



OPW Oifig na
nOibreacha Poiblí
Office of Public Works

Coastal Erosion Hazard Mapping

Technical Methodology Note

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Glossary

Cliffmetrics	A programme, developed by SAGA-GIS, which automatically delineates the estimated cliff top and other cliff metrics from Digital Terrain Models (DTMs).
Climate Change Timeline	Projections of future sea-level rise in Ireland, broadly reflecting Illustrative emission scenarios – or Shared Socio-economic Pathways - as described within the “ <i>IPCC Sixth Assessment Report</i> ”.
Coastal Aerial LiDAR and Imagery Survey (CALS)	A national survey commissioned by the OPW to capture high-resolution LiDAR and aerial imagery at the coast, with survey undertaken between 2021 and 2025.
Coastal Erosion Hazard Mapping (CEHM)	Spatial data mapping the location and potential extent of future coastal erosion.
Coastal Feature Line	The position of the coastline, based on CALS data, which acts as a proxy to both measure historic coastal change against and to project future coastal change from.
Confidence Rating	A rating to measure the relative level of confidence in the assessment undertaken, reflecting the level of uncertainty associated with the data and methods used.
Digital Shoreline Analysis System (DSAS)	Digital Shoreline Analysis System (DSAS) is an automated standalone software package, developed by the US Geological Survey (USGS), used to assist in estimating the historic rate of coastal change over a period of time.
Frontage	A length of coast which is expected to behave in a similar way based primarily on physical characteristics (e.g. hardness, topography, orientation, and the presence of manmade coastal defences).
Geographical Information System (GIS)	Computer-based system that creates, manages, analyses and maps various types of spatial data.
Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report	A comprehensive evaluation of the latest scientific knowledge on climate change, published by the Intergovernmental Panel on Climate Change between 2021 and 2023.
Isostatic Rebound	The gradual rise or rebound of the Earth’s crust after the melting of glaciers, restoring the crust toward its original level.
Management Approach	A hypothetical scenario that considers how existing manmade coastal defences may be managed in the future, in relation to their maintenance and replacement.

Manmade Coastal Defence

An engineered structure, located at the backshore and parallel to the coast, built to protect the coastline against coastal erosion. This excludes an engineered structure which is perpendicular to the coastline (e.g. groynes) or offshore (e.g. breakwaters).

Sea Level Rise

The long-term increase in the average height of the ocean, primarily driven by global warming.

Time Period

A specific duration of time in years, from a defined start point to a defined end point, over which potential future coastal erosion is measured.

1 Purpose and Scope

1.1 Purpose

Increases in sea levels and storm surge arising from climate change will result in increased coastal erosion over the coming years and decades. The impacts of coastal change are already being felt today and will continue to affect many sectors of our economy, including households, transport, agriculture, our environment, tourism and our cultural assets.

Having regards to these issues, the Report of the Inter Departmental Group on National Coastal Change Management Strategy (2023) (the “Report”) sets out a number of recommendations to provide the basis for a long-term strategy for integrated coastal change management. It is within this Report that the need to develop national-scale coastal erosion hazard mapping has been established. The OPW are responsible for delivering this recommendation.

The purpose of national-scale Coastal Erosion Hazard Mapping (CEHM) is to enable the identification of areas at highest risk from coastal erosion both now and in the future. This mapping needs to include an assessment of the potential impact of a range of sea level rise scenarios on coastal erosion rates. To monitor ongoing coastal change and the associated risk from coastal erosion, this national-scale assessment will need to be repeated, and where necessary mapping will need to be reviewed, at regular intervals.

The mapping produced will help inform decisions on the management of coastal change risks, including the need for interventions, spatial planning and development management in the coastal zone, and the long-term planning for the management of potential future coastal change.

This Technical Methodology Note (TMN) sets out the technical methodology to be adopted when developing national-scale coastal erosion hazard mapping in Ireland, ensuring this is done in a nationally consistent manner. The methodology set out within this TMN primarily uses national datasets which are available and readily derivable, but enables these to be supplemented by additional local or site-specific data where this data exists.

1.2 Scope

This TMN relates to the assessment of coastal erosion around the coastline of Ireland, including the impact of sea level rise on coastal erosion rates, and subsequent coastal erosion hazard mapping. It does not cover how the mapping should be used to assess risk associated with coastal erosion and does not cover how the mapping should be used to manage coastal change risks in Ireland.

The TMN may be updated periodically in the future to reflect changes in the available data and to remain up to date with the latest available methodologies

1.3 Structure

The TMN is structured as follows:

- **Section 1** sets out the **Purpose and Scope** of this TMN
- **Section 2** provides an overview of [Coastal Erosion Hazard Mapping](#) and the conceptual approach to developing it at a national-scale
- **Section 3** provides details of the [Data and Software Requirements](#) to undertake the assessment and produce Coastal Erosion Hazard Mapping
- **Section 4** details the process for defining the [Feature Line and Frontages](#)
- **Section 5** details how to undertake the [Historic Coastal Change Assessment](#) component of the methodology
- **Section 6** details how to undertake the [Future Coastal Change Assessment](#) component of the methodology
- **Section 7** details how to assess [Manmade Coastal Defences](#) in the context of future coastal erosion
- **Section 8** details how to combine the various components of the assessment and generate a [Combined Recession and Defence Timeline](#)
- **Section 9** details the required [Mapping Outputs](#) and how to develop these

The **Appendices** include:

- [Appendix 1](#) provides decadal sea-level rise and isostatic rebound values for use in Coastal Erosion Hazard Mapping.
- [Appendix 2](#) provides photos of various examples of typical defence condition grades.

2 Coastal Erosion Hazard Mapping

2.1 What is Coastal Erosion Hazard Mapping?

Coastal erosion hazard maps are maps showing areas where coastal erosion may occur in the future. The maps show both the location where coastal erosion may occur and the extent to which it may occur over various **time periods**.

Different maps are available to show the coastal erosion that may occur under different **management approaches** and under different **climate change timelines**.

2.2 What is Coastal Erosion Hazard Mapping used for?

CEHM is used to help assess risk associated with coastal erosion and to identify areas most vulnerable to coastal erosion. In turn, it can be used to help inform the management of those coastal change risks and to guide decisions on development in coastal areas. Assessing risk associated with the identified coastal erosion will also help inform the need for interventions to reduce or manage that risk, such as the construction of coastal defences or the relocation of vulnerable structures.

2.3 What does Coastal Erosion Hazard Mapping look like?

CEHM is depicted by showing coastal erosion hazard zones as polygons or areas of land that are potentially vulnerable to coastal erosion. An example of CEHM is shown in Figure 2-1.

Coastal erosion hazard zones are shown for three different **time periods**, specifically 2050, 2080, and 2130:

- The 2050 coastal erosion hazard zone shows the area of land that may be vulnerable to coastal erosion at some time before 2050;
- The 2080 coastal erosion hazard zone, shows the area of land that may be vulnerable to coastal erosion at some time before 2080;
- The 2130 coastal erosion hazard zone, shows the area of land that may be vulnerable to coastal erosion at some time before 2130.

When viewed in combination, with the 2050 mapping above the 2080 mapping and the 2080 mapping above the 2130 mapping, it is possible to visually identify the area of land that may be vulnerable to coastal erosion up to 2050, between 2050 and 2080, and between 2080 and 2130.

It is important to note that **any** land within the coastal erosion hazard zone **may** be vulnerable (and lost) to coastal erosion in that time period, but the mapping should not be interpreted to mean **all** land within the coastal erosion hazard zone **will** be lost to coastal erosion in that time period.



Figure 2-1 Example of Coastal Erosion Hazard Mapping in Ireland

2.4 What are Management Approaches, Time Periods, Climate Change Timelines and Confidence Ratings?

2.4.1 MANAGEMENT APPROACHES

CEHM shall be developed for three different **Management Approaches**, only two of which (Approaches 1 and 2) require specific assessment. These Management Approaches are introduced to reflect the uncertainty regarding the future investment in the maintenance and replacement of existing manmade coastal defences, particularly given the multitude of stakeholders with responsibility for maintenance of these manmade coastal defences around the coastline of Ireland.

The two Management Approaches assessed when developing CEHM are defined as follows:

Management Approach 1: The **“Without Maintenance”** Management Approach – In this approach it is assumed that future maintenance of existing manmade coastal defences is limited to works required for health and safety reasons only. No routine maintenance work is undertaken and so the condition of the defence will deteriorate faster relative to Management Approach 2.

Management Approach 2: The **“With Maintenance”** Management Approach – In this approach it is assumed that future maintenance of existing manmade coastal defences is undertaken. Maintenance work is expected to include inspection, monitoring and any necessary repairs. This management approach does not account for any future replacement of the existing manmade coastal defence and so the defence will still deteriorate and fail over time.

At some stage in the future, depending on a variety of factors (Section 7), **all** existing manmade coastal defences will fail under both Management Approach 1 and 2. This is reflective of the fact that all manmade coastal defences have a finite life and the effectiveness of the defences cannot be maintained indefinitely without renewal or replacement.

It is of course very likely in some cases that existing manmade coastal defences will be replaced as and when required (i.e. at or before the end of their residual life), to provide continued protection from coastal erosion to the assets they were originally constructed to protect. In this Management Approach (Approach 3), the **“With Replacement”** approach, the existing manmade coastal defence remains on the existing alignment indefinitely, and there is no coastal erosion hazard zone identified for that frontage. No specific assessment is required for Approach 3, although the CEHM will differ from Approaches 1 and 2 where manmade coastal defences are present.

Where no manmade coastal defence exists, the CEHM developed will be the same for Approaches 1, 2 and 3.

2.4.2 TIME PERIODS

CEHM shall be developed for three different **Time Periods**. The coastal erosion hazard zone generated for each time period is relative to the date and position of the Feature Line, or specifically the survey date of the data used to define the Feature Line (see Section 4.1).

The three time periods shall be defined as follows:

- Short Term: up to 2050
- Medium Term: up to 2080
- Long Term: up to 2130

As noted previously, the time periods shall be viewed in combination, with the 2050 mapping layered above the 2080 mapping and the 2080 mapping layered above the 2130 mapping. This allows the user to visually identify the area of land that may be vulnerable to coastal erosion up to 2050, between 2050 and 2080, and between 2080 and 2130.

All three **Time Periods** shall be presented on the same mapping output, with different colours and / or colour ramps used to differentiate between them (Section 9).

2.4.3 CLIMATE CHANGE TIMELINES

CEHM shall be developed for four different **Climate Change Timelines**, reflecting the uncertainty in the future impacts of climate change. Each climate change timeline will be assessed in relation to each of the three **Time Periods**, and for each of the **Management Approaches** outlined in Sections 2.4.1 and 2.4.2.

The four climate change timelines are the **No climate change allowance (Present Day)** timeline, the **Slower Onset** timeline, the **Medium Onset** timeline, and the **Faster Onset** timeline. These are supported by a national dataset showing decadal values for both sea level rise and isostatic rebound (Appendix 1).

2.4.4 CONFIDENCE RATINGS

CEHM, and more specifically the underlying assessment, shall use **confidence ratings** to reflect the quality of the source data used and the reliability of that information in the context of the assessment methodology. This is a relative measure of confidence, rather than the measurement of a specific uncertainty range.

Confidence ratings are applied to various components of the assessment undertaken – the Historic Coastal Change Assessment, the Condition Grade assigned to a manmade coastal defence and the Performance Standard assigned to a manmade coastal defence.

This approach enables the outputs to be read with full transparency of the level of confidence attached to them, and it also provides the information to enable future iterations of CEHM to target areas where the previous assessment is of lower confidence.

2.5 Overview of Assessment Methodology

The assessment methodology adopted revolves around predicting the extent of potential 'future' recession (landward movement) of the coast. For the purpose of the assessment, this recession is measured by evaluating the historic and future movement of a coastal feature. This coastal feature varies based primarily on the coastal topography, or whether it is a cliffed or non-cliffed coast. The existing position of the coastal feature shall be mapped for the entire coastline, and this forms the **Coastal Feature Line**.

Factoring in also the potential presence of manmade coastal defences, the assessment methodology involves four key components:

- Defining the Feature Line and splitting it into Frontages (Section 4)
- Assessing historic coastal change (Section 5)
- Estimating future coastal change (Section 6)
- Identifying and evaluating manmade coastal defences (Section 7)

The outputs of the above assessment are then combined to generate a future coastal change timeline (Section 8), which in turn enables the development of the coastal erosion hazard mapping (Section 9).

Figure 2-2 below summarises the overall approach to assessing coastal erosion and developing coastal erosion hazard mapping. Section numbers pertaining to the topic within each box in the figure are provided for convenience.

Coastal Erosion Hazard Mapping (CEHM)

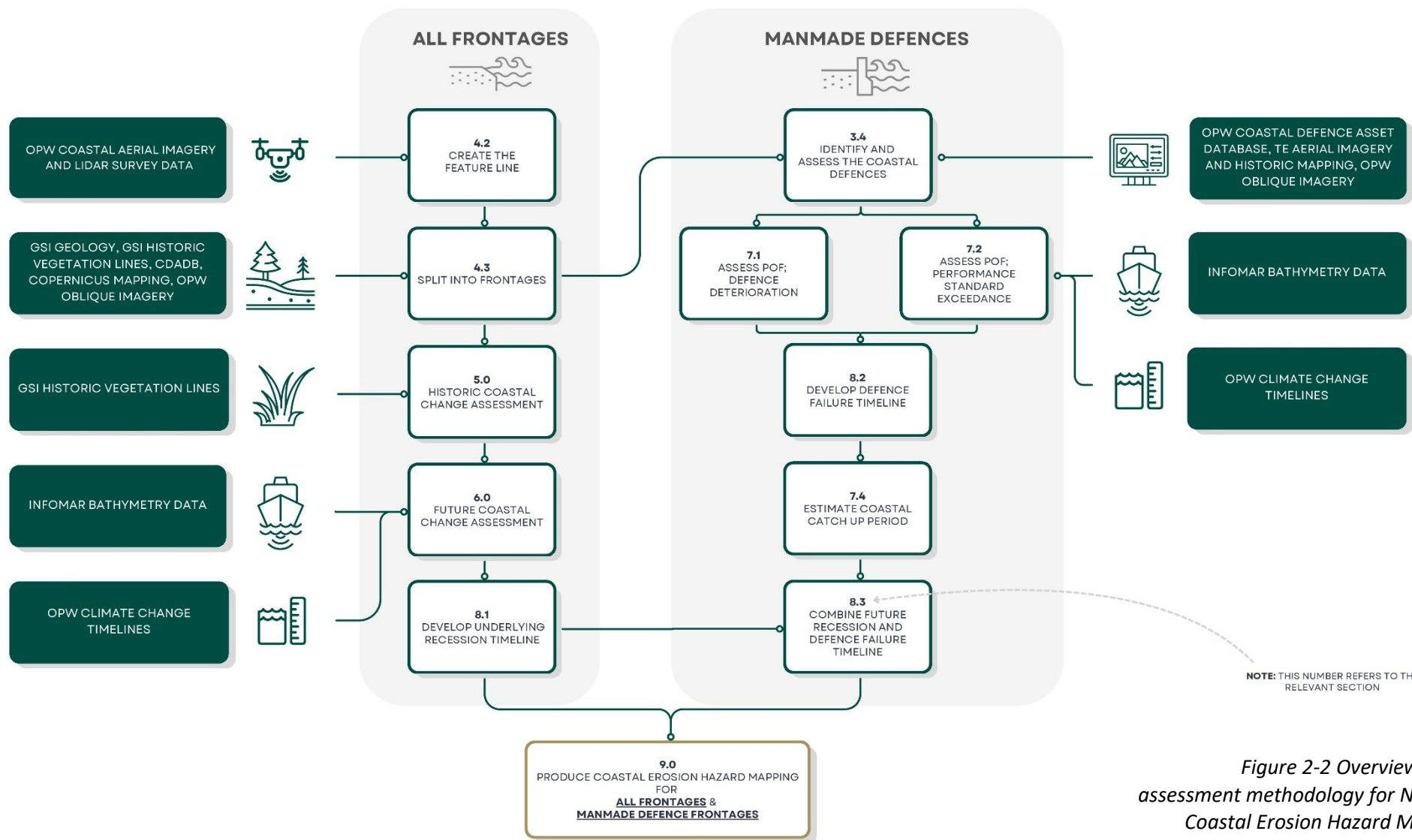


Figure 2-2 Overview of the assessment methodology for National Coastal Erosion Hazard Mapping

2.5.1 COASTAL FEATURE LINE AND FRONTAGES

As noted above, the assessment involves first defining the **Coastal Feature Line**. The coastal feature of interest is selected based primarily on the coastal topography but also the presence of manmade coastal defences (see also Figure 2-3):

- For non-cliffed coasts the **Feature Line** shall follow:
 - The Back of Beach (BoB), which is defined as the seaward edge of terrestrial vegetation (i.e. not including intertidal vegetation like saltmarsh) on coasts with no manmade coastal defences present.
 - The Back of Defence (BoD), which is defined as the landward edge of the defence crest on coasts with manmade coastal defences present.
- For cliffed coasts, the Top of Cliff (ToC) is used as the Coastal Feature Line.

