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Understanding the likely scale of deterioration of Marine Protected Area features due to coastal squeeze: Volume 1- Methodology

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Acronyms, abbreviations and glossary of key terms used in assessment

Term	Acronyms, abbreviations description
AS	Accommodation Space
ATL	Advance The Line – SMP2 Policy
ATT	Admiralty TotalTide
AU	Assessment Unit
CD	Chart Datum
CSAT	Coastal Squeeze Assessment Tool
DTM	Digital Terrain Model
EUNIS	European Nature Information System
FA	Foreshore Area
GIS	Geographic Information System
GN	Guidance Note
H	Harmonic
HAT	Highest Astronomical Tide
HRA	Habitats Regulations Assessment
HTA	Historical Trend Analysis
HTL	Hold The Line - SMP2 Policy
ID	Identification
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide

LiDAR	Light Detecting and Ranging (elevation data)
MCZ	Marine Conservation Zone
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPA	Marine Protection Area
MR	Managed Realignment - SMP2 Policy
MSL	Mean Sea Level
NAI	No Active Intervention - SMP2 Policy
NCERM	NRW National Coastal Erosion Risk Management (Map data layers)
NH	Non Harmonic
NRW	Natural Resources Wales
NTL	Normal Tidal Limit
ODN	Ordnance Datum Newlyn
OS	Ordnance Survey
RCP	Representative Concentration Pathway
SAC	Special Area of Conservation
SFDwA	NRW Spatial Flood Defence with Attributes data layer
SLR	Sea Level Rise
SMP	Shoreline Management Plan
SMP2	Second iteration of the Shoreline Management Plans

SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
TBD	To Be Determined
TFE	Tidal Frame Extent
UCL	University College London
UK	United Kingdom
UKCP	UK Climate Projections
UKCP18	UK Climate Projections 2018
UKHO	United Kingdom Hydrographic Office
VORF	Admiralty Vertical Offshore Reference Frame
WCMC	Wales Coastal Monitoring Centre

Term	**Glossary description**
70th percentile	Higher central allowance for sea level rise projections.
95th percentile	Upper end allowance for sea level rise projections.
Accommodation Space	The low-lying area behind anthropogenic structures / natural frontage that could become intertidal if the structure/frontage was not maintained.
Assessment Unit	Represents an anthropogenic structure / natural frontage, that lies within an SMP2 Policy Unit. At their largest scale an Assessment Unit may represent a single SMP2 Policy Unit, however, where there are different structures, and/or a combination of anthropogenic structures and natural frontages, or multiple Accommodation Spaces along a SMP2 Policy Unit, smaller Assessment Units are defined.
Cliffs	Natural cliff frontages along the open coast that are not protected by an Anthropogenic Structure.
CMAP	Modelling package which turns sea chart information/data in digital form into model bathymetries. (Danish Hydraulics Institute).

Foreshore Area	The intertidal area in front of an anthropogenic structure or natural frontage, which extends from present day MLWS to HAT +1 m in 2155.
Habitat Group	An amalgamation of designated habitats features into a single habitat type. Seven Habitat Groups are defined for the national scale assessment.
High Ground	Natural high ground that limits any inundation of the tide into the hinterland.
Hypsometric Analysis	Analysis based on the distribution of different elevations.
Lower to Mid Intertidal	The lower of the three Tidal Frames used in the assessment of intertidal habitat extents (Ranges from MLWS to MHWN).
Management Scenario	The assessment of coastal squeeze and natural squeeze is undertaken assuming three different management scenarios: • Defences Maintained: assumes all existing structures remain in place; • No Defences: assumes all existing structures have been removed or breached, and SMP2 Policy: Presence of structures is informed by SMP2 Policy.
Natural Ridge	A Natural Ridge, such as shingle / dune ridge that has low lying land behind that could be inundated by the tide if the ridge is breached.
NCERM	NRW National Coastal Erosion Risk Management map data layers.
Potential Habitat Extent	Potential Habitat Extent derived from the Tidal Frame Extent and the present-day percentage habitat cover.
Project DTM	Complete DTM covering the intertidal area in front of anthropogenic structures / natural frontages and low lying area behind these structures/frontages that could become intertidal if the structure/frontage was not maintained.
Ramsar sites	Wetlands of international importance designated under the Ramsar Convention.

Rasters	A raster consists of a matrix of cells (or pixels) organized into rows and columns (or a grid) where each cell contains a value representing information, such as temperature. Rasters are digital aerial photographs, imagery from satellites, digital pictures, or even scanned maps.
Structure	A man made structure that prevents landward migration of the intertidal zone such as a sea defence or railway embankment.
Supralittoral	The upper of the three Tidal Frames used in the assessment of intertidal habitat extents (Ranges from MHWS to HAT +1 m).
Swellies	Narrow rocky passage within the Menai Strait notable for shoals, rocks and rapid and variable tidal currents.
Tidal Frame	The tidal range over which the extent of intertidal habitat is considered. Three Tidal Frames are examined: • Lower to Mid Intertidal (MLWS to MHWN) • Upper Intertidal (MHWN to MHWS) • Supralittoral (MHWS to HAT +1 m)
Tidal Frame Extents	Extent of intertidal area calculated through hypsometric analysis.
Upper Intertidal	The middle of the three Tidal Frames used in the assessment of intertidal habitat extents (Ranges from MHWN to MHWS).

Crynodeb Gweithredol

Mae gwasgfa arfordirol yn golygu colli cynefinoedd naturiol neu ddirywiad yn eu hansawdd, sy'n deillio o strwythurau neu weithredoedd anthropogenig, sy'n atal cynefinoedd rhag symud i gyfeiriad y tir mewn ymateb i lefel y môr yn codi. Mae'n bwysau ac yn fygythiad hysbys i Ardaloedd Morol Gwarchodedig (MPAau) ac mae'n achosi (neu'n debygol o achosi) dirywiad neu golli nodweddion arfordirol a rhynglanwol o amgylch arfordir Cymru. Nod y prosiect hwn oedd gwella dealltwriaeth o leoliad, amseriad a graddfa debygol colli cynefinoedd mewn MPAau yng Nghymru oherwydd gwasgfa arfordirol. Mae angen hyn er mwyn cynllunio'n effeithiol ar gyfer adfer ac ail-greu nodweddion cynefinoedd a gollir drwy wasgfa arfordirol, ac felly cynnal cydlyniad rhwydwaith yr Ardaloedd.

Mae'r adroddiad hwn yn rhoi disgrifiad manwl o'r fethodoleg sydd wedi'i chynllunio a'i rhoi ar waith i nodi effaith bosibl gwasgfa arfordirol ar gynefinoedd rhynglanwol Cymru mewn MPAau. Mae'n ffurfio Cyfrol 1 o Adroddiad dwy ran. Mae Cyfrol 2 yn rhoi trosolwg o ganlyniadau allweddol y dadansoddiad.

Cynlluniodd y prosiect hwn fethodoleg er mwyn rhoi dealltwriaeth o effeithiau posibl gwasgfa arfordirol ar nodweddion dynodedig o'r MPA o amgylch arfordir Cymru. Roedd hyn yn cynnwys nodi pa fathau o gynefinoedd a'u nodweddion MPA cysylltiedig a allai fod yn destun gwasgfa arfordirol, a gweithredu modelau rhagfynegol i fesur colli cynefinoedd posibl. Defnyddiodd y prosiect ddadansoddiad hypsometrig rhagfynegol safonol i gyfrifo newidiadau yn fframwaith y llanw o amgylch arfordir Cymru o ganlyniad i lefel y môr yn codi. Yna defnyddiwyd mapiau cynefinoedd cyfredol i roi asesiad mwy safle-benodol o'r cynefinoedd a oedd yn bresennol, ac felly sut y gallant newid dros amser.

Defnyddiodd y fethodoleg haenau data newydd eu creu, dadansoddiad System Gwybodaeth Ddaearyddol (GIS) a dadansoddiadau taenlen i gwblhau'r asesiadau o wasgfa arfordirol. Darperir y dadansoddiadau taenlen yn yr Offeryn Asesu Gwasgfa Arfordirol (CSAT) atodol. Cedwir y rhain gan CNC fel allbynnau prosiect (gweler yr Atodiad Archif Data).

Cyfrifwyd gwasgfa arfordirol a gwasgfa naturiol (a ddiffinnir fel colli cynefin yn erbyn unrhyw ffryntiad naturiol sy'n cyfyngu ar ddychweliad cynefinoedd rhynglanwol) ar raddfa genedlaethol ar gyfer arfordir Cymru gyfan, yn ogystal ag ar gyfer dyluniadau llai o'r arfordir. Yna, adroddwyd ar raddfa dirywiad posibl nodweddion yr MPA oherwydd gwasgfa arfordirol:

- Yn genedlaethol;
- Yn erbyn MPAau unigol; ac
- Yn erbyn dynodiadau MPA wedi'u cyfuno ledled Cymru:
    - ACAau;
    - SoDdGAau;
    - AGAau; a
    - Safleoedd Ramsar.

Mae gwasgfa arfordirol wedi'i hasesu ar gyfer tri chyfnod (epoc):

- 2025 i 2055 (30 mlynedd) – Yn cyd-fynd ag epoc tymor canolig Cynllun Rheoli Traethlin 2 (SMP2);
- 2055 i 2105 (50 mlynedd) – Yn cyd-fynd ag epoc hirdymor SMP2; a
- 2105 i 2155 (50 mlynedd) – Epoc hir dymor newydd.

Ym mhob achos, cyfrifir gwasgfa arfordirol ar gyfer dau amcanestyniad o gynnydd yn lefel y môr (SLR):

- Llwybr Crynodiad Cynrychioliadol (RCP) Amcanestyniadau Hinsawdd y DU18 (UKCP18) 8.5, lwfans SLR 70ain canradd; a
- Llwybr Crynodiad Cynrychioliadol (RCP) Amcanestyniadau Hinsawdd y DU18 (UKCP18) 8.5, lwfans SLR 95ain canradd.

Er mwyn deall goblygiadau gwasgfa arfordirol yn seiliedig ar yr hyn sy'n digwydd ar y ddaear mewn gwirionedd ar unrhyw adeg ar hyd yr arfordir, archwiliwyd y senarios rheoli canlynol hefyd:

- Amddiffynfeydd a Gynhelir: mae'r holl strwythurau sy'n bodoli ar hyn o bryd yn parhau i fod mewn grym (h.y., ni all cynefinoedd ymestyn i'r gefnwlad isel sydd y tu ôl iddynt);
- Dim Amddiffynfeydd: ystyrir bod pob strwythur wedi'i dynnu (h.y., gall cynefinoedd ymestyn i unrhyw gefnwlad isel sydd y tu ôl iddynt); a
- Polisi SMP2: mae presenoldeb strwythurau yn seiliedig ar weithredu polisi SMP2, sy'n cynnwys:
    - Cynnal y Llinell (HTL): mae strwythurau'n cael eu cynnal/gwella ar hyd yr aliniad presennol;
    - Adlinio Wedi'i Reoli (MR): caniateir i'r arfordir encilio mewn ffordd a reolir;
    - Dim Ymyrraeth Weithredol (NAI): ni wneir unrhyw ymyriadau i gynnal y strwythurau ac aliniad y draethlin bresennol; ac
    - Nid yw categori arall, sef Symud y Llinell (ATL), yn cael ei ystyried yn yr asesiad gan nad yw'r polisi hwn wedi'i gynnig yn SMP2 ar gyfer Cymru, er ei fod yn cael ei nodi fel opsiwn amgen posibl yn Aberystwyth.

Ar gyfer asesiad ar raddfa genedlaethol, nid yw ymchwilio i ffactorau safle-benodol yn ymarferol nac yn realistig. Felly, mae nifer o ragdybiaethau a symleiddio wedi'u mabwysiadu o fewn y dull. Os oes angen asesiad o wasgfa arfordirol ar raddfa cynllun neu brosiect mwy lleol, yna efallai y bydd angen data ac asesiadau ychwanegol i wella hyder yn y canlyniadau ar y raddfa honno.

Executive summary

Coastal squeeze constitutes the loss of natural habitats or deterioration of their quality arising from anthropogenic structures, or actions, preventing landward transgression of habitats in response to sea level rise. It is a known pressure and threat to Marine Protected Areas (MPAs) and is causing (or likely to cause) the deterioration or loss of coastal and intertidal features around the coast of Wales. This project aimed to improve the understanding of the location, timing and likely scale of habitat loss occurring in Welsh MPAs due to coastal squeeze. This is required to plan effectively for restoration and re-creation of habitat features lost through coastal squeeze, and as such maintain the coherence of the MPA network.

This report provides a detailed description of the methodology that has been designed and applied to identify the potential impact of coastal squeeze on Welsh intertidal habitats in MPAs. It forms Volume 1 of a two-part Report. Volume 2 provides an overview of the key results of the analysis.

This project designed a methodology to provide an understanding of the potential effects of coastal squeeze on the MPA designated features around the Welsh coast. This involved identifying which types of habitats and their associated MPA features are potentially subject to coastal squeeze, and the application of predictive models to quantify potential habitat loss. The project applied standard predictive hypsometric analysis to calculate changes in the tidal frame around the Welsh coast as a result of sea level rise. Present-day habitat maps were then used to provide a more site-specific assessment of the habitats present, and hence how they may change over time.

The methodology used newly created data layers, Geographic Information System (GIS) analysis and spreadsheet analyses to complete the coastal squeeze assessments. The spreadsheets analyses are provided in the accompanying Coastal Squeeze Assessment Tool (CSAT). These are held by NRW as project outputs (see Data Archive Appendix).

Coastal squeeze and natural squeeze (defined as the loss of habitat against any natural frontage that restricts the rollback of intertidal habitats) was calculated at a national scale for the whole of the Welsh coastline, as well as for smaller delineations of the coastline. The potential scale of deterioration of MPA features due to coastal squeeze was then reported:

- Nationally;
- Against individual MPAs; and
- Against MPA designations amalgamated across Wales:
  - SACs;
  - SSSIs;
  - SPAs; and
  - Ramsar sites.

Coastal squeeze has been assessed for three timeframes (epochs):

- 2025 to 2055 (30 years) – Equivalent to SMP2 medium-term epoch;
- 2055 to 2105 (50 years) – Equivalent to SMP2 long-term epoch; and
- 2105 to 2155 (50 years) – New long-term epoch.

In each case coastal squeeze is calculated for two sea levels rise (SLR) projections:

- UKCP18 Representative Concentration Pathway (RCP) 8.5, 70th percentile SLR allowance; and
- UKCP18 Representative Concentration Pathway (RCP) 8.5, 95th percentile SLR allowance.

In order to understand coastal squeeze implications based on what actually happens on the ground at any point along the coast, the following management scenarios were also examined:

- Defences Maintained: all structures that currently exist remain in place (i.e., habitats cannot extend into low lying hinterland that lies behind them);
- No Defences: all structures are considered to have been removed (i.e., habitats can extend into any low-lying hinterland that lies behind them); and
- SMP2 Policy: presence of structures is based on the implementation of SMP2 policy, comprising:
    - Hold The Line (HTL): structures are maintained/improved along existing alignment;
    - Managed Realignment (MR): coast is allowed to retreat in a managed way;
    - No Active Intervention (NAI): no interventions are made to maintain the existing structures and shoreline alignment; and
    - A further category, to Advance The Line (ATL), is not considered in the assessment as this policy is not proposed in SMP2 for Wales, although it is noted as a potential alternative option at Aberystwyth.

For a national scale assessment, the investigation of site-specific factors is not practical or realistic. Therefore, a number of assumptions and simplifications have been adopted within the approach. If a coastal squeeze assessment is required at a more local plan or project scale, then additional data and assessments may be required to improve confidence in the results at that scale.

1 Introduction

1.1 Background

This project aims to improve the understanding of location, timing and likely scale of habitat loss occurring in Marine Protected Areas (MPAs) due to coastal squeeze. The project has been funded by Welsh Government's Nature Networks Programme.

Coastal squeeze constitutes the loss of natural habitats or deterioration of their quality arising from anthropogenic structures, or actions, preventing the landward transgression of in response to sea level rise (see Section 1.2). Coastal squeeze is a known pressure and threat to MPAs and is causing, or is likely to cause, the deterioration or loss of coastal and intertidal features around the coast of Wales. For example, in the Severn Estuary Special Area of Conservation (SAC), coastal squeeze is noted as a reason for several features of the site being in unfavourable condition (NRW, 2018). The Habitats Regulations Assessments (HRA) undertaken for the second iteration of the Shoreline Management Plans (SMP2) concluded that the SMP2 would lead to adverse effects on the integrity of one or more MPAs due to anticipated coastal squeeze.

Under the Conservation of Habitats and Species Regulations 2017 (the 'Habitats Regulations'), the natural range of Annex 1 habitat features, and the areas covered by the habitat features within that range, should be stable or increasing. Loss of Annex 1 habitat due to coastal squeeze would therefore be contrary to the objectives of sites and constitute deterioration under Regulation 64. Loss of supporting habitat on which Special Protection Area (SPA) species depend would also be considered contrary to the conservation objectives. There is, therefore, a need to understand the likely scale, location and timing of this deterioration across relevant MPA features over the short, medium and long term. This is required to plan effectively for restoration and re-creation of habitat features lost through coastal squeeze, and so maintain the coherence of the MPA network. Positive management of the MPA network is a priority in contributing to resilient marine ecosystems under the Environment (Wales) Act 2016, and as set out in NRW's Marine Area Statement. This work also provides the opportunity to update the existing coastal squeeze assessments that were undertaken for the SMPs using a consistent methodology and best available data.

This project covers SACs, SPAs, Ramsar sites and Sites of Special Scientific Interest (SSSIs) within Wales, with features which have the potential to be, or area already being, impacted by coastal squeeze. There are 139 MPAs in Wales, twelve of which were scoped out of the assessment (see section 2.2) because the habitats or supporting habitats within these sites would not be affected by coastal squeeze.

ABPmer was commissioned by Natural Resources Wales (NRW) to design a method and undertake analysis to understand the location and likely scale of habitat loss occurring in MPAs due to coastal squeeze in Wales.

The project goals were to:

- Design a methodology to gain insight into the location, timing and extent of future habitat loss (and gain), resulting from coastal squeeze and natural squeeze (refer to definitions in Section 1.2 and Section 1.3 below) around the Welsh coast;

- Design a methodology which can provide an understanding of the potential effects of coastal squeeze on the MPA designated features around the Welsh coast;
- Apply those methodologies to identify the potential impact of coastal squeeze on Welsh intertidal habitats (and MPA features through the consideration of those habitats that occur within MPAs);
- Gain an understanding of how the presence of structures and SMP2 Policy influences coastal squeeze and natural squeeze at various spatial scales, using two sea level rise (SLR) scenarios over three time periods or epochs, and
- Report and communicate the outcomes.

This report outlines the methodology for completing the assessment.

1.2 Definition of coastal squeeze

Coastal squeeze is defined in 'What is Coastal Squeeze?' (Environment Agency, 2021), and is provided below, along with the points of clarification for applying the definition. This definition is also used in NRW Guidance Note GN062 – Assessment of Coastal Squeeze (NRW, 2022):

Coastal squeeze is *"the loss of natural habitats or deterioration of their quality arising from anthropogenic structures, or actions, preventing the landward transgression of those habitats that would otherwise naturally occur in response to sea level rise in conjunction with other coastal processes. Coastal Squeeze affects habitat on the seaward side of existing structures".* (Environment Agency, 2021)

Points of clarification:

1. 'Anthropogenic (man-made) structures' includes features that act as barriers to the inland progression of marine waters and habitats. These would include flood and coastal erosion structures, quay walls and road/railway embankments. 'Anthropogenic actions' include activities that artificially prevent the landward transgression of habitats.
2. 'Natural habitats' include all relevant Annex I coastal/intertidal habitats found in the UK as defined in policy and legislation (including Natural Environment and Rural Communities Act Section 41 priority habitat (England) or Environment Act Section 7 for Wales). The relevant habitats will need to be identified at a site level.
3. Habitat loss is considered in terms of area of the habitat. The area should include changes arising from frontal retreat (for example, of a saltmarsh edge) as well as internal erosion (for example, expansion of creeks within marshes).
4. Coastal processes relevant to identifying coastal squeeze should include those which, under natural unconstrained conditions, can lead to the landward migration of habitats under a scenario of sea level rise - such as waves for shingle beaches, winds for aeolian dunes, and tidal inundation for saltmarshes.
5. The assessment of coastal squeeze in estuaries should consider whether the extent of any intertidal islands is affected by flood defences on the islands themselves or within the wider estuary. This consideration should also take into account the role of natural changes in channel position over time which can influence the size and location of intertidal islands.

Coastal squeeze may occur when ALL of the following apply:

- Structures or coastal management activities (such as shingle re-profiling) fix the position of the coast;
- Sea-level is rising/is predicted to continue rising;
- There is a National Site Network designated site with Annex 1 habitats present seaward of the defence, and
- The habitats would be able to migrate landwards if there was no coastal structure or the management activity was stopped (i.e., the land behind the defence would be susceptible to flooding if the defence failed or would be expected to erode relatively quickly). This can include land behind defences which is currently developed. This is because over the long term, it is expected that there would be degradation and then removal of assets/structures as they become exposed to regular flooding and/or erosion, and that the land would be remediated to allow habitat to develop.

Coastal squeeze also EXCLUDES:

- The historic drainage and land claim of habitat landwards of currently existing structures;
- Other impacts of hard defences such as reductions in sediment supply caused by protecting eroding sediment sources or interrupting longshore transport pathways;
- Impacts of other human activity/structures on habitats, such as alteration of estuary channel morphology due to dredging, training walls or piers, or impacts on habitat quality due to management practices or pollution;
- Other natural or human causes of habitat loss unrelated to creating barriers to landward transgression, for example, the lateral movement of channels which may be unrelated to sea level rise and, while it would erode seaward edges of habitats, would not create landward transgression even under unconstrained condition, and
- Habitat loss against natural steeply rising land (that is, sloping coastal hinterlands) – such losses may need to be considered as a baseline scenario (‘without defences’) against which to judge coastal squeeze losses. This is termed natural squeeze. It should be noted that some areas of rising land formed from unconsolidated sediments may erode relatively rapidly in the future to provide Accommodation Space for habitats. In addition, narrow strips of higher ground which divide a low-lying hinterland from the sea may also be subject to erosion, and therefore the low-lying hinterland may provide space for habitats to develop.

For this present national scale assessment, the general principles and definition of coastal squeeze as defined within (Environment Agency, 2021) have been adopted. However, a number of simplifications to these definitions have been introduced to enable the practical completion of the assessment at a national level.

The scope of the study has also been extended to cover the whole of the Welsh coast, quantifying the likely loss of coastal habitat in areas outside MPAs.

For this study the following clarifications and amendments are therefore made in relation to the definition of coastal squeeze:

- Coastal squeeze will be assessed where intertidal habitat exists in front of an anthropogenic structure which prevents landward migration of the habitat;
- Coastal squeeze is not restricted to areas that lie within the existing MPA Network and will be assessed for all intertidal area lying seaward of anthropogenic structures / managed defence line;

- Coastal squeeze is to be assessed based on the loss of intertidal habitat as determined from present-day bed levels and SLR allowances. The assessment excludes any consideration as to how coastal processes, bed levels and coastal/estuary morphology may change in the future (refer to Sections 1.4 and 1.5);
- The assessment of coastal squeeze is restricted to assessing the extent of habitat loss and does not examine the condition of that habitat;
- Areas not fronted by intertidal habitats such as quayside locations, where the toe of the defences are below MLWS and dock areas such as Port Talbot Docks, Cardiff Bay Docks and Alexandra Dock (River Usk) are excluded from the assessment of coastal squeeze;
- Assessment of supporting terrestrial habitats for bird species of SPA / Ramsar Sites are excluded (other than Dunes and Vegetated Shingle);
- Assessment of subtidal habitat extents which will generally increase as a result of SLR are excluded; and
- The boundaries of the MPA designations are considered fixed and will not change as SLR occurs.

1.3 Definition of natural squeeze

Natural squeeze is defined as the loss of habitat against any natural frontage that restricts the rollback of intertidal habitats. Two types of natural frontage are considered within the assessment of natural squeeze:

- Natural Ridge – e.g. a shingle / dune ridge or a natural bank that has low lying land behind that could be inundated by the tide if the ridge is breached; and
- High Ground – natural High Ground that limits any inundation of the tide into the hinterland.

Natural squeeze is calculated and examined in the same way as coastal squeeze. The only difference being that coastal squeeze is assessed where an anthropogenic structure exists, whilst natural squeeze is assessed where a natural frontage exists.

1.4 Guidance on coastal squeeze assessments

The methodology set out in this document is based upon the latest guidance and understanding on coastal squeeze as set out in Environment Agency (2021).

Environment Agency (2021), identifies, two main types of approaches to assess future habitat loss:

- Extrapolation of past losses – based on historical trend analysis (HTA), and
- Predictive modelling.

These results can then also be brought together in an expert assessment.

A range of predictive models are identified in Environment Agency (2021), ranging from simplistic desk-based assessments and expert geomorphological assessment through to detailed numerical modelling studies. The use and appropriateness of each approach is subject to several factors, including available data, site characteristics, and the effort required to undertake the assessment.

For the present national scale assessment, the investigation of site specific factors is not practical or realistic and a predictive hypsometric approach has been applied as described in Section 1.5.

Whilst, this approach is appropriate for the present national scale assessment, it is identified that the approach does not take account of future erosion and accretion, or potential changes in coastal process because of climate change. Consideration of this change is important when undertaking local scale assessments.

1.5 Overview of methodology

The methodology for this study has been developed to provide a national scale assessment which can be consistently applied using available data. It is not practical or realistic at this scale, to undertake a detailed investigation of site specific factors, this study has therefore, focused upon:

- Identifying which Habitat Groupings and their associated MPA features are potentially subject to coastal or natural squeeze, and
- The application of a predictive model to quantify potential coastal squeeze and natural squeeze.

The project applies standard predictive hypsometric analysis (refer to Section 3.1) to calculate the changes in tidal frame around the Welsh coast as a result of SLR. These tidal frames are calculated from a newly created national Digital Terrain Model (DTM). Present-day habitat maps are then used to inform a site specific assessment of the habitats present, and hence how they may change over time.

The coastal squeeze and natural squeeze assessments are then undertaken. The quantification of coastal squeeze and natural squeeze is analysed at the following three scales:

- Nationally;
- Against SMP2 Policy Unit, and
- Against individual Assessment Units (see Section 3).

In each case coastal squeeze and natural squeeze are analysed for seven Habitat Groups as identified below (refer to Section 2.1):

- Saltmarsh;
- Mudflat and sandflat;
- Intertidal reef;
- Vegetated shingle;
- Dunes, and
- Littoral coarse sediment.

A separate assessment is also undertaken in relation to Coastal lagoon (see Section 3.3).

An assessment of coastal squeeze and natural squeeze across the MPA network has then been undertaken. The potential scale of deterioration of MPAs due to coastal squeeze is reported against individual MPAs. In addition, these results are rolled-up to examine potential coastal squeeze related to the MPA designations, SACs, SSSIs, SPAs and Ramsar Sites.

Results are not reported against MCZ as there is only one Welsh MCZ which is scoped out as the frontage is not considered to be subject to coastal squeeze or natural squeeze.

The methodology uses newly created data layers, GIS analysis and spreadsheet analyses to complete the coastal squeeze and natural squeeze assessments. The spreadsheet analyses are undertaken in the Coastal Squeeze Assessment Tool (CSAT), which can be used in the future by NRW staff to investigate changes in more detail, and to examine alternative management scenarios. These are held by NRW as project outputs (see Data Archive Appendix). The CSAT uses hypsometry data from the DTM to quantify the changes in the Tidal Frame Extents at five yearly intervals. It is anticipated that this will be a useful optioneering tool for the management of MPAs.

Coastal squeeze and natural squeeze are subsequently assessed for three time periods (epochs):

- 2025 to 2055 (30 years) – Equivalent to SMP2 medium-term epoch;
- 2055 to 2105 (50 years) – Equivalent to SMP2 long-term epoch, and
- 2105 to 2155 (50 years) – New long-term epoch.

In each case coastal squeeze and natural squeeze are calculated for two climate change scenarios:

- UKCP18 Representative Concentration Pathway (RCP) 8.5, 70th percentile SLR allowance, and
- UKCP18 Representative Concentration Pathway (RCP) 8.5, 95th percentile SLR allowance.

The following management scenarios are also examined:

- Defences Maintained: assumes all existing structures remain in place, i.e. habitats cannot extend into low lying hinterland that lies behind them;
- No Defences: assumes all existing structures have been removed or breached: i.e. habitats can extend into any low lying hinterland that lies behind them, and
- SMP2 Policy: presence of structures is informed by SMP2 Policy, where:
    - Hold The Line (HTL): structures are maintained/improved along existing alignment i.e. assumes that habitats cannot extend into low lying hinterland that lies behind them;
    - Managed Realignment (MR): coast is allowed to retreat in a managed way i.e. assumes that habitats can extend into any low lying hinterland, and
    - No Active Intervention (NAI): no interventions are made to maintain the existing structures and shoreline alignment i.e. assumes that habitats can extend into any low lying hinterland.
    - A further category, to Advance The Line (ATL), is not considered in the assessment as this policy is not proposed in any SMP2 Policy Unit for Wales, although it is noted as a potential alternative option at Aberystwyth.

It should be noted that SMP2 policies have not been defined for the new long-term epoch (2105 to 2155). Therefore, for the purposes of this assessment, the SMP policy defined for the end of SMP2 long-term epoch (2055 to 2105) was applied.

Within the assessment a defence is generally considered to be any anthropogenic structure. However, in several instances the SMP2 Policy along a natural frontage is HTL. In the instances where this occurred, the sites were examined individually by NRW, and on some occasions the natural frontage was re-defined as a defence, as it is considered that future works are likely to be undertaken to defend the coast. For further details on the development of the Assessment Unit line, which contains this information, see Appendix E.3.2.

Where a frontage is assigned a MR or NAI SMP2 Policy, and the SMP2 management scenario is being followed, the assessment assumes that no defence is present, and habitats will be able to roll back into the hinterland. It is recognised, that under a NAI policy, a defence may still exist and be functioning, however, at this national scale assessment it was not practical to assess this, therefore, it is assumed the defence would not be functioning under an NAI policy.

More detail on the methods that have been adopted to complete the analysis along with the associated 'rules' adopted for assigning any losses and gains in habitat to either coastal squeeze or natural squeeze are provided below.

1.6 Frontages scoped out of the assessment

Sea cliffs have been scoped out of the assessment of natural squeeze. Under SLR, sea cliffs are either likely to erode (soft cliffs) or the intertidal habitats associated with them are likely to migrate up the cliff face and/or their associated rocky foreshore (hard cliffs). Where this occurs, it is anticipated that no natural squeeze will occur.

Therefore, sea cliffs and natural frontages on an open coast that have no low-lying land behind them, have been defined as cliff frontages and have been excluded from the assessment.

There are two exceptions to this:

- Where an existing anthropogenic structure is protecting the cliff from eroding, thus it is not a natural frontage.
- Where key infrastructure is located directly at the top of the cliff, e.g. railway line, and the frontage has been assigned a HTL policy. In this instance an anthropogenic structure may be required in the future to protect the frontage.

In both these cases the frontage is typically assigned to be a defended frontage.

The exclusion of cliff frontages is also consistent with Environment Agency (2021), which specifically scopes out sea cliffs when assessing coastal squeeze.

2 Scoping intertidal habitats and Marine Protected Areas subject to coastal squeeze and natural squeeze

An initial scoping exercise was undertaken to correlate the habitat types that may be subject to coastal squeeze to individual MPA features (see Section 2.1). This scoping exercise also identified a number of MPAs that could be ruled out of the assessment (see Section 2.2).

2.1 Scoping intertidal habitats to Marine Protected Areas features

Environment Agency (2021) identified simplified Habitat Groupings which should be considered within a coastal squeeze assessment. A similar approach was adopted for the present assessment, with seven broad habitats groups having been defined. These seven broad Habitat Groups are:

- Saltmarsh;
- Mudflat and sandflat;
- Intertidal reef;
- Vegetated shingle;
- Dunes;
- Littoral coarse sediment; and
- Coastal lagoon.

These have been further related to the habitat features and supporting habitats (for bird features) that exist within Welsh MPAs.

For SACs and SSSIs, these Habitat Groups have been mapped to habitat features associated with individual MPAs using details provided in Annex 1 of the Welsh Government (2018) – Marine Protected Area Network Management Framework for Wales (2018-2023).

For SPA and Ramsar Sites, Welsh Government (2018) lists the bird species the sites are designated for, rather than the associated supporting habitats. For SPA and Ramsar Sites, Habitat Groups have therefore been attributed to individual SPA / Ramsar Sites, if the habitat is listed in the Natura 2000 – Standard Data Form (for SPA), and Information Sheet on Ramsar Wetlands form (for Ramsar Sites). Where a Habitat Group is described/referenced in the supporting information on these forms this has also been captured within the assessment.

In Welsh Government (2018), the marine features associated the single Welsh MCZ (Skomer / Sgomer) are defined as To Be Determined (TBD). However, as the MCZ consists entirely of cliff frontages, which are not considered to be subject to coastal squeeze or natural squeeze within this assessment, this site has not been considered further within the assessment.

Table 1 presents the results of this scoping exercise and shows how MPA features have been assigned to each Habitat Group and the respective designation types.

During the scoping exercise several MPA features were either scoped out, or were considered implicitly scoped in within one, or more, of the seven Habitat Groups. In addition, Environment Agency (2021), also lists several habitats that are subject to coastal squeeze, but are not specifically cited within Welsh MPAs. Table 2 presents the marine features that are not directly assigned to an individual Habitat Group, and identifies whether the marine feature is either scoped out or included implicitly. This includes, the following three generic physiographic MPA features that could also be subjected to coastal squeeze and natural squeeze:

- Large shallow inlets and bays;
- Estuaries, and
- Intertidal.

It is recognised that many of the broad Habitat Groups may fall under these three MPA features, including mudflats and sandflats, saltmarsh and littoral coarse sediment. However, each individual Habitat Group may not always be present where an MPA is designated for one of these three marine features. Therefore, these three physiographic features are not directly captured within the present assessment, which is restricted to assessing the seven broad Habitat Groups that can be directly associated with an MPA.

The relationship between the Habitat Groups that may be subject to coastal squeeze and are considered to be representative of an MPA feature is summarised in Appendix A. In total 127 Welsh MPAs contain one or more Habitat Groups (as a proxy for a designated feature) that are subjected to coastal squeeze.

Table 3 identifies the source data that has been used to define the present-day (2025) coverage of each Habitat Group (See Appendix H for further information).

Table 1 MPA habitat features assigned to each Habitat Group. The table describes the relationship between the Habitat Groups used in this study and the specific features associated with different types of MPA, as well as information on how this habitat is described in Environment Agency, 2021.

Habitat Group	Listed habitat feature	MPA type	Associated habitat from 'What is coastal squeeze?'
Saltmarsh	Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)	SAC	Saltmarsh
Saltmarsh	Salicornia and other annuals colonising mud and sand	SAC	Saltmarsh
Saltmarsh	Saltmarsh	SSSI / SPA / Ramsar Sites	Saltmarsh
Mudflat and sandflat	Mudflats and sandflats not covered by seawater at low tide	SAC /SPA / Ramsar Sites	Mud and sandflats
Mudflat and sandflat	Sheltered Mud	SSSI	Mud and sandflats
Mudflat and sandflat	Exposed Sand	SSSI	Mud and sandflats
Mudflat and sandflat	Moderately Exposed Sand	SSSI	Mud and sandflats
Mudflat and sandflat	Eelgrass	SSSI	Intertidal seagrass beds
Mudflat and sandflat	Muddy Gravel	SSSI	Mud and sandflats
Mudflat and sandflat	Mixed Substrata	SSSI	Mud and sandflats
Intertidal reef	Reefs	SAC	Intertidal rock platforms

Habitat Group	Listed habitat feature	MPA type	Associated habitat from 'What is coastal squeeze?'
Intertidal reef	Rock Pools	SSSI	Intertidal rock platforms
Intertidal reef	Soft Piddock	SSSI	Intertidal rock platforms
Intertidal reef	Sheltered Rock	SSSI	Intertidal rock platforms
Intertidal reef	Exposed Rock	SSSI	Intertidal rock platforms
Intertidal reef	Moderately Exposed Rock	SSSI	Intertidal rock platforms
Intertidal reef	Sand Influenced Biogenic Reefs	SSSI	Intertidal rock platforms
Intertidal reef	Surge Gullies	SSSI	Intertidal rock platforms
Intertidal reef	Under Boulders	SSSI	Intertidal rock platforms
Intertidal reef	Mixed Substrata	SSSI	Intertidal rock platforms
Intertidal reef	Chalk	SSSI	Intertidal rock platforms
Intertidal reef	Rocky Shores	SPA / Ramsar Sites	Intertidal rock platforms
Vegetated shingle	Annual Vegetation of Drift Lines	SAC	Shingle beaches and barriers
Dunes	Dunes	SPA / Ramsar Sites	Sand dunes

Habitat Group	Listed habitat feature	MPA type	Associated habitat from 'What is coastal squeeze?'
Littoral coarse sediment	Shingle	SPA / Ramsar Sites	Shingle beaches and barriers
Coastal lagoon	Silled Saline Lagoon	SSSI	Saline lagoons located in front of structures
Coastal lagoon	Isolated Saline Lagoon	SSSI	Saline lagoons located in front of structures
Coastal lagoon	Percolation Saline Lagoon	SSSI	Saline lagoons located in front of structures
Coastal lagoon	Coastal Lagoon	SAC / SPA / Ramsar Sites	Saline lagoons located in front of structures

Table 2 Identified marine features that are not directly assigned to an individual Habitat Group. Table identifies whether the marine feature is either scoped out or included implicitly.

Marine feature	MPAs for which the feature is listed	Associated habitat from 'What is Coastal Squeeze?'	How captured	Rationale
Boulder beaches	None identified	Boulder beaches	Captured implicitly within intertidal reef Habitat Group	Identified as a feature subject to coastal squeeze in 'What is Coastal Squeeze?', but is not referenced as a feature of any MPA, therefore not identified separately
Sand beaches	None identified	Sand beaches	Captured implicitly within mudflat and sandflat	Identified as a feature subject to coastal squeeze in 'What is Coastal Squeeze?', but is not referenced as a feature of any MPA, therefore not identified separately
Intertidal sea grass	None identified	Intertidal sea grass	Captured implicitly within mudflat and sandflat	Identified as a feature subject to coastal squeeze in 'What is Coastal Squeeze?', but is not referenced as a feature of any MPA, therefore not identified separately
Intertidal reed beds	None identified	Intertidal reed beds	Scoped out	The Dee Estuary Ramsar data form references the same SSSIs as the Dee Estuary SPA with the addition of the Red Rocks SSSI which is predominantly reedbed and saltmarsh. However, this is exclusively on the English side of the Estuary. There are no other MPA sites identified as having intertidal reedbed and, therefore, not identified as a designated habitat feature within Welsh MPA designated sites.

Marine feature	MPAs for which the feature is listed	Associated habitat from 'What is Coastal Squeeze?'	How captured	Rationale
Sea Caves (Submerged or partially submerged)	SAC	None applicable	Scoped out	Not related to a defined habitat
Large Shallow Inlets and Bays	SAC	None applicable	Scoped out	Generic feature which is not related to a defined habitat
Estuaries	SAC / SSSI	None applicable	Scoped out	Generic feature which is not related to a defined habitat
Intertidal	SSSI	None applicable	Scoped out	Generic feature which is not related to a defined habitat
Caves and Overhangs	SAC	None applicable	Scoped out	Not related to a defined habitat
Maritime Cliff	SSSI	None applicable	Scoped out	Sea Cliffs are not considered to be subject to coastal squeeze or natural squeeze and are scoped out in 'What is Coastal Squeeze?'
Coastal Geomorphology	SSSI	None applicable	Excluded	Not related to a defined habitat
Marine area, sea inlets	SPA	None applicable	Excluded	Generic feature which is not related to a defined habitat
Marine wetland areas including tidal flats	Ramsar Sites	None applicable	Excluded	Generic feature which is not related to a defined habitat

Table 3 Source data sets used to define present-day coverage of each Habitat Group.

Habitat Group	**Source data used to define present-day habitat extents**
Saltmarsh	Reg 9a Saltmarsh (Draft)
Mudflat and sandflat	Article 17 Mudflat and Sandflat
Intertidal Reef	Article 17 Intertidal reef layer
Vegetated Shingle	Reg 9a Vegetated Shingle (Draft)
Dunes	Reg 9a Dune (Draft)
Littoral Coarse Sediment	JNCC EUNIS Level 3 Habitat Map, A2.1 - Littoral Coarse Sediment
Coastal Lagoon	Reg 9a Coastal Lagoon (Draft)

2.2 Marine Protected Areas scoped out

During the scoping exercise it was identified that a number of MPAs do not support a Habitat Group (feature) considered subject to coastal squeeze within Environment Agency (2021). These MPAs were therefore scoped out of the assessment (see Table 4).

Therefore, of the 139 MPA sites in Wales, 12 sites have been scoped out, with the remaining 127 being considered within the assessment.

It should also be noted that a further 28 MPAs included in the assessment returned no habitat changes due to coastal squeeze because they typically contained cliff frontages which are not affected by coastal squeeze. Therefore, 99 MPAs are included in the outputs for this project (see Volume 2 to this Report).

Table 4 MPAs scoped out of the assessment.

MPA site	Designation	Rationale for exclusion
Limestone Coast of South West Wales / Arfordir Calchfaen De Orllewin Cymru	SAC	Site is designated for submerged or partially submerged sea caves, which are not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
Craig Ddu - Wharley Point Cliffs	SSSI	Site is designated for coastal geomorphology and maritime cliff and associated ledges and crevices, which are not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
Creigiau Llansteffan (Llanstephan Cliffs)	SSSI	Site is designated for coastal geomorphology, which is not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
Morfa Dinlle	SSSI	Site is designated for coastal geomorphology, which is not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
Rhossili Down	SSSI	Site is designated for coastal geomorphology, which is not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
Skokholm	SSSI	Site is designated for Grey seal *Halichoerus grypus* and tide-swept channels, which are not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'

MPA site	Designation	Rationale for exclusion
Irish Sea Front	SPA	Site is located offshore and not related to intertidal zone around coastline of Wales
Skomer / Sgomer	MCZ	The frontage covered by the MPA consists of cliffs, that are scoped out of the assessment as cliff frontages are not identified as being subject to coastal squeeze or natural squeeze
North Anglesey Marine / Gogledd Môn Forol	SAC	Feature is Harbour porpoise *Phocoena phocoena* which is not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
West Wales Marine / Gorllewin Cymru Forol	SAC	Feature is Harbour porpoise *Phocoena phocoena,* which is not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
Bristol Channel Approaches / Dynesfeydd Môr Hafren	SAC	Feature is Harbour porpoise *Phocoena phocoena,* which is not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'
Croker Carbonate Slabs	SAC	Feature is submarine structures made by leaking gases, which is not identified as being subject to coastal squeeze in 'What is Coastal Squeeze?'

