SLIGO BAY COASTAL FLOODING AND EROSION RISK MANAGEMENT (CFERM) STUDY

Final Report

IBE 1907
Final
18th May 2023

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
Draft	Client Review	KC	MB	AKB	15/09/2022
Draft	Client Review	KC	MB	AKB	21/09/2022
Final	Client Review	KC	MB	AKB	18/05/2023

Approval for issue

Adrian Bell	Adrian x. Bell	18 May 2023

Prepared by:

RPS

Kristopher Calder
Senior Associate

Elmwood House
74 Boucher Road, Belfast
Co. Antrim BT12 6RZ

T +44 2890 667 914
E Kristopher.calder@rpsgroup.com

Prepared for:

Sligo County Council

Val Baynes
Senior Executive Engineer

Sligo County Council
County Hall, Riverside, Sligo
Ireland, F91 Y763

T 071 9111962
E vbaynes@sligococo.ie

Contents

Tables

Figures

1 INTRODUCTION

RPS was commissioned by Sligo County Council (SCC) to undertake a Coastal Flood Erosion Risk Management (CFERM) study of two individual sites of interest along the Sligo coastline, namely Strandhill and Easkey. The purpose of this study was to provide a basis for establishing appropriate management policies for areas affected by erosion or flooding and to set the framework for managing these risks in the future. Specifically, this study aimed to:

- Establish the risks of coastal flooding and erosion to people and the developed, historic and natural environment in a clear and coherent manner.
- Identify opportunities to maintain and improve the environment by managing the risks from coastal flooding and erosion.
- Identify policies for managing coastal flood and erosion risks over a defined time.
- Consider the social, environmental, and financial consequences of implementing the preferred policies.
- Discourage inappropriate development in areas where coastal flood and erosion risks are high.
- Ensure that any proposed scheme was compatible with international and national environmental conservation legislation.

These aims are achieved through a series of stages, developed by the OPW and specified in Schedule A.1 of the CFERM guidance. These stages are:

1. Review and assess existing Information.
2. Identify information gaps & arrange for necessary field surveys.
3. Undertake condition surveys of existing coastal protection structures and other surveys.
4. Assessment of existing coastal processes and coastline evolution.
5. Preparation of detailed current & future scenario coastal flood & change maps.
6. Detailed risk assessment.
7. Preliminary environmental assessment & consultation.
8. Options & feasibility assessment.
9. Preparation of coastal flood & erosion risk management plan.
10. Economic assessment of benefits & costs.
11. Reporting & recommendations.

Having gathered sufficient survey data to inform this study during the early phase of the project (RPS, 2021), this report presents a comprehensive description and assessment of the coastal flooding and erosion pressures at Easkey and Strandhill, and describes sustainable plans to mitigate coastal flooding and erosion risk at Easkey and Strandhill over the short to long-term.

1.1 Description of the Study Areas

The study area comprised two individual sites, Strandhill and Easkey, both of which are located on the northwest coast of Ireland in County Sligo, within Donegal Bay as illustrated in Figure 1.1

The coastline in this region is Atlantic-facing and therefore exposed to high-energy waves driven onshore during high-magnitude storms. As such, much of the coastline along the Northwest region can be very responsive to storm events over short time scales (Knight, et al., 2009). However, the generally indented and rocky nature of the coastline of County Sligo limits the potential for significant interaction between the sediment transport regimes at the two sites with adjoining areas. As such it is considered reasonable to consider standalone coastal management measures for each area in isolation.

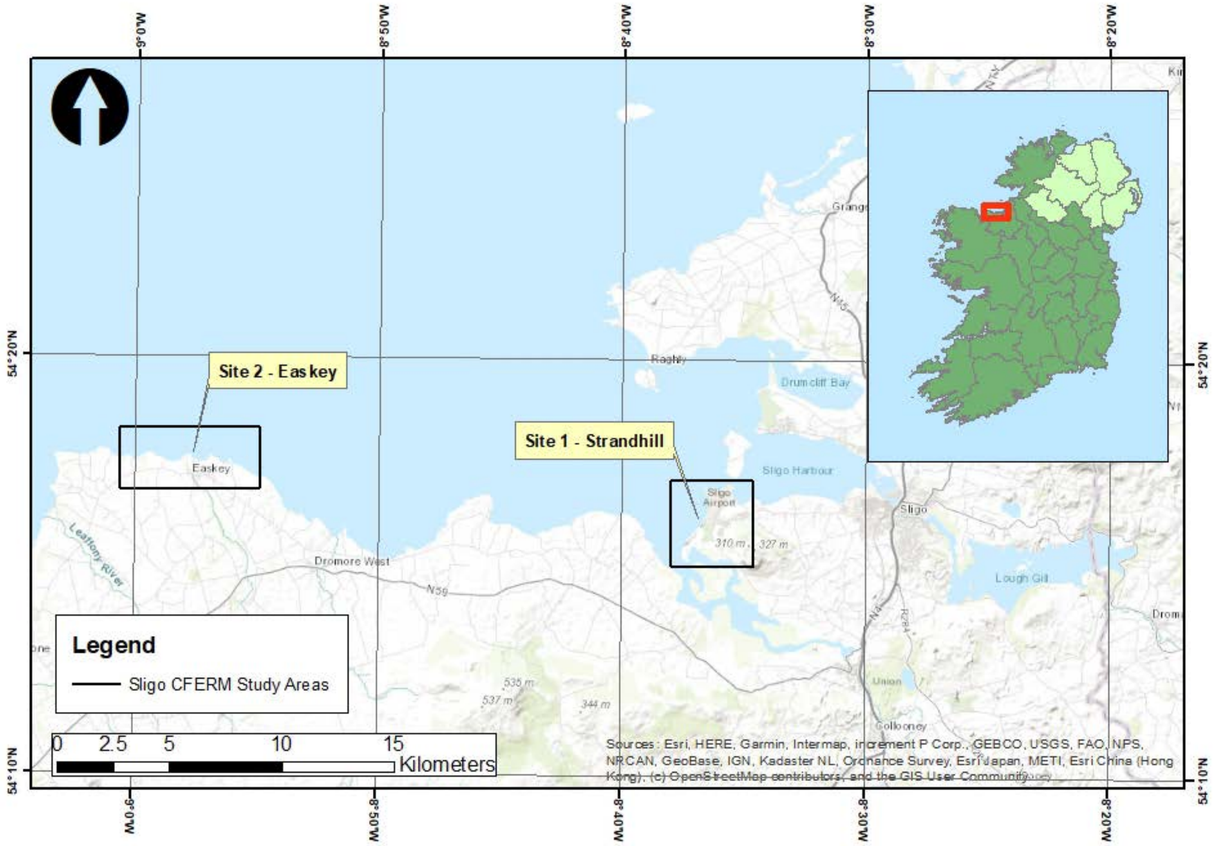


Figure 1.1: Sites included within the Sligo Bay CFERM Study

1.1.1 Site 1 – Strandhill

The study area of Strandhill extends from Dorrins Strand in the north along Strandhill beach to Culleenamore Strand in the south. In 2011, RPS assessed the shoreline movements through appraisal of historical aerial imagery as part of the Irish Coastal Protection Strategy Study (ICPSS) (OPW, 2012) and projected coastline retreat in the mid-section of the Strandhill dune system encroaching on the Strandhill Golf Course and an area of erosion north of Portcurry Point in Culleenamore Strand. The Irish Coastal Protection Strategy Study (ICPSS) (OPW, 2012) also identified a significant flood risk to the north of this study area at Dorrins Strand as well as Strandhill Beach and sections at Culleenamore Strand.

Coastal erosion along the Strandhill coastline has been a longstanding issue, KMM and RPS have been involved in studies and construction work in the area for more than 20 years. Coastal processes around the beach area are complex with extensive wave-driven currents at the beach and a tidal estuary entrance at the southern end of the dune spit.

Following a detailed hydraulic study of the Strandhill beach system in 2000, a rock beach revetment and pathway were constructed 280 metres south of the car park. The purpose of the rock revetment was to protect the low-lying area behind the dunes and to provide access along the beach during high tide. Ten years after construction, beach draw down at the revetment contributed to serious damage to the transition zone at the end of the revetment. This section was subsequently upgraded to a full rock revetment with an extended transition zone and access ramp extending further south.

In 2009, a rock revetment was constructed to protect the sewage works on the northern extent of Strandhill beach. However, the unprotected coastline adjacent to the rock revetment remains vulnerable to storm-induced coastal erosion. Further north, at Kilasprugbone Graveyard, a short stretch of wall has incurred structural damage as a consequence of its exposure to coastal processes.

Figure 1.2: Dune erosion and area of sea ingress into dunes south of rock revetment at WWTP (Sligo County Council, 2021)

Figure 1.3: Kilaspugbone Graveyard – undermining incl. collapse of a short stretch of wall (Sligo County Council, 2021)

1.1.2 Site 2 – Easkey

The study area at Easkey extends from the mouth of the Finned River at Brownstown (in the West) to the east of Temple Rock.

Key areas of interest within this area are Easkey Castle, Easkey pier and a 2.0 km stretch of road from Easkey Castle eastwards towards Cooanmore Bay which forms a popular section of the Wild Atlantic Way. Figure 1.4 shows the coast road near Easkey under threat from coastal erosion.

Despite a 1.4km stretch of the Easkey coast road being susceptible to coastal erosion, an erosion risk in this area was not identified as part of the ICPSS study (OPW, 2012).

Figure 1.4: Northerly 400m section of the coastal road looking west towards 'Poll Gorm' (Sligo County Council, 2021)

1.2 Relevant Planning Documentation

The remit of the coastal flood and erosion risk management study was reviewed with regard to relevant planning and environmental policy. The following documents were consulted during this process:

- **Project Ireland 2040: National Planning Framework (2018)**
- **Sligo County Development Plan 2017-2023**
- **Regional Planning Guidelines (2010-2022)**
- **National Marine Planning Framework (2021)**

The key strategic objectives and aims of the above policy documents that are relevant to this study are summarised as follows:

- To preserve and improve amenities
- To ensure that nature conservation policies contribute to conservation of the abundance and diversity of the Irish wildlife and its habitats
- To protect and support rural areas through careful management of physical and environmental resources and the facilitation of appropriate sustainable development

- To continue sustainable upgrading and improvement works on regional, local and tertiary roads
- To accommodate change, while maintaining the character of the countryside and coastline
- To encourage investment in long-term environmental sustainability to achieve our national goal of preserving the integrity of our natural environment for future generations
- To assess and plan for the effects of climate change in the future
- To implement sustainable, low-impact solutions (where possible) to combat flood and erosion risk
- To meet international responsibilities and obligations for nature conservation

A more detailed review of each of these planning documents is provided in the following sections of this report.

1.2.1 Project Ireland 2040: National Planning Framework

The National Planning Framework (NPF) is the Government’s high-level strategic plan for shaping the future growth and development the country out to the year 2040. It is a framework to guide public and private investment, to create and promote social opportunities and to protect and enhance the environment. The document estimates that by 2040 the population in Ireland will have increased by *c.* one million. The document recognises that this population growth will require significantly more new jobs and homes and that failure to plan for this growth would be detrimental to the built and natural environment, society and the economy.

As a framework document, the NPF defines a process by which more detailed planning documents must follow spatial planning, infrastructure planning, social and economic planning. It also outlines certain principles that these plans will have to follow, for example around sustainability, creativity and community

In relation to the coastal environment, the NPF estimates that 40% of Ireland’s population lives within 5km of the coast. However, there are key issues for planning and flood risk assessment, especially in managing the ongoing development of cities in towns in context of climate change and increasing sea levels and erosion pressures. This is recognised in the following National Policy Objectives (NPO)s:

- **NPO 41a:** Ensure that Ireland’s coastal resource is managed to sustain its physical character and environmental quality.
- **NPO 41b:** In line with the collective aims of national policy regarding climate adaptation, to address the effects of sea level changes and coastal flooding and erosion and to support the implementation of adaptation responses in vulnerable areas.

1.2.2 Sligo County Development Plan 2017-2023

Sligo’s coastline extends over 197 km, featuring sheltered bays, small islands, beaches, wild Atlantic surf and spectacular views. The unspoilt nature of the rugged coastline of Sligo with geological and hydrodynamic variability is a significant attraction (Sligo County Council, 2017).

The impacts of sea level rise on coastal erosion are not easy to estimate as some coastlines are sinking, whilst others are uplifting. Irrespective of this, a sea level rise of at least 0.5 m is specified as a design requirement in many Irish coastal projects (Sligo County Council, 2017). In response to the increasing risk of storm surges and future sea level rise as a result of climate change and the associated work undertaken by the Irish Coastal Protection Strategy Study (ICPSS) in 2013, the most recent version of the Sligo County Development Plan has carefully considered the pressures and requirements on development within the coastal zone area.

To this end, Chapter 10 of the County Development Plan sets out a number of the Council's policies for the development of the coastal zone, objectives/ policies relating to coastal protection and flood risk management. These policies and objectives include the following:

Policies (Coastal Development):

- P-DCZ-1: Generally, restrict development in the coastal zone except where it can be demonstrated that it does not detract from views, visually intrude on the coastal landscape or impact on environmentally sensitive areas. Between coastal roads and the sea, exceptions will be considered only for sustainable tourism development, public infrastructural works and development that is contiguous with existing towns and villages and subject to compliance with the Habitats Directive.

- P-DCZ-2: Restrict the location of industrial development within the coastal zone to resource-based activities that have a clear and demonstrable need, i.e. those dependent on resources available at the sea or coast (e.g. maritime industries, mariculture). All such proposals will be subject to the strict application of location, siting and design criteria and subject to compliance with the Habitats Directive.
- P-DCZ-3: Prohibit development in coastal areas where the natural erosion process is likely to threaten the viability of such development.

Objectives (Coastal Protection):

- O-CP-1: Carry out the coastal zone management and protection works subject to compliance with the Habitats Directive.
- O-CP-2: Identify, prioritise and implement coastal protection works within the coastal zone where considered necessary, subject to the availability of resources and subject to compliance with the Habitats Directive.
- O-CP-3: Monitor existing dune management schemes on an ongoing basis and carry out appropriate repairs, improvements and extensions, subject to the availability of resources and compliance with the Habitats Directive. Where appropriate, continue to employ soft engineering techniques (i.e. dune stabilisation and planting).
- O-CP-4: Examine existing beach byelaws and make appropriate amendments, in the interest of protecting sand dunes from encroachment and damage.

Policies (Coastal Protection):

- P-CP-1: Ensure that visual and environmental considerations are considered in the design of coastal defence works including compliance with the Habitats Directive.
- P-CP-2: Require that any development within the coastal zone is appropriately sited and designed, having regard to coastal flooding, future shoreline erosion, predicted sea-level rise and OPW flood mapping.
- P-CP-3: Require that detailed flood risk assessment is carried out in relation to development proposals within the coastal zone and particularly on all low-lying areas, where appropriate.
- P-CP-4: Establish natural buffers at the coast, particularly in conjunction with the preparation of local area plans and mini-plans.

Policies (Flood Risk Management)

- P-FRM-1: Protect and enhance the County's floodplains, wetlands and coastal areas subject to flooding and ensure that no removal of sand dunes, beach sand or gravel is undertaken. These areas represent a vital green infrastructure, which provides space for storage and conveyance of floodwater, enabling flood risk to be more effectively managed and reducing the need to provide flood defences in the future.
- P-FRM-2: Direct strategically significant growth, projects and infrastructure to areas with a low risk of flooding.
- P-FRM-3: Zone land for development in areas with a high or moderate risk of flooding only where it can be clearly demonstrated, on a solid evidence base, that the zoning will satisfy the justification test set out in chapter 4 of the Planning System and Flood Risk Management Guidelines.
- P-FRM-4: Maintain a 20-metre-wide flood protection zone around lakes and along both sides of all rivers, and a 100-metre-wide flood protection zone from soft shorelines. Development proposals will be required to maintain these flood protection zones free from development.

  Exceptions may be considered for strategic road projects, riverbank enhancement works, bridge and road repair works, brownfield sites, development on lands zoned subject to policy P-FRM-3 and in cases where the maintenance of the flood protection zone is not practically achievable. Such cases will be assessed on an individual basis and subject to compliance with the Habitats and Directive.
- P-FRM-5: Restrict development in areas at risk of flooding unless:
  - it is demonstrated that there are wider sustainability grounds for appropriate development;

- the flood risk can be managed to an acceptable level without increasing flood risk elsewhere;
- the overall flood risk is reduced, where possible.

Developments considered necessary in order to meet the objectives of this Plan, or required on wider sustainability grounds, will be subject to the development management justification test outlined in chapter 5 of the Planning System and Flood Risk Management Guidelines. Measures such as flood compensation storage works, or new hard-engineered flood defences alone will not be acceptable as justification for development in flood risk areas. Such measures will be subject to compliance with the Habitats Directive and will only be considered as part of a proposal if the development is warranted by the justification test on planning and sustainability grounds in the first instance, and where no alternative site is available.

- P-FRM-6: Require development proposals, where appropriate, to be accompanied by a detailed flood risk assessment in accordance with the provisions of the DoEHLG's Planning System and Flood Risk Management Guidelines for Planning Authorities and to address flood risk management in the detailed design of development, as set out in Appendix B of the Guidelines.
- P-FRM-7: Assess flood risk in Local Area Plans in accordance with the DoEHLG's Planning System and Flood Risk Management Guidelines for Planning Authorities in a manner that is appropriate to the scale and circumstances of each area and having regard to the priorities set out in the SFRA that accompanies this Plan.

The County Development Plan recognises that flooding could have serious consequences on settlements located on the coast, beside rivers and in karst limestone areas. The man-made environment can exacerbate the consequences of flooding. Development in a flood plain, or building in areas where drainage infrastructure is inadequate, places property and people at risk. Flooding may impact on the economy, social well-being, public health, and the environment. The impact on individuals and communities can be significant in terms of personal suffering and financial loss.

Coastal flooding is a result of higher sea levels than normal, usually caused by storm surges. Current prediction of climate change in Ireland suggests more intense rainfall and rising sea levels, which will increase the risk for flooding in certain areas in the future.

> County Sligo is vulnerable to flooding as evidenced by the flood events in December 2015 which caused significant socio-economic damage. Particular areas of interest in Sligo have been identified in the OPW's CFRAM programme and ICPSS erosion and flood risk mapping.

Additionally, Section 3 of the Strategic Environmental Assessment accompanying the Sligo County Development Plan describes the purpose of baseline environmental data and how this can be compared against the planning implemented in the development plan (Sligo County Council, 2017). The landscape characterisation mapping produced as part of the scenic evaluation study carried out by CAAS in 1997 (map has been updated) identifies visually vulnerable areas and public roads which are a key consideration for any development proposal.

Figure 1.5 overleaf shows a landscape characterisation map of County Sligo highlighting vulnerable areas (Sligo County Council, 2017). This shows that all of the study areas within the Sligo Bay CFERM study are considered as visually vulnerable and as sensitive rural landscapes.

Other areas of focus within the development plan include tourism development, and specifically maximising Sligo's tourism potential. This focus ties in with other objectives such as:

- Continuing to improve and maintain the road infrastructure along the Atlantic Corridor, which includes the N-15 and the N-17.
- Improving the viability of the non-operational Sligo Airport in accordance with the habitat directives; protecting the natural environment including Natura 2000 sites (SPA's and SAC's), NHAs and pNHAs as well as coastal and marine environments.
- Protecting the key landscape resource which underpins the Wild Atlantic Way.

It is important that any coastal management plan does not diminish key landscape resources within the study areas or hinder or obstruct the viewing points. Any proposed coastal protection measures should be designed and located to minimise potential visual impacts.

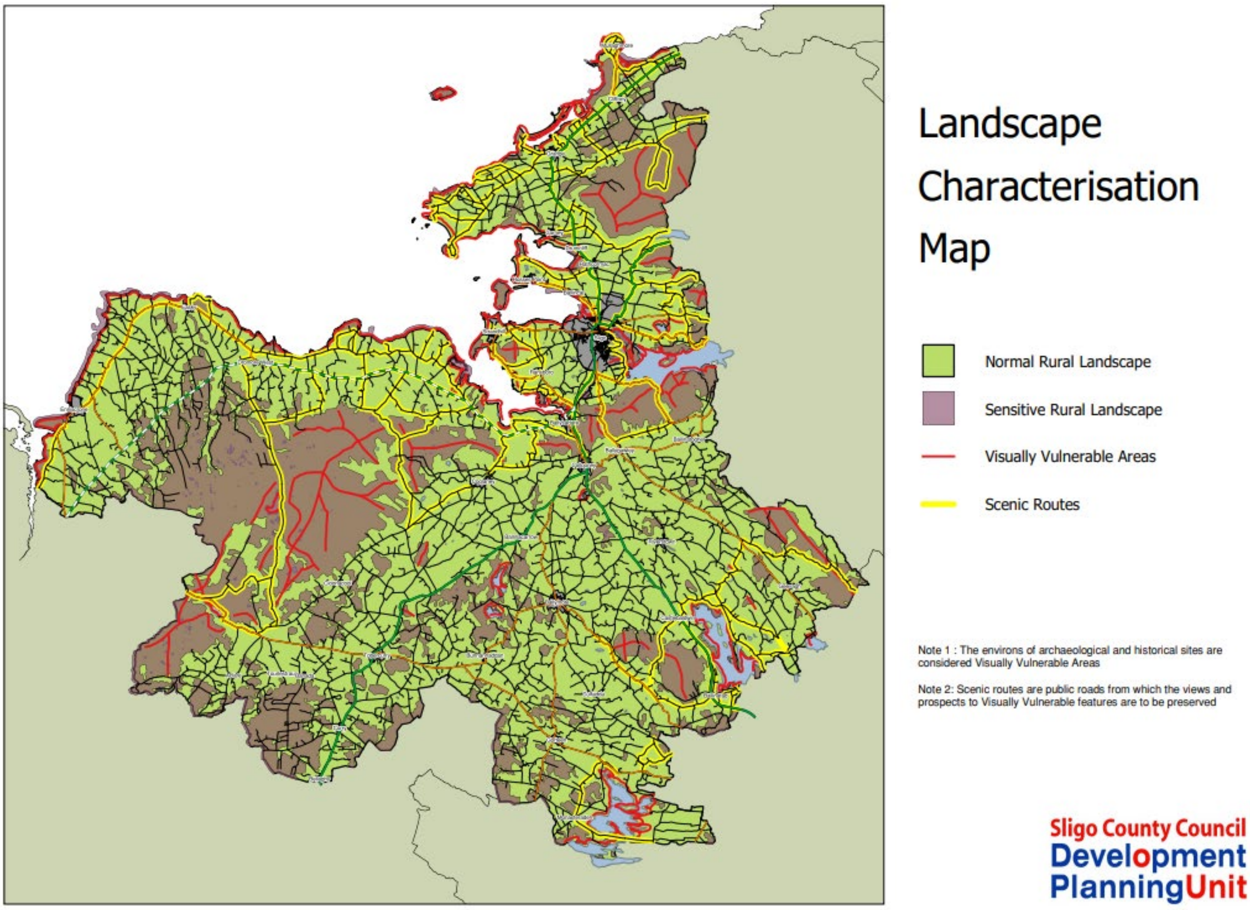


Figure 1.5: Extract from Sligo County Development Plan (Sligo County Council, 2017)

1.2.3 Border Regional Authority Planning Guidelines 2010-2022

The Regional Planning Guidelines (RPG) for Sligo County are encompassed within planning guidelines for the entire border region (Border Regional Authority, 2010). The guidelines state: “The Border Region derives its name from its location in relation to Northern Ireland (NI). It comprises the six counties of Donegal, Sligo, Leitrim, Cavan, Monaghan and Louth, which form the border with Northern Ireland, providing the key interface between the two jurisdictions.”

The Regional Planning Guidelines are prescriptive in setting out a planning framework for the proper planning and development of the Region and ensuring that we provide sustainable communities for our citizens in the coming years. The guidelines provide a long-term planning framework for the region and are complimented by detailed consideration given to areas such as climate change, environmental management, and flood risk management, all of which pose significant challenges for policy makers.

The guidelines recognise that the region encompasses a considerable coastal area, including a wealth of biodiversity and a range of ecological sites and areas of outstanding natural beauty. The guidelines also recognise that one of the key issues for development of the region is the number of designated Natura 2000 sites, as well as the number of sensitive habitats and species which the region supports.

Section 6.8 of the guidelines identifies the need to respect the changing physical nature of the coastline, e.g.:

- Risk of erosion and land instability and changes to the intertidal zone;
- Risk of flooding and the need to protect the coast through sea defences;

- Ensure the conservation and enhancement of the landscape and seascape and its biodiversity, historic and archaeological features; and
- Restrict the development of undeveloped sections of the coastal zone to essential marine and coastal activities, and only where such development would not compromise environmental protection objectives.

Other key points stated in this section of the guidelines included:

- In addition to coastal flooding and loss of coastline, saline inundation can have negative effects on agricultural land, result in the degradation of habitats, the loss of species and can lead to loss of coastal archaeology and sites of architectural or tourism importance.

As such the guidelines include the following policy and coastal strategic objectives:

Coastal Policy

- ENVP14: Promote and support the development of Integrated Coastal Zone Management with all coastal Local Authorities in the Border Region, so that future Development Plans may be guided in relation to the management of coastal areas.

Coastal Strategic Objectives

- ENVO29: Incorporate coastal zone management into relevant County, Town and Local Area Plans;
- ENVO30: Development Plans should respect and accommodate the changing physical nature of the coastline, including the risks of erosion and land instability, changes to the intertidal zone, the risk from flooding by creating and maintaining buffer zones to restrict development in high risk areas; and
- ENVO31: Ensure the conservation and enhancement of the landscape and seascape, biodiversity, historic and archaeological features, and restrict the development of the undeveloped sections of the coastal zone.

Other relevant points to note from elsewhere in the Border Regional Planning Guidelines include those in relation to:

- Natural Heritage
  - Development Plans should incorporate policies and objectives that protect biodiversity of the Region and all National Designations such as pNHAs, Ramsar sites and statutory reserves.
- Landscape
  - Development Plans should incorporate policies and objectives which protect and manage the landscape of the Region, both within, and outside their jurisdiction. Planning Authorities shall collaborate with adjoining authorities in this regard; and
  - A common approach to landscape management should be adopted throughout the region. This should ensure: the quality and character of landscape areas are identified; a common designation and description for areas that require protection; and that common policies are applied to areas that require protection.
- Flood Risk Management
  - Development Plans and Local Area Plans should be consistent with the DEHLG Planning System and Flood Risk Management Guidelines, and adopt strategic, integrated, sustainable, and proactive approach to catchment management to avoid and reduce flood risk within the region (from tidal effects around estuaries and along the coast including the implications of the latest predictions for sea level rise; and
  - Recognising the concept of coastal evolution and fluvial flooding as part of our dynamic physical environment, an adaptive approach to working with these natural processes shall be adopted.

The RPGs recognises coastal pressures such as erosion and flooding will have serious implications for development planning, particularly in the future when these issues are exacerbated by climate change. It is therefore essential that current and future plans and developments do not worsen these issues.

The guidelines also recognised that where coastal areas are bounded by Natura 2000 sites, cognisance should be taken of the need to mitigate the effects of coastal squeeze and that continued investment is required to protect coastal assets from the effects of climate change.

1.2.4 National Marine Planning Framework 2021

The National Marine Planning Framework (NMPF) (DHPLG, 2021) is intended as the marine equivalent to the National Planning Framework. This approach will enable the Government to:

- Set a clear direction for managing our seas;
- Clarify objectives and priorities;
- Direct decision makers, users, and stakeholders towards strategic, plan-led, and efficient use of our marine resources.

Marine Spatial Planning is a process that brings together multiple users of the ocean to make informed and coordinated decisions about how to use marine resources sustainably. It is a process by which the relevant public authorities analyse and organise human activities in marine areas to achieve ecological, economic, and social objectives. A Marine Spatial Plan (MSP) – in Ireland known as the NMPF – is the outcome of that process.

The NMPF:

- Is a national plan for Ireland's seas, setting out, over a 20-year horizon, how we want to use, protect and enjoy our seas.
- The NMPF sits at the top of the hierarchy of plans and sectoral policies for the marine area. The plan has been informed by existing sectoral plans and will, in turn, be used to inform future cycles of those plans in an ongoing feedback loop.
- It will become the key decision-making tool for regulatory authorities and policy makers into the future in a number of ways, including decisions on individual authorisation applications, which will have to secure the objectives of the plan, similar to the way that terrestrial plans form part of the decision-making toolkit in the on-land planning process.

In respect to this CFERM, the NMPF is relevant as it sets out a number of objectives that are related to the coastal environment and any development thereof. In particular, the document states that any proposal must demonstrate that they will, in order of preference a) avoid, b) minimise, or c) mitigate:

- Significant adverse impacts on species adaptation or migration, or on natural native habitat connectivity.
- Significant adverse impacts on marine or coastal natural capital assets, or, if it is not possible to mitigate significant adverse impacts on marine or coastal natural capital assets proposals must set out the reasons for proceeding.
- Significant disturbance to, or displacement of, highly mobile species.

In respect to coastal flooding/erosion management proposals, the NMPF states that:

- Proposals should demonstrate how they avoid contribution to adverse changes to physical features of the coast;
- Enhance, restore or recreate habitats that provide a flood defence or carbon sequestration ecosystem services where possible.
- Where potential significant adverse impacts upon habitats that provide a flood defence or carbon sequestration ecosystem services are identified, these must be in order of preference and in accordance with legal requirements: a) avoided, b) minimised, c) mitigated, d) if it is not possible to mitigate significant adverse impacts, the reasons for proceeding must be set out.

2 DATA AND ANALYSES

2.1 Elevation datasets

Following completion of Stage 1 of this study (RPS, 2021) which involved identifying information gaps, RPS assisted Sligo County Council with the procurement of an aerial survey of the study areas, undertaken by Kilkelly Geo–Spatial Solutions.

At Strandhill, bathymetry information that was recorded in 2021 as part of the OPW's Coastal Monitoring Survey Programme (CMSP) was made available for this study. CMSP survey data was complemented by a topographic survey by Kilkelly Geo–Spatial Solutions (KGSS) which was undertaken during a spring low tide.

In-house bathymetric survey information was used to cover the study area of Easkey alongside the commissioned topographic survey carried out in 2022 by KGSS.

The bathymetric and topographic data were used to develop the computational models described later in this report. The procurement and inclusion of these data were crucial to ensuring the wave climate and coastal flood inundation models were sufficiently accurate and detailed to assess the coastal flood risk in each area.

A summary of the topography and bathymetry information used to develop suitable numerical models and assess the flood risk for this study is summarised in Table 2.1 and Figure 2.1 to Figure 2.2.

