the peak event noted above has a lower return period than one in one year. An approximation of a one in one year value for WaveNet is Hs = 4.39 m, Tz = 6.54 (i.e. this was the largest event recorded in 2003, equalled in 2004 and exceeded once, and again equalled and exceeded once to date in 2005). It is therefore considered that the peak wave event recorded on 13th February 2005 (and represented in Figure 5.6) approximates to a one in one year event.

To determine the predominant wave direction of these events in the context of a larger timescale, Figure 5.7 illustrates data from the Liverpool WaveNet buoy. Between 13th November 2002 and 10th February

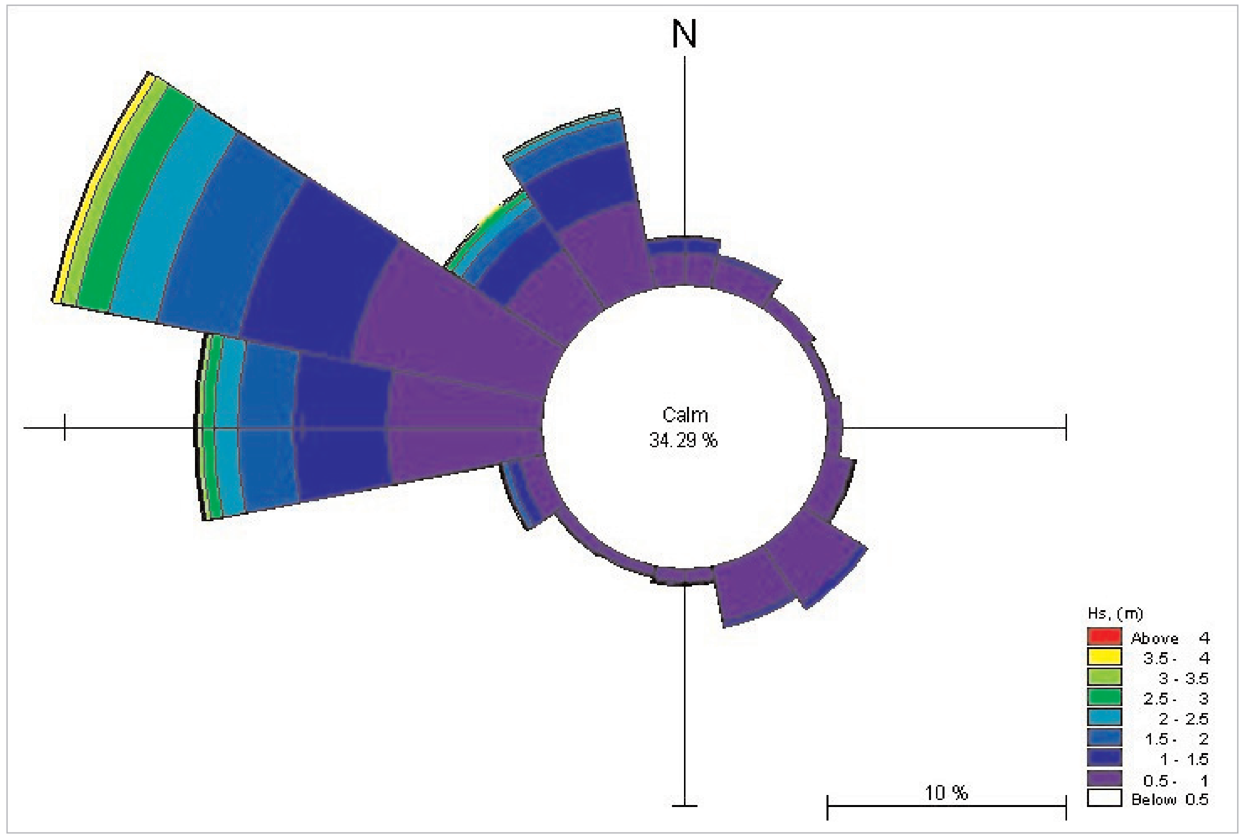

Figure 5.7 Wave rose from the Liverpool Bay WaveNet buoy (13/11/02–10/02/05)

2005 a significant wave height (Hs) above 4 m is observed over less than one percent of the measurement period. This indicates that the event recorded between the 12th and 18th February 2005 at the Gwynt y Môr AWAC deployment sites is a significant event.

5.2 Surface and sub-surface geology

The following sections describe the surface and sub-surface geology of the Irish Sea and Liverpool Bay area and review the findings of the geological investigations completed at Gwynt y Môr.

5.2.1 Geology of the Irish Sea

The solid geology of the Irish Sea broadly divides along a line from the Mull of Galloway through the Isle of Man to Anglesey. To the east a number of basins are present, the largest of which is the eastern Irish Sea Basin. At least three major Permo-Triassic and younger sedimentary basins have developed in this area. The first developed during the early Palaeozoic, the second during the Carboniferous and the last during the Permian and Mesozoic.

All three main phases of sedimentation are represented in the Liverpool Bay area, capped by a thin cover of Pleistocene and Holocene material. The first beds laid down in the basin were Ordovician and Silurian in age. Caledonian crustal movements folded, dislocated and compressed these early Palaeozoic rocks before the overlying discordant Carboniferous rocks were deposited. Later, Variscan crustal movements tilted and dislocated both the Lower Palaeozoic and Carboniferous rocks. The youngest unit of rocks, the Permo-Triassic sedimentary sequence, was then deposited discordantly on the eroded Carboniferous.

5.2.2 Late Quaternary history of the Liverpool Bay region

The seabed of the Liverpool Bay region possesses a sedimentary record of environmental change brought about through a combination of marked climate change, vertical movements of relative sea level and consequent spatial shifts in shoreline location.

The cold temperatures of the last glacial period (the Devensian) not only brought about the advance of ice sheets over the region, but also a global fall in sea level (eustatic change) of the order of 120 m. However, the Irish Sea region also experienced considerable depression of the earth's crust as a result of loading by ice sheets; a process known as glacioisostatic subsidence.

The interaction of eustatic sea level change and glacioisostatic crustal movement has determined the record of relative sea level change during the late Quaternary, and sediments deposited under the influence of a retreating ice mass have been reworked by the advancing surf at least once during the postglacial period.

The seabed of the eastern Irish Sea is predominantly sandy with varying proportions of mud, gravel and pebble/cobble content (BGS, 1995). Much of the southern part of the region is 'armoured' with a bed of coarse gravels and gravelly sands that have remained after the fine grain sizes had been winnowed from exposed fluvioglacial and glaciomarine deposits by the advancing surf. However, whilst eustatic sea level was rising due to climatic warming and ice melt, the earth's crust also experienced crustal rebound as a consequence of unloading.

Lambeck (1991) suggested that the Liverpool Bay region experienced high relative sea levels about 16,000 years BP (Before Present), followed by a falling trend until about 12,000 years BP. During this period, crustal uplift occurred at a greater rate than eustatic sea-level rise. From about 12,000 to 7,000 years BP, relative sea level rose as a result of declining glacioisostatic rebound and enhanced rates of eustatic sea level rise driven by rapid ice melt. Consequently, the seabed, which may well have experienced marine inundation prior to 16,000 years BP, was once again affected by sediment processing under the influence of waves as the surf rose in accordance with rising relative sea level during the early to mid Holocene.

Hence, the seabed sediments of Liverpool Bay not only reflect the nature of their initial depositional environment during the Devensian, but also the overprinting by one, if not two, periods of shallow water wave and nearshore tidal processes.

5.2.3 Seabed features in Liverpool Bay

Liverpool Bay is characterised by three main seabed formations:

- sand ribbons and patches with mega-ripple relief of less than 0.3 m
- sand wave fields, the sand waves having amplitudes of around 2 m and wavelengths of between 10 and 20 m
- individual sand waves with amplitudes of up to 12 m and often carrying minor transverse waves.

The seabed features and corresponding sediment dynamics are represented in Figure 5.8.