3 Quantifying the potential changes in habitat extent at the national scale

This chapter describes the methodology used to complete the national scale assessment of potential habitat losses and gains associated with coastal squeeze and natural squeeze for the seven Habitat Groupings identified. The modified methodology to assess the likely scale of coastal squeeze and natural squeeze for Welsh MPAs is described in Section 4.

The seven Habitat Groups included in this study (see section 2.1) will be affected slightly differently by SLR, therefore different methodologies have been adopted for the following Habitat Groups:

- The four intertidal Habitat Groups of saltmarsh, mudflat and sandflat, intertidal reef and littoral coarse sediment;
- Dunes and vegetated shingle, since these habitats are typically located higher up the foreshore and respond differently to SLR; and
- Coastal lagoons.

To complete the assessment, the entire Welsh coastline has been divided into Assessment Units. For each Assessment Unit, the area seaward of an anthropogenic structure or natural frontage is defined as the Foreshore Area. All low-lying areas (i.e. liable to tidal inundation) behind an anthropogenic structure or natural frontage is defined as the Accommodation Space. An illustration of an individual Assessment Unit and its associated Foreshore Area and Accommodation Space is shown in Figure 1.

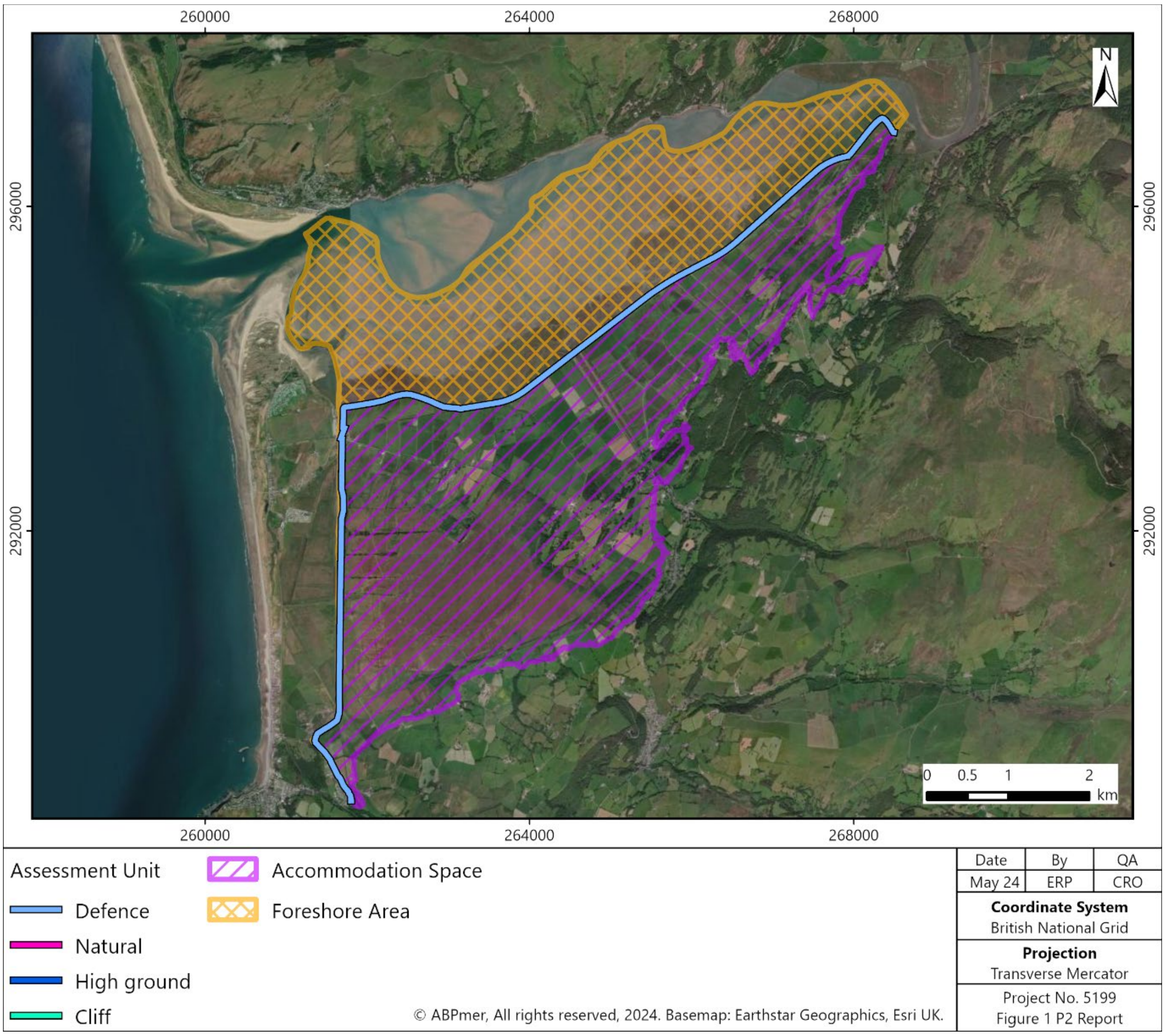


Figure 1 An example of an individual Assessment Unit showing the Foreshore Area and Accommodation Space associated with it.

Assessment Units are categorised as being one of four types (See Section 5.3 and Appendix Es):

- Defence – an anthropogenic structure;
- Natural – a Natural Ridge with low-lying land in its lee, e.g. a shingle or dune ridge;
- High Ground - High Ground within an estuary with no low lying land in its lee; or
- Cliff – natural frontage on open coast with no low lying land in its lee.

High Ground also occurs at the landward edge of the Accommodation Space, where the land is naturally high and will prevent retreat of a habitat further inland. Cliffs frontages are also excluded from the assessment of coastal squeeze and natural squeeze as identified in Section 1.6.

Where there is no low-lying land behind a natural frontage, the Foreshore Area extends up to High Ground and there is no Accommodation Space in its lee.

At their largest scale an Assessment Unit may represent a single SMP2 Policy Unit. Where there are both anthropogenic structures (such as sea defences, rail embankments etc) and natural frontages along a single SMP2 Policy Unit, this is split into separate Assessment Units. This split enables habitat losses (or gains) to be assigned to either coastal squeeze or natural squeeze respectively. Assessment Units are defined along the crest of the primary structure or along the natural frontage that protects the hinterland from coastal flooding. If there is no low-lying land behind the frontage, the Assessment Unit is defined along natural High Ground (within estuaries) and the cliff line (on the open coast).

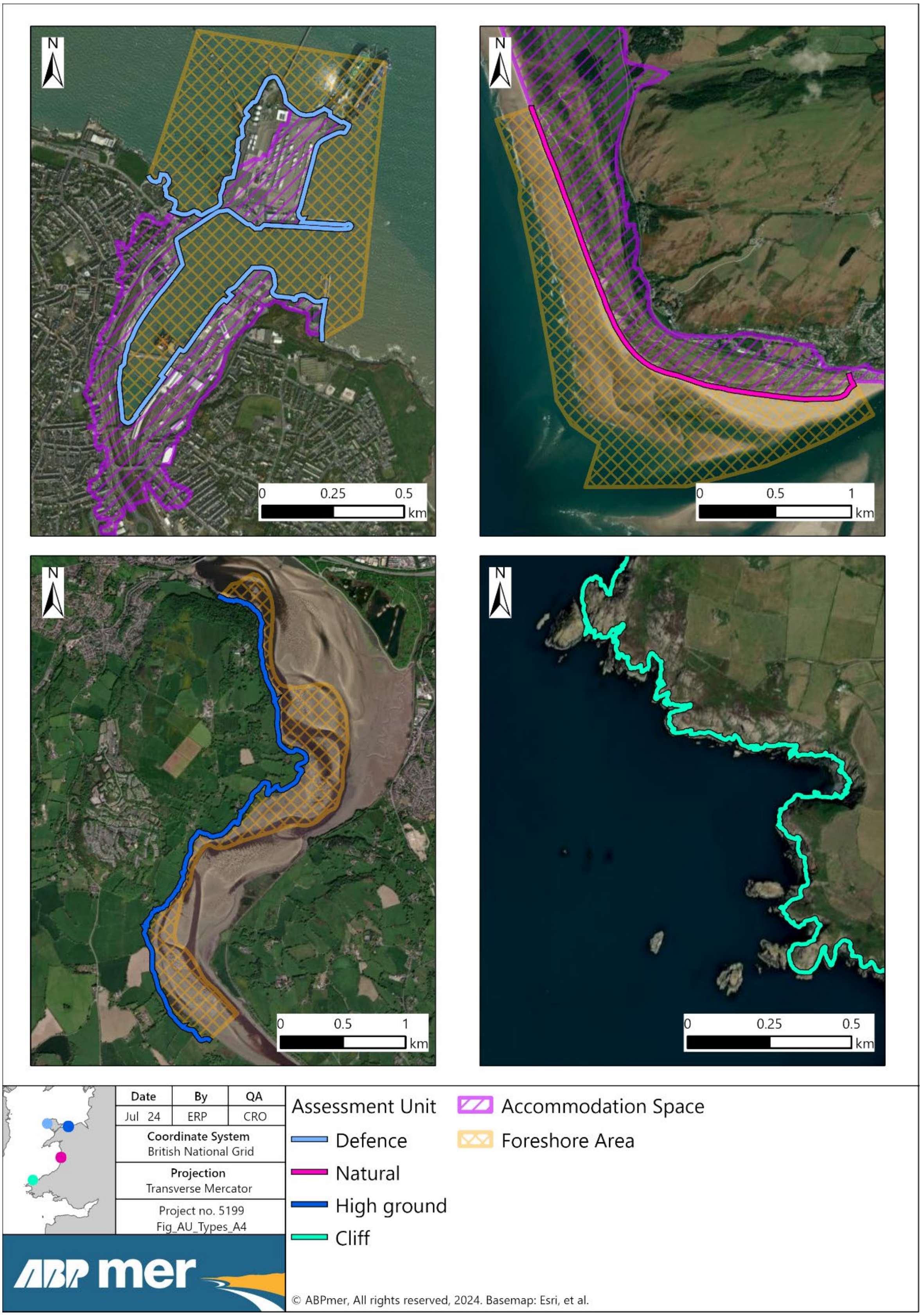


Figure 2 Examples of the four Assessment Unit types, Defence, Natural, High Ground and Cliff, with associated Foreshore Area and Accommodation Space.

3.1 Assessment of coastal squeeze and natural squeeze on intertidal Habitat Groups

The project has derived a three step process for completing the national scale assessment for each of the habitats groups except for coastal lagoons, which have been assessed on a site specific basis. The rules applied within STEP 3 of the assessment are also slightly different for dunes and vegetated shingle, as these habitats are typically located higher up the foreshore and respond differently to SLR (Section 3.2).

This three step process is shown in Figure 3 and consists of:

1. Calculating the intertidal area across different tidal frames (termed the Tidal Frame Extents) for different epochs;
2. Identifying the Potential Habitat Extents for each epoch, based on the present-day (2025) habitat coverage across each tidal frame; and
3. Calculating the loss and gain in Potential Habitat Extent for future epochs, and assigning this to either coastal squeeze or natural squeeze based on the type of frontage and management scenario adopted.

These steps are described and detailed further within in the subsequent sections.

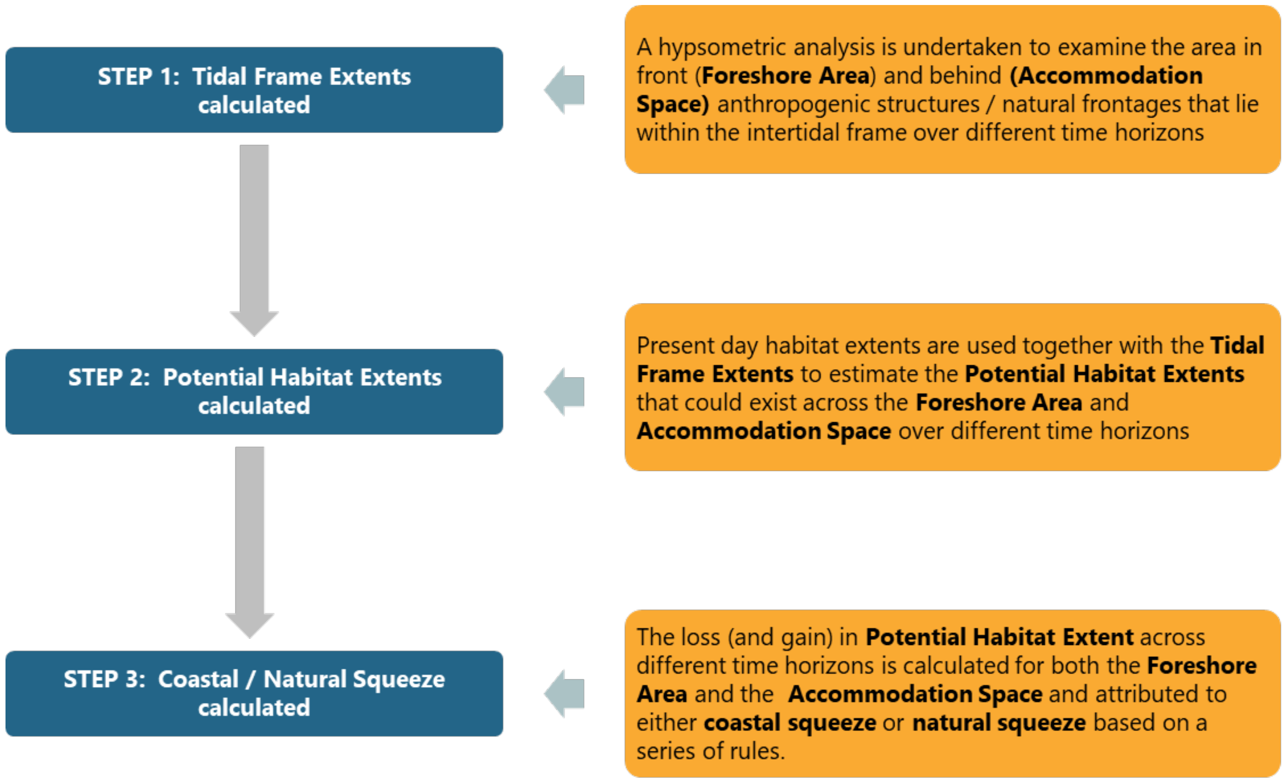


Figure 3 Schematic diagram showing the three step process used in the assessment, listing the three steps and providing a brief overview of the task undertaken for each step. These tasks are described in further detail in subsequent sections.

To undertake the assessment the intertidal zone has been split into three tidal frames which are typically linked to the following Habitat Groups:

- Lower to Mid Intertidal, extending from Mean Low Water Springs (MLWS) to Mean High Water Neaps (MHWN) - intertidal reefs, littoral coarse sediment and mudflat and sandflat;
- Upper Intertidal, extending from MHWN to Mean High Water Springs (MHWS) – Saltmarsh, intertidal reefs, and beaches (either part of littoral coarse sediment or mudflat and sandflat); and
- Supralittoral, extending from MHWS to Highest Astronomical Tide (HAT)+1 m – Transitional saltmarsh, vegetated shingle, dunes and beaches (either part of littoral coarse sediment or mudflat and sandflat).

The upper and lower levels used to define these zones have been taken directly from industry recognised guidance, including the Saltmarsh Restoration Handbook – UK and Ireland (Hudson et. al., 2021) and the Saltmarsh Creation Handbook (Nottage et. al., 2005).

3.1.1 STEP 1: Calculating tidal frame extents

Figure 4 illustrates the present-day (2025) extents of the three tidal frames across both the Foreshore Area and Accommodation Space, for an idealised frontage. If an anthropogenic structure exists along the Assessment Unit Line and remains in place under the management scenario being examined, the intertidal habitat will be restricted to the Foreshore Area. However, if no anthropogenic structure is maintained along the Assessment Unit Line, intertidal habitats can extend into the Accommodation Space. Hence, Tidal Frame Extents are also calculated for the Accommodation Space.

With SLR, and assuming no change in bed morphology (a key assumption adopted for this national scale assessment), the tidal frames move upwards and therefore the extent of the tidal frames are adjusted. This is represented in Figure 4, which shows how the Tidal Frame Extents are adjusted based on the tidal levels in 2155, once SLR has been accounted for.

In the assessment the Tidal Frame Extents within the Foreshore Areas and Accommodation Space are calculated for each Assessment Unit through a hypsometric analysis. This analysis approach is described in Appendix B, and derives the Tidal Frame Extents based on present-day (2025) water levels and those at the end of each epoch.

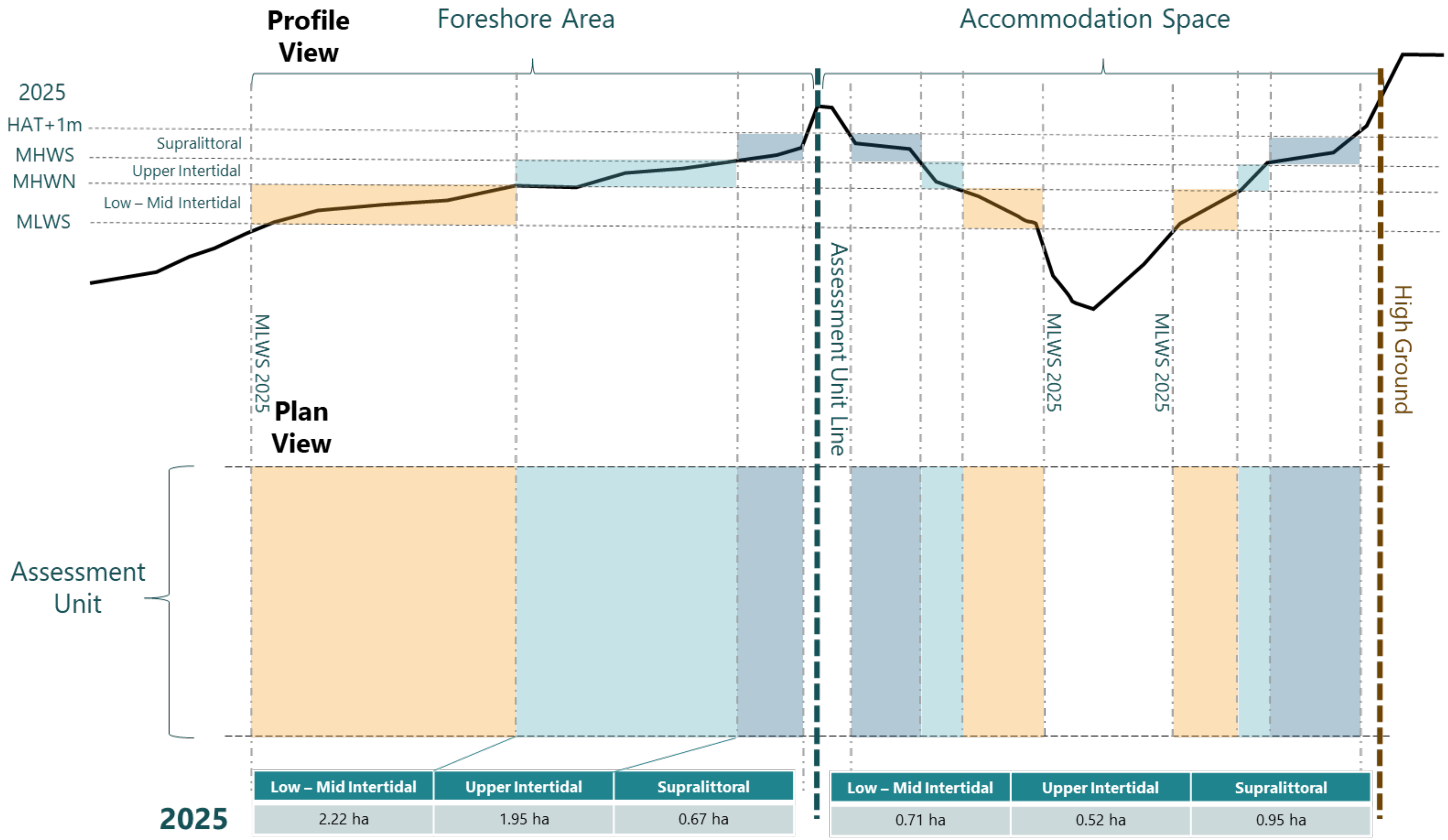
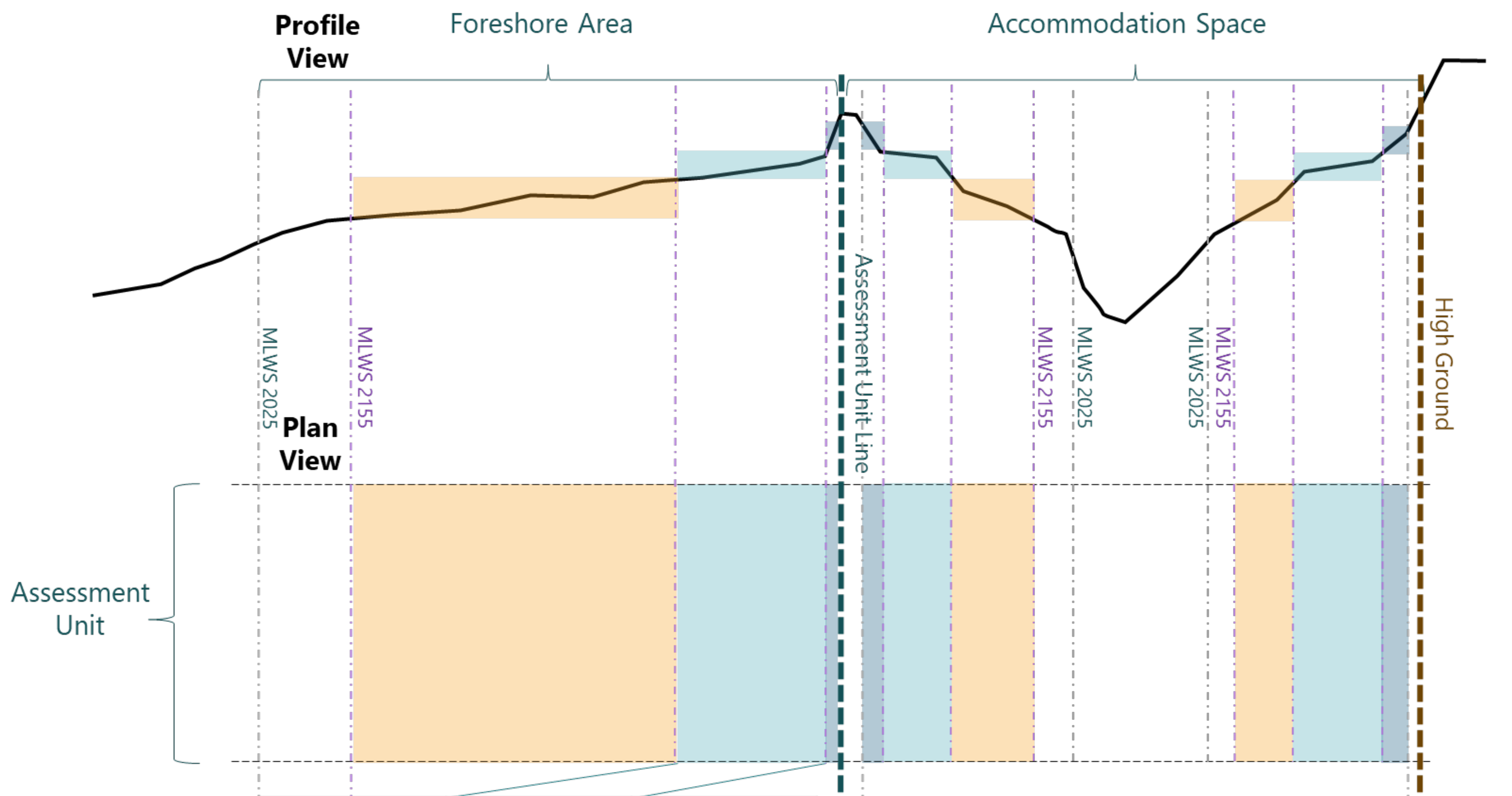


Figure 4 STEP 1: Schematic showing calculation of Tidal Frame Extents for a single Assessment Unit. Figure shows frontage in both Profile (upper part of image) and Plan view (lower part of image), with the Tidal Frame Extents being calculated in both the Foreshore Area and Accommodation Space for present-day (2025) tidal levels.



	Foreshore Area: Low – Mid Intertidal	Foreshore Area: Upper Intertidal	Foreshore Area: Supralittoral	Accommodation Space: Low – Mid Intertidal	Accommodation Space: Upper Intertidal	Accommodation Space: Supralittoral
2025	2.22 ha	1.95 ha	0.67 ha	0.71 ha	0.52 ha	0.95 ha
2155	2.60 ha	1.51 ha	0.02 ha	0.8 ha	1.15 ha	0.05 ha

Figure 5 STEP 1: Schematic showing how Tidal Frame Extents are modified with SLR. Figure shows the calculation of Tidal Frame Extents across the Foreshore Area and Accommodation Space with 2155 tidal level, and compares these against the present-day (2025) extents.

3.1.2 STEP 2: Calculating potential habitat extent

Whilst the upper and lower limits of the tidal frames have been carefully selected to be representative of the types of habitats that may occur across them, the presence of a particular Habitat Group across each tidal frame is subject to other factors, such as wave exposure and bed type. For example, on an open coast wave exposure may prevent saltmarsh being present across the upper intertidal zone, but in an estuary, with limited wave energy, the coverage of saltmarsh across the upper intertidal zone may be significant.

To take account of this, the present-day percentage habitat coverage across the Foreshore Area is examined for each intertidal habitat across the three tidal frames. It is then assumed that the percentage habitat coverage will remain the same into the future. The percentage habitat coverage values, therefore, act as a proxy (or site-specific indicator), which takes account of other site variables such as wave exposure.

Figure 6 and Figure 7, provide a representation of this process, with the present-day habitat percentage coverage across each tidal frame being calculated in Figure 6. In Figure 7, the Tidal Frame Extents have been modified as a result of SLR, but the percentage habitat coverage across each tidal frame has been maintained.

The present-day percentage habitat coverage across the Foreshore Area is therefore utilised to estimate the Potential Habitat Extents across both the Foreshore Area and the Accommodation Space should the latter be inundated by the tide. This approach assumes that other factors that may affect the presence of a habitat, e.g. wave exposure or bed type, are similar between the Foreshore Area and Accommodation Space. This assumption is considered appropriate at a national scale assessment as the two areas are likely to have been subject to similar geomorphological processes in the past. This assumption is commensurate with that used to examine how Potential Habitat Extents vary across the Foreshore Area over different timescales, e.g. that the same proportion of rock is available to support Intertidal Reef habitats in future time horizons.

In Figure 6 and Figure 7 there are three Habitat Groups present over the present-day Foreshore Area. However, within the assessment all Habitat Groups are considered (with the exception of coastal lagoons which are assessed separately).

To avoid double counting in the assessment, it important that no two Habitat Groups overlap. To ensure this is the case, source data used to define habitat extents has been examined and cropped accordingly. Where two or more habitats were found to overlap in the source data, a prioritisation rule has been adopted giving preference to one Habitat Group over another based on the general known accuracies of the source data related to the three Habitat Groups. The priority with which the Habitat Groups are assessed are as follows:

- Saltmarsh
- Vegetated shingle
- Dunes
- Intertidal reef
- Littoral coarse sediments
- Mudflat and sandflat

Further details on how these priority rules were applied is provided in Appendix H.

Furthermore, for most frontages, there are areas across the Foreshore Area that have not been mapped to any specific Habitat Group due to limitations in available data (e.g. due to habitat mapping being undertaken/updated at different times). A further Habitat Group has therefore been utilised called ‘Not Defined’ to capture these gaps. In reality this category is likely to consist of habitats from the other Habitat Groups (e.g. mudflat and sandflat), but there is no certainty attached to this assumption. This Habitat Group is, however, treated the same way within the assessment.

Figure 8 provide an illustrative schematic of the calculations undertaken during STEP 1 and STEP 2 of the analysis.

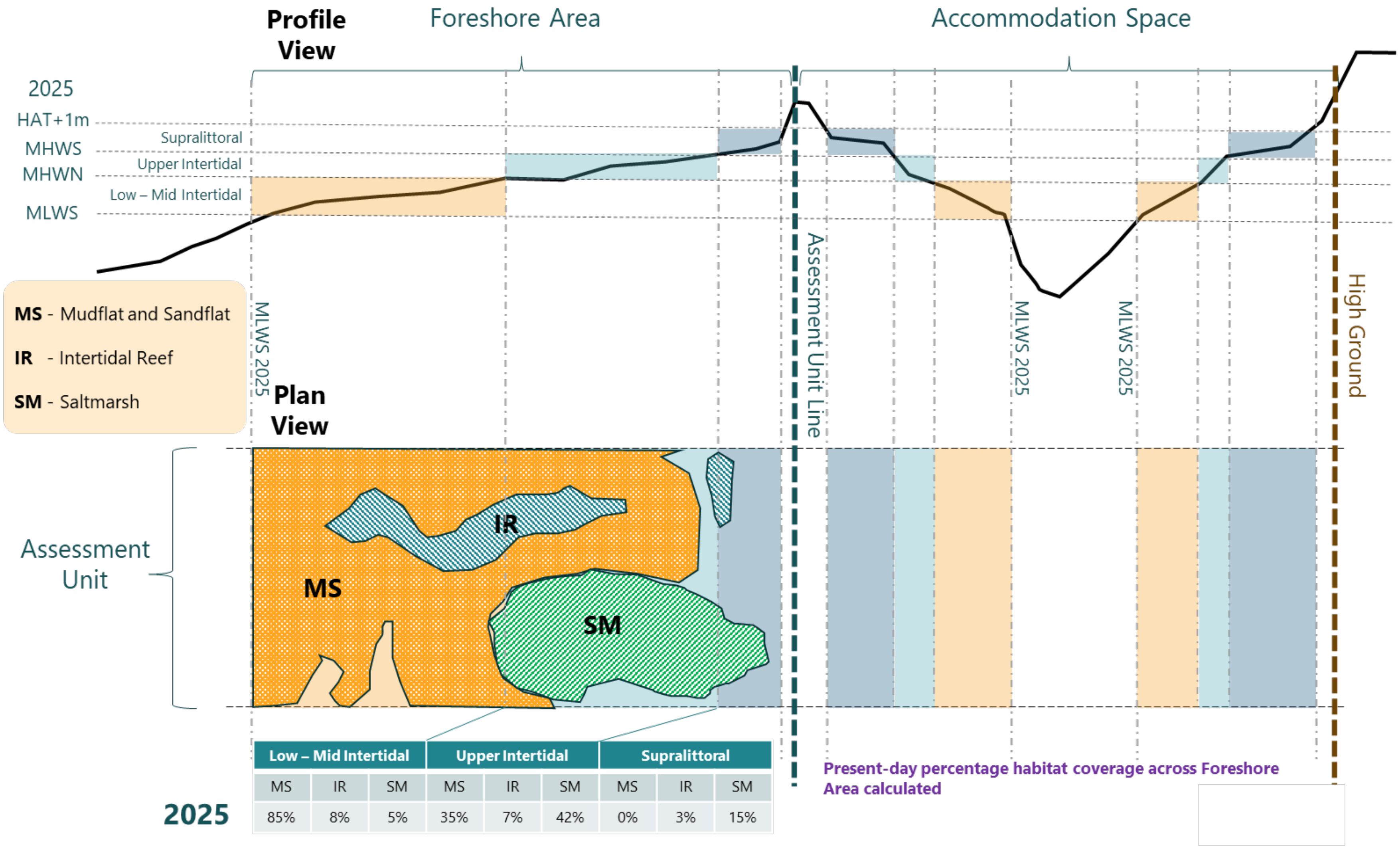
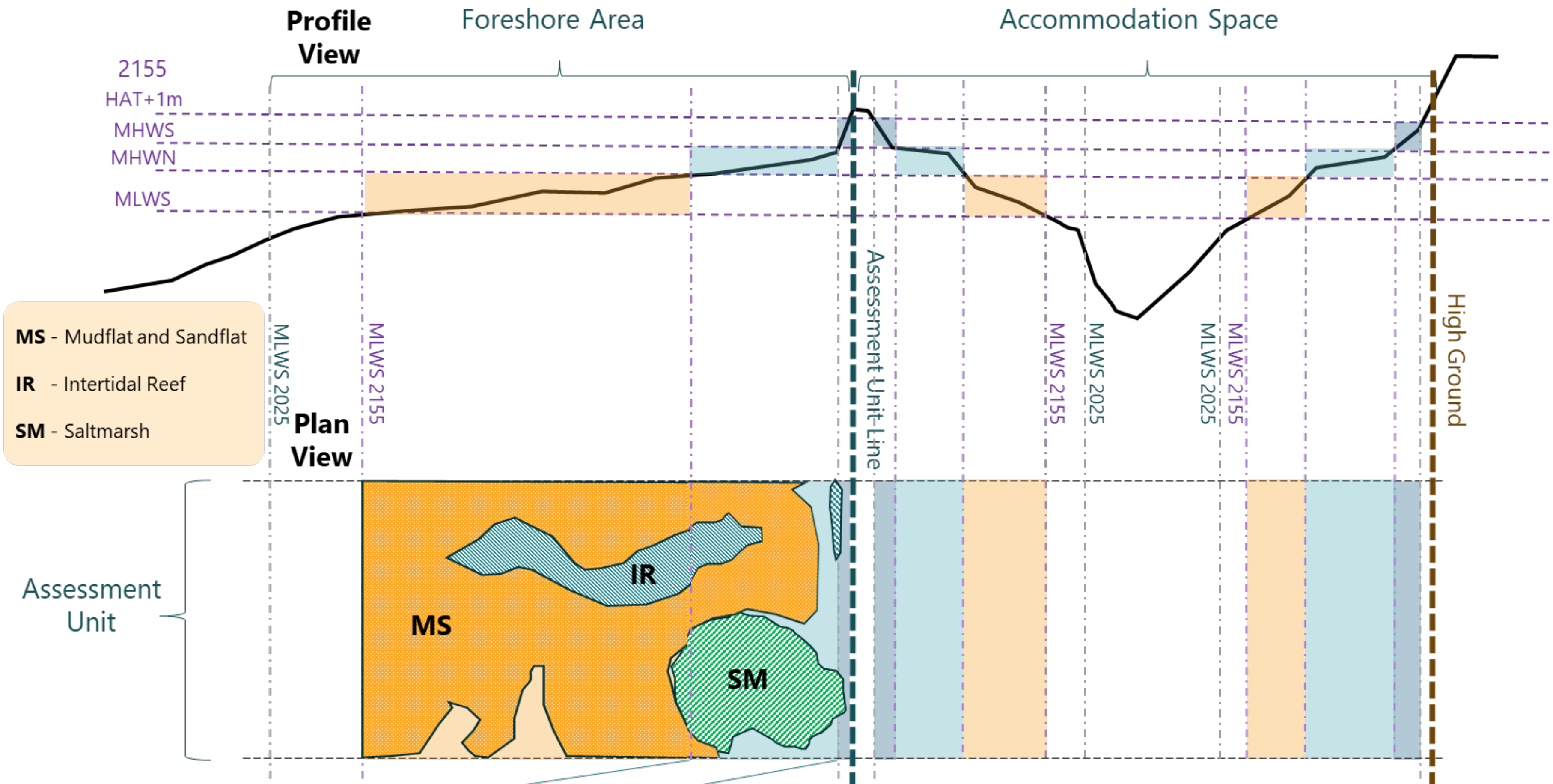


Figure 6 STEP 2: Schematic showing the calculation of present-day (2025) percentage habitat coverage. Habitat Group extents are overlaid over each tidal frame within the Foreshore Area and the percentage habitat coverage is calculated for each tidal frame, for each habitat present.



	Low – Mid Intertidal			Upper Intertidal			Supralittoral		
	MS	IR	SM	MS	IR	SM	MS	IR	SM
2025 / **2155**	85%	8%	5%	35%	7%	42%	0%	3%	15%

Percentage habitat cover across each Tidal Frame maintained

Present-day percentage habitat cover across Foreshore Area assumed to remain the same in future epochs.

Figure 7 STEP 2: Schematic showing how present-day (2025) percentage habitat coverage is maintained in future epochs to 2155. Figure shows that whilst the Tidal Frame Extents vary from the present-day (2025) scenario (Figure 6), there is no change in percentage habitat coverage.

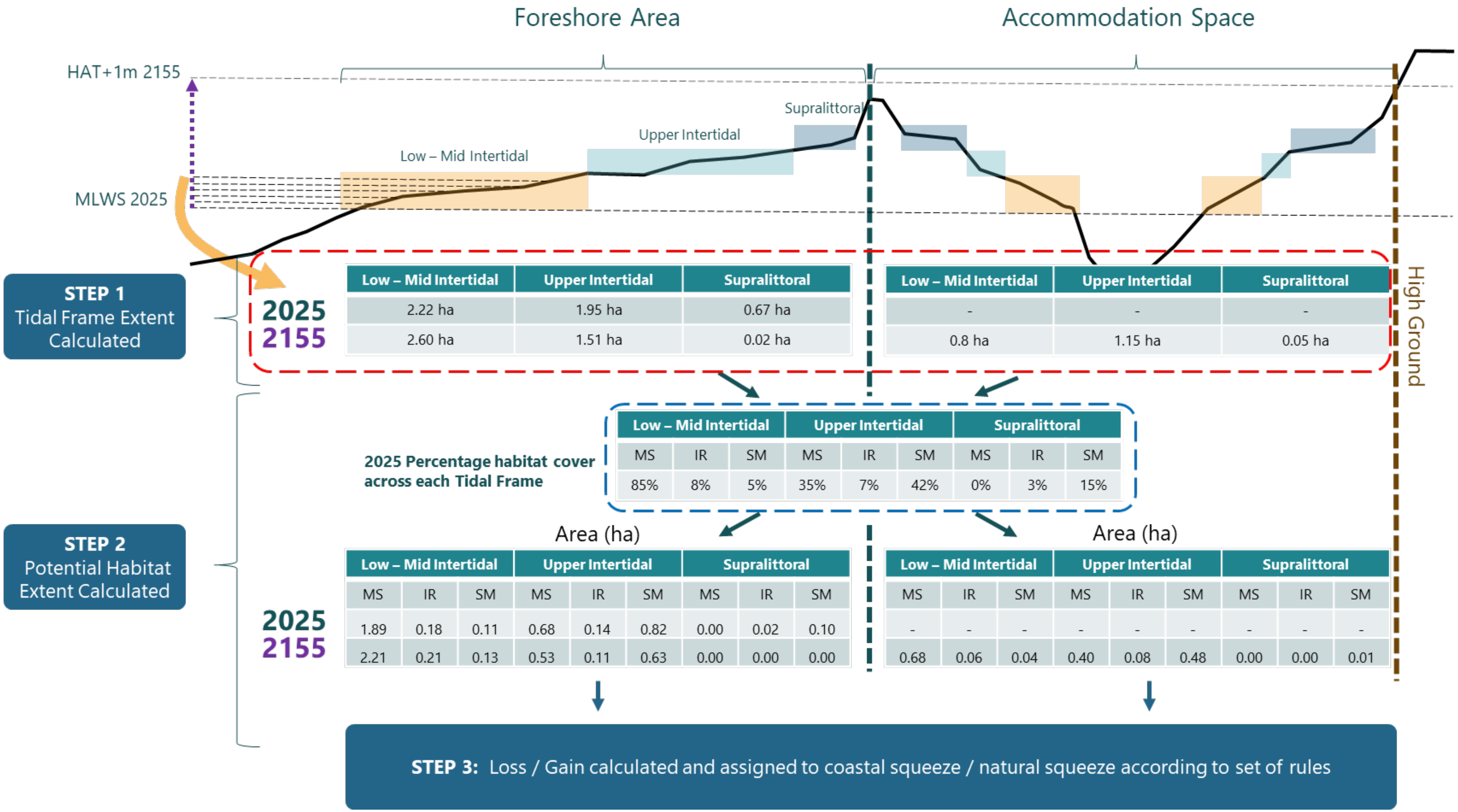


Figure 8 Schematic showing the calculation of Tidal Frame Extent in STEP 1 and the calculation of Potential Habitat Extent in STEP 2. Calculations are presented for Foreshore Area and Accommodation Space associated with a single Assessment Unit.

3.1.3 STEP 3: Assessment of coastal squeeze and natural squeeze

The final step of the assessment is to calculate any loss or gain in Potential Habitat Extent and to assign this to either coastal squeeze or natural squeeze.

Habitat loss and gains are first calculated for each tidal frame and for each Habitat Group present. This is done for each future epoch by comparing the Potential Habitat extents at the end of each epoch to the present-day (2025) Potential Habitat extents. This is done separately for the Foreshore Areas and Accommodation Space related to each individual Assessment Unit.

A loss or gain is then attributed to coastal squeeze or natural squeeze based on:

- Assessment Unit type (Defence, Natural or High Ground);
- Management scenario being considered, (Defences Maintained, No Defences or SMP2 Policy, see Section 1.5);
- SMP2 Policy for the frontage; and
- The availability of Accommodation Space to accommodate the losses within the Foreshore Area.

More specifically, a loss in the Foreshore Area is attributed to coastal squeeze if the following are true:

- The Assessment Unit is classed as a Defence;
- The frontage is Defended, either because:
    - The management scenario is Defences Maintained, OR
    - The management scenario is to follow SMP2 Policy and the policy for the frontage is HTL, and
- The Assessment Unit has Accommodation Space that can accommodate the loss in the Foreshore Area.

If the above are true, but the Accommodation Space can only accommodate part of the loss identified in the Foreshore Area, the loss that can be accommodated in the Accommodation Space is attributed to coastal squeeze and the remainder of the loss is attributed to natural squeeze.

Under all other scenarios, the loss and gains in Potential Habitat Extent that occurs across both the Foreshore Area and any Accommodation Space, is attributed to natural squeeze. This includes the scenario where the Assessment Unit is classed as a Defence, but the frontage is not defended, because:

- The management scenario is No Defences, OR
- The management scenario is to follow SMP2 Policy, and the policy for the frontage is either MR or NAI (In this case it is assumed inundation would occur into the hinterland and any existing Defence will not prevent this).

The workflow to assign loss and gains to coastal squeeze and natural squeeze is illustrated as a flow chart in Figure 9.

