Appendix 6.2

Model Bathymetry Review

Tidal Lagoon (Swansea Bay) Ltd.

Model Bathymetry Review

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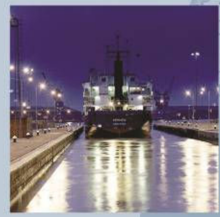
Creating sustainable solutions for the marine environment





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Model Bathymetry Review

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1. Introduction

1.0.0.1 As part of the EIA studies for the proposed tidal lagoon development in Swansea Bay, ABP Marine Environmental Research Ltd (ABPmer) has been commissioned by Tidal Lagoon Swansea Bay Plc. (TLSB) to undertake an assessment of effects on coastal processes. This assessment has been informed by detailed numerical modelling of the physical processes that might potentially be affected by the Project. In order to provide sufficient definition of the bathymetry of Swansea Bay and adjacent regions for this detailed modelling, ABPmer has assembled a composite bathymetric surface from the most suitable datasets covering the area of interest.

1.0.0.2 The work carried out to date in composing and validating this composite bathymetric surface has been reported previously in the following documents:

i. ABPmer, 2013a. Swansea Bay Tidal Lagoon: Bathymetry Data Preparation. Report No. R2111TN; and
ii. ABPmer, 2013b. Swansea Bay Tidal Lagoon: Bathymetry Validation Review. 20 August, 2013

1.0.0.3 Following stakeholder consultation (through the EIA process) requests for further information on the bathymetric surface have been received. This present report seeks to address these comments and provide the additional information requested. Whilst not repeating the full text from the earlier reports (detailed above), a summary of the salient points from each document is included to provide sufficient context.

1.0.0.4 The structure of the present report is defined by the content of the previous reports and the requested further information, as described below:

Section 2: Bathymetry Preparation (as detailed previously in ABPmer, 2013a);
Section 3: Bathymetry Validation (as detailed previously in ABPmer, 2013b); and
Section 4: Bathymetry Sensitivity Testing (as requested during stakeholder consultation)

2. Bathymetry Preparation

2.0.0.1 The preparation of the bathymetry data has previously been described in ABPmer (2013a), and is summarised here, with additional information included where requested.

2.1 Data Sources

2.1.0.1 It should be noted here that the composite bathymetric dataset described herein has been developed specifically for input to the ABPmer detailed numerical model, for use in the subsequent assessment of potential impacts to hydrodynamics and waves. In addition, the bathymetry has also been provided to the other EIA topics (namely the Water Quality assessment) for use in their respective numerical models.

2.1.0.2 The numerical modelling for the Coastal Processes EIA is based on an existing numerical model that has been used previously for other EIA studies, and which has been suitably refined over the current area of interest. The resolution and vertical reference datum of the bathymetric datasets have each been selected to be consistent with this existing numerical model (which also includes the far-field bathymetry into both the Outer Bristol Channel and the Severn Estuary). The input bathymetric datasets are all considered to be of suitable resolution for subsequent use in the detailed modelling stage.

2.1.0.3 Table 1 provides summary details of the composite bathymetry datasets used to improve the source data which underpins the definition of water depths across the Swansea Bay study area, and Figure 1 shows the spatial extent of each of the data sources. It should be noted here that outside of the coverage of these datasets (as shown in Figure 1), the existing model bathymetry has been used to define the water depths across the remaining model extent. A brief description of each of the data sources that make up the composite bathymetry is provided below.

Table 1. Composite bathymetry datasets

Source	Extent	Vertical Precision (Decimal Places)	Year	Vertical Reference Datum of source data
ABP Swansea	Swansea Approach Channel	2	2012	Chart Datum
Tidal Lagoon Swansea Bay	Proposed Lagoon location	2	2012	Chart Datum
Coastline Response Study	Swansea Bay Intertidal Area	1	1991	Ordnance Datum (Newlyn)
UKHO	Outer Swansea Bay and Bristol Channel	1	1980 -1998	Chart Datum
Neath Estuary Working Group	Neath Estuary	2	2010	Dredged Datum

2.1.0.4 **ABP Swansea - Swansea Approach Channel**: A bathymetric survey is undertaken using a single-beam echosounder on an approximately monthly basis to ensure maintenance of the channel, covering the approaches to the Port of Swansea out to the Outer Fairway Buoy. Here, the data from the survey undertaken at the end of October 2012 has been used. This survey was carried out between maintenance dredging operations, with no dredging activity taking place for several months either side of the survey date. Therefore, data is considered to be up-to-date and representative for this specific area.

2.1.0.5 **Tidal Lagoon Swansea Bay - Proposed Lagoon Location**: These data were collected by the multibeam bathymetric survey commissioned by Tidal Lagoon Swansea Bay to cover the proposed location of the lagoon, surveyed between November 2011 and February 2012 (Titan, 2012). The survey data was provided at a resolution of 1m x 1m, covering an approximate 4.5km long stretch of coastline, fronting Swansea Port and extending approximately 4km into the Bay.

2.1.0.6 **Coastline Response Study - Swansea Bay Intertidal Area**: This dataset was collected during 1991 for the Coastline Response Study - Worms Head to Penarth Head (Bullen, 1993), and covers the intertidal area around the full extent of Swansea Bay. The suitability of using alternative Environment Agency LiDAR (Light Detection And Ranging) data to define the baseline intertidal levels was previously investigated. However, the footprint of the LiDAR spans several years and vertical discrepancies between the various sections are evident. These inconsistencies would create problems in establishing a seamless definition of the intertidal within the model. The alternative data source used here is the 1991 Coastal Response Study that comprised a single seamless dataset based on aerial reconnaissance and ground truthing.

2.1.0.7 **United Kingdom Hydrographic Office (UKHO) - Outer Swansea Bay and Bristol Channel**: A licence for this dataset was purchased for use in the project and comprises the UKHO digital survey bathymetric data for Swansea Bay and the coastline between Worms Head and Mumbles Head. These data were collected during various surveys undertaken between 1980 and 1998 (Figure 1), and presently remains as the most contemporary definition of the sub-tidal parts of Swansea Bay. The horizontal resolution of the dataset is variable across the extent, but is generally between 50 and 80m.

2.1.0.8 **Neath Estuary Working Group - Neath Estuary**: Annual single-beam echosounder surveys of the Neath Estuary (including the approach channel) have been provided by the Neath Estuary Working Group for surveys carried out between 2001 and 2010. The most recent (2010) dataset has been used in creating the composite bathymetric dataset.

2.2 Composite Bathymetry Methodology

2.2.0.1 The process of preparation of the composite bathymetric dataset is outlined below:

i. The first stage was to ensure that each of the input datasets were referenced to the same horizontal and vertical datum. In order to maintain consistency with the existing numerical model, the horizontal reference datum was selected as OSGB36 and the vertical reference datum was selected as mean sea-level (MSL).

   Each of the input datasets were received referenced to OSGB36 in the horizontal, except the UKHO digital survey bathymetry which was provided with latitude and longitude referenced to WGS84. This dataset was projected into OSGB36 using ESRI ArcGIS 10.1 software and employing the 'WGS84 to OSGB36 Petroleum' transformation.

   None of the input datasets were provided referenced to MSL in the vertical. Each were referenced to Chart Datum (CD) with the exception of the intertidal data collected for the Coastal Response Study, which was referenced to Ordnance Datum (Newlyn) (ODN), and the Neath Estuary data which was referenced to the dredged datum (stated as 1.5m above CD).

   The recognised method for converting between vertical reference datums is to use the Vertical Offshore Reference Frame (VORF) (UKHO, 2008). The VORF correction for

ODN to CD was first used to apply a correction to the intertidal dataset, before the VORF correction for CD to MSL was applied to each dataset, providing a full set of input data referenced to MSL.

It should be noted that the VORF data includes a stated uncertainty in the reported levels. Across the area of interest, the stated uncertainty in the levels used to convert from ODN to CD is an average 0.09m; whilst the equivalent value for the levels used to convert from CD to MSL is an average of 0.14m.

ii. Once the input data sources were all referenced to the same horizontal and vertical datums, they were merged into a single dataset. During this stage, data were prioritised in areas of overlapping data (as described below), so that one dataset was used in preference to another (normally based on most recent survey taking precedence). This minimised the potential for data collected over different periods to give rise to erroneous spikes in the resulting bathymetric layer (as a result of possible interim changes to the bed level between survey dates).

The data priority was generally assigned based on survey date, with the most recent dataset usually being used in preference to older data. In this way, in overlapping areas, the following data priorities were assigned:

- The ABP Swansea data was used ahead of the TLSB and the intertidal data;
- The TLSB data was used ahead of the UKHO data, the Neath Estuary data and the intertidal data;
- The Neath Estuary data was used ahead of the intertidal data and the UKHO data; and
- The intertidal data was used ahead of the UKHO data.

iii. Once the input datasets had been prioritised and merged, the resulting point dataset was interpolated to a gridded bathymetry surface by a Natural Neighbour interpolation technique, using ESRI AcrGIS 10.1 software. This interpolation technique was selected as it maintains the input point values.

2.2.0.2 The resulting gridded bathymetric surface was created at a resolution of 20m x 20m (to be comparable to the highest resolution of the numerical model mesh), and, in keeping with the input datasets, was referenced to OSGB36 in the horizontal and MSL in the vertical. To provide a reference to the land datum, the elevation of MSL across the intertidal area varies between 0.1 and 0.2m above ODN (UKHO, 2008).