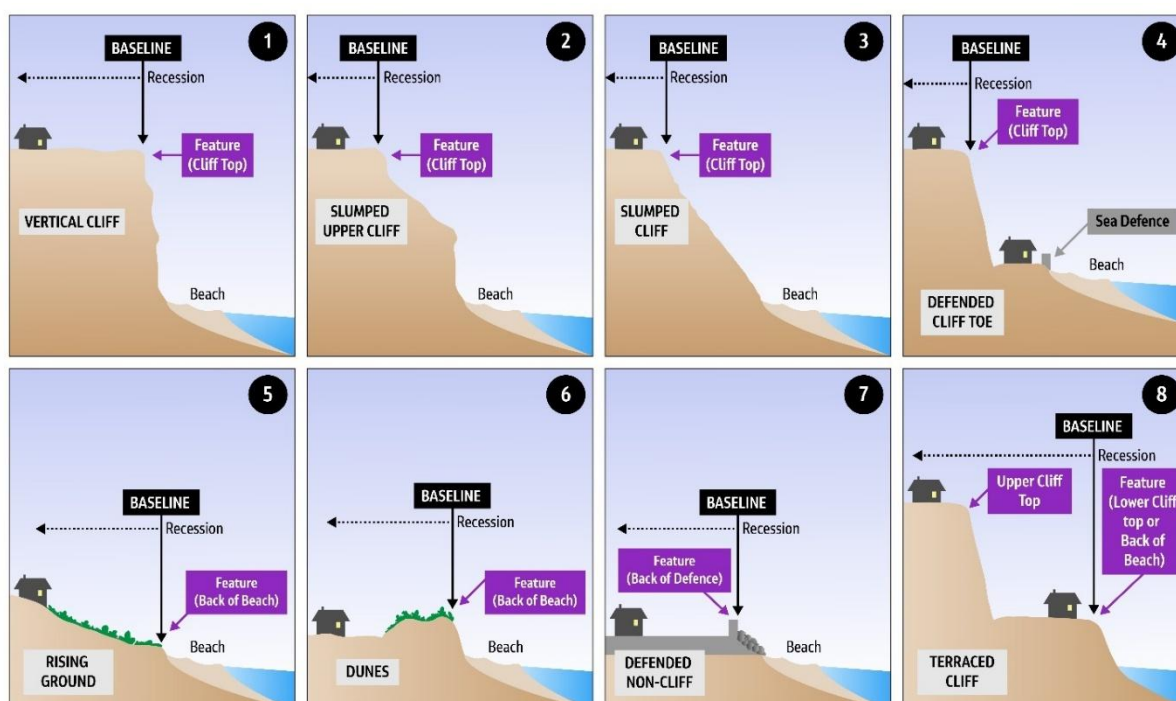


Figure 2-3 Coastal feature used to define the Coastal Feature Line for different coast types

The coastal feature line is split into shorter lengths, or ‘frontages’, based primarily on the coastal topography and geology and the presence or absence of manmade coastal defences. In certain cases, variability in historic coastal erosion observed and orientation of the coast may also impact the split or creation of frontages.

2.5.2 HISTORIC COASTAL CHANGE ASSESSMENT

The assessment of coastal change shall then be undertaken on a frontage by frontage basis, initially by evaluating historic movement of the relevant coastal feature of interest (i.e. ToC or BoB).

Long-term historic coastal change shall be evaluated over a series of transects within each frontage to develop an understanding of the nature, extent, and cause of historic coastal change at each frontage. This exercise shall be undertaken through means of visual inspection

of available imagery and mapping data, professional judgement, and measurement of historic rates of coastal change. Where manmade coastal defences are present, the rate of coastal change prior to their introduction shall be established or estimated.

On completion, the assessment should determine a single **historic coastal change rate**, in metres per year, for each frontage based on the 'representative rate' process.

2.5.3 FUTURE COASTAL CHANGE ASSESSMENT

Climate change is highly likely to impact coastal erosion through sea level rise increasing water depths in the nearshore area, which means that larger waves will be able to propagate further up the shore, exposing the coastline to increased wave energy. In addition, the increased submergence of natural features in the nearshore area will mean the level of protection offered by these will reduce.

The conceptual model developed by Per Bruun in 1962 (commonly referred to as the "Bruun Rule") is the most renowned method for assessing these impacts on coastal erosion and the fundamental concept remains valid. For the purpose of CEHM, the assessment of future coastal change shall be based on the Bruun Rule, with minor modification to measure the nearshore coastal slope rather than the subtidal coastal slope out to depth of closure (where limited shoreline change is typically evident).

This assessment shall be undertaken for all climate change timelines (Section 2.4.3)

It should be noted that this methodology essentially adds two components: the above **future coastal change rate** and the **historic coastal change rate** (Section 2.5.2) to form the cumulative future rate of coastal change. For this reason, future coastal erosion will be identified in some locations, even if no historic coastal erosion has occurred.

2.5.4 MANMADE COASTAL DEFENCES

Where manmade coastal defences are present, the vulnerability of that defence to potential failure in the future, and therefore no longer preventing coastal erosion from taking place, shall be considered. This shall be assessed based on the type, exposure, maintenance, condition and performance standard of the manmade coastal defence.

In locations where manmade coastal defences are present, no coastal erosion will typically be predicted in the coming years as the defence itself is preventing coastal erosion. However, in the future:

- The condition of the defence will deteriorate to the point of failure, with or without maintenance;
- The impacts of climate change on sea level rise (and in turn increased nearshore wave exposure) may make the defence vulnerable to failure if it is unable to withstand this increased wave exposure.

These factors are evaluated to build an understanding of when the manmade coastal defence may be at risk of failure. At this point under Management Approaches 1 and 2 (Section 2.4.1), that frontage would no longer be protected, and coastal erosion would recommence.

2.6 Considering Uncertainty

The dynamic nature of the coastal environment, the variability in the potential impacts of climate change, the inherent uncertainty in the estimation of long-term projections, and the limitations of the available data and methodologies cumulatively mean that there is a level of uncertainty associated with developing coastal erosion hazard mapping.

That aside, the benefits and uses of this mapping, and the contribution it makes towards the long-term sustainable management of coastal change risk in Ireland, far outweighs the residual uncertainty identified.

This level of uncertainty will vary from one frontage to the next, and is embedded in a number of different sources, many of which are difficult – if not impossible – to quantify. For that reason, it is not considered appropriate, or possible, to quantify the total uncertainty associated with the assessment.

Instead, uncertainty is dealt with through a variety of means:

- Uncertainty over the future maintenance of existing manmade coastal defences is dealt with through the various **Management Approaches** assessed;
- Uncertainty over the potential future impacts of climate change is dealt with through the various **climate change timelines** assessed;
- Uncertainty over the underlying data used and methodologies adopted is dealt with through the 'representative rate' process, the assignment of **confidence ratings**, research into potential improvement in available data and methodologies, and the planned review of coastal erosion hazard mapping at a national level at regular intervals (typically every six to twelve years).

3 Data and Software Requirements

3.1 General Data Requirements

A variety of datasets are required to enable the development of CEHM and the associated assessments. The availability and use of these datasets are discussed and described in the following sections and are summarised in Table 3-1 below.

Table 3-1 Available data to be used in the development of coastal erosion hazard mapping

Dataset	Useful for:		Automated or manual?	Section
LiDAR	Feature Line (FL) and Frontages	Defining FL position for cliffed frontage	Semi-automated	3.2
	Manmade Coastal Defences	Estimating water depth at Mean Sea Level (for Performance Standard)	Semi-automated	3.11
Vertical aerial imagery	Feature Line and Frontages	Defining FL position for non-cliffed frontages Verifying hardness classifications	Manual	3.3
	Historic Coastal Change Assessment	Verifying accuracy and suitability of historic vegetation lines	Manual	3.3
Coastal Defence Asset Database	Feature Line and Frontages	Defining FL position of frontages with manmade coastal defences	Semi-automated	3.4
	Manmade Coastal Defences	Initial categorisation of defence type and data attribution	Semi-automated	3.4
GSI vegetation lines	Feature Line and Frontages	Defining FL position for non-cliffed frontages Initial hardness classifications	Semi-automated	3.5
	Historic Coastal Change Assessment	Quantifying historic coastal change	Semi-automated	3.5
ICPSS vegetation lines	Feature Line and Frontages	Defining FL position for non-cliffed coasts (where gaps exist in GSI vegetation lines)	Semi-automated	3.6
	Historic Coastal Change Assessment	Quantifying historic coastal change	Semi-automated	3.5

Dataset	Useful for:		Automated or manual?	Section
Tailte Éireann (TE) Mapping	Feature Line and Frontages	Field boundaries useful for defining FL position for some cliffed frontages MHW line useful as starting geometry for position for all frontages where gaps exist in GSI and ICPSS vegetation lines	Semi-automated	3.7
GSI mapping: quaternary sediments, bedrock, cliff geology	Feature Line and Frontages	Later stages of frontage splitting after initial hardness and topography splits	Semi-automated	3.8
OPW oblique aerial imagery	Feature Line and Frontages	Verifying FL position, hardness and topography classifications, frontage splits.	Manual	3.9
	Manmade Coastal Defences	Verifying manmade coastal defence type and data attribution Assigning condition grade and performance standard to defences	Manual	3.9
Copernicus Coastal Zone Mapping	Feature Line and Frontages	Initial topography classifications	Semi-automated	3.10
INFOMAR	Future Coastal Change Assessment	Assigning a coastal slope to all frontages	Manual	3.11
ICWWS	Manmade Coastal Defences	Estimating Mean Sea Level and Extreme Water Level (for Performance Standard)	Semi-automated	3.12

3.2 LiDAR Data

In 2021, the OPW commissioned a Coastal Aerial LiDAR and Imagery Survey (CALs) project, to gather high resolution LiDAR and aerial imagery for the whole coast of Ireland. This survey was specified to capture LiDAR between the low water mark and the 12m contour or 300m inland, whichever is greater, +/- 2 hours of low tide. Data was captured between 2021 and 2025 inclusive. Digital terrain models and digital surface models are available nationally at 0.25m, 0.5m, 1m, 2m and 5m horizontal resolutions. Following sensitivity testing, the 1m horizontal resolution was considered to be most appropriate for estimating top of cliff using Cliffmetrics and therefore will form the basis of developing the coastal feature line along cliffed coasts.



Figure 3-1 Sample image showing OPW CALs LiDAR at 0.25m resolution

Some additional LiDAR data exists for some locations which can be used to assess historic coastal change of cliffed coasts (Section 5.7).

3.3 Vertical Aerial Imagery

High resolution Red-Green-Blue (RGB) ortho-rectified aerial imagery was also captured as part of the OPW CALS project outlined in Section 3.2 above, at the same date and time as the LiDAR for each part of the coast. Imagery for these projects was captured at 0.1m horizontal resolution. This imagery shall be used to define the coastal feature line for non-cliffed coasts and to assist in verifying whether the coast is hard or soft.



Figure 3-2 Sample image showing OPW CALS aerial imagery at 0.1m resolution

Multiple additional national aerial imagery datasets developed by TE are also available, particularly in the 2000 to 2018 time period, and are used to identify the historic position of the vegetation line (see Section 3.5). Whilst the GSI vegetation lines are used directly in the assessment, the underlying aerial imagery shall be used to verify the accuracy and suitability of the vegetation lines (or to develop new or edited vegetation lines where they are unavailable or inaccurate).

3.4 Coastal Defence Asset Database

The OPW have developed a new national Coastal Defence Asset Database for Ireland. The initial data population phase of this project involves digitising coastal defences that are identifiable in the 2003 oblique imagery (Section 3.9). The spatial extent of these coastal defences and key attributes including the type, material, and purpose are populated based on the 2003 oblique imagery and available vertical aerial imagery.

If Coastal defences are not identifiable in this imagery, they will not be included in the Coastal Defence Asset Database at this stage, however more recent or better quality information may justify an amendment to the Coastal Defence Asset Database. As such, the data extracted from the Coastal Defence Asset Database needs to be reviewed as:

- Defences may be present now which were not present in 2003 (date of the oblique imagery survey);
- Defences may not have been identifiable due to the quality of the available imagery;
- Defence details may not have been populated due to the quality of the available imagery.

The Coastal Defence Asset Database can be used to define the coastal feature line for frontages where manmade coastal defences are present, and the key information available will also support the categorisation of defences as part of the assessment of manmade coastal defences.



Figure 3-3 Example image illustrating Coastal Defence Asset Database assets in red (walls), green (embankments), engineered high ground (brown), and natural coastline (pink and yellow)

3.5 GSI Vegetation Lines

Geological Survey Ireland (GSI) have undertaken a project to digitise the seaward extent of terrestrial vegetation based on available TE vertical aerial imagery (2000 to 2018). The vegetation lines have been manually digitised based on a visual assessment of vegetation for soft non-cliffed coastlines. Whilst every effort has been made to ensure their accuracy, the nature of manual digitisation means that it is prone to subjectivity and potential inaccuracies and therefore there is a need to check the accuracy of the vegetation lines prior to their use. Vegetation lines are not present for hard cliff areas. The GSI vegetation lines are being produced for the entire coastline of Ireland.

The vegetation lines can assist in defining the coastal feature line for non-cliffed frontages more efficiently (editing an existing line rather than drawing a new line). They also allow an initial classification of coasts as hard or soft (as they are only available for soft coasts), and are used directly to quantify historic coastal change.



Figure 3-4 Sample image showing manually digitised GSI Vegetation Lines

3.6 ICPSS Vegetation Lines

The OPW completed the Irish Coastal Protection Strategy Study (ICPSS) in 2013. Similarly to the GSI vegetation lines, this study produced historical vegetation lines for 1973, 2000, and 2006. This data does not have national coverage, and the quality of the vegetation lines are not always suitable, particularly where the quality of geo-referencing of the 1973 imagery is poor. However, in some cases, the vegetation lines can be used in conjunction with the GSI vegetation lines and for the same purpose outlined above in Section 3.5. As with the GSI vegetation lines, manual digitisation means that the ICPSS vegetation lines are prone to subjectivity and potential inaccuracies and therefore there is a need to check the accuracy of the vegetation lines prior to their use.

3.7 Tailte Éireann (TE) Mapping

TE vector mapping includes digitised boundary geometry of a variety of features which can aid National Coastal Erosion Hazard Mapping by providing an initial starting geometry for defining the coastal feature line more efficiently.

The boundaries layer, or more specifically the “Prime 2 divisional polyline” layer, includes definition of field boundaries at cliffed coasts. In some cases, the field boundary will be

proximate to the top of cliff to maximise productive land use. Therefore, the field boundaries can provide a starting geometry for defining the coastal feature line for cliffed coasts more efficiently (editing an existing line rather than drawing a new line) compared to extracting it from LiDAR. This approach will only be suitable in some areas, as field boundaries will not be present in all locations. In all cases, the starting geometry shall be reviewed and adjusted manually to align with top of cliff as per CALS LiDAR data (Section 3.2)

In locations, where no existing vegetation lines (GSI or ICPSS) are available, the Mean High Water line available in TE vector mapping can provide an alternative starting geometry, which shall then be reviewed and manually adjusted to align with CALS aerial imagery data. (Section 3.3)

3.8 GSI Geology Mapping

GSI provide a number of geology mapping datasets (quaternary sediments, bedrock and cliff geology) in polygon format. These can be used to help verify the hardness classification of the feature line after the initial categorisation (using GSI vegetation lines) is complete. The hardness and topography classification in turn assist with splitting the feature line into individual frontages.

3.9 OPW Oblique Imagery

The OPW carried out a survey in 2003 capturing oblique imagery of the entire coastline of Ireland. This dataset consists of geo-referenced still images extracted from a continuous video, and it is a useful dataset for identifying the location of manmade coastal defences and verifying the hardness and topography of the coast which is otherwise hard to determine from vertical aerial imagery. However, this imagery was captured in 2003 and the quality of the imagery varies. A new high-resolution oblique imagery survey is planned and it is intended that this imagery can be used for verifying the coastal feature line position and the hardness and topography of the coast. The resolution of the new imagery will also mean additional manmade coastal defences, which were not identifiable or not present in 2003, can now be identified, and it will also be suitable to enable a condition grade and performance standard to be assigned to all manmade coastal defences.

3.10 Copernicus Coastal Zone Mapping

Copernicus Coastal Zone Mapping are zones depicted by polygon shapefiles which classify coastal types using satellite imagery i.e. various beach types, dunes, salt marshes etc.

The Copernicus Coastal Zones dataset can be used as an initial classification of the coast into “cliffed” or “non-cliffed”, using the “63120 Coastal cliffs” polygon, with the initial assumption that the coast is “non-cliffed” outside of these areas.

3.11 INFOMAR

INFOMAR data refers to the Integrated Mapping for the Sustainable Development of Ireland’s Marine Resource Programme, which maps the physical, chemical, and biological features of Ireland’s seabed. INFOMAR is a collaboration between the Marine Institute (MI) and GSI which creates integrated mapping products to support various sectors including shipping, marine tourism and renewable energy. Survey data dates between 2006 and 2026 inclusive.

INFOMAR bathymetric data shall be used to establish the position of nearshore contours and for determining a representative coastal slope for each frontage. The shoreline position shall be taken to be the 0m contour.

3.12 ICWWS

The Irish Coastal Wave and Water Level Modelling Study (ICWWS) 2018 provides estimated Extreme Coastal Boundary Water Levels, associated with astronomical tide, storm surge and seiche/local wind set-up allowance, for the coast of Ireland. ICWWS 2018 also provides data on Mean Sea Level to mOD Malin (OSGM15) conversion. ICWWS outputs are used to establish water depth at MSL and to estimate extreme water level at each frontage with manmade coastal defences.

3.13 Identification of Additional Site-Specific Data or Local Knowledge

Depending on the area, there may be additional site specific data and localised studies available for use, particularly in locations already experiencing coastal erosion. These data and reports should be reviewed, and where appropriate used, to help produce Coastal Erosion Hazard Mapping in these locations.