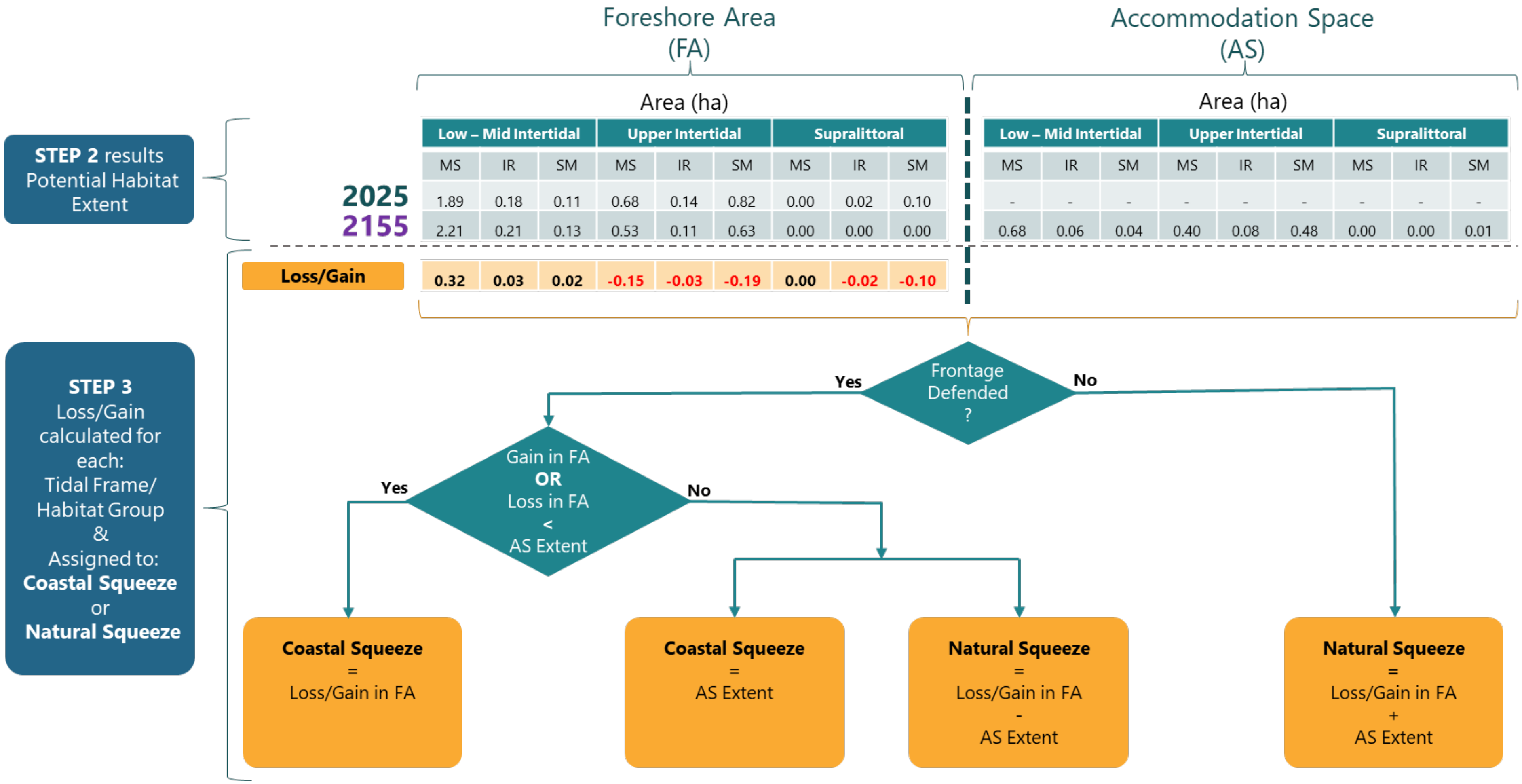


Figure 9 Schematic illustration of STEP 2 and STEP 3, including flowchart used to assign a habitat loss or gain in the Foreshore Area in 2155, to either coastal squeeze or natural squeeze.

3.1.4 Analysis tools

The three-step process used in the national scale assessment is further summarised in Figure 10.

The analysis is primarily conducted within the spreadsheet based CSAT. The CSAT performs the hypsometric analysis to calculate the Tidal Frame Extents for each epoch examined, and then combines this with the information of present-day (2025) habitat extent to estimate Potential Habitat Extents at the end of each epoch. It then utilises the rules identified in Section 3.1.3 (Section 3.2.2 for dunes and vegetated shingle), to assign any loss and gain in habitat to coastal squeeze or natural squeeze.

To populate the CSAT, information contained in the GIS data layers has been extracted and processed using a series of scripts. This includes scripts to:

- Extract the hypsometric data from the Project DTM for each tidal frame within both the Foreshore Areas and Accommodation Space associated with each Assessment Unit. This is done both nationally and for individual MPAs;
- Calculate the present-day (2025) habitat coverage in each Foreshore Area, and
- Extract key data from the:
    - Tidal Level data layer
    - Assessment Unit data layer
    - MPA data layer

Figure 10 identifies which elements of the analysis are completed using scripts that interrogate the GIS data layers, and which elements are undertaken within the CSAT.

Different CSATs have been developed, for the two separate SLR scenarios considered, with each CSAT allowing the management scenario to be modified between the three scenarios examined; Defences Maintained, SMP2 Policy and No Defences.

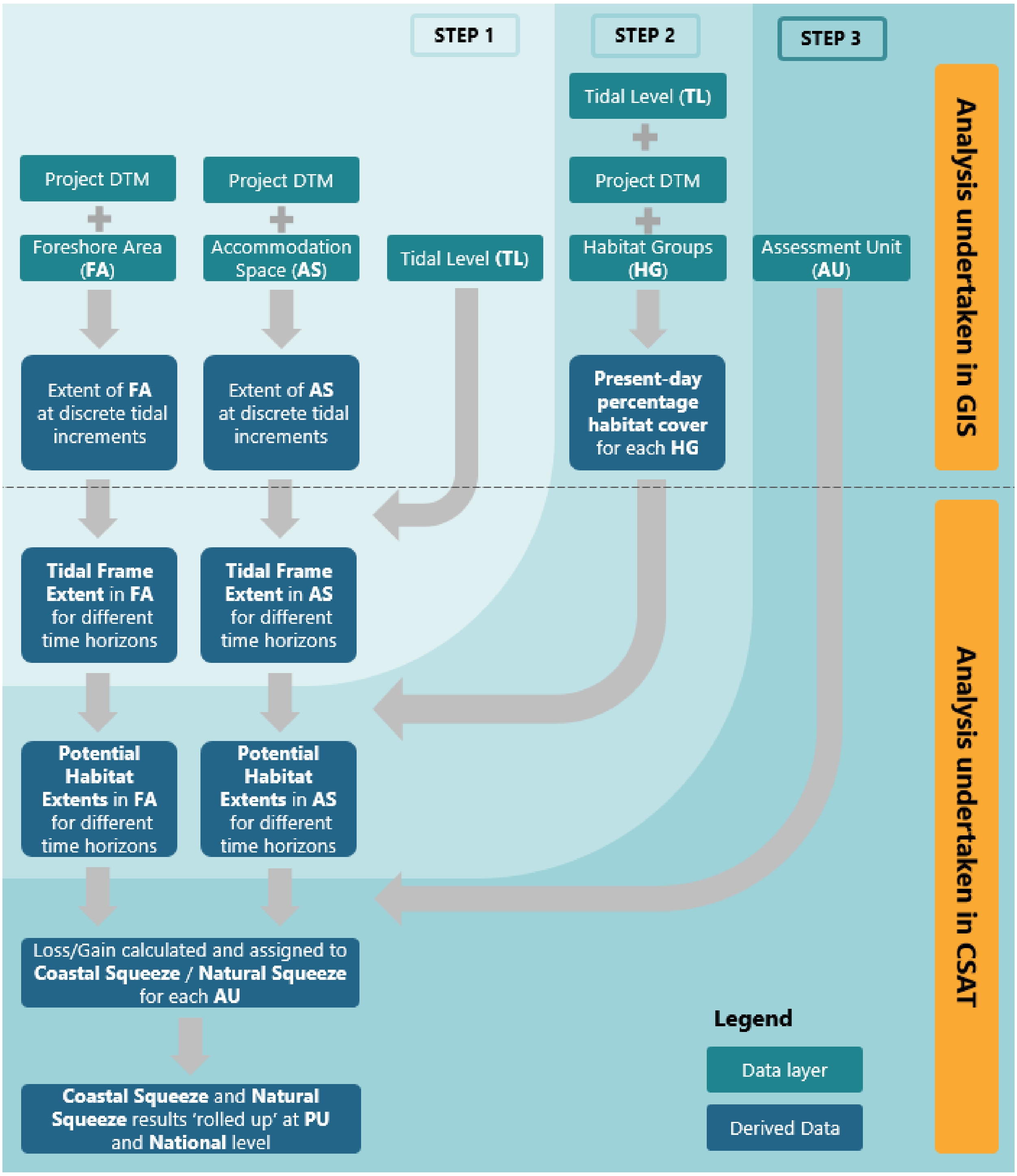


Figure 10 Schematic showing workflow for the national assessment, identifying the tasks undertaken during each of the three identified steps. The figure also identifies which elements of the analysis are completed in GIS and which are completed in the CSAT.

3.2 Modification of the approach for dunes and vegetated shingle

3.2.1 Introduction

Dune and shingle systems are dynamic geomorphological features that respond to SLR by adjusting their morphology. If no anthropogenic structure is present and there is available sand and shingle, the habitat will roll-back with SLR. Therefore, it is not appropriate to use the same hypsometric approach as applied to mudflat and sandflat, intertidal reef, saltmarsh, and littoral coarse sediment.

Furthermore, the habitats associated with dune and vegetated shingle systems occur in the supralittoral zone and above and can extend into the hinterland behind an anthropogenic structure or natural frontage.

Within the present study, the assessment of coastal squeeze and natural squeeze in relation to dunes and vegetated shingle is therefore restricted to examining the potential loss and gain of these habitats that currently exist in the Foreshore Area only. The assessment does not examine how the present-day (2025) extents of these habitats that currently occur within the hinterland may be affected by SLR.

Furthermore, the calculation of coastal squeeze and natural squeeze in STEP 3 of the assessment is also modified for dunes and vegetated shingle as described in the section below.

Ideally coastal squeeze and natural squeeze for these systems should be completed using a local geomorphological assessment, but this is not considered practical for the present national scale assessment.

3.2.2 Calculation of coastal squeeze and natural squeeze for dunes and vegetated shingle

Figure 11 to Figure 13 show how dunes are considered in the assessment, with the same approach applied to vegetated shingle.

Figure 11 shows the present-day (2025) extent of dunes within the Foreshore Area. Where an anthropogenic structure is maintained, it is assumed that the dunes will be squeezed up against the structure (Figure 12), however, where no structure is maintained it is assumed that the dunes would roll-back into the Accommodation Space, providing there is room within the Accommodation Space for them to do so (Figure 13). In this scenario the entire Tidal Frame Extent within the Accommodation Space is considered to be available for the habitat to roll-back into, as bed levels in the Accommodation Space would be modified by the habitat rolling back.

For dunes and vegetated shingle, a loss in the Foreshore Area is therefore attributed to coastal squeeze if the following are true:

- The Assessment Unit is classed as a Defence;
- The frontage is Defended, either because:
    - The management scenario is Defences Maintained, OR
    - The management scenario is to follow SMP2 Policy and the policy for the frontage is HTL, and
- The total Tidal Frame Extent of any Accommodation Space associated with the Assessment Unit can accommodate the loss in the Foreshore Area.

If the above are true, but the total Tidal Frame Extent of the Accommodation Space can only accommodate part of the loss identified in the Foreshore Area, the loss that can be accommodated in the Accommodation Space is attributed to coastal squeeze and the remainder of the loss is attributed to natural squeeze.

If there is no defence being maintained, a further check is then performed to examine if the loss should be assigned to natural squeeze or not. If the loss in the Foreshore Area is less than the total Tidal Frame Extent in the Accommodation Space, it is assumed that there is no natural squeeze as the habitat will simply roll back into the Accommodation Space. If not, the loss that cannot be contained within the Accommodation Space is assigned to natural squeeze.

The workflow to assign loss and gains of dunes and vegetated shingle to coastal squeeze and natural squeeze is illustrated as a flow chart in Figure 14.

The above approach is a minor variation of the rules applied for calculating coastal squeeze and natural squeeze for the other four Habitat Groups of mudflat and sandflat, intertidal reef, saltmarsh and Littoral coarse sediment.

The assessment of dunes and vegetated shingle habitats does not consider whether there may already be dunes and vegetated shingle in the Accommodation Space that could be displaced by the habitats rolling back. Furthermore, it does not account for the possibility that other Habitat Groups may also be rolling back into the Accommodation Space.

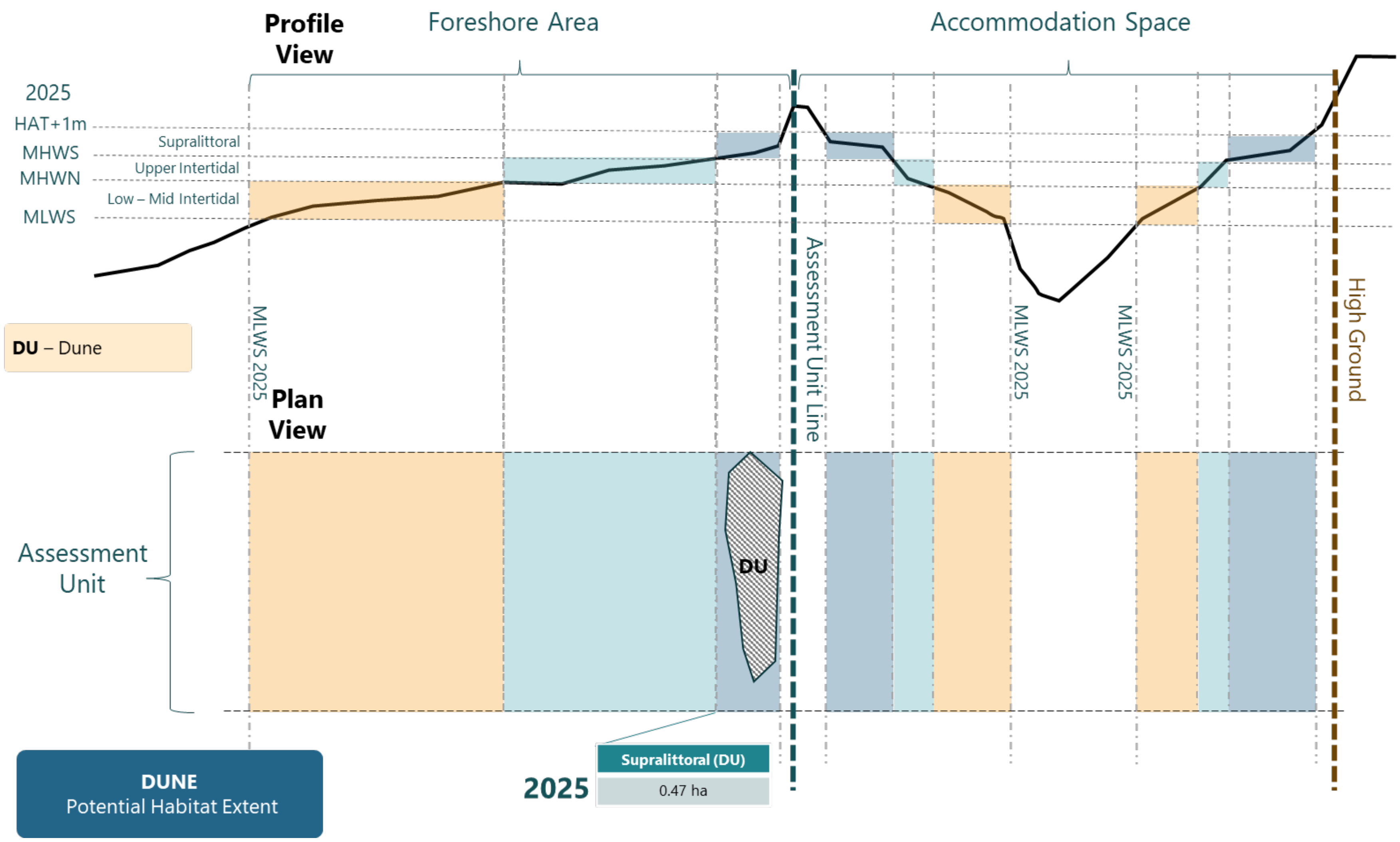


Figure 11 Schematic showing the present-day (2025) extent of dune habitat in the Foreshore Area.

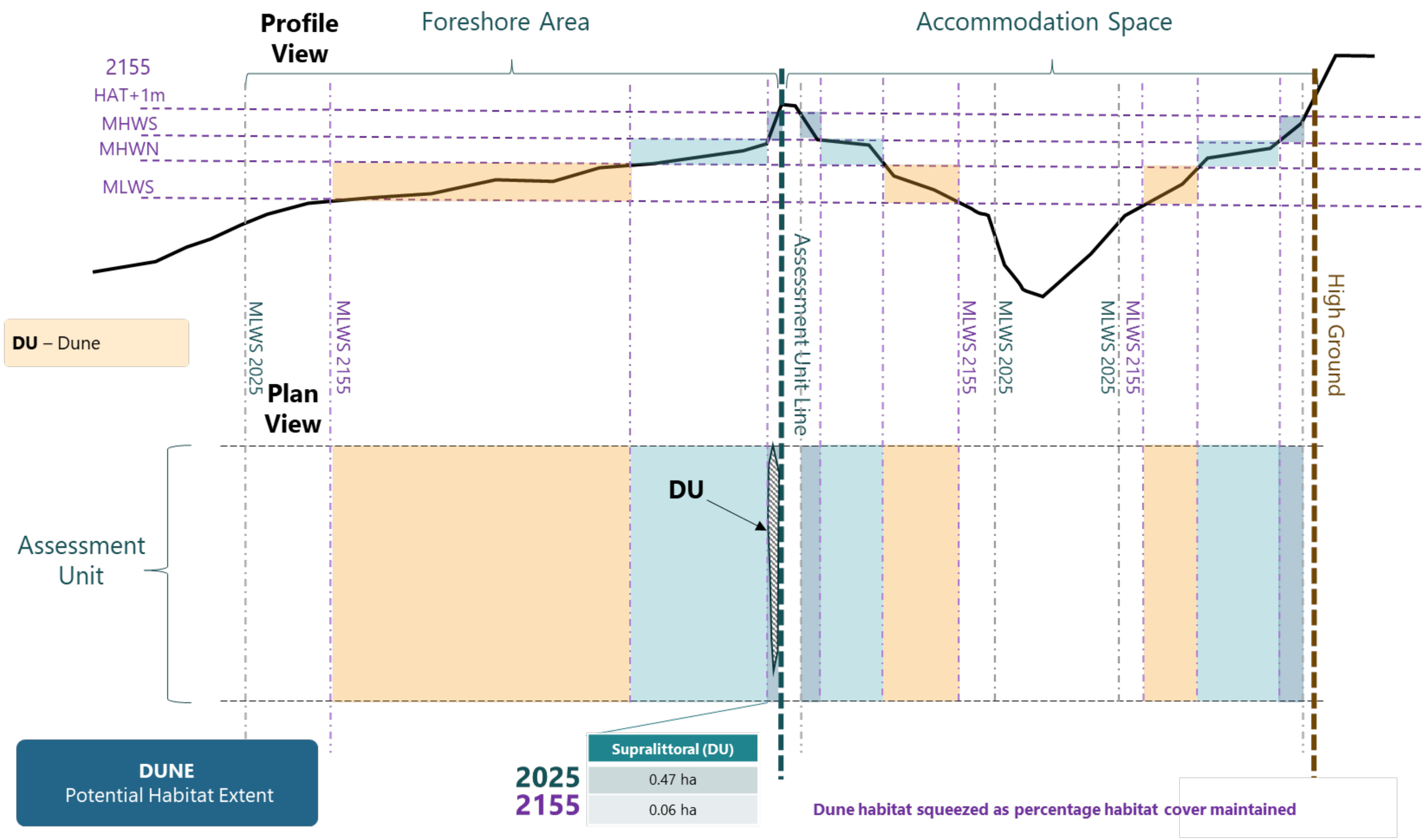


Figure 12 Schematic showing dune habitat being squeezed up against the Assessment Unit line in 2155 when a defence is maintained.

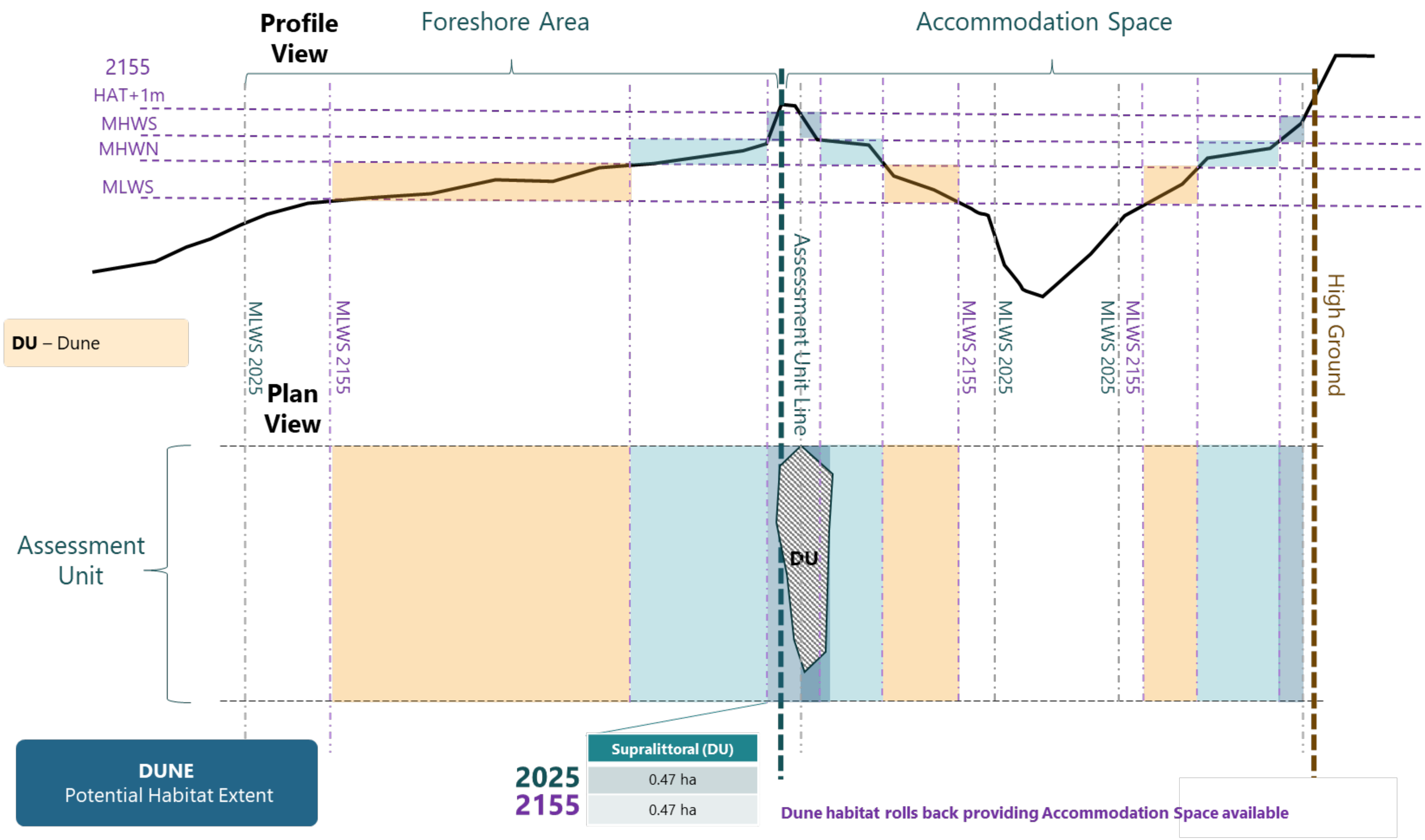


Figure 13 Schematic showing dune habitat rolling back in 2155 when no defence is maintained.

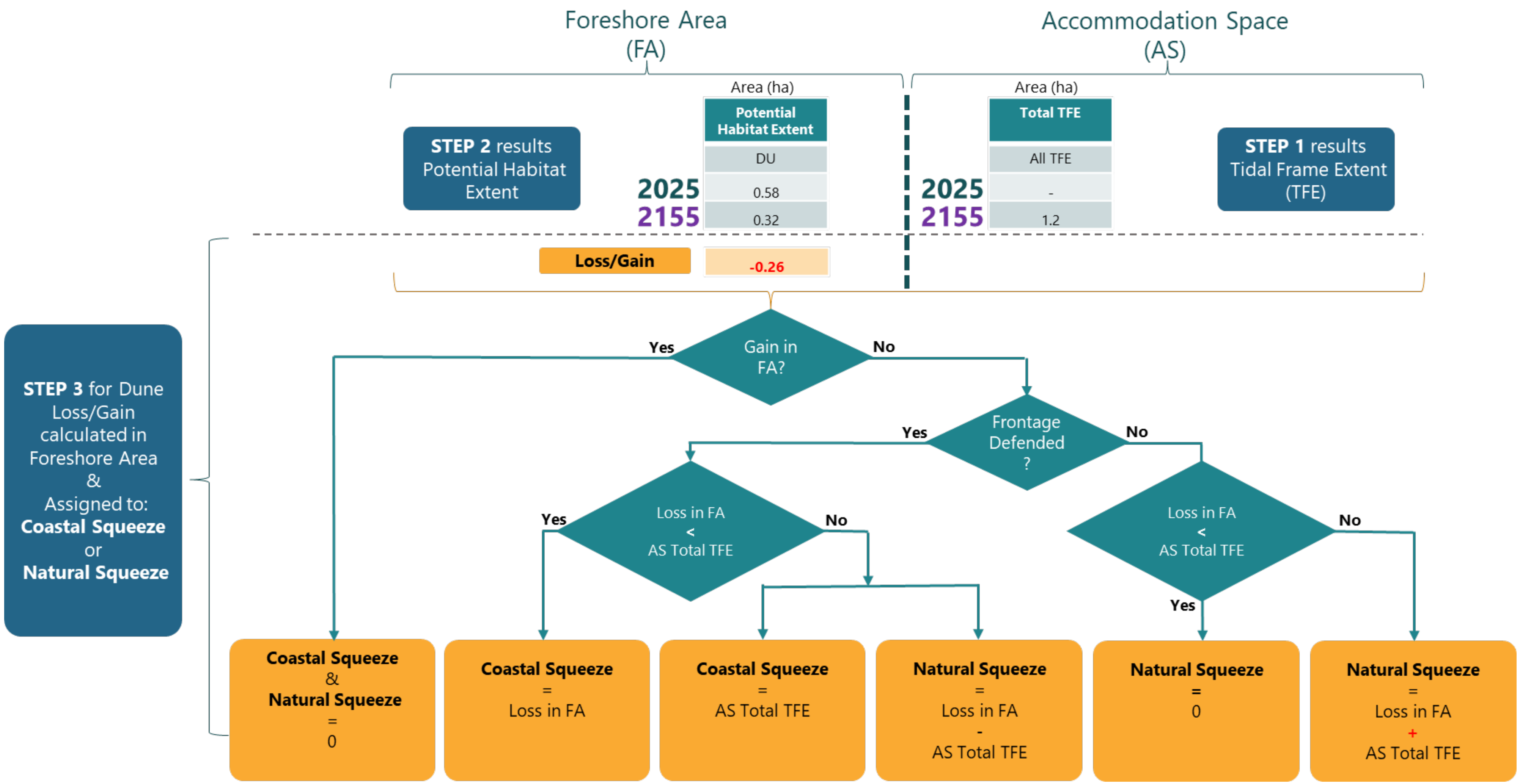


Figure 14 Schematic illustration of STEP 2 and STEP 3 for dunes, including flowchart used to assign a habitat loss or gain in the Foreshore Area in 2155, to either coastal squeeze or natural squeeze. The same rules are applied to vegetated shingle.

3.3 Assessment of coastal squeeze on coastal lagoons

Coastal lagoons typically lie behind anthropogenic structures and Natural Ridges; therefore, they are not generally subject to coastal squeeze (or natural squeeze if the Natural Ridge remains intact and functioning). This is consistent with Environment Agency, (2021), which only considers saline lagoons in front of structures to be subject to coastal squeeze. However, a coastal lagoon within the hinterland, may still be subject to loss and gain as a result of SLR, if a defence is not maintained and/or a Natural Ridge were to roll-back. Therefore, coastal lagoons have been considered in the assessment.

Given the complexity of these features it was not appropriate to assess these features at a national scale using the hypsometric analysis based approach. A separate, high-level desk based assessment has instead been undertaken to examine the potential loss of coastal lagoon habitat as a result of SLR. This assessment is described in Volume 2 – Results and Discussion.

4 Understanding the likely scale of deterioration of Marine Protected Areas

To apply the coastal squeeze and natural squeeze assessments to MPAs the same three step process was applied. However, an additional stage is included during STEP 1. In this step each individual MPA is overlaid over the Foreshore Area and only areas that lie inside the boundary of the MPA designation are included within the hypsometric analysis and the calculation of the Tidal Frame Extents.

Within the assessment, the available Accommodation Space is not restricted to the MPA boundary. This is because coastal squeeze can only be considered to occur if there is Accommodation Space available to accommodate the habitat if it was able to roll-back. Therefore, it is necessary to ensure the Accommodation Space is not restricted to the MPA boundary, which frequently stops at the coastline. As a consequence habitat gains are calculated for MPAs within the assessment, where the habitat can extend into the hinterland. However, it may only be possible to realise some of these gains if MPA boundaries are adjusted accordingly.

Furthermore, within STEP 3 an additional rule is introduced to identify whether coastal squeeze or natural squeeze should be attributed to the MPA. This rule identifies that:

- Coastal squeeze or natural squeeze is only calculated for the MPA if it supports a Habitat Group considered to represent a site feature (Section 2.1 and Appendix A).

Within the assessment, losses and gains are calculated and assigned to coastal squeeze and natural squeeze for habitats within each individual MPA. Calculations are again undertaken at the Assessment Unit level and then amalgamated to provide the results for each MPA.

The individual MPA results are further amalgamated to provide results for each MPA designation type: SACs, SSSIs, SPAs and Ramsar sites.

The modified workflow to assess coastal squeeze and natural squeeze in relation to MPAs is illustrated in Figure 15. Two separate CSATs have been developed to undertake the assessment in relation to MPAs, one for each SLR scenario considered.

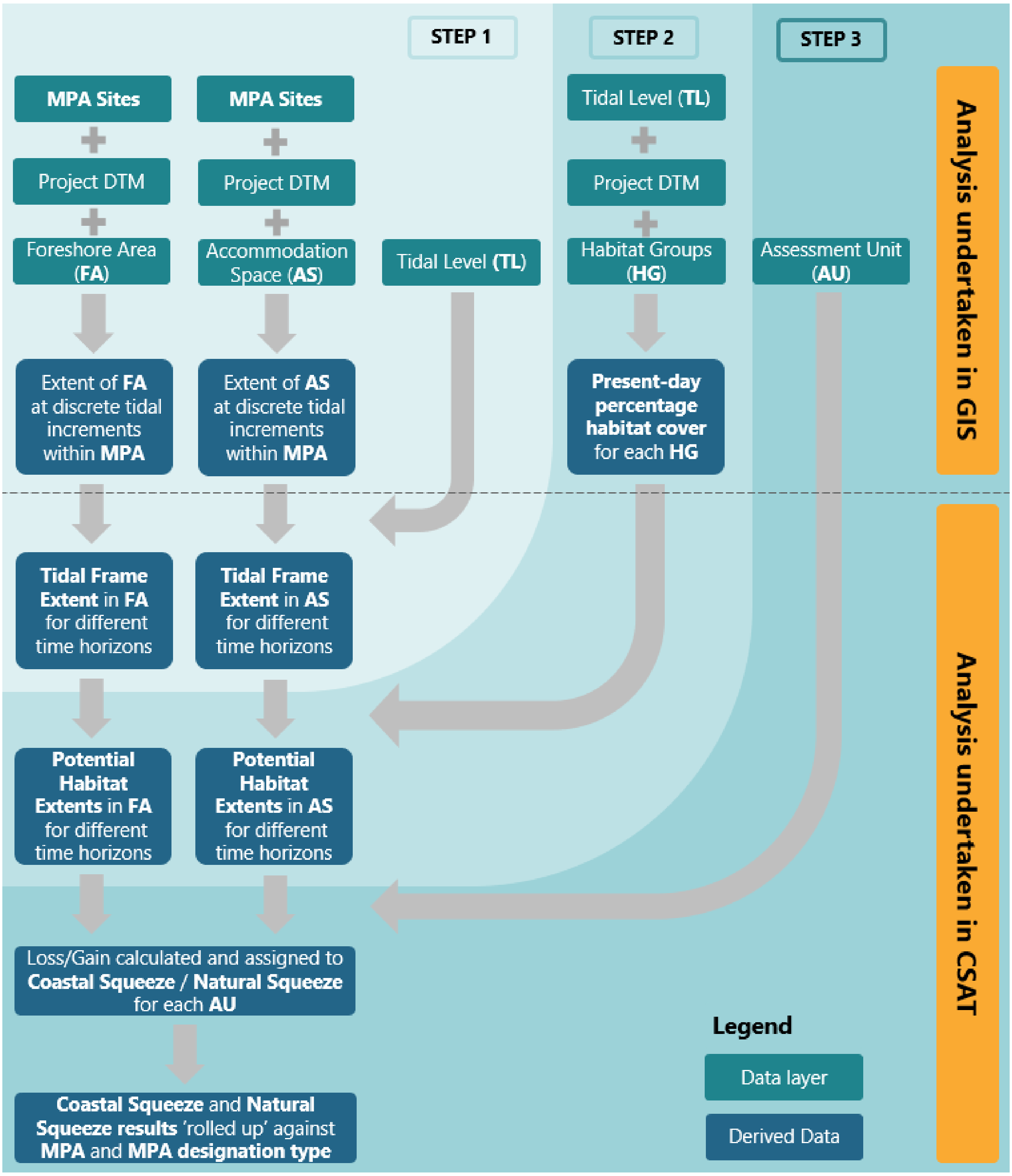


Figure 15 Schematic showing workflow for the MPA assessment, identifying the tasks undertaken during each of the three identified steps. The figure also identifies which elements of the analysis are completed in GIS and which are completed in the CSAT.

5 Data layers

To undertake the analysis the project has created six data layers as identified in Table 5.

Table 5 Data layers developed to undertake the coastal squeeze assessment.

Data layer	Brief description
Project DTM	A continuous DTM covering the entire Welsh coastline extending from present-day MLWS to HAT + 1 m in 2155 (End of the study period).
Tidal Level	Defines the present-day MLWS, MHWN and HAT around the entire Welsh coastline, and associated SLR allowances at 5 year intervals for two scenarios: • UKCP18, RCP 8.5 emission scenario 70th percentile (higher central allowance), and • UKCP18, RCP 8.5 emission scenario 95th percentile (upper end allowance)
Assessment Unit	Defines the Assessment Units that are utilised in the analysis, these are either aligned to SMP2 Policy Units, or sub-divisions of SMP2 Policy Units, where there are different types of frontages (Defence, Natural High Ground and Cliff) within the Policy Unit.
Foreshore Area	Defines the intertidal area seaward of an anthropogenic structure or natural frontage. A Foreshore Area is associated with each Assessment Unit.
Accommodation Space	Defines the area behind an anthropogenic structure or natural frontage, that could be inundated at the end of the assessment period if a defence is not maintained. A single Accommodation Space may be linked to several Assessment Units.
Habitat Group	Defines the present-day coverage of each Habitat Group within the Foreshore Area.
MPA Designated Site	Defines the extent of each MPA and the Habitat Groups it supports (as a proxy for site features).

The data layers, and their derivation are described in Appendix C to Appendix I. A general overview of the data layers and any limitations associated with the data set is provided in the following sub sections.

5.1 Project DTM

Detailed information on the development of the Project DTM is provided in Appendix C.

The Project DTM is utilised in STEP 1 of the coastal squeeze and natural squeeze assessment and provides the basis for undertaking the hypsometric analysis. The Project DTM encompasses the entire Welsh coast, including tidal estuaries. The dataset extends from present-day MLWS to HAT + 1 m for the latest Epoch considered, 2155 (utilising UKCP18 RCP 8.5, 95th percentile SLR allowances). This includes the hinterland lying behind any present-day anthropogenic structures and natural frontages.

The Project DTM has been primarily developed from existing DTM LiDAR datasets, including the All Wales 1.0 m LiDAR (2020-2022) dataset, and has a 1 m grid resolution.

In general, the datasets provided good national coverage and were considered to be very accurate. There are, however, several areas where other historical LiDAR data sets have been used and some data has been infilled from other non-LiDAR data sources. In general, these areas are quite limited and will still be reasonably accurate.

Within estuaries, false LiDAR returns were apparent along many of the main channels, where the LiDAR was returning the water surface, which was significantly higher than MLWS. This was considered unrealistic, and it would have had a significant effect on the assessment within estuaries, where no, or very limited loss, of intertidal zone would then be predicted under future SLR scenarios. Therefore, this false data was removed, and an inferred, interpolated channel was included in the Project DTM. This required significant effort and further details of the approach adopted are provided in Appendix C. There are uncertainties introduced into the Project DTM due to this, however, validation checks were also made to ensure the general width of these inferred channels were similar to historical OS Mapping. In general, towards low water, the sides of these channels typically become relatively steep, thus, whilst a significant proportion of the losses that are experienced within estuaries are often associated with this inferred channel bathymetries, the absolute area effected is relatively small compared to the overall intertidal extent within the estuary.

In general, the data layer is considered to be very highly resolved with a good level of accuracy.

5.2 Tidal level data layer

Detailed information on the development of the Tidal Level data layer is provided in Appendix D.

The Tidal Level data layer is utilised in STEP 1 and STEP 2 of the coastal squeeze and natural squeeze assessment. It is also required to support the development of several of the other project data layers, including the Project DTM, Foreshore Area and Accommodation Space.

The data layer splits the coastline up into discrete sections of the coast over which the following tidal levels are defined (all levels are relative to m Ordnance Datum Newlyn (ODN)):

- MLWS;
- MHWN;
- MHWS;
- HAT; and
- HAT +1.

Each discrete section, is linked to one or more Assessment Unit, such that the tidal range variation across the discrete section and the associated Assessment Unit(s), is typically no greater than 0.2 m.

SLR allowances are defined for each discrete section of the coast for the UKCP18, RCP 8.5 emission scenario 70th percentile (higher central allowance) and UKCP18, RCP 8.5 emission scenario 95th percentile (upper end allowance). These SLR allowances are included from 2025 to 2155 at five yearly intervals for subsequent use in the CSAT. The derivation of these water levels is based on Welsh Government (2022) guidance.

In general, the present-day (2025) tidal levels along the open coast (including open coast along the Severn Estuary), are provided to an accuracy that is comparable with the accuracy of predicted tidal level data around the coast.

Within estuaries a simplified approach has been adopted, with the tidal level at the entrance of the estuary being applied throughout the estuary. This simplification is adopted as there is no suitable available information on tidal level and SLR allowances through the estuary (other than in the Severn Estuary which is treated as open coast frontage in the assessment). In reality, tidal levels and SLR allowances can be expected to vary up estuaries, with MLWS level increasing significantly from the entrance to the natural tidal limit of the estuary. However, for this national level assessment the approach taken is considered proportionate. This is because, within the lower estuary, where the area associated with the lower tidal frame is generally greater, the tidal levels within the estuary are generally similar to those at the mouth. Whilst in the upper estuary, where the low water can vary significantly from those at the mouth, the areas associated with the lower tidal frames is generally much smaller (i.e. steep slopes associated with tidal channels). Furthermore, within the upper estuary, where the intertidal areas are generally related to the upper Tidal Frames, the tidal levels are more generally aligned to those at the mouth of the estuary. However, it is still important to recognise that this simplification is adopted within the approach.

5.3 Assessment Unit data layer

Detailed information on the development of the Assessment Unit data layer is provided in Appendix E.

The assessment of coastal squeeze and natural squeeze is undertaken at the Assessment Unit level, so that results may then be amalgamated at SMP2 Policy Unit, National or MPA level. Each Assessment Unit is defined as a polyline, that represents either:

- An anthropogenic structure (e.g. coastal defence or railway embankment);
- A Natural Ridge (e.g. beach crest / dunes ridge) which has low lying land behind;
- High Ground within an estuary; and
- Cliff along an open coast.

Within the assessment, coastal squeeze is considered to occur in front of anthropogenic structures providing that the habitat would be able to roll-back into the Accommodation Space if the structure was removed. If there is no available Accommodation Space, the loss is then assigned to natural squeeze and not coastal squeeze. Natural squeeze is also considered to occur, where habitat is lost in front of Natural Ridges and High Ground. Cliffs, are scoped out of the assessment as they will either erode, or the intertidal habitat associated with them can be expected to migrate up the rock/cliff face. This is in alignment with 'What is Coastal Squeeze?' (Environment Agency, 2021), which scopes out the Article 17 vegetated cliffs habitat from being subject to coastal squeeze.

At their largest scale an Assessment Unit represents a whole SMP2 Policy Unit, and is defined as a polyline that follows the line of the anthropogenic structure, Natural Ridge, High Ground or cliff that is covered by the Policy Unit. However, the SMP2 Policy Unit is further split into a series of smaller Assessment Units, where:

- Multiple types of frontage occur along the Policy Unit;
- Multiple Accommodation Spaces occur behind an anthropogenic structure or Natural Ridge, and one of these Accommodation Spaces is shared with another Assessment Unit (See Section 4.3.1);and
- The SMP2 Policy Unit extends across two or more Tidal Level features.

Within the generated data layer the following 'Type' definitions are used:

- Defence: Assigned where there is an anthropogenic structure aligned along the coast / estuary;
- Natural: Assigned where there is a Natural Ridge that is aligned along the coast / estuary, that presently prevents the sea encroaching into hinterland, i.e. natural beach ridge / dune, natural embankment barrier. These were typically considered to occur around present-day HAT +1 m contour (on an open coast), and around present-day HAT (within sheltered estuaries);
- High Ground: This is natural High Ground that occurs within estuaries at a level of HAT +1 +SLR in 2155 (using RCP 8.5 95th percentile SLR allowance); and
- Cliff: Natural cliff or rocky foreshore on open coast that has
    - no Accommodation Space behind it
    - no structure in front of it.

Assessment Units which are assigned cliff type are not assessed within the analysis and no Foreshore Area or Accommodation Space is assigned to them.

The development of the Assessment Unit data layers required extensive manual effort and the data set is considered to provide a very good representation of the coastline geometry and the type of frontage present. Nevertheless, it is noted that the actual location and type associated to a specific frontage was at times subjective and therefore, this could influence results locally. However, at a national scale, the data set provides a very good representation of the coastline.

5.4 Foreshore Area data layer

Detailed information on the development of the Foreshore Area data layer is provided in Appendix F.

The Foreshore Area data layer is utilised in both STEP 1 and STEP 2 of the coastal squeeze and natural squeeze assessment. It is used to define the area over which the hypsometric analysis is undertaken and the area over which the present-day percentage habitat coverage is calculated.

A unique Foreshore Area is defined for each Assessment Unit, other than for cliff frontages which are scoped out of the assessment. The Foreshore Area encompasses the area seaward of the Assessment Unit extending from present-day (2025) MLWS, to HAT +1 m in 2155 (using UKCP18, RCP 8.5 95th percentile SLR allowance). Within estuaries, the seaward limit of the Foreshore Area is taken to be the centre line of the main channel running through the estuary.

No limitations have been identified in respect of this dataset that would have a major impact on the results.