2.2.0.3 A series of QA checks were carried out on the gridded bathymetric surface to ensure consistency. These included the checking for artificial ‘steps’ in the surface at the junctions between input datasets; the identification of any artificial ‘spikes’ in the data; and a comparison of the gridded values against both the input data and the regional hydrographic chart.

2.3 Composite Bathymetry Output

2.3.0.1 Figure 2 shows the composite bathymetry dataset. For the detailed modelling phase, areas with no bathymetric data coverage (shown as 'white' areas in Figure 2) have been filled with bathymetry data from the existing regional numerical models. This interpolated bathymetry dataset is based on data from a variety of sources, including surveys of the Helwick Bank and Scarweather Sands, UKHO data for the Severn Estuary and Bristol Channel and GEBCO (Generalised Bathymetric Chart of the Oceans) data covering the approaches to the Bristol Channel.

2.3.0.2 It should be noted here that whilst the composite bathymetry is reported to two decimal places in the vertical, the input data, the datum correction and the gridding process all add uncertainty to the final dataset. In this way, the precision of the input datasets should be considered when assessing the overall accuracy of the elevations (i.e. the input datasets provided to only one decimal place each have an inherent uncertainty of ±0.05m). Furthermore, the average gridding error across the composite bathymetry surface is -0.02m, with a standard deviation of ±0.74m.

2.3.0.3 The overall uncertainty in the assembled bathymetric dataset can be considered by including the individual levels of uncertainty described above, along with the stated uncertainty in the VORF datasets. In this way, the accuracy of the composite bathymetric dataset across the intertidal can be considered to be within ±0.3m, whilst the accuracy of the dataset across the remaining extent can be considered to be within ±0.2m. This level of uncertainty is deemed to be within acceptable limits for subsequent use in the detailed numerical modelling phase.

3. Bathymetry Validation

3.0.0.3 The validation of the bathymetry data has previously been described in ABPmer (2013b), and is summarised here, with additional information included where requested.

3.1 Background to Bathymetry Validation

3.1.0.1 The further validation of the composite bathymetric dataset has been carried out in response to comments received from Natural Resources Wales (NRW) in their letter of 14th May 2013 and also in their consultation response to the Preliminary Environmental Information Report (PEIR) date 5th August 2013. Specifically, NRW requested information to show that the bathymetric data being used to characterise some of the most potentially sensitive areas of the seabed and foreshore is representative of the current topography and elevation.

3.1.0.2 A further review of bathymetry data has been offered which serves to validate the suitability of the existing information. The review is supplementary to previous comments on the choice of bathymetry data used to support the preparation of a detailed coastal process model which have been reported in the following documents:

i. ABPmer, 2013a. Swansea Bay Tidal Lagoon: Bathymetry Data Preparation. Report No. R2111TN; and
ii. ABPmer, 2013c. Swansea Bay Tidal Lagoon Coastal Processes: Model Setup, Calibration and Validation. ABP Marine Environmental Research Ltd. Report No. R2108TN.

3.2 Bathymetry Validation Process

3.2.0.1 Two separate exercises are reported to demonstrate validation of the present bathymetry:

- Further comment to underpin the case that the existing dataset demonstrates the best available option for bathymetry and that it remains suitable for the purposes of the present EIA.
- Comparison of the existing data with other independent validation data to demonstrate that the information currently being used is representative of the current situation.

3.2.0.2 The available bathymetric data is described further in Section 3.4, which also includes consideration of the suitability of each for use in creating the composite bathymetric dataset. The validation of the composite dataset is described further in Section 3.5, and the validation process makes use of some of those datasets identified in Section 3.4, but not used to create the composite bathymetry.

3.3 Approach to Compiling Bathymetry

3.3.0.1 The approach to developing a compiled bathymetry is based on achieving the best available information which is fit-for-purpose for the applications of that data. For coastal process studies, the primary application of the data is describing the levels for interpolation onto a detailed model grid which is focussed on Swansea Bay and extends across a wider area.

3.3.0.2 In the present case, the model being applied is an existing model which already includes Swansea Bay at a broader scale and has previously been considered fit-for-purpose in relation to studies for the Severn Tidal Power SEA (DECC, 2010) and the Atlantic Array EIA (ABPmer, 2013d). To ensure this model is also suitable to support the coastal process investigations for the Swansea Bay Tidal Lagoon the model grid has been refined and deliberate efforts have been made to improve the source data which underpins the definition of water depths across the grid.

3.3.0.3 Many studies of this type might simply select the data available from digital products such as Seazone and assume that this type of information provides the most up to date and accurate description of bathymetry. However, as an experienced user of coastal models ABPmer understand the importance of compiling a data set that can be audited, where the quality of individual data sets is clearly understood and how this understanding can help underpin the selection of the most suitable data. In addition, this approach also allows for the inclusion of other data, such as developers site-specific surveys.

3.3.0.4 Our consideration of the suitability of any dataset includes for:

- Verifying that the information is up-to-date and sufficiently representative.
- Understanding the level of detail provided by the data is consistent to the way the information will be used (i.e. high resolution data for a high resolution grid, etc.).
- Ensuring that geo-referencing of the information is clearly stated to enable further manipulations to a common frame.
- The accuracy of the information can be determined from a survey report.

3.3.0.5 Ideally, the bathymetry requirements would be met by a single dataset capturing the detail of all relevant levels for a single moment in time. However, rarely if ever is this possible or practical, noting that even a single dataset will represent the period of time required to complete the survey. In addition, for very dynamic areas the form of the seabed may also be prone to rapid changes that may mean that a single survey becomes quickly out of date. For these areas it becomes more important to understand the dynamism and to adopt a representative data set. This dynamism may indicate a clear trend or an envelope of variation, or a superposition of the two processes.

3.3.0.6 Consequently, multiple datasets must be merged together to fulfil the overall requirements and the associated issues managed in developing a composite description formed of several datasets. Additional considerations are then made, including:

- Verification that the assembled data provides complete coverage or minimises the potential for any large data gaps.
- That the junctions between adjoining data do not introduce inconsistencies (n.b. this may be especially important when the data are from different sources, time periods or have different original geo-referencing).

3.3.0.7 On the basis of all these considerations it may not always be the case that the latest dataset is necessarily selected in preference to an older dataset, especially where the former is of lower quality, potentially introduces more data gaps or is unrepresentative of the general state of the environment.

3.3.0.8 A further important consideration is the availability of data within the junction between sub-tidal data surveyed by vessels and inter-tidal data surveyed by land levelling, or other similar means. Ideally, the sub-tidal data would extend as far as possible towards the coast (e.g. above mean sea level or thereabouts) and the inter-tidal data would extend as far as possible into the sea (e.g. towards mean low water spring tide) and where possible the two datasets overlap. A further issue in terms of managing this interface is that land levelling and offshore datums are different and a correction must be applied to bring the two datasets to a common vertical datum. A reliance on data products such as Seazone would not enable an accurate definition of this important interface as Seazone is essentially a derivative of sub-tidal data licensed from UKHO. The data used in developing the composite bathymetry dataset provided the most suitable data coverage of this junction.

3.4 Assessment of Available Data

3.4.0.1 Here we offer further comment to underpin the case that the existing dataset demonstrates the best available option for bathymetry and that it remains suitable for the purposes of the present EIA.

3.4.0.2 Various data have been assessed for use in the development of the compiled bathymetry applied to the model grid for Swansea Bay, and also for use in subsequently validating this dataset. The assessment has taken through the data that is considered to meet the project requirements and not all the data has been applied. The assessment process considered the following information.

3.4.1 Inter-tidal data

(i) Swansea Bay beach profiles This data appears to be output from a single survey rather than a sequence of on-going monitoring, provided by SEACAMS (Sustainable Expansion of the Applied Coastal and Marine Sectors), Swansea University. Individual profile lines are too widely separated to support direct interpolation onto a detailed model grid but the data remains helpful in validating beach levels in their local context, and has been used in the validation stage.

(ii) Annual beach profiles (1998 to 2013). This data is an extract of an ongoing monitoring exercise which also extends beyond Swansea Bay, with data provided by the Swansea and Carmarthen Bay Coastal Engineering Group (SCBCEG). The advantage of a monitoring campaign is that a succession of beach profiles over time enables the context of variations to be considered where there is consistent spatial coverage. For this dataset, the relative timing of each profile within a year also remains important for seasonal influences as does the tidal range. For example, the data from 2008 taken on 10 June 2008 was an intermediate tide with low waters outside of the working day, consequently the profile only extended to just above MLWN. As above, the relative wide spacing between profiles does not support complete spatial interpolation for a model grid. This data has been considered previously as part of the technical baseline studies underpinning the present Shoreline Management Plan and is reviewed in Pye (2009) and is helpful in establishing a bounding envelope of dynamism for these specific locations.