3.14 Software Requirements

3.14.1 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

A Geographical Information System (GIS) is a computer system that creates, manages, analyses and spatially maps various types of data. It shall be used to help develop the coastal feature line and to support the assessment of coastal change. GIS is a key tool in the development of coastal erosion hazard mapping as it can use various types of data in unison while developing linework and shapefiles to display data for final outputs.

3.14.2 DIGITAL SHORELINE ANALYSIS SYSTEM (DSAS)

Digital Shoreline Analysis System (DSAS) is an automated standalone software package used for calculating the rate of change of the coastal feature line over time. The outputs can be extracted, viewed and interrogated in GIS alongside other spatial data. DSAS software computes the rate of shoreline change at pre-determined transects aligned perpendicular to the coastal feature line by performing rate calculations relative to a fixed baseline and historical shoreline positions.

Earlier versions of DSAS (version 5 and older) are only compatible with ArcMap and shall not be used. It is acknowledged that alternative software and techniques are available or may be used to replicate the analysis performed by DSAS. Any such software or technique may be deemed acceptable if first approved by the OPW to ensure both the accuracy and compatibility is consistent with the wider CEHM assessment methodology. All references to DSAS in this TMN refer to DSAS or a similar alternative software or technique, subject to approval by the OPW, capable of performing the same analysis.

3.14.3 CLIFFMETRICS

CliffMetrics is a programme developed by SAGA-GIS which automatically determines and delineates the estimated top of cliff position from Digital Terrain Models (DTMs). CliffMetrics, or similar approved, shall be used to develop the coastal feature line for cliffed coasts.

4 Coastal Feature Line and Frontages

This section provides detail of the first stage of the assessment methodology, specifically the approach taken for defining a Feature Line and splitting the coastline into Frontages (see also Section 2.5.1).

The **Coastal Feature Line (CFL)** is used as a proxy to both measure historic coastal change against (Section 5) and to project future coastal change (Section 6) from. As it is exclusively based on the OPW CALS data, the date of the feature line will vary between 2021 and 2025, depending on when the survey was undertaken.

The CFL is then split into individual **Frontages**. Each frontage represents a length of coast which is expected to behave in a similar way based primarily on physical characteristics (e.g. hardness, topography, and orientation). The assessment of historic and future coastal change is undertaken on a frontage by frontage basis, rather than projecting future coastal change at defined alongshore intervals.

4.1 Classifying the Coast

4.1.1 HARDNESS

When mapping the feature line, the first step in the process is to classify the coast by its hardness, typically “hard” or “soft”. This determination is based on the natural erodibility of the underlying geology with igneous and metamorphic rocks typically being “hard” and sedimentary rocks or sand-dominated coasts typically being “soft”.

The GSI Vegetation Lines (Section 3.5) are typically produced for soft coasts only, so this dataset can be used as an initial classification of the coast into “hard” or “soft”, with the assumption that the coast is “hard” where GSI Vegetation Lines are not present.

The GSI Vegetation Lines were not specifically developed for this purpose, and have not been subject to a detailed review to verify that all soft coasts are captured, or that some hard coasts have not been captured. For that reason, a verification process is necessary to review the initial classification of hardness by evaluating vertical aerial imagery and oblique imagery datasets to verify the hardness of the coastline and to ensure alongshore transition points (from soft to hard and vice versa) are accurately mapped. This verification process shall consider:

- Visible evidence of rock falls, land slippages, bare earth, and signs of rotational slope failures to verify “soft” or erodible coasts, as shown in Figure 4-1 and 4-2 below.
- Visible evidence of hard rock outcrops to verify “hard” coasts as shown in Figure 4-3 below;

It is also important to note that the presence of exposed bedrock or rock may also be “soft” depending on the type of bedrock / rock present. GSI mapping shall be used to assist in this element of the evaluation.



Figure 4-1 Typical example of land slippage verifying presence of soft coast



Figure 4-2 Example of bare earth face indicative of soft or erodible cliff coastline



Figure 4-3 Typical example of Hard Rock outcrops

Where a cross-shore transition in hardness exists, for example where “soft” deposits are situated in front of “hard” geology, this type of frontage shall be classified as “soft_to_hard” (Figure 4-4). This is particularly important where the “soft” coast is wide enough or of a shallow enough gradient to support properties or other receptors, or if properties are located close to the top of cliff on the “hard” coast further landward.

The initial classification (using GSI vegetation lines) shall be refined and reclassified accordingly during the verification process. It is critical that this verification / reclassification exercise is undertaken by an experienced coastal scientist.



Figure 4-4 Typical example of coastline classified as “soft_to_hard” where the red line defines the feature line of the soft coast, and exposed rock is evident immediately landward of the feature line

4.1.2 TOPOGRAPHY

The second step in mapping the CFL is to classify the coast by its topography, “cliffed” or “non-cliffed”. This classification is based on the natural topography of the coast, and shall consider whether ToC or BoB is like most appropriate feature for each frontage. The initial classification of the CFL is based on Copernicus Coastal Zone Mapping using the “63120 Coastal cliffs” polygon.

As with the hardness classification, a verification process is necessary to review the initial classification of topography. Oblique aerial imagery (Section 3.9) and LiDAR (Section 3.2) data should be used to undertake this verification process, enabling visual identification of cliff features and evaluation of cross-shore elevation profiles (using hillshade symbology in GIS for efficiency) respectively (see Figure 4-5 below).

The initial classification (using Copernicus Coastal Zone Mapping) shall be refined and reclassified accordingly during the verification process. It is critical that this verification / reclassification exercise is undertaken by an experienced coastal scientist.



Figure 4-5 Typical example of coastlines re-classified as “cliffed” based on oblique imagery (left) and hillshade symbology (right) where Copernicus Coastal Zone Mapping indicated it was “sandy beach”

4.1.3 MANMADE COASTAL DEFENCES

The final step in mapping the CFL is to classify the coast by the presence or absence of manmade coastal defences. The Coastal Defence Asset Database (Section 3.4) provides the spatial extent of manmade coastal defences identifiable in 2003 oblique imagery. This dataset can be used for the initial classification of the coast into “defended” and “undefended” categories.

Given the age and quality of that dataset, it is appropriate to review more recent vertical aerial imagery and oblique imagery to identify additional manmade coastal defences (not identifiable or present in 2003), as well as to refine the spatial extent of identified manmade coastal defences where higher resolution imagery is available. Consultation with the relevant LA shall also be undertaken as this may assist in the identification of more recent (<25 years) manmade coastal defences.

4.2 Mapping the Feature Line

Following classification of the coast by hardness, topography, and manmade coastal defences, the **CFL** can be defined. The subsections below describe the different types of coasts and how the CFL should be defined and mapped in each case.

Any digitisation shall be undertaken (if manual) or reviewed at a scale of 1:200 to 1:2,000 depending on the variability of the feature being mapped, with an average density of 2 to 4 points for every ten metre length.

4.2.1 CLIFFED COASTS

For cliffed coasts, LiDAR data shall be used along with the open-source tool CliffMetrics (or similar approved) to extract the ToC from LiDAR data. This tool delineates the top of cliff from elevation data in a Digital Terrain Model (DTM) and pre-defined Mean High Water (MHW) line. It requires LiDAR (DTM) with a reasonable spatial resolution, typically 2m or better, in order to delineate a ToC line which is broadly representative of the actual top of cliff alignment.

Gaps in the LiDAR coverage, in particular, can cause an erroneous or poorly defined ToC line, and in some cases may mean the input LiDAR data is incompatible with CliffMetrics. The defined ToC line can also include 'spikes' projecting seaward of the true ToC line, caused where points of higher elevation exist seaward of the ToC. For this reason, the output from CliffMetrics shall be assumed to be an initial ToC which will require review.

For hard cliffed coasts only, given the fact that these frontages are typically less erodible than soft coasts, it may be appropriate and more efficient in some cases to use TE mapping (Section 3.7) to define the coastal feature line from the boundary layer defining field boundaries (instead of CliffMetrics and LiDAR data). CliffMetrics can be used on hard cliffed coasts, as well as soft cliffed coasts, if preferred. As with soft cliffed coasts, this approach is still likely to require editing before the final ToC line can be defined and, as such, any output generated using TE mapping layers shall again be assumed to be an initial ToC which will require review.

For all cliffed coasts (whether using CliffMetrics or TE mapping), the initial ToC line shall be reviewed and, where appropriate, manually adjusted to define the final ToC at the required level of accuracy (set out above). This review shall be undertaken by importing the initial ToC line into GIS and comparing it visually with the underlying LiDAR data using hillshade symbology, realigning the ToC line to match the top of cliff interpreted visually from the hillshade symbology as required.

4.2.2 NON-CLIFFED COASTS

The CFL for all non-cliffed coasts shall be defined as the seaward limit of terrestrial vegetation, or Back of Beach (BoB). The process of manually digitising the BoB from aerial imagery is time-intensive, therefore to achieve efficiencies, the following technique for mapping and defining the BoB shall be used:

- (1) The most recent GSI Vegetation Line (Section 3.5) shall be used as an initial BoB. Where no GSI Vegetation Line is available, the most recent ICPSS Vegetation Line shall be used as the initial BoB. If neither GSI nor ICPSS vegetation lines are available, the MHW line from the TE Vector mapping shall be used as the initial BoB line.
- (2) The CFL shall then be visually reviewed and manually re-positioned to the seaward limit of terrestrial vegetation (BoB) visible in the aerial imagery available from the OPW CALS (Section 3.3) project. This re-positioning may be landward or seaward

depending on if any recent erosion or accretion has occurred respectively. Where no recent coastal change is evident, the initial BoB may be adequate as is.

In the event no existing GSI or ICPSS Vegetation Line or MHW line is available, manual digitisation shall be carried out following the rule-based approach defined in Table 4-1 below.

Table 4-1 Rule-based approach to manual digitisation of vegetation lines

Coast Type	Rule-based approach
No manmade coastal defence present	1. Digitise the seaward extent of terrestrial vegetation, not intertidal vegetation like saltmarsh. To inform this, use the colouring of the surrounding vegetation that is clearly terrestrial and intertidal, and also the presence of creeks, pools and patches of bare greyish intertidal muds. 2. Do not trace around individual vegetation patches to create a highly crenulated line; instead digitise based on the general alignment of the coast in that location. Where there is a discontinuity of less than 10 metres, the vegetation line can continue longshore without tracing the discontinuity inland. 3. Follow the boundary of well-established vegetation indicated by strong green colouring, do not trace around very light patchy vegetation that could be ephemeral. 4. Do not trace around any cross-shore structures on the foreshore, (e.g. groynes or breakwaters) or access routes (e.g. pathways through dunes) but instead cut directly across these or stop and start the vegetation line before and after the defence.
Manmade coastal defences present	1. Follow the landward edge of the crest of backshore defences 2. Do not trace around any cross-shore structures on the foreshore, (e.g. groynes or breakwaters) or access routes (e.g. pathways/slipways) but instead cut directly across these or stop and start the vegetation line before and after the defence. 3. If terrestrial vegetation is present seawards of any manmade coastal defence, follow the seaward limit of terrestrial vegetation if it extends >10m seawards of the defences (as there is a possibility for receptors to exist/be built there). In this case, both the back of defence crest and vegetation line will be digitised (e.g. two features). If terrestrial vegetation extends <10m seaward of the defences, follow the landward limit of the defence crest only.

4.3 Splitting the Coastal Feature Line into Frontages

The process of classifying the coast (Section 4.1) by hardness, topography and manmade coastal defences enables the CFL to be split into individual frontages. One frontage will end, and a new frontage will start, every time there is a change in these classifications. This process shall be used initially to split the CFL into frontages.

The outputs shall then be reviewed to consider additional factors which may influence whether these initial frontages are likely to behave in a similar manner, or whether merging (particularly for hard coasts) or further splitting (particularly for soft coasts) may be appropriate. Factors to be considered in this review are detailed below.

Hard coasts:

- Merging frontages to remove short sections of hard coast (e.g. narrow headlands) with soft coast on either side.

Soft coasts:

- Splitting frontages based on varying exposure of bedrock or superficial geology to erosion by coastal processes, typically using GSI geology mapping (Section 3.8);
- Splitting frontages based on the orientation of the coast relative to the predominant wave fetch or proximity to tidal channels.

All Coasts:

Splitting frontages based on significant variation in historical behavior e.g. erosion vs accretion.

In all cases, proportionality shall be considered when reviewing the number of frontages assessed. The general principle shall be to retain a higher resolution of shorter frontages in areas of more erodible coast with receptors present, and a lower resolution of longer frontages in areas of less erodible coast with no receptors present.

The length of each frontage is typically expected to range from 100 metres to 1,000 metres.

The feature line shall be mapped in GIS and the dataset shall include attributes set out within the Coastal Erosion Hazard Mapping Spatial Data Specification.

5 Historic Coastal Change Assessment

5.1 Understanding the principles

One of the three core components of the NCEHM assessment methodology is an assessment of historic coastal change of the coastline. This involves the measurement of historic coastal change over a period of time, typically output as an annualised coastal change rate in metres per year (m/yr). This measurement can then be extrapolated into the future to assist in generating estimates of future coastal change, by combining it with the outputs of the other two core components of the assessment methodology: the Future Coastal Change Assessment (Section 6) and the assessment of Manmade Coastal Defences (Section 7).

The measurement of historic coastal change for CEHM is based upon identifying landward or seaward movement in the position of the Top of Cliff (ToC) or Back of Beach (BoB) (as defined in Section 2.5.1) over time. Movements of these coastal features are used as a proxy for erosion or accretion of the backshore.

As CEHM is estimating future coastal erosion hazards for several decades from the present day (or from the survey date of the OPW CALS), another key principle guiding the measurement of coastal change is to measure longer term (e.g. decadal) historic trends in coastal change, rather than short-term (e.g. sub-decadal) trends which may inaccurately influence long-term predictions. By measuring historic coastal change over a suitably long period of time (e.g. preferably spanning multiple decades), any local short term variability caused by seasonality or single, isolated storm events is smoothed out but still captured.

5.2 Defining the approach

The approach to the assessment of historic coastal change varies depending on the type of frontage (Section 4). Frontages should be grouped into one of the categories in Table 5-1 below, based on the attributed spatial data developed as set out in Section 4.3.

Table 5-1 Selection of assessment methodology based on frontage classification

Type of Frontage	Topography	Hardness	Manmade Coastal Defence	Assessment Method
Cliff (Soft)	Cliff	Soft	Any	Section 5.3
Cliff (Hard)	Cliff	Hard	Any	Section 5.4
Cliff (Soft to Hard)	Cliff	Soft to Hard	Any	Section 5.5
Non-cliffed (Soft)	Non-cliffed	Soft	Any	Section 5.3
Non-cliffed (Hard)	Non-cliffed	Hard	Any	Section 5.4
Non-cliffed (Soft to Hard)	Non-cliffed	Soft to Hard	Any	Section 5.5
Manmade Coastal Defences	Any	Any	Yes	Section 5.6

It should be noted that where manmade coastal defences are present, the assessment method associated with the natural coastline (cliffed / non-cliffed, hard / soft / soft to hard) where the manmade coastal defence is present shall also apply.

5.3 Assessing Soft Coasts (Cliffed and Non-cliffed)

The historic coastal change assessment for all soft frontages (cliffed and non-cliffed) is based on quantifying the historic landward or seaward movement of the seaward limit of terrestrial vegetation.

If and when a new national LiDAR survey is available, a quantitative comparison of top of cliff position can be made and may supplement the assessment methodology set out below. (Section 5.7).

5.3.1 INPUT DATA TO BE USED

Table 5-2 summarises the input data required to assess historic coastal change of soft frontages.

Table 5-2 Data requirements to assess historic coastal change of soft frontages

Data required	Description and use in assessing historic coastal change of soft, cliffed and non-cliffed frontages
Coastal Feature Line (Section 4.2)	This dataset must be generated as part of the assessment as discussed in Section 4. It represents the current position of the seaward extent of the terrestrial vegetation, and as such forms the “ <i>present day</i> ” alignment against which any historic coastal change is compared to. It shall be digitised based on the OPW’s Coastal Aerial LiDAR Survey (2021 to 2025), with the precise survey date varying depending on location.
GSI historic vegetation lines	GSI have undertaken a project to digitise the seaward extent of terrestrial vegetation for all Tailte Éireann (TE) vertical aerial imagery captured between 2000 and 2019. Historic coastal change shall be measured based on the difference between the GSI historic vegetation lines and the CFL.
ICPSS (1973-1975) vegetation lines	The Irish Coastal Protection Strategy Study (ICPSS) digitised the visible vegetation line for soft coasts by individually geo-referencing a series of TE aerial photography digital images dated between 1973 and 1975. Historic coastal change shall be measured based on the difference between the ICPSS vegetation line and the CFL in the same way as is done using the GSI vegetation lines.
Vertical aerial imagery	A variety of vertical aerial imagery is available through Tailte Éireann. This includes national georeferenced imagery (1995 to 2025) and non-georeferenced but digital imagery (1973 to 1975). The quality and resolution of the imagery varies depending on both the date and location, and so the accuracy of the underlying imagery must be considered when using the GSI vegetation lines and the ICPSS vegetation lines.

Tailte Éireann historic mapping should not typically be used to quantify historic coastal change as the accuracy of the survey and mapping is unknown and any coastal change trends dating back over 100s years may not be reflective of more recent trends over the past few decades.