A number of bank features are present within the general Liverpool Bay region. Apart from small banner banks tied to the headlands of Anglesey, there are many banks in the wide embayment of the approaches to the Mersey Estuary and others filling a large proportion of the many wide-mouthed estuaries.

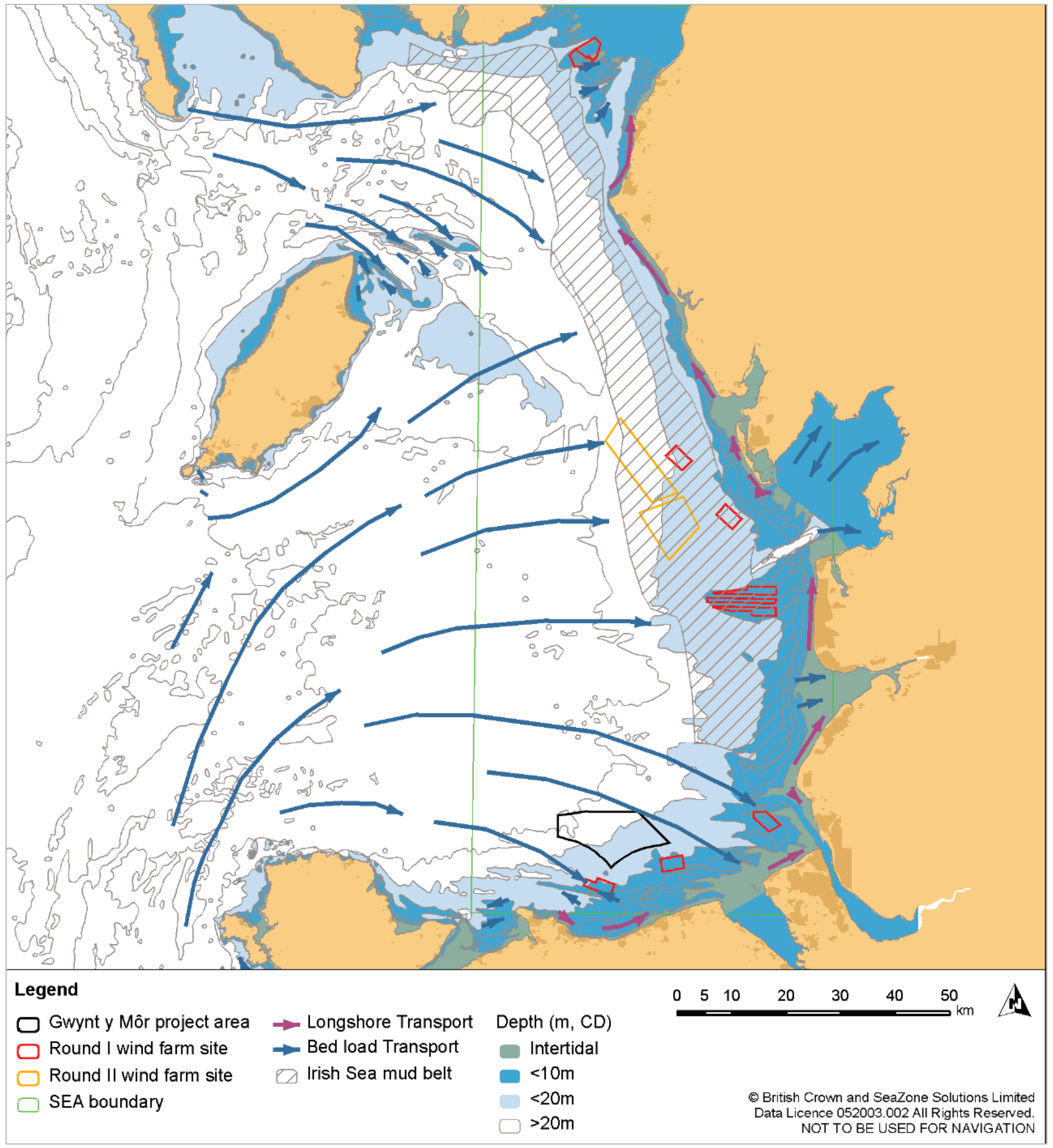

Figure 5.8 Sediment transport within the north west strategic environmental assessment area (Kenyon & Cooper, 2005)

Little is known about the banks in the southern approaches to the Dee and Mersey Estuaries. Unlike banner banks they do not have a gap at the coast and some in the south are unusual in being without steep sides and not being near to sea level, although the long Constable Bank is steeper to the south. It is possible that they are banks formed at lower sea level that are now being reworked rather than maintained by active bank building processes. The inner banks are typical of the wide banks of estuary mouths and have moved dramatically since long retaining walls were placed at the entrance to the channel leading into the Mersey between 1901 and the 1930s.

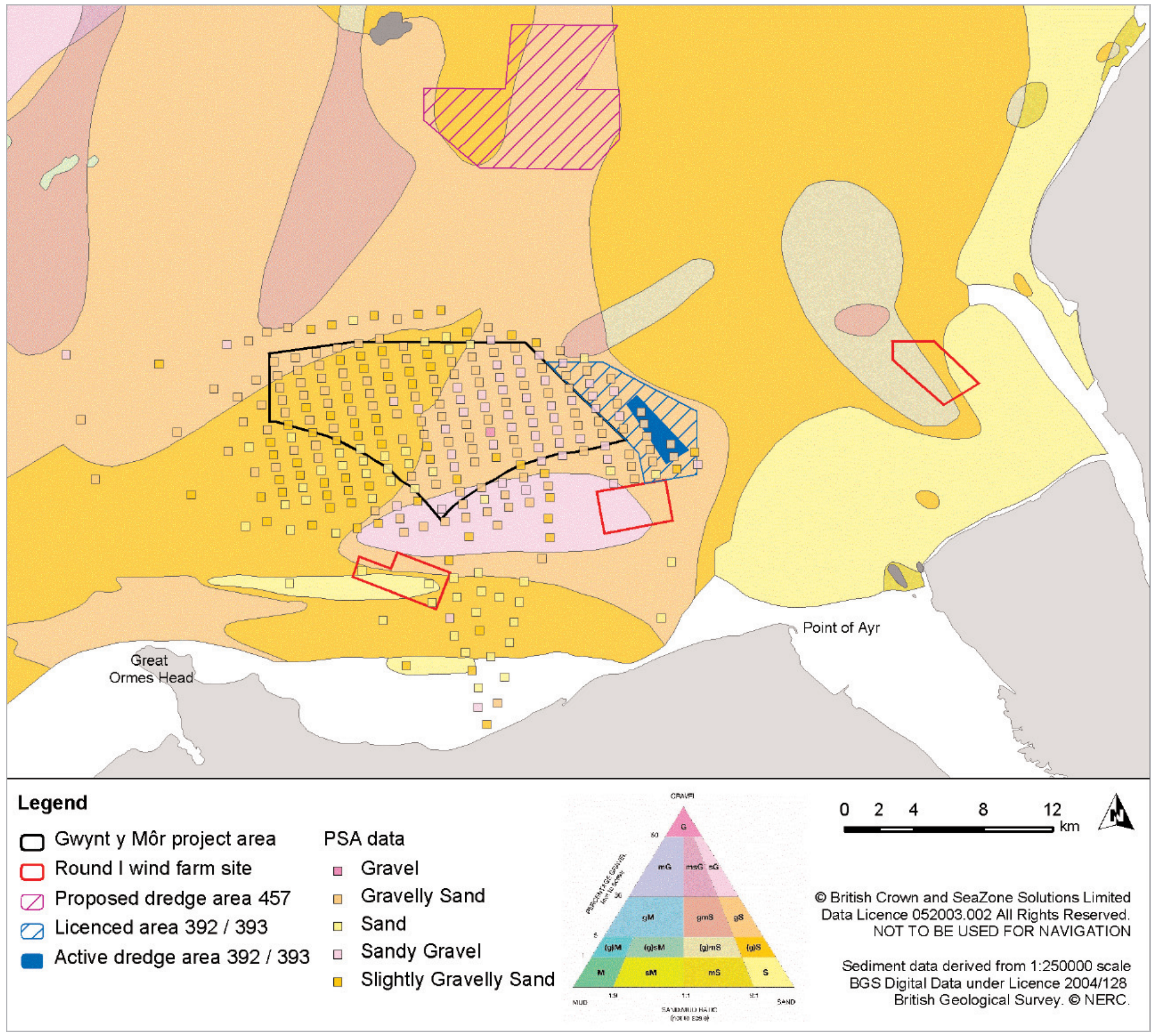

Figure 5.9 Gwynt y Môr site-specific particle size data overlain on the BGS sediment composition classification (RWE npower, 2005)

5.2.4 Sedimentary composition of the Gwynt y Môr project area

The British Geological Survey of Liverpool Bay shows that the seabed within the vicinity of the project area consists of either sandy gravel or gravely sand (see Figure 5.9). Within the western half of the project area a mixture of slightly gravelly sands and gravelly sand was identified. Further to the east the percentage of gravel increases; within this section of the project area sandy gravel predominates. Within the main export cable route corridor sand is the abundant sediment type identified.