Table 2.1: Summary of elevation datasets used to inform this CFERM study

Dataset	Survey date	Typical horizontal resolution (m)
Office of Public Works (OPW) topography	2021	0.25m, 0.5m and 1m
Kilkelly Geo–Spatial Solutions (KGSS) topographic data	2022	0.5m and 1m
In-house bathymetric survey information.	variable	Variable

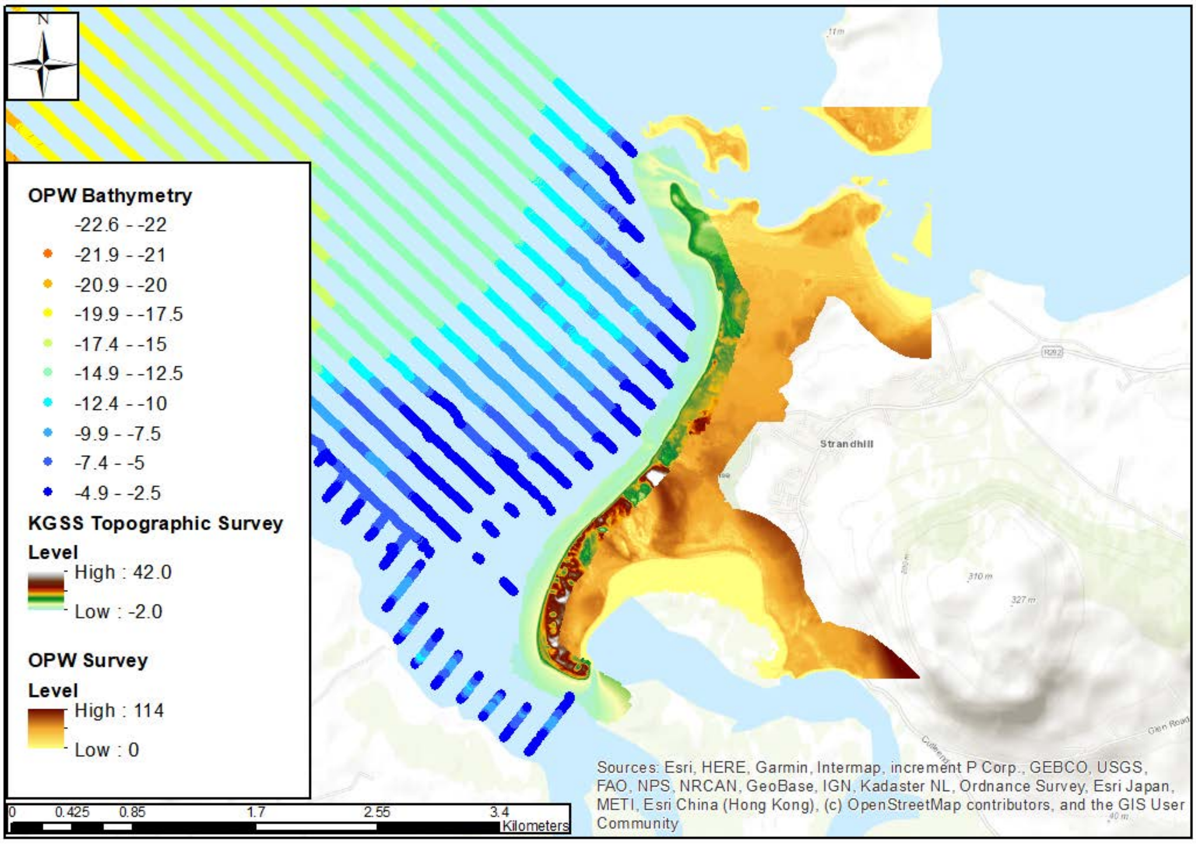


Figure 2.1: Topographic survey extent, provided by KGSS and OPW for the study area of Strandhill

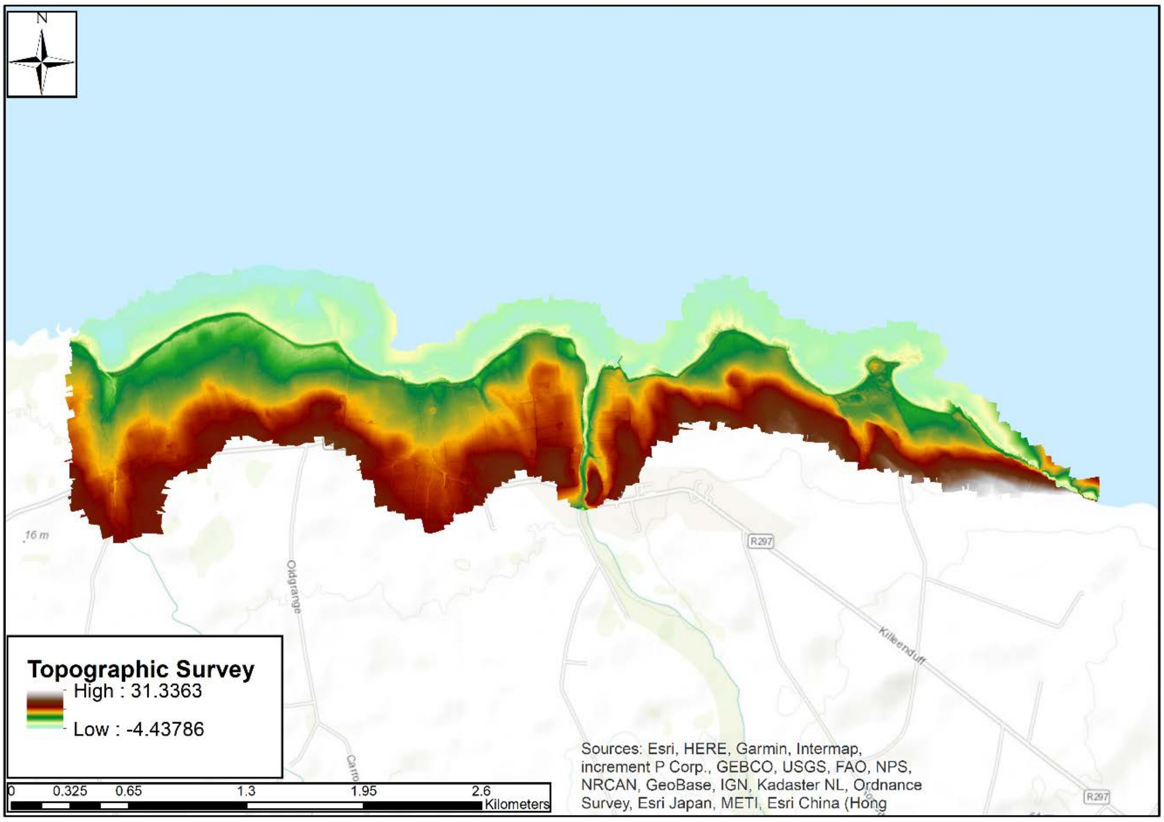


Figure 2.2: Topographic survey extent, provided by KGSS for the study area of Easkey

2.2 Computational Models

2.2.1 Modelling Overview

RPS utilised a combination of the MIKE 21 and LitPack numerical modelling software packages developed by DHI, to assess coastal processes across the study areas.

These models were used in conjunction with hydrographic and topographic survey data to evaluate the following:

- The existing tidal flow regime.
- The average annual and extreme inshore wave climate.
- The shoreline sediment dynamics.
- The current and future scenario coastal erosion risk.
- The current and future scenario coastal flood risk.

2.2.2 Coastal Process Modelling Software

A suite of coastal process models, based on the MIKE software developed by DHI, was used to assess the coastal processes within the Sligo CFERM study areas. The MIKE system is a state-of-the-art, industry standard, modelling system, based on a flexible mesh approach. This software was developed for applications within oceanographic, coastal and estuarine environments.

A brief synopsis of the MIKE system and modules used for this assessment is outlined below:

1. MIKE 21 FM system - This is a flexible mesh modelling system, used to simulate the mutual interaction between currents, waves and sediment transport by dynamically coupling the relevant modules in two dimensions.

2. The Hydrodynamic (HD) module - This module is capable of simulating water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions. The HD Module is the basic computational component of the MIKE 21 Model system providing the hydrodynamic basis for the Sediment Transport and Spectral Wave modules. The Hydrodynamic module solves the two-dimensional incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and hydrostatic pressure. Thus, the module consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain, both Cartesian and spherical coordinates can be used.
3. The Spectral Wave (SW) module – This module simulates the growth, decay and transformation of wind-generated waves and swell waves in offshore and coastal areas and accounts for key physical phenomena including wave generation, dissipation, refraction, shoaling and wave-current interaction.
4. The Sediment Transport module - The Sediment Transport Module simulates the erosion, transport, settling and deposition of non-cohesive sediment in marine and estuarine environments and includes key physical processes such as forcing by waves, flocculation and sliding. The module can be used to assess the impact of marine developments on erosion and sedimentation patterns by including common structures such as jetties, piles or dikes. Point sources can also be introduced to represent localised increases in current flows as a result of various coastal structures such as revetments, groynes or outfalls.
5. Littoral Processes (LitDrift) module - This module is part of an integrated modelling system that simulates non-cohesive transport along quasi-stationary coastlines using an n-line approach. It can be used as a powerful tool for sediment budget analysis which is paramount to all coastal morphology studies. It should be noted that this module simulates potential sediment transport, i.e., the magnitude of sediment transport that could be expected if there was an abundance of freely mobile sediment available. In many instances where there is a shortage of sediment available, the actual rates may be significantly lower than the potential sediment transport rates.

2.2.3 Tide, Waves and Sediment Transport Model

The model used to assess the coastal processes in the two study areas was developed using a range of elevation data sources (see Section 2.1). The principal datasets used to develop these models included the high-resolution data surveyed as part of the OPW's Coastal Monitoring Survey Programme (CMSP) in 2021 and the project-specific survey data recorded by KGSS in 2022. These datasets were further supplemented using in-house bathymetry datasets for the offshore regions.

All bathymetry datasets were set with the depths relative to Ordnance Datum Malin (OSGM15) before being input to the MIKE modelling system. The model was developed to include high-resolution detail around each of the study areas utilising the flexible mesh technology with the mesh size varying from approximately 3,000m at the boundaries to 5m at the shoreline. The overall extent and mesh structure of the Sligo tide, wave and sediment transport model is shown in Figure 2.3 to Figure 2.5 respectively.

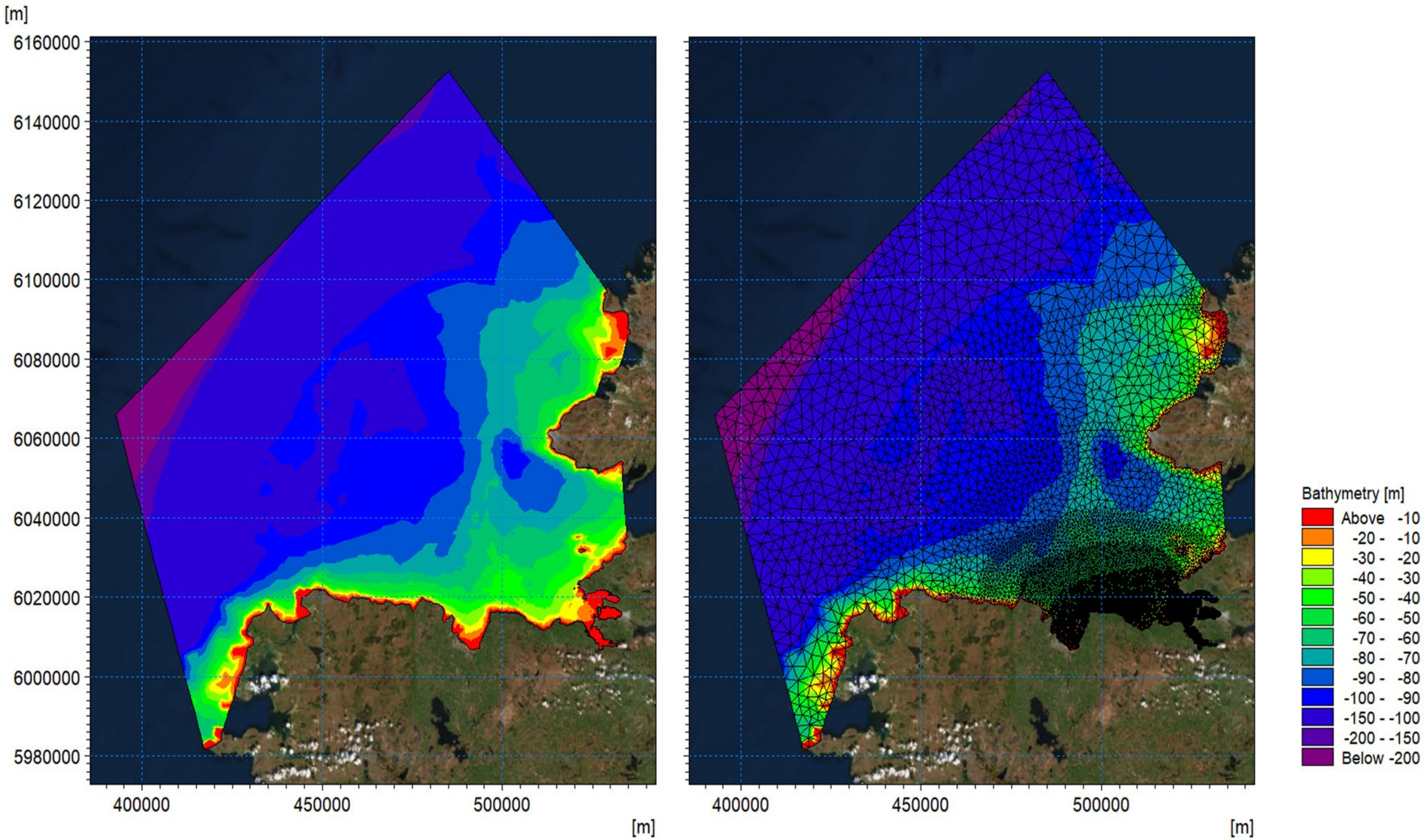


Figure 2.3: Extent, bathymetry (left) and mesh structure of the Sligo Tide, Wave and Sediment Transport model

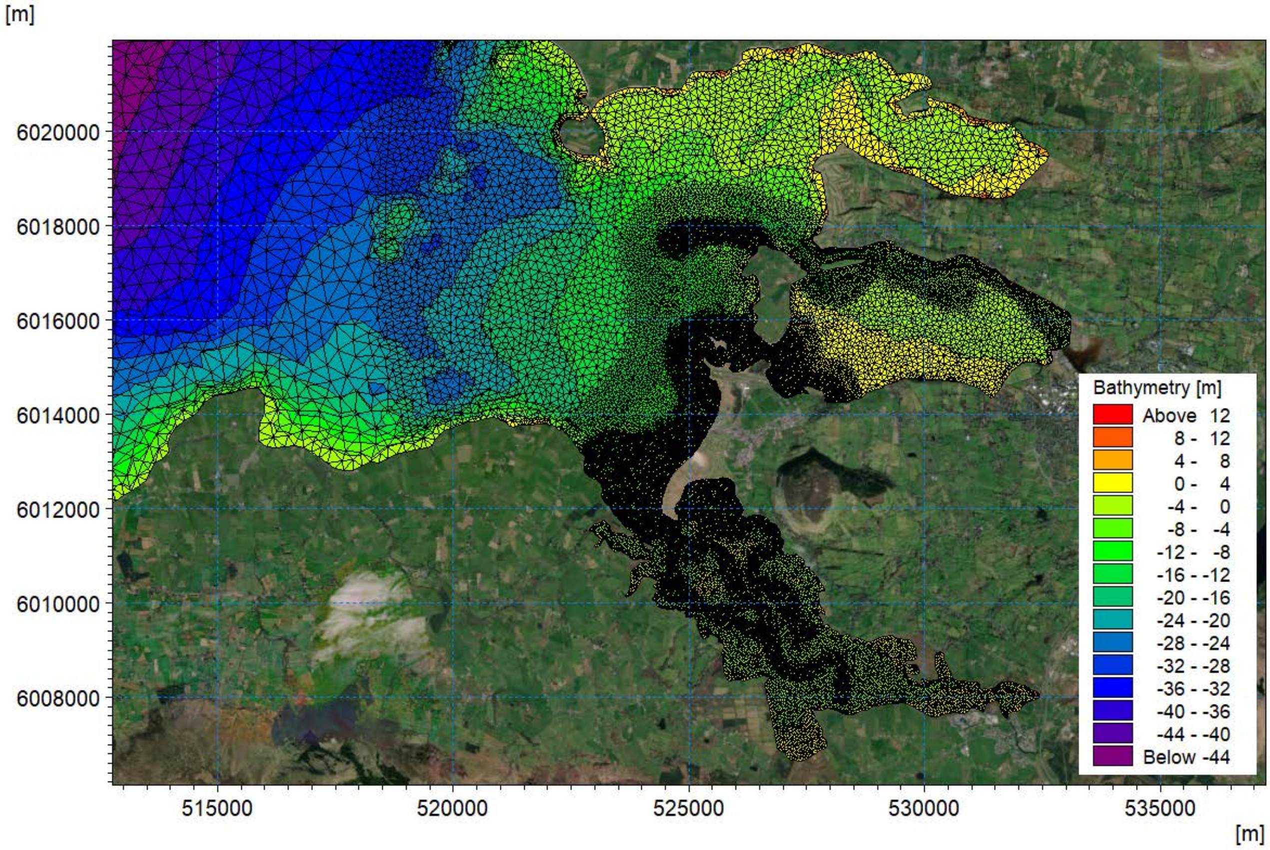


Figure 2.4: Detailed mesh structure of the Tide, Wave and Sediment Transport model in the Strandhill study area

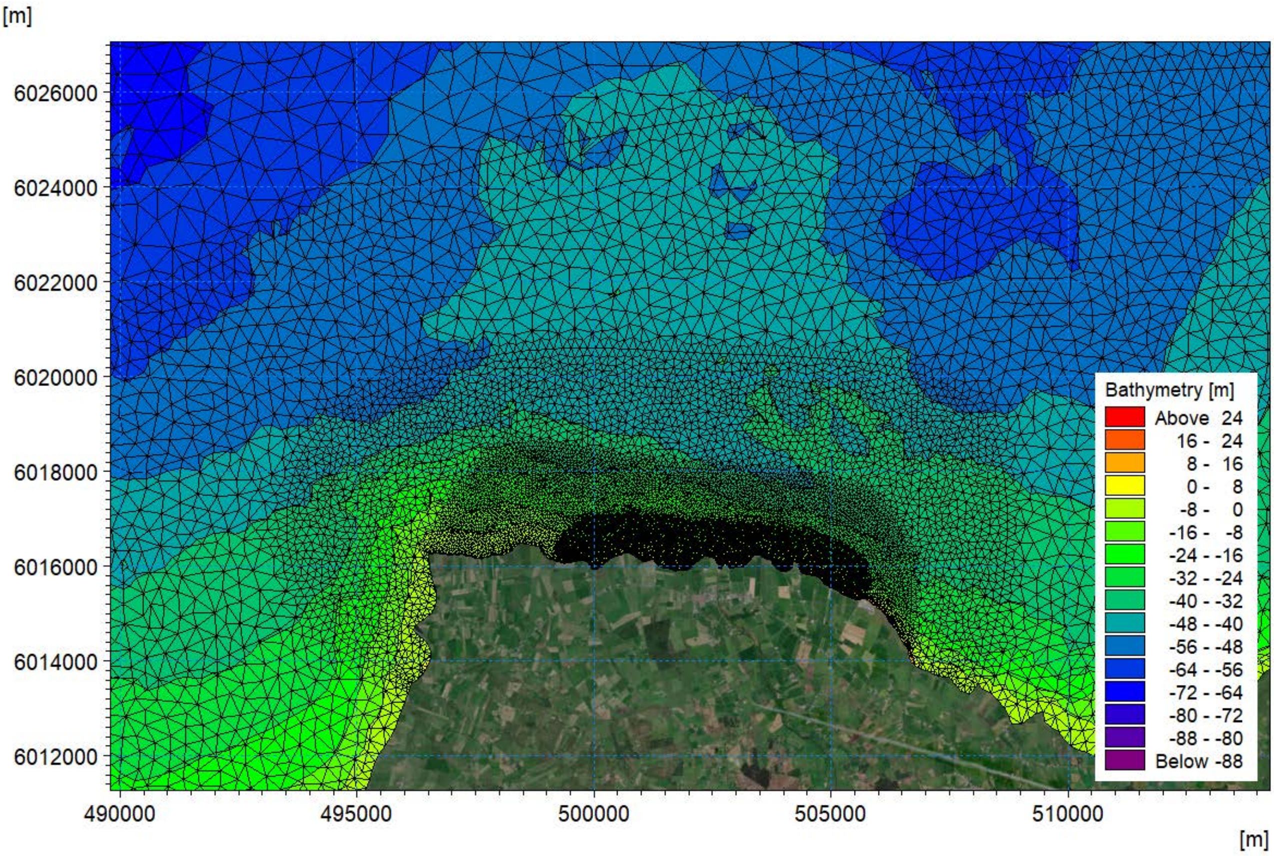


Figure 2.5: Detailed mesh structure of the Tide, Wave and Sediment Transport model in the Easkey study area

2.2.4 Flood Models

The models described in the previous section were modified so that they could be used to assess the threat of coastal flooding across the study areas. This was achieved by increasing the landward extent of the model to include relevant areas of the hinterland.

Relevant areas of the hinterland were determined based on the topography of the study areas, i.e., the model was extended to include areas whereby the elevation was equivalent to a 1 in 1000-year water level based on the Extreme High-end plus Future climate Scenario (H++FS). The H++FS represents a scenario whereby sea levels could increase by +2m by 2100.

During model development, the model mesh was refined in the regions of most importance to achieve satisfactory model performance. The flexible mesh technology allowed the size of the computational cells to vary across the domain of the model, allowing smaller cells of *c.*25m^2 to be positioned in areas of rapidly changing bathymetry, such as offshore banks and channels, along with detailed areas of topography. Larger cells in the order of 300m^2 to 600m^2 were used in areas of more consistent bathymetry/topography.

2.2.5 Tidal Boundary Conditions

The MIKE 21 models described in the previous sections were used to simulate the hydrodynamic regime within the study area. The tidal boundaries for these models were derived from RPS' Tide and Storm Surge Forecast (TSSF) model of Irish coastal waters, (RPS, 2018) the extent and bathymetry of which are illustrated in Figure 2.6.

This model was also developed using flexible mesh technology with the mesh size (model resolution) varying from circa 24km along the offshore Atlantic boundary to circa 200m around the Irish coastline.

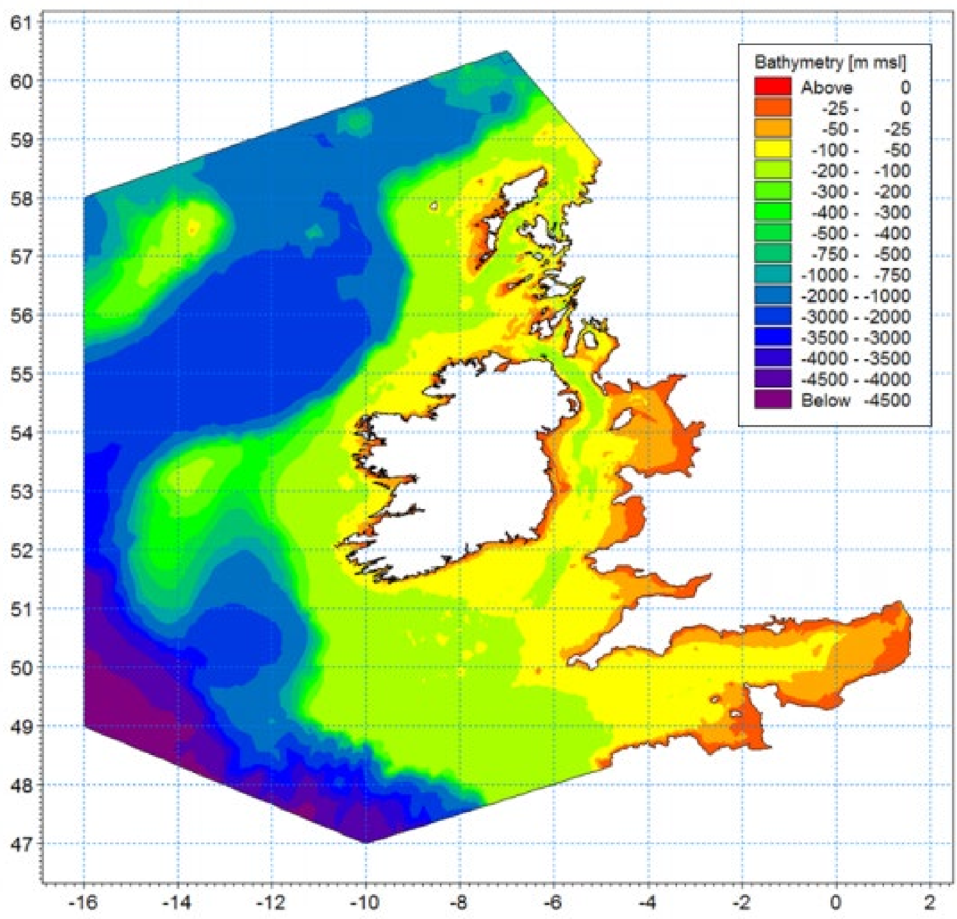


Figure 2.6: Extent and bathymetry of Irish Seas Tidal and Storm Surge model

2.3 Tidal Information

2.3.1 Standard Tidal Information

The normal astronomical tidal levels for the study area were derived using the data presented for Killybegs in the Admiralty Tidal Tables as reproduced in Table 2.2.

The hydrodynamic model used to simulate the tidal conditions in the study area was found to represent these standard tidal conditions to a high degree of accuracy.

Table 2.2: Tidal elevations at Killybegs relative to Chart Datum (CD) & OD Malin (OSGM15)

Tidal Elevation	Chart Datum (CD) [m]	OD Malin (OSGM15) [m]
Mean High Water Spring	4.10	1.91
Mean High Water Neap	3.00	0.81
Mean Low Water Neap	1.50	-0.69
Mean Low Water Spring	0.60	-1.59

2.3.2 Extreme Tidal Levels

As inshore wave conditions and coastal flooding as a result of tidal inundation are both strongly governed by water depth, reference was made to the results of the extreme tidal analysis undertaken as part of the Irish Coastal Wave and Water Level Modelling Study 2018 update (ICWWS) (RPS, 2018).

The ICWWS established extreme high-water levels at several points around the coast of Ireland, including within the study area, for a range of return periods, or Annual Exceedance Probability (AEP) events. The corresponding extreme water levels for an ICWWS point NW6 for the present day are presented in Table 2.3 below.

Table 2.3: Extreme water level information for an ICWWS Point NW6

Return Period	Water Level, OD Malin (OSGM15) [m]
2	2.79
5	2.93
10	3.03
20	3.14
50	3.27
100	3.37
200	3.47
1000	3.70

2.4 Offshore Wave and Wind Information

Offshore wave data from 1979 to 2019 was extracted from a deterministic atmospheric model which is coupled with a wave model allowing two-way interaction between wind and waves. This model is run by the European Centre of Medium Range Forecasts (ECMWF), a research institute and a 24/7 operational service, that produces global numerical weather data for the European Union and the broader community. Corresponding wind parameters were extracted for the same period from the Climate Forecast System Reanalysis (CFSR) model, giving an hourly wind speed and direction dataset. The location of the offshore wave point is illustrated in Figure 2.7.

A wave rose summarising conditions at this offshore point is presented in Figure 2.8 whilst Figure 2.9 presents an equivalent wind rose for the same offshore point.

The wave and wind data were used to simulate the long-term wave climate around the southwest coast of Ireland from 1979 – 2019 on a 3-hourly basis. Information from this model was subsequently extracted and used as a boundary condition for the Sligo Bay model described in Section 2.2.3.

It should be noted that this offshore wave and wind information was also used to undertake an Extreme Value Analysis (EVA) and a comprehensive Joint Probability Assessment (JPA) of wave/wind and water level conditions for the Sligo CFERM study areas. Further information on the EVA and JPA process and the output from this analyses can be found in Appendix A. The output from these assessments was used to develop boundary conditions for the extreme wave model simulations described in Section 3 of this report.

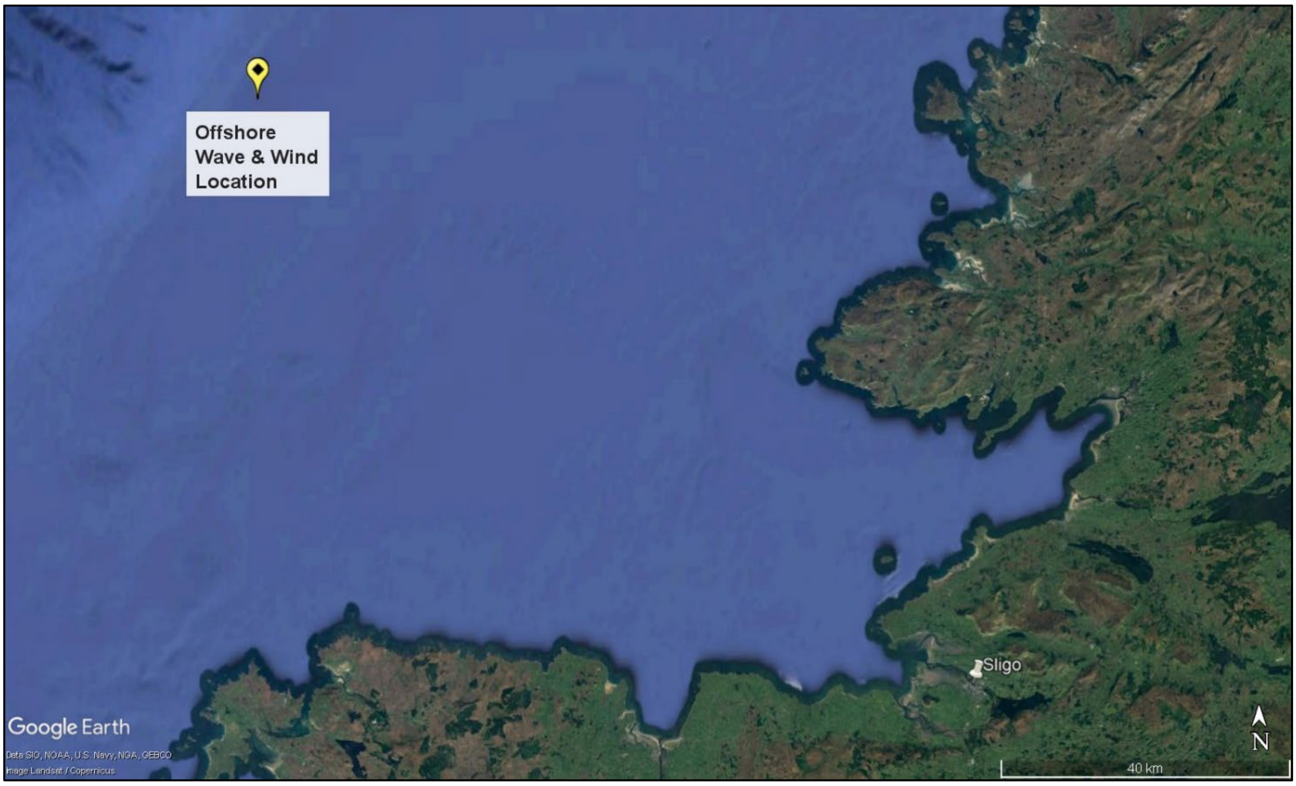


Figure 2.7: Location of offshore wind and wave point used to inform the long-term wave simulations undertaken for this study.