(iii) LIDAR Data. The Project Team has explored the inventory of LIDAR from the EA Geomatics Group to determine the suitability of this information for definition of the inter-tidal area. The survey method relies on airborne mapping and limited ground-truthing to derive a high definition topographic surface of land levels. A number of separate datasets exist for Swansea Bay and for temporal periods including the following years; 2001, 2003, 2006 and 2011. Each survey provides a different level of resolution but without a single dataset providing 100% coverage. In addition, all the surveys have degraded information towards low water. Between the surveys a complete coverage can be developed around the bay, however, junctions between datasets from different years are quite marked and some differences occur in locations where a natural variation would not be expected, suggesting a quality issue.

(iv) Coastline Response Study (CRS). A topographic survey of the inter-tidal was commissioned to support a coastline response study for the area from Worms Head to Lavernock Point, South Wales. The survey was phased to occur with a spring tide on 26 August 1991 in order that coverage could extend beyond MLWN and towards MLWS. The survey method combined aerial mapping and local ground-truthing (beach cross sections around every 1km) to develop a verified high resolution dataset with 100% coverage. The final output comprises of contours at 1m increment, 50m gridded levels, and tied-in profiles. This data has been assessed as the most complete dataset of the intertidal that can be merged with sub-tidal data. In the compilation process, the data is superseded by more recent data where that data can be considered to offer better information.

3.4.2 Sub-tidal data

(v) UKHO surveys. Within Swansea Bay the current navigation chart (Chart 1161 Swansea Bay, 1:25,000) relies upon sub-tidal levels from a survey (in two parts; east and west of the bay) dating from 1980. Such charts are normally updated on a regular basis when the sub-tidal levels are subject to high rates of change and especially for areas adjacent to major ports.

(vi) Tidal Lagoon Swansea Bay surveys. In 2012 a survey of the proposed lagoon location was surveyed in high-resolution. This information supersedes both UKHO and CRS data in overlapping areas.

(vii) ABP Swansea. Data from the most recent 2012 survey of the approach channel into Swansea Docks has been acquired and is used to define levels in this location, superseding any older data for the same area.

(viii) Neath Estuary data. A survey from 2010 along the approach channel into the River Neath. This data is helpful to compliment the inter-tidal data which does not survey within the channel and fill a potential data gap with good quality high resolution information.

(ix) Titan Survey Data. A special survey carried out in 2005 to validate an existing model bathymetry for Welsh Water. The data comprises of a number of transect lines across the bay. This data is helpful to provide an independent data source against which to compare the composite dataset over the sub-tidal, and has been used in the validation stage.

3.5 Bathymetry Validation Comparisons

3.5.0.1 The validation stage compares the data selected for compilation of the model bathymetry with other validation data to further investigate, on a quantitative basis, how representative the information currently being used is of the current situation, and also in the context of the historical variation, where data allows.

3.5.1 Intertidal data: Comparison against annual beach profiles (1998 to 2013)

3.5.1.1 A series of profiles from the composite bathymetry dataset have been plotted against the annual beach profiles collected between 1998 and 2013, as reported in Pye (2009) and updated with data from SCBCEG. There are two profiles located in the western part of the bay, close to Blackpill; two profiles between Swansea Dock and the River Neath, in proximity to the Crymlyn Burrows; one profile fronting Aberavon Sands; and a further profile fronting the Kenfig Burrows. The profiles are shown in Figure 4, with their relative locations around the bay shown in Figure 3.

3.5.1.2 Analysis of the SCBCEG beach profile data for the period 1998 to 2013 at Blackpill (Profiles 205 and 206) identifies a general reduction in beach/ intertidal levels, and a slight landward movement of HAT and MHWS. These observed reductions are relatively consistent along the length (chainage) of the beach profiles, with changes in the region of approximately 0.3 to 0.5 m (i.e. losses of 0.02 to 0.03 m per annum).

3.5.1.3 A comparison of beach profiles from along the Crymlyn Burrows frontage in front of the Swansea University Bay Campus (SUBC) Development (Profiles 214 and 215, approximately 750 m further to the east), identifies that there is a landward migration of an intertidal bar along the Crymlyn shore. This sand bar feature appears to have migrated circa 550 m over the 15-year period (as seen in Profile 215). As this feature approaches the shore at this location, slowly driven in a non-linear fashion towards the shore by the prevailing wind and waves (Beckett Rankine, 2009), it has lost both height and volume whilst the remainder of the beach appears to have been subject to healthy accretion. In contrast, whilst the landward migration of this sand bar can also be identified at Profile 214, beach elevations at this location are considerably more variable with no distinct medium to long-term pattern, i.e. both erosion and accretion of the upper and lower intertidal can be seen over this 15-year period.

3.5.1.4 Contrastingly, further to the east at Aberavon Sands (Profile 220), there has been an observed steepening of the beach between 2008 and 2013, whereby there has been an increase in upper beach levels between approximately 20 and 230 m chainage, with a reduction further offshore. Overall however, there has been a general reduction in beach levels of approximately 0.5 m between 1998 and 2013.

3.5.1.5 To the south of Port Talbot, beach profile analysis undertaken at Kenfig Burrows, for the period 1998 to 2013 (Profile 228), indicates a slight landward movement of MHWS between 1998 and 2008. This has remained largely stable between 2008 and 2013, even showing signs of a small seaward movement of HAT over this period. Further along the beach profile (i.e. 100 to 400m chainage), clear gains in elevation of approximately 0.1 to 0.4 m have been observed between 2008 and 2013, following losses previously seen between 2003 and 2008. This recent reversal from erosion to accretion would suggest that sand supply to this system has been relatively healthy over the past 5 years.

3.5.1.6 The composite profiles shown in Figure 4 generally demonstrate a good level of comparison with the annual beach survey data, with each tending to sit within the envelope of historic variation displayed by the data collected between 1998 and 2013. In this way, it is generally evident that the profiles from the composite dataset are not situated at the extremes of the envelope of historic variation, and can be considered to be representative of the topography observed at this location.

3.5.2 Subtidal data: Comparison against Titan (2005) survey data

3.5.2.1 A series of five profile lines across the outer bay have been plotted against the survey data collected by Titan during 2005. The profiles extend across the full width of the subtidal and offshore from the Port of Swansea to Port Talbot (see Figure 3).

3.5.2.2 The comparison of the five profiles is shown in Figure 5. As with the intertidal comparisons, the composite profiles shown in Figure 5 are derived from a number of source datasets (the limits of which are defined on the profiles).

3.5.2.3 It is seen that the profiles from the composite profiles compare well with the Titan (2005) survey data, with average differences in elevation of approximately 0.15m, across each profile. Maximum differences in elevation are observed in and around the dredged channels forming the approaches to Swansea, Neath and Port Talbot (as can be seen in Figure 5). Overall, it is considered that the composite profiles compare favourably against the Titan dataset over the subtidal part of the Bay.

3.6 Summary of Bathymetry Validation

3.6.0.1 The comparison of the composite dataset against independent bathymetry data has been undertaken to validate that the information currently being used is representative of the current situation. The bathymetric profiles presented show that the composite dataset compares well with both the recent Titan survey data and also when compared against the envelope of historic variation in the topography at a number of locations around the bay.

3.6.0.2 The 20m x 20m resolution composite bathymetry dataset has been interpolated onto a numerical model mesh, in order that the baseline environment across Swansea Bay and the wider area can be characterised for EIA purposes. The model calibration and validation report (ABPmer, 2013a) shows that this model is able to represent the hydrodynamic and wave characteristics of the study area well; by association, therefore, it can be considered that the composite bathymetry dataset used is fit for the intended purpose of developing a well-calibrated model.

3.6.0.3 There remains the possibility of utilising additional bathymetric or topographic where they may assist in helping to characterise and qualify the context of natural variations over a local-scale (i.e. where making use of a continuous dataset may be considered less important).

4. Bathymetry Sensitivity Testing

4.0.0.1 Following consultation with stakeholders (including NRW and Cefas), on the Preliminary Environmental Information Report (PEIR), a series of sensitivity tests were agreed to investigate the effect that changes to the model bathymetry may have on the performance of the hydrodynamic and wave models, and to further improve confidence in the model output. The rationale behind these sensitivity tests, and the results are described further in the following sections of the present report.

4.1 Rationale for Sensitivity Testing

4.1.0.1 Following consultation on the outcomes of the bathymetry validation stage (as described in Section 3), it was considered that whilst the comparisons of beach profiles showed the composite bathymetry was within the envelope of natural historic variability, some differences existed when compared to the most recent data. These differences specifically revealed that the elevation of the foreshore around Swansea Bay, exhibited a varying degree of natural variability (as shown by the annual beach profile data in Figure 4). In addition, the location of the sand bar feature on the Crymlyn foreshore was observed to show a general landward migration over time, and a similar sand bar feature in the western part of the bay (to the north of Blackpill, and fronting the Swansea University campus) was found to have been absent in the input bathymetry data (and, hence, also absent from the composite bathymetry).

4.1.0.2 It is worth noting here that the beach profile analysis described in Section 3.5.1 has revealed likely differences in the longevity of the two sand bar features described. Whilst the sand bar feature fronting Crymlyn Burrows is shown to exist throughout the monitoring period (1998 to 2013), the sand bar in the western part of the bay (north of Blackpill) appears to be a more recent feature, apparent in the profiles since approximately 2006. As such, it may be considered that this latter feature is a more transient bedform, which may not always be observed. Conversely, whilst it has been shown to exhibit a generally landward migratory trend, the feature fronting Crymlyn might be considered to be a more permanent feature of the bathymetry in this region.