The seabed is relatively free of fines (defined as particles of less than 0.063 mm), with waves generally preventing the deposition of mud or silt, whilst tidal currents prevent the deposition of mud further offshore within Liverpool Bay.

From the available data, the mean particle size of sand in the outer parts of Liverpool Bay is as large as 0.42 mm, equivalent to medium to coarse sand. In general, the median sand size decreases further inshore, this being indicative of a net shoreward transport of the finer fractions with the residual coarser

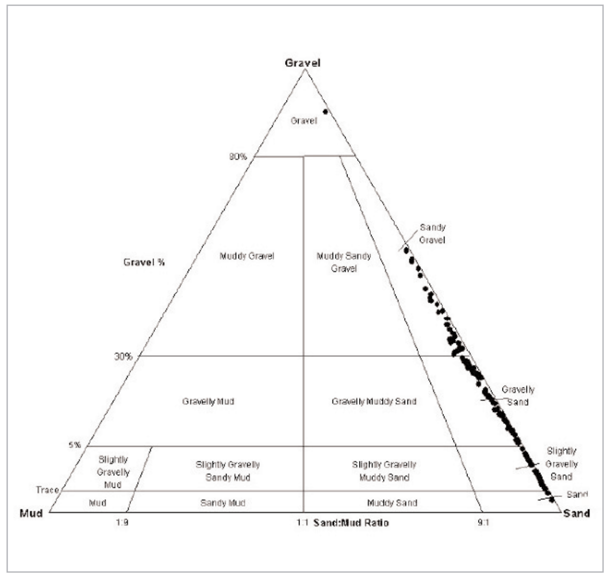

Figure 5.10 PSA results within the Gwynt y Môr Offshore Wind Farm boundary

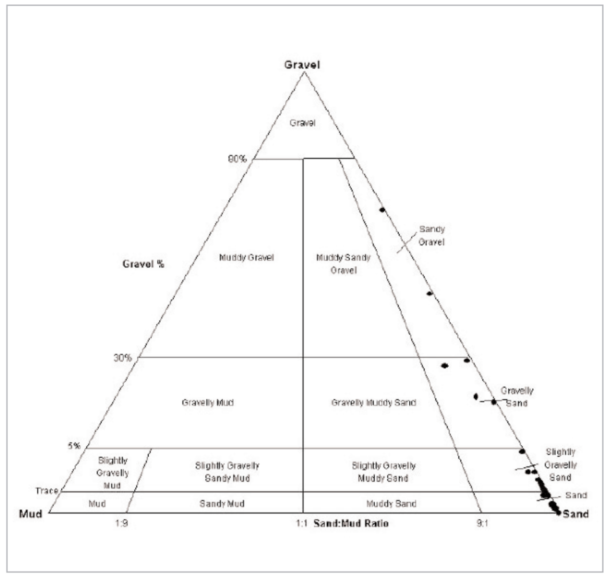

Figure 5.11 PSA results within the export cable route corridor

fractions remaining offshore. Closer inshore there is a significant reduction in particle size with the material on the near-shore banks being about 0.20 mm in diameter. However, within the intertidal zone in areas where sandy sediment dominates, there is an increase in grain size, the median diameter of 0.25 mm being fairly constant along the coastline. There is no discernible difference in grain size along the wide sand foreshore between Prestatyn and Point of Ayr.

The Dee and Clwyd Estuaries are located within the Liverpool Bay area, to the south and south east of the Gwynt y Môr project area. Much of the seabed sediments in the Dee are characterised by silty sand sediments, which overlie partly eroded boulder clay (glacial till). The seabed sediments in the upper reaches of the Clwyd Estuary are largely composed of well-sorted sand and mud. The seabed in the lower reaches of the estuary is largely composed of mud and gravel (Parsons, 1979).

Within the Gwynt y Môr project area, the recent geophysical survey (Osiris, 2004) has interpreted the seabed to be composed of gravelly sand, sandy gravel, and slightly gravelly sand. These observations are confirmed by the results of the particle size analysis (PSA) on samples collected from within the project area, as shown in Figures 5.10 and 5.11 (Osiris, 2004). The absence of fines suggests that the area is probably a high-energy environment.

5.2.5 The geophysical interpretation of the Gwynt y Môr Offshore Wind Farm project area

The Gwynt y Môr geophysical survey report (Osiris, 2004) has been completed over three different periods of survey between 2002 and 2004. Geophysical surveys were completed using a combination of side-scan sonar and sub-bottom profiling survey techniques with grab samples collected in the early phases to assist with seabed interpretation of the geophysical data. Figure 5.12 provides a seabed classification of the Gwynt y Môr project area derived from the site-specific geophysical studies.

Granular sediments are present at seabed level across the whole of the survey area. These deposits range from mobile finer-grained sands to less mobile coarser-grained gravelly sands and sandy gravels, with cobbles and occasional boulders.

The interpretation of the geophysical data indicates that the Gwynt y Môr project area can be divided into various sections of distinctive seabed sediment distribution. Two large sand sheets cover much of the south western and north eastern sections of the survey area. These sand sheets exhibit numerous bedforms, with sand waves, mega-ripples and ripples all present. Some of the larger bedforms reach heights of up to 5.0 m, although the average mega-ripple height is nearer to 1.0 m. The larger bedforms are generally orientated north to south, with wavelengths of between 6.0 m and 38.0 m. It is likely that many of the smaller bedforms are transient, with subtle changes in both magnitude and position occurring over time.

In between these sand sheets the seabed sediments exhibit more isolated mega-ripple bedforms, with intermittent large areas of relatively featureless sand. In parts of the south-eastern corner of the project area the seabed appears, from the geophysical data, to be markedly 'streaked', with alternate banding of 'pale coloured' areas of finer-grained sands and streaks of 'darker-coloured' sandy gravels. In the north-eastern corner of the project area the seabed sediments exhibit more isolated mega-ripple bedforms, within a large area of streaked sand.

Evidence of the trenched gas pipeline, which links the Douglas Oil Field to the Point of Ayr terminal, can be clearly seen on each of the nine survey cross lines, traversing the western part of the survey area from north to south.The survey indicates that there are no muddy sediments present within the Gwynt y Môr project area.

5.3 Sediment transport in Liverpool Bay

Tidal currents, together with the agitation of the seabed by wave action, are sufficiently high to induce shear stresses, which exceed the critical shear stress for initiating the movement of sand on the seabed. Thus, net movement will take place in the dominant direction, which will be dictated by both the currents magnitude and duration. There are a number of ways in which sediment transport can take place (NWPO, 2002):

- **bed load:** in this mode, particles roll and saltate along the bed in a layer a few particles thick above the bed. Saltation is a mode of transport that carries sediment down-current in a series of short leaps or bounces. The weight of the particles is supported wholly by the bed. The collision of moving particles with those on the bed is an important mechanism for the initiation of further movement and the modification of existing motions
- **suspended load:** in this mode, the ambient fluid motions above the bed load layer advect the particles. The weight of the particle is supported wholly by the fluid
- **sheet flow:** if the stress due to the motion of the fluid exceeds a certain value then ripples on the seabed may be washed out and replaced by a thin moving carpet of particles of high concentration. Particle-to-particle interactions are very important in this mode, which is dependent upon both the hydrodynamic size of the particle and the magnitude of the fluid motions.