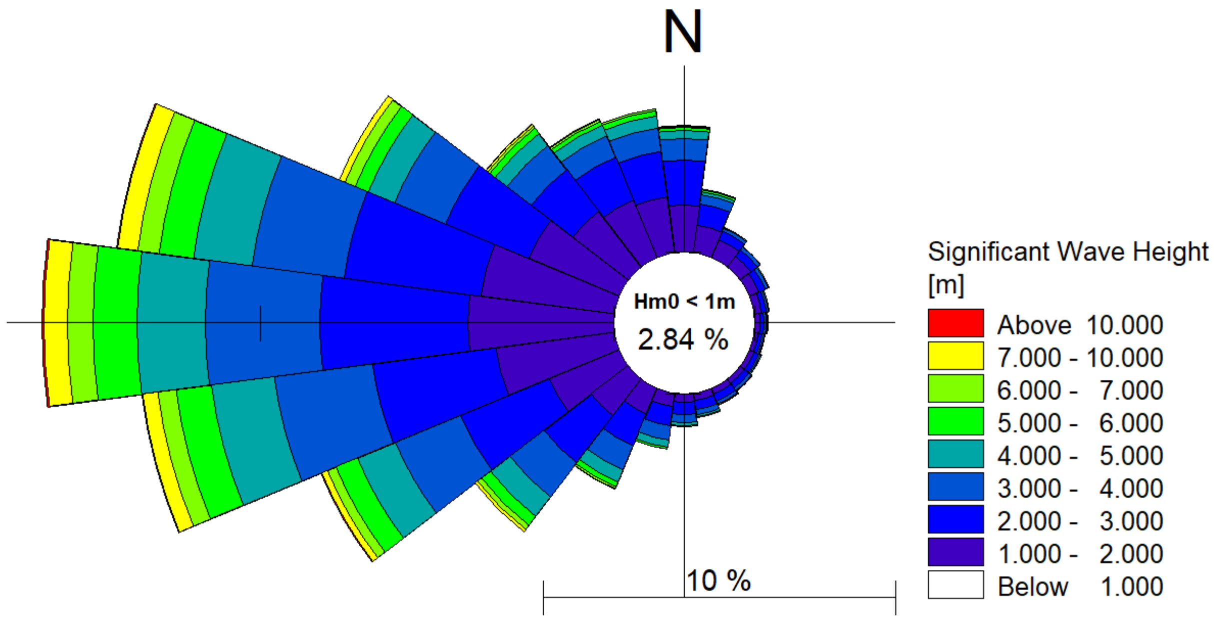


Figure 2.8: Long-term wave conditions based on the offshore ECMWF data from 1979 to 2019

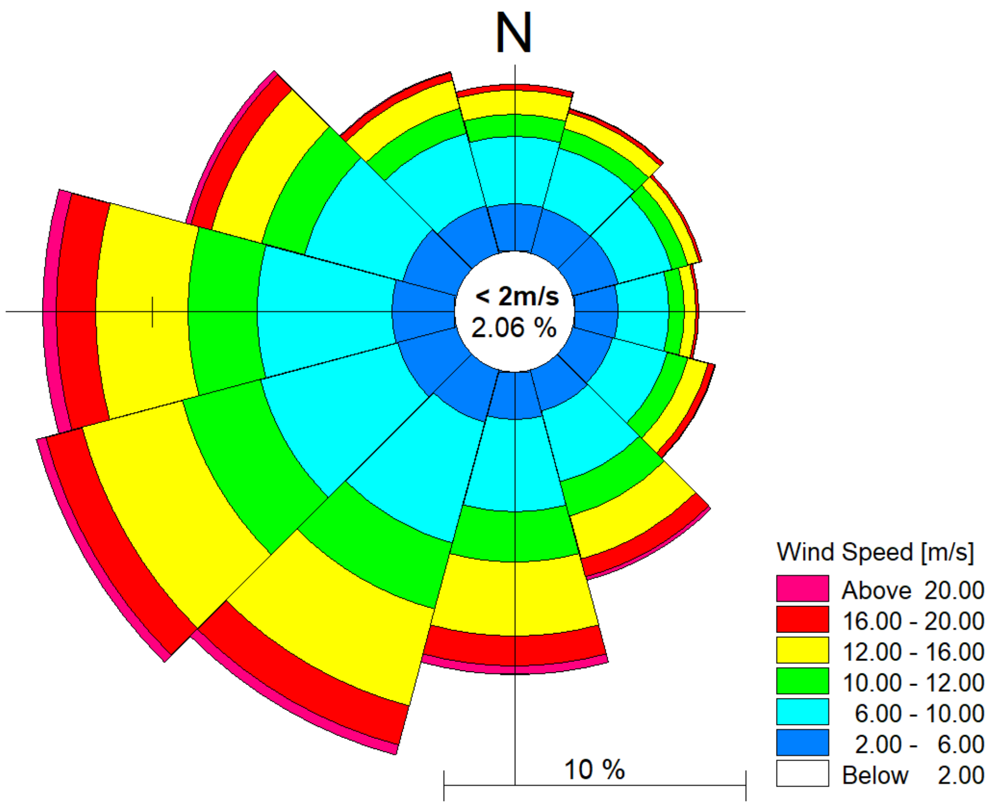


Figure 2.9: Long-term wind conditions based on the offshore CFSR data from 1979 to 2019

3 COASTAL PROCESS MODELLING

The following Sections of this report present the outputs from the numerical models that were used to assess and evaluate the prevailing coastal processes at Easkey and Strandhill. This includes an assessment of the littoral current regime (combined tide, wind and wave currents) and the wave climate. Output from this assessment was subsequently used to inform the coastal erosion and flooding risk assessment presented in Sections 4 and 5.

3.1 Assessment of Littoral Current Regime

Tidal currents are produced by the global movement of water which is itself controlled by the gravitational forces exerted by the sun, moon and other planetary bodies. Tidal currents are of great importance as they govern sediment transport and morphological processes along a coastline such as accretion and/or coastal erosion.

Whilst it is possible to simulate tidal currents in each of the study areas without the effect of wind or waves, the west coast of Ireland is nearly always exposed to some wave action, even during summer conditions. Thus, to accurately represent actual tidal conditions in each area, RPS also included the effect of wind and wave-driven tidal currents which are collectively known as ***littoral currents.***

This section of the report presents the littoral current regime as derived using a coupled tide and wave model. The period chosen for this assessment was October 2018 during which a modest westerly swell prevailed. This scenario was found to be broadly reflective of “calm conditions” in which waves of <1m approached both study areas from between *c.*270º and 360º degrees.

A residual littoral current plot is also presented which represents the *net* direction and speed of littoral current flows based on an entire tidal cycle. These plots are useful as they indicate the net direction of sediment transport over the longer term

A summary of the littoral current regime plots for Easkey is presented in Table 3.1 below.

Table 3.1: Summary of littoral current plots for Easkey

Tidal phase	Figure
Spring, mid flood	Figure 3.1
Spring, high water	Figure 3.2
Spring, mid-ebb	Figure 3.3
Spring, low water	Figure 3.4
Residual (*i.e., average*) littoral current	Figure 3.5

3.1.1 Littoral currents at Easkey

It will be seen from Figure 3.1 to Figure 3.4 that the prevailing direction of the littoral current regime at Easkey is generally along an east-west axis, with the flow travelling towards the east during flood tides and vice versa during ebb tides. Whilst littoral current speeds do not generally exceed 0.18m/s, velocities can increase closer inshore.

This can be attributed to the rocky heterogeneous nature of the coast in this area which is characterised by rocky outcrops that result in local accelerations of the tidal flows. As illustrated in Figure 3.5, the residual littoral current flows in an easterly direction. This is reflective of the net sediment transport in this region.

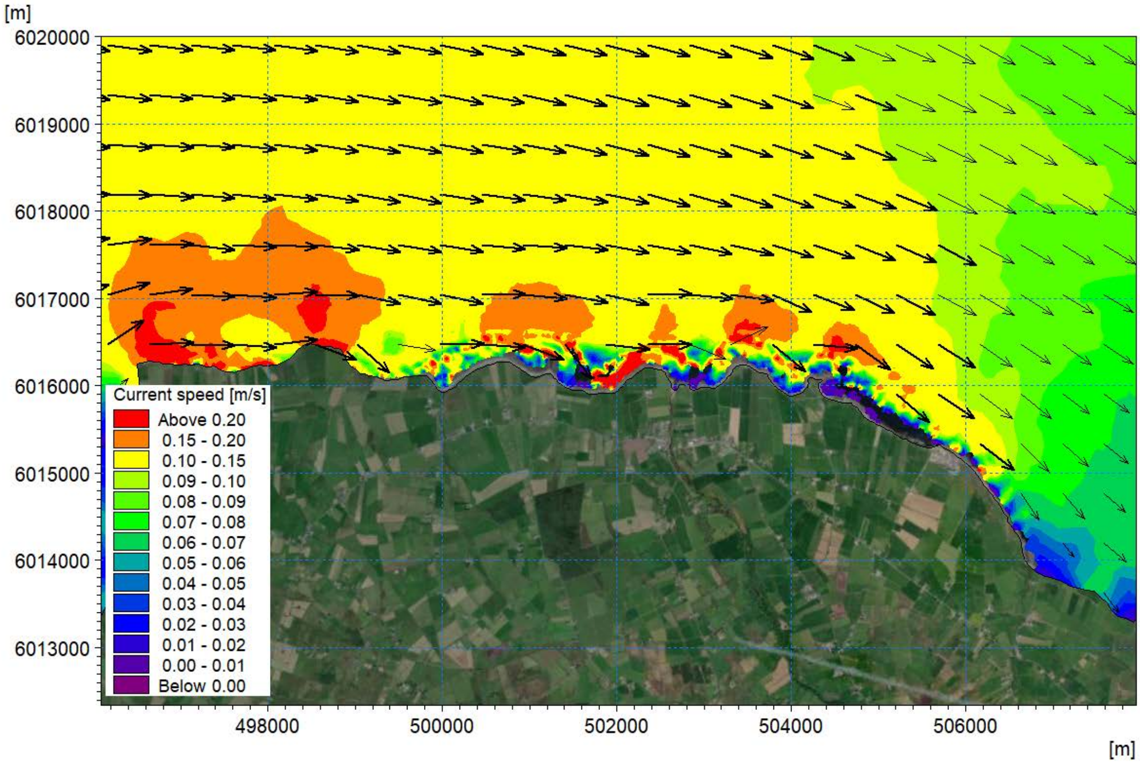


Figure 3.1: Littoral current regime during a typical spring, mid-flood tidal cycle at Easkey

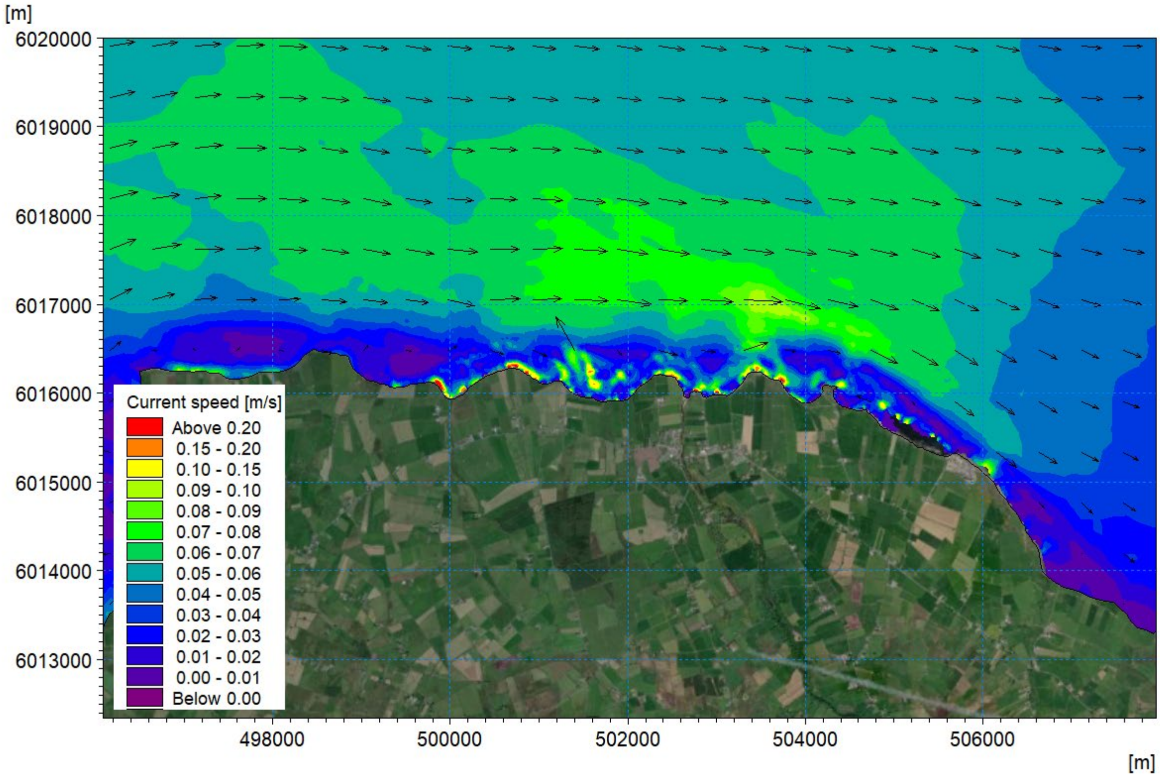


Figure 3.2: Littoral current regime during a typical spring, high water tidal cycle at Easkey

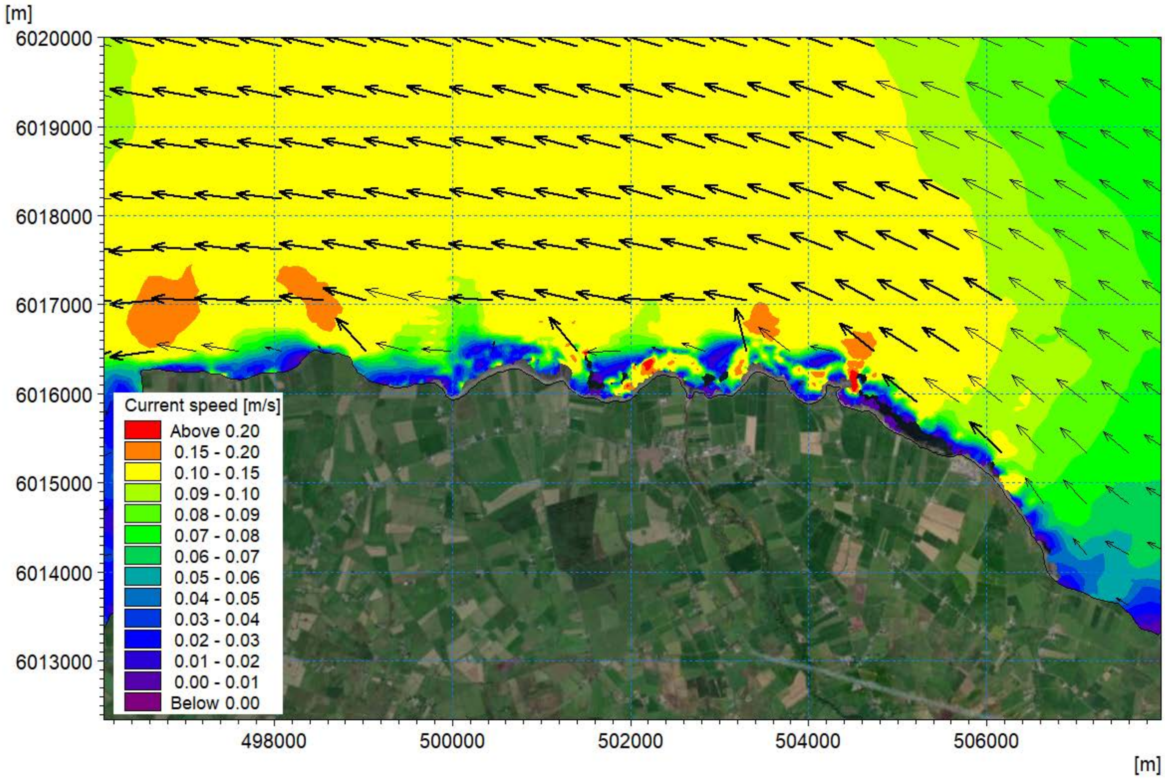


Figure 3.3: Littoral current regime during a typical spring, mid-ebb tidal cycle at Easkey

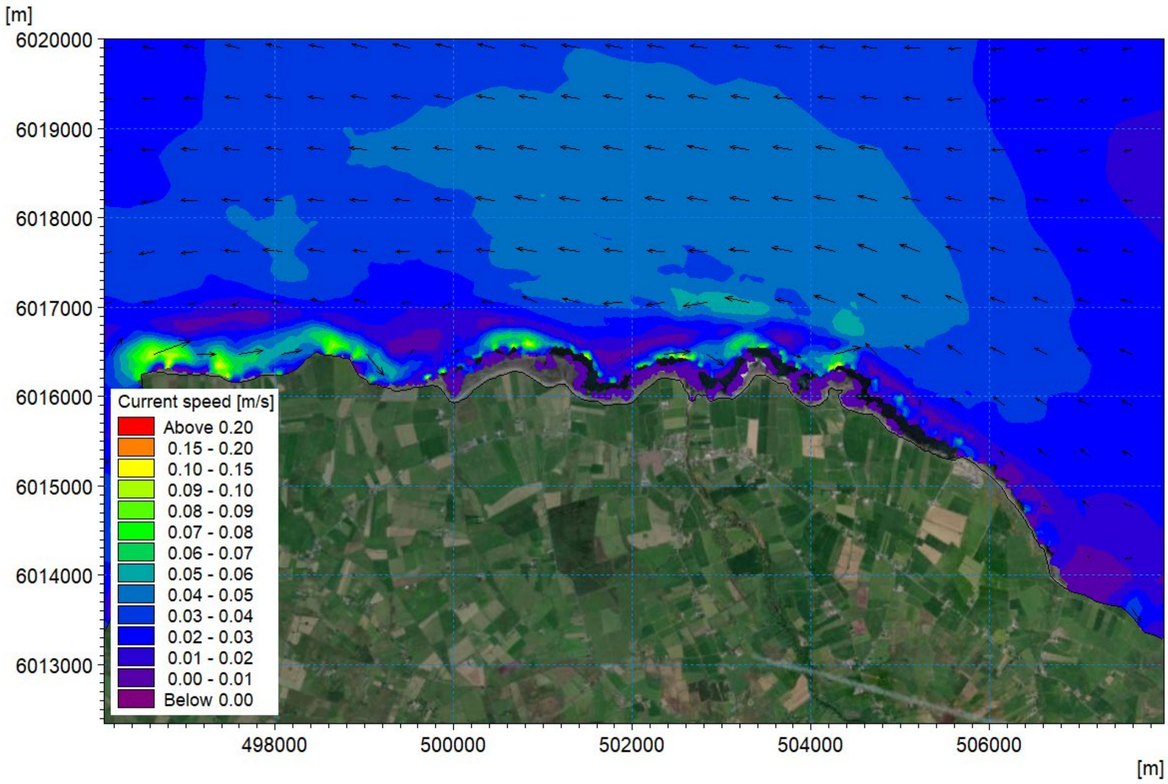


Figure 3.4: Littoral current regime during a typical spring, low water tidal cycle at Easkey

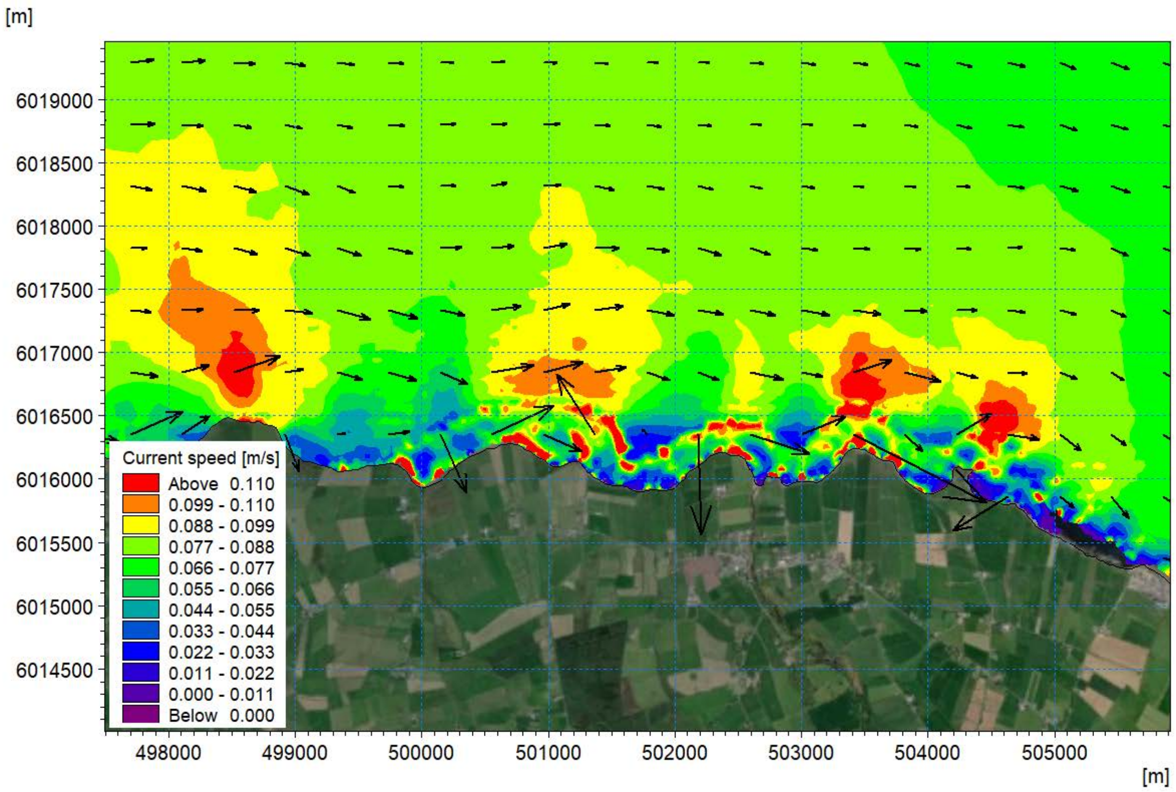


Figure 3.5: Residual littoral current regime over an entire spring tidal cycle at Easkey

3.1.2 Littoral currents at Strandhill

A summary of the littoral current regime plots for Strandhill is presented in Table 3.2 below.

Table 3.2: Summary of littoral current plots for Strandhill

Tidal phase	Figure
Spring, mid-flood	Figure 3.9
Spring, high water	Figure 3.10
Spring, mid-ebb	Figure 3.11
Spring, low water	Figure 3.12
Residual (*i.e., average*) littoral current	Figure 3.13

It will be seen from the model simulations that during mid-flood and high water conditions, the primary direction of the littoral current and thus sediment transport along Strandhill is from the north to the south. Approaching high water conditions, a back eddy structure on the lee side of Carrowdough spit would act as a sediment sink. This is demonstrated by the continued accretion of sediment at the distal of this feature. As illustrated Figure 3.9 and Figure 3.10, littoral currents velocities are generally greatest at the entrance to Ballysadare bay and in the narrow channel between Strandhill and Maguins and Coney Island which leads into Sligo Harbour.

When the tide turns during mid-ebb and low water conditions, it will be seen that the direction of littoral currents and thus sediment transport is almost perpendicular to some regions of the coastline at Strandhill. The results illustrated in Figure 3.11 and Figure 3.12 indicate that both longshore and cross-shore processes govern the overall sediment transport regime at Strandhill.

Overall, the effect of Killaspug Point and Carrowdough Spit results in complex wave current patterns which vary with wave direction and tidal levels. However, as illustrated in Figure 3.9 to Figure 3.13, there is a persistent south-going circulation along the beach from Killaspug Point to an area to the south of the car park. There is also generally an east-going drift along the northern side of Carrowdough Spit. The result is that there is normally a strong outgoing current (rip) located south of the car park. During the upper part of the tidal cycle, particularly with the rising tide, there is a sediment drift current running south along the southern end of the dune line towards Portcurry Point.

The residual littoral current regime at Strandhill illustrated in Figure 3.13 demonstrates that the net average direction of flow throughout an entire cycle, flows from north to south. This is in line with observations and anecdotal evidence that sediment is generally eroded in the north and transported towards Carrowdough spit. Nevertheless, significant volumes of sediment are expected to be lost to cross-shore transport mechanisms, particularly during storm conditions.

Previous studies have demonstrated that large volumes of sand are carried offshore by the steep breaking waves during gales at Strandhill. This sand is deposited in bars from where it tends to migrate back to the beach during prolonged periods of calmer weather when long low swell waves push the sand back to the intertidal beach (KMM, 2000).

However, an underlying stone/cobble layer beneath the northern and central sections of the beach limits the extent of draw-down of the beach during major storm events. Nevertheless, large waves during extreme events can move the smaller fractions to result in additional changes to the beach profile.

An example of the extensive storm beach comprised of cobbles between 30-200mm towards Shelly Valley is illustrated in Figure 3.6 below. Examples of the underlying cobble layer to the north of Strandhill as observed during a site visit in February 2022 are illustrated in Figure 3.7 and Figure 3.8.

Figure 3.6: Example of the extensive upper storm beach comprised of cobbles at Shelly Valley, Nov 2021.

Figure 3.7: Example of cobble basement layer just north of Strandhill in February 2022

Figure 3.8: Example of cobble basement layer further north of Strandhill in February 2022

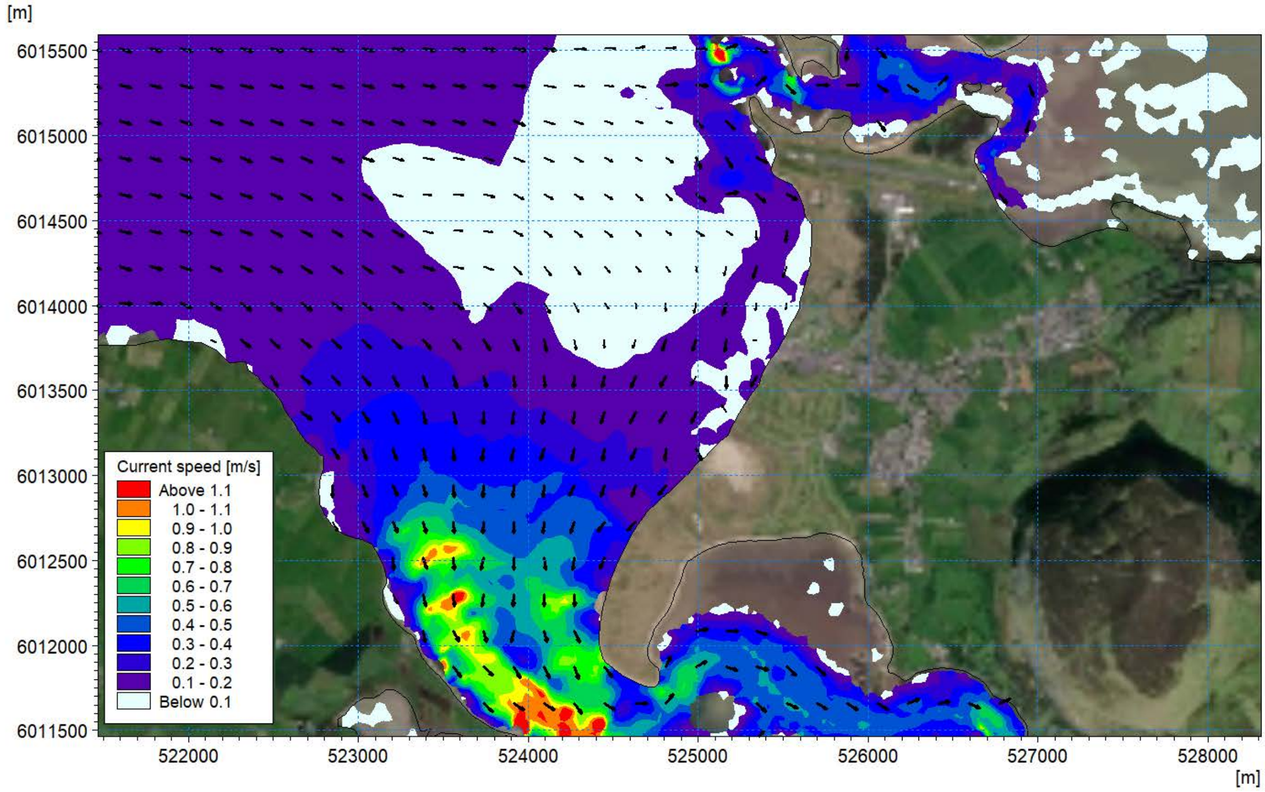


Figure 3.9: Littoral current regime during a typical spring, mid-flood tidal cycle at Strandhill

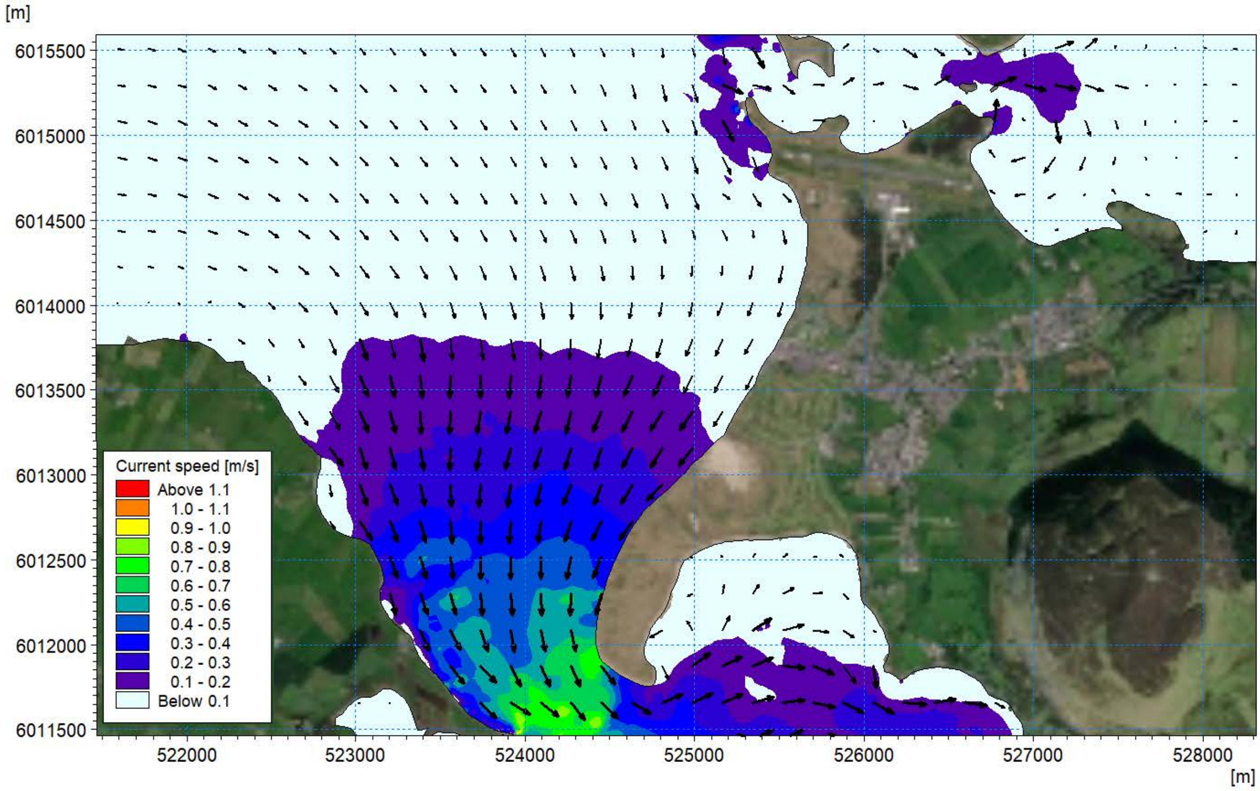


Figure 3.10: Littoral current regime during a typical spring, high water tidal cycle at Strandhill

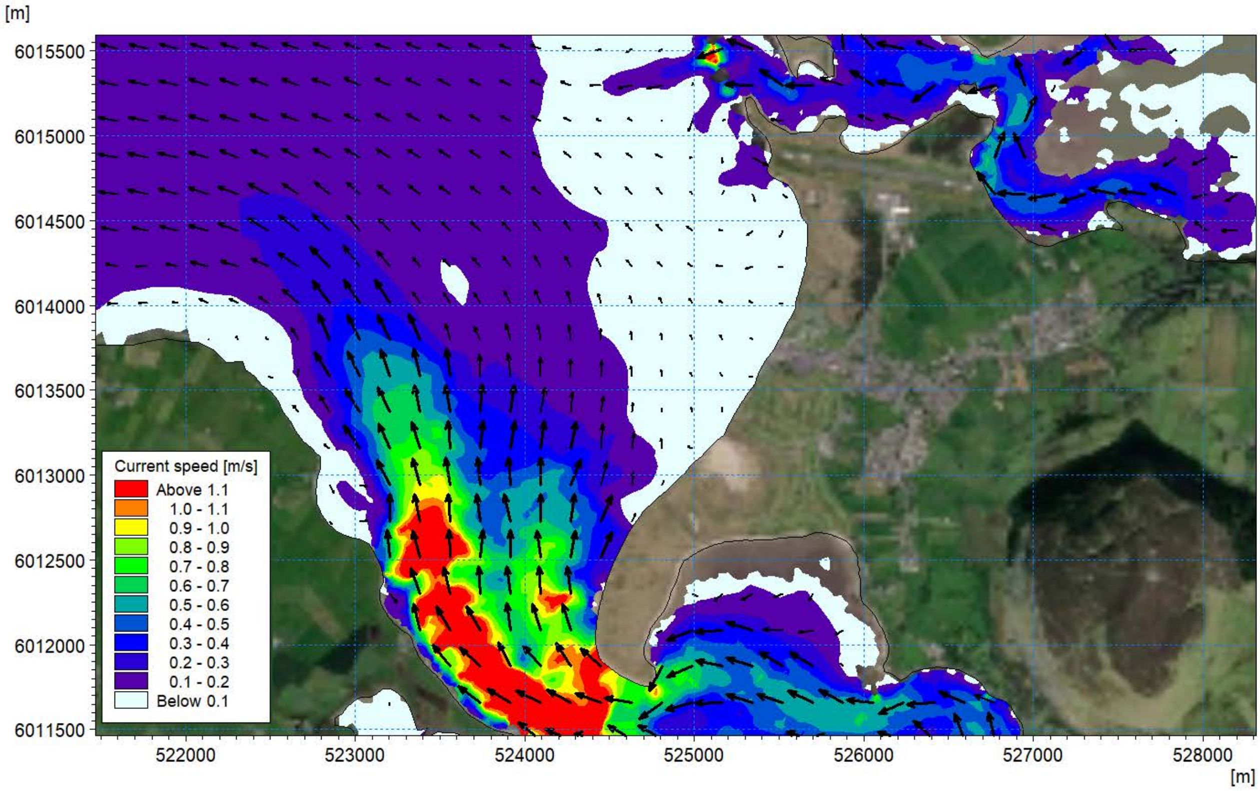


Figure 3.11: Littoral current regime during a typical spring, mid-ebb tidal cycle at Strandhill