5.3.2 ASSESSMENT METHODOLOGY

CEHM shall use vegetation lines produced by the OPW and GSI (Table 5-2) to quantify historic coastal change for each frontage individually. These can be supplemented with additional historic vegetation lines where reliable and available. This assessment shall be done by generating a series of cross-shore transects from a defined reference baseline which will run broadly parallel to the CFL.

The reference baseline and cross-shore transects may be generated within the Digital Shoreline Analysis System (DSAS), or using alternative software or techniques that adopt a similar approach. Once generated, the baseline and cross-shore transects must be reviewed, and where appropriate amended, to ensure they are placed at locations which provide a good representation of historic coastal change for each frontage, and avoid pulling identified inaccuracies or anomalies in the underlying vertical aerial imagery or historic vegetation lines through into the assessment. Further guidance on the generation of the baseline and cross-shore transects is provided below.

Reference baseline

The baseline is the origin point from which rates of coastal change are measured from. It is recommended that the baseline is generated landwards of the CFL to reduce the risk of it crossing over itself in narrow inlets / estuaries or in places where significant coastal erosion has occurred in the past.

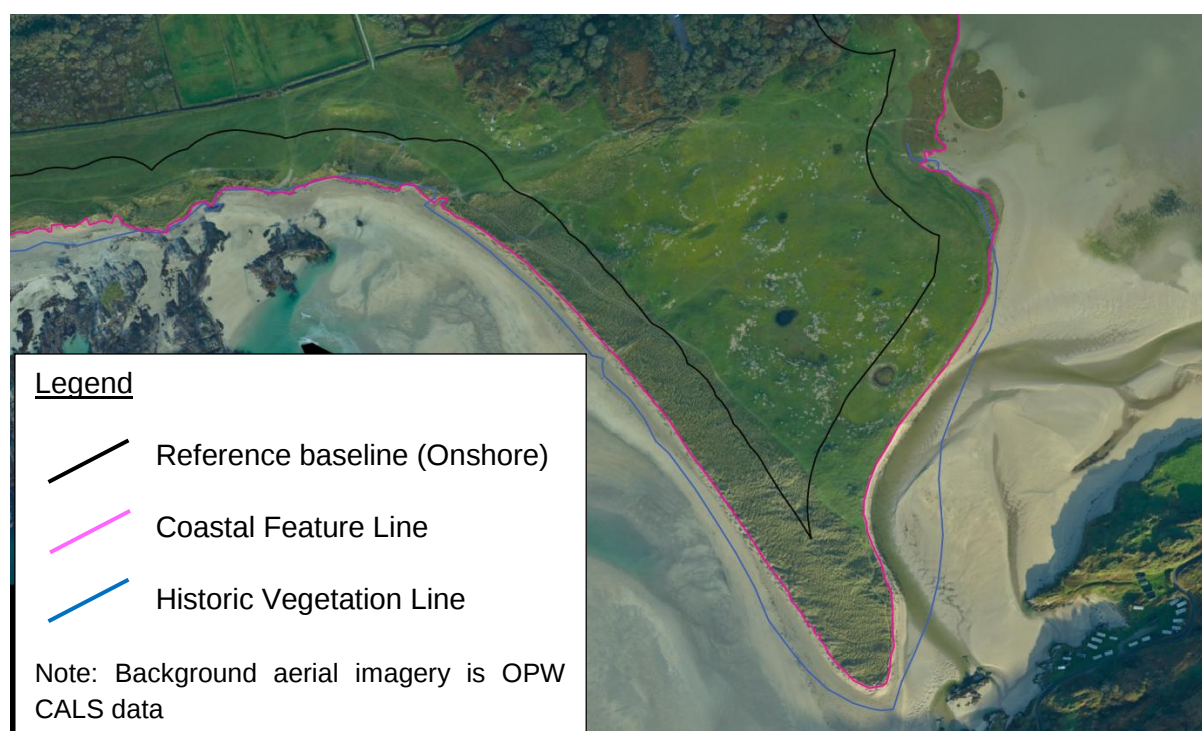


Figure 5-1 Example of an onshore reference baseline relative to the Coastal Feature Line and Historic Vegetation Line

The baseline should flow in a clockwise direction around the national coastline of Ireland. A single continuous baseline for the entire study area is not essential. However, it is recommended to avoid numerous assessments (e.g. each frontage) for efficiency and data management reasons.

Cross-shore transects

Cross-shore transects represent the lines along which historic coastal change will be measured. Rates of coastal change are generated along each transect based on the points at which it intersects the historic vegetation line and the CFL, the cross-shore distance between those intersections, and the survey dates associated with the historic vegetation line and CFL. The number of transects will vary depending on the length and characteristics of the frontage, but there should be a minimum of three transects for each individual frontage.

Cross-shore transects will always extend seaward and to the left of the baseline as the baseline is located landwards of the CFL and is generated in a clockwise direction. Cross-shore transects should be spaced at 100 metre intervals by default, however this spacing may be extended to a maximum of 500 metres by exception where (a) historic coastal change appears to be negligible, (b) the frontage is at least 1,000 metres in length, and (c) there is no photographic evidence of significant variation in coastal change along the frontage.

A “smoothing distance” must be entered when generating transects in DSAS. This factor may vary depending on which part of the coastline is being assessed, but will typically fall between 50 and 200, with 100 being the recommended default value.

Review of Reference baseline and Cross-shore transects

Users should import the generated reference baseline and cross-shore transects into a geographic information system (GIS) and review these to ensure they are compatible with the coastline orientation, the CFL, and the historic vegetation lines. In most cases, the generated reference baseline and cross-shore transects may require amendment to ensure a robust assessment. This amendment can be done manually in GIS, then importing back into DSAS.

Common issues that may occur and which need to be incorporated in the review include:

- i. Reference baseline crossing over itself, particularly at narrow headlands or inlets;
- ii. Reference baseline flowing in an anti-clockwise, not clockwise, direction;
- iii. Cross-shore transects being affected by localised undulations or not being perpendicular to the general orientation of the coastline;
- iv. Cross-shore transects being of insufficient length to intersect all historic vegetation lines;
- v. Cross-shore transects being placed in locations not representative of coastal change along that frontage, particularly where larger transect spacing is used.

5.3.3 DIGITAL SHORELINE ANALYSIS SYSTEM (DSAS)

The Digital Shoreline Analysis System (DSAS; version 6) is a stand-alone, desktop application that complements a geographic information system (GIS) such as QGIS or ArcPro. In DSAS, the user inputs a reference baseline, a series of cross-shore transects, the CFL, and a compilation of historic vegetation lines. DSAS then calculates rates of historic coastal change based on the input data and the dates associated with the input vegetation lines. Caution must be applied when formatting dates for use in DSAS as the software was developed by United States Geological Survey (USGS) and so the United States format is used (i.e. mm/dd/yy).

Information on how to use DSAS is available within the application itself (including a short tour demonstration) and online (including user guide) via the [DSAS project](#) page.

The main DSAS outputs of interest in the development of CEHM are the End Point Rate and the Shoreline Change Envelope at all cross-shore transects assessed. Other statistics generated by DSAS are of limited use at this stage due to the relatively low number of historical vegetation lines available over a relatively short timeframe.

Time periods

DSAS is capable of generating annualised rates of coastal change between two vegetation lines (e.g. the Feature Line and one other historic vegetation line) or the total coastal change (Shoreline Change Envelope) from a compilation of historic vegetation lines. The former (defined in DSAS as the End Point Rate) shall be the primary measurement used in the CEHM assessment, however the Shoreline Change Envelope is appropriate for use in locations where cyclical patterns of coastal change are evident.

Given there are typically 7-8 vegetation lines available for use in the CEHM assessment, and as the CEHM is focused on long-term coastal change, it is not efficient or necessary to quantify rates of coastal change for all time intervals.

Rates of coastal change shall be estimated for the following default time periods as a minimum:

- 2000 to Present Day (2021 to 2025, based on the CALS aerial imagery survey data) for all frontages;
- 1973 to 1975 to Present Day (2021 to 2025, based on the CALS survey) for all frontages where the 1973 to 1975 vegetation line is both available and sufficiently accurate.

The appropriateness of assessing additional or alternative time intervals should be reviewed on a frontage by frontage basis. This may be appropriate, for example where:

- i. The 2000 vertical aerial imagery or historic vegetation line is unavailable or inaccurate (select next oldest accurate and available historic vegetation line instead);
- ii. A manmade coastal defence has been introduced since 2000, and so a time period pre-dating the introduction of the manmade coastal defence should be considered instead (e.g. 1970s to 2005, defence introduced in 2005);
- iii. There is clear evidence of accelerated coastal change over a more recent time period (but not less than 10 years).

5.3.4 MANUAL MEASUREMENTS OF HISTORIC COASTAL CHANGE

In certain cases, it may not be possible to measure historic coastal change using DSAS. This would most commonly be due to historic vegetation lines not being available. Whilst the GSI vegetation lines are being produced for all soft coasts around the coastline of Ireland, it is possible that some soft coasts have been missed or mis-classified during the process. This may be particularly evident where manmade coastal defences are present on soft coasts, where soft cliffed (rather than non-cliffed) frontages are present, or where there is a cross-shore transition from soft to hard coasts.

Where no historic vegetation lines are available, manual measurements of historic coastal change shall be undertaken while considering the potential issues associated with manual digitisation outlined in Section 3.5. This shall be done using GIS and following the same principles set out in Section 5.3.1 to 5.3.3 particularly in relation to the review of input data, transect spacing, time intervals, and the choice between End Point Rate and Shoreline Change Envelope.

If manual measurements of historic coastal change are being undertaken, there is no requirement to manually digitise the entire longshore extent of all vegetation lines. It is only necessary to identify the intersection points between each cross-shore transect and historic vegetation line on the vertical aerial imagery for the time intervals being assessed.

Manual measurements of historic coastal change must be undertaken at a scale ranging between 1:200 and 1:2,000, depending on the level of variation in longshore direction.

Where automated tools and techniques are available for the digitisation of vegetation lines to the required accuracy, these can also be used as an alternative to manual measurement as described above.

5.3.5 SELECTION OF 'REPRESENTATIVE RATE'

The historic coastal change assessment for soft coasts concludes with the selection of a 'representative rate' for each frontage. The key principle of this is that a single historic rate of coastal change is selected and applied to each frontage, rather than using rates generated for each individual cross-shore transect.

The cross-shore transect results output from DSAS (Section 5.3.3) or through manual measurement (Section 5.3.4) shall be reviewed and expert judgement applied in the selection of a single 'representative rate' for each frontage. Table 5-3 below provides guidance on the factors to consider in the selection process.

Table 5-3 Factors to consider in the selection of the 'representative rate' for a frontage

Factor	Consideration
Frontage extent	Frontages have been identified on the basis they are expected to behave in a similar fashion from a coastal change perspective. If the rates of coastal change vary significantly longshore, consider the merit of splitting the frontages further and assigning a different representative rate to each frontage
Time intervals	The longest available time period (typically between 20 and 50 years) should be used as default. However the quality of the underlying input data, the introduction of manmade coastal defences (see Section 5.6), and any step change in coastal processes may all justify the selection of a shorter or more recent time interval and associated rate.
End Point Rate or Shoreline Change Envelope	The End Point Rate (annualised rate of change over the assessed time period) shall be used as default. However, evidence of cyclical patterns in coastal change may justify the use of the Shoreline Change Envelope.

Factor	Consideration
Cross-shore transects	The minimum, maximum, mean, median, and range of coastal change rates across all cross-shore transects assessed on the frontage shall be considered, as well as any spatial or temporal variation in this. Cross-shore transects can be excluded during the 'representative rate' process if the assessment evidences that they are anomalies or are not representative of the frontage. This may include, for example, transects which coincide with less accurate vegetation lines (see Section 3.5 and 3.6) or locally specific erosion features such as access points.
Introduction of bias	The inclusion of manual inputs or tasks in the assessment can inadvertently introduce an element of bias. For example, a transect being manually placed in an area exhibiting locally significant erosion over a short time interval which may not be representative of long-term coastal change on that frontage. The 'representative rate' process is designed to act as a key quality control step to help mitigate this risk.

'Borrowing' rates of coastal change from other frontages

In some cases, it may not be possible to select a 'representative rate' based on measurements of historic coastal change taken directly for that frontage. Examples of this include:

- Where a manmade coastal defence was introduced between 2000 and 2010, and there is insufficient data (less than 10 years) to develop a reliable rate of historic coastal change that pre-dates the introduction of a manmade coastal defence;
- Where the quality of data (e.g. cloud cover, poor resolution, poor georeferencing, trees, shadowing) has prevented the accurate digitisation of historic vegetation lines.

In these circumstances, there is an option of 'borrowing' a 'representative rate' from an alternative frontage which may be expected to have exhibited similar rates of coastal change and where a more reliable rate of coastal change has been selected (typically based on direct assessment using DSAS outputs or similar).

Where the 'borrowing' approach is adopted, frontages with similar characteristics shall be used. This will typically be based on proximity, geomorphology, geology, and exposure / orientation.

5.4 Assessing Hard Coasts (Cliffed and Non-cliffed)

The historic coastal change assessment for hard frontages shall be based on a desk based visual inspection for any signs of historic erosion, based on available imagery, followed by a quantitative assessment in areas where signs of historic erosion are identified visually.

Historic vegetation lines are not typically available for hard frontages so any quantification of coastal change shall be by exception only to ensure proportionality.

5.4.1 INPUT DATA TO BE USED

Table 5-4 summarises the input data required to assess historic coastal change of hard (cliffed and non-cliffed) frontages.

Table 5-4 Data requirements to assess historic coastal change of hard, cliffed frontages

Data required	Description and use in assessing historic coastal change of hard, cliffed and non-cliffed frontages
Feature Line (Section 4.2)	This dataset must be generated as part of the assessment as discussed in Section 4. It represents the current position of the top of cliff (for cliffed frontages) or the seaward limit of terrestrial vegetation (for non-cliffed frontages), and as such forms the “ <i>present day</i> ” alignment against which any historic coastal change is compared to. It shall be digitised based on the OPW’s Coastal Aerial LiDAR & Imagery Survey (2021 to 2025), with the precise survey date varying depending on location.
Oblique imagery (2003 and 2026)	The OPW commissioned an oblique imagery survey of the entire Irish coastline in 2003. Images are georeferenced and can be used to identify any signs of historic coastal erosion of cliffed coasts with an additional oblique imagery survey planned.
LiDAR	The recent OPW LiDAR data (2021 to 2025) provides high resolution elevation data from which cross-shore profiles can be extracted. This shall be used to digitise the top of cliff position, and can also assist in quantifying historic coastal change where signs of historic coastal erosion have been visually identified.
Vertical aerial imagery	A variety of vertical aerial imagery is available through Tailte Éireann and the OPW. This includes national georeferenced imagery (1995 to 2025) and non-georeferenced but digital imagery (1973 to 1975). The quality and resolution of the imagery varies depending on both the date and location, but can be used to identify signs of historic coastal erosion of non-cliffed coasts, as well as quantifying historic coastal change (cliffed and non-cliffed frontages) where signs of historic coastal erosion have been visually identified.

5.4.2 ASSESSMENT METHODOLOGY

CEHM shall adopt a two stage approach to first assess and then, where necessary, quantify historic coastal change for each frontage individually. The first stage of the assessment shall be done by a desk-based visual inspection of available imagery and mapping datasets to identify signs of historic coastal erosion (Section 5.4.3), with oblique imagery (for cliffed frontages) and vertical aerial imagery (for cliffed and non-cliffed frontages) being most useful for visual inspection of hard frontages.

Where signs of historic coastal erosion are observed, a second stage of the assessment shall include manual measurement to quantify the historic coastal erosion observed. This shall be done by manually generating a cross-shore transect at any location where historic coastal erosion is evident (maximum three per frontage) and quantifying historic change in the top of cliff position, alongside interrogation of available vertical aerial imagery and LiDAR.

5.4.3 VISUAL INSPECTION FOR SIGNS OF HISTORIC COASTAL CHANGE

Hard, cliffed frontages

At this stage of CEHM, it is not possible to reliably quantitatively compare a historic top of cliff position with the present day top of cliff position due to the absence of a national, high

resolution, historic LiDAR dataset. In the future, when a new national LiDAR survey is available, a quantitative comparison can be made (Section 5.7).

The CEHM assessment of hard, cliffed frontages shall instead first focus on desk-based visual inspection of available imagery to identify signs of historic coastal erosion. Expert judgement shall be applied when undertaking this review.

Signs of historic coastal erosion may include, but not be limited to:

- i. Areas of bare rock or soil, evident in available oblique imagery and other imagery datasets;
- ii. Displacement of cliff features (e.g. slumping, undercutting, cracking, leaning or fallen trees, etc.), particularly those identifiable in the oblique imagery;
- iii. Significant change in the width and distribution of vegetation seawards of the top of cliff, identified visually by comparing the Feature Line against vertical aerial imagery;
- iv. Significant deposits at the toe of the cliff consistent with a historic collapse.

Figures 4-1 and 4-2 provide visual examples of signs of historic coastal erosion of cliffed frontages identified around the Irish coastline. Whilst Figures 4-1 and 4-2 relate to soft cliffed frontages, they provide a useful visual for similar failure mechanisms at hard cliffed frontages (e.g. slip failures, evidence of bare earth / rock on an otherwise vegetated cliff face). Evidence of rock falls would also indicate instability of hard cliffed frontages, typically including rock debris at the cliff toe (e.g. rock fall at Bin Bán, Dingle, County Kerry in 2023).