The eastern Irish Sea mud belt divides the open sea to the west, where bedload transport dominates, and to the east a coastal area with many estuaries, where complex coastal processes take place (Figure 5.13). Bedload transport is controlled by peak currents, which are described by Sager and Sammler (1975) and Kenyon and Cooper (2005), and are shown to decrease to the east, away from the narrows between the southern side of the Isle of Man and the coast of Anglesey.

Glacial deposits to the south of the Isle of Man and in St George's Channel are subjected to high tidal currents. Erosion of these deposits causes sand-sized material to be transported northwards and eastwards in the direction of the strongest tidal flow. The Irish Sea is thus a major source of sand deposited within Liverpool Bay.

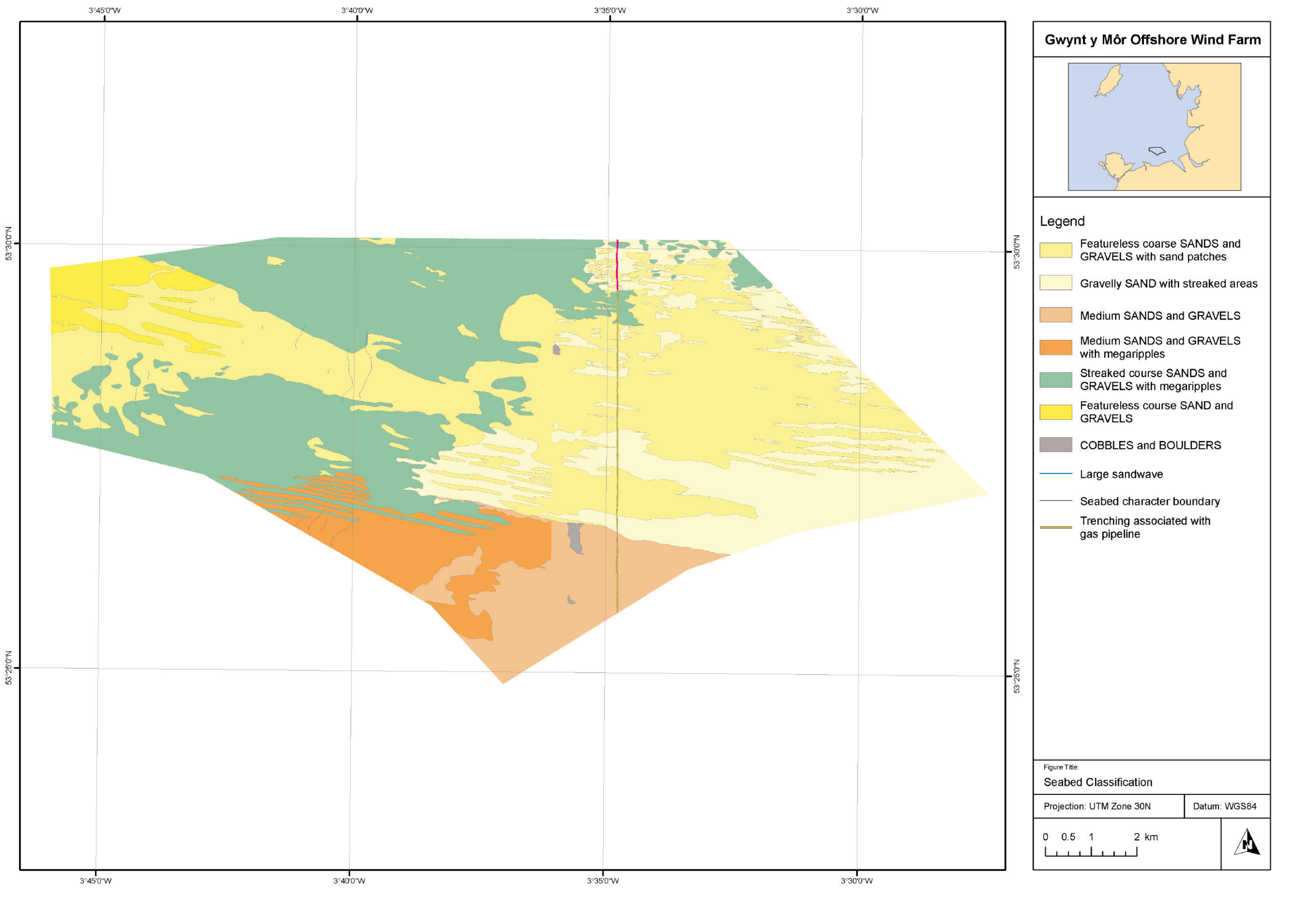

Figure 5.12 Seabed classification of Gwynt y Môr project area (Osiris, 2005)

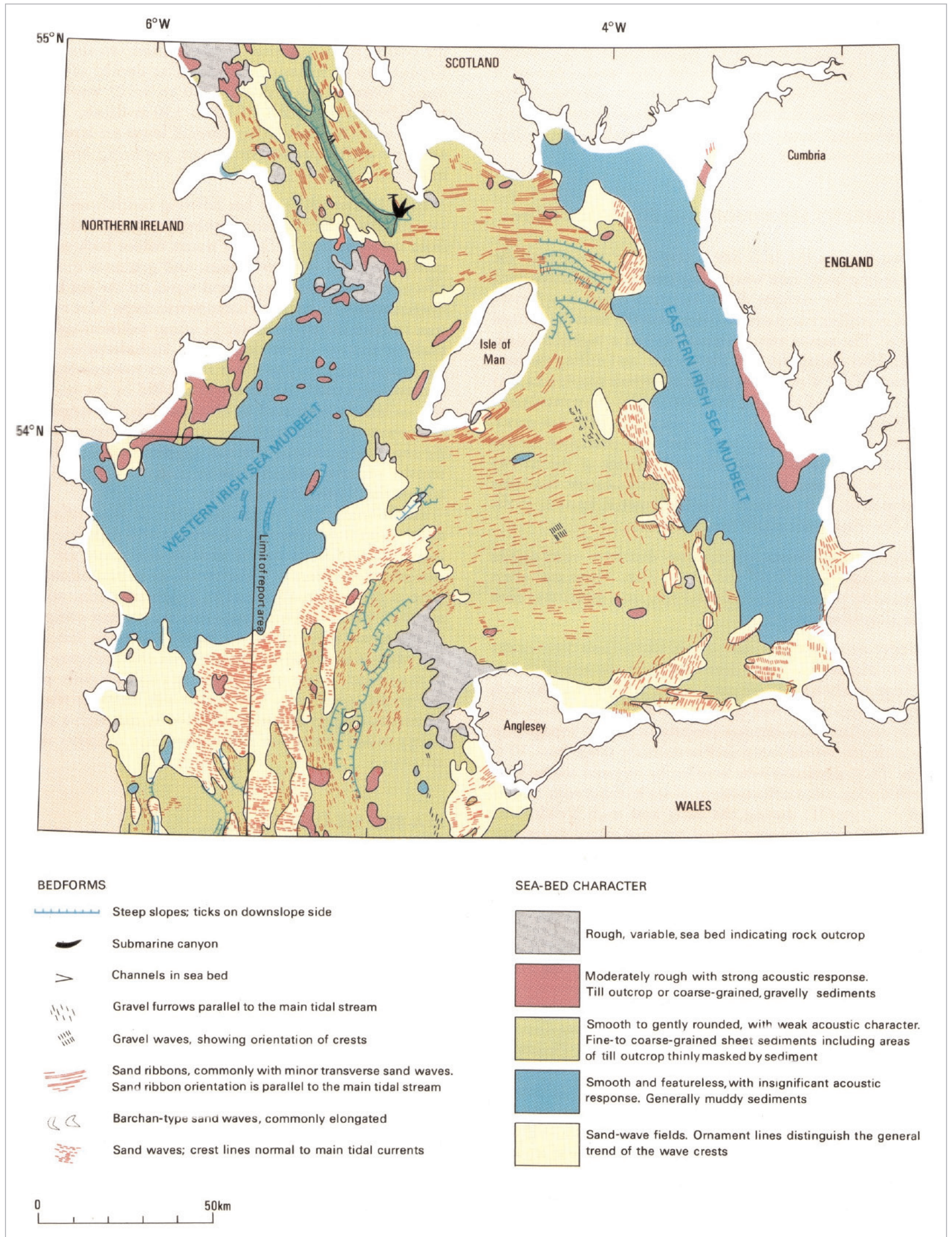

Figure 5.13 The character of the seabed and the distribution of active bedforms (Jackson, et al 1995)