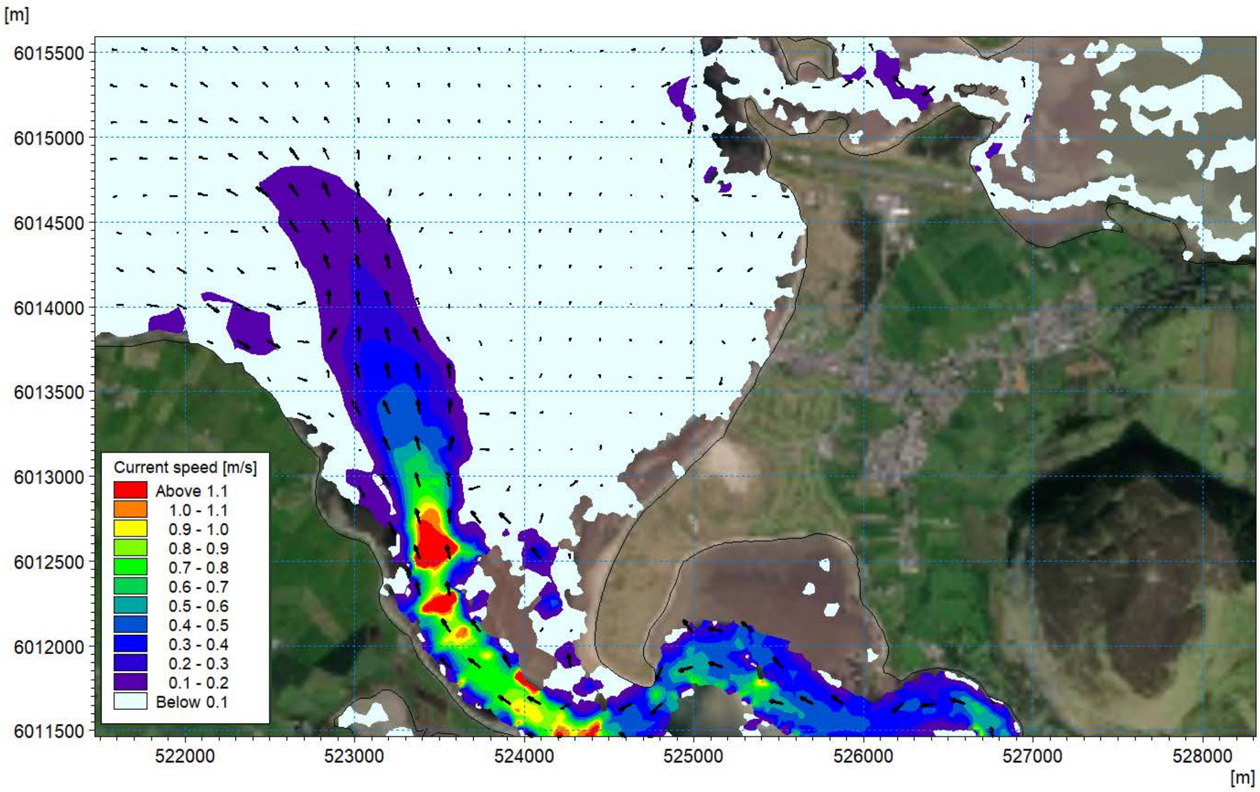


Figure 3.12: Littoral current regime during a typical spring, low water tidal cycle at Strandhill

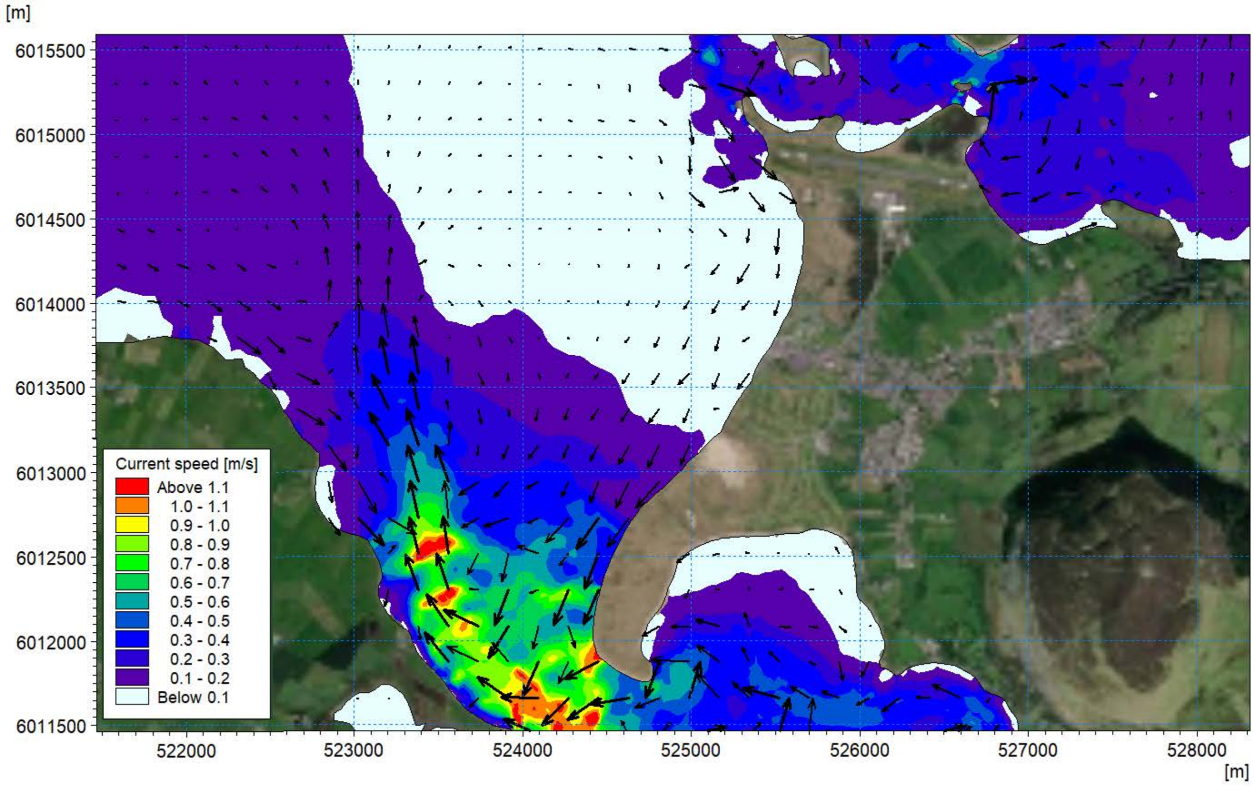


Figure 3.13: Residual littoral current regime over an entire spring tidal cycle at Strandhill

3.2 Assessment of Long-term Inshore Wave Climate

The inshore wave climate within the study area was established by transforming offshore waves derived from the European Centre of Medium Range Forecast (ECMWF) model for the period from 2000 to 2019 inshore. These simulations were undertaken using the MIKE 21 SW model outlined in Section 2.2.2.

A description of the long-term inshore wave climate at Easkey and Strandhill is presented in the following Sections of this report.

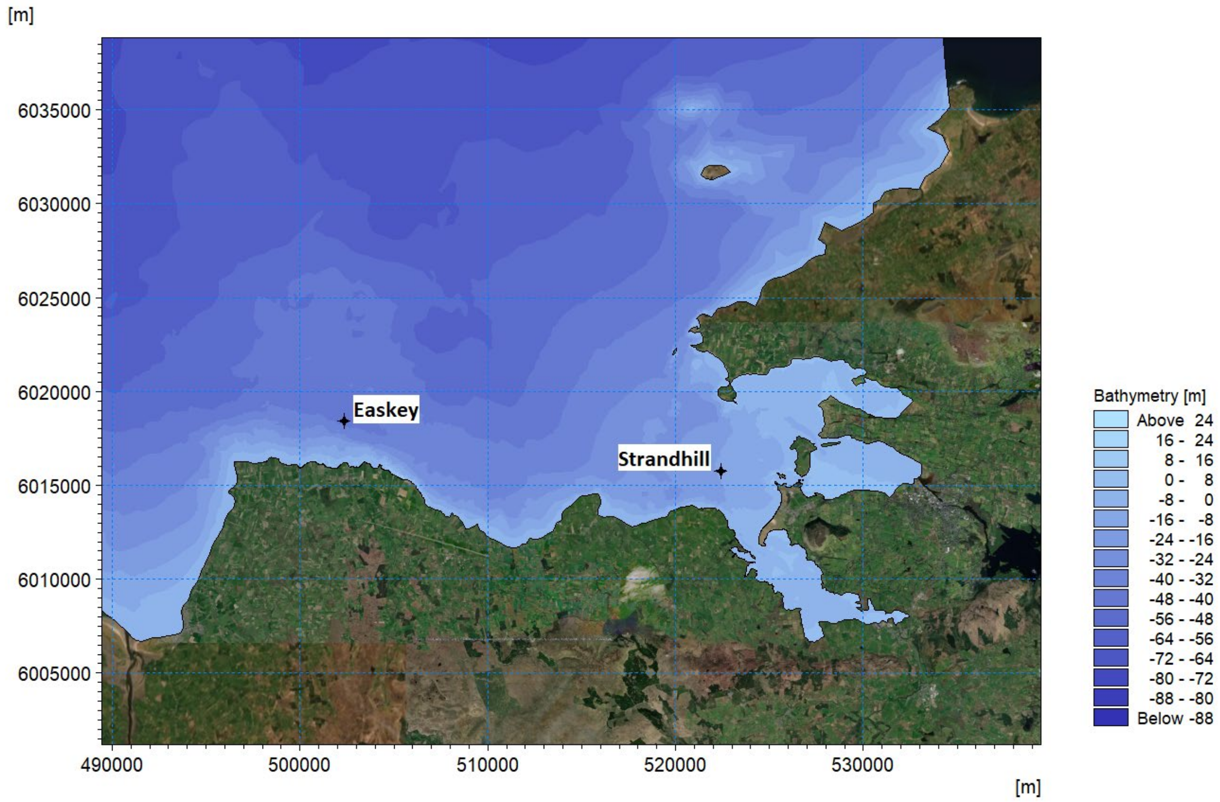


Figure 3.14: Location of inshore wave climate points in Sligo Bay

3.2.1 Long-term wave climate at Easkey

As illustrated in Figure 3.15, the dominant direction of waves approaching Easkey is between *c.*300 – 345º. This is unsurprising given the exposed nature of this study area to incident waves from the Atlantic.

The annual average nearshore significant wave heights at Easkey between 2000 and 2019 were found to be 1.44m. As would be expected, the monthly average significant wave heights were much larger during the winter months between November and March. The annual and monthly average significant wave heights at Easkey are illustrated in Figure 3.17. It will also be seen from this figure that wave heights of between 2 – 3m and corresponding peak wave periods of 11 – 15s account for more than half of all wave energy at this site.

The probability exceedance curve for nearshore significant wave heights at Easkey between 2000 and 2019 is presented in Figure 3.16. Based on this information it can be seen that on average, the offshore significant wave heights could reach *c*. 5.00m and 8.25m during a 1 in 1 and 1 in 200-year event respectively.

Closer inshore, at the point illustrated in Figure 3.18, RPS extracted inshore wave climate information for all relevant return period events. For brevity, the extreme inshore wave comate conditions for 1 in 2, 1 in 50 and 1 in 200-year events are presented in Table 3.3.

It will be seen from this table that the inshore wave conditions during all the simulated extreme return period storm events are relatively similar, ranging between 1.28m and 1.71m for a 1 in 2 and 1 in 200 year event respectively. This is because the wave conditions in this area are generally depth limited. These results also indicate that coastal pressures in this area could increase significantly under future climate conditions which are expected to increase water levels by at least +0.50m by 2100.

Table 3.3: Extreme inshore wave conditions at Easkey at an offshore wave direction of 300°N

Return Period	Significant Wave Height (Hm0) [m]	Max Wave Height [m]	Peak Wave Period (Tp) [s]	Mean Wave Period (T01) [s]
1 in 2	3.76	4.47	14.08	11.69
1 in 50	4.12	4.84	15.28	12.68
1 in 200	4.27	4.99	15.70	13.03

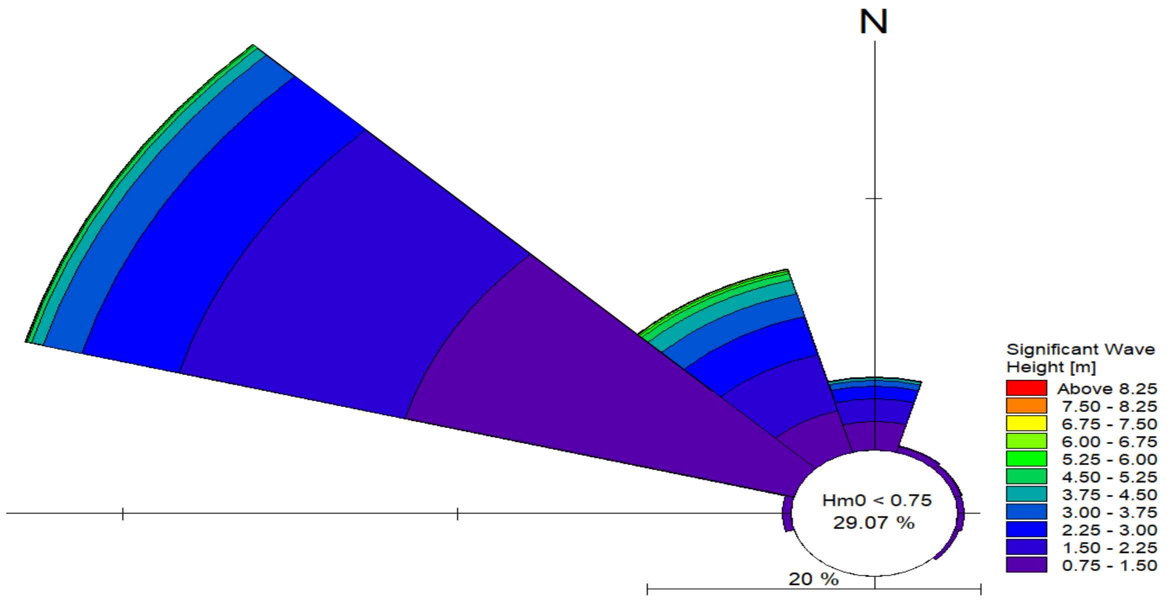


Figure 3.15: Long-term inshore wave rose for Strandhill, Sligo

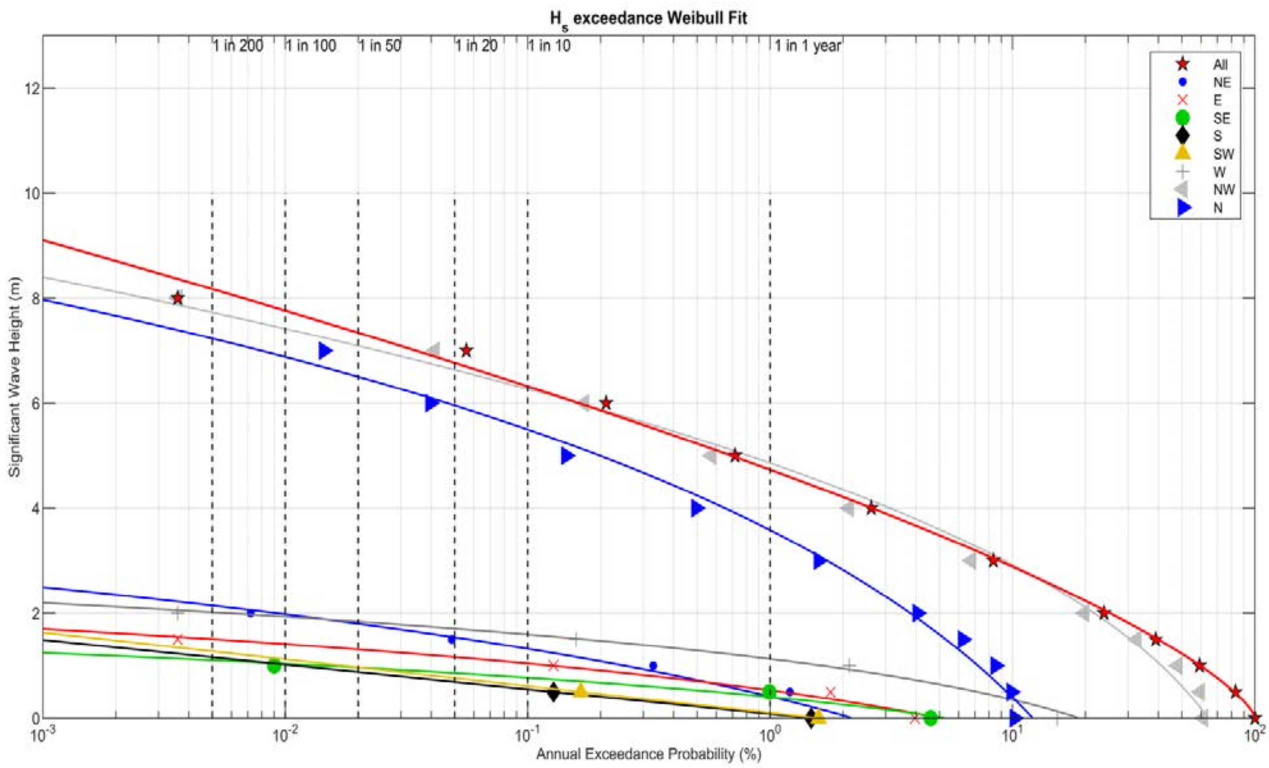


Figure 3.16: Nearshore significant wave height exceedance curve at Easkey between 2000 and 2019

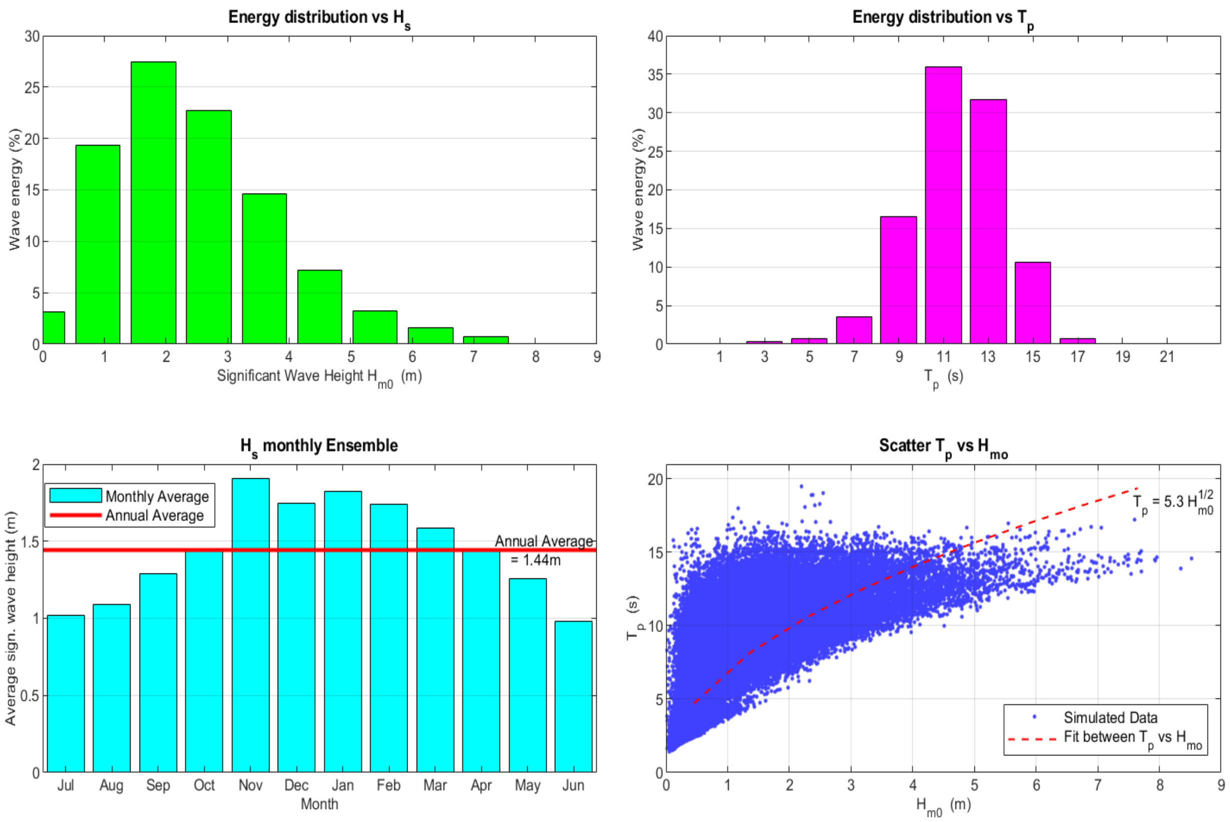


Figure 3.17: Wave energy distribution vs wave height and peak wave period (upper left and right), average annual and monthly wave heights (bottom left) and wave height vs peak wave period (bottom right) for a nearshore point at Easkey.

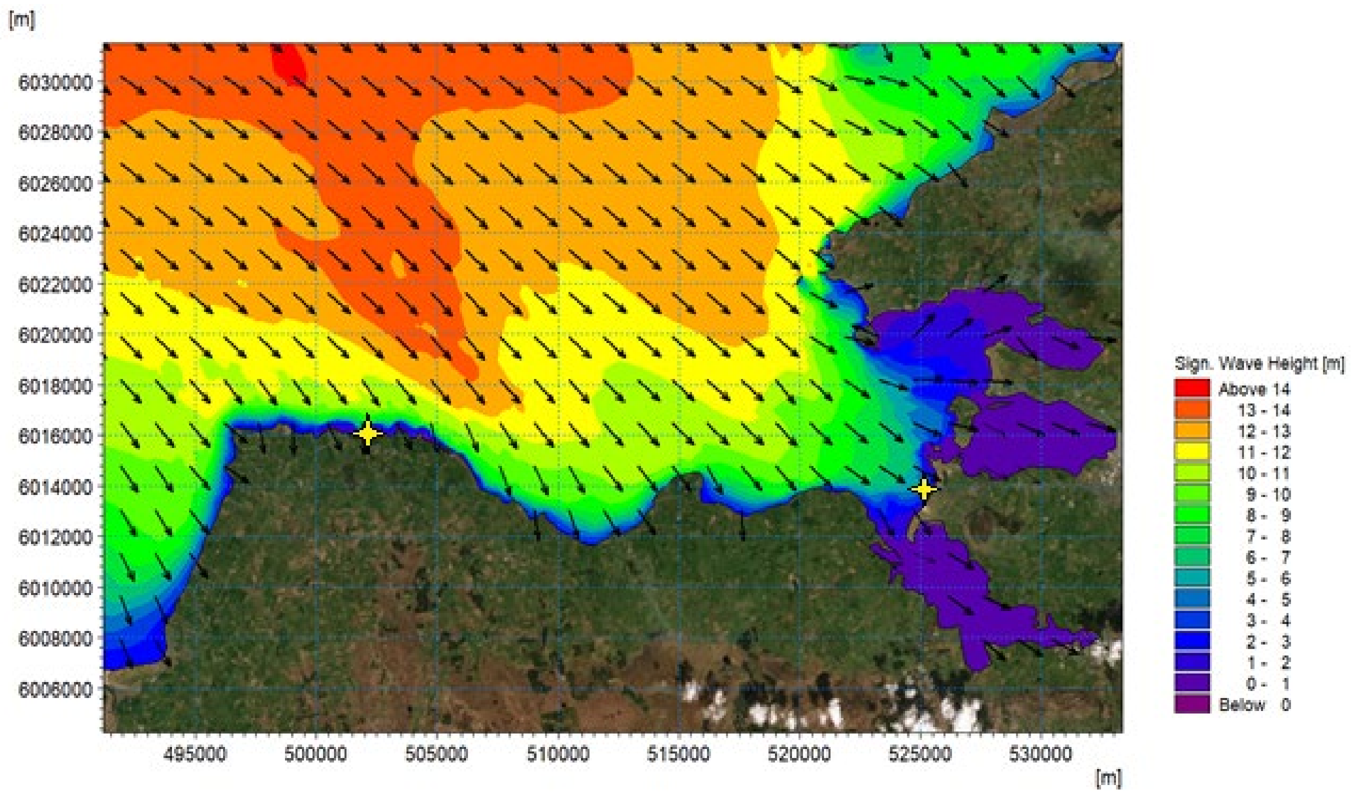


Figure 3.18: Inshore wave climate during a 1 in 50-year storm event from 300°N based on present-day climate conditions showing the extraction location for the extreme inshore wave conditions presented below

3.2.2 Long-term wave climate at Strandhill

Similar to the wave climate at Easkey, the dominant wave direction at Strandhill is between *c.*300 – 345º as illustrated in Figure 3.19.

The annual average nearshore significant wave heights at Strandhill between 2000 and 2019 were found to be 1.32m. As would be expected, the monthly average significant wave heights were much larger during the winter months between November and March. The annual and monthly average significant wave heights at Strandhill are illustrated in Figure 3.21. As demonstrated by this figure, the average wave height and peak wave period at Strandhill of *c.*1.75m and 11s respectively are less than those at Easkey. This can be attributed to the fact that wave energy is gradually attenuated as waves propagate further into Ballysadare bay.

The probability exceedance curve for nearshore significant wave heights at Strandhill between 2000 and 2019 is presented in Figure 3.20. Based on this information it can be seen that on average, the offshore significant wave heights could reach *c*. 4.20m and 8.00m during a 1 in 1 and 1 in 200-year event respectively.

Closer inshore, at the point illustrated in Figure 3.18, RPS extracted inshore wave climate information for all relevant return period events. The extreme inshore wave comate conditions for 1 in 2, 1 in 50 and 1 in 200-year events are presented in Table 3.4. It will be seen from this table that the inshore wave conditions during all the simulated extreme return period storm events are relatively similar, ranging between 2.26m and 2.67m for a 1 in 2 and 1 in 200year event respectively.

It should be noted that these values are only indicative of one location and there is a significant spatial variation in the extreme inshore wave climate at both Strandhill and Easkey.

Table 3.4: Extreme inshore wave conditions at Strandhill at an offshore wave direction of 300°N

Return Period	Significant Wave Height (Hm0) [m]	Max Wave Height [m]	Peak Wave Period (Tp) [s]	Mean Wave Period (T01) [s]
1 in 2	2.26	2.92	10.02	8.32
1 in 50	2.55	3.28	10.69	8.87
1 in 200	2.67	3.43	10.93	9.07

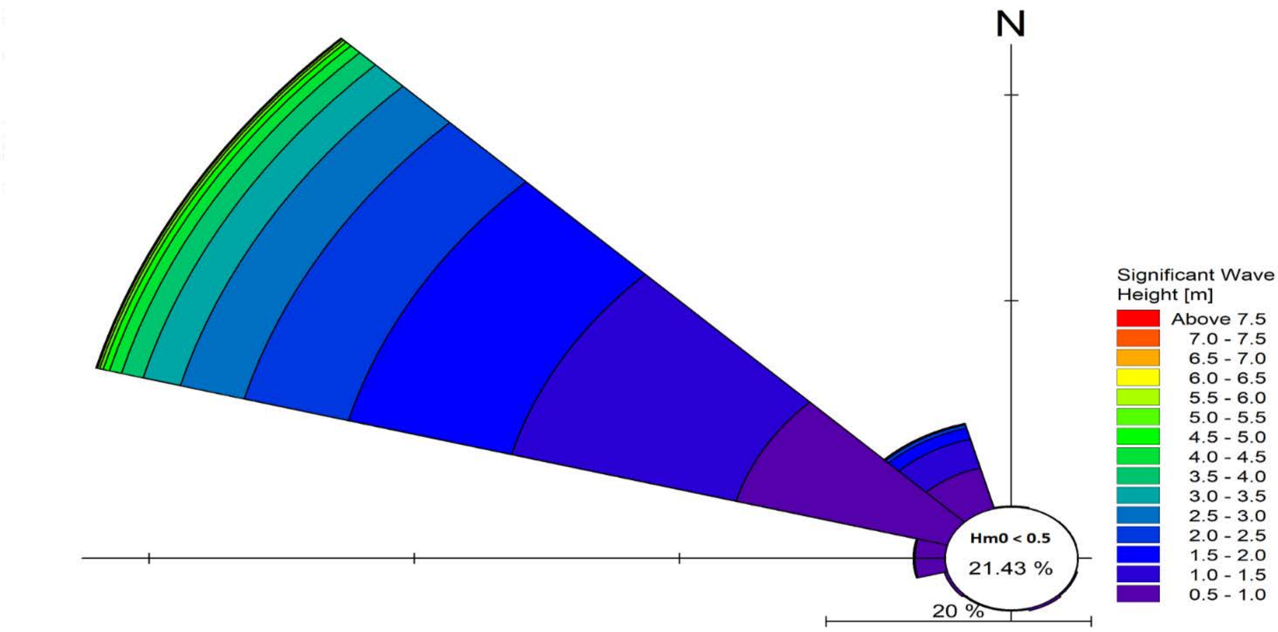


Figure 3.19: Long-term inshore wave rose for Strandhill, Sligo

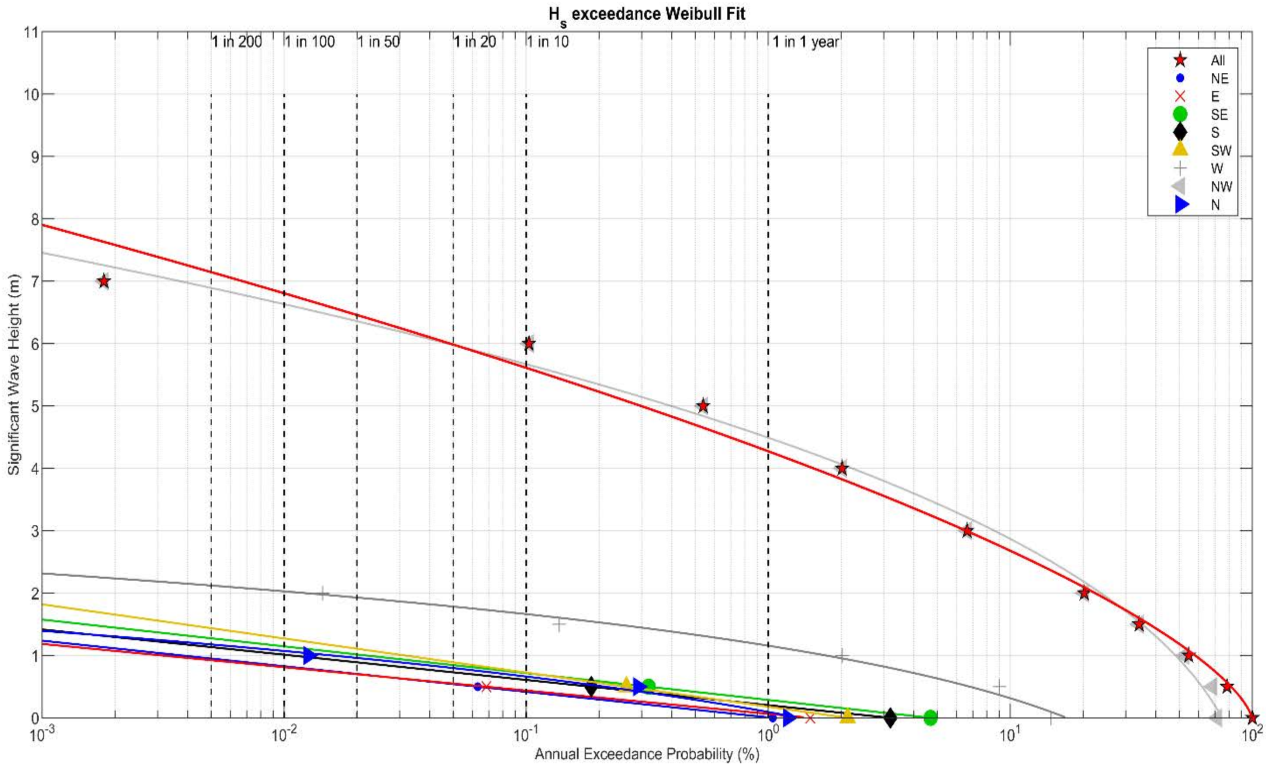


Figure 3.20: Nearshore significant wave height exceedance curve at Strandhill between 2000 and 2019

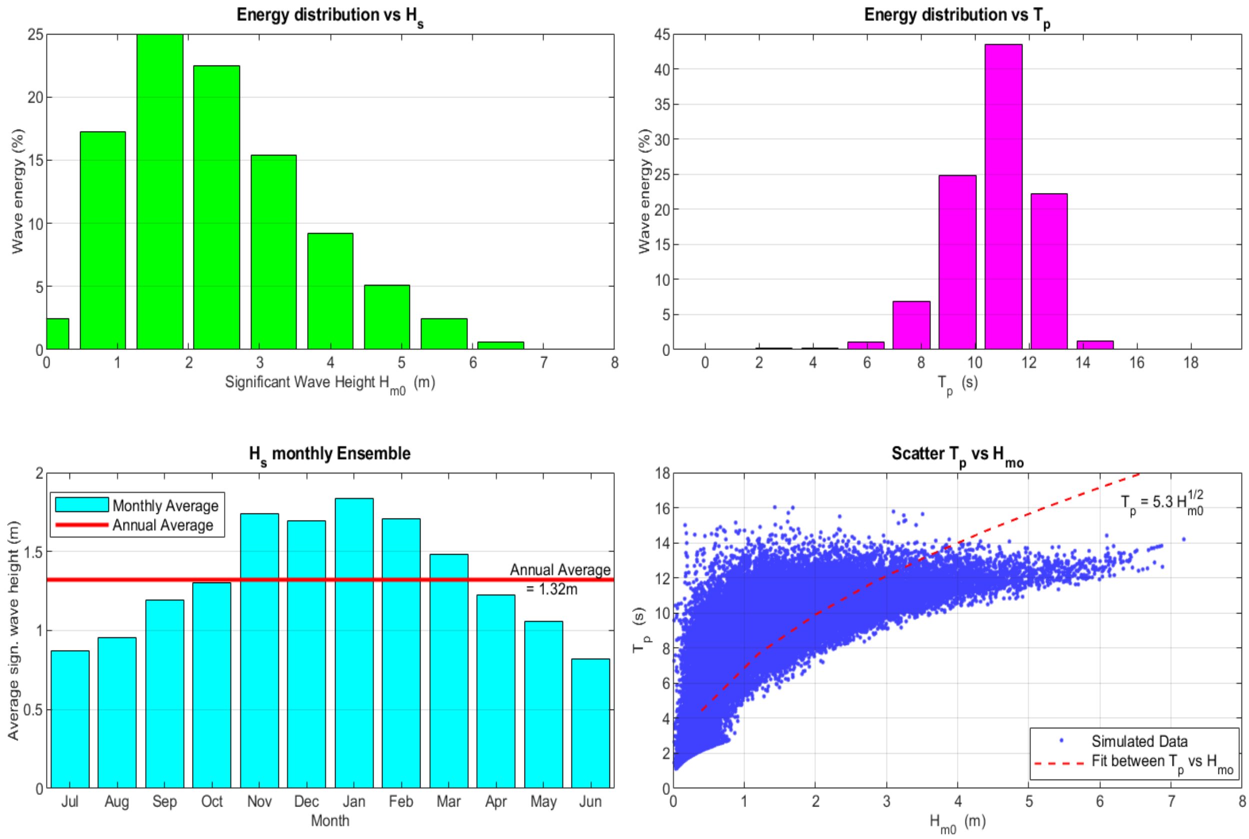


Figure 3.21: Wave energy distribution vs wave height and peak wave period (upper left and right), average annual and monthly wave heights (bottom left) and wave height vs peak wave period (bottom right) for a nearshore point at Strandhill.