Hard, non-cliffed frontages

For non-cliffed frontages, desk-based visual inspection of vertical aerial imagery shall be undertaken to identify any signs of lateral movement in the seaward limit of terrestrial vegetation. Professional judgement shall then be applied to evaluate whether this is consistent with coastal change at that location, and on that frontage, or if it is linked with other factors instead (e.g. land-use change, seasonality of the vertical aerial imagery).

Where signs of historic coastal change are identified on hard frontages, manual measurement of historic coastal change shall be undertaken and a 'representative rate' selected using the same methodology that is used for soft frontages (Sections 5.3.4 and 5.3.5). Cross-shore transects shall be positioned at, and assessed for, the locations where signs of historic coastal change have been identified.

There is no requirement to quantitatively assess historic coastal change for hard frontages where the desk-based visual inspection of available imagery indicates there is no sign of historic coastal change.

5.5 Assessing Soft to Hard Coasts (Cliffed and Non-cliffed)

In some circumstances a frontage will have been classified as "Soft_to_Hard" (Section 4.1). This is typically where softer deposits, at a shallow cross-shore gradient, are present in front of harder geology located further landwards.

The assessment of historic coastal change in these circumstances should adopt the same methodology as that outlined for soft coasts (Section 5.3). This will conclude with the selection of a 'representative rate' for that frontage. This output will in turn be combined with Future

Coastal Change Assessment (Section 6) and the assessment of Manmade Coastal Defences (Section 7), before developing a future coastal change timeline (Section 8).

If the quantum of future coastal change exceeds the width of the softer deposits in front of the harder geology in any management approach or climate change timeline, the cross-shore extent of the coastal erosion hazard mapping shall be clipped to reflect the transition from softer, more erodible coastline to the harder, less erodible coastline.

5.6 Assessing coasts protected by Manmade Coastal Defences

An assessment of historic coastal change is still required where a manmade coastal defence is present. This is a core component of projecting future coastal change, as a coastline will become susceptible to coastal erosion again if and when a manmade coastal defence reaches the end of its residual life.

The key difference in assessing historic coastal change for frontages where a manmade coastal defence is present is to factor in the year of introduction of the coastal defence. The historic coastal change assessment must consider the coastal change observed in the period up to the introduction of the manmade coastal defence, and not the period after introduction (which will typically exhibit no or negligible erosion).

For frontages with manmade coastal defences, the rates of coastal change should be estimated for the following time periods:

- 2000 to Year of Introduction for all frontages with manmade coastal defences;
- 1973 to 1975 to Year of Introduction for all frontages within manmade coastal defences where the 1973 to 1975 vegetation line is both available and sufficiently accurate.

As discussed previously in Section 5.3.5, where insufficient data exists (less than 10 years) to develop a reliable rate of historic coastal change that pre-dates the introduction of a manmade coastal defence, rates of coastal change can be 'borrowed' from an alternative frontage. This will be most relevant for coastal defences introduced prior to 2000, where less aerial imagery is available. Further detail is provided in Section 5.3.5.

5.7 Quantitative assessment of cliffed coasts where additional LiDAR is available

Where additional LiDAR is available, this can be used to generate a top of cliff position for that dataset, in the same way that the top of cliff position is digitised in the creation of the CFL for cliffed frontages.

Having a second top of cliff position means that it is possible to compare the CFL with the historic ToC position to identify any lateral or vertical movement in top of cliff position in the time period between which those datasets were collected.

This shall not negate the need for the relevant parts of the assessment methodology described in Section 5.3 and 5.4, but will instead supplement them. An automated assessment to identify lateral or vertical movement in top of cliff over a certain threshold shall ensure greater efficiency and targeted assessment of historic coastal change.

This assessment will not typically be required until a new national LiDAR survey is available.

5.8 Updating the Feature Line and Frontages

Throughout the assessment of historic coastal change it is appropriate to review and, where necessary, update the spatial extent and attribution of the CFL and frontages created prior to the assessment being undertaken.

Examples of where update may be necessary include:

- i. Spatial variation in the historic coastal change assessed for a defined frontage (may require the frontage to be split again);
- ii. Visual inspection of available imagery indicating that further refinement of the extent or attribution / characteristics of a frontage are necessary.

This will typically be as a result of the assessment undertaken. Changes to the spatial extent of a frontage will not typically require any rework of the assessment itself (e.g. the existing transects and DSAS analysis can be used). Spatial variation in historic coastal change may require a frontage to be split, but the assessment will not require any rework, with the amendment instead being dealt with through the selection of a 'representative rate' process (e.g. a different representative rate selected for each of the 'new' frontages).

5.9 Assigning a Confidence Rating

On completion of the assessment of historic coastal change, the final task is to attribute a Confidence Rating to the assessment undertaken for each frontage. The purpose of this is to ensure the level of confidence attached to the selected 'representative rate' is captured.

A rating score between 0 (zero) and 10 (ten) for each frontage shall be derived based on the assessment methodology used. The rating score shall be translated into an assigned Confidence Rating (High, Medium, or Low) as set out in Table 5-5 below.

Table 5-5 Derivation of a rating score and Confidence Rating for the Historic Coastal Change Assessment

Assessment methodology	Rating score (0 to 10)	Confidence Rating (H/M/L)
Representative rate selected using detailed monitoring / measurement / analysis from this frontage and spanning >20 yrs	10	High
Representative rate selected using detailed monitoring / measurement / analysis from this frontage and spanning >10 yrs	9	High
Representative rate selected using measurements taken directly from this frontage and spanning >20 yrs	8	High
Representative rate selected using measurements taken directly from this frontage and spanning >10 yrs	7	Medium

Assessment methodology	Rating score (0 to 10)	Confidence Rating (H/M/L)
Representative rate selected using measurements 'borrowed' from one adjacent similar frontage	6	Medium
Representative rate selected using measurements 'borrowed' from one or more similar frontage (Mean)	5	Medium
Representative rate selected using measurements taken directly from this frontage and spanning <10 yrs	4	Low
Representative rate selected using measurements 'borrowed' from multiple similar frontages (Typical / Most Common / Median)	3	Low
Representative rate selected based on approximation only (no measurements possible)	0	Low

6 Future Coastal Change Assessment

The second of the three core components of the CEHM assessment methodology is an assessment of future coastal change of the coastline. This involves the estimation of future coastal change over a period of time, typically output as an annualised coastal change rate in metres per year (m/yr), varying over time, and a cumulative total erosion distance (metres).

When carrying out the future coastal change assessment and estimating the future coastal change rate, climate change must be considered. Section 6 outlines the technical methodology for incorporating climate change, or more specifically Sea Level Rise (SLR), within the future coastal change assessment. The potential increased frequency and magnitude of storms are not explicitly included in CEHM due to there being greater uncertainty in the underlying climate science.

Climate change will affect erosion because of the increase in tidal levels (due to SLR) at the shoreline, combined with an increase of wave energy reaching the shoreline because of submergence of the foreshore or other sheltering features. Greater water depth results in waves of a greater height propagating to the shoreline. Increased wave heights have more wave energy, in turn potentially resulting in increased erosion. This concept is directly applicable to erodible shorelines. Coasts that are characterised by harder geology may be more able to resist this increased wave energy and, for cliffed coasts, the factors influencing cliff toe stability are more complex.

6.1 Soft coasts (Cliffed and Non-cliffed)

For the purpose of CEHM, a modified version of the established and widely used 'Bruun Rule' (Bruun, 1962) shall be adopted for the future coastal change assessment of soft, non-cliffed shorelines. The modifications incorporated consider historic and future sea level rise (rather than just future sea level rise) and assume the majority of cross-shore sediment exchange occurs at the upper part of the coastal slope (typically at depths less than 10 metres) rather than the lower part.

The basic physical concept of the Bruun Rule is that, considering a cross-shore coastal profile in equilibrium:

- (1) If sea levels rise by a height of (S), the elevation of the seabed must also increase by that same height to sustain its profile; and,
- (2) The volume of material required to achieve that increase in height must be derived from an equivalent volume of material acquired through erosion of the shoreline (deposited material = eroded material); and,
- (3) There is a defined seaward limit within which sediment transport occurs (such that the bottom profile remains unaffected beyond that limit).

The Bruun Rule is directly applicable to erodible, non-cliffed coasts. Whilst it was not specifically developed for soft, cliffed coasts, any beach fronting a soft cliff can be assumed to fit the same basic physical concept whereby eroded material from the upper part of the coastal profile is deposited at the lower part of the coastal profile if that profile is in an equilibrium state.

The basic physical concept of the Bruun Rule is illustrated in Figure 6-1 below where $B + h$ is the height of the coastal profile, (L) is the width of the coastal profile beyond which the bottom profile remains unaffected, (S) is the increase in sea level, and (R) is the erosion distance in response to that increase in sea level.

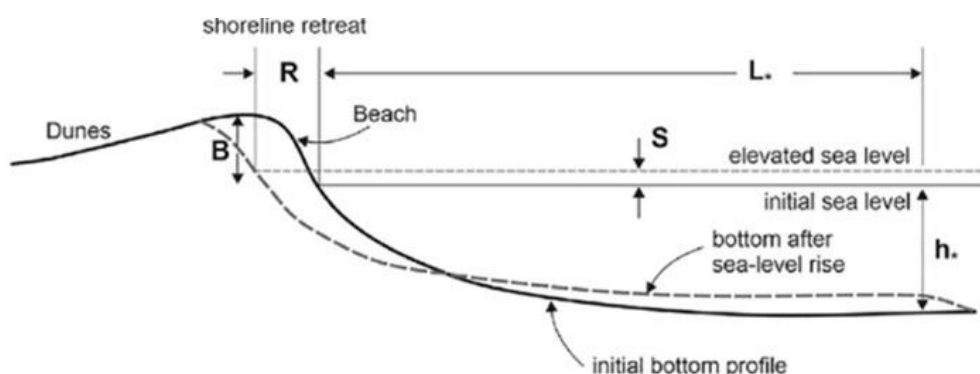


Figure 6-1 Cross-shore coastal profile illustrating the basic concept of the Bruun Rule

The calculation used to estimate future coastal change assessment for the purpose of CEHM can be simplified and expressed as follows:

$$R_2 = R_1 + (S_c \times \text{Coastal Slope})$$

Where:

R_2 = recession distance based upon future coastal change rate (metres).

R_1 = recession distance based upon historic coastal change rate (metres).

S_c = the difference between historic and future rate of Sea Level Rise, including an allowance for isostatic rebound (m/yr)

and,

Coastal slope (C_s); defined by profile length / difference in level over that profile.

R_1 is the representative rate of historic coastal change identified for the frontage being assessed (see Section 5 for detail of the Historic Coastal Change Assessment).

S_c , is the future sea level rise (S_2) over which the future coastal change assessment is being undertaken, including an allowance for isostatic rebound, minus the historic rate of sea-level rise (S_1). This approach assumes that historic coastal change (R_1) is related to historic sea-level rise (S_1) in the same way that future coastal change (R_2) will be related to future sea-level rise (S_2).

S_2 shall be extracted directly, or interpolated, from the decadal values of sea level rise provided for use as part of CEHM (see Section 2.4.3 and Appendix 1). This shall also include an allowance of -0.6mm/yr for isostatic rebound for County Waterford to Mayo inclusive (Stockamp et al., 2015), as set out in Appendix 1. No allowance shall be included for County Sligo to Donegal inclusive or County Wexford to Louth inclusive.

S_1 , historic sea level rise shall be assumed to be 2.5mm/yr, the mid-point of a 2-3mm per year average increase in sea level observed between 1992 and 2019 (EPA, 2023; Cámara García et al, 2021). Isostatic rebound shall also be included as above.

Present Day climate change timeline (see Section 2.4.3), future sea-level rise shall be assumed to be the same as the historic sea-level rise, so S_2 shall be equal to S_1 (see Appendix 1) and therefore S_c is zero.

Coastal Slope (C_s) shall be estimated based on a profile length extending from the 0m contour to the -10m contour (both relative to mOD OSGM15). National bathymetric data available from INFOMAR shall be used to determine the -10m contour (again, noting this shall be relative to mOD OSGM15 and not Chart Datum). Where the -10m contour has not been surveyed by INFOMAR, typically due to offshore features or proximity to the shoreline impacting navigation, the closest bathymetric contour that could be identified from INFOMAR shall be used instead. LiDAR data shall be used to determine the 0m contour. Where the horizontal distance between the 0m contour and the CFL is minimal, such that it will have negligible impact on the estimation of C_s (e.g. near vertical cliffs), the CFL may be used to represent the 0m contour for efficiency for the purpose of CEHM.

The coastal slope shall be estimated perpendicular from the CFL to a contour line reflecting the longshore changes in the general orientation of the coast. For more complex areas of coast, or where the contours of bathymetry do not align well with the CFL orientation, professional judgement shall be necessary with respect to the offshore point to use (which may include selection of an alternative contour). Each frontage shall be attributed with its own coastal slope, but this slope may remain the same for multiple sequential frontages (depending on orientation and bathymetry). Measurements shall be taken along a series of points along the selected contours and a representative slope determined. Generally, changes in slope attribution occur where there is a significant change in coastal orientation or a notable flattening or steepening of the subtidal area.

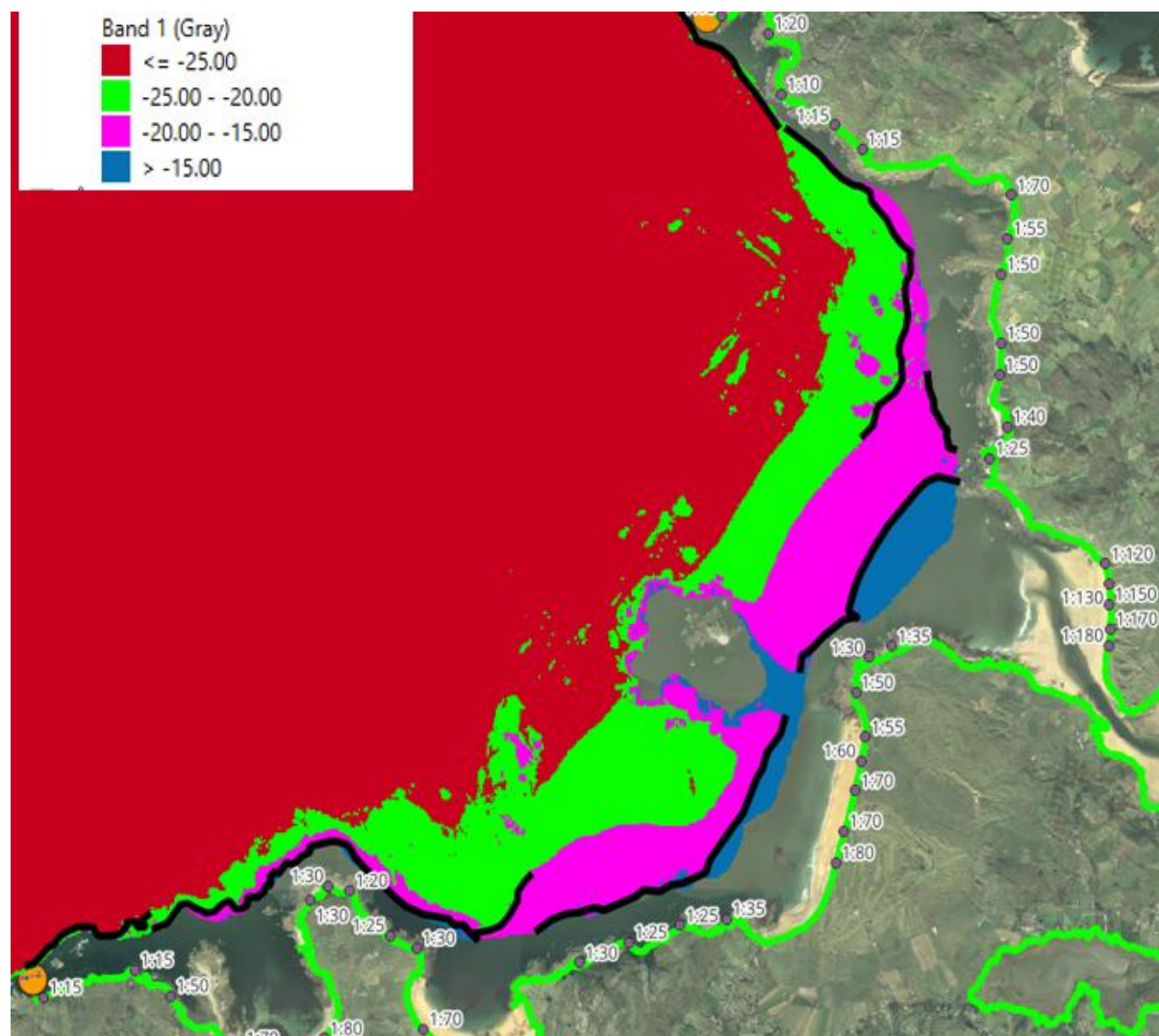


Figure 6-2 Bathymetric data available from INFOMAR and chosen contour (black) to determine the coastal slope at Trawbreaga Bay, Co. Donegal



Figure 6-3 Coastal slope (1:X) assigned to different lengths of coast in Trawbreaga Bay, Co. Donegal, based on the chosen contour (Figure 6-1) and the coastline

Figure 6-2 and 6-3 above illustrate the contour line and coastal slope for a given part of the coastline. It should be noted that the coastal slope is generalised into groups, reflecting the fact it is a representative rather than exact value. This is considered appropriate given the dynamic nature of the coast, inconsistency in the survey dates between INFOMAR and the available LiDAR, and the national-scale of the assessment.