5.5 Accommodation Space data layer

Detailed information on the development of the Accommodation Space data layer is provided in Appendix G.

The Accommodation Space data layer is utilised in STEP 1 of the coastal squeeze and natural squeeze assessment. It is used to define the area over which the hypsometric analysis is undertaken landward of any anthropogenic structure or natural frontage.

An Accommodation Space is defined to be the maximum extent within the hinterland across which the tide could propagate if the anthropogenic structure or natural frontage were removed or breached. Any secondary structures, features or man-made infrastructure within the hinterland are ignored in the assessment. Therefore, the inland limit of an Accommodation Space is taken to be a ground level of HAT +1 m in 2155 (using UKCP18, RCP 8.5 95th percentile SLR allowance). However, the extent of the Accommodation Space that a habit can potentially transgress into, is subject to the hypsometry within the Accommodation Space and the level of SLR that occurs.

An individual Accommodation Space may be associated with one or more Assessment Units, such that habitat is able to roll back into the Accommodation Space if the structure or natural feature associated with one or more of the Assessment Units is removed.

Where an Accommodation Space is associated with multiple Assessment Units, the available Potential Habitat Extent within the Accommodation Space is pro-rated based on the available length of the individual Assessment Units associated with it. This introduces a large assumption into the assessment, which may not physically align with the hinterland and the space that would be available to any specific part of the frontage.

It is assumed that all land within the Accommodation Space is available for habitat to develop subject to elevation (hypsometry) and tidal levels. The viability of the land within the Accommodation Space for habitat to develop has not otherwise been assessed, and constraints such as infrastructure or communities have not been removed from the Accommodation Space.

The assessment results related to Potential Habitat Extent gains within the Accommodation Space, which are often observed as large gains in natural squeeze, therefore, need to be considered with caution when interpreting the results. The approach adopted is considered appropriate for a national scale assessment, but it should be noted that accuracy and viability of achieving these gains will be subject to other factors that need to be considered at a local scale.

5.6 Habitat Group data layer

Detailed information on the development of the Habitat Group data layer is provided in Appendix H.

The Habitat Group data layer is utilised in STEP 2 to derive Potential Habitat Extents within the Foreshore Area and Accommodation Spaces for the different time horizons. The habitat features included within each Habitat Group, their relationship to MPAs and the base data utilised for each Habitat Group are set out in Section 2.

The seven key Habitat Groups defined and considered within the assessment are identified below:

- Saltmarsh;
- Coastal lagoons;
- Vegetated shingle;
- Dunes;
- Intertidal reef;
- Mudflats and sandflats; and
- Littoral coarse sediments.

However, to undertake the assessment a further 'Not Defined' Habitat Group is also utilised. This Habitat Group is used to represent areas of the intertidal zone that have not been classified as being part of any of the other Habitat Groups. This predominantly occurs where there are gaps between the other Habitat Groups, and, in many instances, it is expected that these unclassified areas are likely to fall within the mudflats and sandflat Habitat Group.

In general, the saltmarsh, coastal lagoon, dune and vegetated shingle data layer, which have been updated more recently by NRW, are better resolved , with the other data sets less well resolved. The accuracy of the data set is considered appropriate for the national scale assessment, but some inconsistencies in the dataset have been noted which may affect results when examined at a local scale.

Where gaps occur in the data sets, coastal squeeze and natural squeeze are calculated in relation to the Not Defined Habitat Group. At a local scale it may be possible to proportion this loss to a specific Habitat Group. For example, in estuaries where the gap occurs as a result of a channel having migrated the gap may primarily relate to the mudflat and sandflat Habitat Group. However, such an assumption cannot be made more generally as in other areas the gaps may relate to a different Habitat Group.

5.7 MPA designated site data layer

Detailed information on the development of the MPA Designated Site data layer is provided in Appendix I.

The MPA data layer is utilised in STEP 1 and STEP 3 when coastal squeeze and natural squeeze are assessed within MPAs. The MPA designated sites data layer ensures that only those areas that lie within the MPA designated boundary are subsequently used in the assessment of coastal squeeze. The data layer includes the boundaries of each individual MPA for which coastal squeeze and natural squeeze is examined.

Within the analysis coastal squeeze and natural squeeze is reported against individual MPAs for those Habitat Groups that are associated with each MPA. The data layer, therefore, also identifies the Habitat Groups that are associated with each MPA (as a proxy of site features).

Within the assessment, results are amalgamated to provide information on coastal squeeze and natural squeeze against the different MPA designations:

- SACs;
- SSSIs;
- SPAs; and
- Ramsar Sites.

The individual MPAs for which coastal squeeze and natural squeeze have been examined are identified in Section 2.

The boundaries of the MPA are clearly prescribed by the available source data and therefore there are no direct limitations with respect to this data layer. However, there are a couple of points of note related to the data layer:

- In a small number of instances, individual MPA boundaries have an inshore boundary that lies along an approximate low water contour. In these instances, there is only limited sporadic overlap between the MPA boundaries and the present study extent that extends down to present-day MLWS;
- MPA boundaries are fixed, however, with SLR, habitats may be able to migrate inshore. This has an implication for the assessment, since a loss in the Foreshore Area due to a defence, can only be assigned to coastal squeeze, if there is room in the Accommodation Space to enable the habitat to roll back (if the defence was removed or breached). Therefore, potential habitat gains in the Accommodation Space are calculated even if the Accommodation Spaces lies outside the MPA boundary; and
- In some instances, the MPA boundary may extend into the hinterland and Accommodation Space, but the habitats lying in this area would typically be classified as terrestrial. Within the assessment, habitat gains in the Accommodation Space may be calculated. However, this gain is likely to be associated with the loss of the terrestrial habitat that is currently present. Such losses are not considered or assessed as part of this study.

6 Limitations of the methodology

The methodology is considered to provide an appropriate understanding of the likely deterioration of MPA features due to coastal squeeze, natural squeeze and total squeeze (coastal + natural squeeze) at a national level. However, it is not considered appropriate to apply these findings directly at a local level. This is because of the broad scale assumptions that are required to derive a practical methodology for national scale use.

As outlined in Environment Agency (2021), local ecological and geomorphological assessments may also be required along with the application of expert geomorphological understanding to provide a robust site specific assessment. The following key limitations should be considered when using the results of this national scale analysis:

*Related to Section 1.2 (*Definition of coastal squeeze*)*

The assessment does not consider how changes in coastal process and geomorphological processes, including erosion and accretion, will affect coastal squeeze. Consideration of which is identified within Environment Agency, (2021).

*Related to Section 3 (*Quantifying the potential changes in habitat extent at the national scale*)*

The analysis utilises the present-day percentage habitat coverage across each tidal frame as a basis for assessing the extent of the habitat across the same tidal frame in the future. This is a practical measure that has been adopted to encompass the likely presence of the habitat in the future which takes account of other site specific details, such as wave exposure and bed type.

For example, as a result of SLR, the available bed type in each Tidal Frame may change, i.e. intertidal rock may be lost in the present-day lower foreshore, but the proportion of available rock to support Intertidal Reef habitats higher up the tidal frame may be different. Therefore, in such circumstances, there is a limitation to the accuracy that can be achieved through the assessment. However, it is noted that where the habitat substrates are more mobile, e.g. mudflats and sandflats, these do have greater potential to rollback and therefore this issue is considered to be less of a limitation.

Related to Section 3.2 (Modification of the approach for dunes and vegetated shingle)

Dunes and vegetated shingle habitats are classified as terrestrial habitats which are not generally associated with Marine SACs and SSSIs. However, they are identified in Environment Agency, (2021), as being subject to coastal squeeze and as such have been considered in the assessment. However, the assessment is restricted to assessing the potential loss of these habitats within the Foreshore Area due to coastal squeeze or natural squeeze, or, whether there is potential for them to roll back. The assessment does not consider the present-day extent of these Habitat Groups within the hinterland (Accommodation Space), and how this may change as a result of SLR.

*Related to Section 4 (*Understanding the likely scale of deterioration of Marine Protected Areas*)*

The assessment relates Habitat Groups to an individual MPA, based on a broadscale alignment of MPA habitat features for which is it has been designated. The results of the MPA analysis are therefore not directly correlated with the features for which an MPA has been designated.

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Appendices

A MPA associated Habitat Groups

Table A1 MPA sites and their associated Habitat Groups ('X' indicated habitat is associated with the MPA, otherwise a hyphen, '-' is shown).

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
Burry Inlet	Ramsar	UK14001	X	X	X	X	X	X	-
Severn Estuary	Ramsar	UK11081	X	X	X	X	-	X	-
The Dee Estuary	Ramsar	UK11082	X	X	-	X	X	X	-
Y Fenai a Bae Conwy / Menai Strait and Conwy Bay	SAC	UK0030202	-	X	X	-	-	-	-
Severn Estuary / Môr Hafren	SAC	UK0013030	X	X	X	-	-	-	-
Kenfig / Cynffig	SAC	UK0012566	X	-	-	-	-	-	-
Glannau Mon: Cors heli / Anglesey Coast: Saltmarsh	SAC	UK0020025	X	X	-	-	-	-	-
Dee Estuary / Aber Dyfrdwy (Wales)	SAC	UK0030131	X	X	-	X	-	-	-
Cardigan Bay / Bae Ceredigion	SAC	UK0012712	-	-	X	-	-	-	-
Bae Cemlyn / Cemlyn Bay	SAC	UK0030114	-	-	-	X	-	-	X
Pembrokeshire Marine / Sir Benfro Forol	SAC	UK0013116	X	X	X	-	-	-	X
Carmarthen Bay and Estuaries / Bae Caerfyrddin ac Aberoedd	SAC	UK0020020	X	X	-	-	-	-	-
Pen Llyn a'r Sarnau / Lleyn Peninsula and the Sarnau	SAC	UK0013117	X	X	X	-	-	-	X
Bae Caerfyrddin / Carmarthen Bay	SPA	UK9014091	-	X	-	-	-	-	-

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
Burry Inlet	SPA	UK9015011	X	X	X	X	X	X	-
Severn Estuary	SPA	UK9015022	X	X	X	-	X	-	-
The Dee Estuary	SPA	UK9013011	X	X	-	X	X	X	-
Traeth Lafan / Lavan Sands, Conway Bay	SPA	UK9013031	X	X	-	-	-	-	-
Grassholm	SPA	UK9014041	-	X	-	X	-	X	-
Liverpool Bay / Bae Lerpwl	SPA	UK9020294	X	X	X	-	-	-	-
Dyfi Estuary / Aber Dyfi	SPA	UK9020284	X	X	X	X	-	X	-
Glannau Aberdaron ac Ynys Enlli / Aberdaron Coast and Bardsey Island	SPA	UK9013121	-	X	X	X	X	X	-
Northern Cardigan Bay / Gogledd Bae Ceredigion	SPA	UK9020327	-	X	X	X	-	X	X
Skomer, Skokholm and the seas off Pembrokeshire / Sgomer, Sgogwm a Moroedd Benfro	SPA	UK9014051	-	X	-	X	-	X	-
Anglesey Terns / Morwenoliaid Ynys Môn	SPA	UK9013061	X	X	X	X	-	X	X
Twyni Chwitffordd, Morfa Landimôr a Bae Brychdwn / Whiteford Burrows, Landimore Marsh and Broughton Bay	SSSI	33WWA	X	X	X	-	-	-	-
Aber Afon Conwy	SSSI	31WLZ	-	-	X	-	-	-	-
Aber Mawddach / Mawddach Estuary	SSSI	31WVS	X	X	X	-	-	-	-
Aber Taf / Taf Estuary	SSSI	33WPV	X	-	-	-	-	-	-

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
Aberarth - Carreg Wylan	SSSI	32WBP	-	-	X	-	-	-	-
Arfordir Gogleddol Penmon	SSSI	31WTH	-	-	X	-	-	-	-
Afon Dyfrdwy (River Dee)	SSSI	31WDW	X	-	-	-	-	-	-
Borth - Clarach	SSSI	32WXW	-	-	X	-	-	-	-
Afon Teifi	SSSI	32WLU	X	-	-	-	-	-	-
Arfordir Abereiddi	SSSI	32WQP	-	-	X	-	-	-	X
Arfordir Penrhyn Angle / Angle Peninsula Coast	SSSI	32WWH	-	-	X	-	-	-	-
Afon Tywi	SSSI	32WPO	X	-	-	-	-	-	-
Allt Wen a Traeth Tanybwlch	SSSI	32WCD	-	-	X	-	-	-	-
Arfordir Marros-Pentywyn / Marros-Pendine Coast	SSSI	32WGH	-	-	X	-	-	-	-
Arfordir Niwgwl - Aber Bach / Newgale to Little Haven Coast	SSSI	32WSS	-	-	X	-	-	-	-
Arfordir Pen-bre / Pembrey Coast	SSSI	32WM2	X	X	X	-	-	-	-
The Skerries	SSSI	31WCB	-	-	X	-	-	-	-
Arfordir Saundersfoot - Telpyn / Saundersfoot - Telpyn Coast	SSSI	32WVX	-	X	X	-	-	-	-
Beddmanarch-Cymyran	SSSI	31WYB	X	X	X	-	-	-	-
Blackpill, Swansea	SSSI	33WAM	-	X	-	-	-	-	-
Castlemartin Range	SSSI	32WQ3	-	-	X	-	-	-	-
Bracelet Bay	SSSI	33WWK	-	-	X	-	-	-	-

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
Broadwater	SSSI	31WMQ	X	-	-	-	-	-	X
Burry Inlet and Loughor Estuary	SSSI	33WWL	X	X	X	-	-	-	-
Caswell Bay	SSSI	33WWM	-	X	X	-	-	-	-
St. David's Peninsula Coast	SSSI	32WTJ	-	-	X	-	-	-	-
Cemlyn Bay	SSSI	31WYK	-	-	-	X	-	-	X
Dale and South Marloes Coast	SSSI	32WTB	-	-	X	-	-	-	-
Skomer Island and Middleholm	SSSI	32WAG	-	-	X	-	-	-	-
Glannau Rhoscolyn	SSSI	31WZY	X	X	X	-	-	-	-
Strumble Head - Llechdafad Cliffs	SSSI	32WTN	-	X	X	-	-	-	-
Freshwater East Cliffs to Skrinkle Haven	SSSI	32WUS	-	-	X	-	-	-	-
Creigiau Rhiwledyn / Little Ormes Head	SSSI	31WAP	-	-	X	-	-	-	-
Craigyfulfran & Clarach	SSSI	32WCW	-	-	X	-	-	-	-
Creigiau Aberarth-Morfa	SSSI	32WCZ	-	-	X	-	-	-	-
Creigiau Cwm-ceriw a Ffos-las (Morfa Bychan)	SSSI	32WZA	-	-	X	-	-	-	-
Creigiau Pen y Graig	SSSI	32WDB	-	-	X	-	-	-	-
Crymlyn Burrows	SSSI	33WDC	X	-	-	-	-	-	-
Milford Haven Waterway	SSSI	32WP3	X	X	X	-	-	-	X
Cynffig / Kenfig	SSSI	33WAD	-	-	X	-	-	-	-

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
De Porth Sain Ffraid / St Bride's Bay South	SSSI	32WHS	-	-	X	-	-	-	-
Ramsey / Ynys Dewi	SSSI	32WTH	-	-	X	-	-	-	-
Dee Estuary / Aber Afon Dyfrdwy	SSSI	31WHJ	X	X	X	-	-	-	-
Lydstep Head to Tenby Burrows	SSSI	32WUT	-	-	X	-	-	-	-
Dyfi	SSSI	32WDF	X	X	X	-	-	-	-
East Aberthaw Coast	SSSI	33WTY	-	-	X	-	-	-	-
Flat Holm	SSSI	33WAG	-	-	X	-	-	-	-
Glannau Porthaethwy	SSSI	31WWE	-	X	X	-	-	-	-
Glanllynnau a Glannau Pen-ychain i Gricieth	SSSI	31WPX	-	X	X	-	-	-	-
Glannau Aberdaron	SSSI	31WEJ	-	-	X	-	-	-	-
Glannau Penmon - Biwmares	SSSI	31WYW	-	X	X	-	-	-	-
Glannau Ynys Gybi / Holy Island Coast	SSSI	31WYX	-	-	X	-	-	-	-
Glannau Tonfanau i Friog	SSSI	31WVV	-	X	X	-	-	-	-
Glaslyn	SSSI	31WEK	X	-	-	-	-	-	-
Gower Coast: Rhossili to Porteynon	SSSI	33WWT	-	-	X	-	-	-	-
Grassholm / Ynys Gwales	SSSI	32WSX	-	-	X	-	-	-	-
Gronant Dunes and Talacre Warren	SSSI	31WJP	X	X	-	-	-	-	-
Gwydir Bay	SSSI	31WPW	-		X	-	-	-	-

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
Hook Wood	SSSI	32WSZ	X	-	-	-	-	-	-
Horton, Eastern and Western Slade	SSSI	33WEO	-	-	X	-	-	-	-
Merthyr Mawr	SSSI	33WLW	X	-	X	-	-	-	-
Penrhynoedd Llangadwaladr	SSSI	31WYC	-	-	X	-	-	-	-
Monknash Coast	SSSI	33WVB	-		X	-	-	-	-
Morfa Dyffryn	SSSI	31WNS	X	-	X	-	-	-	-
Morfa Harlech	SSSI	31WNT	X	X	-	-	-	-	-
Morfa Uchaf, Dyffryn Conwy	SSSI	31WGG	X	-	-	-	-	-	-
Porth Ceiriad, Porth Neigwl ac Ynysoedd Sant Tudwal	SSSI	31WEV	-	-	X	-	-	-	-
St. Margaret's Island	SSSI	32WWD	-	-	X	-	-	-	-
Porth Dinllaen i Borth Pistyll	SSSI	31WEW	-	X	X	-	-	-	-
Mynydd Penarfynydd	SSSI	31WES	-	-	X	-	-	-	-
Mynydd Tir y Cwmwd a'r Glannau at Garreg yr Imbill	SSSI	31WTA	-	X	X	-	-	-	-
Newport Cliffs	SSSI	32WTD	-	-	X	-	-	-	-
Rhosneigr Reefs	SSSI	31WZZ	-	-	X	-	-	-	-
Stackpole Quay - Trewent Point	SSSI	32WQ5	-	-	X	-	-	-	-
Pen y Gogarth / Great Ormes Head	SSSI	31WAN	-	-	X	-	-	-	-
Oxwich Bay	SSSI	33WXA	X	X	-	-	-	-	-

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
Penard Valley	SSSI	33WXD	X	-	-	-	-	-	-
Penarth Coast	SSSI	33WVF	-	-	X	-	-	-	-
Porth Towyn i Borth Wen	SSSI	31WSQ	-	-	X	-	-	-	-
Pwll-du Head and Bishopston Valley	SSSI	33WXE	-	-	X	-	-	-	-
Puffin Island - Ynys Seiriol	SSSI	31WZX	-	-	X	-	-	-	-
Severn Estuary	SSSI	33WGX	X	X	X	-	-	-	-
Southerndown Coast	SSSI	33WLY	-	-	X	-	-	-	-
Stackpole	SSSI	32WQ4	-	-	X	-	-	-	-
The Offshore Islets of Pembrokeshire / Ynysoedd Glannau Penfro	SSSI	32WSM	-	-	X	-	-	-	-
Tenby Cliffs and St. Catherine's Island	SSSI	32WUV	-	X	X	-	-	-	-
Sully Island	SSSI	33WVJ	-	-	X	-	-	-	-
Wig Bach a'r Glannau i Borth Alwm	SSSI	31WJY	-	-	X	-	-	-	-
Tiroedd a Glannau Rhwng Cricieth ac Afon Glaslyn	SSSI	31WER	-	X	X	-	-	-	-
Traeth Lafan	SSSI	31WAZ	-	X	X	-	-	-	-
Traeth Llanon	SSSI	32WZB	-	-	X	-	-	-	-
Traeth Lligwy	SSSI	31WKJ	-	-	X	-	-	-	-
Twyni Lacharn - Pentywyn / Laugharne - Pendine Burrows	SSSI	32WWK	-	X	-	-	-	-	-

MPA	Designation	Code	Designated for Saltmarsh	Designated for mudflat and sandflat	Designated for intertidal reef	Designated for vegetated shingle	Designated for dunes	Designated for Littoral coarse sediment	Designated for coastal lagoons
Ty Croes	SSSI	31WB2	-	-	X	-	-	-	-
Ynys Enlli	SSSI	31WFA	-	-	X	-	-	-	-
Tywyn Aberffraw	SSSI	31WCG	X	-	-	-	-	-	-
Waterwynch Bay to Saundersfoot Harbour	SSSI	32WUW	-	X	X	-	-	-	-
Y Foryd	SSSI	31WGN	-	X	-	-	-	-	-
Ynys Feurig	SSSI	31WCH	-	-	X	-	-	-	-
Ynysoedd y Gwylanod, Gwylan Islands	SSSI	31WFB	-	-	X	-	-	-	-
Newborough Warren - Ynys Llanddwyn	SSSI	31WZP	X	X	X	-	-	-	-
Coedydd Afon Menai	SSSI	31WBM	-	-	X	-	-	-	-

B Hypsometric analysis

As part of the assessment the Tidal Frame Extents are calculated through a hypsometric analysis. This analysis is done for both the Foreshore Area and Accommodation Space for three tidal frames:

- Lower to Mid Intertidal (MLWS to MHWN);
- Upper Intertidal (MHWN to MHWS); and
- Supralittoral (MHWS to HAT +1 m).

The assessment is undertaken separately for each Assessment Unit.

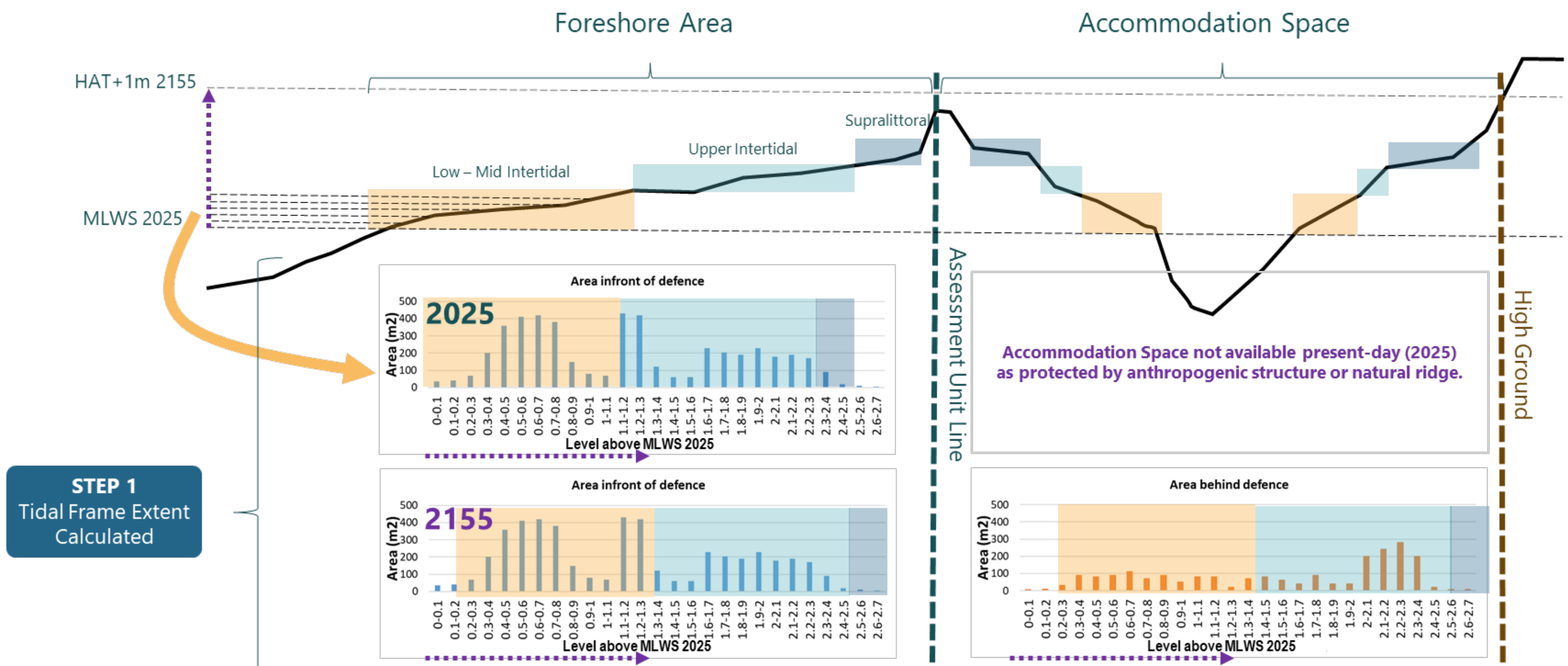
When coastal squeeze and natural squeeze is predicted for MPAs, the Tidal Frame Extents in the Foreshore Area are also restricted to those areas that lie in the MPA site boundary.

Within the hypsometric analysis Tidal Frame Extents are derived by first extracting a histogram from the Project DTM that identifies the extent of the intertidal area for small discrete increments (0.2 m intervals) in bed level. Therefore, for each 0.2 m increment in bed level, the area within the Foreshore Area and any associated Accommodation Space is extracted from the Project DTM.

These histograms are developed to cover the full tidal range considered within the assessment, i.e. present-day (2025) MLWS through to HAT +1 m in 2155 (using RCP 8.5, 95th percentile SLR allowance). Separate histograms are developed for each Assessment Unit.

These histograms are then referenced against the tidal levels that define each of the three tidal frames (e.g. MLWS, MHWN, and HAT +1 m), to determine the total intertidal area that lies within each tidal frame. This is done for both present-day (2025) tidal levels and the tidal levels at the end of each epoch.

This process is schematised in Figure B1.



Foreshore Area

	Low – Mid Intertidal	Upper Intertidal	Supralittoral
2025	2.22 ha	1.95 ha	0.67 ha
2155	2.60 ha	1.51 ha	0.02 ha

Accommodation Space

	Low – Mid Intertidal	Upper Intertidal	Supralittoral
2025	-	-	-
2155	0.8 ha	1.15 ha	0.05 ha

Figure B1 Schematic diagram showing how Tidal Frame Extents are determined for two different time horizons, present-day (2025) and 2155. Using hypsometric analysis, histograms are initially generated, showing the area associated with small increments in bed levels. The areas in each tidal frame are then summed to derive the Tidal Frame Extents. This is done separately for the Foreshore Area and Accommodation Space.

C Project DTM

C.1 Overview of data layer

The Project DTM is utilised in STEP 1 of the coastal squeeze and natural squeeze assessment and provides the basis for undertaking the hypsometric analysis. It encompasses the entire Welsh coast, including tidal estuaries. The dataset must therefore extend from present-day MLWS to HAT + 1 m at the end of the last Epoch considered, being 2155 (utilising UKCP18 RCP 8.5, 95th percentile SLR allowances). This includes the hinterland lying behind any present-day anthropogenic structures and natural frontages. Additionally, as exclusion of built infrastructure (which is a factor in the viability of the Accommodation Space for habitats to develop) is outside the scope of this project, a DTM rather than a Digital Surface Model is required for the analysis.

C.2 Preliminary data sources

Recent LiDAR for 2020-22, available from DataMapWales, was identified as the primary source of elevation data for the DTM, as it provides the most current and detailed LiDAR data set available for Wales. This All Wales 1.0 m LiDAR Dataset, however, had incomplete coverage at the time the analysis was undertaken, with significant gaps along the coast and adjacent hinterland, as indicated in Figure C1.

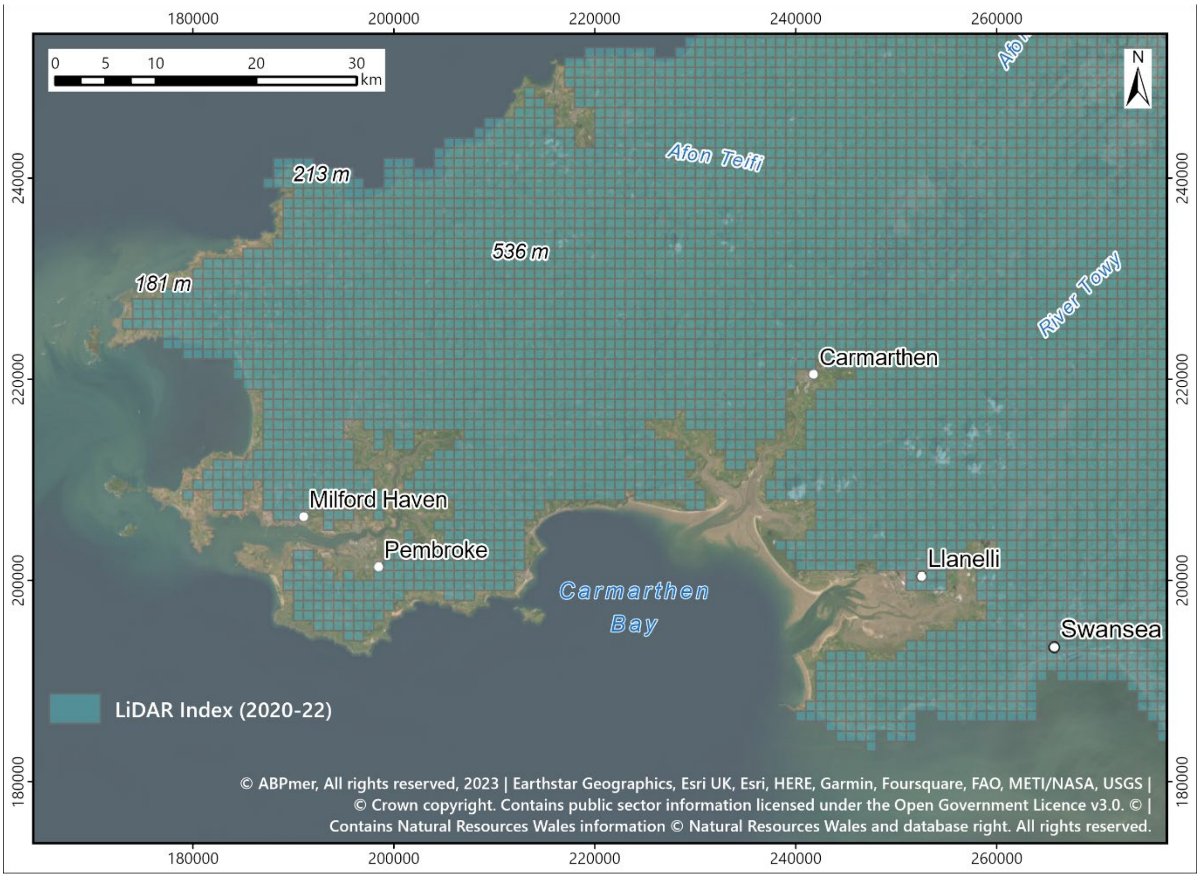


Figure C1. All Wales 1.0 m LiDAR (2020-2022) Index, showing an example location where data was missing (i.e. where aerial imagery of land is visible rather than the blue grid cells).

In these areas, historical LiDAR data from DataMapWales was initially examined and used to fill most of the gaps.

Where gaps remained, a combination of alternative data sets were used to provide elevations in these areas. For areas where data is missing at higher elevations, the OS Terrain® 50 (OS Open Data) gridded data set was used. In the intertidal zone, a combination of topographical beach profiles (available from the Wales Coastal Monitoring Centre (WCMC)) and bathymetry data (available from the UK Hydrographic Office (UKHO)) were used to extend the DTM down to the MLWS limit.

The following datasets were therefore used to support the production of the Project DTM:

- All Wales 1.0 m LiDAR (2020-2022) dataset from https://datamap.gov.wales/ (Welsh Government, 2023);
- LiDAR 1 m and 2 m data (historical) from https://datamap.gov.wales/;
- MLWS Line from OS MasterMap as provided by NRW in 2023;
- OS Terrain® 50 (OS Open Data) from https://osdatahub.os.uk/downloads/open/Terrain50;
- WCMC Topographic Beach Profiles from https://www.wcmc.wales/data (WCMC, 2023); and
- Bathymetry data from https://seabed.admiralty.co.uk (UKHO, 2023).

To ensure traceability, the developed Project DTM is accompanied by a Project DTM Source Index. This additional data layer identifies which of the above sources was used for a specific data tile.

C.3 Production of the data layer

C.3.1 Selecting historical LiDAR data for download

Using the All Wales 1.0 m LiDAR dataset (2020-2022) tile index, the historical LiDAR index was ‘clipped’ to remove tiles already covered by the 2020-22 LiDAR data (Figure C2), identifying only those areas where historical LiDAR data was needed. From these, any tiles extending below MLWS were additionally removed, where MLWS defines the lower limit of the DTM (Figure C3).

As the historical LiDAR data includes multiple acquisitions, only the 1 m and 2 m resolution datasets were selected for review initially, as these looked to provide the best coverage. Of these, the 1 m historical data was identified as the preferred historical LiDAR source to use in creating the DTM, being the same resolution as the 2020-22 LiDAR data, and thus prioritised over the 2 m data where possible. Where suitable 1 m resolution data was not available the 2 m data was then considered. For both 1 m and 2 m datasets, the most recent data was prioritised and/or the best indicated coverage, depending on what was available for the area. Each corresponding tile was then selected from the historical tile catalogue, and a merged tile index created, indicating the preferred data source for download.

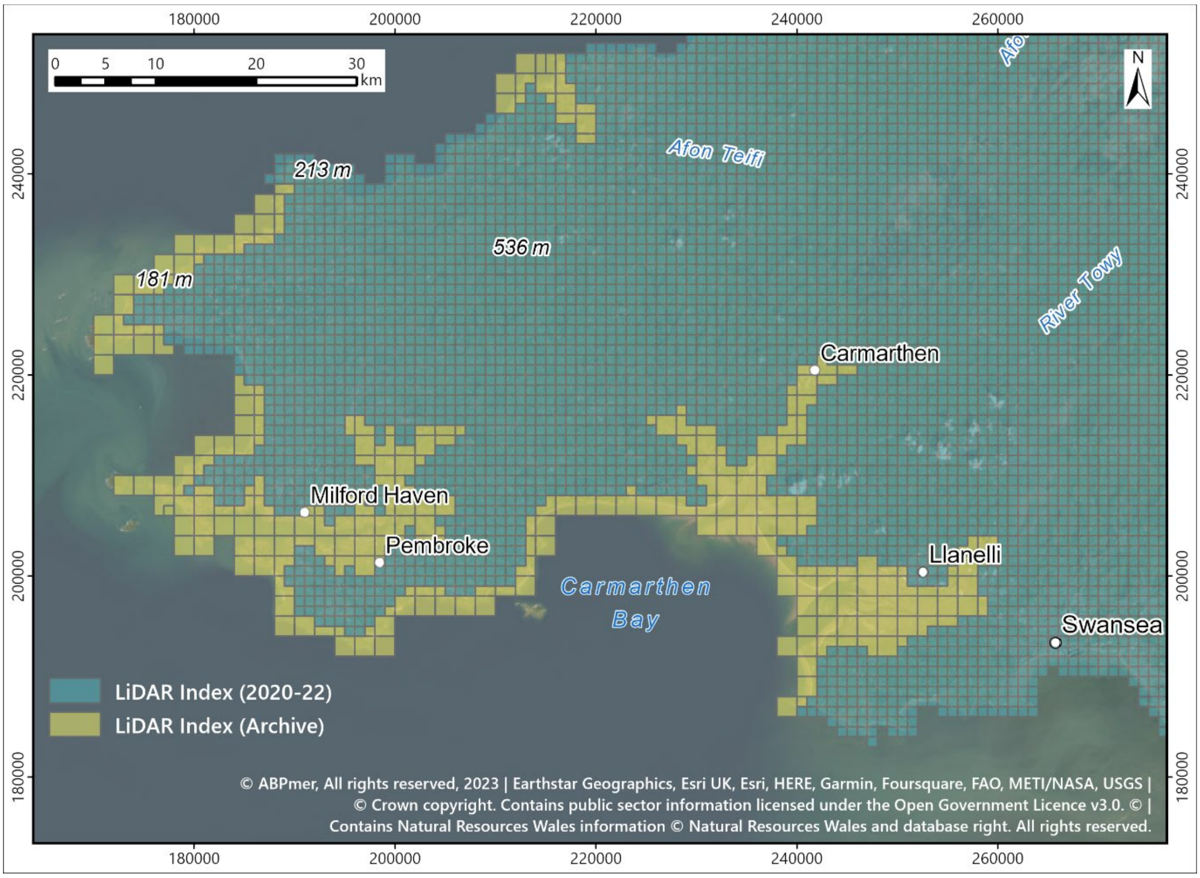


Figure C2. LiDAR Index (Archive) – Data coverage (clipped) i.e. yellow grid cells provide historical LIDAR for use in DTM generation.

Figure C3. LiDAR Index (Archive) - Tiles outside of required limits.

Having selected the preferred historical LiDAR source from the tile index, individual tiles were manually downloaded, working around the Welsh coastline, and visually inspected to assess data quality and coverage. In some areas, the 1 m resolution tiles did not have good coverage and were replaced by the 2 m data if it provided better coverage. Having, selected the preferred tiles, these were again visually inspected and any gaps within the preferred tile were highlighted (Figure C4). In these areas, where possible, the gaps were supplemented with data from other over historical LiDAR tiles.

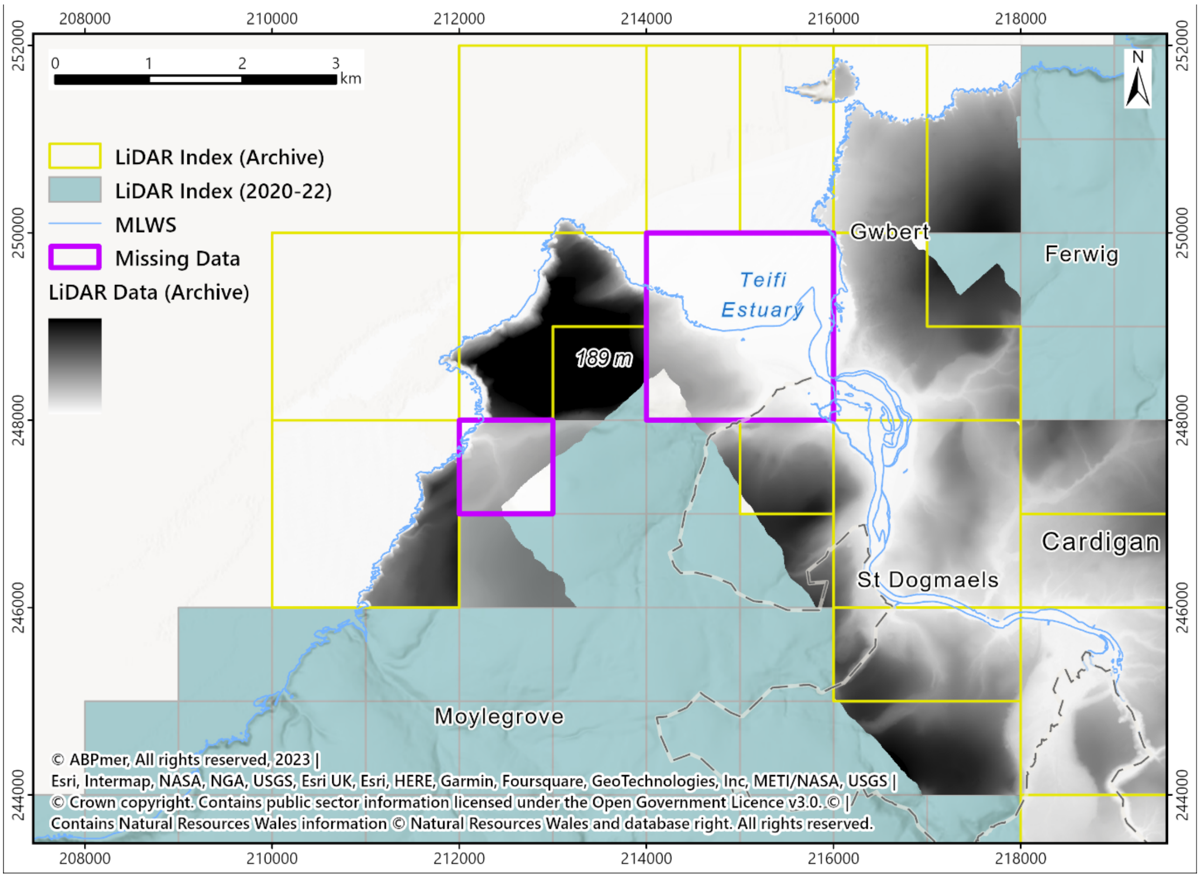


Figure C4. LiDAR (Archive) – Missing data in the Teifi Estuary.

C.3.2 Processing historical and 2020-22 LiDAR data

As the historical LiDAR data includes both 1 m and 2 m resolution datasets, the 2 m data was resampled to 1 m, to the same resolution as the All Wales 1.0 m LiDAR (2020-2022) dataset. Then, where multiple tiles from the historical LiDAR data were selected to achieve better coverage, they were merged to create a new gridded 'patched' tile, using the most recent LiDAR for the overlapping pixels. The tiles were then visually inspected, and a note made in the source index of any tiles that were merged.

From the All Wales 1.0 m LiDAR (2020-2022) tile index, a 10 km buffer was created to select all tiles extending 10 km inland from the SMP2 Policy line, as the proposed upper limit for the DTM (Figure C5). This was then used to clip the All Wales 1.0 m LiDAR (2020-2022) data to include only what was needed and to reduce the size of the dataset. Both data sets were merged and then visually inspected to identify areas with missing data from both the historical and 2020-22 LiDAR, and to see where additional elevation data was needed (Figure C6). As shown in Figure C6, the majority of these gaps were for areas above HAT +1 in SLR, therefore outside area of concern for the assessment.