4 COASTAL EROSION RISK ASSESSMENT

4.1 General

Coastal erosion is an important natural phenomenon that has been occurring uninterrupted, for millions of years (until recent human intervention). Erosion plays a fundamental role in re-distributing sediment throughout a coastal system and contributes to the formation of a variety of coastal landscapes, many of which have now been designated as special habitats owing to their unique environmental characteristics.

Excessive erosion, however, can result in significant negative impacts in areas where there is not enough hinterland to accommodate the ongoing exchange of sediment and the potential retreat of the shoreline. This is particularly problematic in urbanised areas where important infrastructure, sites of cultural heritage and/or public amenities can be threatened by erosion.

Assessing the potential consequences of coastal erosion, therefore, forms a key element in the development of any coastal erosion management strategy. The following section of this report describes how RPS used the Historical Trend Analysis method to calculate the current erosion risk and how these risks were projected forward to enable RPS to quantify the potential risk associated with future coastal erosion in later sections of this report.

4.2 Historical Erosion at Strandhill

4.2.1 Erosion between 2000 and 2012

Coastal erosion along the Strandhill coastline has been a longstanding issue and RPS (previously KMM) has been involved in localised studies and construction work in the area for more than 20 years. The coastal processes around the beach area are complex with extensive wave-driven currents at the beach and a tidal estuary entrance at the southern end of the dune spit.

A detailed hydraulic study of the Strandhill beach system was undertaken in 2000. This study identified a low-lying and vulnerable section of the dunes immediately to the south of the car park which if breached would enable flooding of property adjoining the dune area. Following the completion of this study, a rock revetment and pathway were constructed from the southern end of the car park to a high dune area some 280 metres south of the car park. The scheme as illustrated in Figure 4.1 also included a new slipway to give access to the beach for public and emergency vehicles. The purpose of the rock beach revetment was twofold:

1. To protect the low-lying area behind the dunes to the south of the car park
2. To provide access along the beach, particularly at times of high tide.

For 10 years following construction in 2001 of the rock beach revetment and new slipway to the south of the car park, there was no extensive damage to the dune system to the south of the car park. Only relatively small levels of maintenance work were required to the transition zone at the southern end of the rock beach revetment where it blends into the cobble storm beach at the toe of the large dune

However, in April 2011 the beach became drawn down exposing the underlying stone and cobble. Some damage occurred to the transition zone in late April 2011 and then extensive damage to the transition zone and dune cutback occurred during May 2011. During the events in May, the cobble storm beach was removed from the toe of the dunes and the beach in front of the dune was further drawn down exposing layers of peat beneath the beach which had not been seen in more than 30 years. A record of the damage to the dunes to the south of the rock beach during this period is shown in Figure 4.2 to Figure 4.4.

Further damage occurred in early November 2011 after which the Council installed a low-level rock berm at the cut back at the termination of the damaged transition zone. The rock berm was installed as an emergency measure to prevent erosion of the sand behind the end of the rock beach revetment. Further storms occurred from late November and mid-December 2011 which resulted in erosion of the dunes along the frontage to the south of the rock beach revetment to a point well to the south of the Shelly Valley as can be seen in Figure 4.4.

Sand that had been built up over many years using sand fencing at the entrance to the Shelly Valley was washed away during the December 2011 storms and the shingle storm beach at the foot of the dunes was greatly reduced during these extreme beach drawdown events. The beach levels started to recover during late January and early February 2012 and a very substantial cobble storm beach deposit at the toes of the dunes appeared during this time.

In addition to the scheme improvements at Strandhill, coastal protection works comprising 260 linear metres of rock armour and a coastal path were constructed in 2011 to protect the wastewater treatment plant at Killasupugbrone.

Figure 4.1: Rock revetment protecting the slipway access at Strandhill

Figure 4.2: Damage to the transition zone and evidence of terminal erosion to the dune 5th May 2011

Figure 4.3: Damage to a considerable length of the dunes during large high tides on 11th May 2011

Figure 4.4: Resultant damage to the dunes south of Strandhill which also exposed a peat layer on 24th May 2011.

Figure 4.5: The coastal protection works at the Wastewater treatment works following construction in Feb 2011

4.2.2 Erosion since 2012

Since the extreme storm events in November 2011, the coastline at Strandhill has continued to be exposed to extreme wave action which has often resulted in extensive erosion and damage to existing defences. A succession of storm events whilst the beach profiles were in a lowered state resulted in significant damage to the coastline in 2014 which included:

- Removing and re-profiling of *c.* 60m of the revetment at the sewage treatment plant. In this instance, incident wave energy displaced large 3-4 tonne rocks and broke some primary armour. The broken material was not suitably sized to provide adequate protection and required replacement and re-profiling. Furthermore, the damage to the primary armour led to the formation of voids beneath the concrete path and flood wall on top of the revetment which threatened the integrity of the defence.
- Notable damage to the revetment taper to the south of Strandhill. Much of the material comprising this defence was displaced and required re-profiling. This structure subsequently required repairs and modification to prevent further outflanking of the revetment by extreme storm events.

It was following the winter storms of 2014 that unprotected dune to the south of the WWTP coastal defences began to be outflanked by wave energy which in turn accelerated terminal erosion as illustrated in Figure 4.6.

Figure 4.6: The coastline south of the WWTP revetment in Dec 2011 (left) and Mar 2014 (right)

Whilst there is a lack of continuous monitoring records and information available, it is well established from anecdotal evidence that the coastline at Strandhill has been subject to storm damage during almost every winter period between 2012 and 2022.

One area whereby erosion is evident is just north of the beach car park whereby a storm drain access chamber that was once at the edge of the dunes in *c.* 1997 is now 20.2m seaward of the coastline as illustrated in Figure 4.7. This suggests that the coastline in this area has retreated at an average rate of 0.80m per year during this period.

Further north, the coastline just south of the revetment which protects the WWTP has retreated by *c.*20m between the period it was first constructed in February 2011 and February 2022. This equates to an average rate of coastal retreat of 1.80m per year. This extensive erosion is illustrated in Figure 4.8.

Figure 4.7: Exposed storm water manhole north of Strandhill, February 2022

Figure 4.8: Extensive erosion south of the revetment at the WWTP, February 2022

Using beach survey data recorded at Strandhill in 2006 and most recently in 2022, RPS assessed the volume of sediment exchange and the evolution of the coastline between Killaspug Point to the north and Carrowdough Spit to the south. This assessment found that between 2006 and 2022, *c.*182,000 m^3 of sediment material had been lost from the beach and dune system along the northern section of the coast, between Killaspug Point and Strandhill. Between Strandhill and Carrowdough Spit, *c.*70,000 m^3 of sediment had accreted along the beach and dune. This indicates that more than half of the sand material eroded from the northern beach has been transported offshore, into Rosses Harbour or Ballysadare Bay, or a combination of all three.

Cross-shore profiles for a location just south of the WWTP revetment and at the stormwater manhole just north of Strandhill are presented in Figure 4.9 and Figure 4.10 respectively. These figures demonstrate the coastline at the WWTP and stormwater manhole have retreated by 29m and 16m respectively between 2006 and 2022. Of particular concern in the region of the WWTP is the significant reduction of the dune crest of *c.*5m. This would significantly reduce the ability of this dune to act as a natural flood barrier during extreme storm conditions when tidal surge activity can increase sea levels by up to a metre. As such, the vulnerability of the hinterland to extreme flooding is increased significantly.

Further information on the historical coastal change along this coastline is presented in the following Sections of this report.

It should be noted that a similar analysis has not been undertaken for Easkey owing to a lack of historical survey data.

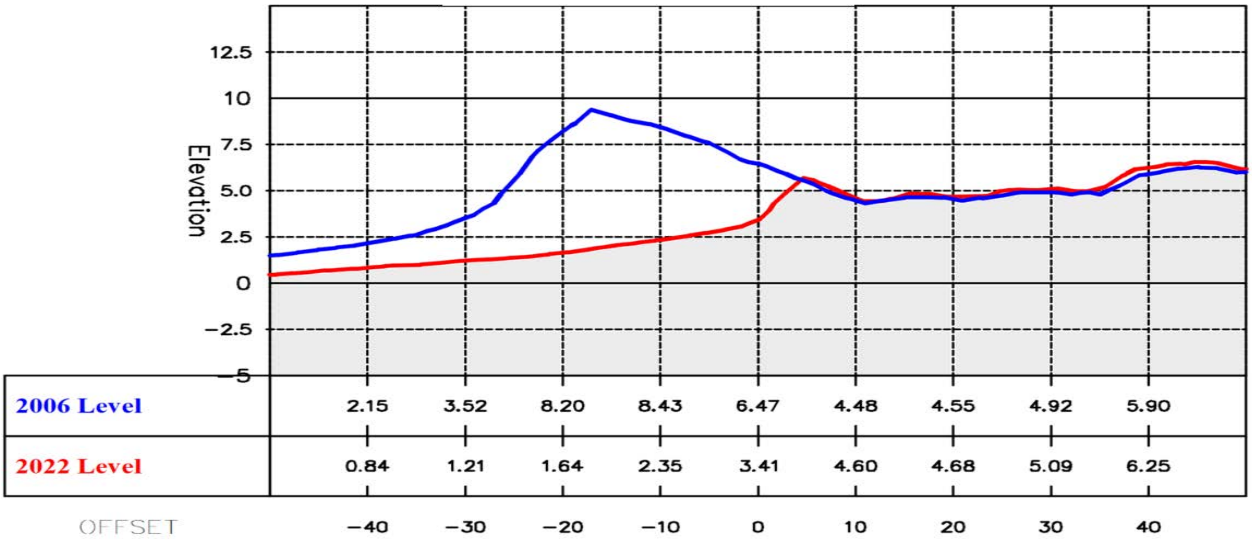


Figure 4.9: Change of the dune profile between 2006 and 2022 adjacent to the WWTP revetment.

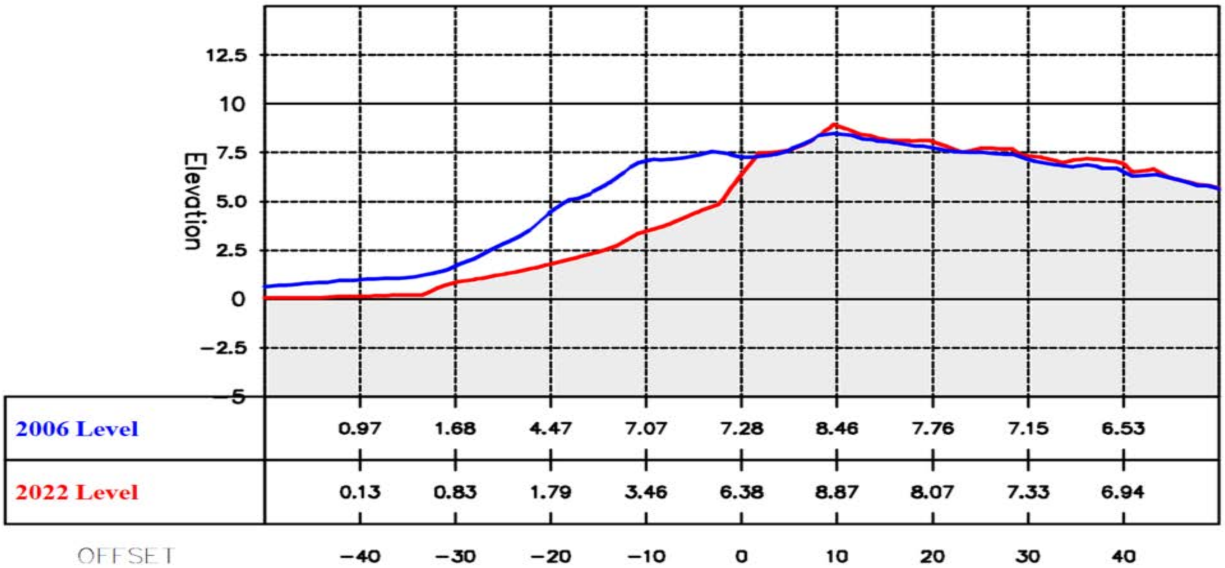


Figure 4.10: Change of the dune profile between 2006 and 2022 at the stormwater manhole

4.3 Historical Trend Analysis

4.3.1 Background

Historical Trend Analysis is one of the key approaches used in the analysis of coastal change over historical timescales. By quantifying and assessing past coastal change, it is possible to project and estimate future trends based on events that have already occurred.

The historical trend analysis across the study area was completed using the Digital Shoreline Analysis System (DSAS) which is a tool produced by the US Geological Society (USGS, 2018). One of the main benefits of using DSAS in coastal change analysis is its ability to compute the rate of change statistics for a time series of shoreline positions. The statistics allow the nature of shoreline dynamics and trends in change to be evaluated.

4.3.2 Schematisation of the shoreline & workflow

For the analysis of the areas of interest, shoreline data was available from 1995 to 2021, spanning 26 years. However, it will be seen from Table 4.1 which summarises the available shoreline information across each study site that aerial imagery was not available for Easkey from 2009, 2018 -2019 and 2022.

Table 4.1: Summary of available shoreline data

Year	Strandhill	Easkey
1995	✓	✓
2000	✓	✓
2009	✓	✗
2012	✓	✓
2018	✓	✗
2019	✓	✗
2021	✓	✓
2022	✓	✗

Using the DSAS tool, the shoreline of each area of interest was divided into 25m transects. The DSAS tool was then used to calculate the linear regression rate for each 25m transect.

- **Linear Regression Rate (LRR):** determines a rate-of-change statistic by fitting a least square regression to all shorelines at a specific transect. Further statistics associated with LRR include Standard Error of Linear Regression (LSE), Confidence Interval of Linear Regression (LCI) and R-Squared of Linear Regression.

Figure 4.11 shows an example of how the 25m transects were cast from a baseline to intersect shoreline data along Strandhill.

Reference was also made to quaternary layer information published by Geological Survey Ireland to determine which regions of the areas of interest were likely to erode based on the composition of the substratum and which areas would likely remain stable due to the presence of hard rock and rocky outcrops. The underlying geology across the study areas is illustrated in Figure 4.12 and Figure 4.13.

The yellow and pale brown regions in the figures represent areas where the lithology is characterised by marine gravel and sands (often raised) and thus susceptible to coastal erosion. The lithology of the other regions in the figures is characterised by other bedforms which are more resistant to erosion over the timescales that this study considers.

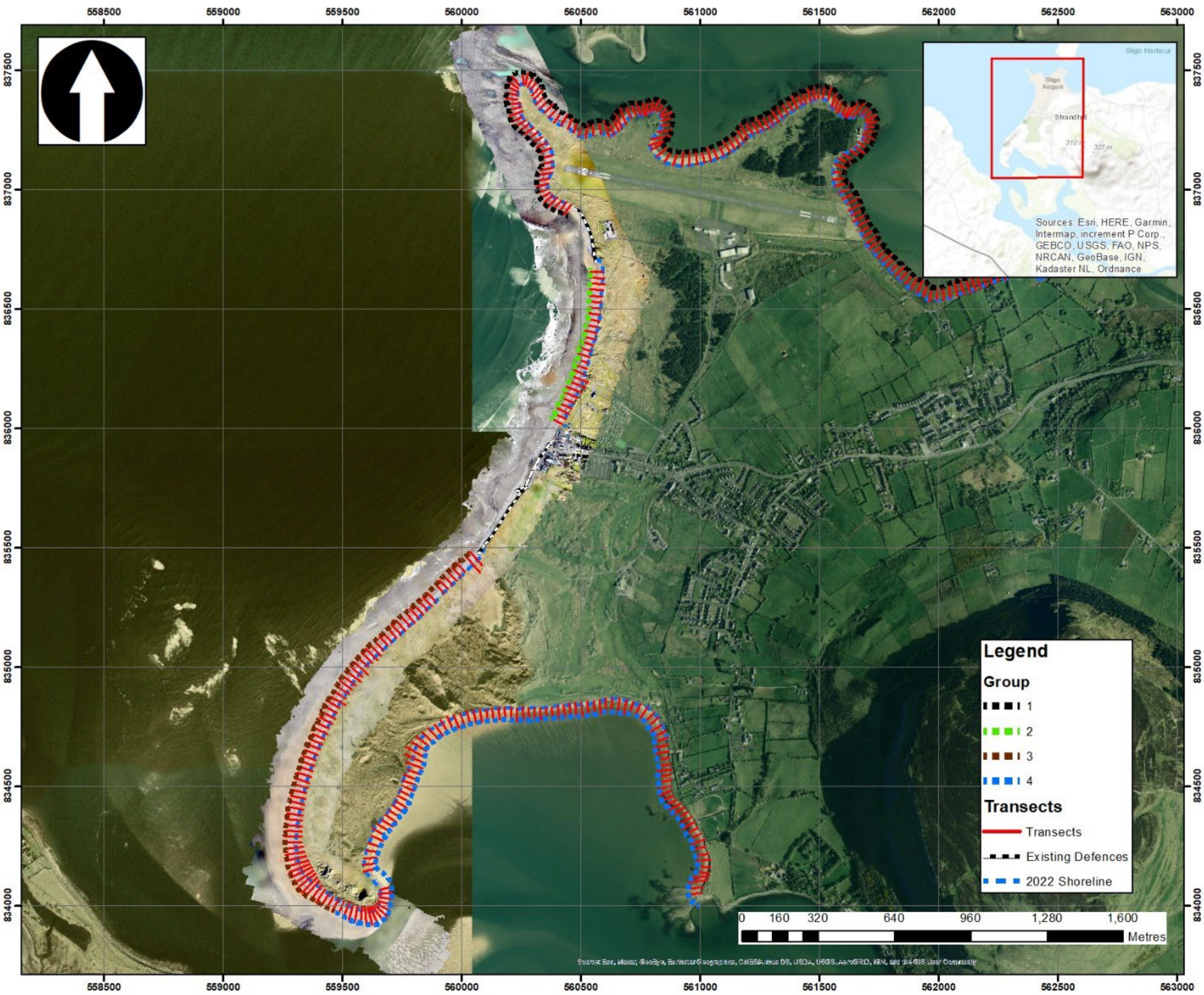


Figure 4.11: Example of 50m transects intersecting shoreline data at Strandhill

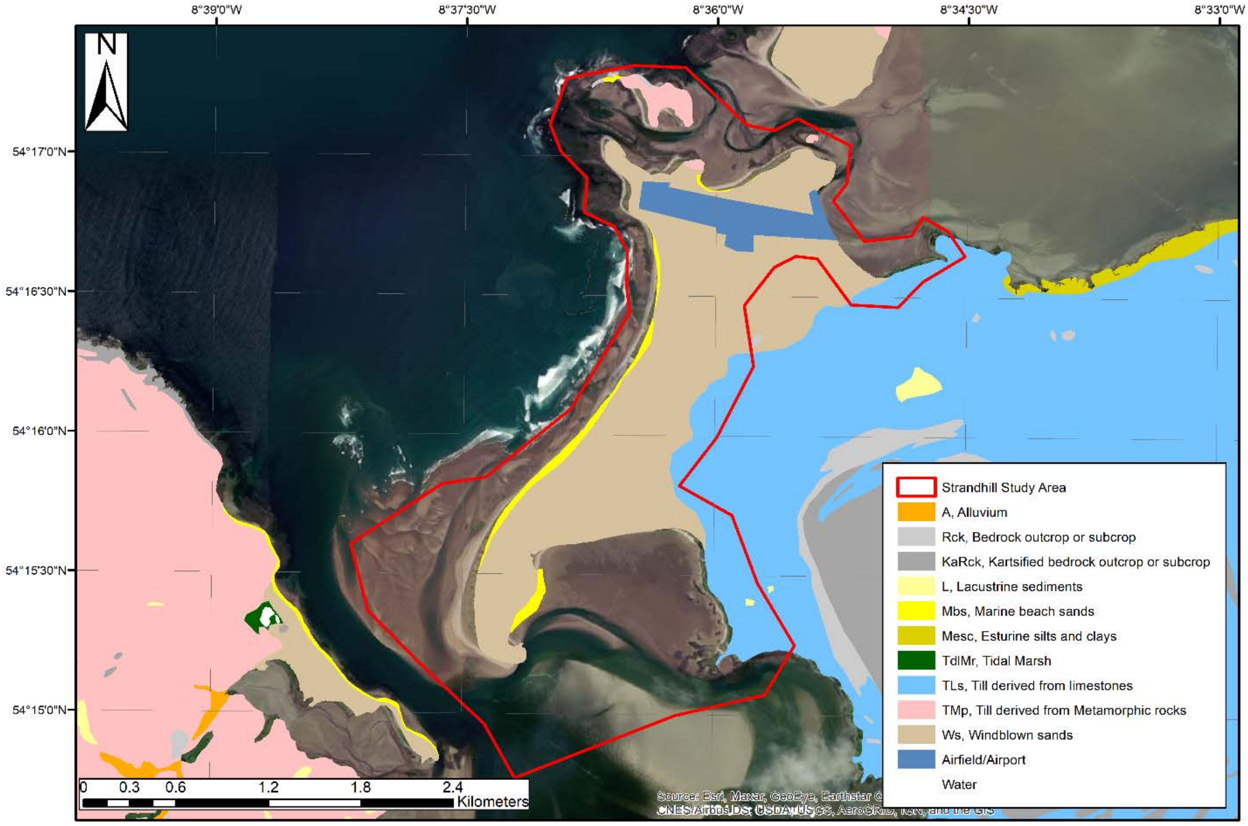


Figure 4.12: Quaternary sediments across the Strandhill study areas with regions susceptible to erosion are shown in yellow and pale brown (Geological Survey Ireland, 2021)

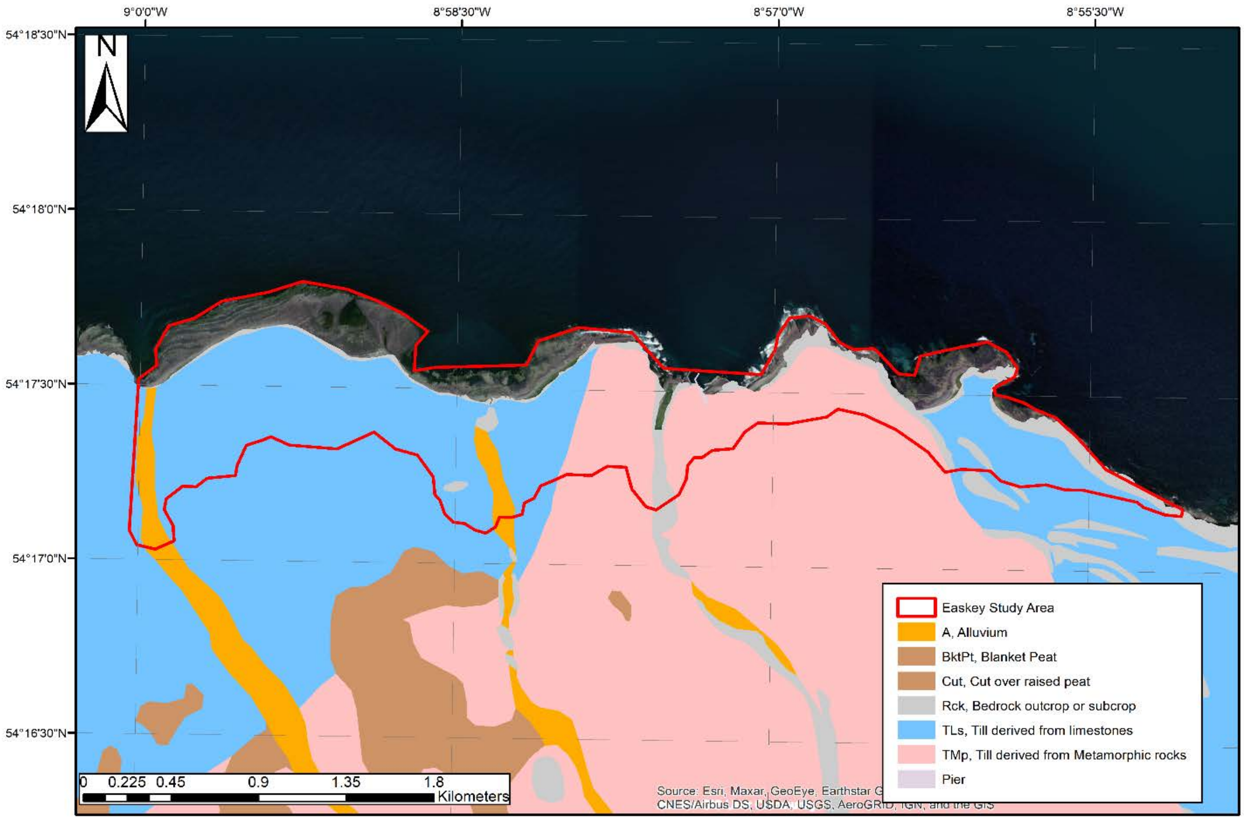


Figure 4.13: Quaternary sediments across the Easkey study area (Geological Survey Ireland, 2021)

4.3.3 Coastal Change Assessment at Strandhill

The output from the historical shoreline analyses for Strandhill north and south is presented in Figure 4.14 and Figure 4.15 respectively. These figures illustrate the *average* rate of coastal change in each area at 25m intervals.

Along the northern section of Strandhill, the greatest rates of coastal change of -1.5 to -2.0m per year were observed immediately south of the revetment at the WWTP. These results are in line with the historical erosion in this area as described in Section 4.2.2. It should be noted that erosion in this area before the construction of this defence was significantly less at *c.* -0.25 to -0.50m per year.

It will be seen from Figure 4.14 that the rates of coastal change gradually reduce further down the beach towards Strandhill. This can be attributed to the orientation of the coastline in this area changing and approaching *equilibrium* whereby a lack of oblique wave attack significantly reduces sediment transport.

Further north towards Kilasprugbone it will be seen from Figure 4.14 that regions of this coastline have also retreated between 1995 and 2022. However, it should be noted that the resolution of historical data in this region was very low which in turn significantly reduces the confidence associated with the shoreline analysis process described in Section 4.3.2.

South of Strandhill, it will be seen from Figure 4.15 that much of the coastline has experienced modest levels of accretion, particularly towards the distal end of Carrowdough Spit and into Ballysadare Bay. In some areas, this coastline has advanced seaward by up to 1m per year. This is unsurprising given that the direction of sediment transport is generally towards the south, thus sand eroded from the north is likely to be transported towards this region.