6.2 Hard coasts (Cliffed and Non-cliffed)

The methodology set out in Section 6.1 shall not be applied for hard coasts as these are less erodible. Where erosion does occur, this is typically associated with sudden or catastrophic, rather than chronic, failure (e.g. cliff collapse due to oversteepening) and the associated eroded material is larger and less likely to be redistributed. The behaviour of cliffs in response to sea-level rise is a further source of uncertainty in this regard.

For hard coasts, the future coastal change rate shall instead be assumed to equal the historic coastal change rate (e.g. $R_2 = R_1$).

It is acknowledged that further research into, and the development of alternative methods for, the behaviour of cliffed coasts in response to sea-level rise (in particular the sensitivity and stability of the toe of the cliff) would be beneficial.

7 Manmade Coastal Defences

The third of the three components of the CEHM assessment methodology is on assessment of manmade coastal defences present on the coastline. Manmade coastal defences are assessed by evaluating two potential failure mechanisms: failure due to defence deterioration and failure due to performance standard exceedance. An estimated year of failure is determined in each case, with the earlier of these two years then representing the year in which defence failure is anticipated to occur in each case.

Section 7.1 and 7.2 detail how to undertake the assessment of the two potential failure mechanisms.

7.1 Probability of Failure due to Defence Deterioration

The first potential failure mechanism assessed for manmade coastal defences relates to the **Defence Deterioration**, and the deterioration of the condition of a manmade coastal defence gradually over time, leading to its failure at the end of its life.

Defence deterioration curves for a range of different manmade coastal defences are developed within *Practical guidance on determining asset deterioration and the use of condition grade deterioration curves* (Environment Agency, 2013), and are adapted for use in developing CEHM in Ireland.

This publication identified the estimated deterioration curve of a defence, or the time taken for the condition of the defence to transition from 'very good' to 'very poor'. These defence deterioration curves are influenced by various factors:

- Defence type, with less robust defences likely to deteriorate faster;
- Maintenance, with poorly maintained defences likely to deteriorate faster; and,
- Exposure, where more exposed defences are likely to deteriorate faster.

The assessment also requires the existing condition of the manmade coastal defence to be estimated, as the majority of manmade coastal defences in Ireland will have been in place for many years and have therefore already been subject to varying levels of deterioration.

The age of the defence is not required to assign a defence deterioration curve. This is because a defence may have been subject to extensive maintenance, or replacement, meaning the age of the original defence has little bearing on either the current condition or future deterioration.

7.1.1 DEFENCE TYPE

Defence deterioration curves have been published for a number of different defence types. It was necessary to generalise all manmade coastal defences into a series of groups or classifications to allow a defence deterioration curve to be assigned. These groups are representative of the vast majority of manmade coastal defences that would be encountered in Ireland and are listed in Table 7-1 below.

Initial categorisation of the defence type shall be undertaken using the relevant details (e.g. asset type, material) within the Coastal Defence Asset Database. This initial categorisation shall be reviewed, and where necessary updated, through desk-based visual inspection of more recent and higher quality imagery available for use in CEHM relative to that available when the coastal defence asset database was populated (Section 3).

Table 7-1 Classification of manmade coastal defences in Ireland for the purpose of assessing defence deterioration and assigning defence deterioration curves

Defence Classification for use in assigning defence deterioration curves

Vertical Wall	Concrete
	Brick/Masonry
	Timber
	Gabion
	Sheet Piles
Embankment	Turfed only
	With Slope / Toe Protection
Sloping Wall	Turfed only
	With Slope Protection or Revetment (Permeable)
	With Slope Protection or Revetment (Impermeable)
Minor Structure	Minor Walls
	Ad Hoc Revetments / Mounds

7.1.2 DEFENCE EXPOSURE

Each manmade coastal defence shall be categorised as either 'Open Coast' or 'Estuary / Sheltered' for the purpose of identifying an appropriate defence deterioration curve. This detail shall be ascertained through available imagery and mapping, and through professional judgement, with the predominant wave direction and fetch length typically the key determining factors.

7.1.3 DEFENCE MAINTENANCE

The level of maintenance being undertaken on a given defence shall be categorised as either 'Low', 'Medium', or 'High'. The approach to this categorisation shall be as follows.

For the 'With Maintenance' management approach:

- If a public sector body or local authority has been identified as having maintenance responsibility, the 'High' maintenance approach shall be assumed;
- If the owner or maintainer has been identified as being 'private', or is unknown, the 'Medium' maintenance approach shall be assumed.

For the 'Without Maintenance' management approach, the 'Low' maintenance approach shall be assumed for all manmade coastal defences.

7.1.4 DEFENCE CONDITION

Each manmade coastal defence must be assigned an existing condition grade ranging from 1 ('very good') to 5 ('very poor'). This shall be assessed through desk-based visual inspection of available imagery.

Guidelines on how to assign defence condition are provided below:

- 1 ('very good') should typically be assigned to defences which are recently constructed (<5 years) with no sign of any deterioration;
- 2 ('good') should typically be assigned to defences which show evidence of minor defects only which do not reduce the overall performance of the defence;
- 3 ('fair') should typically be assigned to defences which show evidence of defects that may reduce the overall performance of the defence;
- 4 ('poor') should typically be assigned to defences which show evidence of defects in need of urgent repair that may significantly reduce the overall performance of the defence;
- 5 ('very poor') should typically be assigned to defences which have severe defects which mean the defence is no longer performing effectively as a coastal protection structure;

Where the quality of imagery available is insufficient to inform an assessment of defence condition with any level of confidence, then a condition of 3 ('fair') shall be assigned with the confidence rating (Section 7.3) reflecting the quality of the data available. In all cases, the date of the imagery used to assess conditions should be noted, so that deterioration since that date can be factored into the assessment. Appendix 2 includes photos of typical coastal defences as an example of the various condition grades to be assigned.

When assigning a condition grade to the manmade coastal defence, the weakest point shall be used as failure of one location may compromise the entire manmade coastal defence. If there is a significant longshore variation in the condition grade, then consideration should be given to splitting the frontage and assigning the appropriate condition grade to ensure this variation is adequately captured in the assessment and production of coastal erosion hazard mapping. An example of this would include where a continuous manmade coastal defence has been constructed in stages (even if the defence type is the same), or if some but not all of the manmade coastal defence has been subject to refurbishment works (and therefore an improved condition grade).

7.1.5 SELECTION OF DEFENCE DETERIORATION CURVE

The information derived from Section 7.1.1 to 7.1.4 shall be used to select the appropriate defence deterioration curve from Table 7-2 below.

A manmade coastal defence shall be assumed to fail in the year where the defence condition deteriorates to 5 ('very poor'). For example, take a manmade coastal defence which is:

- A vertical wall of masonry construction;
- Located on the open coast;
- Maintained by a public body; and,

- Is currently in 'good' condition (Condition Grade: 2) based on photographs dated 2025.

Based on the defence deterioration curves in Table 7-2, under the 'With Maintenance' management approach, this manmade coastal defence can be expected to deteriorate from Condition Grade 2 (good) to Condition Grade 5 (very poor) in 70 years.

The year of failure based on defence deterioration would therefore be **2096** (2026 plus 70 years).

Table 7-2 CEHM defence deterioration curves for a variety of defence types, maintenance regimes, and exposure

Defence Type	Maintenance Regime	Expected deterioration times (years) from specified Condition Grade to failure									
		Open Coast					Estuary/Sheltered				
		1	2	3	4	5	1	2	3	4	5
Vertical Wall – Concrete and Brick/Masonry	Low	50	40	20	10	0	80	65	35	20	0
	Medium	70	55	30	15	0	100	80	40	20	0
	High	90	70	40	20	0	120	95	45	20	0
Vertical Wall - Timber	Low	14	10	6	4	0	20	15	7	4	0
	Medium	28	20	10	5	0	38	24	10	5	0
	High	38	25	10	5	0	55	34	13	7	0
Vertical Wall - Gabion	Low	20	17	12	5	0	25	22	17	5	0
	('Low' only provided)	-	-	-	-	-	-	-	-	-	-
Sheet Piles Walls	Low	40	30	25	10	0	60	45	30	10	0
	Medium	60	45	35	10	0	70	50	30	10	0
	High	70	50	35	10	0	80	55	30	10	0

Defence Type	Maintenance Regime	Expected deterioration times (years) from specified Condition Grade to failure									
		Open Coast					Estuary/Sheltered				
		1	2	3	4	5	1	2	3	4	5
Embankments – turfed only	Low	30	27	24	8	0	60	55	50	20	0
	Medium	50	36	22	10	0	80	60	40	20	0
	High	60	45	30	15	0	110	88	65	30	0
Embankments with slope/toe protection	Low	40	31	21	9	0	60	50	40	20	0
	Medium	60	45	30	10	0	100	80	50	25	0
	High	80	60	40	20	0	130	100	70	30	0
Sloping walls – Turfed only	Low	30	27	24	8	0	60	55	50	20	0
	Medium	50	36	22	10	0	80	60	40	20	0
	High	60	45	30	15	0	110	88	65	30	0
Sloping walls with slope protection or revetment – Permeable & Impermeable	Low	40	31	21	9	0	60	50	40	20	0
	Medium	60	45	30	10	0	100	80	50	25	0
	High	80	60	40	20	0	130	100	70	30	0

Asset class (additional)	Maintenance Regime	Expected deterioration times (years) from specified Condition Grade to failure									
		Open Coast					Estuary/Sheltered				
		1	2	3	4	5	1	2	3	4	5
Wall – <i>Minor</i>	Low	30	25	15	9	0	50	40	20	10	0
Revetment/Mound – <i>Ad Hoc</i>	Low	15	12	7	5	0	40	31	21	9	0

7.2 Probability of Failure due to Performance Standard exceedance

The second potential failure mechanism assessed for manmade coastal defences relates to the **Performance Standard**, and the probability that a storm event occurs which exceeds the performance standard that the structure was designed, or is expected, to withstand. This is independent of the defence deterioration (Section 7.1) as a newly constructed manmade coastal defence could potentially fail, regardless of the condition, if it is exposed to a storm event greater than that which it was designed to withstand.

Whilst manmade coastal defences will typically be designed to withstand a storm event with a certain probability of occurring in any given year (e.g. 1-in-100 year, or 1% Annual Exceedance Probability), records of this are not readily available at a national-scale. In addition, there is no readily available and nationally consistent nearshore wave data suitable for use in this assessment.

The methodology set out here instead makes best use of the data which is readily available, or can be reasonably derived, for the entire coastline

7.2.1 GENERAL APPROACH

The adopted methodology requires an estimation of the current performance standard of the manmade coastal defence to be made, and uses the potential impact of sea-level rise on depth-limited wave heights, under extreme water level conditions, to assess the increasing probability over time of the performance standard being exceeded.

The steps in the process can broadly be categorised as follows:

1. Estimate the present day depth-limited wave breaking height for the 5% (1:20), 2% (1:50), 1% (1:100), and 0.5% (1:200) Annual Exceedance Probability (AEP) event based on ICWWS data;
2. Estimate future increases in these wave heights in response to future sea-level rise, for the Climate Change Timelines included in CEHM (Section 2.4.3 and Appendix 1);
3. Assign a Performance Standard (1:20, 1:50, 1:100, or 1:200) to the manmade coastal defence based on the defence details and the surrounding environment;
4. Estimate the future Performance Standard, for different Climate Change Timelines and Time Periods, based on the estimated wave heights in (1) and (2);
5. Estimate the probability of the manmade coastal defence encountering a storm event which exceeds the Performance Standard (for different Performance Standards and for each year);
6. Based on (5), determine the year of failure of the manmade coastal defence due to Performance Standard exceedance (when the probability of failure is greater than or equal to 0.99, or a 99% chance of occurring).

Steps 1 to 6 are discussed in further detail in Section 7.2.2 to 7.2.7 below.

Location of Assessment

The majority of manmade coastal defences have some form of foreshore (where waves will typically break) in front of them, and so assessing wave breaking heights at the defence would not be appropriate as waves will break further seaward in the majority of cases.

Equally, it would not be appropriate to select a point further offshore (e.g. the ICWWS estimation points) where water depths will far exceed the wave height), and it is not proportionate to undertake detailed nearshore wave modelling at the national-scale to inform CEHM.

Therefore, the point at which the foreshore is at Mean Sea Level (MSL) shall be taken as a representative location where depth-limited breaking wave heights shall be assessed. This is appropriate as (a) there is readily available national data on MSL to inform CEHM, (b) the majority of manmade coastal defences are likely to reside within or close to the normal tidal regime, and (c) this element of CEHM is a 'relative' assessment' of change over time, rather than an 'absolute' assessment which may require more detailed assessment (e.g. site-specific studies or appraisals).

7.2.2 ESTIMATING PRESENT-DAY WAVE HEIGHTS

As waves enter shallow water, they decrease in speed (bed friction), shoal, and then break. A variety of literature and published research has resulted in broad acceptance that this process typically occurs when the wave height equates to approximately $0.78 \times$ water depth (whilst acknowledging other factors like bed slope can influence this).

For the purpose of CEHM, National Coastal Extreme Water Levels for the 5% (1:20), 2% (1:50), 1% (1:100), and 0.5% (1:200) Annual Exceedance Probability (AEP) events shall be extracted from the nearest or most appropriate ICWWS estimation point. Mean Sea Level shall be extracted from the Mean Sea Level to OD Malin (OSGM15) Corrective Surface developed as part of ICWWS.

This data can then be used to determine the water depth, at a representative location where foreshore is at Mean Sea Level (MSL), for each of the four AEP events set out above.

For example at Strandhill, Co. Sligo, the nearest and most appropriate ICWWS estimation point for use is North West Point NW6 and MSL is -0.060mOD (OSGM15). The water levels corresponding to NW6, water depths at the representative location, and corresponding breaking wave heights are illustrated in Table 7-3 below.

Table 7-3 Example estimation of present day water depths and breaking wave heights for a representative location where the foreshore level is equal to MSL at Strandhill, Co. Sligo (ICWWS estimation point NW6)

AEP	Extreme Water Level (EWL) (mOD)	Water Depth above MSL (m)	Breaking Wave Height (m)
<i>Extracted from published ICWWS (2018) data</i>		<i>(EWL – MSL)</i>	<i>0.78 x Water Depth above MSL</i>
5% (1:20)	3.14	3.20	2.50
2% (1:50)	3.27	3.33	2.60
1% (1:100)	3.37	3.43	2.68
0.5% (1:200)	3.47	3.53	2.75

Given the spatial distribution of the ICWWS estimation points and the resolution of the MSL corrective surface, multiple manmade coastal defences may use the same ICWWS estimation point or MSL in some instances.

7.2.3 ESTIMATING FUTURE WAVE HEIGHTS

The exact same principle as described in Section 7.2.2 applies, with the only variation being that the corresponding sea-level rise component is added to the water depth, and the wave breaking height recalculated accordingly.

For the Slower Onset Climate Change Timeline, sea-level rise of 0.50m is estimated by 2100 (with no adjustment for isostatic rebound as Strandhill, Co. Sligo resides north of County Waterford to Mayo inclusive). Therefore, in 2100, the water depth for the 5% AEP event will increase from 3.20m to 3.70m and the corresponding breaking wave height will increase from 2.50m to 2.89m.

7.2.4 ASSIGNING PERFORMANCE STANDARD

The performance standard of manmade coastal defences relates to the storm event that a defence has been designed to withstand. This is independent of condition grade.

Acknowledging the lack of as-built data or design reports to accurately assign a performance standard to manmade coastal defences at a national-scale, for the purpose of NCEHM each manmade coastal defence will be assigned one of four performance standards: 1:20 (or 5% AEP), 1:50 (or 2% AEP), 1:100 (or 1% AEP), and 1:200 (or 0.5% AEP).

Suitably experienced qualified and experienced staff (typically engineers, geologists, or coastal scientists) shall apply professional judgement to assign a performance standard to each manmade coastal defence. Defence details (e.g. defence type, size and width, construction material, quality and detail of construction), the surrounding environment (e.g. foreshore levels, presence of bedrock, degree of exposure to waves), and the appropriateness of the defence to the surrounding environment shall be considered when assigning

performance standard. A variety of datasets discussed previously will assist in this assessment with oblique imagery, aerial imagery and the manmade coastal defence data being of particular value.

Guidelines on how to assign performance standard are provided below:

- 1:20 should typically be assigned to less robust structures such as gabions and timber walls, and also other minor works such as small walls and ad-hoc mounds of rock or rubble, but may also be applied to other types of structure if they appear to be of poor quality construction or are of an inappropriate or inadequate design given the surrounding environment.
- 1:200 should typically only be assigned to very robust structures (e.g. large concrete seawalls) which have been subject to detailed engineering design and appear to be substantial, of good quality construction, and well suited to the surrounding environment.
- The distinction between 1:50 and 1:100 should be on a case by case basis, considering the above factors when assessing the suitability of the defence given the surrounding environment. Masonry walls and rock revetments would typically be expected to fall under these performance standards.

As an example, the existing rock revetment and seawall at Strandhill, Co. Sligo (Figure 7-1) would be assigned a performance standard of 1:100.

This is on the basis that it is a well-designed, good quality structure appropriate to the surrounding environment, however the potential of damage to the masonry wall and displacement of rock means that a 1:200 is not considered appropriate when considering the exposed location. As with defence condition, the date of the imagery used to estimate Performance Standard should be noted.