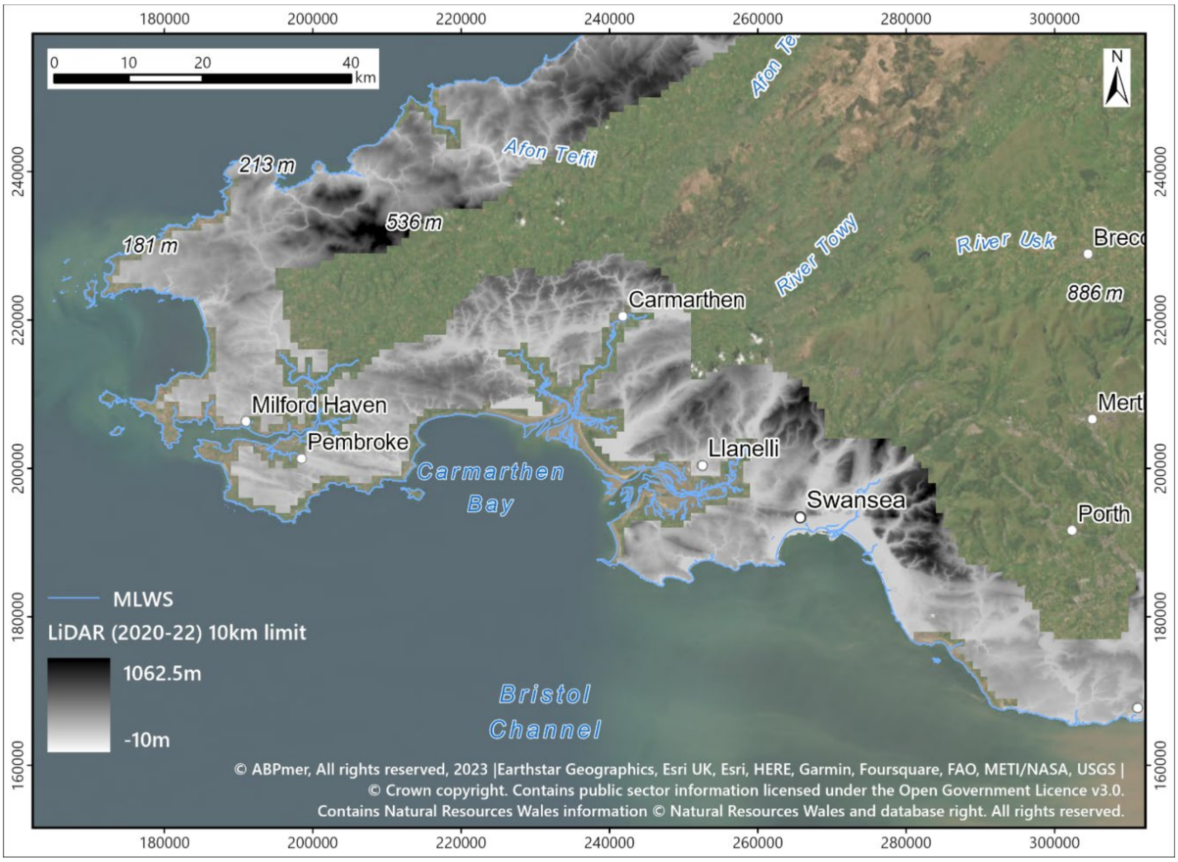


Figure C5. All Wales 1.0 m LiDAR (2020-22) – data clipped to 10 km inland limit.

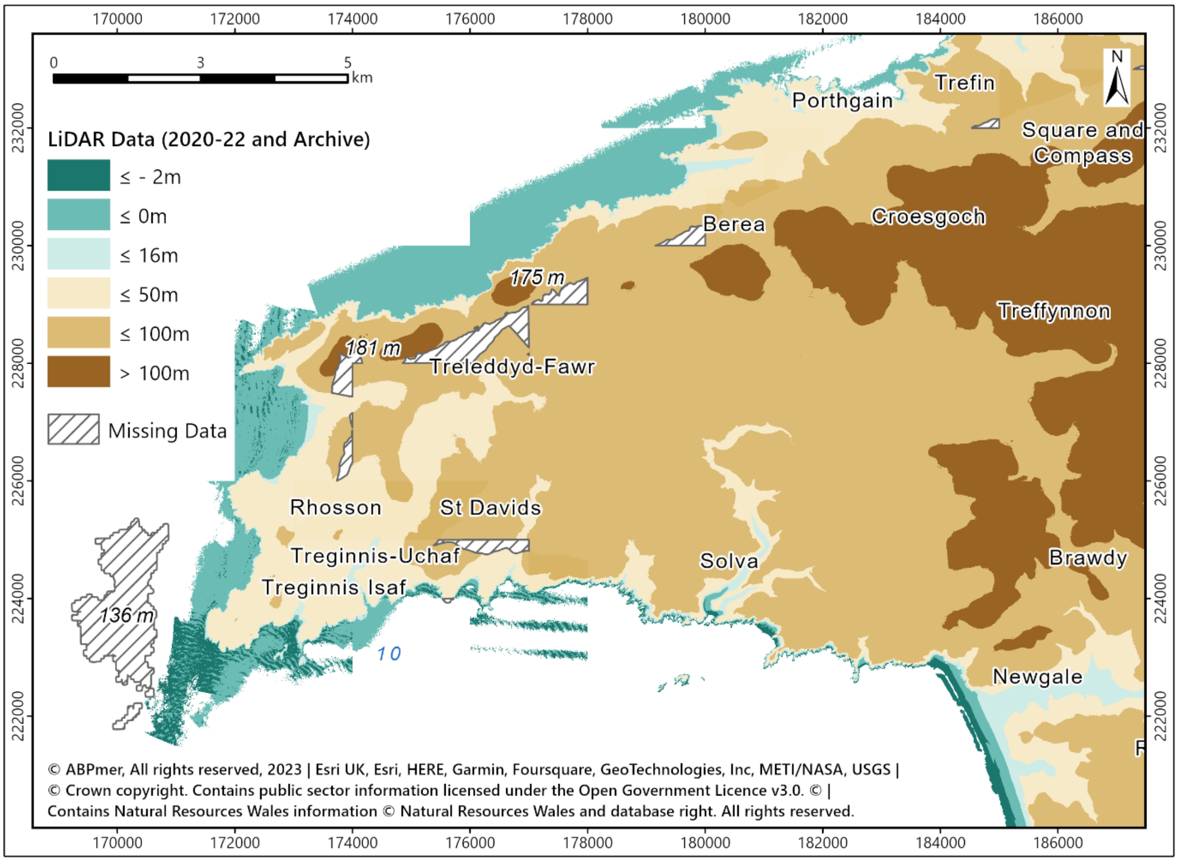


Figure C6. Combined All Wales 1.0 m LiDAR (2020-22) and Historical LiDAR datasets showing example locations where gaps remain LiDAR (2020-22 and Archive) – Data coverage (missing data).

C.3.3 Additional data processing (LiDAR and OS Terrain® 50)

To provide elevations in areas with data missing from both the 2020-2022 and historical LiDAR datasets, the OS Terrain® 50 was initially used, available from the OS Open Data portal. Although this data set has quite a low resolution (50 m) compared to the LiDAR data primarily used, the majority of the areas where data was identified to be missing were in areas of relatively high elevation (Figure C6) and generally outside the upper SLR limit, therefore of no relevance to the assessment. However, for consistency and to ensure there were no gaps within the data set the OS Terrain® 50 data for these locations was downloaded and resampled to 1 m, the same resolution as the All Wales 1.0 m LiDAR (2020-2022) data, and then merged with combined All Wales 1.0 m LiDAR (2020-2022) and historical LiDAR data.

To check that the upper limit of the DTM extended to all areas where SLR may reach HAT +1 m for the latest Epoch (2155), a 16 m ODN contour was generated from the combined elevation data (including a 3 m additional buffer), accounting for the largest estimated tidal level. After visual inspection of the 16 m contour, a few locations were identified where the 10 km initial buffer did not extend far enough inland (Figure C7). In these areas, additional tiles were selected from the All Wales 1.0 m LiDAR (2020-2022) data set and merged with the combined elevation data. To ease data processing and to reduce the size of the combined datasets the combined elevation data was clipped to the 16 m contour and a 1 km buffer from the coastline (as delineated by the SMP2 Policy line) to account for areas with high coastal elevations.

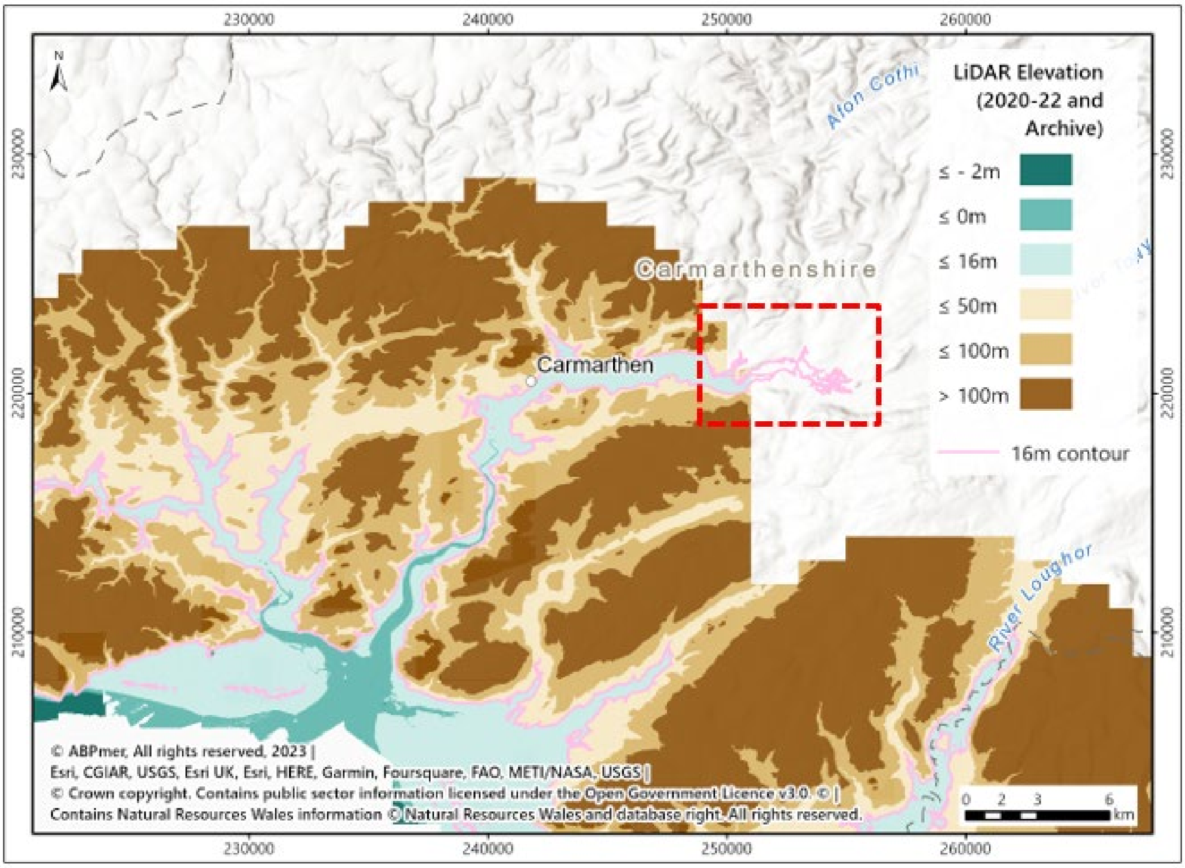


Figure C7. Combined elevation data showing an example location where the 16 m ODN contour limit extended inshore of the initial 10 km buffer used to clip the data set.

C.3.4 Checking of upper and lower limits of the combined LiDAR data sets

To check the upper and lower extents of the DTM, the Tidal Level data layer (Appendix D) was used to find the MLWS (lower) and HAT +1 m +SLR (upper) elevation limits for each Policy Unit in the SMP. Then, working around the coastline, contours were generated for each value along the extent of each SMP2 Policy Unit. The resulting contours were merged and visually inspected to check the coverage of the DTM and to identify any gaps in the data still remining (Figure C8).

The DTM was found to have good coverage to the defined upper project limit. However, significant areas were identified where the DTM did not provide full coverage down to the MLWS values identified in the Tidal Level layer. This typically occurred, where historical LiDAR data was used which was flown at higher tide levels and false data was returned from the sea surface. The All Wales 1.0 m LiDAR (2020-2022) LiDAR data typically provided good general coverage down to MLWS (or very close to MLWS) along the open coast. However, the coverage down to MLWS was more limited in estuaries.

Additionally, areas were identified where the MLWS contour generated from the combined DTM appeared 'stepped' due to the data being captured from different surveys, sometimes years apart. Where possible, tiles in these areas were updated to achieve a more contiguous MLWS contour. However, this was not always possible and achieving full coverage was prioritised over choosing tiles of the same acquisition date if the coverage was poor.

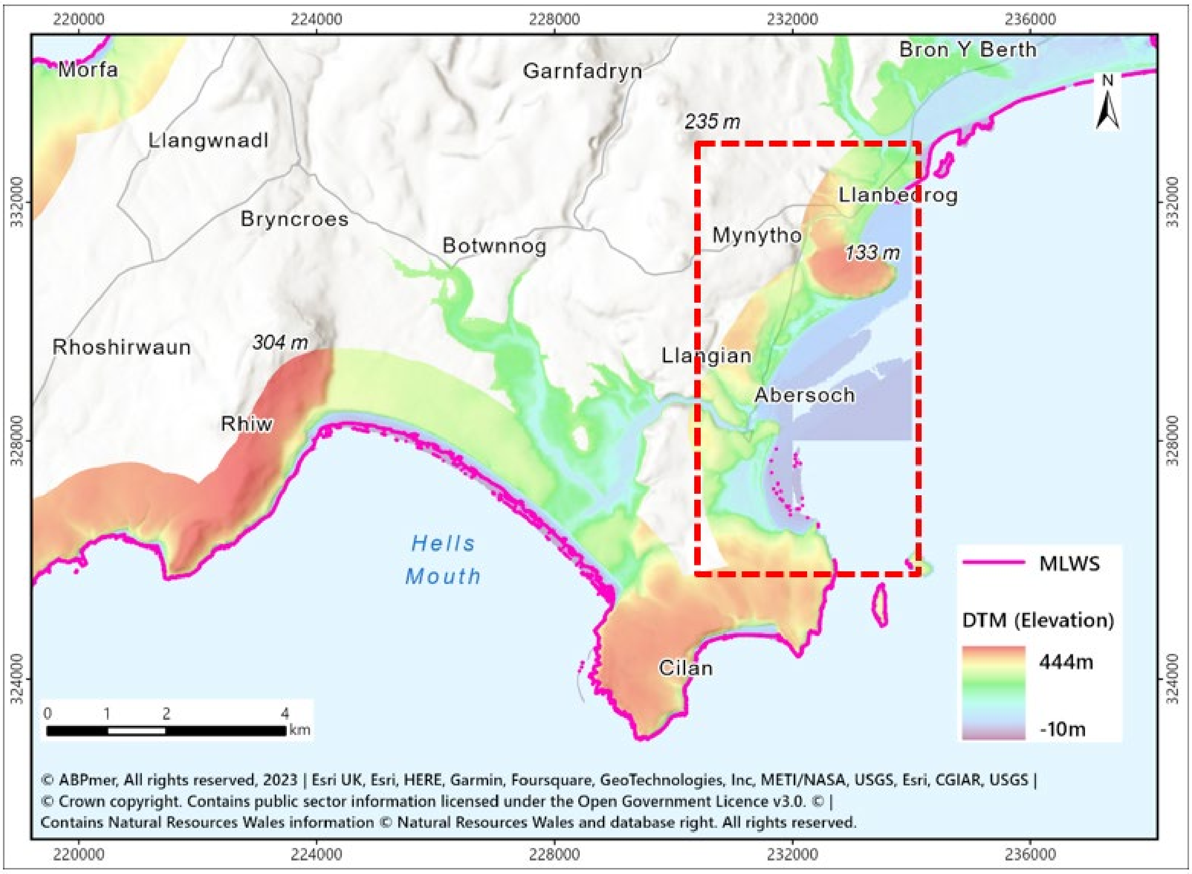


Figure C8. Combined LiDAR data sets – showing example location where DTM did not extend to MLWS (in this instance data supplemented with WCMC data).

C.3.5 Removing false LiDAR data from the combined LiDAR data set

As referred to in the previous section, the combined LiDAR data set was found to include areas of false data along the coastline and within estuaries where the LiDAR was flown at higher states of tide and data was returned from the sea surface. False data related to the water surface also occurred, where water bodies existed in the hinterland, e.g. lakes and docks, that could become tidal in the future. These areas were identified initially by visual inspection (Figure C9) and manually clipped out by digitising clipping lines and polygons along the edge of the false data, and then extracting the false data.

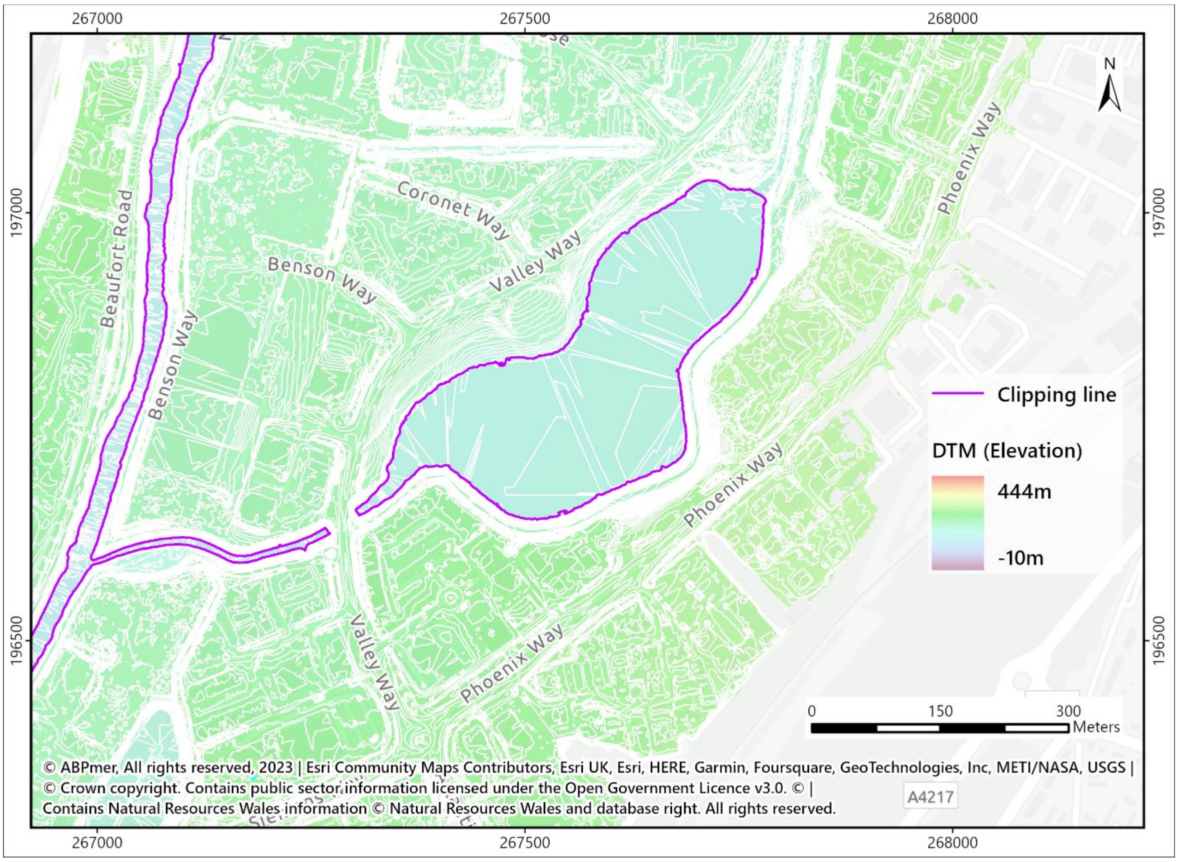


Figure C9. Typical example of false data along channels and within lakes, showing digitised clipping line and polygons used to remove the false data.

C.3.6 Extending data set down to MLWS using additional topographical and bathymetry data

Where possible, topographical beach surveys from the WCMC were sourced to fill in gaps where the combined LiDAR data did not go down to MLWS. Where additional topographical data was not available, bathymetric data was also sourced to provide elevation data to MLWS. In those areas where no topographic and bathymetric data exists, MLWS and Chart Datum (CD) contours from OS mapping and CMAP digital chart data (through Danish Hydraulics Institute CMAP) respectively were used. The Vertical Offshore Reference Frame (VORF) dataset was then used to transform elevations from CD to the vertical datum of the Project DTM (ODN). Resampling of the additional available data to 1 m, and additional interpolation, as discussed in the following section, was undertaken to infill the gaps within the data set.

C.3.7 Data interpolation

Interpolation within estuaries

Where false data was removed from the estuaries, the natural neighbour interpolation method (https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-natural-neighbor-works.htm) was applied to estimate the elevation of the DTM down to MLWS. To do this, elevation values were extracted along the banks of the estuary (edge of the false data) at 1 m intervals and a separate set of points created along the mid-point of the main channel. This was done from the estuary mouth up to the present-day normal tidal limit (NTL) for each estuary. Beyond this it was assumed that any false data related to natural river surface and no interpolation down to MLWS was required.

To the mid-channel points, an inferred level (below that of MLWS) was then applied, such that when interpolated the channel width at MLWS was similar to that typically observed on OS Mapping. The OS Mapping typically related to a historical form of the estuary where the channel morphology is significantly different from that shown in the present-day LiDAR data, hence, the OS Mapping MLWS contours could not be used directly. The inferred depth used along the central line of the channel to inform the interpolation was typically -4 m ODN, but this value was adjusted in some cases to ensure channel width at MLWS was more consistent with that observed in the OS Mapping. The resulting interpolated data through the channel was then merged back into the combined LiDAR data set replacing the false data (Figure C10).

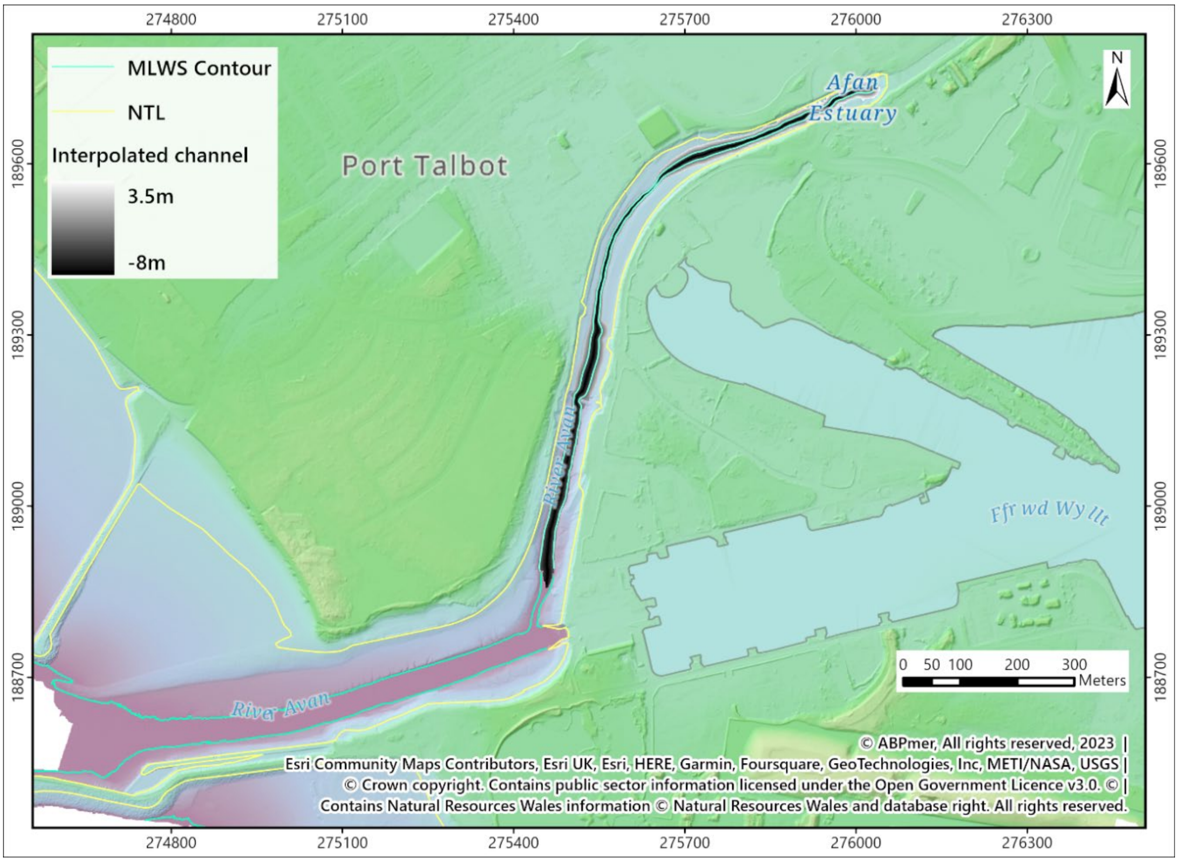


Figure C10.Example where combined LiDAR dataset included false data along tidal channel – interpolated data is derived across the main channel (overlaid on figure), then merged back into the data set, replacing the false data.

Interpolation along open coast

Where the LiDAR data sets did not extend down to MLWS along the open coast the natural neighbour interpolation method (https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/how-natural-neighbor-works.htm) was again applied to fill the missing gaps. This interpolation made use of any suitable available topographic data or bathymetric data. However, in situations where neither existed, the interpolation utilised either the OS MLWS line or the CD contour (having first been converted to mODN). The interpolated data was then merged back into the combined data sets.

C.3.8 Merging of data sets

The final data sets, including the LiDAR, topographical, bathymetry, and interpolated rasters were merged to create the final composite Project DTM.

C.4 Data layer deliverable

The deliverables for the Project DTM include the following outputs within a single GIS geodatabase:

- Project DTM, and
- Project DTM Source Index.

C.5 Data limitations

Several limitations are identified with the data used in the Project DTM:

- Although the 2020-2022 LiDAR data covers most of the areas required for the Project DTM, there are significant areas across the intertidal zone where data is missing;
- The historical LiDAR data includes varying acquisition dates and times of the day. It therefore includes some areas where 'steps' occur in the merged elevations (i.e. between two different LiDAR surveys), primarily where the LiDAR has been flown at different tidal levels;
- The historical LiDAR data includes varying resolutions (1 m and 2 m), with the 2 m resolution being 'coarser' than the 1 m resolution data, despite being resampled to the 1 m resolution, as it contains fewer data returns;
- There were significant areas in the 1 m data that needed to be replaced with the 2 m resolution data, where the 1 m data had poor coverage;
- There are areas where older LiDAR surveys were selected where they had better coverage than the more recent surveys;
- In areas where elevation data was missing from both the 2020-2022 and historical LiDAR data the OS Terrain® 50 was used, which has a much lower resolution (at 50 m), although this mostly tends to occur in areas of higher elevation, outside the area of interest, and
- Both the 2020-2022 and historical LiDAR data sets include areas of 'false' data i.e. where the LiDAR has reflected on the water and does not represent the underlying bathymetry. Elevations have been interpolated in these areas.

D Tidal level data layer

D.1 Overview of data layer

The Tidal Level data layer is utilised in STEP 1 and STEP 2 of the coastal squeeze and natural squeeze assessment. It is also required to support the development of several of the other project data layers, including the Project DTM, Foreshore Area and Accommodation Space.

The data layer splits the coastline up into discrete sections of the coast over which the following tidal levels are defined (all levels relative to mODN):

- MLWS;
- MHWN;
- MHWS;
- HAT; and
- HAT +1.

Each discrete sections, is linked to one or more Assessment Unit, such that the tidal range variation across the discrete section and the associated Assessment Unit(s), it typically no greater than 0.2 m

SLR allowances are also associated with each discrete section of the coast for the UKCP18, RCP 8.5 emission scenario 70th percentile (higher central allowance) and UKCP18, RCP 8.5 emission scenario 95th percentile (upper end allowance). These SLR allowances are included from 2025 to 2155 at five yearly intervals for subsequent use in the CSAT. The derivation of these water levels is based on Welsh Government (2022).

D.2 Primary data sources

The primary data sources utilised in the development of the data layer are:

- Admiralty Tide Tables / Admiralty TotalTide (ATT) tool (Accessed 16/05/2023);
- Admiralty Vertical Offshore Reference Frame (VORF) dataset (Version V2.11, dated 2011); and
- UKCP18 national SLR datasets, from UK Climate Projections (Met Office) user interface Downloaded 21/06/23).

D.3 Production of the data layer

D.3.1 Tide levels

To develop present-day data tidal levels for the assessment the following Admiralty tidal products have been used:

- Admiralty Tide Tables / Admiralty TotalTide (ATT); and
- Admiralty Vertical Offshore Reference Frame (VORF) dataset.

The use of site-specific water levels data is not considered appropriate for a national scale assessment and has therefore not been used.

The above two datasets are discussed in the following sub-sections:

Admiralty tide tables/ ATT

The Admiralty Tide Tables and ATT tool enables tidal predictions around the globe based on harmonic constituents derived from observations at a network of primary ports and transformed to a system of secondary ports. Water levels at the secondary ports are either derived via a harmonic (H), or non harmonic (NH) based transformation. These primary and secondary ports are unevenly distributed along the Welsh coastline as shown in Figure D1.

At most locations, present-day water levels are provided in relation to:

- HAT*1;
- MHWS*1;
- MHWN*1;
- Mean Sea Level (MSL) ;
- MLWN;
- MLWS*1, and
- Lowest Astronomical Tide (LAT)

(*1 – required for this assessment).

At a few of the locations, particularly those within estuaries, water levels are not available in relation to some of these parameters. Within the central and northern section of Cardigan Bay the tidal predictions for the secondary ports are also noted to be of ‘secondary quality’, identifying the prediction to be less accurate.

To develop present-day tidal levels around the entire Welsh Coast using this data set:

- Tide levels between different primary and secondary ports could be derived through linear interpolation, although this ignores more complex variation in the tide and tidal range around the coast; or
- Tide levels could be adopted as provided, and utilised to cover an area that extends half-way to the neighbouring site.

Neither option above is considered optimal, as they do not fully account for how the tidal range varies around the coast.

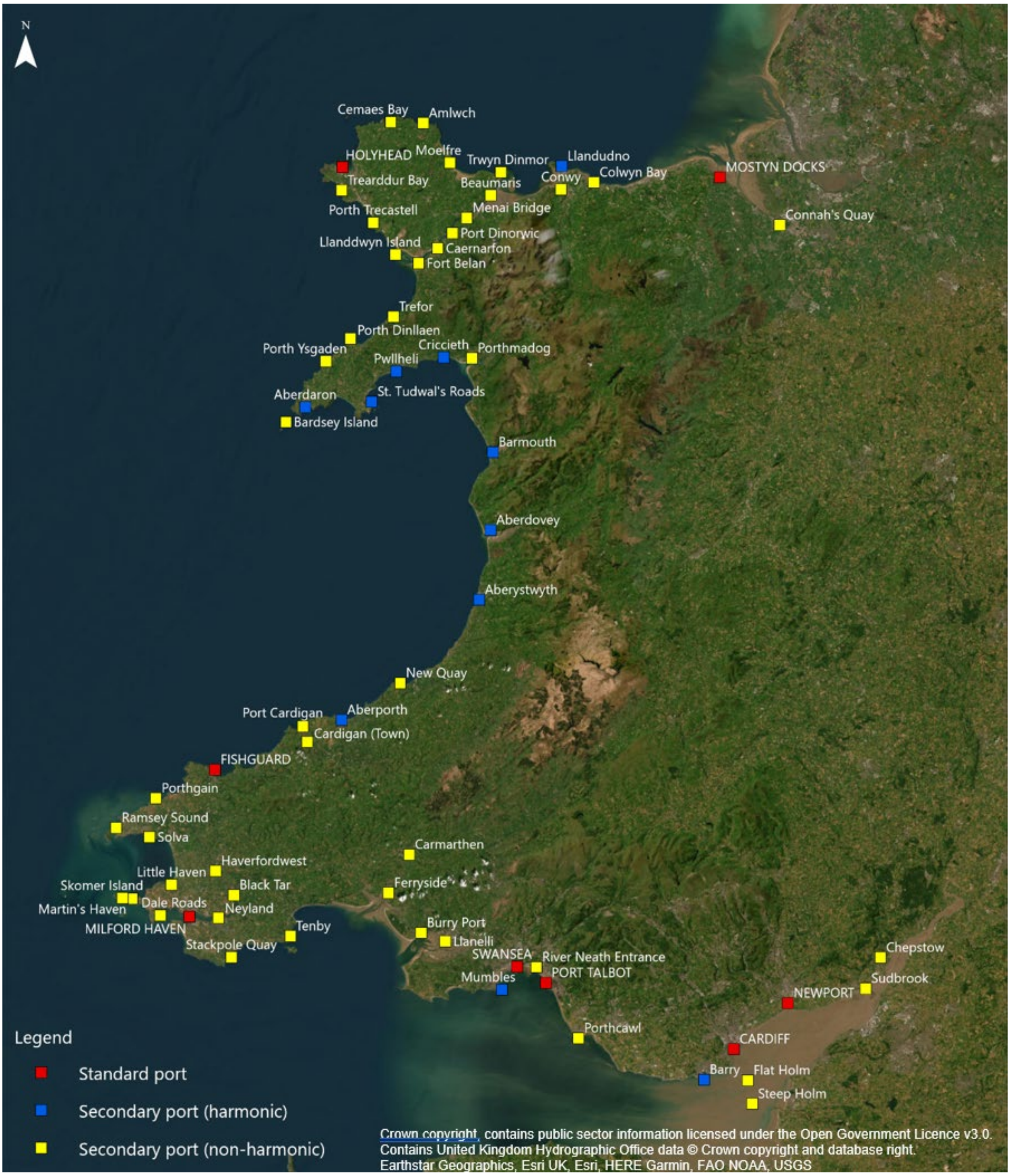


Figure D1 Location of Admiralty TotalTide prediction points.

Admiralty VORF data

The latest VORF model (VORF-UK08) was created by University College London (UCL) for the UK Hydrographic Office (UKHO), with development starting in 2005. The VORF solution for UK and Ireland was completed in 2008. The dataset provides the vertical distance between a number of reference frames at ~1 km resolution around the UK coast, including:

- HAT relative to LAT;
- MHWS relative to LAT;
- MSL relative to LAT;
- MLWS relative to LAT;
- CD relative to LAT;
- CD relative to ODN; and
- MSL relative to CD.

The VORF dataset is available through https://datahub.admiralty.co.uk/ as a paid for service, based on blocks required. However, ABPmer obtained a version of the VORF dataset in 2011, which is labelled V2.11. The release date of the data is 02/06/2008, and is available for use in this project through an existing ABPmer licence agreement. It is understood that the base data between the two datasets is identical and thus the V2.11 datasets has been utilised in the present study.

The national coverage of the VORF (V2.11) datasets is presented in Figure D2 to Figure D4. These figures show the derived tidal levels at: HAT, MHWS and MLWS, in relation to mODN.

This dataset provides good national coverage, and overcomes the issues associated with the Admiralty Tide Tables / ATT data, as the dataset is continuous across the study frontage and takes account of the complex variation in tide around the coastline. However, three noticeable issues are identified with the VORF dataset:

- There are some significant discontinuities in levels within some estuaries;
- There are some differences between ATT tidal levels and VORF tidal level, and
- The VORF dataset does not include levels associated with MHWN which is required for the analysis.

These issues are considered further below.

Discontinuities in VORF dataset up estuaries

The VORF dataset has a general resolution of around 500-1,000 m, however, within several of the estuaries' more detailed data has been derived and used within the VORF dataset to better represent the change in tidal level up through the estuaries. The areas where this is most prominent, as shown in Figure D2 - Figure D4, are the:

- Upper Severn Estuary;
- Afon Tywi (Carmarthen);
- Milford Haven; and
- The Dee Estuary.

These detailed areas can be seen more clearly in the MLWS to mODN dataset (Figure D4), which clearly identifies that MLWS increases through the estuary as would be expected. In many instances, it is significantly higher than ODN, at the top of the estuaries. However, on closer inspection there are anomalies ('jumps') in levels toward the entrance of the estuaries where the more detailed data sets are included. These anomalies are identified in the VORF-UK08 (UKHO, 2021) User Manual, but there is no clear method identified to address them. There is also a very significant anomaly/error in the dataset relating to the Dee Estuary as seen in Figure D2 and Figure D3, where there is reported to be a very large change in HAT and MHWS at the entrance to the estuary, which is not correct. This is further emphasised in Figure D5, which presents MSL in relation to mODN.

Therefore, within estuaries, the VORF dataset cannot be relied upon.

Differences between ATT levels and VORF levels

The VORF dataset (HAT, MHWS and MLWS) values have been compared to the predicted tidal levels from the ATT Tool. This comparison is provided in Table D1.

In general, there is reasonable agreement, between the datasets, with MHWS and MLWS typically within 0.2 m of one another. The differences in HAT values are typically a little higher, however, it is important to also recognise how each dataset is derived. Many of the ATT datasets are derived / interpolated from primary ports some distance away, where the tidal range and regime is different. The VORF dataset, which is also an Admiralty product, was developed utilising information on recorded water levels at primary and secondary ports as well as hydrodynamic models that predict variation in water levels along the coast. Therefore, the VORF dataset may be as good / if not sometimes better at estimating the tidal levels at secondary port locations.

Other than the estuarine locations listed above, where VORF water levels are often considered unreliable, the differences between ATT and VORF levels is significant at two further locations as noted below:

- Menai Bridge – At this site the tidal range changes rapidly through a narrow rocky passage known as the 'Swellies'. Levels at Port Dinorwic and Beaumaris, either side are in better agreement; and
- Skomer Island – This site is very close to Martin Haven and Little Haven, where the tidal ranges are significantly smaller, and the ATT and VORF data are in good agreement. Therefore, it is suspected that the ATT data for Skomer Island is poor.

It is therefore considered that the VORF dataset provides a reasonable basis for describing tidal level around the open coast of Wales. However, the dataset cannot be relied upon up estuaries, other than along the open coast of the Severn Estuary where it is considered reliable.

VORF dataset does not include MHWN levels

The MHWN values are required to undertake the coastal squeeze and natural squeeze assessment but is not present in the VORF dataset.

To develop a continuous MHWN dataset the relationship between MHWN and MSL and MHWN and MHWS (Using ATT tide levels) has been examined at every primary and secondary port where there is available data. The following relationship has subsequently been used to describe the ratio in tidal range between MHWS and MHWN, with respect to MSL, as identified below:

$$F = \frac{MHWN - MSL}{MHWS - MSL}$$

The ratio F for each port was found to vary spatially, however, with the three general regions noted below the F factor is relatively consistent (Table D2 to Table D4):

- South Wales/Severn Estuary;
- West Wales/Cardigan Bay; and
- North Wales

The F factor has therefore been averaged separately over each of these three regions. Values of F are not calculated where MSL values are not presented within ATT. In a couple of instances, the factor F was also considered poorly defined, therefore these values were removed before obtaining the average F factor value for each region.

The derived F factors for the three regions have then been applied to the VORF MHWS to MSL dataset to derive a continuous MHWN value around the Welsh coast. A comparison of these VORF derived MHWN levels with the ATT MHWN levels is also presented in Table D2 to Table D4. For completeness these tables also included the comparison of HAT, MHWS and MLWS tidal levels, between the VORF dataset and ATT.

The overall agreement is considered good and therefore, the derived MHWN dataset is considered to provide a suitable continuous MHWN level along the open coast for use in the assessment.

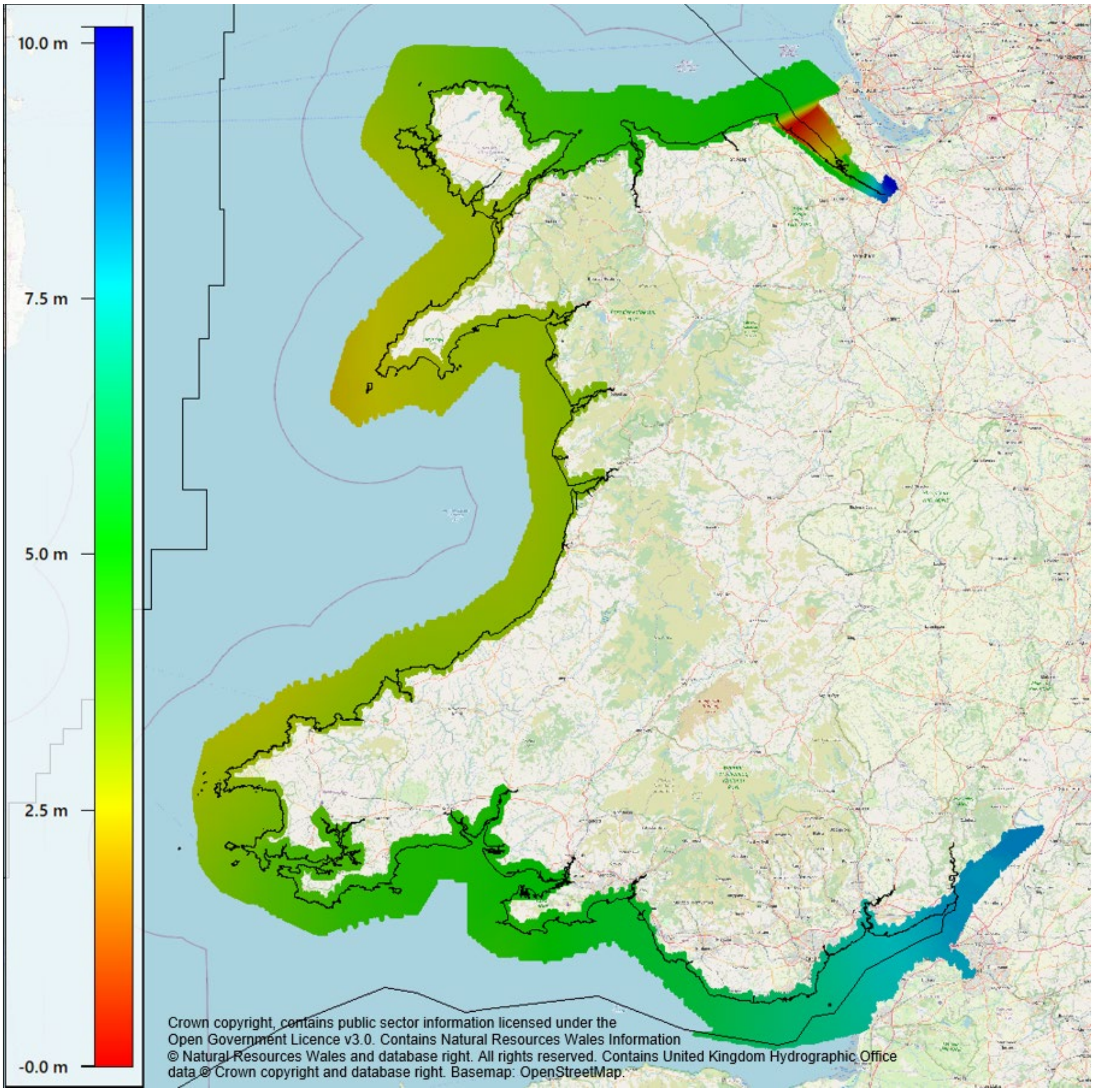


Figure D2 VORF (V2.11) HAT to mODN - national coverage.