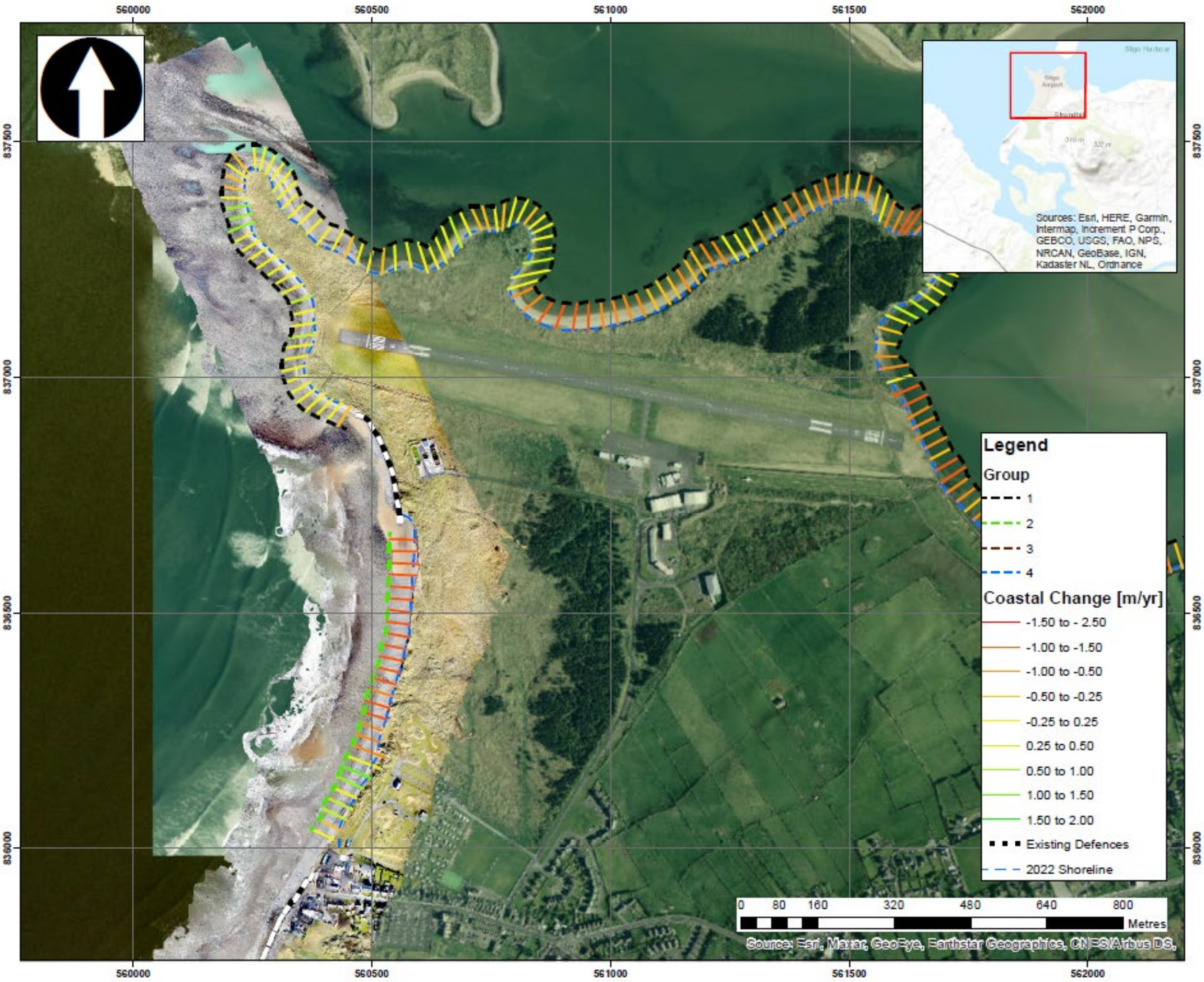


Figure 4.14: Linear regression analyses coastal change at two sections in North Strandhill based on shorelines from 1995 to 2022

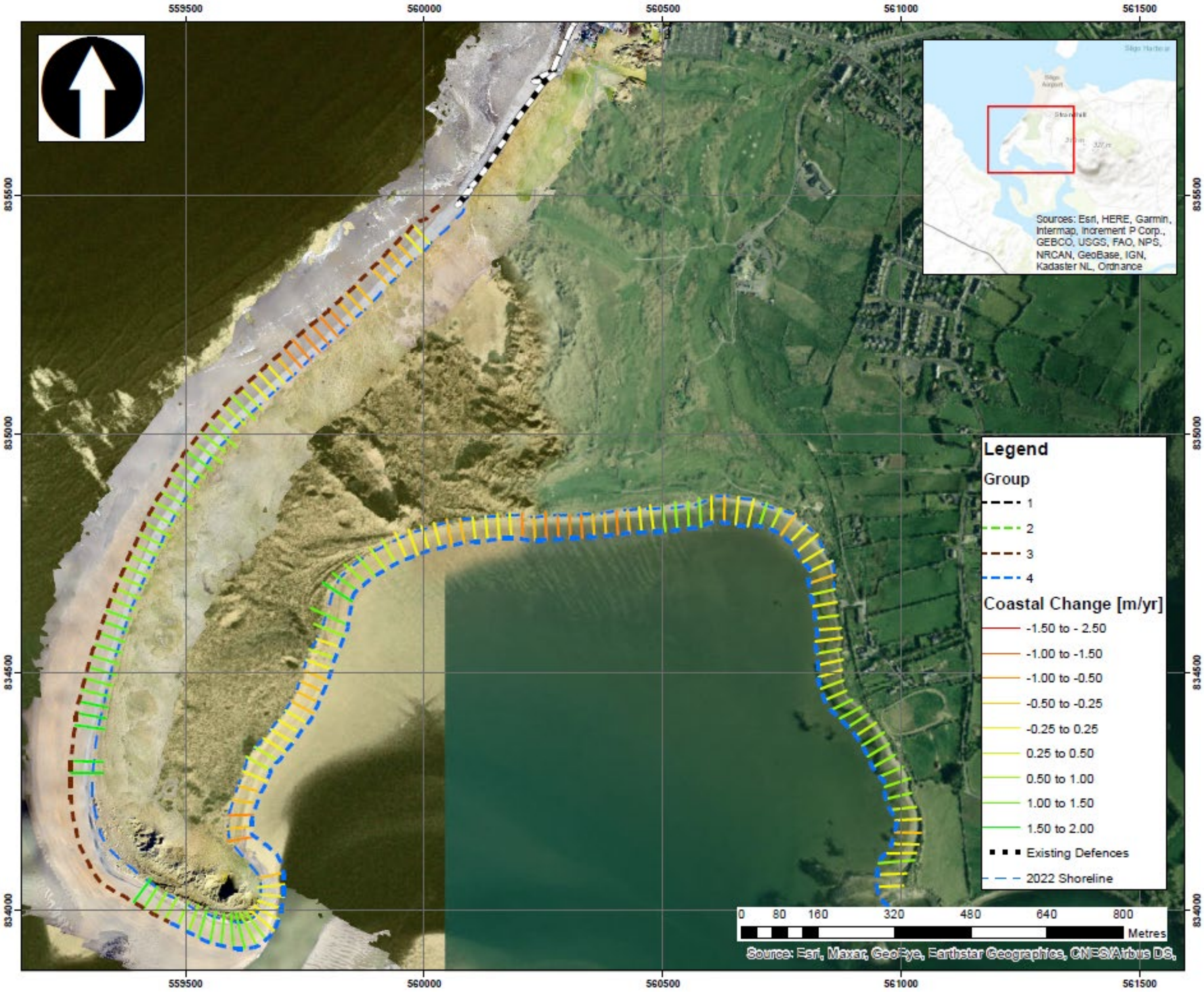


Figure 4.15: Linear regression analyses coastal change at Strandhill based on shorelines from 1995 to 2022

A summary of the historical shoreline analyses for the four shoreline groups considered at Strandhill is presented in Table 4.2 below. It will be seen from this information that the highest rate of coastal change is observed between Strandhill and the revetment at the WWTP towards the north. Furthermore, it is important to note that whilst the average rate of coastal change in this area equated to *c.*0.95m per year, some localised regions of this Section were found to have retreated by up to -2.5m per year.

Table 4.2: Summary of the shoreline movements across Strandhill beach between 1995 and 2022

Metric	North of the WWTP	South of the WWTP	South of Strandhill	Ballysadare Bay
Total number of transects:	165	27	76	112
Average rate of change between 1995 to 2022 [m/yr]	**-0.01**	**-0.95**	**+0.41**	**0.12**
% of transects that are eroding	51%	85	27%	26%
Maximum rate of retreat [m/yr]	-0.89	-2.5	-2.33	-3.00
% of transects that are advancing	49%	15%	73%	74%
Maximum rate of advance [m/yr]	0.52	1.3	6.92	1.60
Typical confidence [m/yr]	+/- 0.06	+/- 1.44	+/- 0.18	+/- 0.08

4.3.4 Coastal Change Assessment at Easkey

By utilising the workflow as described in Section 4.3.2, a similar analysis was undertaken for the coastline at Easkey. Unlike at Strandhill, this analysis found that no sections of the coastline at Easkey were in a state of continuous retreat based on available information. The average rate of coastal change in this area equated to *c*.-0.01m per year.

However, it should be noted that the accuracy and thus confidence of this assessment was compromised owing to a lack of suitable high-resolution survey data. Indeed, the only year for which high-grade information was available was 2021 when the area was surveyed by KGSS for this study.

Evidence gathered during a site visit to Easkey in September 2021 indicated that whilst this site may not be subject to continuous coastal erosion, there are certainly some localised sections that are vulnerable to wave action during extreme events as illustrated in Figure 4.16.

In summary, it was concluded that the scale of historical coastal change at Easkey was significantly less than the accuracy of any accepted method to calculate historical retreat. This was largely due to the lack of continuous, high-resolution survey information available for the study area.

Figure 4.16: Evidence of localised wave-induced erosion at Easkey, Sept 2021

4.4 Coastal Change Assessment – Strandhill Future Projection Maps

In line with the OPW guidance, future coastal change maps were produced for Strandhill by extrapolating the historical coastal change rates described in Section 4.2 for the following epochs:

- The short term (0-10 years)
- The medium term (10 – 30 years)
- The long term (30 – 100 years)

The projected extent of future coastal change along the northern and southern regions of Strandhill for these epochs is illustrated in Figure 4.17 and Figure 4.18 respectively.

In line with the results of the historical assessment, it will be seen from Figure 4.17 that the highest rate of project future coastal erosion is just south of the revetment at the WWTP. Based on the existing *average rate* of coastal change, the shoreline in this location could retreat by up to *c*.94m by 2100. It is expected that under this scenario, the coastline would naturally taper back into the hard defence at Strandhill (assuming that it is maintained into the future).

It is important to recognise that this projected coastal change is based on the *average rate* of coastal change of -0.94m per year. However, as summarised in Table 4.2, the maximum rate of coastal change of -2.5m per year was observed immediately after the installation of the rock armour at the WWTP. Fortunately, erosion rates in this area have since reduced and are more in line with the average rate of -0.94m per year now the coastline is in a semi-stable state. Nevertheless, it is feasible that the extent of actual future erosion by 2100 could be significantly greater than illustrated in Figure 4.17. As this coastline retreats, the effect of terminal erosion will likely reduce which will, in turn, reduce the high rates of coastal change in this area.

As illustrated in Figure 4.17, very little coastal change has been predicted over the next 100 years in the region of Kilasprugbone owing to an informal seawall which in combination with the underlying geology fixes the position of this coastline.

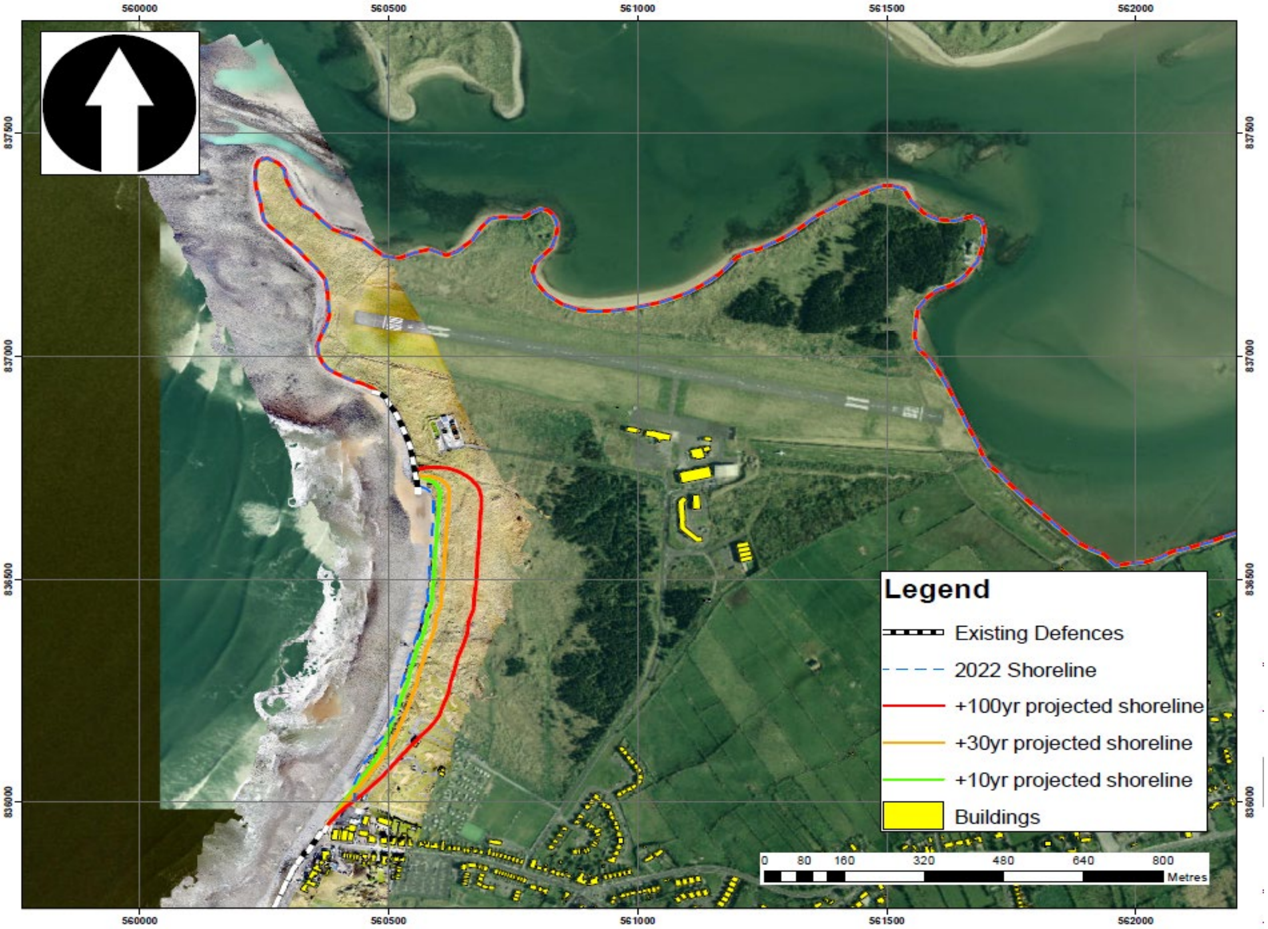


Figure 4.17: Projected coastal change along the northern section of Strandhill over the next 100 years.

Based on *historical* data, most of the southern region of Strandhill is considered to be in a state of accretion and could theoretically advance seawards by up to 41 metres. This can be attributed to the local sediment transport regime which has been demonstrated to transport sediment from the north towards Carrowdough spit, including sand material eroded from the northern section of Strandhill beach. The small embayment behind Shelly Valley and Ballysadare bay are both expected to act as sediment sinks.

However, results from numerical modelling undertaken as part of this study indicate that this coastline is close to natural equilibrium whereby the coastline may fluctuate from its current position in response to storm and calm conditions, but overall remain near its present average position.

It should be noted that whilst most of this coastline is expected to remain stable, or indeed experience modest levels of accretion, the area immediately south of the existing hard defences and ramp is likely to continue to suffer from terminal erosion following extreme storm events. This is likely to affect the stability of the dune in a localised region as illustrated in Figure 4.18.

Future projection maps have not been produced for Easkey given that the scale of historical coastal change in this area was significantly less than the accuracy of any accepted method to calculate historical retreat. As such, the confidence associated with any future projection maps would be very low.

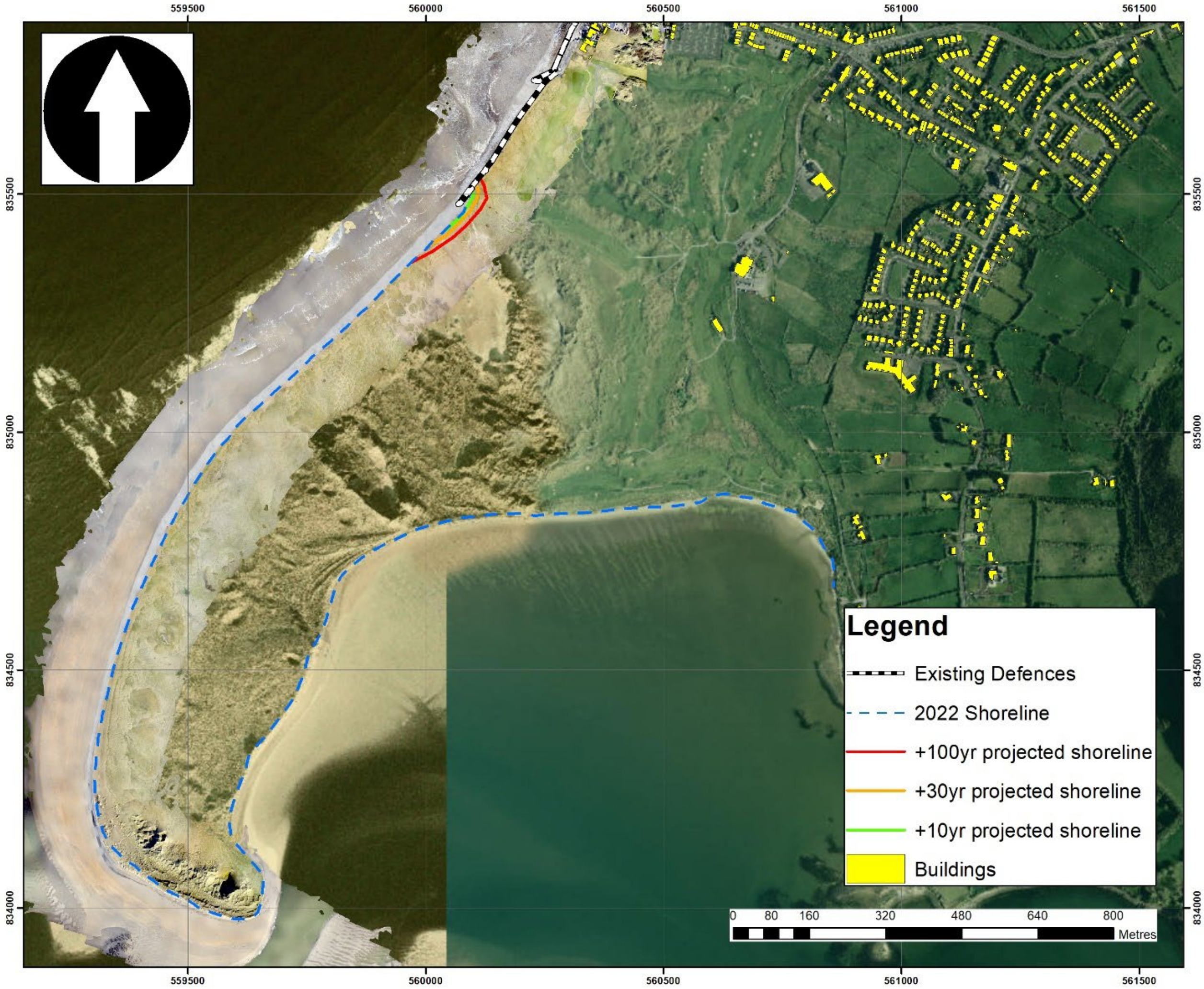


Figure 4.18: Projected coastal change along the southern section of Strandhill over the next 100 years.

4.5 Considering Future Climate Change

As per the OPW guidelines for CFERM studies, it was also necessary to consider coastal change based on the following climate change scenarios:

1. Medium Range Future Scenario (MRFS) climate conditions whereby sea levels are expected to rise by +0.50m by 2100.
2. High-End Future Scenario (HEFS) climate conditions whereby sea levels are expected to rise by +1.00m by 2100.
3. High + Future Scenario (H+FS) climate conditions whereby sea levels are expected to rise by +1.50m by 2100.
4. High ++ Future Scenario (H++FS) climate conditions whereby sea levels are expected to rise by +2.00m by 2100

A description of how RPS accounted for the impact of future climate change in the context of the coastal change assessment is presented in Section 4.5.1 of this report.

4.5.1 Considering the impact of Climate Change at Strandhill

Several quantitative models relate sea level rise (i.e., climate change) to coastal change with the most well-known being the Bruun rule (Bruun, 1962). This rule proposes that, in the absence of sediment sources and sinks, a beach profile gradually re-adjusts after a rise in relative mean sea level, as sediment is eroded from the upper beach profile and deposited onto the adjacent seafloor. This rule is represented by:

$$\Delta y = -S * \frac{L}{h+B} = -\frac{S}{\tan\beta}$$

Whereby shoreline change (Δy) is related to sea level rise (S), the horizontal length of the active profile (L), the depth of the active profile base (h), the berm crest elevation above sea level (B) and the average slope of the active profile ($\tan\beta$).

Several studies have noted the limited applicability of the Bruun rule to most coastal environments due to the theory's limiting assumptions of physical setting and constraints within the sediment transport regime (Thieler et al. 2000; Cooper and Pilkey 2004). To overcome this, alternative models have been developed that combine the Bruun rule with different assumptions to represent the net sediment budget.

The alternative, which was used to assess the impact of future climate change at Strandhill is the R-DA model (Davidson-Arnott, 2005). In this model it is assumed that as the sea level rises, the beach and foredune are eroded and sediment is transported landward, causing a landward and upward migration of the beach–foredune intersection. Similarly, there is a net onshore migration of sediment in the nearshore, causing an upward and landward migration of the shoreline and the seaward limit of the active profile.

The expression for the coastal change in the R-DA model is identical to that of the Bruun rule described in the equation above. However, in the R-DA model, the term $\tan\beta$ is the nearshore slope averaged over only the submerged portion of the active beach profile, not the entire profile, so it does not depend on the berm crest elevation (B). By explicitly including the beach–dune sediment exchange and landward aeolian (windblown) sediment transport, the R-DA model allows for the preservation of the foredune system under rising sea levels.

The differences between the Bruun Rule and the R-DA model are illustrated in Figure 4.19.

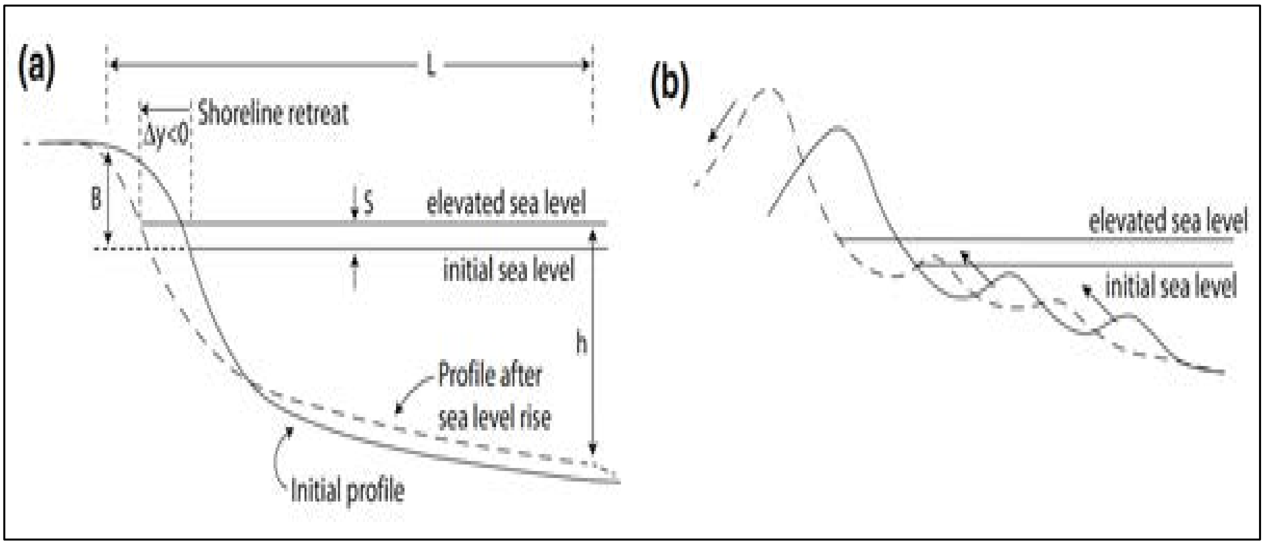


Figure 4.19: Shoreline change according to the Bruun Rule (a) and the R-DA model (B)

Whilst the future coastal change assessment for Strandhill has been undertaken by a team of experienced coastal engineers using the best available data and industry-accepted methods, the assessment has been based on several important assumptions and caveats, primarily:

- There will be no significant changes to the coastal processes, particularly the incident wave climate by 2100.
- The linear regression analysis of historic shoreline change across the study areas will be representative of future shoreline change.
- There will be no significant changes in sediment sources or sinks by 2100.
- There will be no significant changes in anthropogenic features or pressure by 2100.
- The underlying geology across the study area is comprised of soft, erodible sediment.
- The beach profile across the study area can dynamically adjust to prevailing conditions to maintain the existing hydraulic conditions.

The actual rate of coastal change across the study areas will be determined by the rate of future climate change and potential changes to the factors described above which were assumed to have remained constant for the purposes of this study. However, the overwhelming consensus of the recent scientific literature is that climate change is occurring much more rapidly than initially expected.

Most of these studies indicate the effects of climate change will increase the frequency and magnitude of extreme coastal conditions and will thus have a detrimental impact on many coastal communities (Baatesen et al, 2015).

4.5.2 Considering the impact of Climate Change at Easkey

As the coastline at Easkey is not comprised primarily of a sandy dune like at Strandhill, a simplified approach that relates existing and future coastal retreat rates with existing future sea level rise conditions was used at Easkey. This approach is described by the following equation:

$$\mathbf{R_2 = (R_1/S_1). * S_2}$$

Where:

S_1=historical sea-level rise rate (m/yr)	*S_2= future sea level rise rate (m/yr)*
R_1= historical retreat rate (m/yr)	*R_2= future retreat rate (m/yr)*

As summarised in Figure 4.20, this assessment found that the coastline at Easkey could retreat by between 8 and 24m for the MRFS and H+FS climate scenarios respectively. This assessment was based on a historical sea level rise rate of 3mm per year and an average rate of coastal retreat of -0.01m per year.

It is important to recognise the high level of uncertainty associated with this analysis.

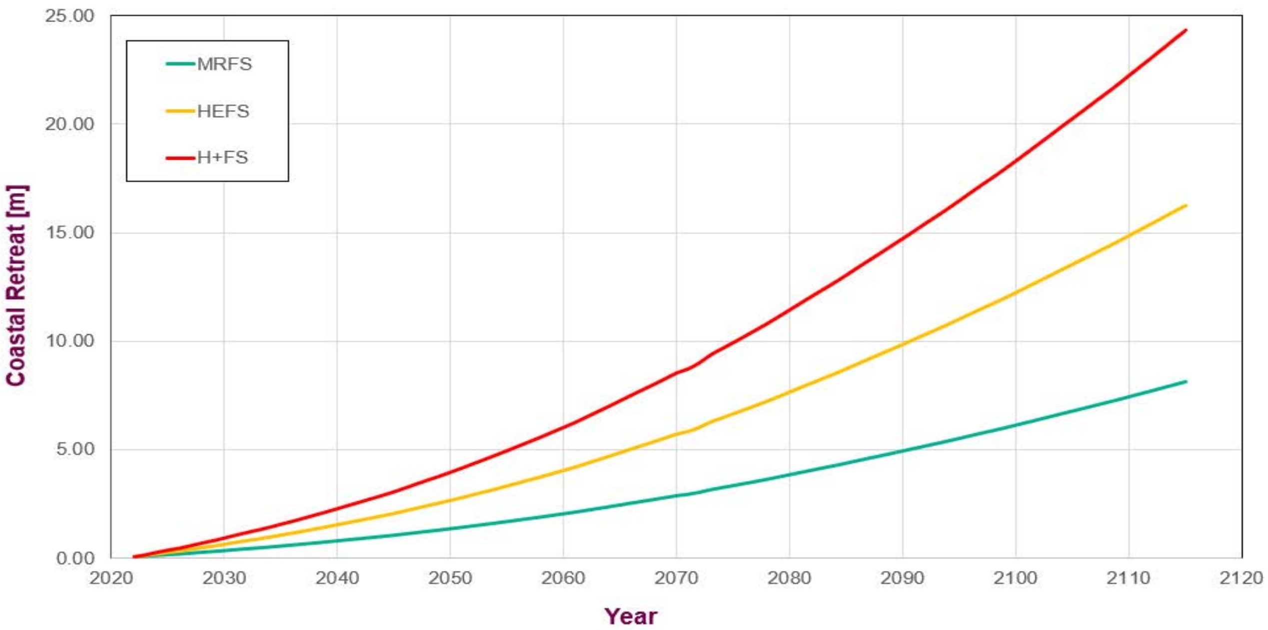


Figure 4.20: Projected coastal retreat associated with future sea level rise scenarios at Easkey

4.5.3 Coastal Change Maps at Strandhill with Climate Change

The projected extent of future coastal change at Strandhill for various future climate scenarios is summarised in Table 4.3 and illustrated in Figure 4.21. These future shoreline projections were calculated using the method described in Section 4.5.1.

It will be seen from Figure 4.21 that under the most probable future climate scenario, the MRFS whereby sea levels are expected to increase by +0.50m over the long term that some sections of the coastline could retreat by *c.*130m. Under this scenario, it is expected that even if the existing revetment at the WWTP is maintained, the structure would be completely outflanked by rising sea levels and incident wave energy. Under this scenario, the defence could become detached from the shoreline. The hinterland directly behind this defence, including the WWTP, would be at significant risk of coastal erosion under this scenario.

Figure 4.21 also demonstrates that the east and western extents of the airfield at Sligo airport would be susceptible to coastal erosion under this future scenario.

It is important to acknowledge that the actual magnitude of coastal change will be dependent on the frequency and severity of future storm events, both of which will be affected of future climate change. The actual coastal change may therefore be significantly different to that described in this report.

Table 4.3: Summary of potential coastal change by 2100 at each study area based on the MRFS, HEFS and H+FS climate scenarios

Site	Potential coastal retreat by 2100 [m]		
	Medium Range Future Scenario (*SLR = +0.50m by 2100*)	**High End Future Scenario** (*SLR = +1.0m by 2100*)	**High End + Future Scenario** (*SLR = +1.50m by 2100*)
Strandhill	16.61	33.32	49.83

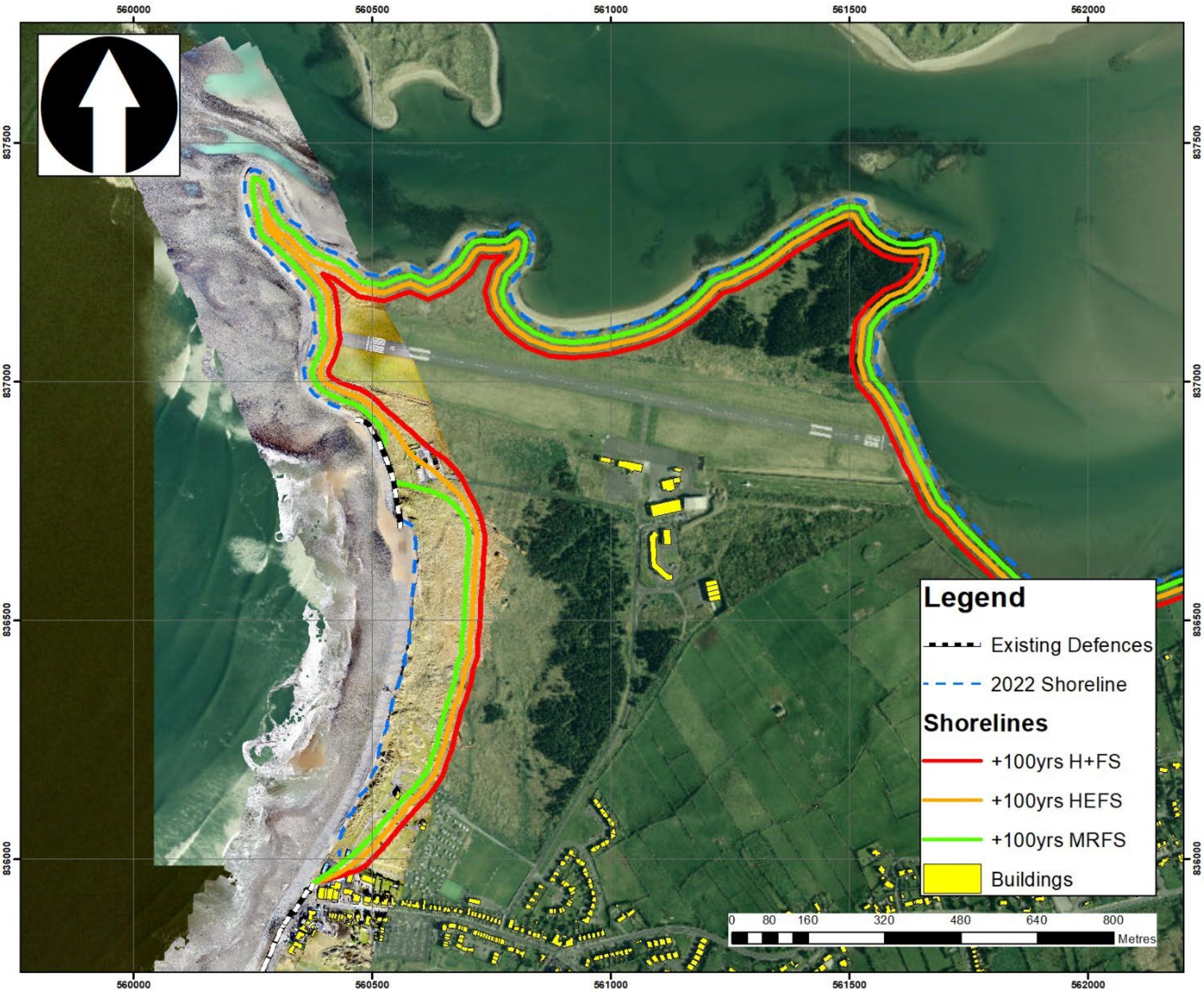


Figure 4.21: Projected coastal change along the northern section of Strandhill over the next 100 years under future climate change scenarios.