4.1.0.3 As a result of the consultation on the validation review, the following sensitivity tests have been carried out, in order to investigate the potential effects on the outputs of the baseline hydrodynamic and wave models:

i. Increasing and decreasing the elevation of the foreshore along the eastern and western parts of the bay by an amount equivalent to one standard deviation in the average measured beach profile elevation between 1998 and 2013 (considered to be representative of the range of natural historic variability in these regions);
ii. Increasing and decreasing the elevation of the foreshore along the north-eastern area of the bay (fronting the Crymlyn Burrows and Aberavon Sands) by an amount equivalent to one standard deviation in the average measured beach profile elevation between 1998 and 2013 (this section of the bay was found to exhibit a slightly larger degree of variation in annual mean elevation than the eastern and western parts of the bay);
iii. Inclusion of the sand bar feature in the western part of the bay (fronting the Swansea University campus);
iv. Landward movement of the sand bar feature on the foreshore fronting the Crymlyn Burrows (considered to be more representative of the location of this feature in the latest beach profile survey in 2013); and
v. Seaward movement of the sandbar feature on the foreshore fronting the Crymlyn Burrows (considered to be more representative of the historic location of this feature in the earliest beach profile survey in 1998).

4.1.0.4 When including or adjusting the location of the sand bar features (in points iii to v, above), the height of the feature has been informed by the measured beach profile data, and the extent has been informed through both the beach profile data and also analysis of satellite imagery (Google Earth, 2014).

4.1.0.5 The results of these sensitivity tests are provided in the following Section.

4.2 Results of Sensitivity Testing

4.2.0.1 The sensitivity tests on the model bathymetry (as listed above) have been carried out on the baseline model (i.e. before any inclusion of the proposed scheme), and the results of each test have been compared against the original baseline scenario (with no adjustments to the bathymetry). The resultant effects on the performance of the model (in terms of changes to both water levels and flow speeds) are presented in Figures 6 and 7, and discussed further below.

4.2.0.2 The results provided in Figure 6 show the predicted water levels for the original bathymetry and for each of the different sensitivity tests, at a number of locations across Swansea Bay. For the locations that do not dry at low water (the proposed lagoon site and a point offshore of Crymlyn Burrows), the results show that there is no predicted effect on either the HW or LW elevation, or the phase of the tide as a result of raising or lowering the bathymetry (as described in (i) and (ii), Section 4.2). At the remaining sites, which dry out at LW, the results again show no predicted difference in the elevation of HW or the phasing of the tide. At these locations, the only observed difference is that the raising or lowering of the bathymetry (either through a general adjustment, or as a result of site-specific changes to the sand bar features), acts to increase or decrease the duration of the drying period around LW.

4.2.0.3 The results provided in Figure 7 show the predicted current speeds for the original bathymetry and for each of the different sensitivity tests, at a number of locations across Swansea Bay. For the locations that do not dry out, the results show that there is a negligible difference in peak flow speed (less than ±0.01m/s). As with the water level results, the shallower locations (that dry out at low water) show a slightly larger predicted difference in flow speeds. As a result of the general raising or lowering of the bathymetry, a predicted difference in peak flow speeds of approximately ±0.01m/s is observed.

4.2.0.4 The largest predicted difference in flow speeds is observed in the sensitivity tests on site-specific adjustments to the sand bar features (Section 4.2, (iii), (iv) and (v)). The inclusion of the sand bar in the western part of the bay results in a predicted increase in peak flow speeds of up to 0.05m/s at a location above the crest of the bar feature. This increase is observed on the peak ebb flow as a result of the lower water depths above the sand bar. The seaward adjustment in the location of the Crymlyn sand bar results in predicted increases in peak flow speed of up to 0.01m/s – again observed on the peak ebb flow as a result of the shallower water depths. Meanwhile, a landward adjustment of the location of the Crymlyn sand bar results in predicted increases of up to 0.04m/s in peak ebb flow.

4.2.0.5 When considering the potential changes to the results of the wave model, adjustments to the model bathymetry for these sensitivity tests were found to have a negligible effect. Both the general raising and lowering of the bathymetry and the site-specific adjustments to the location of the sand bar features resulted in differences in wave height significantly less than 0.01m, in wave period of less than 0.05s and in wave direction of less than 0.1°.

4.3 Discussion

4.3.0.1 A number of sensitivity tests on adjustments to the model bathymetry have been undertaken to investigate the effect on model performance. These tests have demonstrated that raising or lowering the bathymetry by an amount equivalent to one standard deviation in the annual mean profile elevation (between 1998 and 2013) has no discernible effect on either the elevation of or the phasing of the tide. As might be expected, adjustments to make the bathymetry deeper or shallower does result in changes to the duration of intertidal exposure around low water, with larger changes in bathymetry resulting in larger changes in the duration of the drying time. From the tests undertaken, the general raising and lowering of the bathymetry resulted in changes to LW exposure in the order of 10 minutes. Local changes to the location of the sand bar features resulted in changes in LW exposure in the order of 30 minutes, although these changes were only observed at the sand bar location, with no observed changes in exposure outside of these sites.

4.3.0.2 As a result of the general raising and lowering of the bathymetry, predicted changes in flow speeds ranged from less than ±0.01m/s in subtidal locations, to up to ±0.01m/s in shallower intertidal sites. Larger changes of up to 0.04m/s were observed when making adjustments to the sand bar features, but as with changes to water levels, these predicted changes are limited in extent to the location of the sand bar feature only. No observed changes in flow speeds are observed outside of these sites. In all cases, the raising of the bathymetry (resulting in a shallower water depth) acted to increase in flow speeds, whilst lowering the bathymetry (resulting in a deeper water depth) acted to reduce flow speeds.

4.3.0.3 Differences in the outputs of the wave model, as a result of the sensitivity tests on model bathymetry have revealed negligible effects. Effects on wave height, period and direction were found to be significantly lower than 0.01m, 0.05s and 0.1°, respectively.

4.3.0.4 When taking account of the predicted magnitude and extent of differences in water levels and flow speeds, it is considered that the results of the sensitivity tests show that the adjustments to model bathymetry do not have a significant effect on model performance (either locally or more generally across the wider study area).

5. References

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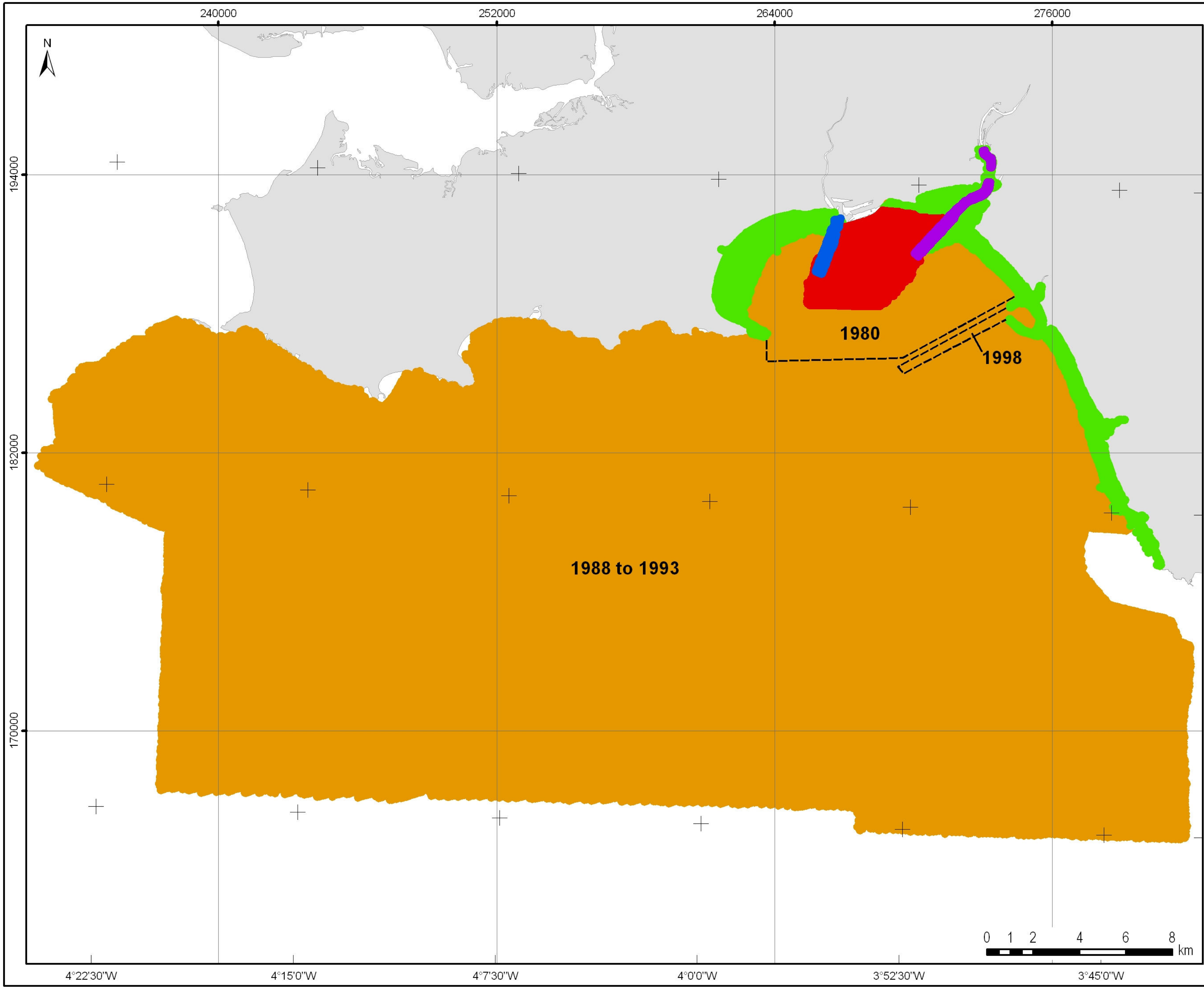
Figures