The movement of sediment offshore in Liverpool Bay occurs primarily as bed-load and is in a net west to east direction, with some finer sediments being transported in suspension (see Figure 5.8). The transport rate is moderate to high for sand, but lower for shingle as a consequence of the hydrodynamic energy climate (Motyka and Brampton, 1993). The transport of sand between Liverpool Bay, the Dee and the Mersey follows the residual currents within the Bay. There are few natural barriers to the net eastward drift in this region, although down drift problems are prominent due to coastal protection schemes (Motyka and Brampton, 1993).

The transport of material into the near-shore areas of Liverpool Bay takes place as a result of the action of tidal currents and residual flow. The tidal currents move material primarily from west to east, as mentioned earlier. Residual currents are more complex, but generally move fine material in a landward direction.

5.3.1 The existing coastline and shoreline dynamics

The FutureCoast study (Defra, 2002) identified that littoral drift occurs from west to east along the North Wales and Wirral coasts (see Figure 5.8). It corresponds to a current located in the surf zone, moving generally parallel to the shoreline. It is generated by waves breaking at an angle with the shoreline and as successive wave fronts advance and retreat they create a longshore current. Consequently, the magnitude of drift varies with wave exposure and the pattern is segmented into sub-units by estuaries and bays where tidal currents and local wave patterns dominate sediment transport.

Erosion of the nearshore and coastal drift deposits over the past 10,000 years has provided a vast reservoir of sands, gravels and muds that have been redistributed along the coastline of Liverpool Bay by waves and tidal currents, with oblique breaking waves thought to be the prime mover of sediments. Deposits have accumulated as beaches, estuary deposits and sand dunes in some areas. However, the natural processes of erosion and deposition have been disrupted by coastal defence and navigation/port works along much of the north Wales coastline.

The north Wales coastline is susceptible to beach erosion, resulting in the release and redistribution of large quantities of material which in turn lead to:

- accretion at the Point of Ayr and on East Hoyle Bank
- siltation of the Clwyd and Dee.

In general, Liverpool Bay has been accreting sediment due to the net eastward drift, with the Dee Estuary being a particular sink for sand and silt, the area having a long history of siltation and salt marsh formation. Situated to the north of the Dee and Mersey Estuaries, the Ribble Estuary acts as a sand sink. However, by contrast, erosion of the shoreline occurs in a number of areas particularly where development has taken place and prevented natural erosion of the shoreline from providing feed to the beaches, for example the sea walls at Towyn and Prestatyn.

The extension of the Great Orme beyond the general coastline provides a major drift divide between the adjacent littoral cells of Bardsey Sound to Great Orme (Cell 10) and Great Orme to Solway Firth (Cell 11) (Motyka and Bampton, 1993). Between Great Orme and the River Clwyd there is a pronounced easterly drift of sediment, fed principally by the local erosion of cliffs at Little Orme.

From the River Clwyd east to the Point of Ayr, at the mouth of the Dee Estuary, the coast is dominated by expansive sandy beaches backed by sand dunes, alluvium or, locally, peat. Further west, between

Prestatyn and Point of Ayr shingle deposits have formed a complex of ridges, bars and spits. Where this larger sediment size is evident, steeper upper beach gradients due to sorting by the action of the waves and tides have resulted.

The urban frontages of Rhyl and Prestatyn have, in addition, been protected by sea walls and groyne systems. From Gronant to the Point of Ayr natural shoreline dominates with a 2 km long dune ridge. The Point of Ayr is a prominent 'ness' of shingle and sand, and the coastal belt of high dunes capped with marram grass continues but lowers as one approaches the Dee Estuary.

The Dee Estuary is a valley drowned by the Holocene sea level rise. The general trend within the estuary, since Roman times, is one of long term siltation with mud, silt and fine sand deposits generally reducing water depths. The tidal capacity of the estuary has been reduced further in more recent times with extensive land reclamation occurring since the 17th century in the inner parts of the estuary.

The waters of the Dee outlet through two main channels – the Welsh channel on the west side, which turns around the point of Ayr and runs roughly parallel to the coast across the Gronant frontage; and the Hilbre Channel on the east side, which is more north/south orientated, passing to the west of Hilbre Island off West Kirby. Elsewhere the mouth of the estuary is characterised by a series of sand banks and secondary channels. The Dee Estuary is and will continue to be a major sink for sand, silt and mud due to the prevailing, generally low energy nature of the environment.

Along the north coast of the Wirral peninsula between the Dee and Mersey Estuaries, the natural shoreline is one of extensive sand dunes backed by alluvium but, as at Rhyl and Prestatyn, sea walls and breakwaters now artificially protect the majority of the shoreline. The foreshore along this frontage comprises generally medium to fine sand deposits. Onshore and longshore sediment transport has formed an extensive series of bank features in front of the Wirral shoreline notably the East Hoyle Bank off Hoylake and Meols and the Great Burbo Bank on the west side of the Mersey channel. Local early Holocene peat deposits are exposed at a number of locations along the Wirral foreshore and these give an indication of sea level changes in the area over the last few thousand years.

The intertidal sand beaches that characterise these sections of north Wales and the north Wirral shoreline are noted for a particular bedform generally only seen in Liverpool Bay. ‘Ridges’ and ‘Runnels’, also known as ‘lows’ and ‘fulls’, are ridges and troughs that run approximately parallel to the coast.

5.3.2 The impacts of climate change on the coastal processes of Liverpool Bay

The coastal process regime within Liverpool Bay will respond to climate change. The most immediate and quantifiable effect is sea level rise. Long-term sea level changes across Liverpool Bay are a function of both global change in sea level, estimated in this region as rising in the order of 1.23 mm/year, and the local change in land levels due to glacial rebound. However, the latter effect is negligible for this part of the UK due to the close proximity of the line of zero change, which passes across England from the River Dee and River Tees along the north east-south west axis (Shennan, 1989). The recommended value for flood and coastal defence planning for the north-west region of the UK is 4 mm/year (MAFF, 1999).

Climate change is also expected to affect the wind and wave climate in Liverpool Bay. It is expected that in the winter winds will be stronger than currently experienced and in the summer they will be weaker. These changes, combined with the predicted change in sea level, are likely to have an impact on coastal processes and sea defences. However, at present, climate models (which in themselves are not capable of adequately predicting wind speed and direction) do not incorporate ocean models; hence it is not possible to quantify the impact of climate change on the wind and wave environment in Liverpool Bay.

In addition, depressions passing to the north of the Irish Sea promote northerly and westerly winds over the region, which are likely to increase the incidence of storm surges in the eastern Irish Sea and Liverpool Bay (Flather, 1987). The height of storm surges across the area increases from east to west, with the estimated height of the 50-year storm surge being in excess of 2 m along most of the eastern coasts, which incorporate the Liverpool Bay area (Flather, 1992). It is generally considered that the frequency and severity of storm events will increase as a result of climate change. The combination of a modified tidal regime and increased storm frequency is a likely driver for future coastal change within Liverpool Bay. This is likely to be most evident along the shorelines where much of the wave energy is ultimately dissipated, leading to modified rates of littoral drift.