4.5.4 Coastal Change Maps at Easkey with Climate Change

As described in Section 4.5.2, it is possible that the shoreline at Easkey could retreat by between 8 and 24m under the MRFS and H+FS climate scenarios respectively. The resultant projected extent of future coastal change at Easkey for these future climate scenarios is illustrated in Figure 4.22.

Under these future scenarios, it is possible that the regional road which forms part of the Wild Atlantic Way could be threatened by coastal erosion. There are no other natural or built assets considered at risk under the scenarios considered in this study.

Again, it is important to acknowledge that the actual magnitude of coastal change will be dependent on the frequency and severity of future storm events, both of which will be affected by future climate change. The actual coastal change may therefore be significantly different to that described in this report.

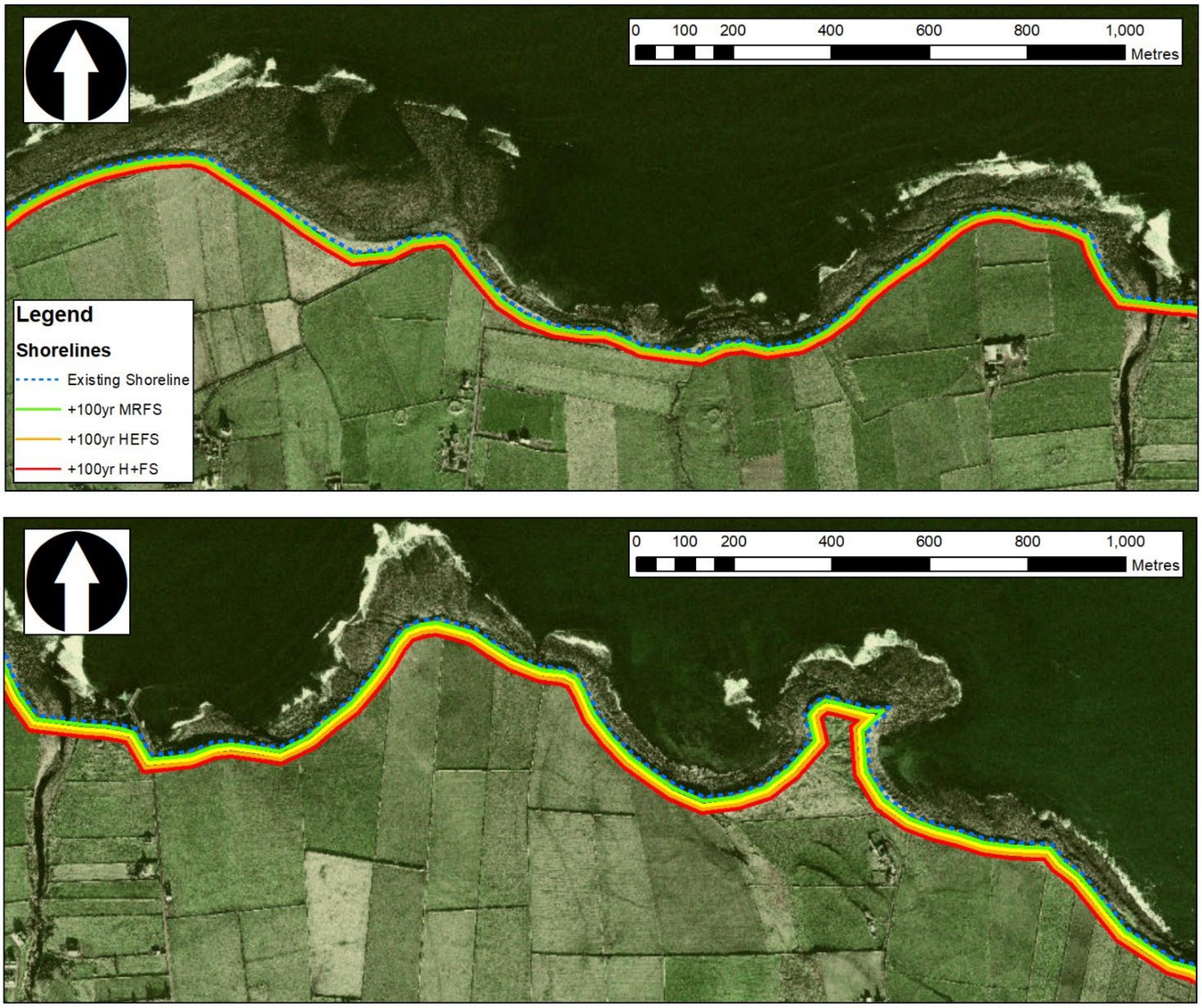


Figure 4.22: Projected coastal change at Easkey over the next 100 years under future climate change scenarios.

5 FLOOD RISK ASSESSMENT

5.1 Background

Coastal flooding can cause damage to homes and businesses, along with damage to and loss of service from infrastructure, such as water supply or roads. Flooding may also impact the environment by damaging or polluting habitats and damaging cultural heritage assets.

An assessment of coastal flooding is a key element in the development of any coastal protection strategy, particularly in regions in both the north and south of Strandhill (Kilasprugbone and Ballysadare Bay) which have areas of low-lying land.

The following section of this report quantifies the potential coastal flood risk from both combined tide and surge (mechanism 1 of coastal flooding) and wave over-topping (mechanism 2 of coastal flooding).

5.2 Mechanism 1 – Combined Tide and Surge

Owing to the relatively low-lying nature of sections of the coastal hinterland within the study area, the effect of combined tide and surge activity is expected to be the main source of coastal flood risk at both sites. The method used to assess this flooding mechanism is described below.

5.2.1 Assessing Combined Tide and Surge Flooding

5.2.1.1 Flood Model Boundary Conditions

The flood model described in Section 2.2.4 was constructed with only one seaward boundary. This meant that it was possible to simulate specific tidal levels across the study area by applying a single sinusoidal surface elevation curve to this boundary. This allowed temporally varying water levels to be used to represent the coastal influence at the study sites.

The inclusion of a temporal element within a detailed assessment of tidal flood risk is an important consideration due to the relatively rapid variation in even extreme tidal levels associated with the normal tidal cycle. In general, this limits the duration of exposure and consequently is an important consideration in establishing the potential propagation of flood water into vulnerable areas.

RPS' experience of detailed coastal flooding modelling is that it's seldom sufficient to model a single tidal cycle, as extreme tidal surges often persist over multiple tidal cycles. Consequently, the most onerous tidal flooding is normally a result of the accumulation of flood waters entering the area over multiple tidal cycles.

Tidal boundary conditions were taken from the Irish Seas Tidal and Storm Surge Model and scaled using the extreme levels described in the Irish Coastal Wave and Water Level Modelling Study (ICWWS) (OPW, 2020) as summarised in Table 5.1 below.

Table 5.1: Summary of extreme water levels used to undertake flood modelling across Sligo Bay water levels

Return Period [*n* years]	Water Level (m) [OD Malin, OSGM15]				
	Current Scenario	MRFS	HEFS	H+FS	H++FS
2	2.79	3.29	3.79	4.29	4.79
5	2.93	3.43	3.93	4.43	4.93
10	3.03	3.53	4.03	4.53	5.03
20	3.14	3.64	4.14	4.64	5.14
50	3.27	3.77	4.27	4.77	5.27
100	3.37	3.87	4.37	4.87	5.37
200	3.47	3.97	4.47	4.97	5.47
1000	3.7	4.2	4.7	5.2	5.7

5.3 Mechanism 2– Wave overtopping

An additional source of potential coastal flooding is from wave overtopping (i.e., flood mechanism 2). Owing to the topography and nature of the prevailing wave climate throughout Sligo Bay, this study found that the only location vulnerable to wave overtopping was Strandhill. At Easkey, the hinterland is relatively low lying meaning that coastal flooding by tidal inundation was the main risk in this area.

As such, wave overtopping was calculated for a series of relevant return period events for the rock armour revetment along the middle section of Strandhill. The location of the rock armour defence is illustrated in Figure 5.1 below.

Figure 5.1: Location of the coastal defences at Strandhill whereby wave overtopping was assessed

An example of wave overtopping the rock armour revetment at Strandhill town during an extreme storm event in February 2022 is illustrated below in Figure 5.2.

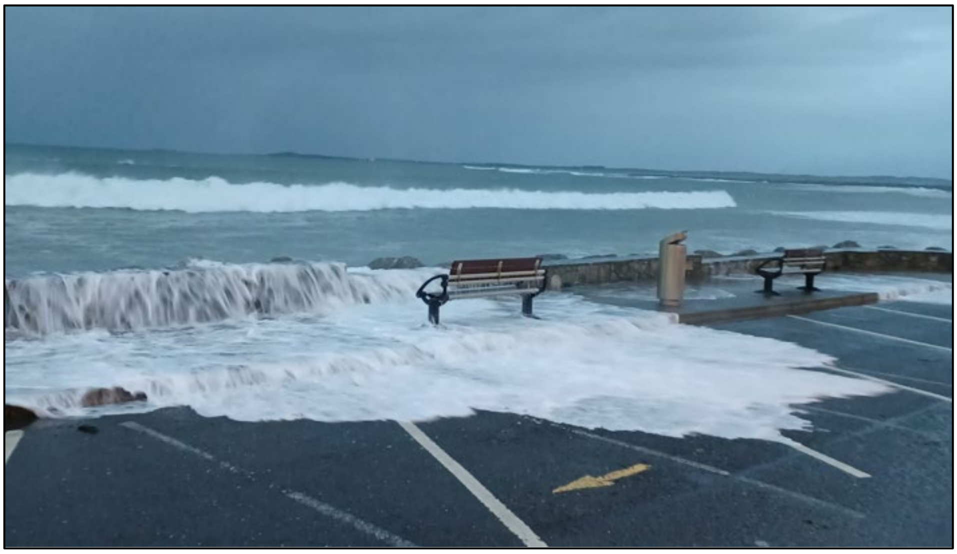


Figure 5.2: Wave overtopping of the rock armour revetment at Strandhill town in February 2022

5.3.1 Assessing Wave Overtopping

The second edition of the EurOtop "Manual on wave overtopping of sea defences and related structures" (EurOtop, 2018) describes methods to predict wave overtopping at coastal structures. The manual recommends a series of empirical methods to represent the physics of the overtopping process in a series of equations that relate the main overtopping response parameter to key wave and structure parameters. These equations were therefore used to quantify wave overtopping at Strandhill as described in the next section of this report.

5.3.2 Wave Overtopping at Strandhill

To assess the overtopping risk at Strandhill, RPS utilised the extreme wave information presented in Section 3.2 in conjunction with the geometry of the existing defences as defined by the survey data described in Section 2.1. It should be noted that wave overtopping rates were calculated for 3 different profiles along sections of Strandhill to account for the variable wave climate conditions but that only the most onerous wave rates have been included in this report of brevity.

The average wave overtopping discharge rates along revetment and seawall at Strandhill are presented in Table 5.2 for multiple return period events under existing, MRFS, HEFS, H+FS H++FS and climate conditions.

Table 5.2: Mean wave overtopping discharge rates at Strandhill

	Overtopping Discharge Rate [L/s/m]				
Return Period [*n* years]	Current Scenario	MRFS	HEFS	H+FS	H++FS
2	0.38	6.25	35.98	115.43	311.66
5	0.96	11.39	53.44	162.66	409.34
10	1.77	16.53	68.39	206.24	489.45
20	3.38	24.44	89.69	251.55	586.24
50	6.49	37.84	120.21	330.03	711.81
100	10.08	51.83	153.17	394.96	817.73
200	14.98	66.21	193.87	470.76	929.48
1000	32.80	114.46	302.13	673.66	1195.99

The discharge rates presented in Table 5.2 were used to create overtopping discharge curves for all return period events for all climate change scenarios. The discharge curve for each flood scenario was then applied as a source term in each flood simulation.

5.3.2.1 Assumptions, Limitations and Uncertainty

The flood risk analysis undertaken as part of this study has been based primarily on available bathymetric and topographic data together with the various Annual Exceedance Probability (AEP) water levels presented in Table 5.1.

The modelling does not consider other hydrological factors that affect flood risk such as the hydrological response of a catchment area which is determined by a range of factors including but not limited to urbanisations, vegetation, soils and geology. Other factors such as rainfall and ground saturation levels are also excluded from the flood analysis. Similarly, as the scope of this study was to assess coastal flooding, i.e., flooding from combined tide and surge activity (flood mechanism 1) and wave overtopping (flood mechanism 2), the potential impact of fluvial or pluvial flooding has not been considered in this assessment.

5.4 Flood Risk Assessment – Flood Maps

5.4.1 Presentation of Model Results

Following the simulation of each AEP event, ArcGIS was used to present the results of the flood simulations on suitable background mapping. Before commencing with the mapping procedure, the raw outputs of the numerical models were checked and cleaned to remove outliers and isolated ponding that was not connected to the coastal flooding mechanisms.

For brevity, only flood maps for the MRFS scenario whereby sea levels could rise by *c.*0.50m by 2100 have been included in the main body of this report. Flood maps for other climate scenarios can be found in the supplementary material provided.

The MRFS coastal flooding scenario is particularly important as this is widely considered to be the most likely climate scenario by 2100. Flood risk from rivers (i.e., fluvial flooding) may add to this risk but consideration of this mechanism was beyond the scope of this study.

5.4.2 Flood Risk Assessment – Mid-Range Forecast Scenario (MRFS)

In line with the project scope, simulations were undertaken for eight return period flood events ranging from a 0.1% AEP event to a 50% AEP event. Given the extent of the area of interest, individual maps have been produced to cover the full extent of both Easkey and Strandhill.

Figure 5.3 to Figure 5.4 illustrate the flood extents for the Easkey and Figure 5.5 to Figure 5.6 for tidal and wave overtopping flood extents at the Strandhill study area. Flood extents are based on the MRFS climate scenario with corresponding extreme water levels with sea level rise. The figures illustrate the flood extents for the 1 in 10 (10% AEP), 1 in 200 (0.5% AEP) and 1 in 1000 year (0.1% AEP) return period events.

As will be seen from Figure 5.3, a region to the west of Easkey town is at significant risk of coastal flooding owing to the low-lying nature of the site. At Strandhill, several areas are particularly vulnerable during MRFS climate conditions illustrated in Figure 5.5, including the northern section of Kilasprugbone and the southern section of Ballysadare Bay due to tidal inundation of low-lying areas.

Figure 5.6 shows the risk of flooding from wave overtopping of the rock armour situated in front of the town's carpark. Further information on the specific flood risk in each of these areas, together with an assessment of properties at risk of flooding is presented in Section 6 of this report.

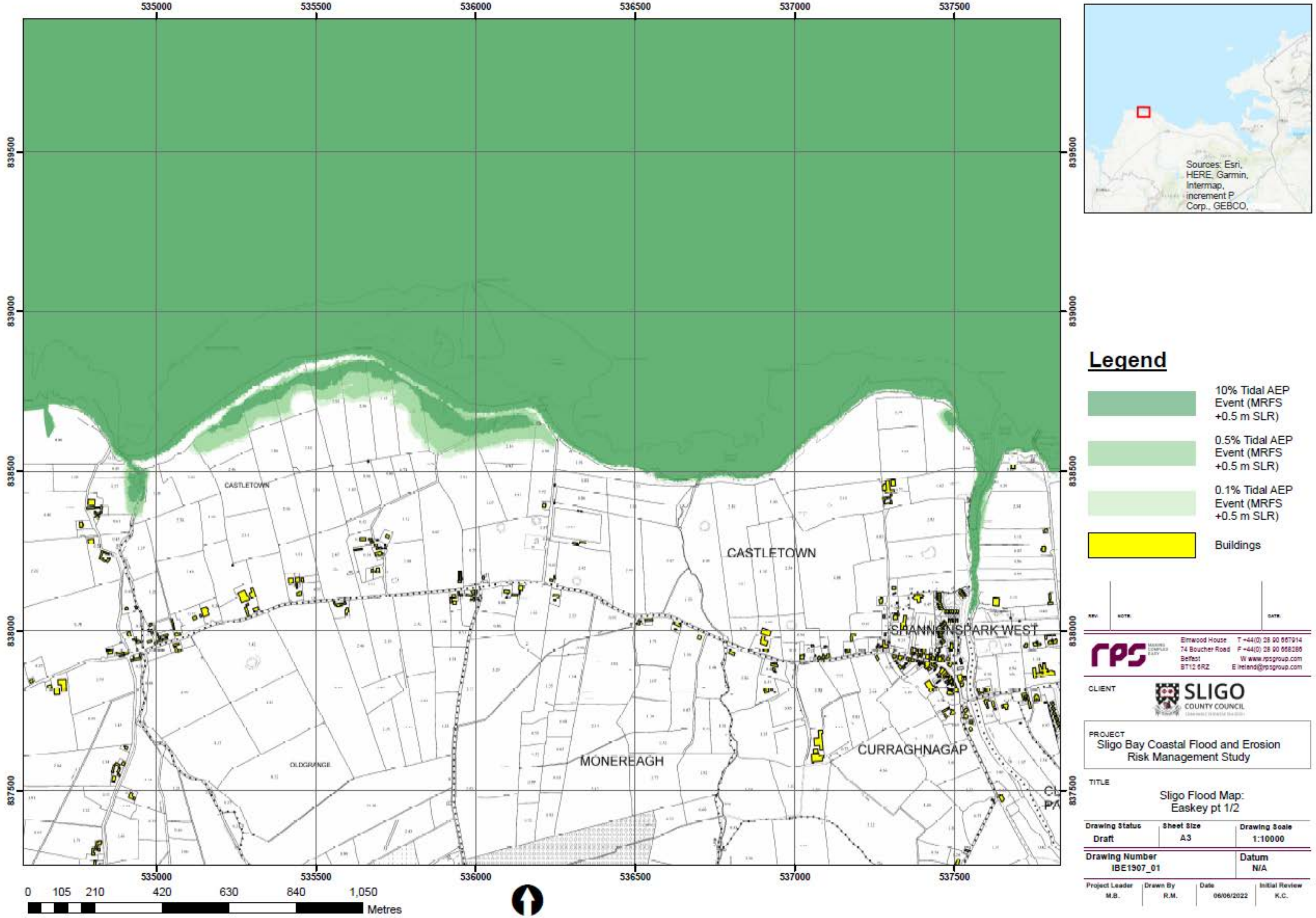


Figure 5.3: Tidal Flood Extent Map: Easkey pt. 1/2 – Medium Range Future Scenario (i.e., +0.50m sea level rise)

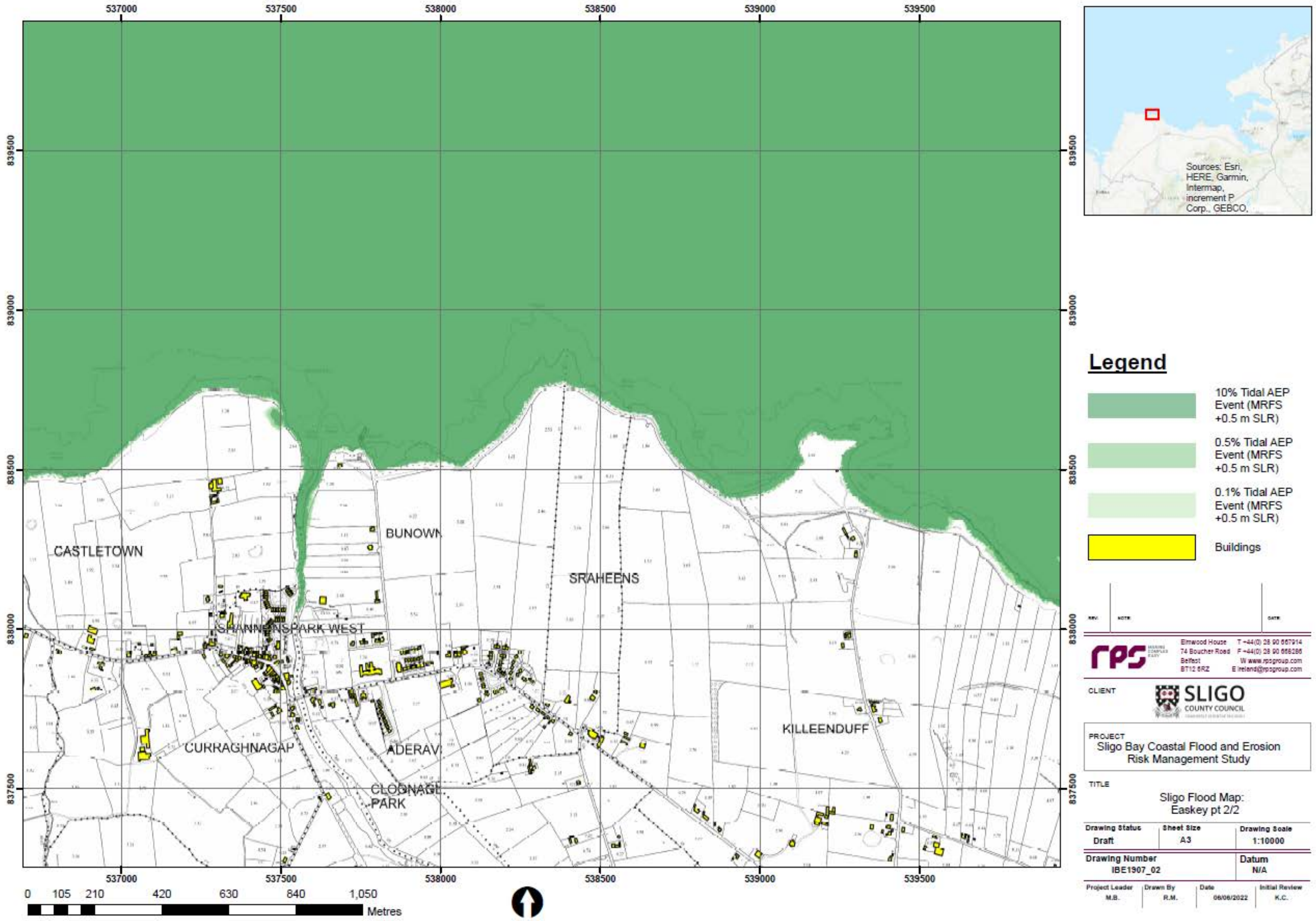


Figure 5.4: Tidal Flood Extent Map: Easkey Spit pt. 2/2 – Medium Range Future Scenario (i.e., +0.50m sea level rise)

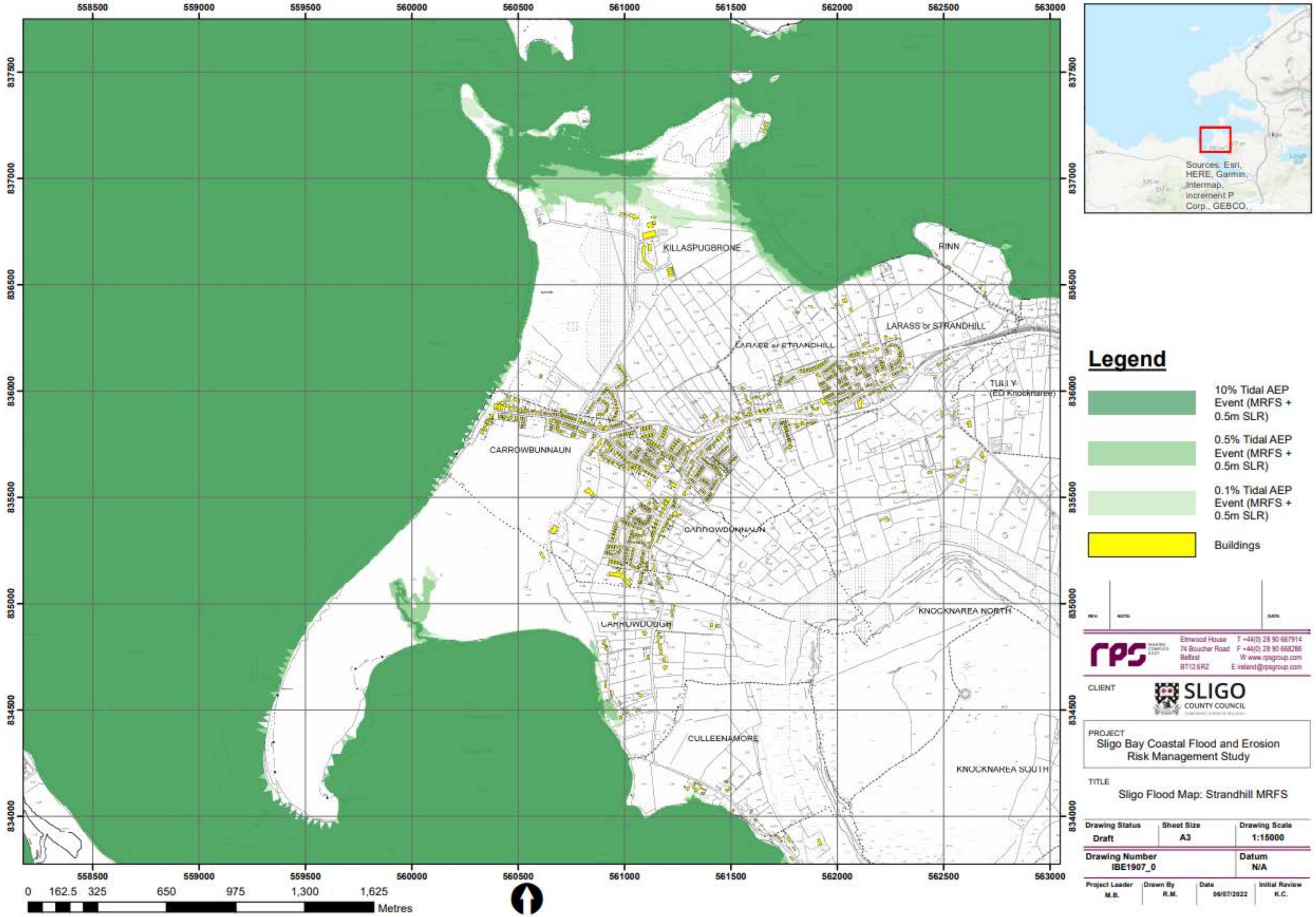


Figure 5.5: Tidal Flood Extent Map: Strandhill – Medium Range Future Scenario (i.e., +0.50m sea level rise)

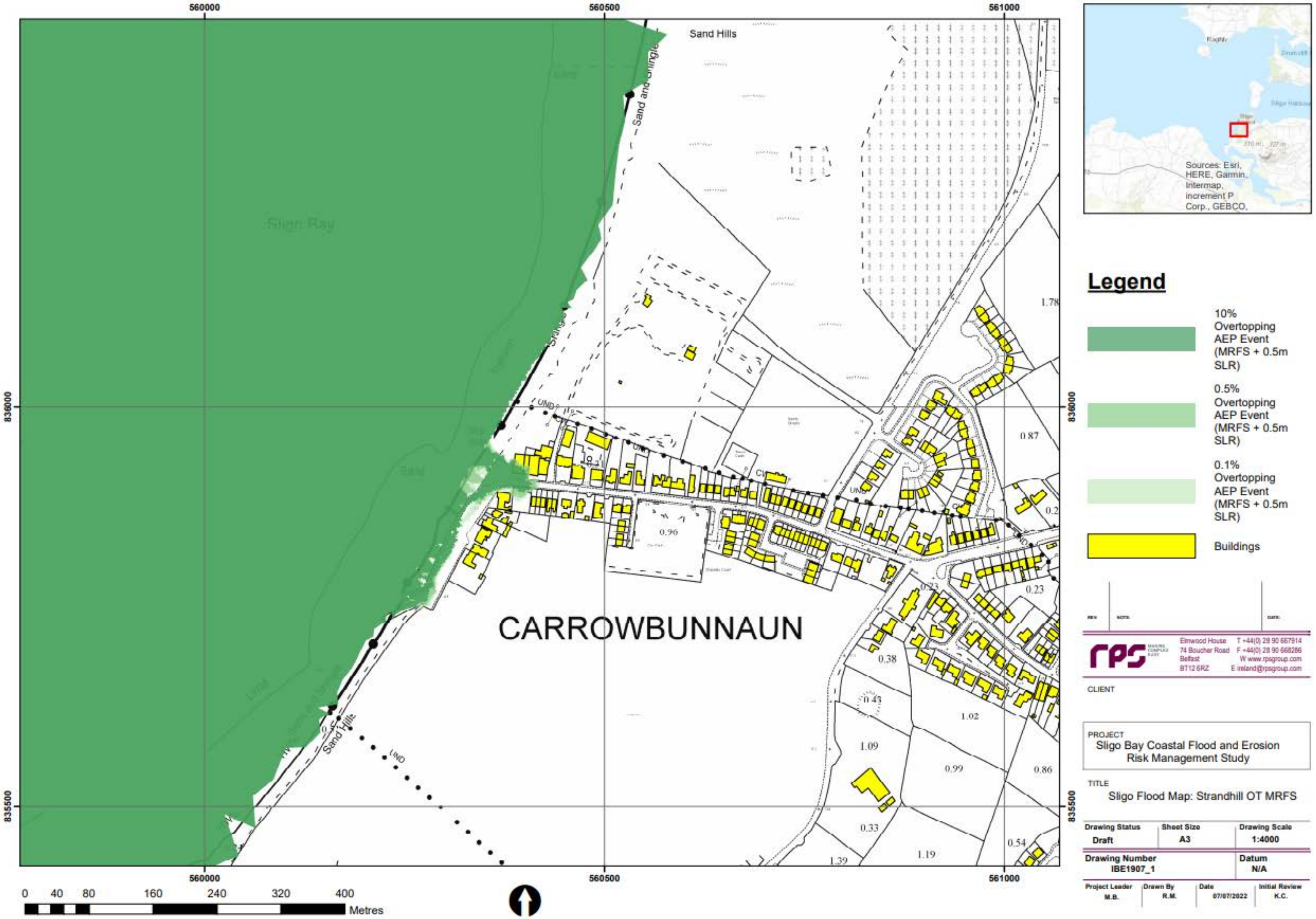


Figure 5.6: Overtopping Flood Extent Map: Strandhill detailed view – Medium Range Future Scenario (i.e., +0.50m sea level rise)

6 DETAILED RISK ASSESSMENT

The following Sections of this report provide a detailed assessment of the risk associated with coastal flooding and erosion across the Easkey and Strandhill study areas. This risk assessment has been based on:

- Information from relevant scientific literature and local anecdotal evidence
- Spatial data from www.data.gov.ie, www.floodinfo.ie and internal RPS records
- Coastal process modelling presented in Section 3
- The coastal erosion assessment presented in Section 4
- Flood risk assessment presented in Section 5.
- The 1 in 200 MRFS flood extent has been used to represent the indicative flood risk in each study area. The actual extent of flooding and associated risk from flooding will be determined by the return period of any extreme storm surge event. Specific flood maps can be found for alternative return periods and climate change combinations provided in supplementary pdfs.

Figure 6.1: Individual study areas as defined in the project briefing document (Sligo County Council, 2021)

6.1 Easkey

6.1.1 Coastal erosion risk at Easkey

The initial concern that prompted Easkey to be included in this study related to coastal erosion and the potential loss of or damage to sections of the coastal road which forms part of the popular Wild Atlantic Way. A *c.*1.8km section of this regional road runs parallel to and in very close proximity (<5m) to the shoreline.