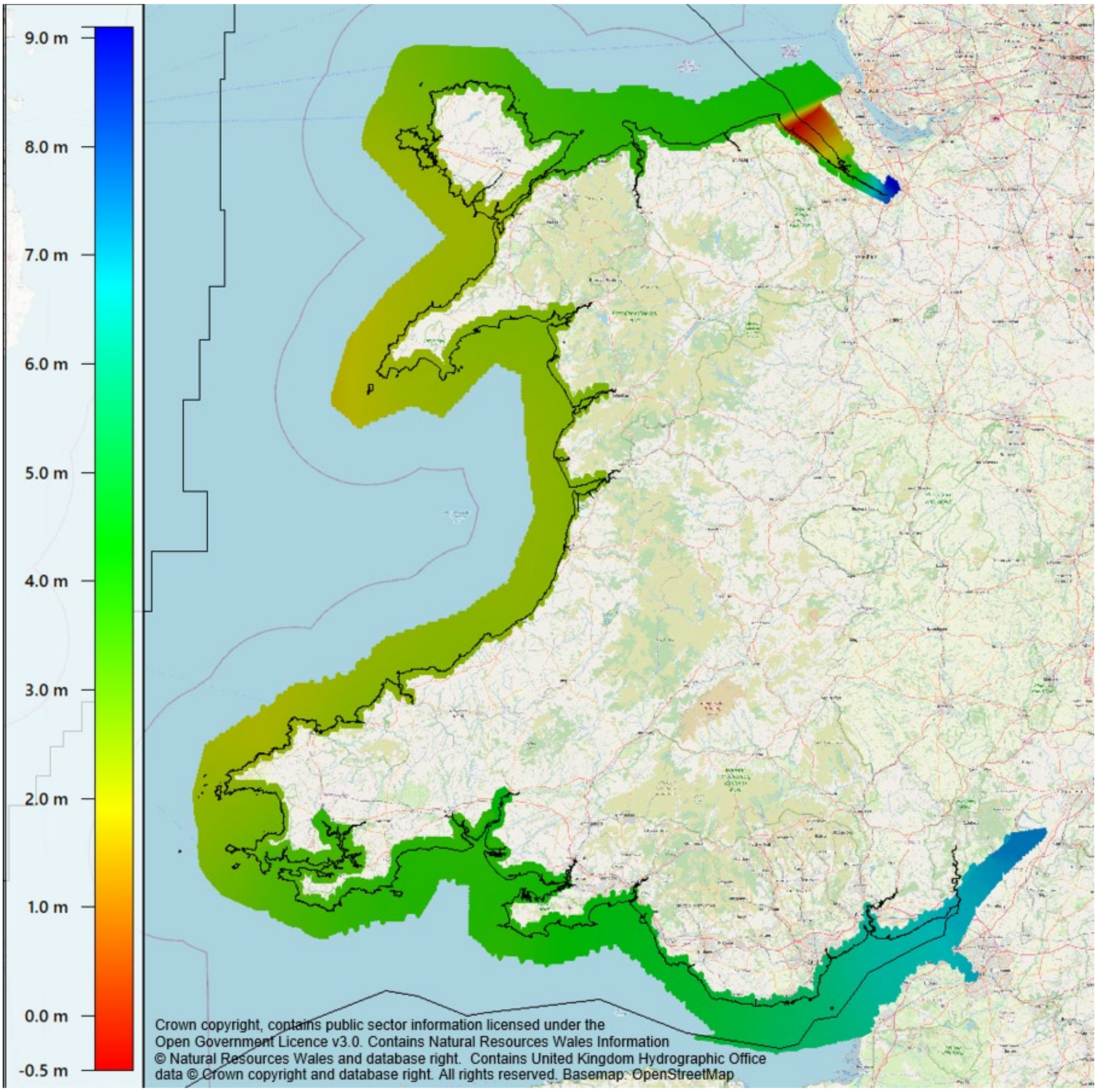


Figure D3 VORF (V2.11) MHWS to mODN - national coverage.

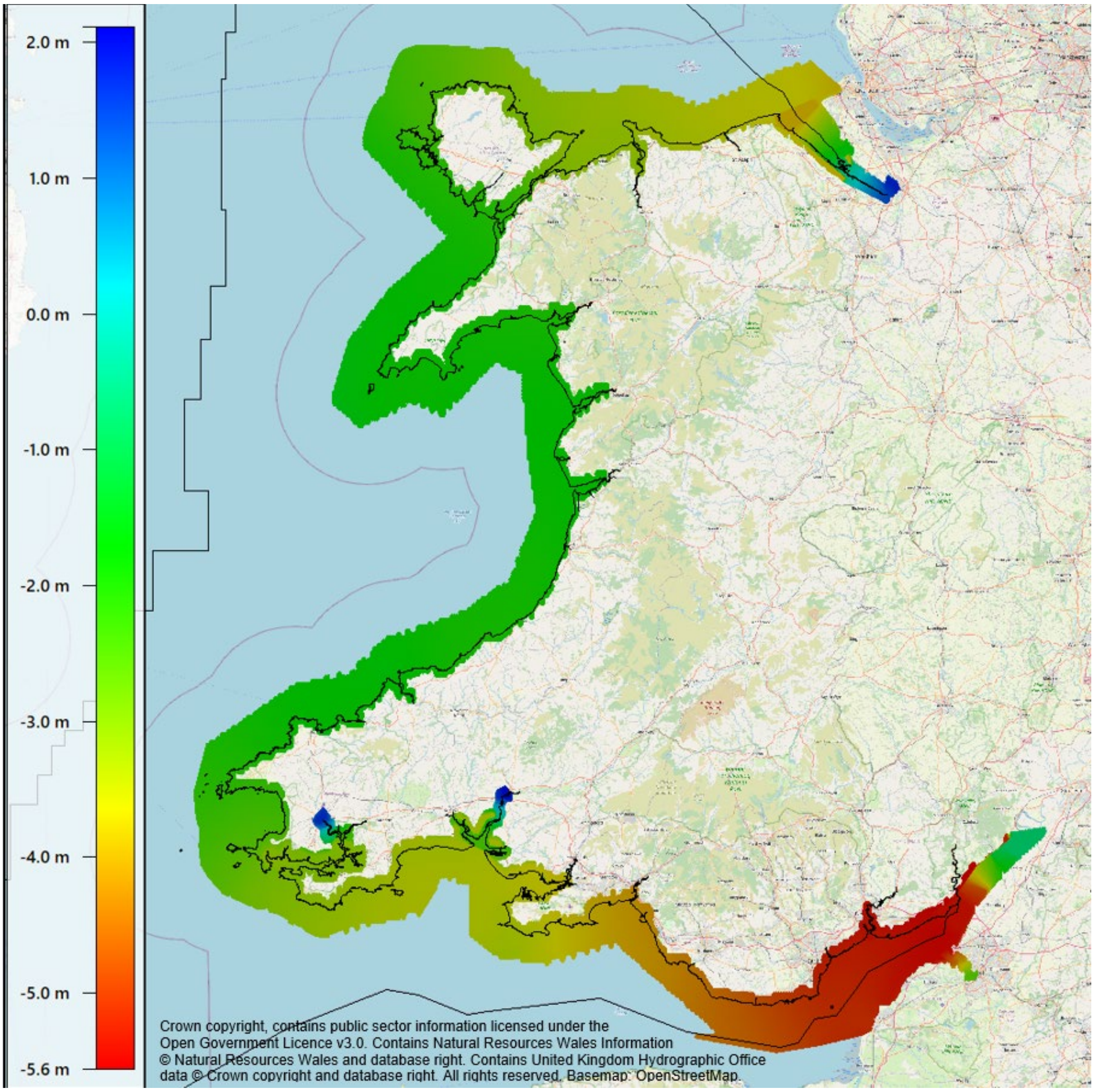


Figure D4 VORF (V2.11) MLWS to mODN - national coverage.

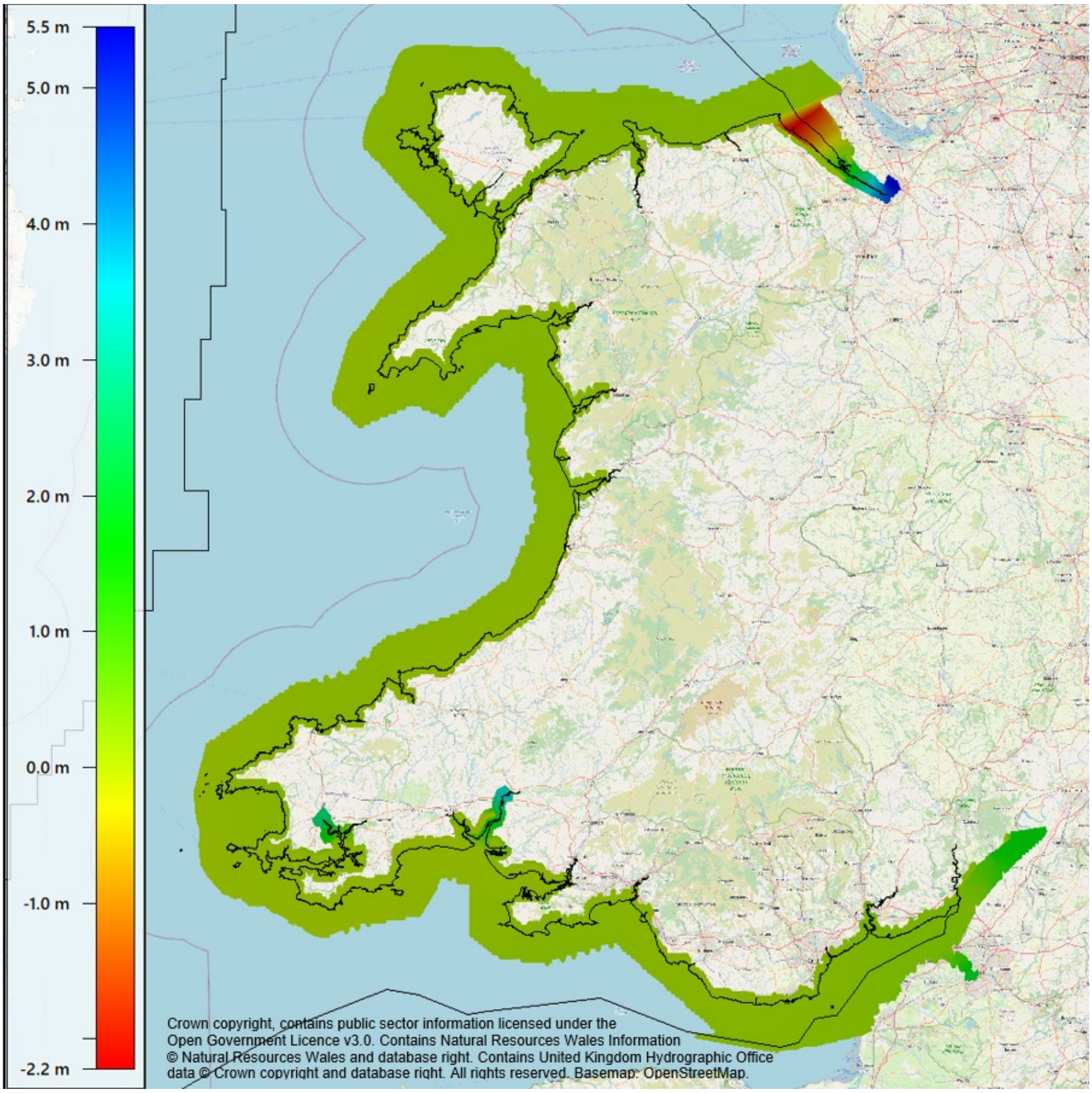


Figure D5 VORF (V2.11) MSL to mODN – national coverage.

Table D1 Comparison of tidal levels between ATT and VORF (v2.11) (Difference values are colour coded, with larger negative differences shaded darker blue and larger positive differences shaded darker red). (H) – Harmonic; (NH) – Non-Harmonic.

Name	Prediction	Main Port	ATT HAT Level (mCD)	ATT MHWS Level (mCD)	ATT MHWN Level (mCD)	ATT MSL Level (mCD)	ATT MLWN Level (mCD)	ATT MLWS Level (mCD)	ATT LAT Level (mCD)	VORF HAT Level (mCD)	VORF MHWS Level (mCD)	VORF MLWS Level (mCD)	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comments
Inward Rocks	Secondary (NH)	Bristol	13.7	12.2	8.7	5.74	2.4	0.4	-0.4	14.8	13.5	1.1	-1.1	-1.3	-0.7	Limit of study area up Severn Estuary, approx. 8 km upstream of Sudbrook, where agreement good
Sudbrook	Secondary (NH)	Bristol	14.9	13.4	9.9	6.86	3.7	1.1	0.1	14.7	13.4	1.1	0.2	0.0	0.0	Blank
Newport	PRIMARY	n/a	13.6	12.3	8.9	6.26	3.6	0.8	-0.4	13.2	12.1	0.4	0.4	0.2	0.4	Blank
Cardiff	PRIMARY	n/a	13.5	12.3	9.1	6.58	4	1.2	-0.1	13.1	12.1	1.1	0.4	0.2	0.1	Blank
Barry	Secondary (H)	n/a	13	11.7	8.7	6.27	3.8	1.2	0.2	12.7	11.6	1.1	0.3	0.1	0.1	Blank
Porthcawl	Secondary (NH)	Milford Haven	11	9.9	7.5	5.31	3.3	1	0.1	11.0	10.0	1.1	0.0	-0.1	-0.1	Blank
Port Talbot	PRIMARY	n/a	10.7	9.7	7.3	5.41	3.5	1.1	0.2	10.8	9.8	1.1	-0.1	-0.1	0.0	Blank
River Neath	Secondary (NH)	Milford Haven	10.8	9.7	7.4	n/a	n/a	n/a	n/a	10.6	9.6	0.9	0.2	0.1	n/a	Blank
Swansea	PRIMARY	n/a	10.4	9.5	7.2	5.11	3.1	0.9	0	10.5	9.5	1.0	-0.1	0.0	-0.1	Blank
Mumbles	Secondary (H)	n/a	10.5	9.5	7.2	5.22	3.3	1.1	0.1	10.5	9.5	1.1	0.0	0.0	0.0	Blank
Llanelli	Secondary (NH)	Swansea	8.7	7.8	5.8	n/a	n/a	n/a	n/a	8.8	7.7	1.0	-0.1	0.1	n/a	Blank
Burry Port	Secondary (NH)	Swansea	9.5	8.6	6.6	4.75	3	1.1	0.3	9.7	8.7	1.1	-0.2	-0.1	0.0	Blank

Name	Prediction	Main Port	ATT HAT Level (mCD)	ATT MHWS Level (mCD)	ATT MHWN Level (mCD)	ATT MSL Level (mCD)	ATT MLWN Level (mCD)	ATT MLWS Level (mCD)	ATT LAT Level (mCD)	VORF HAT Level (mCD)	VORF MHWS Level (mCD)	VORF MLWS Level (mCD)	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comments
Carmarthen	Secondary (NH)	Milford Haven	3.6	2.6	0.4	n/a	n/a	n/a	n/a	3.7	3.3	0.0	-0.1	-0.7	n/a	Site located up estuary, where agreement is expected to be poor
Ferryside	Secondary (NH)	Swansea	7.7	6.7	4.5	n/a	0.8	0.1	-0.2	7.5	6.7	0.1	0.2	0.0	0.0	Blank
Tenby	Secondary (NH)	Swansea	9.4	8.4	6.3	4.49	3	0.9	0.1	9.2	8.4	1.1	0.2	0.0	-0.2	Blank
Stackpole Quay	Secondary (NH)	Milford Haven	8.8	7.9	5.9	4.3	2.7	1	0.3	8.7	7.9	1.1	0.1	0.0	-0.1	Blank
Neyland	Secondary (NH)	Milford Haven	7.8	7	5.2	n/a	2.5	0.7	0	7.8	7.0	0.7	0.0	0.0	0.0	Blank
Black Tar	Secondary (NH)	Milford Haven	7.9	7.1	5.3	n/a	2.5	0.6	-0.2	7.9	7.1	0.8	0.0	0.0	-0.2	Site located up estuary, where agreement is expected to be poor
Haverfordwest	Secondary (NH)	Milford Haven	3.1	2.2	0.3	n/a	n/a	n/a	n/a	7.9	7.1	0.8	-4.8	-4.9	n/a	Site located up estuary, where agreement is expected to be poor
Milford Haven	PRIMARY	-	7.8	7	5.2	3.85	2.5	0.7	0	7.8	7.0	0.7	0.0	0.0	0.0	Blank
Dale Rocks	Secondary (NH)	Milford Haven	7.8	7	5.2	n/a	2.5	0.6	-0.2	7.7	7.0	0.6	0.1	0.0	0.0	Blank
Martin’s Haven	Secondary (NH)	Milford Haven	6.9	6.2	4.7	3.54	2.6	0.8	0.1	6.9	6.2	0.8	0.0	0.0	0.0	Blank

Name	Prediction	Main Port	ATT HAT Level (mCD)	ATT MHWS Level (mCD)	ATT MHWN Level (mCD)	ATT MSL Level (mCD)	ATT MLWN Level (mCD)	ATT MLWS Level (mCD)	ATT LAT Level (mCD)	VORF HAT Level (mCD)	VORF MHWS Level (mCD)	VORF MLWS Level (mCD)	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comments
Skomer Island	Secondary (NH)	Milford Haven	7.3	6.6	5.1	n/a	2.5	0.7	0	6.7	6.0	0.7	0.6	0.6	0.0	Very close to Martin Haven & Little Haven, where range is smaller, suspect poor ATT data
Little Haven	Secondary (NH)	Milford Haven	6.6	5.9	4.4	3.32	2.3	0.7	0.1	6.8	6.1	0.8	-0.2	-0.2	-0.1	Blank
Solva	Secondary (NH)	Milford Haven	6.1	5.5	4.2	3.18	2.3	0.7	0.1	6.3	5.6	0.8	-0.2	-0.1	-0.1	Blank
Ramsey Sound	Secondary (NH)	Milford Haven	5.7	5.1	3.9	2.89	2.2	0.7	0.1	5.9	5.3	0.8	-0.2	-0.2	-0.1	Blank
Porthgain	Secondary (NH)	Milford Haven	5	4.5	3.4	2.65	1.9	0.7	0.2	5.3	4.6	0.6	-0.3	-0.1	0.1	Blank
Fishguard	PRIMARY	n/a	5.5	4.8	3.4	2.71	2	0.8	0.2	5.5	4.8	0.7	0.0	0.0	0.1	Blank
Port Cardigan	Secondary (NH)	Milford Haven	5.3	4.7	3.4	2.39	2	0.7	0.2	5.7	4.9	0.8	-0.4	-0.2	-0.1	Blank
Cardigan town	Secondary (NH)	Milford Haven	5.4	4.8	3.6	n/a	n/a	n/a	n/a	5.6	4.8	0.7	-0.2	0.0	n/a	Blank
Aberporth	Secondary (H)	n/a	5.5	4.9	3.4	2.52	1.9	0.6	0.1	5.7	4.9	0.6	-0.2	0.0	0.0	ATT data of Secondary Quality
New Quay	Secondary (NH)	Milford Haven	5.6	4.9	3.4	n/a	1.9	0.6	0.1	5.5	4.9	0.5	0.1	0.0	0.1	Blank
Aberystwyth	Secondary (H)	n/a	5.8	5	3.5	2.7	1.8	0.7	0.1	5.5	4.8	0.5	0.3	0.2	0.2	ATT data of Secondary Quality
Aberdovey	Secondary (H)	n/a	5.6	5	3.5	2.61	2	0.7	0	5.7	5.0	0.7	-0.1	0.0	0.0	ATT data of Secondary Quality

Name	Prediction	Main Port	ATT HAT Level (mCD)	ATT MHWS Level (mCD)	ATT MHWN Level (mCD)	ATT MSL Level (mCD)	ATT MLWN Level (mCD)	ATT MLWS Level (mCD)	ATT LAT Level (mCD)	VORF HAT Level (mCD)	VORF MHWS Level (mCD)	VORF MLWS Level (mCD)	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comments
Barmouth	Secondary (H)	n/a	5.7	5	3.7	2.72	1.9	0.7	0.3	5.7	5.0	0.7	0.0	0.0	0.0	ATT data of Secondary Quality
Porthmadog	Secondary (NH)	Milford Haven	5.9	5.1	3.4	n/a	n/a	n/a	n/a	5.5	5.1	0.5	0.4	0.0	n/a	Blank
Criccieth	Secondary (H)	n/a	5.8	5	3.4	2.56	1.8	0.4	-0.2	5.5	5.1	0.5	0.3	-0.1	-0.1	ATT data of Secondary Quality
Pwllheli	Secondary (H)	n/a	5.8	5.1	3.6	2.76	1.9	0.6	-0.3	5.5	5.0	0.6	0.3	0.1	0.0	ATT data of Secondary Quality
St Tudwal's Roads	Secondary (H)	n/a	5.6	4.8	3.3	2.52	1.8	0.5	0	5.4	4.9	0.6	0.2	-0.1	-0.1	ATT data of Secondary Quality
Aberdaron	Secondary (H)	n/a	5.3	4.6	3.3	2.5	1.9	0.5	-0.1	5.1	4.6	0.6	0.2	0.0	-0.1	ATT data of Secondary Quality
Bardsey Island	Secondary (NH)	Holyhead	5.1	4.4	3.2	n/a	1.5	0.6	0.1	4.8	4.3	0.6	0.3	0.1	0.0	Blank
Porth Ysgaden	Secondary (NH)	Holyhead	5.2	4.5	3.4	2.4	1.9	0.6	-0.1	5.1	4.6	0.7	0.1	-0.1	-0.1	Blank
Porth Dinllaen	Secondary (NH)	Holyhead	5.3	4.6	3.4	2.51	1.8	0.5	-0.2	5.2	4.6	0.6	0.1	0.0	-0.1	Blank
Trefor	Secondary (NH)	Holyhead	5.6	4.8	3.5	2.55	1.8	0.6	0	5.4	4.8	0.7	0.2	0.0	-0.1	Blank
Fort Belan	Secondary (NH)	Holyhead	5.3	4.6	3.5	2.84	1.8	0.6	0	5.5	4.8	0.6	-0.2	-0.2	0.0	Entrance to Menai Straits
Caernarfon	Secondary (NH)	Holyhead	5.9	5.2	4	3.01	1.9	0.6	-0.1	6.0	5.3	0.6	-0.1	-0.1	0.0	Blank

Name	Prediction	Main Port	ATT HAT Level (mCD)	ATT MHWS Level (mCD)	ATT MHWN Level (mCD)	ATT MSL Level (mCD)	ATT MLWN Level (mCD)	ATT MLWS Level (mCD)	ATT LAT Level (mCD)	VORF HAT Level (mCD)	VORF MHWS Level (mCD)	VORF MLWS Level (mCD)	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comments
Port Dinorwic	Secondary (NH)	Holyhead	6.3	5.6	4.4	3.34	2	0.8	0.2	6.5	5.7	0.6	-0.2	-0.1	0.2	Blank
Menai Bridge	Secondary (NH)	Holyhead	8.2	7.3	5.8	4.05	2.3	0.7	-0.1	7.5	6.8	0.8	0.7	0.5	-0.1	Rapid changing range through 'Swellies', mainly rocky coastline. Port Dinorwic and Beaumaris, either side where better agreement
Llanddwyn Island	Secondary (NH)	Holyhead	5.5	4.9	3.9	2.95	1.9	0.7	0.1	5.7	5.0	0.8	-0.2	-0.1	-0.1	Blank
Porth Trecastell	Secondary (NH)	Holyhead	5.7	5	3.8	2.97	2	0.7	0	5.7	5.0	0.7	0.0	0.0	0.0	Blank
Trearddur Bay	Secondary (NH)	Holyhead	5.9	5.2	4	3.08	2	0.8	0.2	5.9	5.2	0.8	0.0	0.0	0.0	Blank
Holyhead	PRIMARY	n/a	6.3	5.6	4.4	3.27	2	0.7	0	6.3	5.6	0.7	0.0	0.0	0.0	Blank
Cemaes Bay	Secondary (NH)	Holyhead	7.5	6.6	5.1	3.67	2.3	0.8	0	7.4	6.6	0.9	0.1	0.0	-0.1	Blank
Amlwch	Secondary (NH)	Holyhead	8.1	7.2	5.7	4.08	2.5	0.9	0.1	7.9	7.1	1.0	0.2	0.1	-0.1	Blank
Moelfre	Secondary (NH)	Holyhead	8.5	7.5	5.8	4.17	2.5	0.9	0.1	8.2	7.4	1.0	0.3	0.1	-0.1	Blank
Trwyn Dinmor	Secondary (NH)	Holyhead	8.4	7.5	5.9	4.23	2.5	0.9	0.1	8.4	7.6	0.8	0.0	-0.1	0.1	Blank
Beaumaris	Secondary (NH)	Holyhead	8.5	7.6	6	4.22	2.5	0.8	-0.1	8.2	7.5	0.9	0.3	0.1	-0.1	Blank

Name	Prediction	Main Port	ATT HAT Level (mCD)	ATT MHWS Level (mCD)	ATT MHWN Level (mCD)	ATT MSL Level (mCD)	ATT MLWN Level (mCD)	ATT MLWS Level (mCD)	ATT LAT Level (mCD)	VORF HAT Level (mCD)	VORF MHWS Level (mCD)	VORF MLWS Level (mCD)	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comments
Conwy	Secondary (NH)	Holyhead	8.9	7.9	6.2	4.43	2.6	1.1	0.3	8.7	7.7	0.9	0.2	0.2	0.2	Blank
Llandudno	Secondary (H)	n/a	8.6	7.7	5.9	4.06	2.3	0.5	-0.4	8.5	7.7	0.6	0.1	0.0	-0.1	Blank
Colwyn Bay	Secondary (NH)	Liverpool (Gladstone)	8.7	7.8	6.1	n/a	n/a	n/a	n/a	8.8	7.9	0.7	-0.1	-0.1	n/a	Blank
Mostyn Docks	PRIMARY	n/a	9.8	8.9	7	4.89	2.9	1.1	0.2	4.5	4.0	0.6	5.3	4.9	0.5	Issue noted with VORF dataset up estuary
Connah's Quay	Secondary (NH)	Liverpool (Gladstone)	5.5	4.7	3	n/a	n/a	n/a	n/a	5.3	4.7	0.7	0.2	0.0	n/a	Site located up estuary, where agreement is expected to be poor

Table D2 Derivation of VORF MHWN levels and comparison with ATT tidal levels, for South Wales /Severn Estuary. MHWN levels are derived from VORF (v2.11) using method described in Section 4.1.2. (Derived factors colour coded, with smaller factors (below 35%) shaded darker brown and larger factors (above 52%) shaded darker green; Difference values colour coded, with larger negative differences (below -1m) shaded darker blue and larger positive (above +1m) differences shaded darker red). Primary Ports are identified using bold text for site Name.

Name	Derived Factor	Factor Used in Calculation of Average	Average Factor	VORF MHWN to MSL	VORF MHWN to CD	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MHWN (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comment
Inward Rocks	45.82%	45.82%	45.77%	3.00	9.80	-1.1	-1.3	-1.1	-0.7	Limit of study area up Severn Estuary, approx. 8 km upstream of Sudbrook, where agreement good
Sudbrook	46.48%	46.48%	45.77%	2.99	9.85	0.2	0.0	0.1	0.0	Blank
Newport	43.71%	43.71%	45.77%	2.70	8.90	0.4	0.2	0.0	0.4	Blank
Cardiff	44.06%	44.06%	45.77%	2.56	9.05	0.4	0.2	0.0	0.1	Blank
Barry	44.75%	44.75%	45.77%	2.43	8.72	0.3	0.1	0.0	0.1	Blank
Porthcawl	47.71%	47.71%	45.77%	2.09	7.54	0.0	-0.1	0.0	-0.1	Blank
Port Talbot	44.06%	44.06%	45.77%	2.03	7.39	-0.1	-0.1	-0.1	0.0	Blank
River Neath	n/a	n/a	45.77%	2.02	7.20	0.2	0.1	0.2	0.0	Blank
Swansea	47.61%	47.61%	45.77%	1.99	7.17	-0.1	0.0	0.0	-0.1	Blank
Mumbles	46.26%	46.26%	45.77%	1.96	7.18	0.0	0.0	0.0	0.0	Blank
Llanelli	n/a	n/a	45.77%	1.79	5.58	-0.1	0.1	0.2	0.0	Blank
Burry Port	48.05%	48.05%	45.77%	1.76	6.56	-0.2	-0.1	0.0	0.0	Blank

Name	Derived Factor	Factor Used in Calculation of Average	Average Factor	VORF MHWN to MSL	VORF MHWN to CD	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MHWN (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comment
Carmarthen	n/a	n/a	45.77%	0.68	2.52	-0.1	-0.7	-2.1	0.0	Site located up estuary, where agreement is expected to be poor
Ferryside	n/a	n/a	45.77%	1.38	5.04	0.2	0.0	-0.5	0.0	Blank
Tenby	46.29%	46.29%	45.77%	1.72	6.32	0.2	0.0	0.0	-0.2	Blank
Stackpole Quay	44.44%	44.44%	45.77%	1.61	5.98	0.1	0.0	-0.1	-0.1	Blank
Neyland	n/a	n/a	45.77%	1.46	5.27	0.0	0.0	-0.1	0.0	Blank
Black Tar	n/a	n/a	45.77%	1.48	5.29	0.0	0.0	0.0	-0.2	Site located up estuary, where agreement is expected to be poor
Haverfordwest	n/a	n/a	45.77%	1.48	5.30	-4.8	-4.9	-5.0	0.0	Site located up estuary, where agreement is expected to be poor

Table D3 Derivation of VORF MHWN levels and comparison with ATT tidal levels, for West Wales / Cardigan Bay. MHWN levels are derived from VORF (v2.11) using method described in Section 4.1.2. (Derived factors colour coded, with smaller (below 35%) shaded darker brown and larger factors (above 52%) shaded darker green; Difference values colour coded, with larger negative differences (below -1m) shaded darker blue and larger positive differences (above +1m) shaded darker red). Primary Ports are identified using bold text for site Name.

Name	Derived Factor	Factor Used in Calculation of Average	Average Factor	VORF MHWN to MSL	VORF MHWN to CD	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MHWN (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comment
Millford Haven	**42.86%**	42.86%	39.79%	1.27	5.08	0.0	0.0	0.1	0.0	Blank
Dale Rocks	n/a	n/a	39.79%	1.26	5.10	0.1	0.0	0.1	0.0	Blank
Martin's Haven	43.61%	43.61%	39.79%	1.05	4.59	0.0	0.0	0.1	0.0	Blank
Skomer Island	n/a	n/a	39.79%	1.05	4.45	0.6	0.6	0.7	0.0	Very close to Martin Haven & Little Haven, where range smaller, suspect ATT poor
Little Haven	41.86%	41.86%	39.79%	1.04	4.47	-0.2	-0.2	-0.1	-0.1	Blank
Solva	43.97%	43.97%	39.79%	0.93	4.22	-0.2	-0.1	0.0	-0.1	Blank
Ramsey Sound	45.70%	45.70%	39.79%	0.89	3.91	-0.2	-0.2	0.0	-0.1	Blank
Porthgain	40.54%	40.54%	39.79%	0.79	3.43	-0.3	-0.1	0.0	0.1	Blank
Fishguard	**33.01%**	n/a	39.79%	0.86	3.47	0.0	0.0	-0.1	0.1	Blank
Port Cardigan	43.72%	43.72%	39.79%	0.93	3.52	-0.4	-0.2	-0.1	-0.1	Blank
Cardigan town	n/a	n/a	39.79%	0.91	3.45	-0.2	0.0	0.2	0.0	Blank
Aberporth	36.97%	36.97%	39.79%	0.95	3.51	-0.2	0.0	-0.1	0.0	ATT data of Secondary Quality
New Quay	n/a	n/a	39.79%	0.93	3.52	0.1	0.0	-0.1	0.1	Blank
Aberystwyth	34.78%	34.78%	39.79%	0.92	3.58	0.3	0.2	-0.1	0.2	ATT data of Secondary Quality
Aberdovey	37.24%	37.24%	39.79%	0.94	3.58	-0.1	0.0	-0.1	0.0	ATT data of Secondary Quality
Barmouth	42.98%	42.98%	39.79%	0.94	3.60	0.0	0.0	0.1	0.0	ATT data of Secondary Quality
Porthmadog	n/a	n/a	39.79%	0.97	3.59	0.4	0.0	-0.2	0.0	Blank
Criccieth	34.43%	34.43%	39.79%	0.96	3.60	0.3	-0.1	-0.2	-0.1	ATT data of Secondary Quality

Name	Derived Factor	Factor Used in Calculation of Average	Average Factor	VORF MHWN to MSL	VORF MHWN to CD	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MHWN (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comment
Pwllheli	35.90%	35.90%	39.79%	0.93	3.57	0.3	0.1	0.0	0.0	ATT data of Secondary Quality
St Tudwal's Roads	34.21%	34.21%	39.79%	0.89	3.53	0.2	-0.1	-0.2	-0.1	ATT data of Secondary Quality
Aberdaron	38.10%	38.10%	39.79%	0.81	3.40	0.2	0.0	-0.1	-0.1	ATT data of Secondary Quality
Bardsey Island	n/a	n/a	39.79%	0.76	3.19	0.3	0.1	0.0	0.0	Blank

Table D4 Derivation of VORF MHWN levels and comparison with ATT tidal levels, for North Wales. MHWN levels are derived from VORF (v2.11) using method described in Section 4.1.2. (Derived factors colour coded, with smaller (below 35%) shaded darker brown and larger factors (above 52%) shaded darker green; Difference values colour coded, with larger negative differences (below -1m) shaded darker blue and larger positive differences (above +1m) shaded darker red). Primary Ports are identified using bold text for site Name.

Name	Derived Factor	Factor Used in Calculation of Average	Average Factor	VORF MHWN to MSL	VORF MHWN to CD	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MHWN (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comment
Porth Ysgaden	47.62%	47.62%	47.86%	0.98	3.50	0.1	-0.1	-0.1	-0.1	Blank
Porth Dinllaen	42.58%	42.58%	47.86%	1.00	3.55	0.1	0.0	-0.1	-0.1	Blank
Trefor	42.22%	42.22%	47.86%	1.02	3.71	0.2	0.0	-0.2	-0.1	Blank
Fort Belan	37.50%	n/a	47.86%	0.95	3.78	-0.2	-0.2	-0.3	0.0	Entrance to Menai Straits
Caernarfon	45.21%	45.21%	47.86%	1.05	4.14	-0.1	-0.1	-0.1	0.0	Blank
Port Dinorwic	46.90%	46.90%	47.86%	1.17	4.46	-0.2	-0.1	-0.1	0.2	Blank
Menai Bridge	53.85%	n/a	47.86%	1.39	5.29	0.7	0.5	0.5	-0.1	Rapid changing range through 'Swellies', mainly rocky coastline. Port Dinorwic and Beaumaris, either side where better agreement
Llanddwyn Island	48.72%	48.72%	47.86%	0.95	3.96	-0.2	-0.1	-0.1	-0.1	Blank
Porth Trecastell	40.89%	40.89%	47.86%	0.98	3.97	0.0	0.0	-0.2	0.0	Blank
Trearddur Bay	43.40%	43.40%	47.86%	1.01	4.07	0.0	0.0	-0.1	0.0	Blank
Holyhead	48.50%	48.50%	47.86%	1.13	4.38	0.0	0.0	0.0	0.0	Blank
Cemaes Bay	48.81%	48.81%	47.86%	1.37	5.16	0.1	0.0	-0.1	-0.1	Blank
Amlwch	51.92%	51.92%	47.86%	1.47	5.54	0.2	0.1	0.2	-0.1	Blank
Moelfre	48.95%	48.95%	47.86%	1.53	5.73	0.3	0.1	0.1	-0.1	Blank
Trwyn Dinmor	51.07%	51.07%	47.86%	1.61	5.84	0.0	-0.1	0.1	0.1	Blank
Beaumaris	52.66%	52.66%	47.86%	1.57	5.80	0.3	0.1	0.2	-0.1	Blank
Conwy	51.01%	51.01%	47.86%	1.66	5.88	0.2	0.2	0.3	0.2	Blank

Name	Derived Factor	Factor Used in Calculation of Average	Average Factor	VORF MHWN to MSL	VORF MHWN to CD	Difference in HAT (ATT - VORF)	Difference in MHWS (ATT - VORF)	Difference in MHWN (ATT - VORF)	Difference in MLWS (ATT - VORF)	Comment
Llandudno	50.55%	50.55%	47.86%	1.70	5.81	0.1	0.0	0.1	-0.1	Blank
Colwyn Bay	n/a	n/a	47.86%	1.71	6.02	-0.1	-0.1	0.1	0.0	Blank
Mostyn Docks	52.62%	52.62%	47.86%	0.83	3.12	5.3	4.9	3.9	0.5	Issue noted with VORF dataset up estuary
Connah's Quay	n/a	n/a	47.86%	0.97	3.65	0.2	0.0	-0.6	0.0	Site located up estuary, where agreement is expected to be poor

Derivation of present-day tidal levels

To derive present day tide levels around the Welsh coast the continuous VORF derived dataset representing tidal range (HAT - LAT) was overlaid against the SMP2 Policy Units.

Separate Tidal Level entities were then defined along the open coast. The boundary of each tidal level entity coincides with the boundary of an SMP2 Policy Unit. Different Tidal Level entities were then defined where the tidal range (HAT – LAT) varied by up to ~0.2 m across the Tidal Level entity.

In many instances, such as within Cardigan Bay, where the tidal range is very similar throughout the bay, a single Tidal Level entity extends across numerous SMP2 Policy Units. However, the end of each Tidal Level entity always coincides with the boundary of two separate SMP2 Policy Units.

In some other locations, e.g., along the open coast of the Severn Estuary, the tidal range (HAT-LAT) can vary by much more than 0.2 m along a single SMP2 Policy Unit. In these instances, two or more separate Tidal Level entities are defined along an SMP2 Policy Units. Again, the extent of each entity was chosen to ensure that the tidal range across the entity did not typically vary by more than ~0.2 m (maximum of 0.3 m in a few instances).

The resultant Tidal Level entities are presented in Figure D6.

For each Tidal Level entity, a single reference point was defined at a point just offshore, that was located midway along the entity. These points are indicated on Figure D6, and were subsequently used to extract the required tide levels from the continuous VORF dataset. This includes the MHWN values that were derived from the ATT and VORF datasets.

The generation of the above Tidal Level entities is based on the open coast VORF data, including the main open coast along the Severn Estuary, where the VORF data is considered reliable.

Whilst it is noted that tide levels will typically vary up estuaries, limited available data exists to define the change in water levels up each estuary. Therefore, the open water tide levels at the entrance of each estuary are also adopted for SMP2 Policy Units that exist within the estuary.

This approach is considered acceptable for the present national scale assessment, since:

- The extensive intertidal areas that occur within the lower tidal frames tend to occur near the mouth of the estuary, where the low water levels are relatively similar to those just offshore of the estuary mouth;
- Further upstream, where low water levels can vary significantly, there is typically less seabed within the lower tidal frame. These areas are often depicted by steep sided channels with limited habitat extent;
- In the upper estuary where the intertidal areas may be more extensive around the higher tidal frames, high water levels are more commensurate with those at the mouth of the estuary, and
- The hypsometric based approach adopted for the national scale assessment does not account for morphological responses that may also occur as a result of SLR, which would also affect actual habitat extents into the future.

Therefore, whilst it is acknowledged that the adoption of the tide levels at the mouth of the estuaries throughout the estuary is an oversimplification of the physical variation in tidal levels that will occur, this simplification may not be that significant in respect to assessing intertidal habitat extents in the upper estuary for the reasons given above. Therefore, the approach is considered appropriate for this national scale assessment.

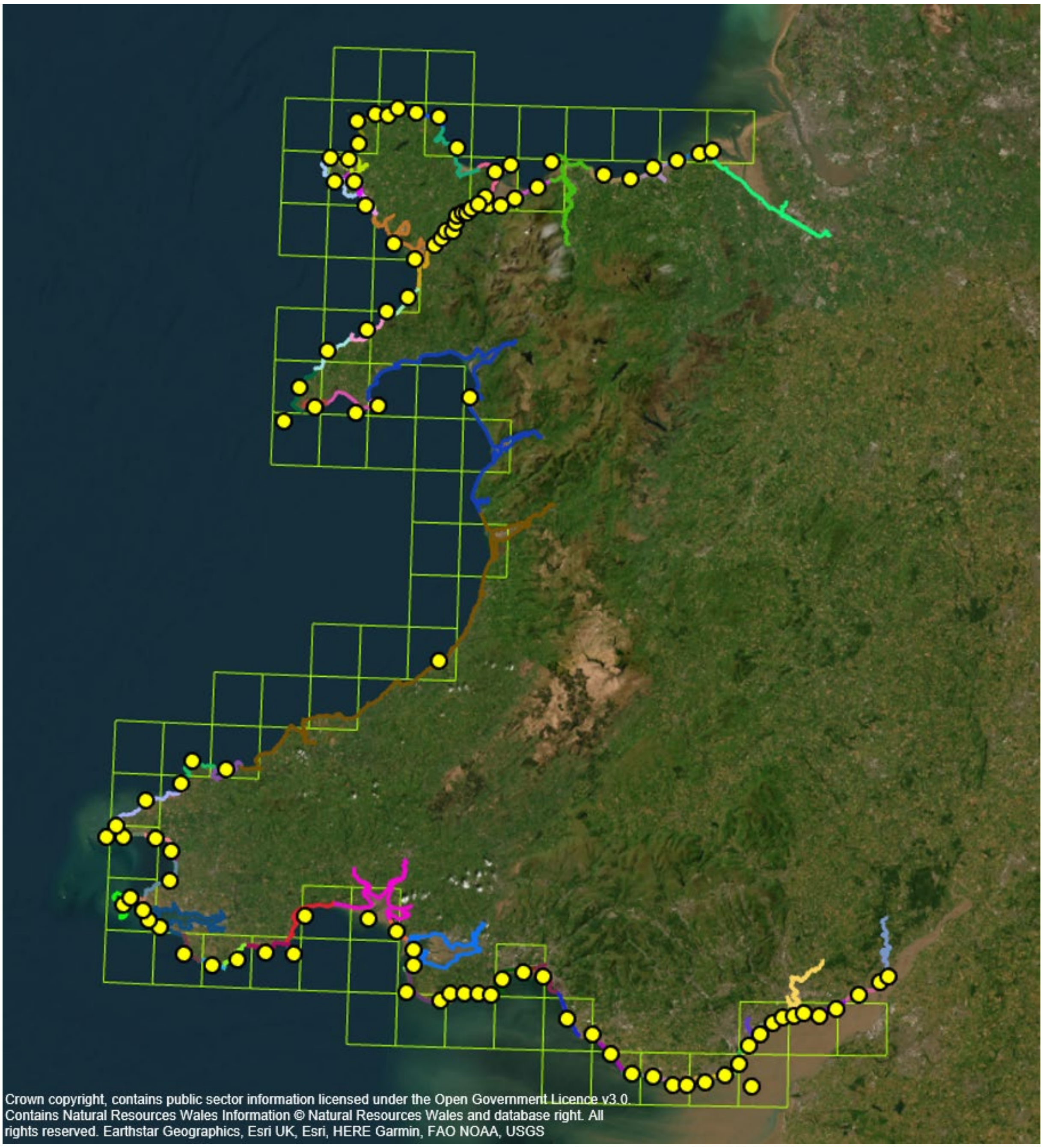


Figure D6 Tidal Level entities with central points (yellow dots) and UKCP tiles overlaid.

Present-day tide level base date

As the VORF data was derived in 2008, a further check was undertaken to examine if the tidal levels are still relevant to the present-day (2025), or whether any adjustment was required.