- ABP Swansea (2012)
- Neath Estuary data (2010)
- TLSB bathymetry survey (2012)
- Coastline Response Study (1991)
- UKHO
(including approximate survey areas and associated dates)

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Gridded bathymetry created from multiple datasets
NOT TO BE USED FOR NAVIGATION

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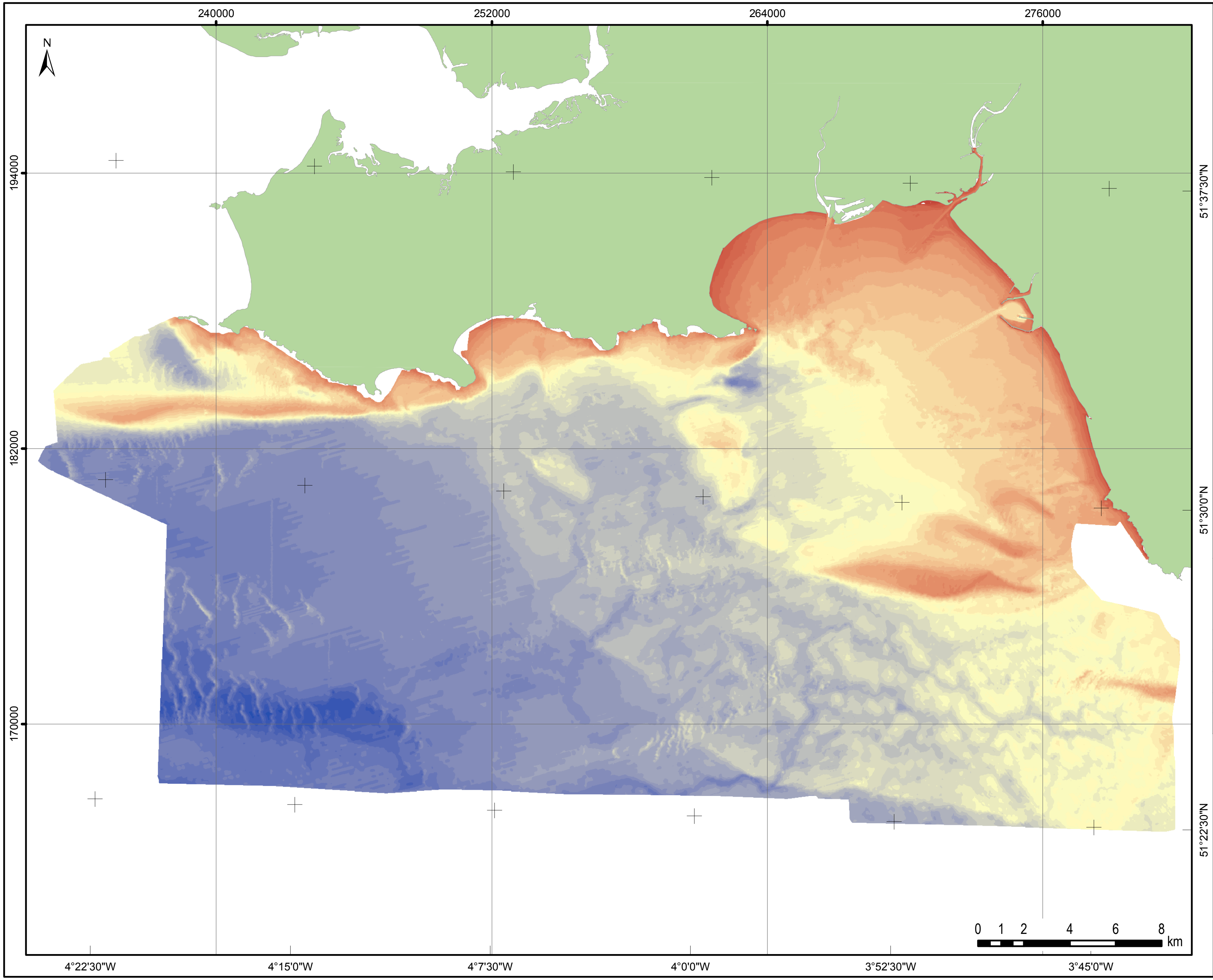
Sources of bathymetry data for local Swansea Bay region

Figure 1



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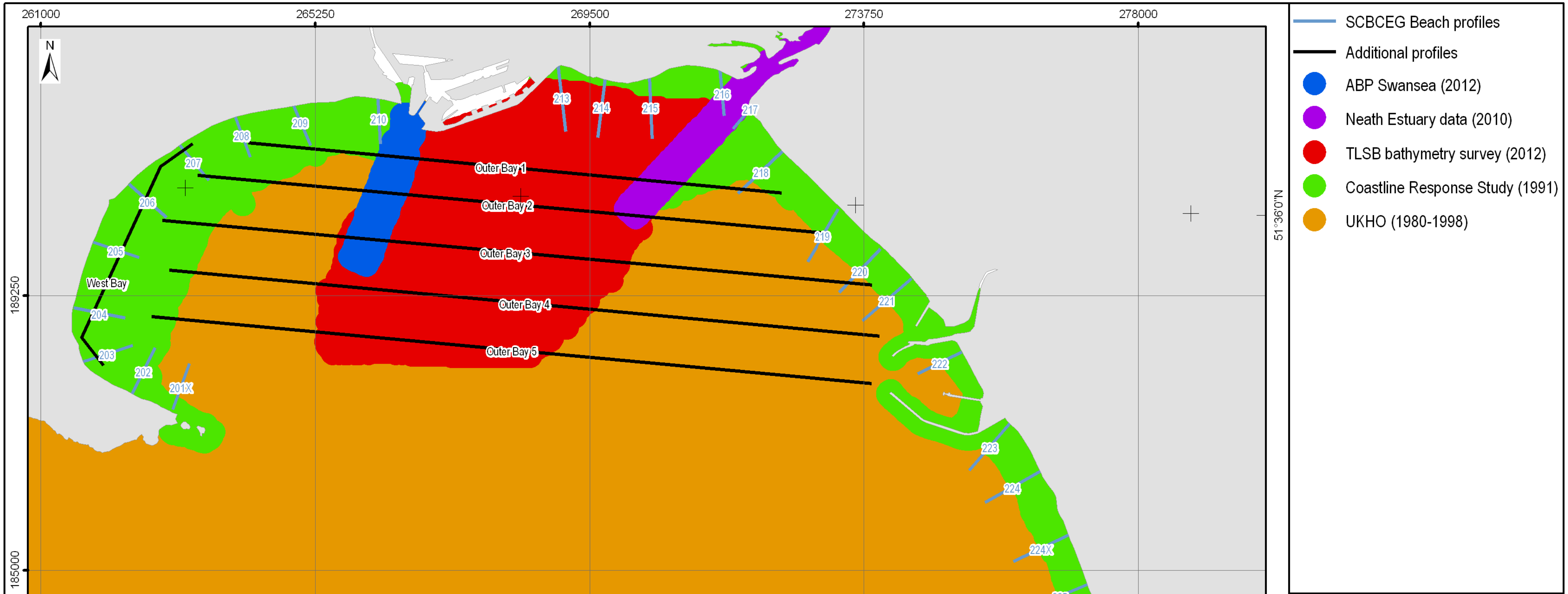
Gridded bathymetry surface created from composite data sources