When assigning a performance standard to the manmade coastal defence, consideration should be given to any significant longshore variation in the performance standard, and the potential merit of splitting the frontage and assigning the appropriate performance standard to ensure this variation is adequately captured in the assessment and production of coastal erosion hazard mapping. An example of this would include where a continuous manmade coastal defence has been constructed with no erosion protection to the landward face but a significant variation in crest level (indicating the length with a lower crest level may be more susceptible to structural damage in extreme events).



Figure 7-1 Existing coastal defence at Strandhill, Co. Sligo consisting of masonry seawall fronted by a rock revetment in an exposed location

7.2.5 ESTIMATING FUTURE PERFORMANCE STANDARD

Future performance standard is subsequently estimated by evaluating the change in exposure to depth-limited wave heights in response to sea-level rise, based on the estimated wave heights (Section 7.2.2 and 7.2.3) and the assigned estimated current Performance Standard (Section 7.2.4).

The existing performance standard of the manmade coastal defence at Strandhill, Co. Sligo is determined to be 1:100, corresponding to a breaking wave height of 2.68m (see Table 7-3). However, increasing water depth associated with sea-level rise, and corresponding increasing breaking wave heights means that it may not be able to withstand a storm event of that magnitude in the future.

Table 7-4 below sets out how the performance standard will reduce for Strandhill, Co. Sligo in the future under the Slower Onset Climate Change Timeline and for selected time periods for illustrative purposes only.

As the manmade coastal defence at Strandhill can withstand breaking wave heights of 2.68m, by 2080 this is only sufficient to withstand the 10% AEP storm event in the Slower Onset Climate Change Timelines due to the impacts of sea-level rise.

Table 7-4 Example estimation of future performance standard based on estimated breaking wave heights for a representative location where the foreshore level is equal to MSL at Strandhill, Co. Sligo (ICWWS estimation point NW6). Note: current performance standard estimated to be 1:100 (see Section 7.2.4)

Year	AEP	Present-Day Extreme Water Level (mOD)	Sea-Level Rise (m)	Water Depth above MSL (m)	Breaking Wave Height (m)
2025	1% (1:100)	3.37	-	3.43	2.68
2040	2% (1:50)	3.27	0.10	3.43	2.68
2080	10% (1:10)	3.03	0.35	3.44	2.68
2110	50% (1:2)	2.79	0.58	3.44	2.68

Note: MSL at Strandhill, Co. Sligo is -0.060mOD (Section 7.2.2)

7.2.6 ASSESSING PROBABILITY OF EXCEEDANCE IN ANY GIVEN YEAR

The probability, P , of a manmade coastal defence encountering a storm event which exceeds the performance standard, T (years), during a time period, N (years), shall be estimated using the following formula:

$$P = 1 - \left(1 - \frac{1}{T}\right)^N$$

For example, again looking at Strandhill, Co. Sligo, and with reference to Table 7-4, the manmade coastal defence is able to withstand a 2% AEP storm event in 2040 ($N = 15$ years), so the equation becomes:

$$P = 1 - \left(1 - \frac{1}{50}\right)^{15}$$

This yields a probability of 0.26 (or a 26% chance). However, by 2080 ($N = 55$ years), it is only able to withstand the 10% AEP storm event ($T = 10$). This equates to a probability of 0.997 (or 99.7%).

7.2.7 ASSESSING PROBABILITY OF FAILURE DUE TO EXCEEDANCE

For the purpose of CEHM, the threshold for the probability of failure due to exceedance shall be set at 0.99 (or a 99% chance), given a probability of 1.00 (or 100%) is a statistical impossibility.

Therefore, by following the approach set out above, it is possible to determine the year in which the probability of failure is first equal to or greater than 0.99.

This determined year of failure will vary from one defence to another based primarily on the present-day performance standard, the extreme water levels at that location, and the climate change timeline assumed.

Table 7-5 below illustrates the output of the assessment for Strandhill, Co. Sligo and the corresponding year of failure due to exceedance determined.

Table 7-5 Probability of failure due to exceedance for a representative location where the foreshore level is equal to MSL at Strandhill, Co. Sligo (ICWWS estimation point NW6). Note: current performance standard estimated to be 1:100 (see Section 7.2.4)

Year	AEP	Probability of Failure (P)	Defence Failure (Yes or No)
2025	1% (1:100)	-	No
2040	2% (1:50)	0.26 (26%)	No
2060	5% (1:20)	0.83 (83%)	No
2075	8% (1:12.5)	0.98 (98%)	No
2080	10% (1:10)	0.996 (99.6%)	Yes

In this example, the year of failure due to exceedance would be taken as **2080** (nearest five years), as the probability of failure in 2075 is less than 0.99.

7.3 Assigning a Confidence Rating

On completion of the assessment of manmade coastal defences, the final task is to attribute a Confidence Rating to the assessment undertaken for each manmade coastal defence. The purpose of this is to ensure the level of confidence attached to the selected 'condition grade' and 'performance standard' is captured. A rating score and Confidence Rating shall be assigned to each of the 'condition grade' and 'performance standard' assessments individually.

A rating score between 0 (zero) and 10 (ten) for each manmade coastal defence shall be derived based on the assessment methodology used. The rating score shall be translated into an assigned Confidence Rating (High, Medium, or Low) as set out in Table 7-6 below.

Table 7-6 Derivation of a rating score and Confidence Rating for the Historic Coastal Change Assessment

Assessment methodology		Rating score (0 to 10)	Confidence Rating (H/M/L)
Condition Grade	Performance Standard		
Full and recent site-based condition survey (<1 year)	Detailed design details available	10	High
Recent site-based visual inspection (<2 years)		9	High
High quality recent imagery (e.g. high resolution oblique imagery, <2 years)	Detailed Local Authority knowledge / information	8	High
Site-based visual inspection (2-5 years)		8	High
	Observational data / evidence (e.g. storm records, photographs) to inform estimate	7	Medium
Good quality photographs (<5 years)	High quality recent imagery (e.g. high resolution oblique imagery, <2 years)	5	Medium
Older imagery (5-10 years)	Local anecdotal opinion	3	Low
Poor or restricted older imagery (> 10 years)	Default value based on defence type only	2	Low
Assumption based on age / type		1	Low

7.4 Coastal Catch Up

Where manmade coastal defences are present, these will prevent coastal erosion for the period of time that they continue to operate effectively, or up to defence failure (see sections 7.1 and 7.2 with regard to potential failure mechanisms). After this point, coastal erosion will recommence.

Coastal catch up refers to the phenomenon, backed by observational evidence (Walkden, 2015) whereby a previously defended shoreline, upon failure of the defence, displays accelerated erosion until the shoreline returns to a more natural recession rate in line with the adjacent undefended shoreline (or the point that it 'catches up' with the adjacent undefended shoreline).

Once the manmade coastal defence fails, the initial coastal erosion that occurs (the coastal catch up period) will be faster than the historic rate of coastal change (Section 5), as the shoreline tends towards its 'natural' trajectory, i.e. the projected position it would have been by that time had no manmade coastal defence been built. Figure 7-2 illustrates this process where:

- A. Represents the year the manmade coastal defence was introduced (1990);
- B. Represents the period the coastline was protected for (1990 to 2040);
- C. Represents the estimated year of defence failure (2040);
- D. Represents the coastal catch up period (2040 to 2060); and,
- E. Represents the point at which the previously defended coastline catches up with the 'natural' trajectory or the adjacent undefended coastline.

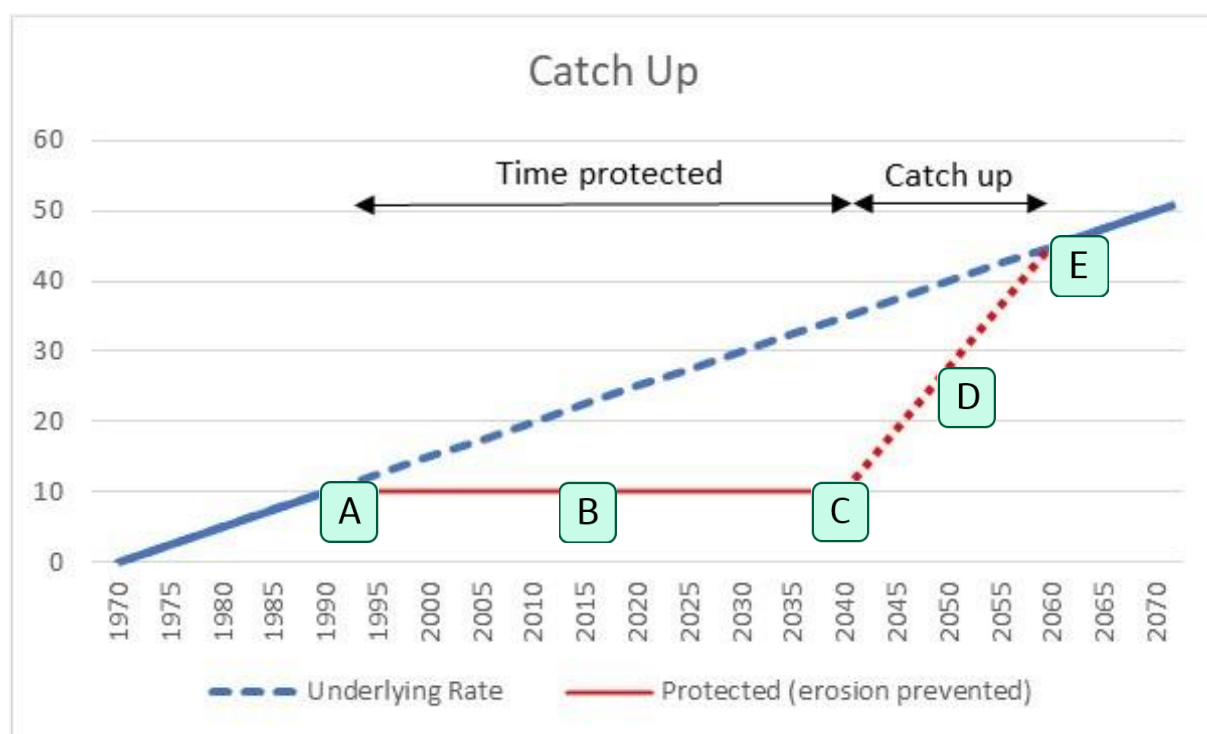


Figure 7-2 Example timeline of coastal change, including coastal catch up, for a frontage where a manmade coastal defence is present

The main factors that influence coastal catch up are the historic coastal change rate, as determined in Section 5, and the period of time that the frontage has been protected by the manmade coastal defence i.e. year of introduction to year of failure.

Observational evidence available indicates that coastal catch up occurs at a rate of between 3 and 5 times the historic rate of coastal change. Whilst observational information on coastal catch up remains sparse, it is also reasonable to assume that a shoreline which has been defended for longer will have a longer expected coastal catch up period.

7.4.1 YEAR OF INTRODUCTION

In the absence of comprehensive as-built records at a national level, engagement with the defence owner offers the best opportunity to accurately identify the year of introduction of a manmade coastal defence, and this shall be populated in the Coastal Defence Asset Database where known.

Where it is unknown, desk-based visual inspection of aerial photography and oblique imagery provides the basis of determining the year a manmade coastal defence was first introduced, based on a simple visual check of presence or absence. If a manmade coastal defence is evident (present) in 2000 aerial imagery but is not evident (absent) in 1995 aerial imagery, the year of introduction would be between 1995 and 2000.

For manmade coastal defences introduced prior to 1995, the available imagery and mapping is limited, and this will mean the year of introduction will be estimated as a range rather than an exact year. In these cases, the mid-year of the range will be selected as the year of introduction as per Table 7-7 below. For manmade coastal defences constructed more recently (since 1995), more frequent imagery is available so the “To” year in the range shall be used as the year of introduction.

Table 7-7 Determining Year of Introduction from available imagery

Available Data (From)	Year (From)	Available Data (To)	Year (To)	Assumed Year of Introduction
-	-	Historic mapping*	1924*	1924
Historic mapping	1924	Aerial imagery	1973	1949
Aerial imagery	1973	Aerial imagery	1995	1984
Aerial imagery	1995	Aerial imagery	2000	2000
Aerial imagery	2000	Oblique imagery	2003	2003
Oblique imagery	2003	Aerial imagery	2005	2005
Aerial imagery	From	Aerial imagery	To**	To**

*All available 6” and 25” historic mapping in Ireland was surveyed in 1924 or earlier.

**Same principle of adopting the “To” year as the year of introduction applies to all data (typically Tailte Éireann aerial imagery but also OPW imagery) more recent than 2005

7.4.2 ESTIMATING COASTAL CATCH UP PERIOD

Coastal catch up is applied at the year of failure, not the year of assessment. As such, the coastal catch up period is estimated based on the number of years the shoreline has been protected at the time of defence failure. This is the period between the assumed year of introduction (see Section 7.4.1 and Table 7-7) and the estimated year of failure (the earlier of the year of failure due to defence deterioration, Section 7.1, and the year of failure due to exceedance, Section 7.2).

If the year of introduction is estimated to be 2000, the year of failure due to defence deterioration is estimated to be 2065, and the year of failure due to exceedance is estimated to be 2090, then the number of years the shoreline has been protected at failure would be 65 years (2000 to 2065).

In line with observational evidence, the coastal catch up period shall be assumed to occur approximately 3 and 5 times faster than the historic rate of coastal change. For the purpose of CEHM, this principle shall be applied by assigning the coastal catch up period over a number of generalised bands (Table 7-8 below) of 'years protected', to avoid using a level of precision that could be misleading. In the example above, a manmade coastal defence which has protected the shoreline for 65 years at the time of failure would fall into the "50-70 years" band and be assigned a coastal catch up period of 20 years.

Table 7-8 Coastal catch up periods to be assigned based on the total number of years protected at the time of failure

Years Protected (at time of failure)	Coastal Catch Up Period
< 15 years	5 years
15 – 30 years	10 years
30 – 50 years	15 years
50 – 70 years*	20 years
70 – 100 years*	25 years
100+ years	30 years

**Where a range of 50-100 years is determined and this cannot be refined further, a coastal catch up period of 20 years shall be assumed.*

8 Combining Recession and Defence Timelines

As outlined in Section 2, CEHM is a map identifying areas where coastal erosion may occur in the future. This mapping is produced by generating a future coastal change timeline from the Historic Coastal Change Assessment and Future Coastal Change Assessment only (for undefended frontages) or the Historic Coastal Change Assessment, Future Coastal Change Assessment and Manmade Coastal Defences assessment (for defended frontages). These future coastal change timelines are produced for, and vary between, each management approach and climate change timeline. An individual future coastal change timeline shall be generated for each individual frontage (as well as each management approach and climate change timeline) and will vary from frontage to frontage depending on their characteristics.

It is important to note that CEHM does not predict the future coastline position; it instead identifies an area of land that may potentially experience coastal erosion over the timescales specified under each management approach and climate change timeline. It also does not provide projections of how coastal erosion can affect the foreshore or nearshore - i.e. areas of land/seabed frequently or always covered by the tide.

CEHM focusses on coastal erosion, therefore the hazard mapping does not display areas where seaward progradation of the backshore may occur in future due to coastal accretion. However, the predictions of future coastal change do show potential accretion distances over time (as a negative distance) where relevant.

The following sections set out how to generate:

- An underlying recession timeline, based primarily on the Historic Coastal Change Assessment and the Future Coastal Change Assessment;
- A defence failure timeline, based primarily on the Manmade Coastal Defence assessment including coastal catch up;
- A combined future coastal change timeline, based on combining the 'underlying recession' and 'defence failure' timelines.

8.1 Underlying Recession Timeline

The underlying recession timeline must be generated for all frontages. Where no manmade coastal defences are present, it also represents the future coastal change timeline. It shows the estimated coastal erosion (or recession) over time with recession distance on the y-axis and year on the x-axis.

The underlying recession timeline is generated by extrapolating the assessed historical coastal change rate into the future with (for the Slower Onset, Medium Onset and Faster Onset climate change timelines) and without (for the Present Day climate change timeline) climate change.

For the Present Day climate change timeline, this uses the historic coastal change rate (m/yr) estimated for each frontage (Section 5), with the total recession distance a product of that rate multiplied by the number of years.

For the Slower Onset, Medium Onset and Faster Onset climate change timelines, this uses the future coastal change rate (m/yr) estimated for each frontage (Section 6), with the total recession distance a product of that rate multiplied by the number of years.

Figure 8-1 below illustrates an example ‘underlying recession’ timeline for each of the Present Day, Slower Onset, and Faster Onset climate change timelines for a given frontage. It should be noted that whilst the coastal erosion hazard mapping is produced for selected time periods (Section 2.4.2), the underlying recession timeline shall estimate the cumulative total recession distance for each intervening year as this (a) enables easy generation of CEHM for other years on an as required basis and (b) may be non-linear.