The VORF dataset was derived in 2008 with tide levels and tidal reference to CD. To undertake the assessment the extracted VORF levels have been converted to mODN, using the VORF data layer CD_ODN.

The VORF data layer CD_ODN, has been compared to CD to mODN values extracted from ATT in 2023, and the differences are generally within 2 cm, other than in those areas that have already been accounted for e.g. sites up estuaries where the VORF data is not to be used.

Hence, the VORF derived tide levels are considered to represent present-day levels as used in the start of the first epoch examined, being 2025.

Table D5 Comparison between ATT CD to ODN values compared to VORF CD to ODN values (Difference values colour coded, with larger negative differences shaded darker blue and larger positive differences shaded darker red).

Name	ATT CD_ODN (2023)	VORF CD_ODN	Difference	Comments
Inward Rocks	-5.18	-6.533	1.353	Limit of study area up Severn Estuary, approximately 8 km upstream of Sudbrook, where agreement is good. Difference is not related to a change in base date.
Sudbrook	-6.5	-6.506	0.006	Blank
Newport	-5.81	-5.81	0.000	Blank
Cardiff	-6.3	-6.301	0.001	Blank
Barry	-6.1	-6.072	-0.028	Blank
Porthcawl	-5.3	-5.276	-0.024	Blank
Port Talbot	-5.2	-5.191	-0.009	Blank
River Neath	-5	-5.01	0.010	Blank
Swansea	-5	-5.008	0.008	Blank

Name	ATT CD_ODN (2023)	VORF CD_ODN	Difference	Comments
Mumbles	-5	-5.018	0.018	Blank
Llanelli	-3.66	-3.659	-0.001	Blank
Burry Port	-4.7	-4.704	0.004	Blank
Carmarthen	2	1.202	0.798	Site located up estuary and difference is not related to change in base date
Ferryside	-2.5	-2.5	0.000	Blank
Tenby	-4.5	-4.491	-0.009	Blank
Stackpole Quay	-4.3	-4.283	-0.017	Blank
Neyland	-3.71	-3.709	-0.001	Blank
Black Tar	-3.71	-3.715	0.005	Site located up estuary
Haverfordwest	1.5	-3.734	5.234	Site located up estuary and difference is not related change in base date
Milford Haven	-3.71	-3.709	-0.001	Blank
Dale Roads	-3.71	-3.71	0.000	Blank
Martin's Haven	-3.45	-3.4	-0.05	Blank
Skomer Island	n/a	-3.263	n/a	Blank
Little Haven	-3.25	-3.243	-0.007	Blank
Solva	-3.1	-3.096	-0.004	Blank
Ramsey Sound	-2.9	-2.883	-0.017	Blank
Porthgain	n/a	-2.505	n/a	Blank

Name	ATT CD_ODN (2023)	VORF CD_ODN	Difference	Comments
Fishguard	-2.44	-2.439	-0.001	Blank
Port Cardigan	-2.44	-2.445	0.005	Blank
Cardigan (Town)	-2.44	-2.444	0.004	Blank
Aberporth	-2.44	-2.439	-0.001	ATT data of Secondary Quality
New Quay	-2.44	-2.465	0.025	Blank
Aberystwyth	-2.44	-2.436	-0.004	ATT data of Secondary Quality
Aberdovey	-2.44	-2.451	0.011	ATT data of Secondary Quality
Barmouth	-2.44	-2.448	0.008	ATT data of Secondary Quality
Porthmadog	-2.44	-2.422	-0.018	Blank
Criccieth	-2.44	-2.436	-0.004	ATT data of Secondary Quality
Pwllheli	-2.44	-2.433	-0.007	ATT data of Secondary Quality
St. Tudwal's Roads	-2.44	-2.438	-0.002	ATT data of Secondary Quality
Aberdaron	-2.44	-2.437	-0.003	ATT data of Secondary Quality
Bardsey Island	n/a	-2.284	n/a	Blank
Porth Ysgaden	-2.4	-2.386	-0.014	Blank
Porth Dinllaen	-2.4	-2.396	-0.004	Blank
Trefor	-2.5	-2.507	0.007	Blank
Fort Belan	-2.6	-2.609	0.009	Entrance to Menai Straits
Caernarfon	-2.8	-2.842	0.042	Blank

Name	ATT CD_ODN (2023)	VORF CD_ODN	Difference	Comments
Port Dinorwic	-3.05	-3.052	0.002	Blank
Menai Bridge	-3.8	-3.675	-0.125	Rapid changing range through 'Swellies', mainly rocky coastline. Port Dinorwic and Beaumaris, either side where better agreement. Difference is not related to change in base date
Llanddwyn Island	-2.79	-2.785	-0.005	Blank
Port Trecastell	-2.8	-2.771	-0.029	Blank
Trearddur Bay	-2.9	-2.854	-0.046	Blank
Holyhead	-3.05	-3.057	0.007	Blank
Cemaes Bay	-3.6	-3.613	0.013	Blank
Amlwch	-3.9	-3.881	-0.019	Blank
Moelfre	-4	-4.006	0.006	Blank
Trwyn Dinmor	-4	-4.004	0.004	Blank
Beaumaris	-4	-4.002	0.002	Blank
Conwy	-4	-4.025	0.025	Blank
Llandudno	-3.85	-3.865	0.015	Blank
Colwyn Bay	-4.1	-4.111	0.011	Blank
Mostyn Docks	-4.5	-4.418	-0.082	Issue noted with VORF dataset up estuary, and difference is not related to change in base date

Name	ATT CD_ODN (2023)	VORF CD_ODN	Difference	Comments
Connah's Quay	-0.75	-0.759	0.009	Site located up estuary and difference is not related to change in base date

D.3.2 SLR allowances

SLR Guidance

Welsh Government 2022, identifies that SLR allowances should be developed from the UKCP18 national dataset available through the UK Climate Projections (Met Office) user interface.

UKCP18 is a national dataset, presenting projected, non-linear SLR predictions around the UK coastline in 12 km^2 grids. With reference to a baseline period (1981-2000) this dataset predicts changes to mean sea surface elevation depending on emission scenarios. This is considered a robust dataset and will be used without amendment in the project.

The two datasets of relevance to this assessment were downloaded in December 2023, including:

- Sea level anomalies for marine projections around the UK coastline, 2007-2100; and
- Sea level anomalies for marine projections around the UK coastline using exploratory methods, 2007-2300.

The extent and coverage of the data tiles associated with both datasets is presented in Figure D7, and provides national coverage, other than up estuaries (see Section 2.2.5).

Both datasets include the following projections as required for the study:

- UKCP18, RCP 8.5 emission scenario 70th percentile (higher central allowance); and
- UKCP18, RCP 8.5 emission scenario 95th percentile (upper end allowance)

According to Welsh Government, 2022:

'Location specific allowances, projections for different epochs and projections beyond 2100 can be obtained from the UK Climate Projections (Met Office) user interface.

The UKCP18 dataset projects to 2100. To calculate epochs beyond 2100, the average incremental increase from the last 5 years of the dataset for the site location should be used (2094 to 2099) from RCP 8.5 and multiply by the required number of years after 2100.'

This therefore recommends that projection beyond 2100 should be based on the extension of the 2007-2100, rather than using the 2007-2300 dataset uplift values beyond 2100.

This guidance differs from that provided by Welsh Government for use in Flood Consequences Assessments (Welsh Government, 2021). This guidance is stated below, and identifies that the 2007-2300 data set should be used for levels beyond 2125:

‘When considering proposals with a lifetime of development beyond 2120 an appropriate assessment will be required for the whole of the development lifetime. Allowances up to 2125 should be calculated using the average incremental increase from the last 5 years of the dataset (2095-2099) for the relevant regional area, multiplied by 25. Allowances beyond 2125 can be obtained from the UKCP18 User Interface, using the exploratory method dataset (2007-2300) for RCP 8.5.’

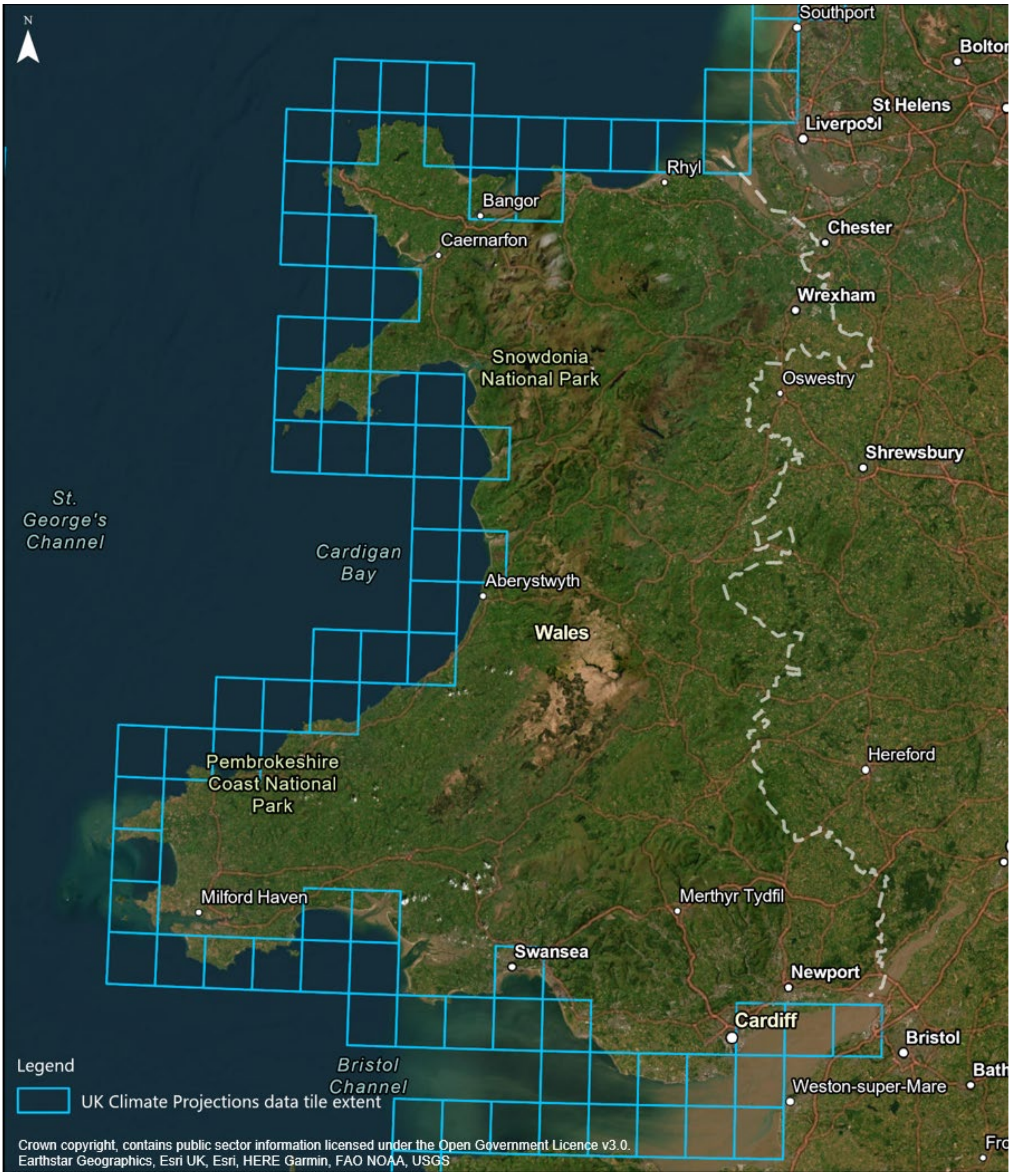


Figure D7 UK Climate Projections (Met Office), data tile extent and locations for future Sea Level Anomalies.

The difference between extending the 2007-2100 dataset uplift values to 2155, compared to adopting the 2007-2300 uplift values beyond 2125, is presented in Figure D8 for the Dyfi Estuary. This shows that the difference is relatively minor.

Therefore, for consistency with other coastal studies that are expected to utilise Welsh Government, 2022 guidance for SLR, the Welsh Government 2022's approach is adopted for this study.

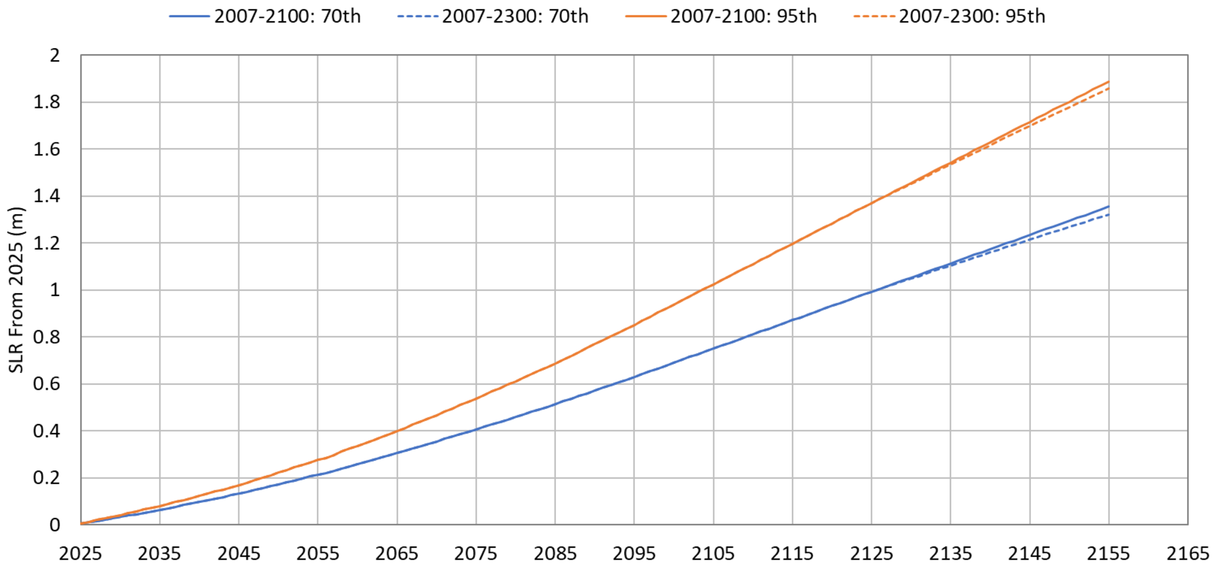


Figure D8 Sea level projections for Dyfi Estuary, using comparative approaches, a) extending 2007-2100, according to Welsh Government 2022 (solid lines) and, b) adopting 2007-2300 dataset, beyond 2125, according to Welsh Government 2021(dashed lines).

To produce the SLR allowance for the Welsh coast the UKCP18 RCP 8.5 emission scenario sea level anomalies for marine projections around the UK coastline 2007-2100 dataset was re-downloaded in June 2023, and the annual SLR allowances beyond 2025 were determined for the 70th percentile (higher central allowance), and 95th percentile (upper end allowance) projections.

Beyond 2100, the annual SLR allowances were determined using the Welsh Government 2022, approach.

Each Tidal Level entity identified through the derivations of present-day sea levels (Section D.3.1), were then associated with the most appropriate related UKCP18 tile, using the central pointed located along each Tide Level entity (Figure D9). In many cases, two or more Tide Level entities lie within the same UKCP18 tile, however, within Cardigan Bay where the tidal range is relatively similar throughout the bay a single Tidal Level entity may cover many UKCP18 tiles. Where this occurred, the variation in SLR allowance (based on RCP 8.5, 95th percentile for period 2025 – 2155) is very small (<0.04 m). Therefore, the SLR values have been adopted from the single tile located centrally along the Tide Level entity.

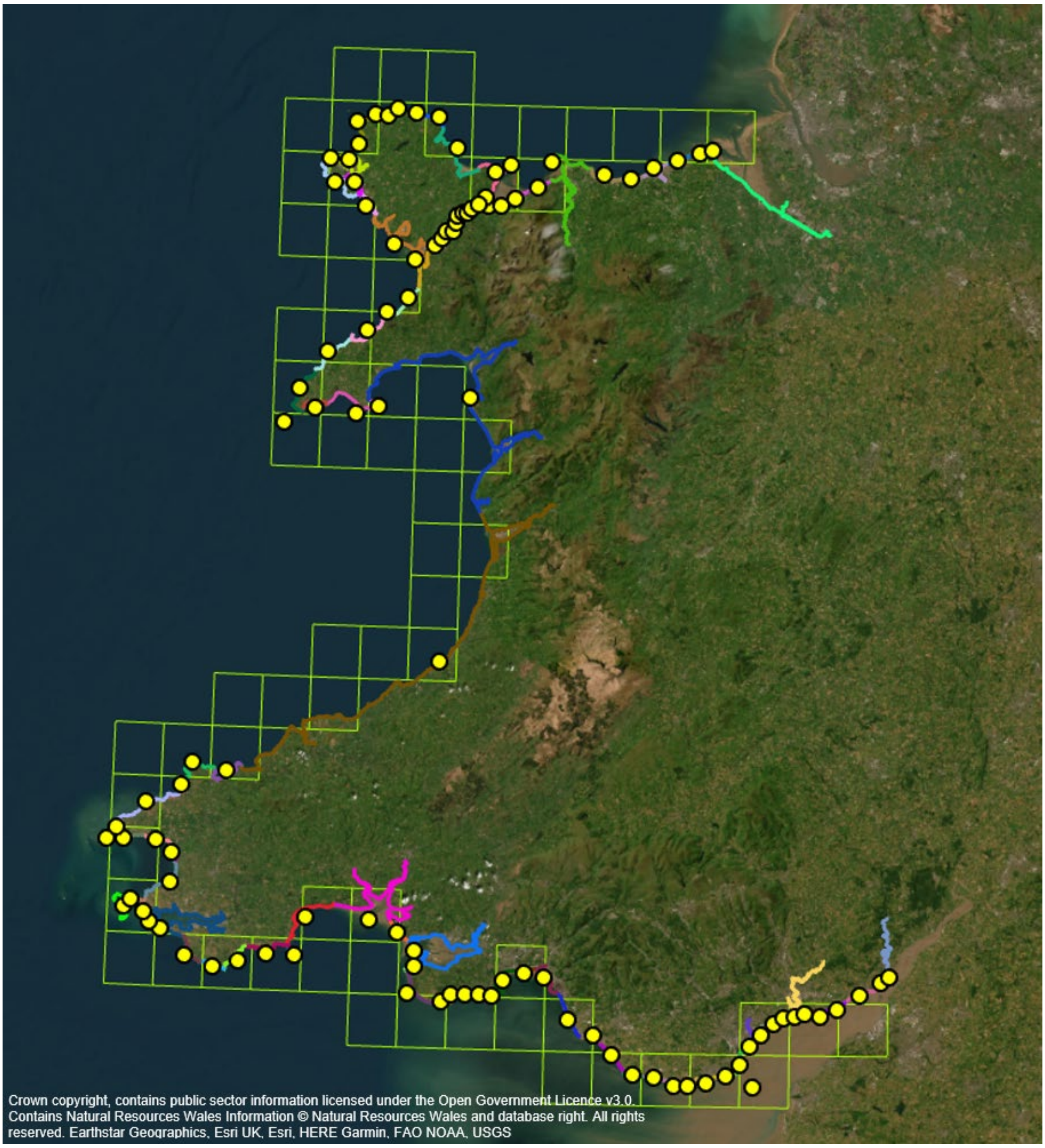


Figure D9 Tidal Level entities with central points (yellow dots) overlaid with UKCP Tiles (green boxes) which provide associated SLR data.

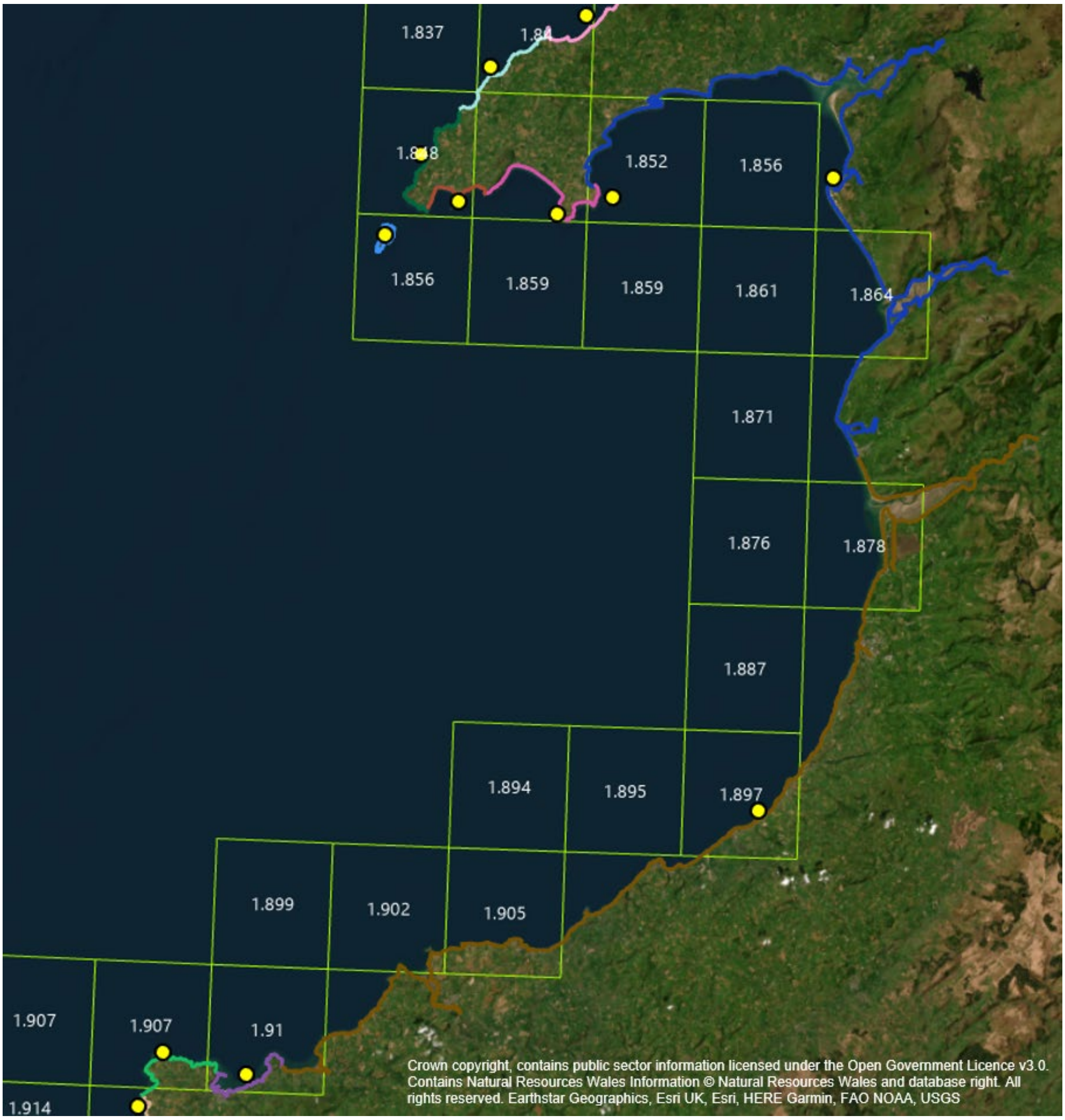


Figure D10Tidal Level entities with central points (yellow dots) overlaid with UKCP18 RCP 8.5 95th percentile SLR Allowances 2025 – 2155, within Cardigan Bay. Single Tidal Level entities cover multiple UKCP18 tiles, but SLR allowance only show minimal variation across the associated tiles.

SLR allowances from UKCP18 are only provided for the open coast and along the open coast of the Severn Estuary. Within estuaries, SLR could vary significantly from that along the open coast, due to the physical process involved as the tide propagates into the estuary.

This simplification will have greater significance in the upper reaches of estuaries which have significant Accommodation Space. Within the lower estuary the SLR allowances will be more comparable with those directly offshore of the estuary.

D.4 Data layer deliverable

The deliverables for the Tidal Level data layer consists of a single GIS feature-class consisting of polylines related to each Tide Level entity. Associated with each Tide Level entity are:

- Present-day (2025) tidal levels relative to mODN:
  - MLWS
  - MHWN
  - MHWS
  - HAT
  - HAT +1 m
  - HAT +1 m +SLR 2155 (95th percentile)
- SLR allowances from 2025, at 5 yearly intervals up to 2155, based on UKCP18, RCP 8.5 emission scenario projections:
  - 70th percentile (higher central allowance)
  - 95th percentile (upper end allowance)

D.5 Data limitations

Tide levels along the open coast (including along open coast of the Severn Estuary), are generally provided to an accuracy of around 0.1 m, and the Tidal Level entities are defined so that the difference in tidal range is typically no more than 0.2 m across the area to which the specific tidal level data relates to. Thus, along the open coast, the values associated with the Tide Level entities are generally provided to the accuracy of the available Tide Level data. However, it is noted:

- That the tide levels are poorly defined higher up in the estuaries (Section D.3.1);
- There are some discrepancies between the Admiralty VORF dataset and ATT datasets, with most of these discrepancies occurring up estuaries (Section D.3.1), and
- A simplified approach is adopted to address the lack of information on tidal levels up estuaries which will have an effect on the results returned from sites on estuaries, but this is considered appropriate at this national level assessment. (Section: D.3.1)

The SLR allowances have been adopted direct from national guidance (Welsh Government 2022), however, it is noted that:

- There are uncertainties as to the actual SLR that will occur by 2155 (end of project assessment period), and
- National guidance does not provide SLR allowance estimates higher up in estuaries, therefore, the allowances up estuaries have been assumed to be the same as that on the open coast at the mouth of the estuary.

E Assessment Unit data layer

E.1 Overview of data layer

The assessment of coastal squeeze and natural squeeze is undertaken at the Assessment Unit level, so that results may then be amalgamated at SMP2 Policy Unit, National or MPA level. Each Assessment Unit is defined as a polyline, that represents either:

- An anthropogenic structure (e.g. coastal defence or railway embankment);
- A Natural Ridge (e.g. beach crest / dunes ridge) which has low lying land behind;
- High Ground within an estuary; or
- Cliff along an open coast.

Within the assessment, coastal squeeze is considered to occur in front of anthropogenic structures providing the habitat would be able to roll-back into the Accommodation Space if the structure was removed. Natural squeeze is then considered to occur in front of Natural Ridges and High Ground. Natural squeeze may also occur in front of an anthropogenic structure, if the extent of the Accommodation Space is unable to accommodate the losses observed in front of a structure. Cliffs, however, are scoped out of the assessment as they will either erode, or the intertidal habitat associated with them can be expected to migrate up the rock/cliff face. This is in alignment with Environment Agency, 2021, which scopes out cliff habitat from being subject to coastal squeeze.

E.2 Data review and availability

E.2.1 Primary datasets

For each Assessment Unit, it was necessary to define the spatial location (geometry) and the associated SMP2 Policies for the frontage. From an initial review no single existing data set provided a suitable geometric representation of the Welsh coastline at a scale that was appropriate for this assessment.

Therefore several datasets were utilised in order to develop the Assessment Unit data layer:

- Updated SMP2 Policy Unit line data layer;
- NRW Spatial Flood Defence with Attributes (SFDwA) data layer;
- NRW National Coastal Erosion Risk Management mapping (NCERM) data layer;
- The Project DTM;
- Aerial and Terrestrial Imagery; and
- OS MasterMap layers.

Each of these data sets and the key issues identified with them are described in the following sections.

Updated SMP2 Policy Unit line data layer

The Updated SMP2 Policy Unit data layer is continuous along the coast (Figure E1), including major islands, and includes the following:

- **Location description**: site specific;
- **SMP2 Policy**: over three epochs (HTL, MR, NAI, ATL); and
- **Local Authority**: site specific.

The dataset was developed to convey management policy across wider frontages and was not developed to provide a detailed representation of the coastline. As such the identified issues related to this data set are noted below:

- Policy Unit lines can lie along the edge of natural channels where there are no anthropogenic structures or natural High Ground;
- Policy Unit lines are often poorly aligned with anthropogenic structures or natural frontages (Figure E2);
- The SMPs and therefore the SMP2 Policy Unit line does not always extend to the project boundary (defined as HAT +1 m +SLR). This is most apparent in the Cleddau Estuary, where the SMP2 Policy Unit line stops considerably short of the existing Natural Tidal Limit (NTL); and
- There is no differentiation between types of frontage, i.e. whether the line represents an anthropogenic structure, Natural Ridge, High Ground or a cliff.

Nevertheless, the data layer was of fundamental use in the derivation of the Assessment Unit data layer, as it was imperative that Assessment Units do not extend across different SMP2 Policy Units where the SMP2 Policy may be different.

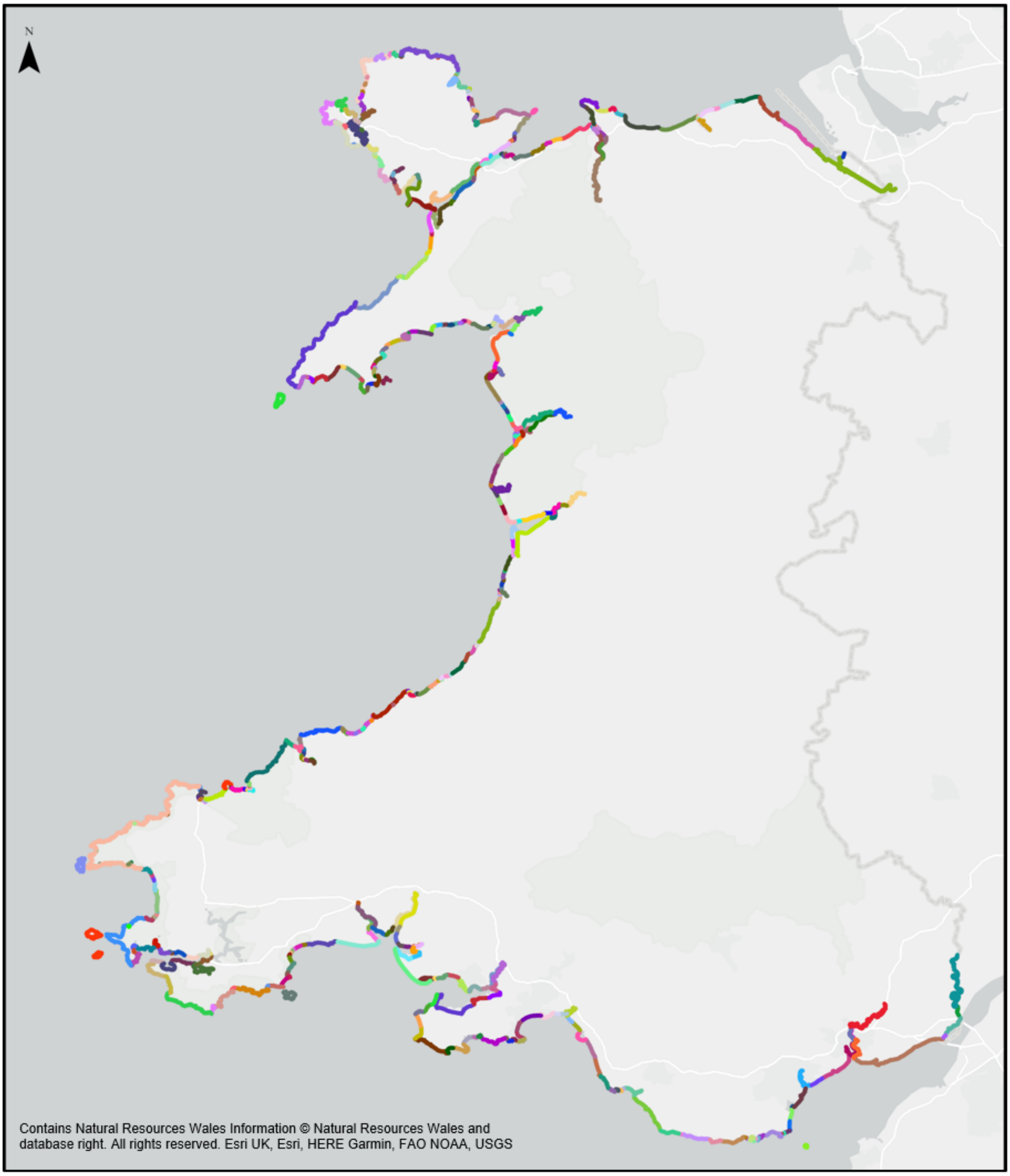


Figure E1 National coverage of Updated SMP2 Policy Unit data layer (Line colours represents different Policy Units).

Figure E2 Example of SMP2 Policy Unit data layer, showing how Policy Unit lines are poorly aligned with anthropogenic structures and natural frontages.

E.2.2 NRW Spatial Flood Defence with Attributes (SFDwA)

The SFDwA data layer provides details of anthropogenic structures (coastal defences) that occur along the coast. The data set typically identifies the following:

- **Name:** various;
- **Type**: wall, embankment, quay, demountable, flood gate, promenade, High Ground, cliff, beach, barrier beach, Bridge Abutment (Fluvial only);
- **Protection type:** Coastal, Tidal, Fluvial;
- **Design standard of Protection**: years;
- **Current Condition:** 1 – very good, to 5 - very poor (many null values); and
- **Crest level:** various descriptions, including design and actual (many null values).

However, the data layer is of variable quality and includes major gaps as identified in Figure E3. There are also numerous areas where defences are known to exist which are not included in the data layer. As an example, there are significant defences around Swansea (and Mumbles) and Porthcawl, which are not included. Even in areas where several defences are shown, e.g. around the Dyfi and Conwy Estuaries, there are many defences that are not included within the data layer.

There are also a number of additional issues associated with the data layer as summarised below:

- Assets are shown to overlap (Figure E4);
- Asset line does not follow structure/natural frontage (Figure E5); and
- Natural frontages are not included in the database.

Therefore, whilst the data set provided useful information to help develop the Assessment Unit data layer, it also needed to be used with caution.

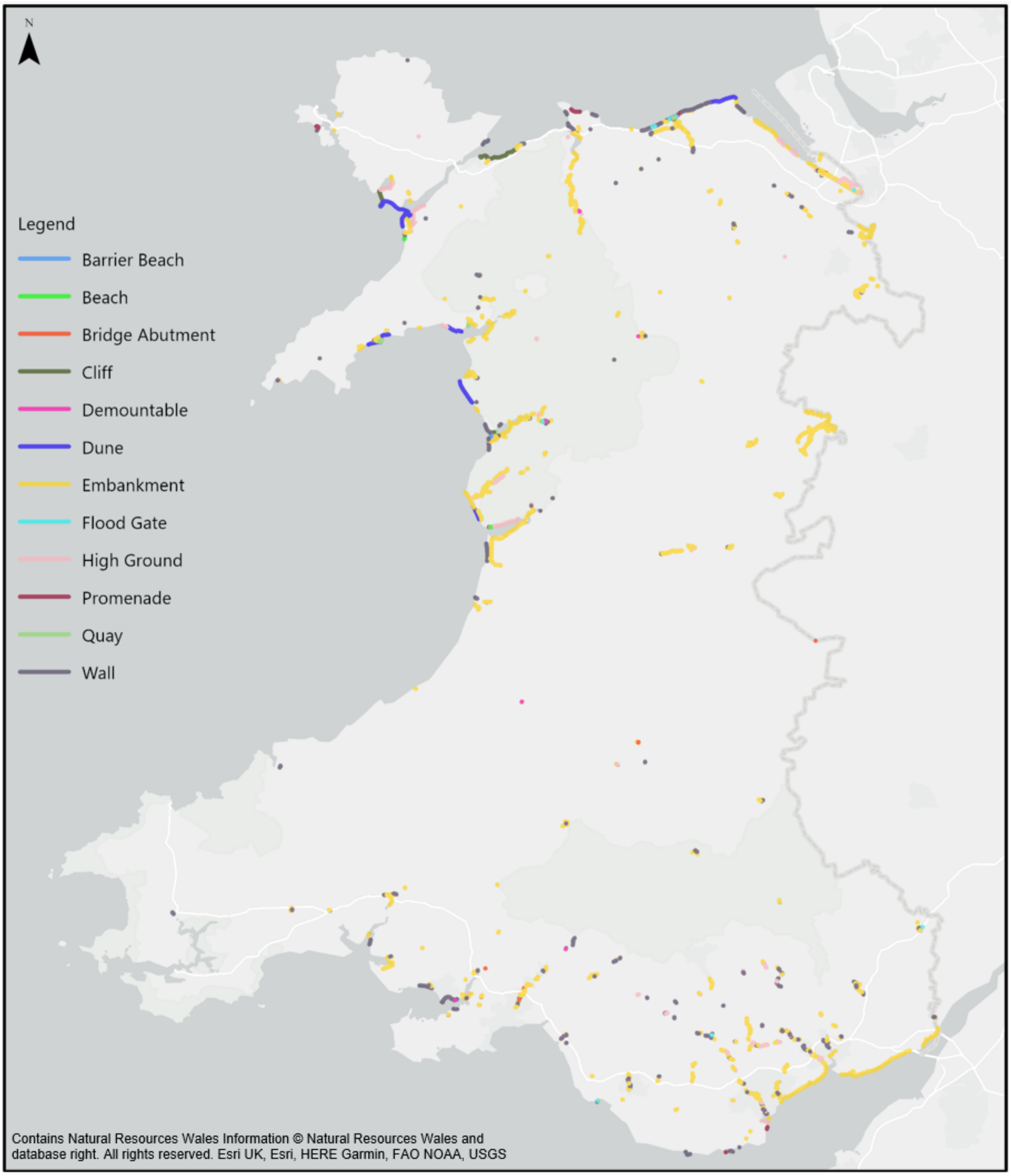


Figure E3 National coverage of SFDwA data layer.

Figure E4 Example of Issues associated with SFDwA data layer – Overlapping assets.

Figure E5 Example of Issues associated with SFDwA data layer – Asset line does not follow structure.

NCERM data layer

The NCERM data layer exists along the entire Welsh coastline covering the following four regions that equate to the extents of individual SMPs:

- Great Orme – England;
- West Wales;
- Swansea / Carmarthen Bay; and
- Severn.

The lines are continuous along the coast, include major islands, and include the following:

- **SMP2 Policy;**
- **Defence Type**: (Embankment, Gabions, Natural, Revetment, Seawall, Timber Structure); and
- **Type:** (Erodible, Floodable, Complex Cliff).

The NCERM data layer provides a reasonably good representation of the coastline across the entire study site, defining the frontage as either an anthropogenic structures, or as a natural frontage.

There are, however, several issues related to the data layer, namely:

- The Defence Type is often mis-labelled;
- The NCERM lines are often poorly aligned with anthropogenic structures or natural frontages (Figure E6); and
- The NCERM line does not always extend to the project boundary (defined as HAT +1 m +SLR)

Figure E6 Example of Issues associated with the NCERM data layer – anthropogenic structures and natural frontages not represented correctly (Left: Defence line does not follow embankment, Right: defence does not extend along tidal channel).

Nevertheless, the NCERM data layer provides beneficial information and a reasonable representation of the coastline and the anthropogenic structures and natural frontages along it. Therefore this was one of the primary datasets that was utilised to define the Assessment Unit data layer.

OS MasterMap layers

OS MasterMap layers provide a detailed representation of anthropogenic structures and natural frontages throughout the entire study site. They provide information on whether structures are buildings, roads, paths, tracks, land, or water. This is particularly useful when the Assessment Unit data layer continues through built-up areas or follows a railway embankment (Figure 7).

There are, however, a series of limitations associated with this data, namely:

- At some points the OS lines do not line up with anthropogenic structure as identified through the Project DTM (Figure E7); and
- The OS line data layer is incomplete, whereas the OS polygon data layer provides a more complete view of the data.

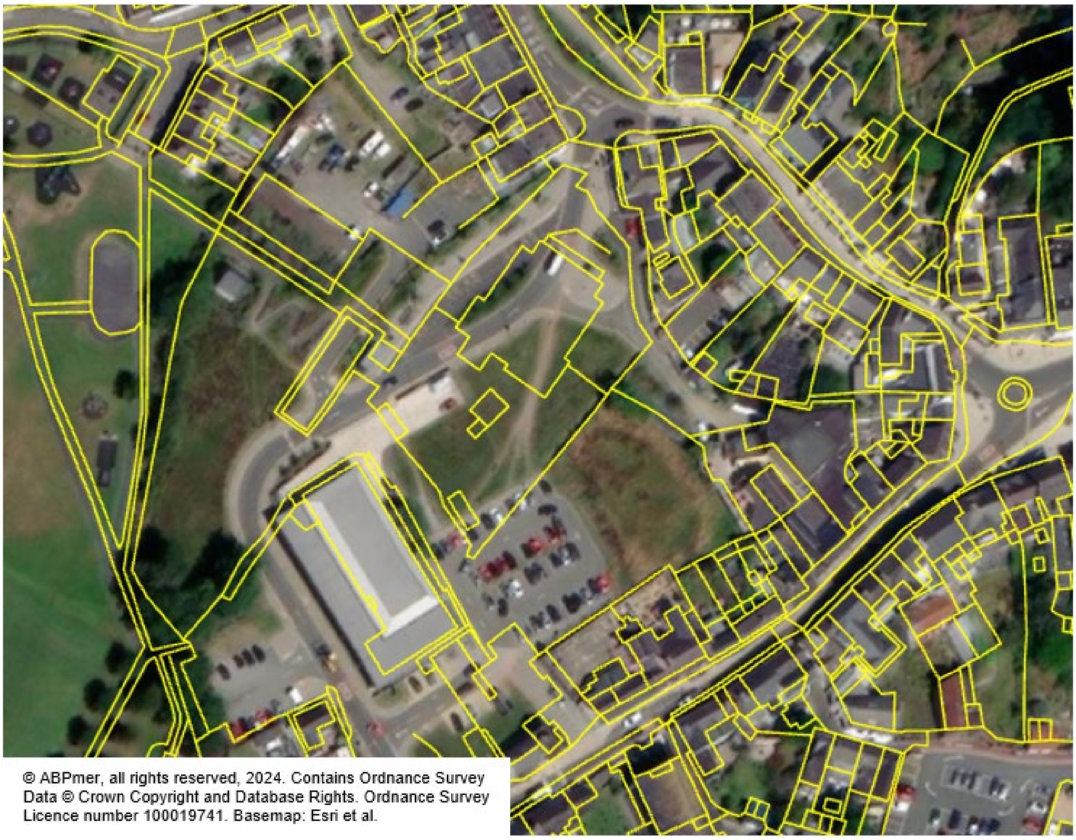


Figure E7 Visualisation of residential area using OS MasterMap layers where there is misalignment with aerial imagery.

Project DTM

The Project DTM provides detailed topographic data over the entire frontage. This dataset can be examined, contoured and visually interrogated to help define the location of both anthropogenic structures and natural frontages where they are poorly defined in the linear feature datasets above.

Aerial and terrestrial imagery

Aerial and terrestrial imagery, in particular Google Earth, Google Streetview, and Bing imagery, can be examined to help ascertain the nature of anthropogenic structures and natural frontages.

E.3 Production of the data layer

E.3.1 Overview

The production of the Assessment Unit data layer was a manual GIS task that utilised the available datasets identified above.