Figure 2



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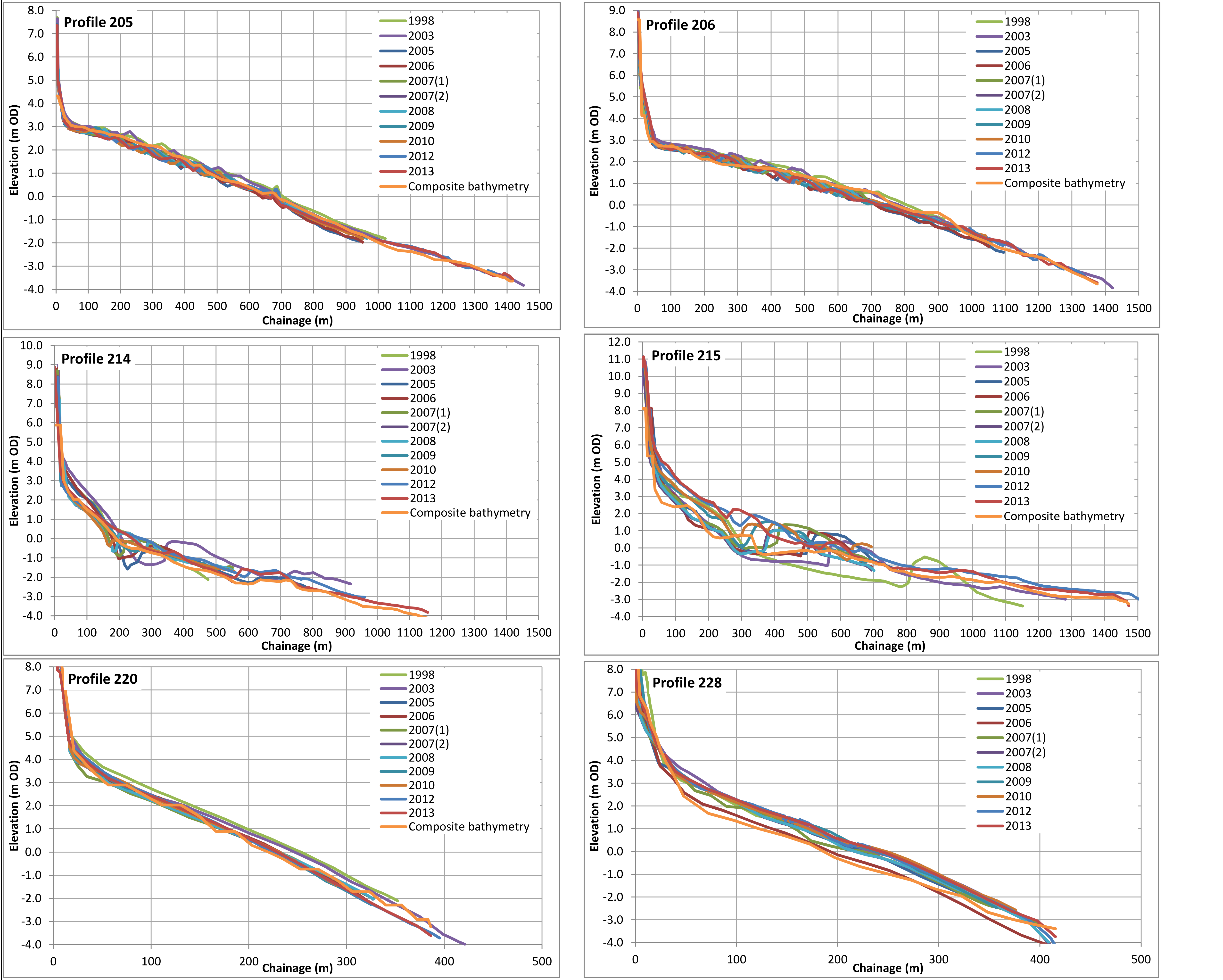
Location of bathymetric and topographic profiles

Figure 3



Note: Differing axes on plots

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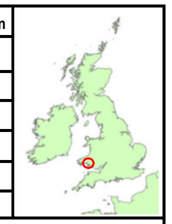

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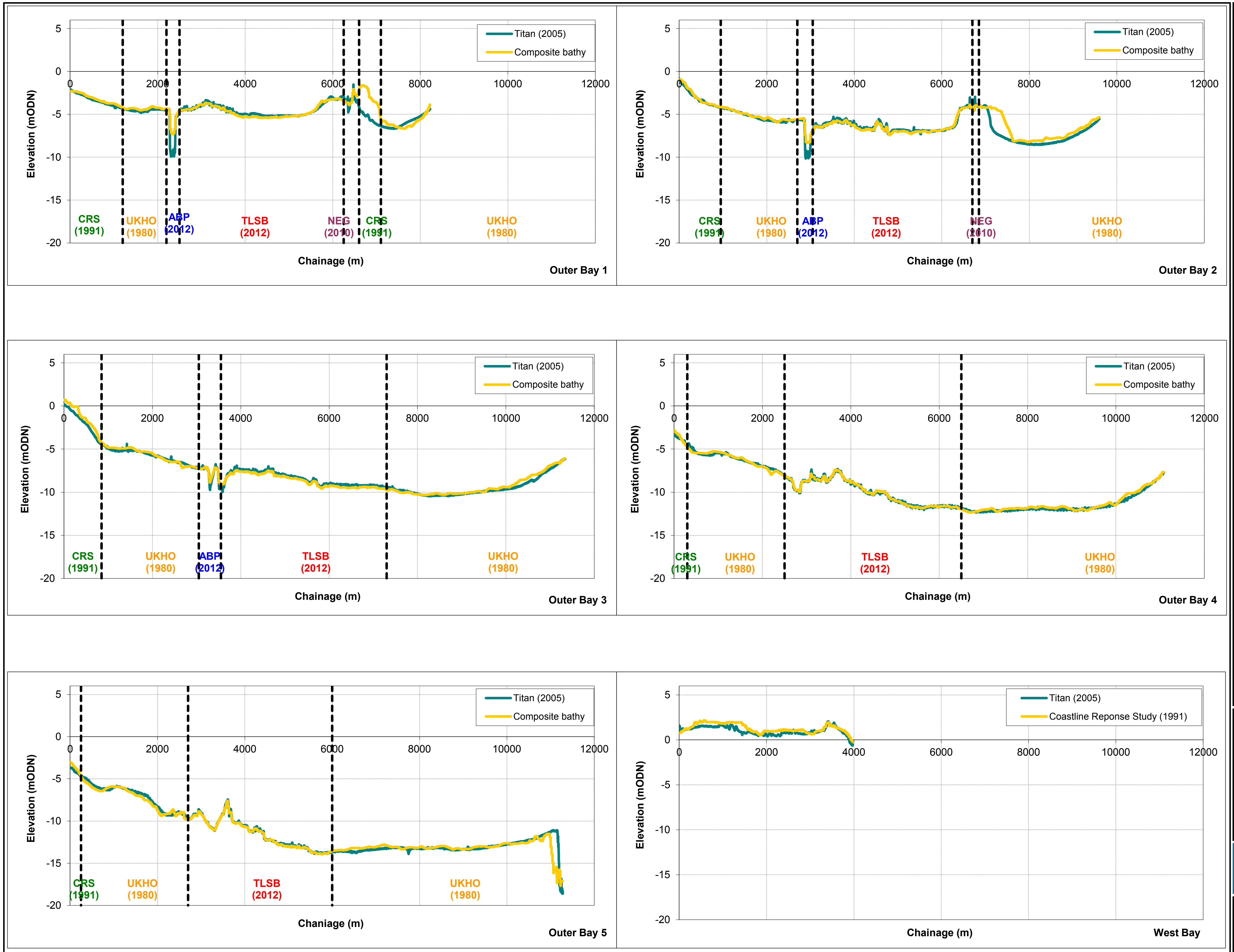
Beach profile comparisons

Figure 4



--- defined limits of survey data:

CRS Coastline Response Study
UKHO UK Hydrographic Office
ABP Associated British Ports
TLSB Tidal Lagoon (Swansea Bay)
NEG Neath Estuary Group

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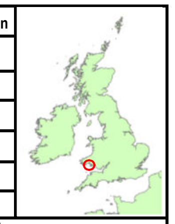