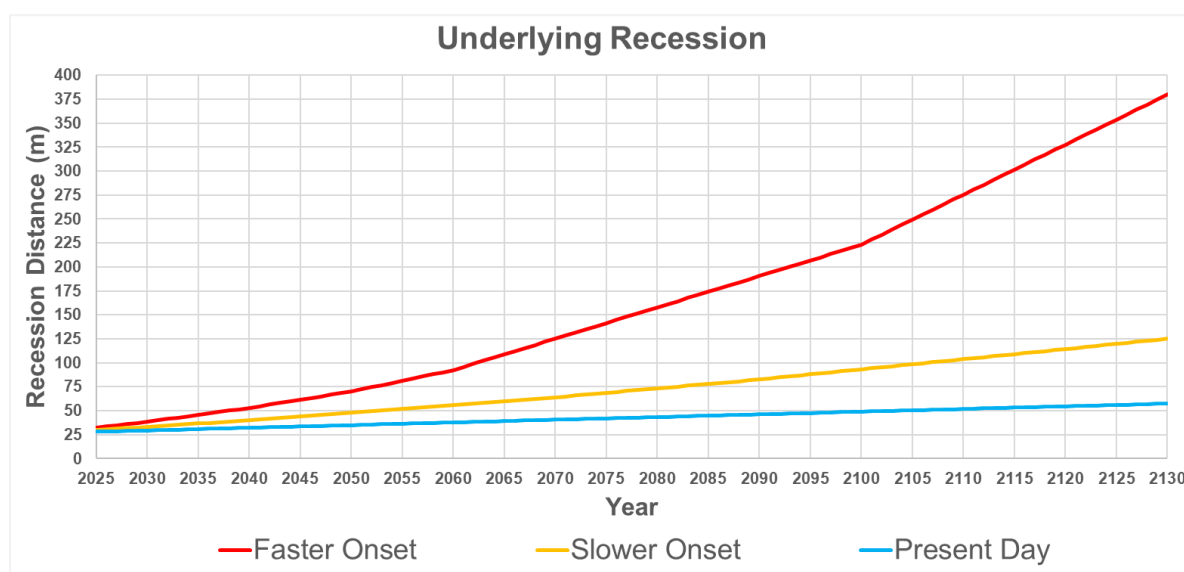


Figure 8-1 Example underlying recession timeline generated for a given frontage for the purpose of producing coastal erosion hazard mapping

8.2 Defence Failure Timeline

A defence failure timeline must be generated for all frontages where a manmade coastal defence is present. There is no requirement to generate it for undefended frontages. The ‘defence failure’ timeline shows the time over which a manmade coastal defence is expected to perform effectively and subsequently deteriorate to the point of no longer functioning and preventing erosion from occurring (defence failure).

The probability of failure between 1 (99% chance of occurring) and 0 (1% chance of occurring) is on the y-axis and year is on the x-axis. Again, 99% and 1% are selected given 100% and 0% are a statistical impossibility.

For the purpose of CEHM, a manmade coastal defence is assumed to move from a 1% chance of failure occurring to a 99% chance of failure occurring in the year of defence failure as estimated in Section 7. As a reminder, this year of defence failure is the earlier of the estimated year of failure due to defence deterioration and the estimated year of failure due to exceedance. As sea-level rise directly impacts the future performance standard, it is possible that this year of failure, or indeed the cause of failure, may vary for the same frontage under

different climate change timelines (e.g. a defence may fail due to defence deterioration in the Present Day climate change timeline, but it may fail instead due to performance standard exceedance in the Slower Onset climate change timeline).

As a result of this approach, whilst the underlying recession timeline is curved in shape, the defence failure timeline has a rigid 's' shape with the 'protected' period preceding the 'unprotected' period, and the two being linked by a vertical line (Figure 8-2).

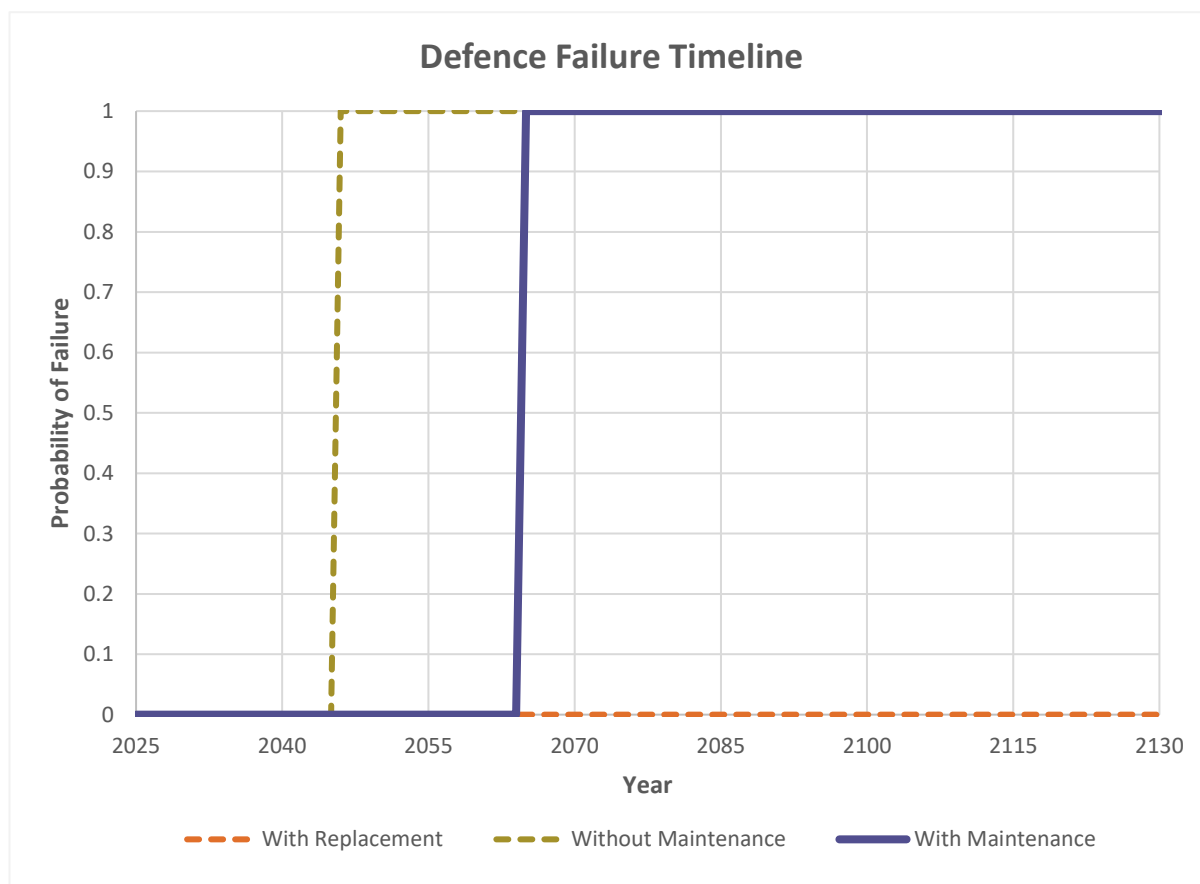


Figure 8-2 Example defence failure timeline generated for a given defended frontage for the purpose of producing coastal erosion hazard mapping

8.3 Combined Future Coastal Change Timeline

Where no manmade coastal defence is present, the future coastal change timeline is the underlying recession timeline. No work is required to combine it with the defence failure timeline.

Where manmade coastal defences are present, the future coastal change timeline is generated by combining:

- The period of time that the defence protects the shoreline, up to the year of defence failure;
- The duration of the coastal catch up period following defence failure; and,

- The underlying recession anticipated once the previously defended frontage has 'caught up', and the shoreline returns to a more natural recession rate in line with the adjacent undefended shoreline.

The approach for combining the underlying recession timeline and the defence failure timeline is set out below.

1. Up until the year of defence failure, there will be no recession, or zero (0) metres recession distance. This is identical to the defence failure timeline;
2. In all years following the coastal catch up period (determined as per Section 7.4), or year of defence failure plus coastal catch up period, the future recession will revert to that of the natural recession rate of the shoreline. This is identical to the underlying recession timeline;
3. In the intervening years representing the coastal catch up period, a linear recession (single gradient line) shall be assumed commencing in the year of defence failure and concluding with the end of the coastal catch up period (when the natural, not accelerated, recession rate will occur again).

This combined future coastal change timeline will vary for the "With Maintenance" and "Without Maintenance" management approaches for each frontage.

An example of a combined future coastal change timeline is provided in Figure 8-3.

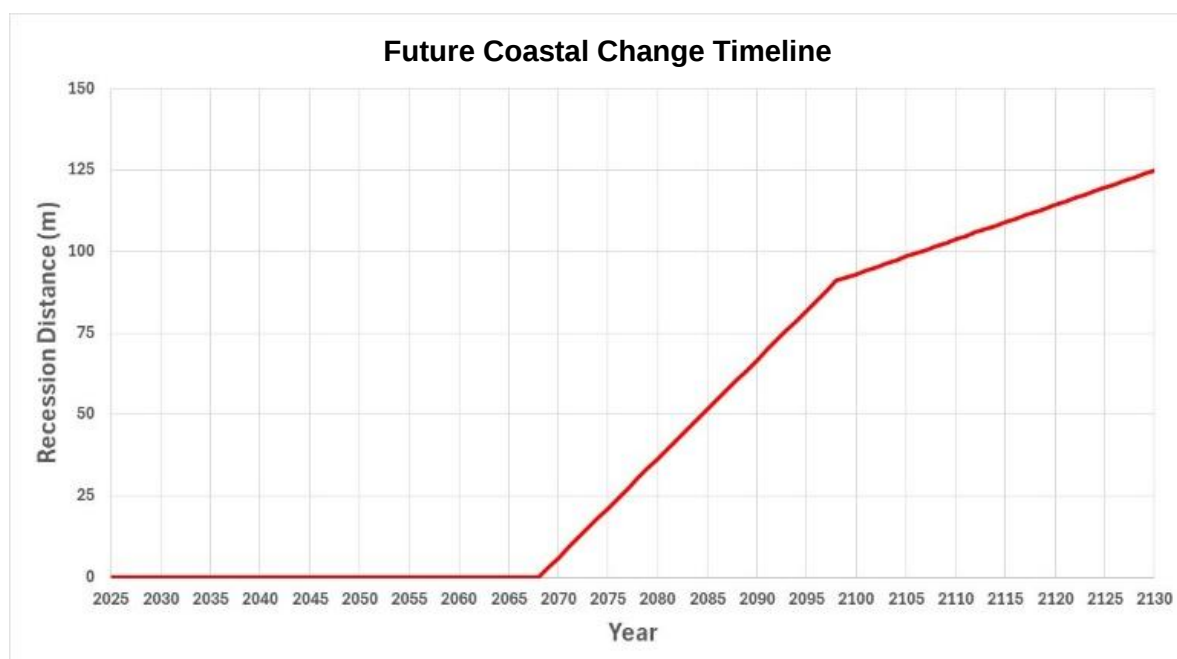


Figure 8-3 Example future coastal change timeline generated for a given defended frontage for the purpose of producing coastal erosion hazard mapping

9 Mapping Outputs

This section details the mapping outputs and summarises how the coastal erosion hazard mapping shall be generated. Coastal erosion hazard mapping shall be displayed by polygons rather than polylines on a map. This is done to avoid indicating the future coastline position but rather to indicate an area of land that may be impacted by the effects of coastal erosion in the future.

9.1 Presentation and Symbolology

Mapping outputs shall be presented in a manner which is clear, consistent and can easily be interpreted by a non-technical audience. Coastal erosion hazard mapping shall be presented through the use of areas (polygons) at potential risk of coastal erosion, with transparency set to an appropriate level to allow background mapping or aerial imagery to be visible and interpretable. The use of linear extents (polylines) in isolation shall not be accepted.

The CFL shall be presented on all mapping outputs as a continuous linear feature. The colours used to identify coastal erosion hazard zones shall be yellow (2050), brown (2080) and grey (2130). An example of these is illustrated in Figure 9-1 below.



Figure 9-1 Example of coastal erosion hazard mapping symbology, produced as part of the Predictive Coastal Erosion Hazard Mapping pilot study

9.2 Non-Erodible Features

The draft CEHM developed is based on the Future Coastal Change Timeline and the assessment undertaken to inform that timeline. The Future Coastal Change Timeline does not directly account for any change in geology in a cross-shore direction. As the coastline is

projected to retreat in a landward direction (coastal erosion), the extent of that landward movement may be constrained by a shift from a softer, more erodible coast transitioning into a harder, less erodible geology present further landward.

A desk-based visual inspection of available geology mapping and aerial imagery shall be undertaken to verify whether any features are visible or evident that may be expected to prevent erosion from occurring beyond that point (e.g. hard rock outcrop or subcrop). This verification process shall use available aerial imagery (Section 3.3), GSI Geology Mapping (Section 3.8), and OPW Oblique Imagery (Section 3.9).

Where less erodible features are identified within the draft CEHM, a 'masking polygon' shall be created to spatially identify those features and consider editing the CEHM to reflect the likely behaviour of the coastline as and when those features are encountered. There is no requirement to undertake this exercise for areas beyond the extent of the coastal erosion hazard mapping.

9.3 Spatial Data Requirements

Spatial Data Requirements for the purpose of CEHM are set out in "*Coastal Erosion Hazard Mapping Spatial Data Specification V1.0*" (OPW, 2026). All spatial data developed when producing CEHM deliverables shall meet the requirements sets out in this document, including:

- Data management
- Quality assurance requirements
- Data delivery
- File type and file naming
- Attribute fields and attribute naming
- File structure

The spatial data required to be created when developing coastal erosion hazard mapping are set out in the above document and includes, but is not limited to, manmade coastal defences (polyline), the CFL (polyline), and the coastal erosion hazard mapping (polygon).

9.4 Mapping Requirements

All coastal erosion hazard mapping shall be produced in a GIS-compatible format. Coastal erosion hazard mapping shall be generated for each combination of management approaches, climate change timelines, and time periods:

- Management Approaches – **Without Maintenance, With Maintenance and With Replacement**
- Climate Change Timelines – **Present Day, Slower Onset, Medium Onset and Faster Onset**
- Time Periods – **2050, 2080 and 2130**

This will equate to a combined set of thirty-six (36) unique coastal erosion hazard areas for each frontage, although in some cases the hazard areas will be identical for a given frontage. For example:

- Where no manmade coastal defence is present, the coastal erosion hazard mapping for the **Without Maintenance**, **With Maintenance**, and **With Replacement** management approaches will all be identical.
- Where manmade coastal defences are present, but the year of failure occurs after 2050 in all management approaches, the 2050 coastal erosion hazard mapping for the **Without Maintenance**, **With Maintenance** and **With Replacement** management approaches will all be identical

Coastal erosion hazard mapping shall typically be viewed at a scale of 1:5,000 to 1:10,000 and on a dedicated web-based viewer to be developed by the OPW. There is no requirement to generate pdf maps.

Coastal erosion hazard mapping shall comply with the spatial data requirements set out in Section 9.

Appendix 1 – Decadal future sea-level rise and isostatic rebound projections for Ireland

Climate Change Timeline	Future Sea Level Rise (metres)											
	2021	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130
Present Day	0.00	0.025	0.05	0.075	0.10	0.125	0.15	0.175	0.20	0.225	0.25	0.275
Slower Onset	0.00	0.05	0.10	0.16	0.22	0.28	0.35	0.42	0.50	0.58	0.66	0.74
Medium Onset	0.00	0.05	0.11	0.18	0.26	0.35	0.45	0.57	0.70	0.85	1.00	1.15
Faster Onset	0.00	0.09	0.20	0.33	0.50	0.75	1.00	1.25	1.50	1.90	2.30	2.70

Climate Change Timeline	Isostatic Rebound, County Waterford to Mayo inclusive <u>only</u> (metres)											
	2021	2030	2040	2050	2060	2070	2080	2090	2100	2110	2120	2130
Present Day	0.000	-0.006	-0.012	-0.018	-0.024	-0.030	-0.036	-0.042	-0.048	-0.054	-0.060	-0.066
Slower Onset	0.00	-0.006	-0.012	-0.018	-0.024	-0.030	-0.036	-0.042	-0.048	-0.054	-0.060	-0.066
Medium Onset	0.00	-0.006	-0.012	-0.018	-0.024	-0.030	-0.036	-0.042	-0.048	-0.054	-0.060	-0.066
Faster Onset	0.00	-0.006	-0.012	-0.018	-0.024	-0.030	-0.036	-0.042	-0.048	-0.054	-0.060	-0.066

Note: isostatic rebound in the south of Ireland refers to subsidence, or a negative vertical land movement. Therefore the cumulative impact of sea-level rise and isostatic rebound (S₂, see Section 6.1) in the south of Ireland would be 0.75 metres plus 0.03 metres (Faster Onset, 2070), equating to a combined 0.78 metres. Same principle applies to all climate change timelines and time periods.

Appendix 2 – Condition Grade Photographs

Available Imagery	Condition grade
	Type: Wall Condition Grade: 2. Defence is in “good” condition, with minor defects only which do not reduce the overall performance of the defence.
	Type: Wall Condition Grade: 2. Defence is in “good” condition, with minor defects only which do not reduce the overall performance of the defence.

Available Imagery	Condition grade
	Type: Wall Condition Grade: 3. Defence is in “fair” condition, with some evidence of defects (e.g. cracking, spalling) that may reduce the overall performance of the defence.
	Type: Rock Revetment Condition Grade: 2. Defence is in “good” condition, with minor defects only which do not reduce the overall performance of the defence.

Available Imagery	Condition grade
	Type: Rock Revetment Condition Grade: 3. Defence is in “fair” condition, with some evidence of defects (e.g. inconsistent profile) that may reduce the overall performance of the defence.
	Type: Rock Revetment Condition Grade: 4. Defence is in “poor” condition, with evidence of defects (e.g. missing and displaced rock) in need of urgent repair that may significantly reduce the overall performance of the defence.

Available Imagery	Condition grade
	Type: Revetment Condition Grade: 5. Defence is in “very poor” condition, with evidence of severe defects which mean the defence is no longer performing effectively as a coastal protection structure.