Climate change is an external influence that will affect coastal processes on a regional scale, and at a level that is likely to be greater than any locally derived effects attributed to any of the existing or planned activities within Liverpool Bay.

5.4 Existing water quality in the Liverpool Bay region

5.4.1 Introduction

The Liverpool Bay region receives inputs of waste water from coastal sewage outfalls, trade effluent outfalls and contaminated riverine discharges, particularly from the Mersey and Dee Estuaries. The River Mersey and its estuary receive substantial amounts of sewage and industrial wastes from the heavily populated area of north west England, which includes the conurbations of Liverpool and Manchester. The shoreline of the Mersey Estuary and its catchments also contain a particularly high concentration of manufacturing industries, particularly chemical industries (Collings et al, 1996). Any discharges into these estuaries are inevitably carried into the waters of Liverpool Bay.

Discharges to the aquatic environment within England and Wales are controlled under legislation such as the Water Resources Act (1991), the Urban Waste Water Treatment Regulations (1994), the Surface Waters (Shellfish) (Classification) Regulations (1997), the Surface Waters (Shellfish) Directions (1997) and the Bathing Waters (Classification) Regulations (1991). The Environment Agency takes overall control for discharges to the aquatic environment, including the overall water quality of coastal and marine waters out to 3 nm; further offshore Defra is the responsible regulatory authority in England whilst the National Assembly of Wales is responsible in Welsh territorial waters.

Trade effluents involving hazardous substances are subject to Integrated Pollution Control under the Environmental Protection Act (1990). European legislation, such as The Water Framework Directive, (WFD) also requires all inland and coastal waters to reach "good status" by 2015.

The UK is also a signatory to a number of international agreements relating to marine water quality including The Convention on the Protection of the Marine Environment of the North-East Atlantic, 1992 (OSPAR Convention); The North Sea Conferences; Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter, 1972 (London Convention); and the International Convention on the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78).

As a result of the various legislation introduced over the preceding decades, the water quality of Liverpool Bay has considerably improved over recent years with a significant reduction in the amount of hazardous substances going to sea and a decline in the loads from industrial and sewage treatment works.

The following sections review the water quality of the offshore and inshore waters of Liverpool Bay, based on a review of the available literature and monitoring data.

5.4.2 Offshore water quality

Water quality in the offshore part of Liverpool Bay, away from the coastal bathing waters, is affected predominantly by contaminants from rivers, sewage effluent or industrial discharges. A variety of contaminants can be present in seawater, including:

- trace metals
- organic micro-pollutants (such as pesticides or PCBs)
- hydrocarbons
- radioactive isotopes
- litter.

Trace metals can occur naturally in seawater as a consequence of geological weathering processes and subsequent land run off. However, additional inputs can be derived from anthropogenic sources such as mining or industrial activities. In seawater, dissolved metals rarely achieve concentrations that are directly toxic to marine biota but through bioaccumulation, some metals can achieve tissue concentrations that are toxic to organisms and their predators.

Within Liverpool Bay, the levels of trace metals from trade and sewage outfalls and levels of lead, cadmium and mercury are known to be higher than Background Reference Concentration (BRC) values, set by OSPAR in 1997. Studies regarding metal concentration in the waters of the Irish Sea have been carried out by Abdullah et al (1973) and Preston (1972), and recorded a gradient of metal concentrations from high levels near the Mersey and Dee Estuaries to lower concentrations further offshore, tending to confirm the importance of rivers and estuaries as sources for these pollutants.

Historically, much of Liverpool Bay has been contaminated with mercury (MAFF, 1991), which has been attributed to inputs from the Mersey Estuary, primarily as the result of industrial effluents specifically from the chlor-alkali industry. The Irish Sea also receives the largest single input of lead nationally from the river Mersey (DEFRA, 2005) and elevated copper levels in the region (when compared with the rest of the Irish Sea) are also attributed to inputs from the Rivers Dee and Mersey (MPMMG, 1998). River discharge is also a major source of cadmium and zinc in the region (Norton et al, 1984).

Micro-pollutants, such as pesticides or chemicals arising from the oil and gas industry, can also affect seawater quality. Liverpool Bay is subject to relatively low level inputs of hydrocarbons from the River Mersey (Defra, 2000) and monitoring studies, carried out by the National Marine Monitoring

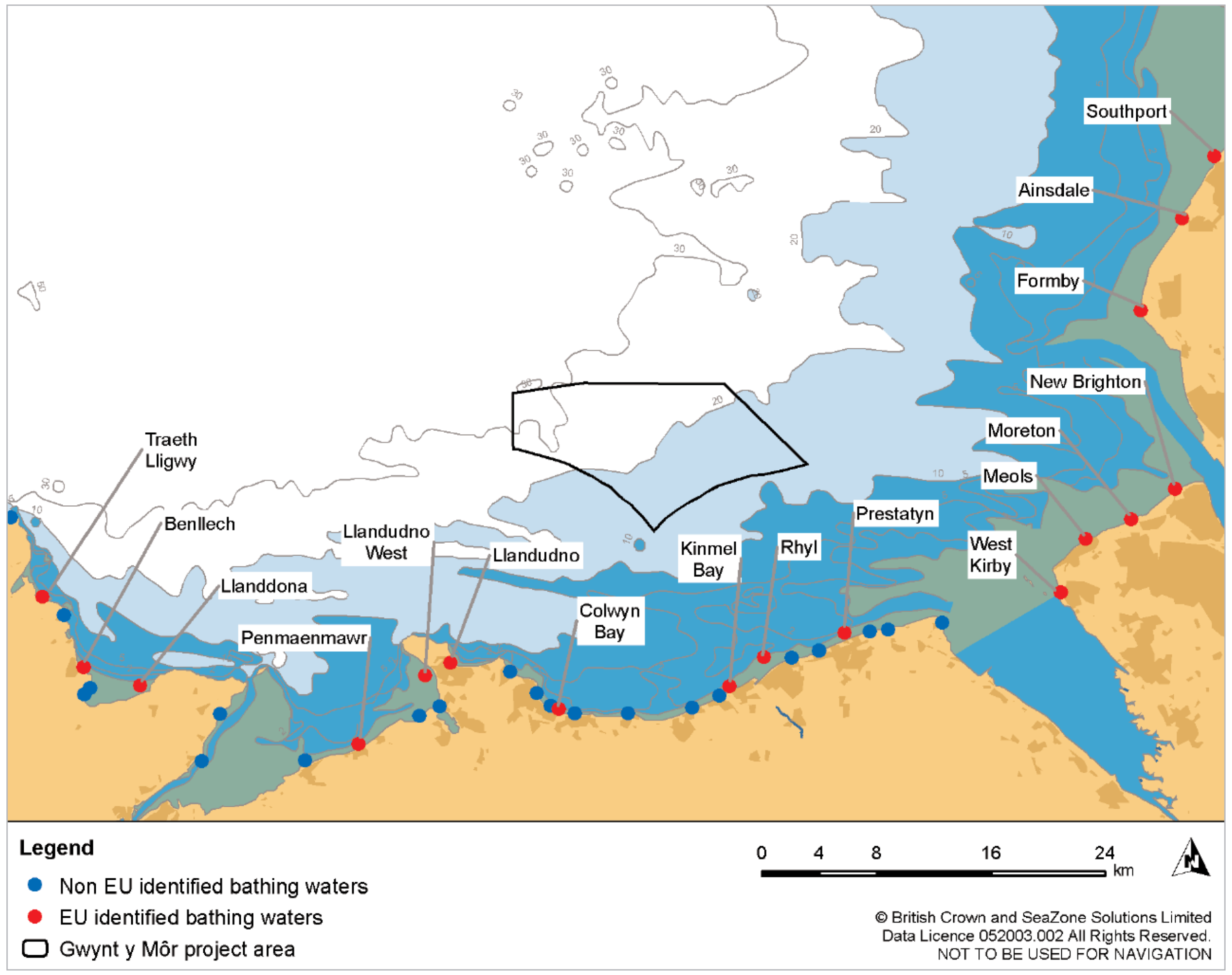

Figure 5.14 Current EU and non-EU identified bathing waters tested by the environment agency for bathing water quality

Programme (NMMP), have confirmed that concentrations of hydrocarbons are below quality standards set by OSPAR. Polychlorinated biphenyls (PCBs) are persistent man-made compounds and have the potential for long-range atmospheric transportation. However, they have extremely low water solubility and as a result their concentrations in seawater tend to be generally very low, being more often associated with sediments.