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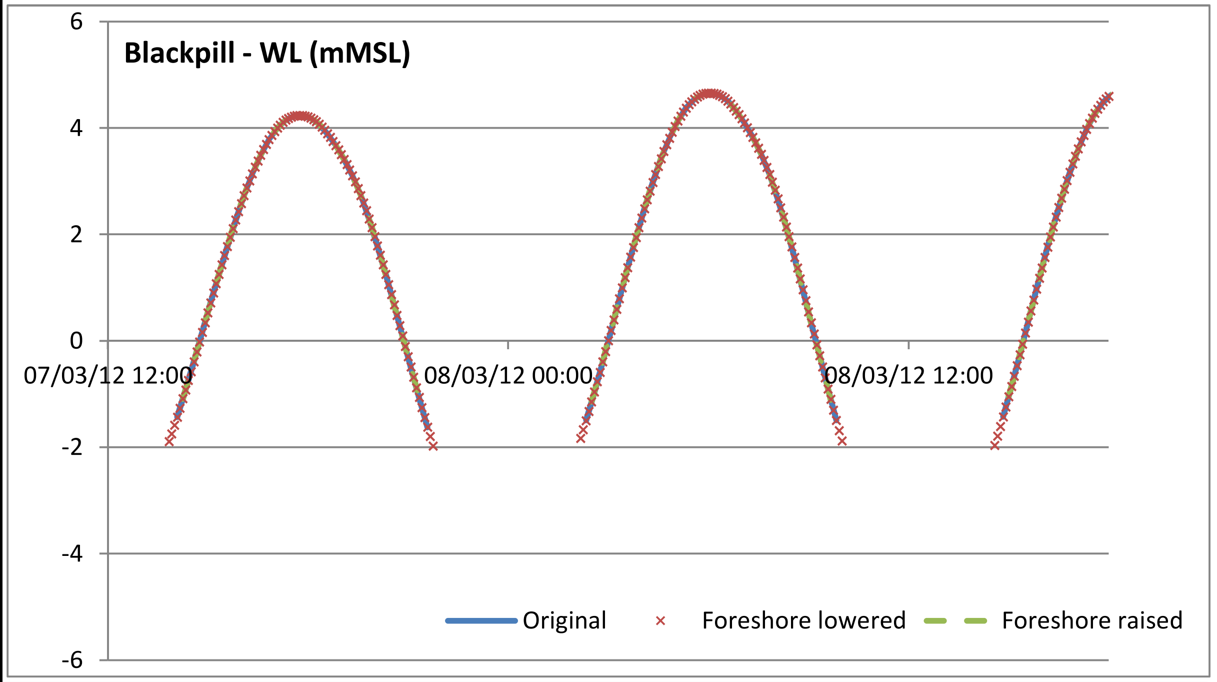
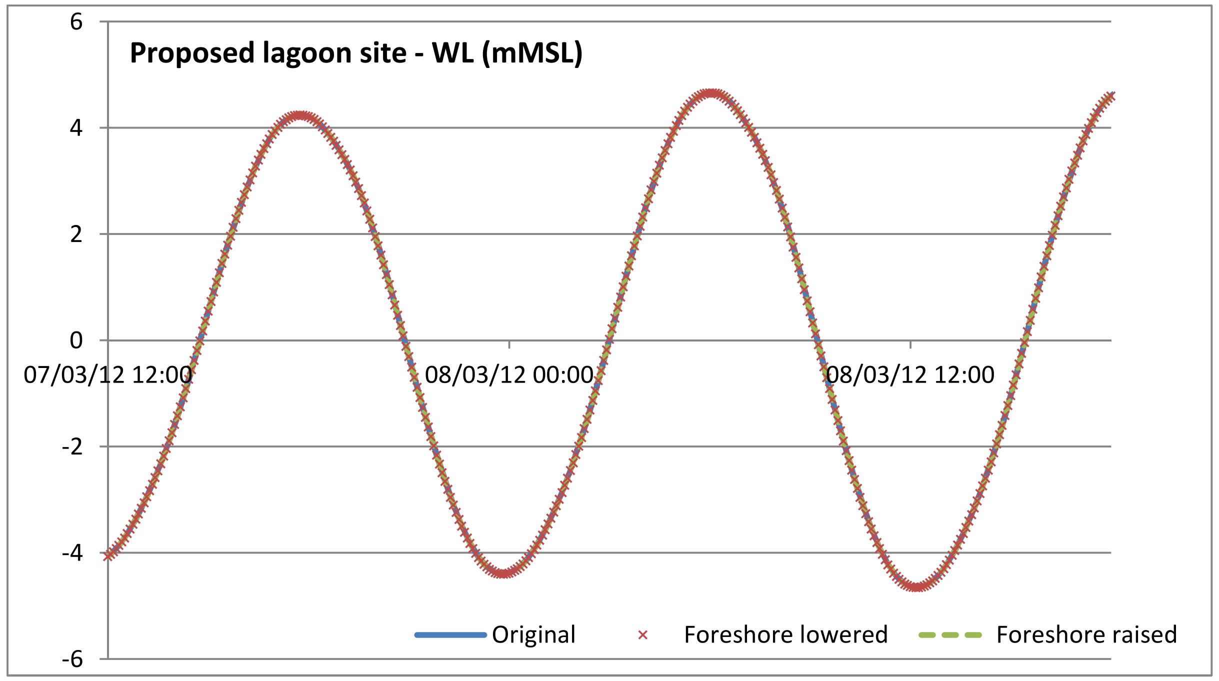
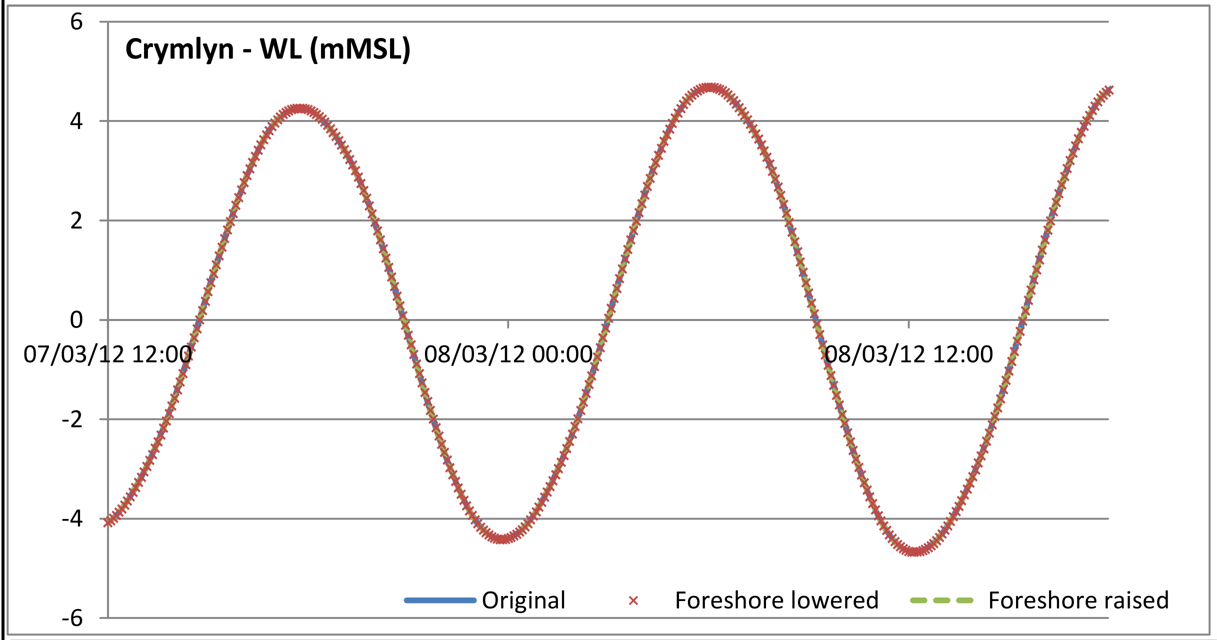
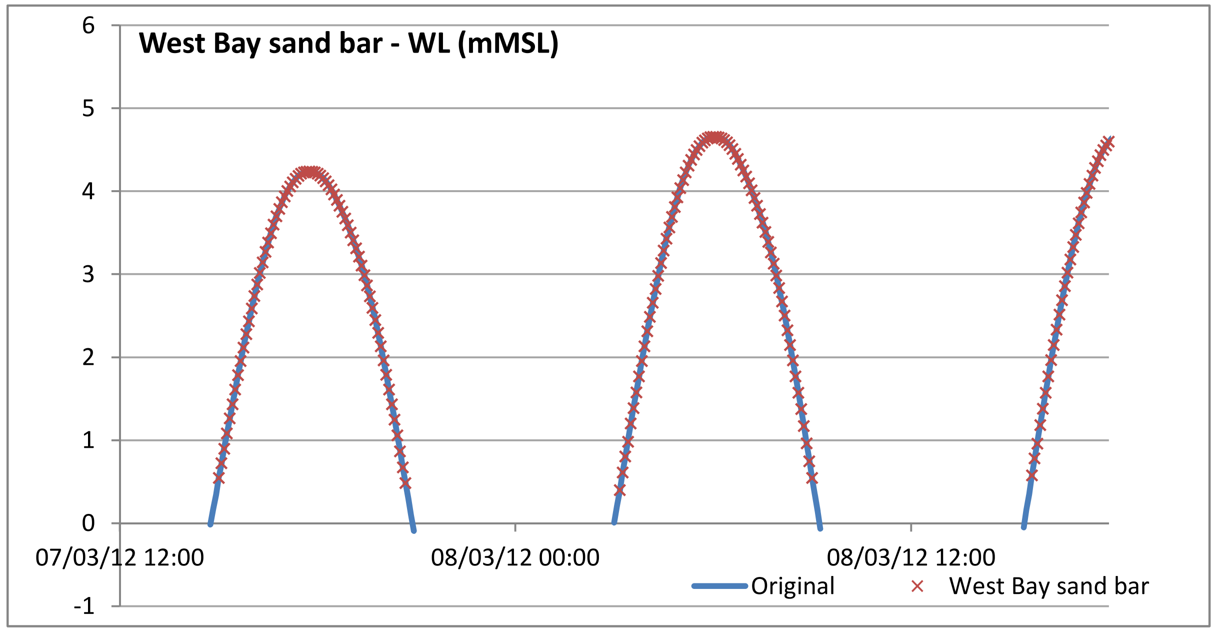
Outer and West Bay profiles