At their largest scale an Assessment Unit represents a whole SMP2 Policy Unit and is defined as a polyline that follows the line of the anthropogenic structure, Natural Ridge, High Ground or cliff that is covered by the Policy Unit. However, the SMP2 Policy Unit is further split into a series of smaller Assessment Units, where:

- Multiple types of frontage exist along the Policy Unit;
- Multiple Accommodation Spaces occur behind an anthropogenic structure or Natural Ridge and one of these Accommodation Spaces is shared with another Assessment Unit (See Section E.3.3), and
- The SMP2 Policy Unit extends across two or more Tidal Level entities.

Within the generated data layer the following '***Type***' definitions are used:

- **Defence**: Is any anthropogenic structure aligned along the coast / estuary?;
- **Natural**: Is any Natural Ridge aligned along the coast / estuary, that presently prevents sea encroaching into hinterland, i.e. natural beach ridge / dune, natural embankment barrier? These were typically considered to occur around present-day HAT +1 m contour (on an open coast), and around present-day HAT (within a sheltered estuary);
- **High Ground:** This is natural High Ground that occurs within estuaries at a level of HAT +1 +SLR in 2155 (using RCP 8.5 95th percentile SLR allowance), and
- Cliff: Natural cliff or rocky foreshore on open coast that Has no Accommodation Space behind it and no structure in front of it.

Assessment Units assigned as Cliff Type were not assessed within the analysis and no Foreshore Area or Accommodation Space are assigned to them.

E.3.2 Assessment Unit development rules

The following datasets were utilised simultaneously, to define the extent, and physical location of each Assessment Unit.

- Updated SMP2 Policy Unit line data layer;
- NRW SFDwA data layer;
- NRW NCERM data layer;
- The Project DTM;
- Aerial and Terrestrial Imagery, and
- OS MasterMap layers

Where a Defence or Natural frontage could be adequately schematised within these data layers, this data has been used directly. However, as identified in the data review, there were numerous issues related to each dataset and therefore the development of the Assessment Units data layer could not be automated and required significant manual work. To support this task a series of rules were also identified to ensure consistency across the Assessment Unit data layer, as described below:

- **Rules to define the extent of Assessment Units:**
  - At their largest extent an Assessment Unit extends the length of an SMP2 Policy Unit.
  - These are broken down further where:
    - There is a change in 'Type', e.g. between:
      - Defence
      - Natural
      - High Ground
      - Cliff
    - Part (not all) of the Accommodation Space backing an Assessment Unit would be shared with another Assessment Unit in a different SMP2 Policy Unit.
    - The Assessment Unit extends across two or more Tidal Level units.
  - The minimum length to be assigned to any an Assessment Unit is ~ 200 m. Therefore, sections of frontage that would have an Assessment Unit of less than 200 m are typically attached to the most appropriate neighbouring cell (See Rule F, Section E.3.3).

- **Rules regarding the Assessment Units 'Type':**
  - Where a continuous Natural Ridge exists along the coast/estuary acting as the present-day primary measure to prevent flooding of the hinterland, the Assessment Unit should follow the Natural Ridge and the 'Type' is noted as Natural.
  - However, if the Natural Ridge is not continuous, i.e. it does not provide any level of protection against the flooding of the hinterland, then the Assessment Unit should follow either the:
    - Defence line in its lee, or
    - High Ground in its lee.
  - If there are only intermittent dunes in front of a Defence / High Ground, a Defence line or High Ground should be utilised, and the Assessment Unit 'Type' noted as such.
  - On open coasts, where a natural cliff occurs, with:
    - No Defences present in front of it, and
    - No low lying land (Accommodation Space) behind it,

    Then a Cliff type is to be defined (See Rule D, Section E.3.3).

  There are two occasional exceptions to the above:
  - On 24 occasions a natural frontage was found to have a HTL policy in SMP2. In these instances, the frontages were examined by NRW and 6 of these frontages were amended to Defence. These amended sites are located at:
    - Mostyn
    - Abersoch
    - Pwllheli (Traeth Glan-y-Don)
    - Llanelli
    - Swansea
    - Cardiff

- In a number of other locations major infrastructure, such as a railway line at the top of a cliff frontage, exists with no structure at the toe of the cliff. These frontages are also typically associated with a HTL policy. In these cases the frontages have generally been defined as a Defence 'Type' rather than a Cliff.

- **Rules regarding the location and alignment of the Assessment Unit:**
  - Assessment Units are to be aligned along the crest of anthropogenic structures and Natural Ridges where these exist, so they appropriately provide a break between the Foreshore Area (in front of the Assessment Unit) and the Accommodation Space (behind the Assessment Unit).
  - Along Cliffs and High Ground the Assessment Unit should be placed along the HAT +1 +SLR in 2155 (using RCP 8.5 95th percentile SLR allowance) contour.
  - Where a Defence, Natural or High Ground 'Type' is adequately schematised within existing data layers, this data may be used directly. However, in many cases it will need to be manually amended or even digitised freehand.
  - Where a Defence 'Type' is schematised, the Assessment Unit should follow the crest of the Defence (this could for example be railway track on a railway embankment).
  - Where a Natural 'Type' is schematised, the present-day HAT +1 m contour should be utilised to help define the alignment on an open coast and the present-day HAT contour should be utilised to help define the alignment in a sheltered estuary.
  - Where High Ground type is schematised, the HAT +1 m, +SLR in 2155 (using RCP 8.5 95th percentile SLR allowance) contour should principally be adopted.
  - Assessment Units must not overlap. Where this is found to occur in the available datasets, an assessment will be made on the most likely location of the interface between the two frontages.
  - The end of each SMP2 Policy Unit must be defined using the SMP2 data layer, and not a definition from within other data layers, such as NCERM. Errors are known to exist in these. However, where the Policy Unit endpoints in the SMP2 data layer do not align with the frontage being schematised, the SMP2 Policy Unit endpoint will need to be adjusted in a landward/seaward direction accordingly, so it lies on the Assessment Unit line.
  - At the upper reaches of estuaries, the Assessment Unit should be extended to the HAT +1 m +SLR 2155 (RCP 8.5, 95%) contour. This may require the Assessment Unit line to extend beyond the SMP2 Policy Unit. The rules related to this are set out in Rule E, Section E.3.3.
  - Where small breaks / gaps occur along an anthropogenic structure or Natural Ridge, the Assessment Unit line should continue along the main line of the anthropogenic structure or Natural Ridge (See Rule F, Section E.3.3)

E.3.3 Rule clarifications

The following sub-sections identify some of the key issues encountered and provides clarification on how rules were applied in these instances.

Rule A: Shared Accommodation Space

Issue

Clarification on when an Assessment Unit needs to be split to allow Accommodation Space to be represented correctly.

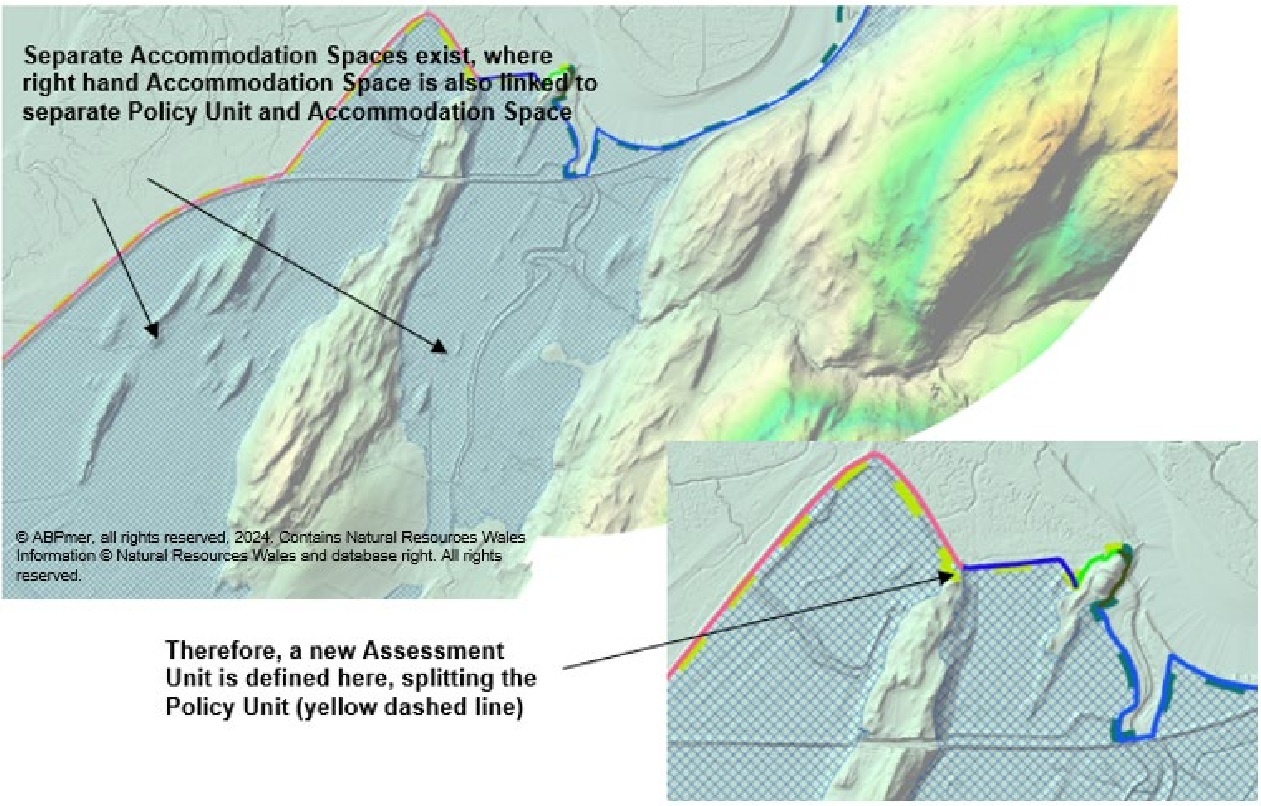
Rule

Accommodation Space Definition:

- An individual Accommodation Space is defined as an area behind the Defence/Natural frontage across which flow could occur without any impedance from natural High Ground in 2155 (i.e. if there is no continuous High Ground across it), and
- The presence of man-made structures across an Accommodation Space are ignored.

Multiple Assessment Units can occur along a frontage that share the same Accommodation Space. Furthermore, several discrete Accommodation Spaces can be grouped into a single Accommodation Space where they lie behind a single Assessment Unit. However, where multiple Accommodation Spaces would occur along an Assessment Unit and only one of them would be associated with an adjacent Assessment Unit, the Assessment Unit needs to be split to prevent this.

Example



Rule B: Minimum length of an Assessment Unit (typically < ~200 m)

Issue

Clarification related to the scale at which Assessment Units should be schematised.

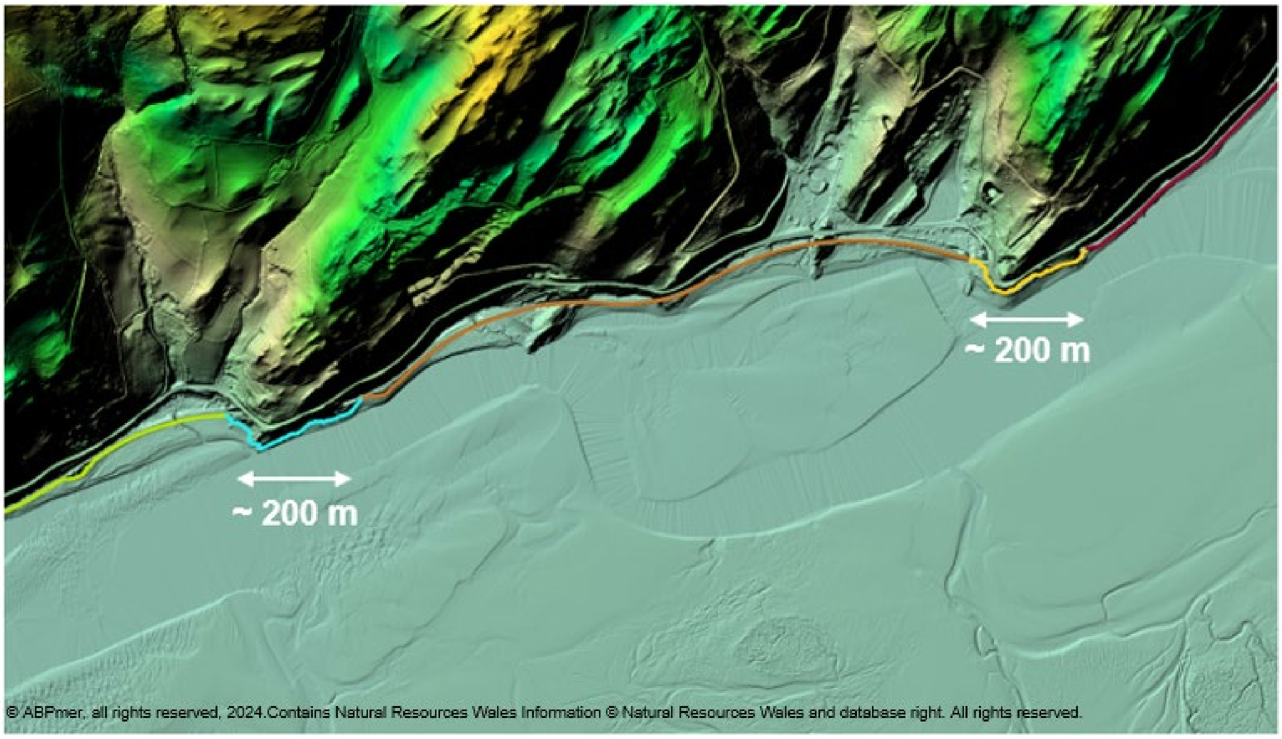
Rule

The study is being undertaken at a national scale, therefore it is not required to break the Assessment Unit line down to a detailed site specific level since this will not have a significant impact on the results of the assessment at a national scale.

From initial trials it is considered that a minimum Assessment Unit length of around 200 m is appropriate. Where there is a change in Assessment Unit type of less than this length, then the frontage can be associated with the most appropriate neighbouring frontage under a single Assessment Unit.

Since the study is principally focused on the effect structures have on coastal squeeze, there is a priority to consider defended frontages over natural frontages. Therefore, if two small (< ~200 m) adjacent frontages occur where one is Defence and one Natural, that can be considered together, they should be assigned a Defence type.

Example



Rule C: Selection of Assessment Unit Type: Natural vs High Ground

Issue

Additional clarification on when to use Natural or High Ground Type.

Rule

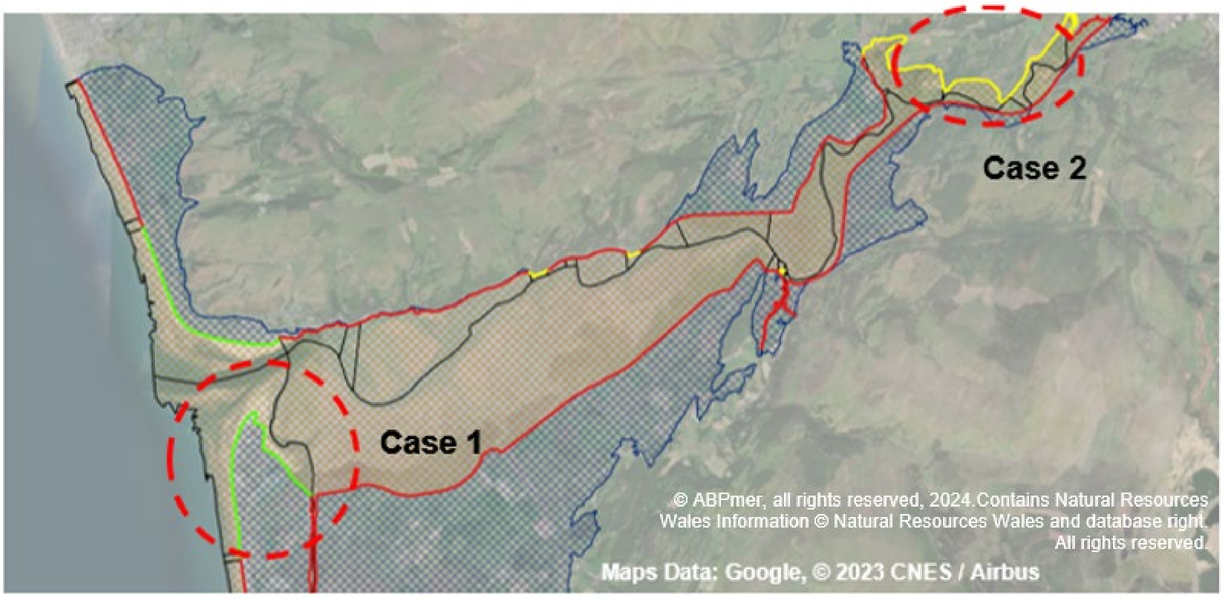
Where a continuous Natural Ridge exists along the coast/estuary acting as the present-day primary measure to prevent flooding of the hinterland, the Assessment Unit should follow the Natural Ridge and the Assessment Unit Type should be noted as Natural (See **Example of Case 1**). In this instance:

- On open coast the present-day HAT +1 m contour can be used to help align Assessment Unit, and
- In an estuary the present-day HAT contour can be used to help align Assessment Unit (HAT is used as opposed to HAT +1m as wave exposure it typically much lower in an estuary than on the open coast).

However, if the Natural Ridge is not continuous i.e. it does not provide any level of protection against the flooding of the hinterland, then the Assessment Unit should follow either the:

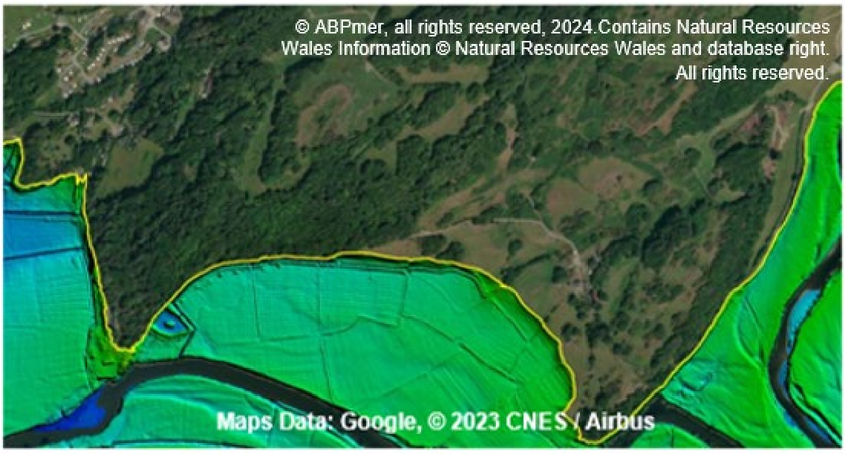
- Defence line in its lee, or
- High Ground in its lee (**See Example of Case 2**)

Examples



Example of Case 1

Example of Case 2



Rule D: Selection of type Cliff

Issue

Additional clarification on when to use Cliff Type.

Rule

On open coasts, where a natural cliff occurs, with:

- No Defences present in front of it, and
- No low-lying land (Accommodation Space),

Then a Cliff type is to be defined. In this instance:

- The HAT +1 m +SLR 2155 (RCP 8.5, 95%) contour can be used to help align Assessment Unit

If a similar frontage occurs in an estuary, it should be defined as High Ground.

Examples

Example 1

Example 2

Example 3

Rule E: Extension of Assessment Unit line beyond existing SMP2 Policy Unit line

Issue

At the upper end of estuaries as Assessment Units are extended to the HAT +1 m +SLR 2155 (RCP 8.5, 95%) contour, Assessment Unit lines will often need to be extended beyond the SMP2 Policy Unit.

Rule

In these instances, the Assessment Unit(s) should be continued upstream and should adopt the SMP2 Policy at the end of the SMP2 Policy Unit. If the type does not change, there is no requirement to split Assessment Unit at the end of the SMP2 Policy Unit. However, if the type does change at some point, a new Assessment Unit will need to be defined (again adopting the same SMP2 Policy).

Example

Assessment Unit Lines (solid lines), extend upstream of the SMP Policy limited (denoted by dashed lines.

Exception

An exception to this is noted on the Cleddau Estuary (Milford Haven), where the SMP2 Policy stops significantly short of the estuary limits. In this case new Assessment Units are defined from the end of the SMP2 Policy Unit. Frontages are assigned as a Defence, Natural or High Ground following the standard rules, but the SMP2 Policy Unit is defined as 'no policy'. For these frontages a HTL policy is assigned to Defences across all epochs and a NAI policy is assigned to Natural and High Ground frontages across all epochs.

Rule F: Small breaks /gaps in an Assessment Unit

Issue

In many cases, small breaks / gaps may occur along an anthropogenic structure or Natural Ridge.

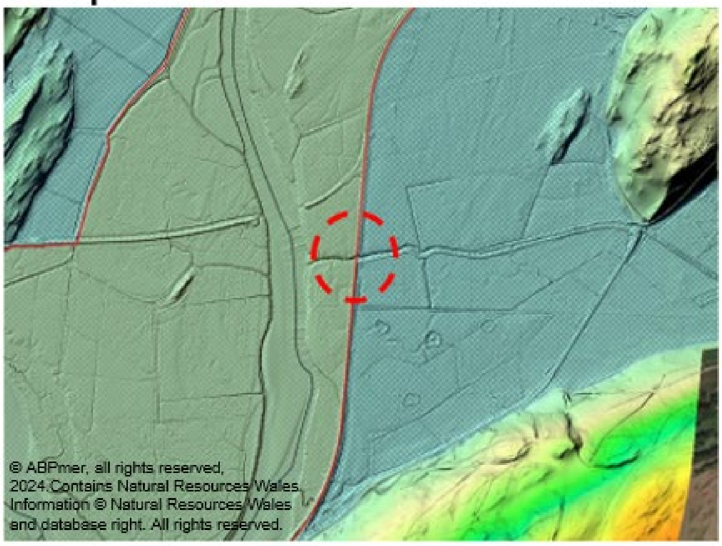
Rule

In these instances, the Assessment Unit line should be aligned along the anthropogenic structure or Natural Ridge and the gap should be ignored.

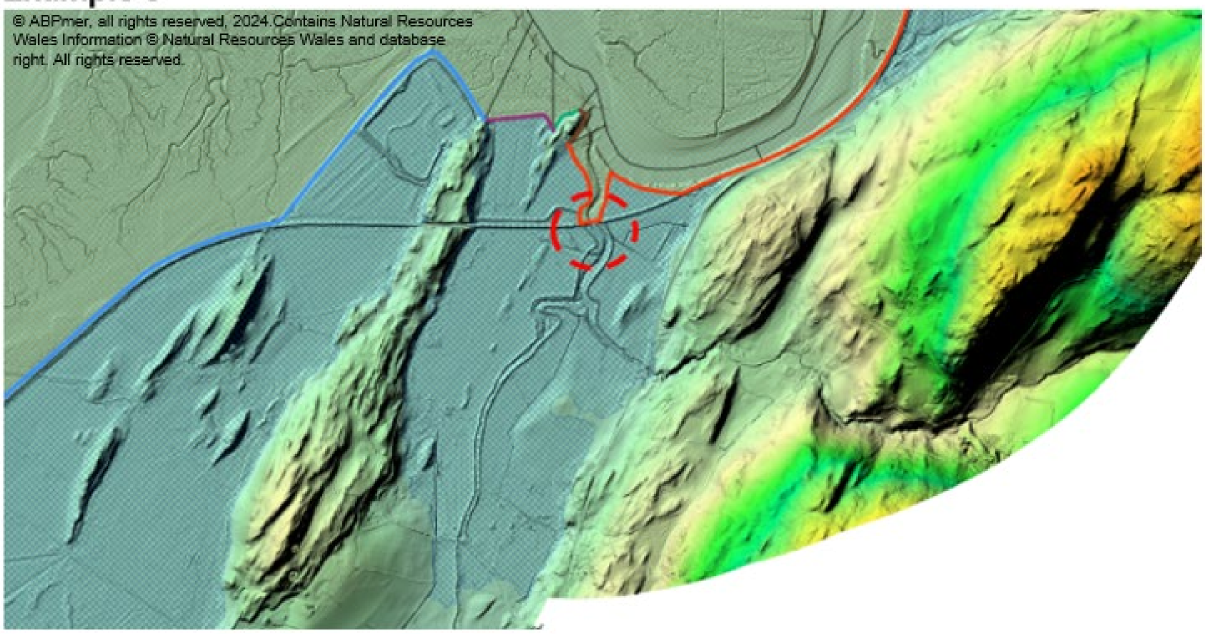
Examples

Example 1

Example 2



Example 3



Rule G: Low cliffs (and beaches backed by higher land)

Issue

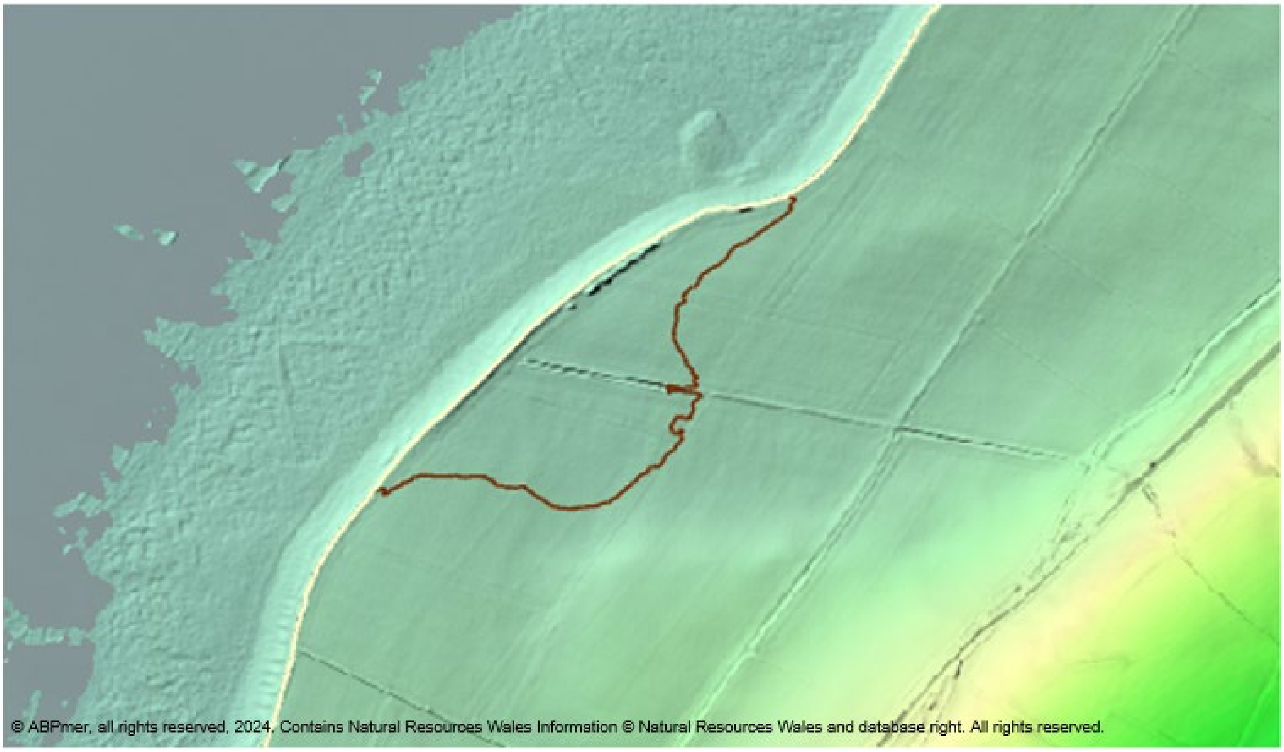
There are areas of natural coastline on an open coast where coastal squeeze and natural squeeze will NOT occur as the coast will roll back (rather than breach through a gap), but there are land levels behind the present shoreline that are lower than HAT +1 m +SLR 2155.

Rule

To assign the Assessment Unit to a Cliff as effectively it will behave in the same way as rolling back as a result of erosion, rather than breaching to allow habitats into low lying areas in their lee. In these instances, the 'test' as to whether to class as Cliff or Natural Ridge is whether a hole punched though the ridge is likely to result in habitat occurring in its lee (thus classed as Natural Ridge) or whether coastline is more likely to rollback (thus classed as Cliff).

Examples

Example 1 Land behind frontage is less than HAT +1 m +SLR (2155) but breach would not occur as coastline would rollback instead.



E.4 Data layer deliverable

The deliverables for the Assessment Unit data layer consist of a single GIS feature-class consisting of single polylines related to each Assessment Unit entity. A series of attributes are associated with each Assessment Unit, including:

- Assessment Unit 'Type'
- SMP2 Policy Unit Number
- SMP2 Policies for each epoch
- Identification (ID) of associated Foreshore Area
- ID of associated Foreshore Area and Accommodation Space
- ID of associated Tidal Level entity

E.5 Data limitations

The development of the Assessment Unit data layer could not be automated and extensive manual work was required to develop the data layer. Whilst significant effort has been used to define the Assessment Units from the data sets available, it is appreciated that there may be some errors still with the 'Type' assigned to each Assessment Unit. Furthermore, the exact location of the Assessment Unit is also partially subjective, and in some locations, there were alternative ways to schematise a frontage, whilst still keeping to the defined rules that have been set out. Nevertheless, the developed data set is considered to provide a very good representation of the coastline and the data layer is considered appropriate for use for the national level assessment of coastal squeeze and natural squeeze.

F Foreshore Area data layer

F.1 Overview of data layer

The Foreshore Area data layer is utilised in both STEP 1 and STEP 2 of the coastal squeeze and natural squeeze assessment. It is used to define the area over which the hypsometric analysis is undertaken and the area over which the present-day percentage habitat coverage is calculated.

A unique Foreshore Area is defined for each Assessment Unit, other than cliff frontages which are scoped out of the assessment. The Foreshore Area encompasses the area seaward of the Assessment Unit extending from present-day (2025) MLWS, to HAT +1 m in 2155 (using UKCP18, RCP 8.5 95th percentile SLR allowance). Within estuaries, the seaward limit of the Foreshore Area is taken to be the centre line of the main channel running through the estuary, or a sub-branch on an estuary.

F.2 Primary data sources

The Primary data sources used to develop the data layer are the:

- Project DTM data layer
- Tidal Level data layer
- Assessment Unit data layer

F.3 Production of the data layer

Foreshore Areas are defined as polygons extending offshore from the Assessment Units to the MLWS line (developed from Project DTM and Tide Level data layers), or just beyond. The polygons are formed by the MLWS line (or a line just beyond this), the Assessment Unit line and lines that are approximately shore normal / perpendicular to the coastline at either end of the Assessment Unit.

Within estuaries, the Foreshore Areas extend down to the central line of the main estuary channel, and the main channel within any sub-branches, such that the intertidal areas either side of these central channels can be associated with the different Assessment Units that lie on either bank of the channel/estuary.

Assessment Units defined as cliff do not have a Foreshore Area associated with them as they are not included in the assessment of coastal squeeze and natural squeeze.

Figure F1 shows an example of the Foreshore Areas located along the South Wales coastline.

Figure F1 Schematisation of Foreshore Areas for a location along South Wales coastline, with separate Foreshore Areas identified for each Assessment Unit.

F.4 Data layer deliverable

The deliverable for the Foreshore Area data layer consists of a single GIS feature-class consisting of multiple polygons depicting the extents of Foreshore Areas.

F.5 Data limitations

Foreshore Areas are continuous across the full intertidal zone other the Assessment Units with Type Cliff. The boundaries between adjacent Foreshore Areas are based on judgements which are appropriate for a national scale assessment. However, at a project level the definition of the boundaries may need to be considered further as this could affect any results derived from the analysis.

G Accommodation Space data layer

G.1 Overview of data layer

The Accommodation Space data layer is utilised in STEP 1 of the coastal squeeze and natural squeeze assessment. It is used to define the area over which the hypsometric analysis is undertaken landward of any anthropogenic structure or natural frontage.

An Accommodation Space is defined as an area behind an anthropogenic structure or natural frontage, across which the tide could propagate if the anthropogenic structure or natural frontage were removed. Any secondary structures or man-made infrastructure within the hinterland are ignored in the assessment. Therefore, a single Accommodation Space is assigned where the water at a level of HAT +1 m in 2155 could flow across it, unimpeded by natural High Ground.

The Accommodation Space therefore encompasses the area landward of an Assessment Unit into which habitat could roll back and extends from present-day (2025) MLWS, to HAT +1 m in 2155 (using UKCP18, RCP 8.5 95th percentile SLR allowance). However, the extent of the Accommodation Space that a habitat can potentially transgress into, is subject to the hypsometry within the Accommodation Space and the level of SLR that occurs.

An individual Accommodation Space may be associated with one or more Assessment Units, such that habitat is able to roll back into the Accommodation Space if the anthropogenic structure associated with one or more of the Assessment Units is removed, or there are one or more Assessment Units that comprises a Natural Ridge.

Where multiple Assessment Units are linked to an Accommodation Space, the Accommodation Space is pro-rated based on the length of the varying Assessment Units that are linked to it.

G.2 Primary data sources

The Primary data sources used to develop the data layer are the:

- Project DTM data layer;
- Tidal Level data layer; and
- Assessment Unit data layer.

G.3 Production of the data layer

Accommodation Space extents are defined as polygons extending inshore from the Assessment Units to the HAT +1 m at the end of Epoch 3. The polygons are formed by selecting the HAT +1 m +SLR UKCP18, RCP 8.5 95th percentile contour and Assessment Unit line. Where High Ground attaches to the Assessment Unit line, this demarks the end/start of each Accommodation Space.

If multiple, non-connected, Accommodation Spaces exist along an Assessment Unit, then they are grouped into a single multipart polygon. However, it is not possible to group multiple Accommodation Spaces, when one of the Accommodation Spaces is also attached to a separate Assessment Unit. In this instance the Assessment Unit has been further split to prevent this. This rule is incorporated since not all of the multipart Accommodation Spaces would be accessible from the adjacent Assessment Unit.

Figure G1 shows an example of the Accommodation Space located along the South Wales coastline.

Figure G1 Schematisation of Accommodation Space Extents (in grey) along the South Wales Coastline.

G.4 Data layer deliverable

The deliverable for the Accommodation Space data layer consists of a single GIS feature-class consisting of multiple polygons depicting the extents of Accommodation Space.

G.5 Data limitations

No specific limitations are identified in relation to the data layer, however, it is identified that Accommodation Spaces can be associated with numerous Assessment Units. In these cases, it is assumed that the available Potential Habitat Extent within the Accommodation Space is pro-rated based on the available length of the individual Assessment Units associated with it. This introduces a large assumption into the assessment, which may not physically align with the hinterland and the space that would be available to any specific part of the frontage. Similarly, it is noted that developed infrastructure in the Accommodation Space is also excluded from the assessment, thus the Accommodation Space can extend over highly built up areas which are not likely to be available for habitat. Hence, when utilising the results, the potential habitat gain within the Accommodation Space needs to be considered with caution.

H Habitat Group data layer

H.1 Overview of data layer

The Habitat Group data layers are utilised in STEP 2 to derive Potential Habitat Extents within the Foreshore Area and Accommodation Spaces for the different time horizons.

The habitat features included within each Habitat Group, their relationship to MPAs and the base data utilised for each Habitat Group are set out in Section 2 of the main report.

The seven key Habitat Groups defined and considered within the assessment are identified below:

- Saltmarsh
- Coastal lagoons
- Vegetated Shingle
- Dunes
- Intertidal Reef
- Mudflat and sandflat
- Littoral Coarse Sediments

However, to undertake the assessment a further, Not Defined, Habitat Group is also utilised. This Habitat Group is used to represent areas of the intertidal zone that have not been classified as being part of any of the other Habitat Groups. This predominantly occurs where there are gaps between the other Habitat Groups, and, in many instances, it is expected that these unclassified areas are likely to fall within the mudflats and sandflat Habitat Group.

H.2 Primary data sources

The primary data sources used to develop the data layer are:

- Reg9a Saltmarsh (Draft) - provided by NRW 12/10/23
- Reg9a Coastal lagoon (Draft) - provided by NRW 12/10/23
- Reg9a Vegetated Shingle (Draft) - provided by NRW 12/10/23
- Reg9a Dune (Draft) - provided by NRW 12/10/23
- Article 17 Intertidal Reef from https://datamap.gov.wales/ (Downloaded 27/03/23)
- Article 17 Mudflat and Sandflat from https://datamap.gov.wales/ (Downloaded 27/03/23)
- JNCC EUNIS Level3 Habitat Map, including A2.1 Littoral Coarse Sediment (Downloaded 23/10/23)

The Reg9a (Draft) data layers noted above, and provided by NRW, are updated versions of earlier Article 17 Maps.

H.3 Production of the data layer

The source data for each Habitat Group incorporate numerous entities with their own specific attributes. These attributes are either removed or amalgamated when the individual entities are aggregated in to a single entity which represent the full extent of the of the Habitat Group.

The Reg 9a (Draft) habitat data sets are intrinsically well integrated, e.g. the habitats within them have been developed so that they do not overlap one another (or overlaps are minimal). However, there are noticeable overlaps between the Reg9a data and the Article 17 and EUNIS Level 3 A2.1 Littoral Coarse Sediment data. Furthermore, there are also some habitats that exist in both the Article 17 Intertidal Reef and Mudflat and Sandflat maps.

Therefore, a prioritisation filtering routine was used to ensure no overlaps occurred between the individual Habitat Groups. The prioritisation order is noted below with prioritisation given to those identified first:

- New Reg9 Saltmarsh layer
- New Reg9 Coastal lagoon layer
- New Reg9 Shingle layer
- New Reg9 Dune layer
- Art 17 Intertidal Reef Layer
- Littoral Coarse Sediment (EUNIS Level 3 Data A2.1 Littoral Coarse Sediments)
- Art 17 Mudflat and Sandflat layers

Where overlaps were found between the merged Habitat Groups, those with a Habitat Group with lower priority were clipped out to ensure no overlap.

H.4 Data layer deliverable

The deliverables for the Habitat Group data layer consists of a single classification consisting of multiple polygons depicting the extents of each Habitat Group.

H.5 Data limitations

Key limitations associated with the data layer are noted below:

- The primary limitation related to the data layer relates to the accuracy of the source data used to define the individual Habitat Group. The saltmarsh, coastal lagoon, dune and vegetated shingle data layer, which have been updated more recently by NRW, are typically of reasonable quality, with the other data sets more poorly resolved.
- The coverage of the Habitat Group data layer across the intertidal area is not complete and some of the intertidal area within the Foreshore Area cannot be directly associated to any of the seven identified Habitat Groups. To ensure these areas are still captured within the assessment, and not missed in the analysis, loss and gain of intertidal area is also calculated for a further, Not Defined Habitat Group within the CSAT.

I MPA designated site data layer

I.1 Overview of data layer

The MPA data layer is utilised in STEP 1 and STEP 3 when coastal squeeze and natural squeeze are assessed for MPAs. The MPA designated sites data layer ensures that only those areas that lie within the MPA designated boundary are subsequently used in the assessment of coastal squeeze. The data layer includes the boundaries of each individual MPA for which coastal squeeze and natural squeeze is examined.

Within the analysis coastal squeeze and natural squeeze is reported against individual MPAs for those Habitat Groups that are associated with each MPA. In addition, the results are amalgamated to provide information on coastal squeeze and natural squeeze against the different MPA designations:

- SACs;
- SSSIs;
- SPAs; and
- Ramsar Sites.

As there is a slight overlap between two SSSIs and two SACs, additional entities are included within the data layer to cover the areas that overlap, so that this overlap can be accounted for then results are amalgamated against MPA designations.

The individual MPAs for which coastal squeeze and natural squeeze are examined are identified in Section 2, of the main report. This includes all MPAs listed in Welsh Government (2018) - Marine Protected Area Network Management Framework for Wales, 2018–2023, except those identified in Table I1 .

Table I1. MPA designated sites scoped out of the assessment

MPA Site	Designation
Limestone Coast of South West Wales / Arfordir Calchfaen De Orllewin Cymru	SAC
Craig Ddu - Wharley Point Cliffs	SSSI
Creigiau Llansteffan (Llanstephan Cliffs)	SSSI
Morfa Dinlle	SSSI
Rhossili Down	SSSI
Skokholm	SSSI
Irish Sea Front	SPA
Skomer / Sgomer	MCZ
North Anglesey Marine / Gogledd Môn Forol	SAC
West Wales Marine / Gorllewin Cymru Forol	SAC
Bristol Channel Approaches / Dynesfeydd Môr Hafren	SAC
Croker Carbonate Slabs	SAC

I.2 Primary data sources

The primary data sources used for to develop the data layer are:

- SAC published date 28/11/2022 from https://datamap.gov.wales/ (Downloaded 20/04/23);
- SSSI published date 24/05/2023 from https://datamap.gov.wales/ (Downloaded 25/10/23);
- SPA published date 28/11/2022 from https://datamap.gov.wales/ (Downloaded 20/04/23); and
- Ramsar published date 28/11/2022 from https://datamap.gov.wales/ (Downloaded 20/04/23).

I.3 Production of the data layer

Individual MPA boundaries were taken directly from the DataMapWales for each MPA category considered within the assessment (Section 2 of main report). Unnecessary attributes and MPAs for which a coastal squeeze assessment was not undertaken (as outlined in Table I1 were removed.

Additional attributes were then assigned to each MPA, to identify the Habitat Groups that are associated with each MPA (Section 2 of main report).

I.4 Data layer deliverable

The deliverable for the MPA Designated Site data layer consists of a single classification consisting of multiple polygons depicting the:

- Boundaries of each individual MPA considered in the assessment, and
- The Habitat Groups that each MPA are designated for.

I.5 Data limitations

No specific limitations are identified in respect to the generation of the MPA Designated Site data layer, although several key points are noted:

- In a small number of instances, individual MPA boundaries have an inshore boundary that lies along an approximate low water contour. In these instances, there is only limited sporadic overlap between the MPA boundaries and the present study extent that extends down to present-day MLWS, and
- MPA boundaries are fixed, however, with SLR, habitats may be able to migrate inshore. This has an implication for the assessment, since a loss in the Foreshore Area due to a defence, can only be assigned to coastal squeeze, if there is room in the Accommodation Space to enable the habitat to roll back (if the defence was removed or breached). Therefore, potential habitat gains in the Accommodation Space are calculated even if the Accommodation Spaces lies outside the MPA boundary; and
- In some instances, the MPA boundary may extend into the hinterland and Accommodation Space, but the habitats lying in this area would typically be classified as terrestrial. Within the assessment, habitat gains in the Accommodation Space may be calculated. However, this gain is likely to be associated with the loss of the terrestrial habitat that is currently present. Such losses are not considered or assessed as part of this study.

Data archive appendix

Data outputs associated with this project are archived in NRWs corporate geospatial drive on server–based storage at Natural Resources Wales.

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] A series of GIS layers

[C] Associated data outputs on Microsoft Excel

Metadata for this project is publicly accessible through Natural Resources Wales' Data Discovery Service https://metadata.naturalresources.wales/geonetwork/srv (English version) and https://metadata.cyfoethnaturiol.cymru/geonetwork/cym/ (Welsh Version). The metadata is held as record no **NRW_DS161284**

Further copies of this report are available from library@cyfoethnaturiolcymru.gov.uk