By contrast, radioactive isotopes are relatively soluble in seawater and are dispersed throughout the eastern Irish Sea from the Sellafield reprocessing plant on the Cumbrian coastline, it being the largest single input of radioactive material in the Irish Sea (DEFRA, 2000). However, the resulting exposure levels to marine species in the eastern Irish Sea and Liverpool Bay remain well below those known to cause adverse effects.

Liverpool Bay also has a sizeable amount of shipping, port operations, offshore developments, commercial fishers and recreational users all of which can contribute to offshore marine litter, which can affect water quality. In some cases, such as for the shipping industry, controls are in place although it is considered that improvements in education and enforcement are needed to make them fully effective (Defra, 2005). Plastics are the most prevalent litter type in the marine environment and marine litter can have adverse ecological impacts, including entanglement, ingestion, smothering, and the transport of invasive species (MPMMG, 1998).

5.4.3 Coastal bathing water quality

Inputs of waste water and contaminants from the various coastal effluent and riverine inputs can similarly affect coastal bathing water standards. For example, along the Liverpool Bay coastline are many sewage outfalls, with the largest being at Liverpool, which discharges approximately 950,000 m^3 of primary treated sewage daily (primary treatment being the settling out of circa 70% solids from the sewage in large settlement tanks) (Defra, 2002).

The European Union Bathing Water Directive (76/160/EC) sets the standards for water quality guidelines for the coastal areas and requires the identification and monitoring of bathing waters. The Bathing Water Directive is intended primarily to safeguard public health and the environment by reducing the pollution of bathing waters and protecting such waters against further deterioration. Two standards are stipulated; the EC Mandatory Standard and the EC Guideline Standard. These set the maximum levels of faecal coliforms, total coliforms and faecal streptococci that may be present in seawater. Within England and Wales the monitoring of marine bathing waters is co-ordinated by the Environment Agency, which takes samples from designated beaches at regular intervals between May 1st and September 30th (the designated “Bathing season”) each year.

Around the Merseyside, Wirral and north Wales coastlines, there are 17 locations subject to testing by the Environment Agency as part of the Bathing Water Directive requirements (Figure 5.14). In addition, a further 20 non-EU identified bathing waters are also tested by the Environment Agency along the north Wales coastline (Figure 5.14). This allows local councils in north Wales to continue to apply for the various bathing beach awards at non-EU bathing waters, an initiative which is coordinated by the Environment Agency involving the Welsh Assembly Government, Wales Tourist Board, Keep Wales Tidy (KWT), Dwr Cymru Welsh Water (DCWW) and the maritime local authorities (EA, 2005).

Overall the coastal bathing water quality within this region is considered to be good, with the majority of the EU identified sites passing the mandatory standards over the last five years. Notable exceptions were failures during 2001 at the sites of Prestatyn, Rhyl, Kinmel Bay, Llandudno and Llandudno West.

Of the non-EU identified sites tested, all passed the mandatory standards over the last five years with the exception of Penrhyn Bay (failed 2000), Towyn (failed 2000 and 2004), Rhyl (failed 2000) and Talacre (failed 2002).

At beaches where strict water quality (compliance with EU “Guideline” standards) is in addition to other land-based requirements, a blue flag may be awarded as part of the European Blue Flag Scheme. Within this region Benllech, Llandona, Formby and Ainsdale beaches have all been awarded blue flags. Other beaches in the region with awards include Kinmel Bay, which received a “Green Coast Award” (developed by the Green Sea Partnership) in 2004 (EA, 2005). This award is designed to acknowledge beaches which meet EU guideline water quality and are prized for their natural and unspoiled environment.

The Environment Agency has identified a number of the EU bathing water locations as having a risk of future non-compliance with mandatory standards, notably Rhyl and Kinmel Bay. Previous water quality failures at these sites have been attributed to agricultural run-off increasing bacterial levels within the River Clwyd subsequently affecting these adjacent beaches.

5.5 The existing sediment quality in Liverpool Bay

5.5.1 Introduction

The seabed sediments of Liverpool Bay will tend to reflect and integrate the contaminant inputs to the marine environment discussed in relation to water quality in the preceding section. The following section reviews the sediment quality of the region based on the available literature and also considers the results of the site-specific sampling for sediment contaminants undertaken within the project area and the export cable corridor.

5.5.2 Historic review of sediment quality in Liverpool Bay

The sediments of the eastern Irish Sea and Liverpool Bay ultimately act as a sink for contaminants originating from coastal discharges and estuaries such as the Mersey and Dee.

Trace metal concentrations in the marine sediments around the coastal zone and around the estuaries of the region are historically higher than from sediments further offshore. Cadmium, mercury, lead and zinc occur at relatively high concentrations in the eastern Irish Sea sediments, particularly off the estuary of the Mersey (Defra, 2000). Camacho-Ibar (1992) found the level of mercury within sediments at the mouth of the Mersey Estuary to be almost six times higher than natural levels, as a result of industrial discharge into the river predominantly from the alkali-chemical industry. Reduced inputs of mercury in recent times have, however, resulted in some long-term reduction in sediment concentrations throughout the area (Leah et al. 1993).

Arsenic is also known to occur above background levels within the sediments of Liverpool Bay (Camacho-Ibar et al, 1992). Studies suggest that such elevated arsenic levels are not attributable to loads from the River Mersey or historic offshore spoil disposal (although sewage sludge does contain some arsenic) (Leah et al. 1992). Instead, it is postulated that the main sources are of natural origin resulting from lithogenic inputs from the north Wales area as a result of geological weathering. Thornton et al (1975) reported high values of arsenic in the sediments of the River Conwy, the tributaries of which drain the mineralised areas of north Wales. Other trace elements present in very high concentrations in the sediments of the River Conwy Estuary include zinc and lead, thought to result from sphalerite and galena mining in the past (Elderfield et al. 1971).

Contaminants such as polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) tend to result from sources such as sewage discharges, surface run-off, industrial discharges, oil spillages and deposition from the atmosphere. The Irish Sea as a whole is thought to contain relatively large amounts of hydrocarbons attributable to oil and gas extraction activities, shipping and proximity to geological (pyrogenic) sources.

PAHs were not detected within sediments at offshore spoil disposal sites within Liverpool Bay (Defra, 2000). PCBs are noted as being of concern in the Liverpool Bay area because of elevated levels recorded in fish and other biota. It is known that relatively high levels of PCBs can be contained in sewage sludge, although PCB levels in sediments of the wider area of Liverpool Bay are not reported as being the highest concentrations within the UK. Levels within the Mersey Estuary have been reported as being relatively high (NMMP, 2004), with a general trend for PCB sediment concentration within the region to decrease offshore from the estuary (Camacho-Ibar, 1996). The sediments of the eastern Irish Sea, including

Liverpool Bay also act as a long-term sink for plutonium and other artificial radionuclides originating from Sellafield, Cumbria (Defra, 2000).

The Gwynt y Môr project area is located to the south of and relatively close to the historic Liverpool Bay sludge disposal site (Norton et al, 1984). Approximately 50,000 dry tonnes of treated and untreated sewage sludge and industrial wastes were discharged annually at this offshore spoil disposal ground before this activity ceased in 1998. The fine sediments recorded at the disposal site showed elevated concentrations of organic carbon and trace metals (similar to concentrations recorded at the mouth of the Mersey Estuary) whilst dumping was occurring (Norton et al, 1984). However, the dispersive nature of the disposal site has tended to preclude the long-term accumulation of pollutants (Jones et al, 1997).