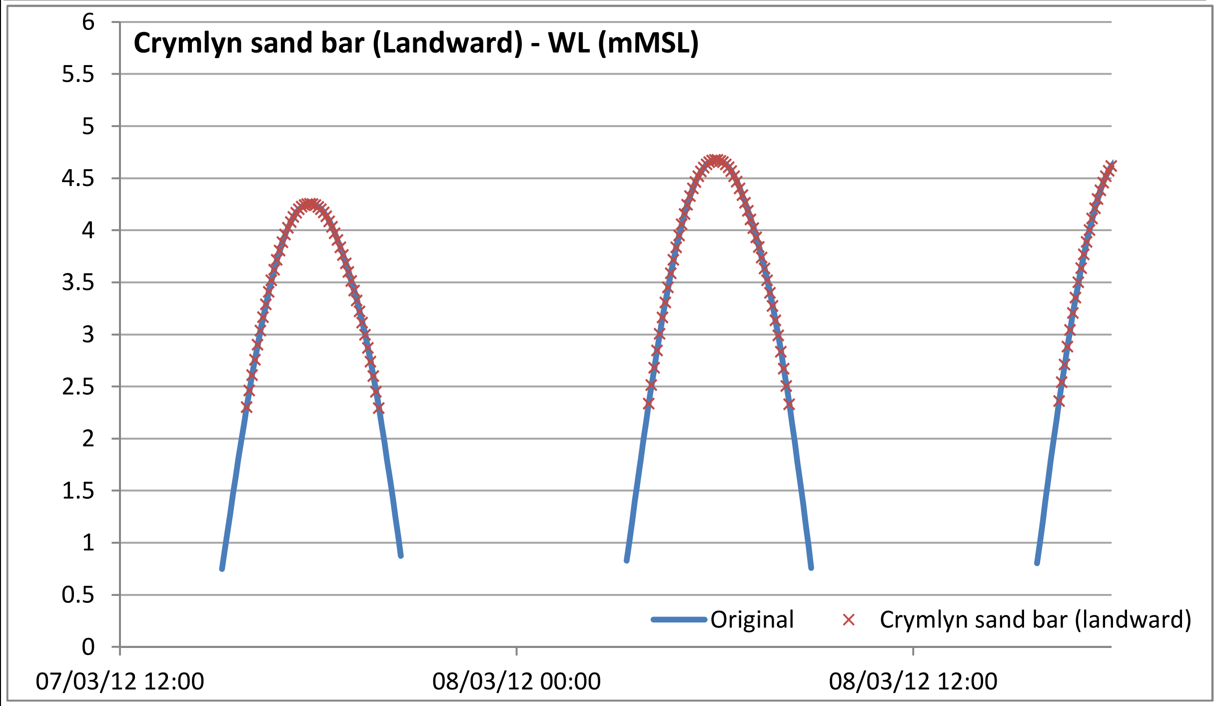
Figure 5

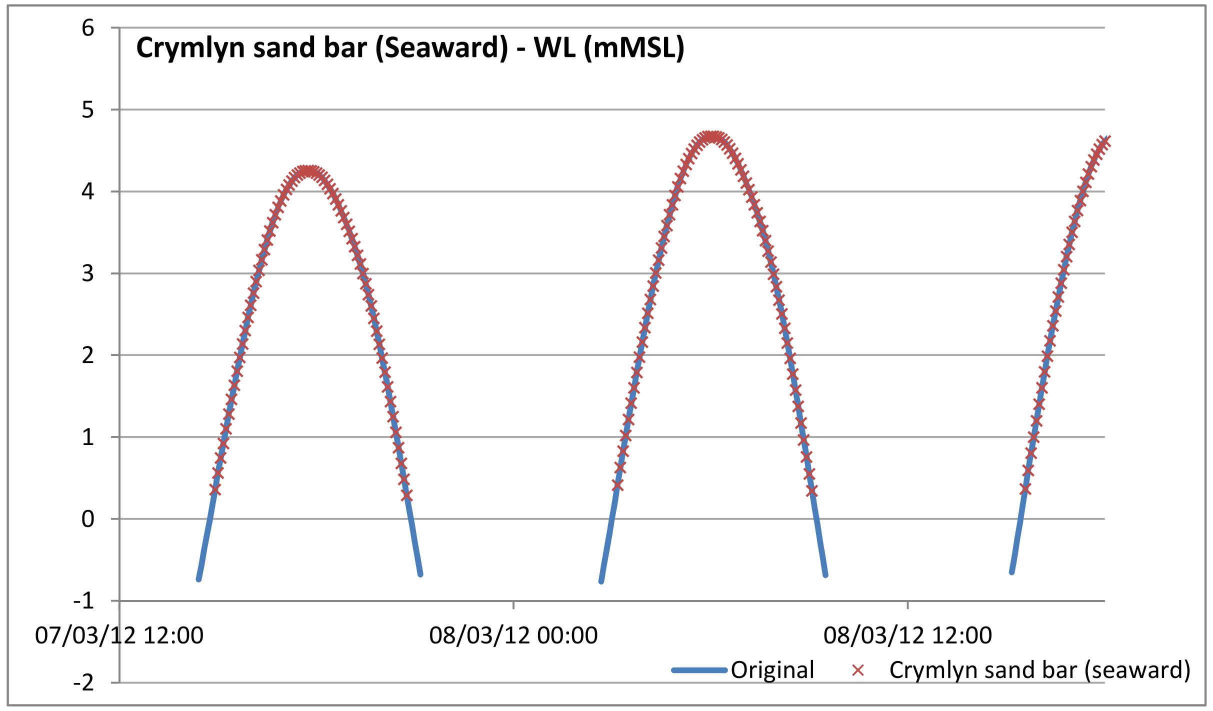












Note: Differing axes on plots

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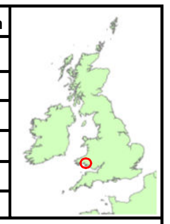

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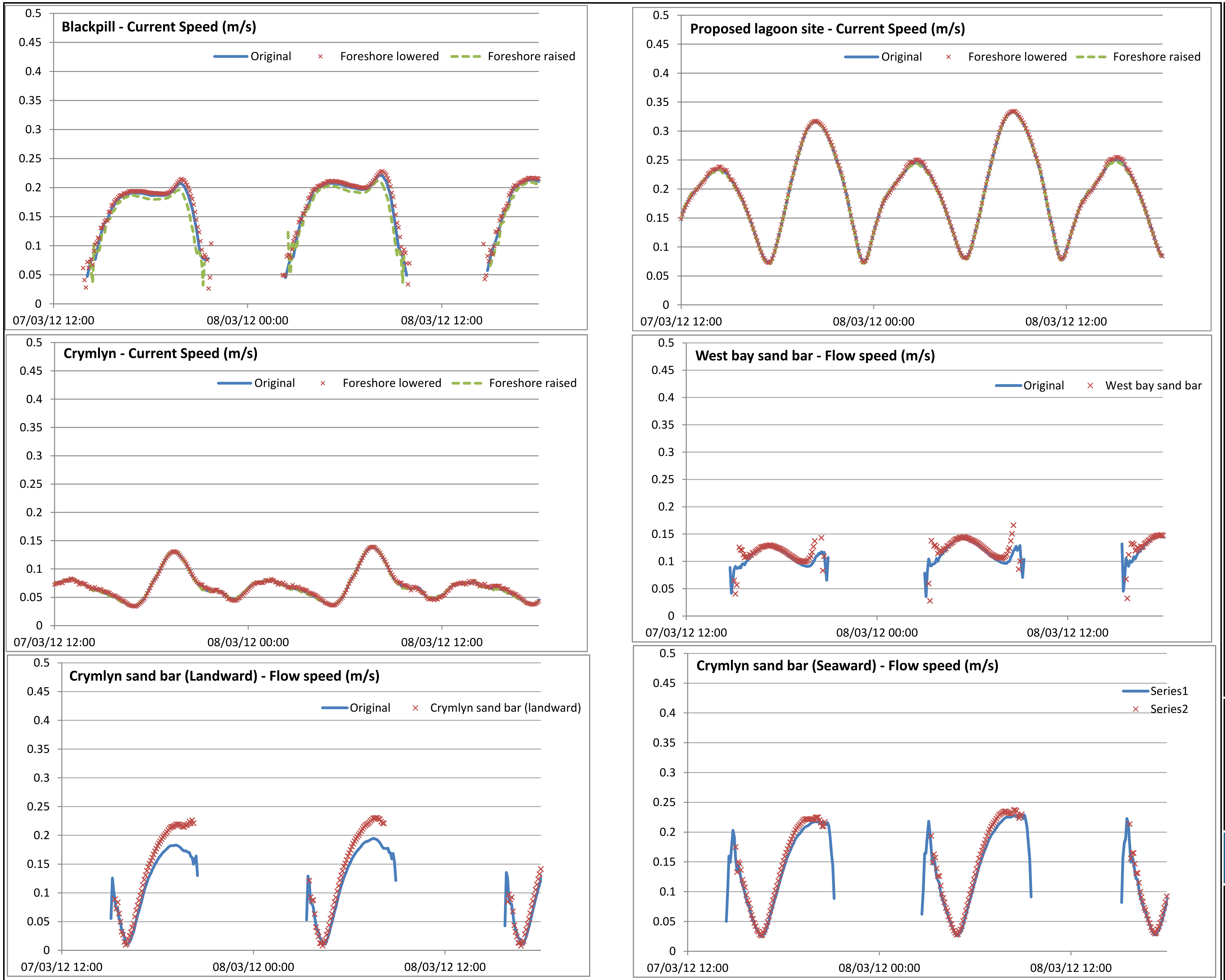
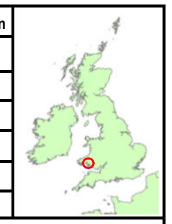
Comparison of modelled water level

Figure 6





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Comparison of modelled current speed

Figure 7

ABP Marine Environmental Research Ltd (ABPmer)
Quayside Suite, Medina Chambers, Town Quay, Southampton SO14 2AQ

T +44 (0)23 80 711840
F +44 (0)23 80 711841
E enquiries@abpmer.co.uk

www.abpmer.co.uk

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