A specific study of contaminant concentrations within Liverpool Bay sediments was undertaken as part of the baseline survey at the North Hoyle Offshore Wind Farm project area. This included site-specific sediment sampling during 2001. Arsenic was found to exceed recommended sediment quality guidelines at five of the eight sampling sites with all other contaminants tested for (including other trace metals, pesticides and hydrocarbons) recorded at low levels (CMACS, 2001).

5.5.3 The site-specific sediment sampling and analysis

In line with the guidance produced for the assessment of offshore wind farms (CEFAS, 2004), sampling of seabed sediments for a range of contaminants has been completed across Gwynt y Môr as part of the site -specific benthic ecology survey programme. Sampling methods were agreed with CCW and CEFAS.

Samples for contaminant testing were collected from 24 sites both within and around the main Gwynt y Môr project area and at inshore locations along the proposed export cable route corridor (Figure 5.15). The samples collected were analysed for the contaminants listed in Table 5.4.

Determinand	
Trace metals	Cu, Cd, Cr, Pb, Zn, Hg, Ni and As
Organochlorines	Organochlorine suite including pp-DDE, pp-DDD, pp-DDT, op-DDD, A-HCH, B-HCH, G-HCH, HCB, aldrin, endrin and dieldrin
Polychlorinated biphenyls (PCBs)	ICES 7 congeners (28, 52, 101, 118, 153, 138 and 180)
Polyaromatic hydrocarbons (PAH)	EPA 16 (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluoroanthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd) pyrene, dibenzo(ah)anthracene, benzo(ghi)perylene)
Total EPA	

Table 5.4 Summary of sediment sample contaminants analysis

The results of the contaminant testing have been assessed against the available guidelines for sediment quality standards. Specifically, the Habitats Directive Water Quality Technical Advisory Group (HDTAGWQ, 2001) determined that in the absence of any statutory guidelines in England and Wales, it is appropriate to use guidelines that have been developed and used elsewhere, their approach being to use Canadian Interim Sediment Quality Guidelines (ISQGs) (CCME, 2001).

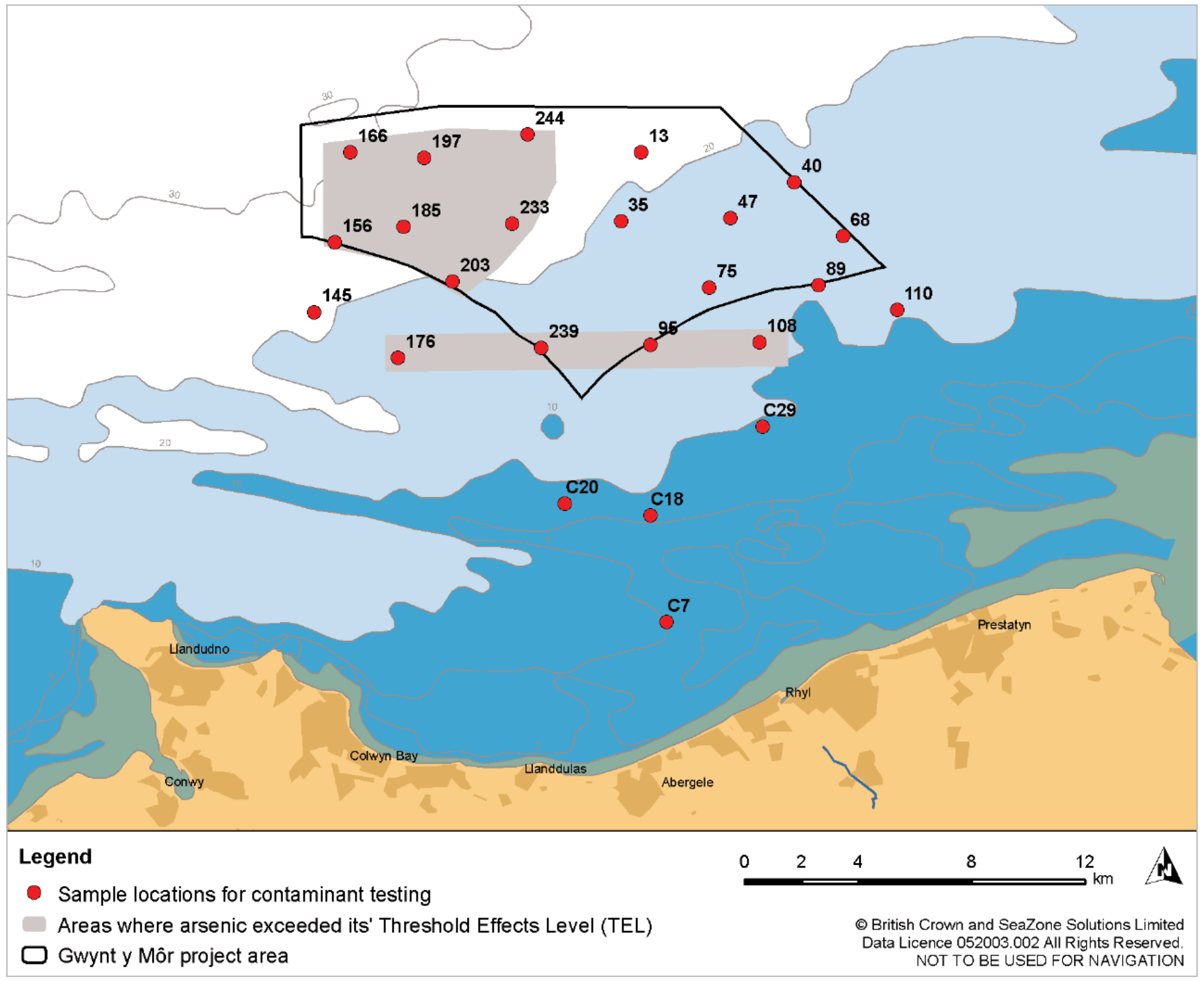

Figure 5.15 Sample locations for sediment contaminant testing and areas where arsenic exceeded its threshold effects level (TEL)

The Canadian guidelines define threshold effects levels (TEL), which represent the lower end of the range of concentrations at which biological effects are occasionally observed and probable effects levels (PEL) where the level of contaminant within sediments could have an affect on a wider range of organisms.

The results for the trace metals analysis showed low concentrations within the sediments sampled, with all being below the TEL levels, with the exception of arsenic, which was recorded at concentrations slightly above the TEL (but well below PEL levels) at nine sites (Figure 5.15). This result for arsenic is taken to reflect the lithogenic inputs from the north Wales region as a result of the geological weathering referred to previously. In general, levels of trace metals were found to be comparable to results from the North Hoyle sediment contaminant survey including the levels of arsenic, which was the only metal to exceed its TEL during this survey (CMACS, 2001).

Both organochlorine and PCB residues were below the minimum limit of detection at all of the sampling sites.

The concentrations of PAHs within the Gwynt y Môr sediments were also below the limits of detection or below the equivalent TEL or PEL values in most cases. A few exceptions were, however, noted where the concentrations of a number of PAHs exceeded the TEL levels. At two sites the PEL levels were also exceeded, including a single site within the Gwynt y Môr project area (sampling site 110).

Somewhat elevated levels of certain PAHs are not wholly unexpected within the Gwynt y Môr area given the proximity to the riverine discharges of Liverpool Bay and the adjacent oil and gas extraction activities. It has, however, been concluded that the overall level of PAHs within the Gwynt y Môr project area are at a level such that adverse biological effects are unlikely to occur.

It is concluded from the results of the Gwynt y Môr sediment sampling that the majority of contaminants subject to analysis are found at low concentrations and below the guideline levels likely to cause effects to marine biota. The elevated levels of arsenic found within certain areas are below probable effects levels and are in keeping with results from previous surveys of Liverpool Bay such as the North Hoyle Offshore Wind Farm baseline survey (CMACS, 2002). PAH levels exceeded Probable effects levels at two sites, one of which is located within the western boundary of Gwynt y Môr. However, overall the sediments within the project area do not contain any persistent contaminants at levels which are considered to pose a risk of adverse impact on the marine environment.