The assessment described in Section 4 concluded that the long-term *average rate* of coastal retreat in this area was *c.*0.01m per year. However, it was noted that there was low confidence associated with this assessment due to the lack of long-term high-resolution data for this area.

This same assessment estimated that this coastline could retreat by up to 24m depending on the rate and magnitude of future climate change. Whilst the lack of long-term data was also an inherent limitation in this assessment, it can be concluded that under a future climate scenario, the coastal road at Easkey would be at considerable risk from coastal erosion.

These conclusions are supported by anecdotal evidence and information recorded during a site visit which found that a localised section of this coastal road is vulnerable to wave action and undercutting as illustrated in Figure 6.2 and Figure 6.3.

Importantly, it will be seen from these figures that this area is characterised by a hard, rocky substrate which would likely reduce, but not prevent future coastal erosion of this site.

Given this risk, it is likely there would be an economic and social benefit to developing a suitable coastal management plan to ensure the future Wild Atlantic Way tourism asset in this area.

Figure 6.2: A section of the road showing signs of coastal erosion (Sligo County Council, 2021)

Figure 6.3: The road near Easkey Castle indicating erosion/ damage (Sligo County Council, 2021)

6.1.2 Coastal flood risk at Easkey

The area around Easkey is characterised by extensive raised agricultural land with topographic elevations of > 3.5m (OD Malin OSGM15) which is equivalent to a *c.* 1 in the 1000 year return period flood event based on existing climate conditions.

When the topography of this area was compared with standard tidal levels in Table 2.2 it was found that virtually all of the study area was above Mean High Water Spring tidal levels, even under the MRFS climate scenario whereby sea levels are expected to rise by +0.50m by 2100. In respect of flood risk associated with the current climate, only localised sections of the coastline are at risk of very minor tidal inundation as demonstrated in Figure 5.4.

Subject to the magnitude of the flood event and climate change scenario, up to 2 buildings were found to be at risk of coastal flooding as summarised in Table 6.1 under the most extreme return period event with climate change. Furthermore, localised sections of the coastal road which form part of the Wild Atlantic Way were found to be susceptible to flooding during a 1 in 200-year flood event under existing climate conditions. This has the potential to result in temporary road closures and traffic diversions.

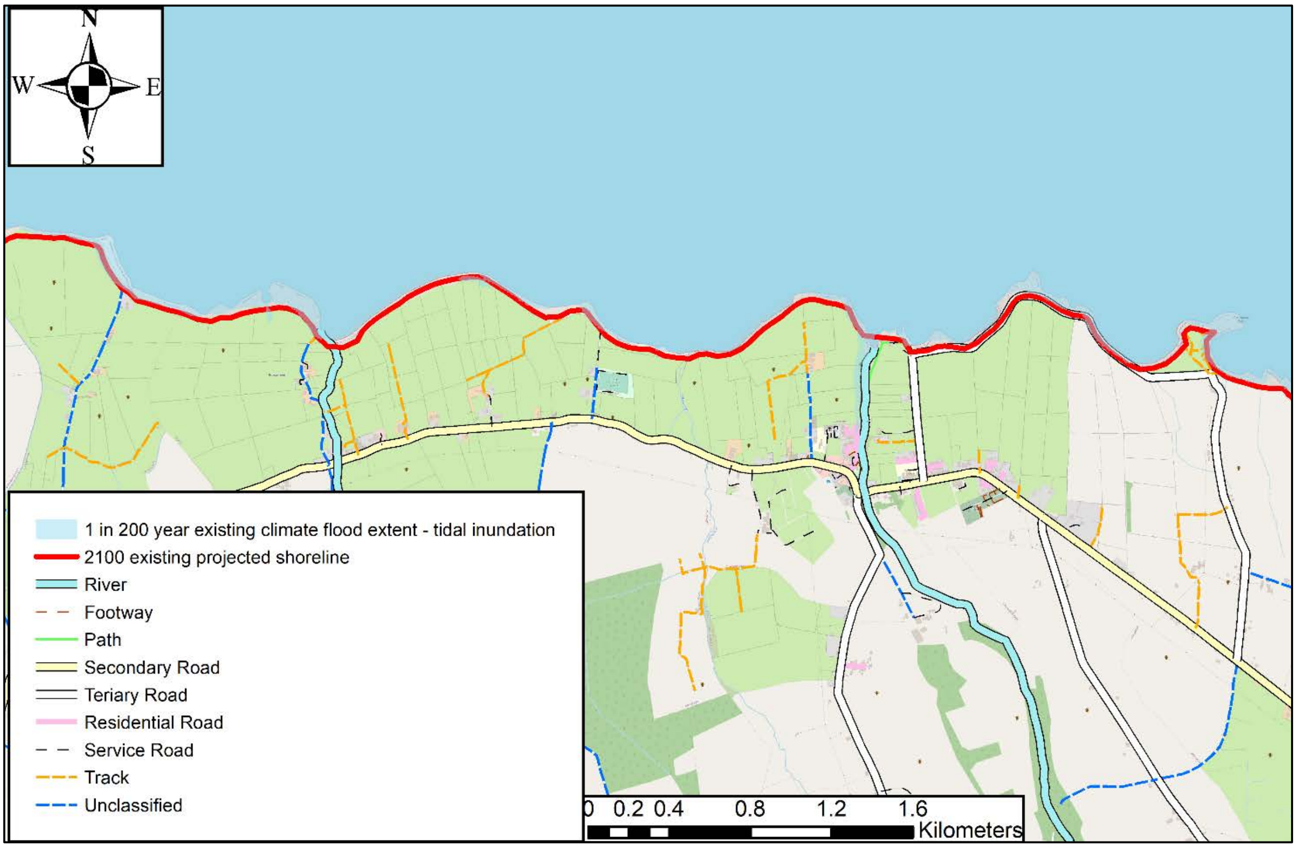


Figure 6.4: Summary of the coastal flooding risk at Easkey with the 1 in 200 year MRFS flood event shown

Table 6.1: Summary of buildings at risk of flooding at Easkey for multiple return period events under existing, MRFS, HEFS and H+FS climate conditions.

Return Period [*n* years]	Buildings at Risk			
	Current Scenario	MRFS	HEFS	H+FS
2	0	0	1	1
5	0	0	1	1
10	0	0	1	1
20	0	0	1	2
50	0	0	1	2
100	0	0	1	2
200	0	1	1	2
1000	1	1	2	2

6.2 Strandhill

6.2.1 Coastal erosion risk at Strandhill

As previously described in Section 4.2 there have been long-standing issues with coastal erosion at Strandhill which were partially addressed in 2011 with a suite of improvements comprising rock armour with a concrete wall and a coastal path. Following, storm events in 2011 and 2014 many of the existing defences were damaged. Since 2012, much of the coastline has retreated by up to *c.* 20m which has exposed a storm manhole at Kilasprugbone WWTP and resulted in the significant loss of an extensive and well established dune near the WWTP.

Owing to the significant defences found along the middle of the coastline, the risk of coastal erosion to Strandhill town has been effectively mitigated. Looking into the longer term (i.e., +100years), the risk to this section of this coastline is expected to be negligible, but only if the existing defences are regularly maintained. Based on a recent site inspection, the northern half of the existing rock revetment appears to be in very poor condition with much of the primary armour having been displaced or removed by arduous storm conditions as illustrated in Figure 6.5, giving rise to considerable concern as to the continued effectiveness of this asset. The southern section of this defence appears to be well maintained and is highly likely to continue to provide effective coastal erosion protection.

Figure 6.5: Poor condition of northern rock revetment (left) compared to the well-maintained southern section (right)

Regarding the future risk it was concluded that based on an *average rate* of coastal erosion, the northern section of the coastline could retreat by up to 94m over the long-term. Under this scenario, the retreat of the shoreline could result in the loss of a significant area of the marram dune system which is a qualifying feature of the Cummeen Strand/ Drumcliff Bay Special Areas of Conservation (SAC) and Natural Heritage Area (pNHA).

Aside from an environmental perspective, this magnitude of erosion would also result in a significant loss of land belonging to the Strandhill Camping and Caravan Park which is vital in servicing the local tourism asset.

At present, the Strandhill WWTP is afforded good protection by the existing rock armour revetment. However, under future climate conditions, there is a moderate probability that this defence could be outflanked by wave action and could become detached from the shoreline. The hinterland directly behind this defence, including the WWTP, would be at significant risk of coastal erosion under this scenario.

Whilst the coastline in the area to the north at Kilasprugbone church and graveyard is currently fixed by an old wall which acts as an informal coastal defence, there is a high probability that this structure could be breached during future storm events. Indeed, some sections of this wall are already undermined and failing as illustrated in Figure 6.6.

If this informal defence were to fail, coastal erosion would likely begin to encroach on this coastline, exposing the graves and potentially threaten the Sligo airport runway which is presently used by the Irish Coast Guard rescue helicopter.

Towards the southern section of Strandhill, the coastline was found to be much more stable and indeed accreting significant volumes of sediment. This can be attributed to the local sediment transport regime which tends to transport sediment from the north towards Carrowdough spit and Ballysadare Bay. This is likely to include a notable proportion of any sand material lost through coastal erosion along the northern section of the coast.

Based on the assessment presented in this study, it can therefore be concluded that there is no significant risk of coastal erosion to the southern section of the coast at Strandhill under existing climate conditions. Under future climate conditions, rising sea levels may increase pressure along this coastline, but sand transported from the northern half of the beach could mitigate this pressure.

Nevertheless, localised sections of this southern shoreline can be eroded during wave action, particularly following a succession of extreme storm events when beach levels are drawn down.

In respect of the coastal erosion risk at Strandhill, it can be concluded that:

The coastline between Strandhill and the WWTP revetment could retreat by up to *c.*94m over the long term.

- Over the long-term (+100yrs) this magnitude of erosion could:
  - Result in the partial but significant loss of the Cummeen Strand/ Drumcliff Bay SAC
  - Result in the partial but significant loss of Strandhill Camping and Caravan Park
  - Potentially threaten the runway at Sligo airport
  - Potentially threaten the Strandhill WWTP
- The stormwater manhole which is currently detached from the coastline will likely incur significant damage over the short term.
- It is imperative that the existing coastal defences at Strandhill are maintained to mitigate any risk of erosion to the town.
- The coastline along the southern section of the coast is considered to be relatively stable and at little risk of coastal erosion. However, some localised sections maybe eroded following a succession of extreme events.

Figure 6.6: Failure of the informal coastal defence at Kilasprugbone Graveyard

6.2.2 Coastal flood risk at Strandhill

Aside from coastal erosion, some areas of Strandhill are also at risk of coastal flooding from both tidal inundation and wave overtopping.

The areas most vulnerable to tidal inundation are Kilasprugbone in the north, including Sligo Airport and Ballysadare Bay in the south (see Figure 5.5). Much of the land in these areas is low lying < 3m (OD Malin OSGM15) which is equivalent to a *c.* 1 in 10-year return period flood event based on existing climate conditions.

In the south at Ballysadare Bay, coastal flooding during extreme events could propagate into the Strandhill Golf Course. Similarly, in the north tidal inundation during a 1 in 200 year existing climate flood event was found to impact the runway at Strandhill airport, and Kilasprugbone church/graveyard. However, it should be noted that the WWTP at Strandhill is also at low to moderate risk of tidal inundation under future climate scenarios whereby sea levels will increase as a result of climate change (refer to additional flood maps in Appendix B).

Whilst flooding during some extreme return period scenarios was found to affect the assets described above, no main roads or buildings were found to be at risk from flooding caused by tidal inundation.

Figure 6.7: Summary of the coastal flooding risk at Strandhill with a 1 in 200 year existing climate flood event from tidal inundation shown

Strandhill town is relatively well elevated and therefore naturally protected against tidal inundation. However, wave overtopping at the existing rock armour revetment was found to result in coastal flooding as illustrated in Figure 6.9.

As shown in this Figure, during existing climate conditions the risk is minimal, however under future conditions multiple properties, mostly comprising commercial premises, and localised sections of Shore Road were particularly vulnerable to flooding from wave overtopping. The number of buildings affected by wave overtopping ranged between 2 and 18 during a 1 in 200 year event, depending on the future climate scenario. Figure 6.9overleaf summarises the number of buildings affected by coastal flooding for a range of return period events and climate change scenarios.

In summary, it can be concluded that extensive regions of Strandhill would be adversely affected by coastal flooding caused by both tidal inundation and wave overtopping. It is also important to note that the duration of a coastal flood event is generally very limited owing to the natural rise and fall of any tidal regime. Nonetheless, significant damages can still be incurred during these events which should be mitigated by means of a suitable coastal management plan were considered appropriate.

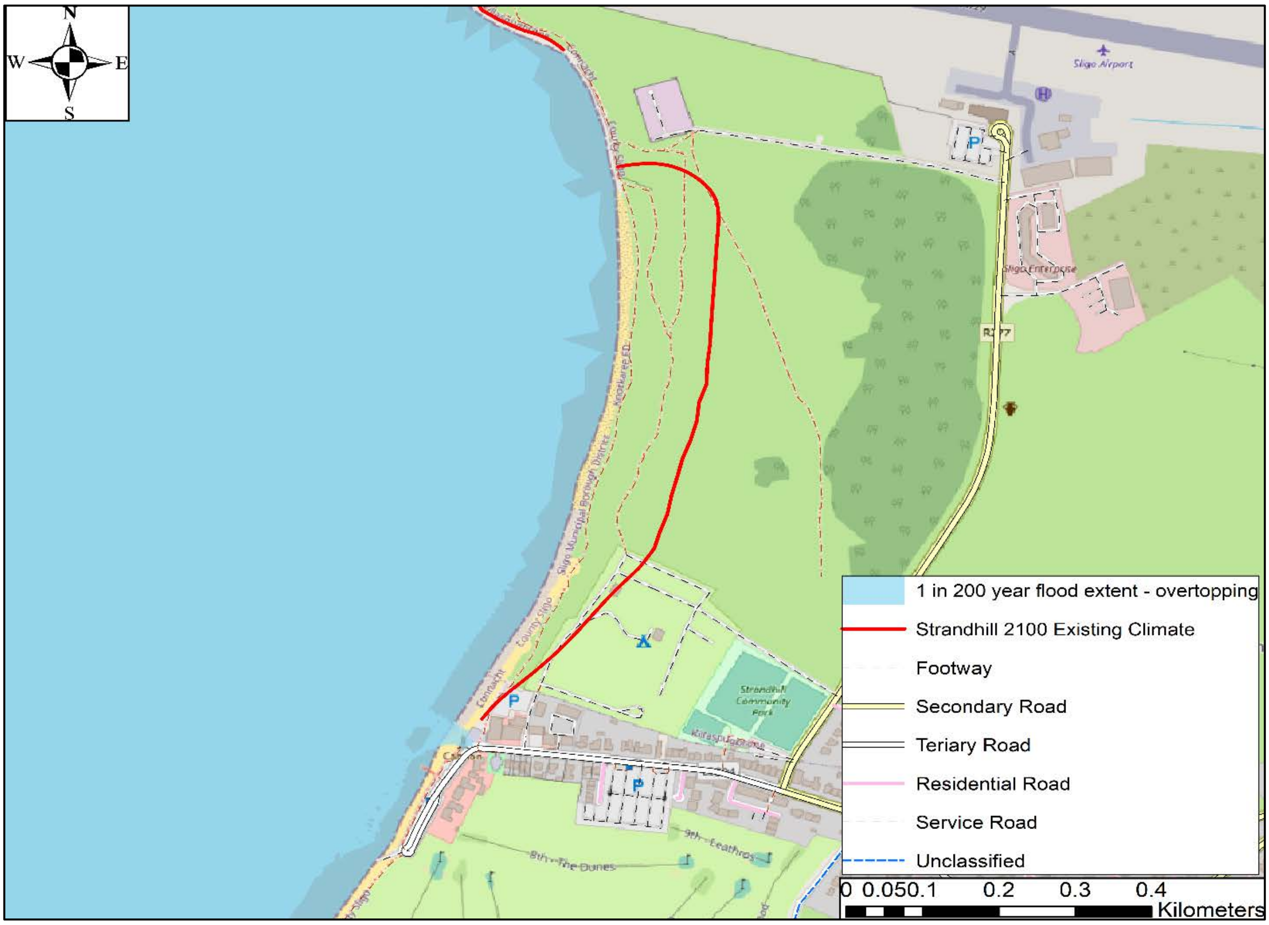


Figure 6.8: Summary of the coastal flooding risk at Strandhill with the 1 in 200 year existing climate flood event from overtopping shown

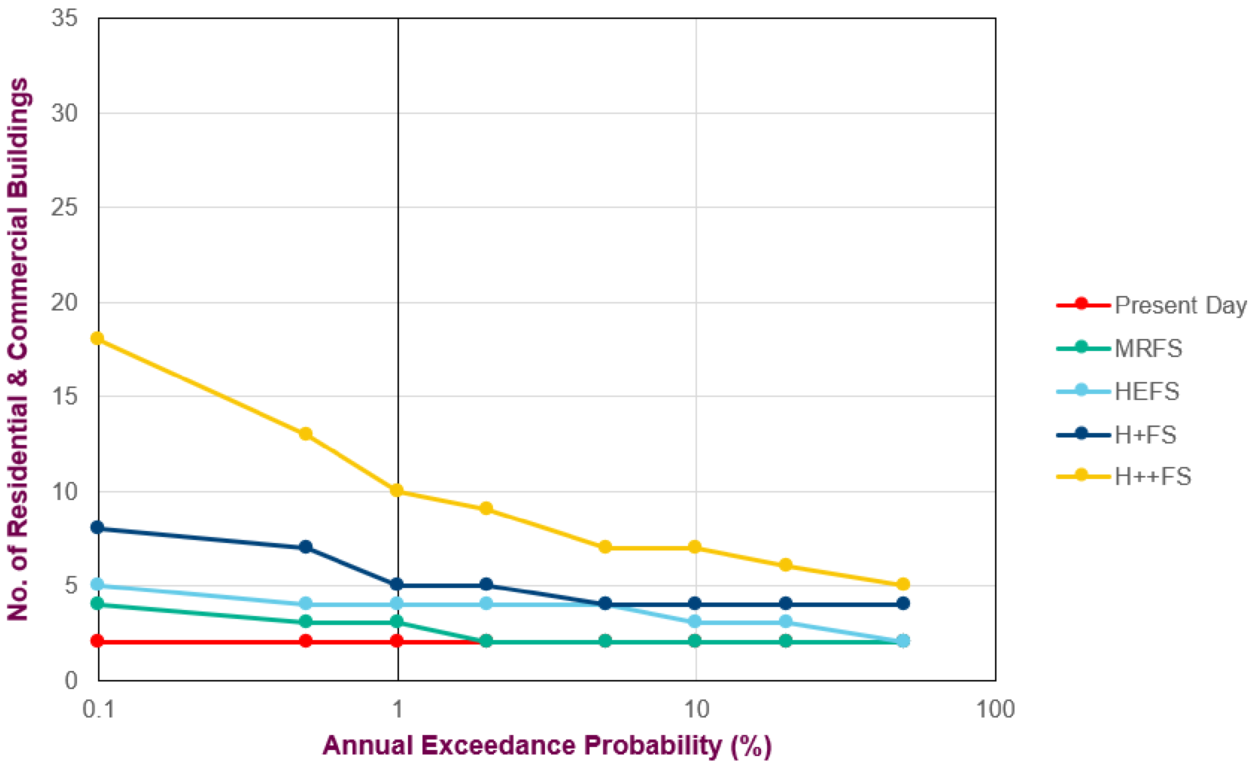


Figure 6.9: Number of residential and commercial buildings at risk of flooding from wave overtopping at Strandhill frontage based on various return period and climate change combinations

7 PRELIMINARY ENVIRONMENTAL ASSESSMENT

The study area includes several areas of high ecological value, with a variety of habitats and species of conservation concern that are protected under European and National designations. There are also several areas designated for the protection of water quality and cultural heritage assets. A desktop study was carried out to identify those areas which have been designated for the protection of these features. These designated areas are summarised in sections 7.1 to 7.4 below.

7.1 European/International Designations

7.1.1 Special Areas of Conservation (SACs)

Special Areas of Conservation (SAC) are prime wildlife conservation areas, considered to be important on a European as well as National level. In Ireland, most SACs are in rural areas, although a few sites reach into town or city landscapes, such as Dublin Bay, Cork Harbour and Wexford Harbour.

SACs are selected under the Habitats Directive for the conservation of several habitat types, which in Ireland include raised bogs, blanket bogs, turloughs, sand dunes, machair (flat sandy plains on the north and west coasts), heaths, lakes, rivers, woodlands, estuaries and sea inlets. The Directive also affords protection to various species of flora and fauna, including Salmon, Otter, Freshwater Pearl Mussel, Bottlenose Dolphin and Killarney Fern.

Collectively, these are known as Annex I habitats (including priority types which are in danger of disappearance) and Annex II species (other than birds). SACs form part of the Natura 2000 European Union-wide network of protected areas. Natura 2000 is aimed to conserve ecosystems (‘habitats’) and species of outstanding conservation importance by applying appropriate measures for their protection and restoration.

The SACs discussed below pertain to Strandhill as Easkey does not overlap with any designated SAC. The designated SACs at the Strandhill site are depicted in Figure 7.1 and described in Table 7.1.

7.1.1.1 Ballysadare Bay SAC

Ballysadare Bay extends for about 10 km westwards from the town of Ballysadare, Co. Sligo, and is the most southerly of three inlets of the larger Sligo Bay. The site was designated as a SAC due to its inclusion of several Annex I / II Habitats and/or species listed in the Habitats Directive. These include Estuaries, Tidal Mudflats and Sandflats, Embryonic Shifting Dunes, Marram Dunes (White Dunes), Fixed Dunes (Grey Dunes), Humid Dune Slacks, Narrow-mouthed Whorl Snail, and Common Harbour Seal.

The site is of significant ecological interest as it includes an extensive area (circa 1,500 ha) of mudflat and intertidal sand. The mudflat provides food in the form of colonising plants of Eelgrass and Tasselweed and numerous invertebrates for wildfowl and waders to feed on.

Additionally, Ballysadare bay is of high ecological value due to a range of good-quality coastal habitats. Actively developing dune systems are rare on the west coast and the sand dune system at the Strandhill study site is of particular interest as a large and intact example of an Annex I priority habitat under general threat from development.

7.1.1.2 Cummeen Strand/Drumcliff Bay (Sligo Bay) SAC

Cummeen Strand/Drumcliff Bay (Sligo Bay) is an important site of high conservation significance, which includes a wide variety of habitat types, including several listed in Annex I of the E.U. Habitats Directive, several species listed in Annex II of this Directive, large and important populations of waterfowl and seabirds, and several rare plant species. These qualifying interests include Estuaries, Tidal Mudflats and Sandflats, Embryonic Shifting Dunes, Marram Dunes (White Dunes), Fixed Dunes (Grey Dunes), Juniper Scrub, Orchid-rich Calcareous Grassland, Petrifying Springs, Narrow Mouthed Whorl Snail, Sea Lamprey, River Lamprey, and Common Harbour Seal. This SAC similarly to the Ballysadare Bay SAC protects rare sand dune habitats in the Strandhill site, namely the Marram dunes.

7.1.2 Special Protection Areas SPAs

Special Protection Areas (SPA) are conservation areas which are important sites for rare and vulnerable birds (as listed in Annex I of the Birds Directive) and/or for regularly occurring migratory species. SPAs are designated under the 'Birds Directive' (Council Directive 2009/147/EC - codified version of Directive 79/409/EEC on the Conservation of Wild Birds, as amended).

Ireland's SPA network encompasses over 5,700km² of marine and terrestrial habitats. The marine areas include some of the productive intertidal zones of bays and estuaries that provide vital food resources for several wintering wader species. Marine waters adjacent to breeding seabird colonies and other important areas for sea ducks, divers and grebes are also included in the network.

The remaining areas of the SPA network include inland wetland sites important for wintering waterbirds and extensive areas of blanket bog and upland habitats that provide breeding and foraging resources for species. Both SPAs discussed below form part of the Natura 2000 network. The designated SPAs with overlap with the Strandhill site are depicted in Figure 7.1. The SPAs discussed below pertain to the Strandhill study area, the Easkey site has no overlap with SPAs. The qualifying interests of the Strandhill SPAs are presented in Table 7.2.

7.1.2.1 Ballysadare Bay SPA

Ballysadare Bay gained a SPA designation under the Birds Directive due to its special conservation interests for several special, namely: Light-bellied Brent Goose, Grey Plover, Dunlin, Bar-tailed Godwit and Redshank. The wetlands forming areas of this SPA are of significant ecological importance and are of special conservation interest for Wetland & Waterbirds. The SPA supports a range of wintering waterfowl species, particularly the internationally important Light-bellied Brent Goose. The site also supports four other species that are of international importance: grey plover, Dunlin, Bar-tailed Godwit, and Redshank.

7.1.2.2 Cummeen Strand SPA

Cummeen Strand is a large shallow bay stretching from Sligo Town westwards to Coney Island. It is one of three estuarine bays within Sligo Bay and is situated between Drumcliff Bay to the north and Ballysadare Bay to the south. The site qualified for SPA designation under the Birds Directive due to conservation interests for the following species: Light-bellied Brent Goose, Oystercatcher and Redshank. Like Ballysadare Bay SPA the wetlands forming areas of this SPA are of significant ecological importance and are considered to be of special conservation interest for Wetland & Waterbirds.

This area is of high ornithological importance with one species, Lightbellied Brent Goose, occurring in numbers of international importance. In addition, the site supports internationally important populations of a further two species. The regular presence of Golden Plover and Bar-tailed Godwit is of particular note as these species are listed in Annex I of the E.U. Birds Directive.

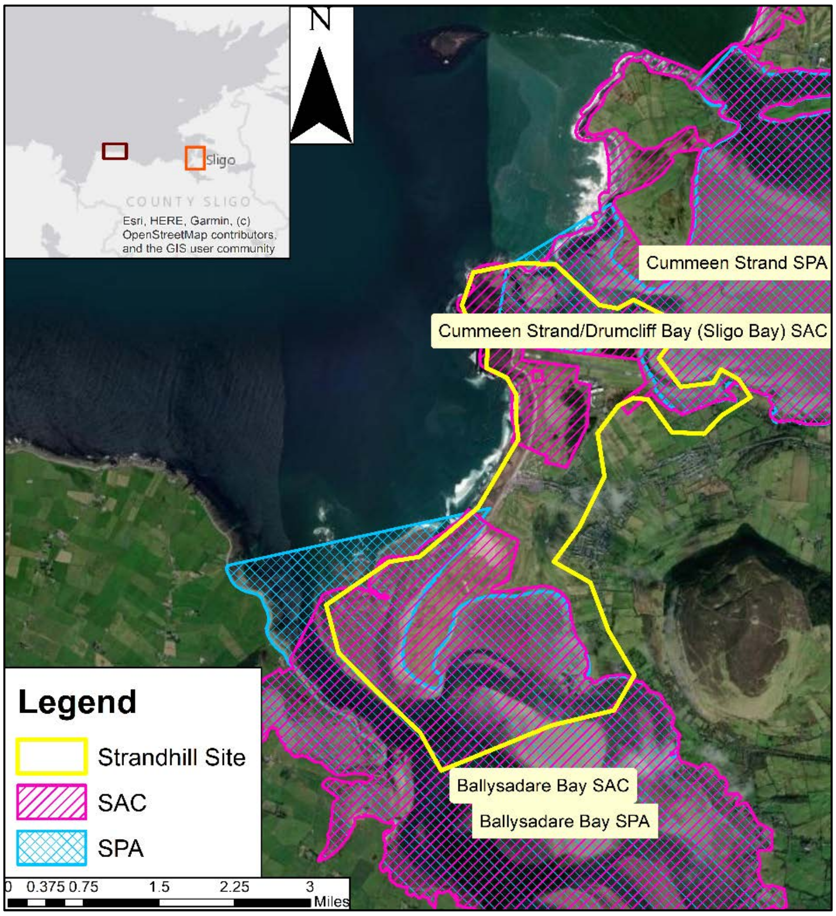


Figure 7.1: SAC and SPA designated sites within the vicinity of Strandhill study area

7.1.3 Ramsar Sites

Ramsar Sites are designated for the protection of wetland areas (which are important feeding habitats for birds) under the 'Convention on Wetlands of International Importance' which took place in Ramsar, Iran in 1971. In Ireland, all Ramsar sites have also been recognised as SPA and/or SAC areas and so are afforded protection by the European Communities (Birds and Natural Habitats) Regulations 2011.

Coinciding with the Cummeen Strand/Drumcliff Bay (Sligo Bay) SAC and Cummeen Strand SPA, Cummeen Strand also boasts a Ramsar designation. One of 45 Ramsar sites across the Republic of Ireland, this 1,491-hectare area is protected under the intergovernmental treaty, in Ireland Ramsar sites are not given specific legislative protection as such but are instead protected through SACs/SPAs.

The Easkey site does not have any overlap with any Ramsar sites, however, two can be found within a 15km radius of the study area. The Easkey bog Ramsar site is located to the Southeast and the Killala Bay/ Moy Estuary Ramsar site is located to the Southwest of the Easkey study area.

Table 7.1: Summary description of qualifying features of Special Areas of Conservation found in the Sligo Bay Study Sites

Qualifying Features	Sligo Bay	
	Ballysadare Bay SAC	Cumeen Strand/ Drumcliffe Bay SAC
Estuaries [1130]	✓	✓
Mudflats and sandflats not covered by seawater at low tide [1140]	✓	✓
Embryonic shifting dunes [2110]	✓	✓
Shifting dunes along the shoreline with Ammophila arenaria (white dunes) [2120]	✓	✓
Fixed coastal dunes with herbaceous vegetation (grey dunes) [2130]	✓	✓
Humid dune slacks [2190]	✓	
Vertigo angustior (Narrow-mouthed Whorl Snail) [1014]	✓	✓
Phoca vitulina (Harbour Seal) [1365]	✓	✓
Juniperus communis formations on heaths or calcareous grasslands [5130]		✓
Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites) [6210]		✓
Petrifying springs with tufa formation (Cratoneurion) [7220]		✓
Petromyzon marinus (Sea Lamprey) [1095]		✓
Lampetra fluviatilis (River Lamprey) [1099]		✓
Total qualifying features	**8**	**12**

Table 7.2: Summary description of qualifying features of Special Protection Areas found in the Sligo Bay Study Sites

Qualifying Features	Sligo Bay	
	Ballysadare Bay SPA	Cumeen Strand SPA
Light-bellied Brent Goose (Branta bernicla hrota) [A046]	✓	✓
Grey Plover (Pluvialis squatarola) [A141]	✓	
Dunlin (Calidris alpina) [A149]	✓	
Bar-tailed Godwit (Limosa lapponica) [A157]	✓	
Redshank (Tringa totanus) [A162]	✓	✓
Wetland and Waterbirds [A999]	✓	✓
Oystercatcher (Haematopus ostralegus) [A130]		✓
Total qualifying features	**6**	**4**

7.2 National Designations

7.2.1 Natural Heritage Areas (NHAs) and proposed Natural Heritage Areas (pNHAs)

Natural Heritage Areas (NHAs) are designated under the Wildlife Act (1976 - 2000). They are considered notable habitats that support animals or vegetation of importance.

Proposed Natural Heritage Areas (pNHAs) were published on a non-statutory basis in 1995 but have not since been statutorily proposed or designated. All pNHAs are subject to limited statutory protection but are recognised for their ecological value by planning and licensing authorities. Two pNHAs coincide with the Strandhill site, namely: Ballysadare Bay proposed Natural Heritage Area, and Cummeen Strand/Drumcliff Bay (Sligo Bay) proposed Natural Heritage Area, as shown in Figure 7.2. There is no overlap between the Easkey site and any pNHAs however an area of the River Easkey 1km south of the study site is designated as a pNHA.

7.2.2 Other National Designations

- **Nature Reserves -** These sites are identified as being important habitats to support wildlife and are protected under Ministerial Order. There are 3 nature reserves in Co. Sligo, but none are located within the study areas, the nearest being Easkey Bog Nature Reserve which is located within 15km of both study sites.

- **National Parks** - These sites are established under the International Union for the Conservation of Nature and are areas identified as being not materially altered by human exploitation and occupation and where steps have been taken to prevent exploitation or occupation in respect of ecological, geomorphological, or aesthetic features. There are no National Parks in Co. Sligo.

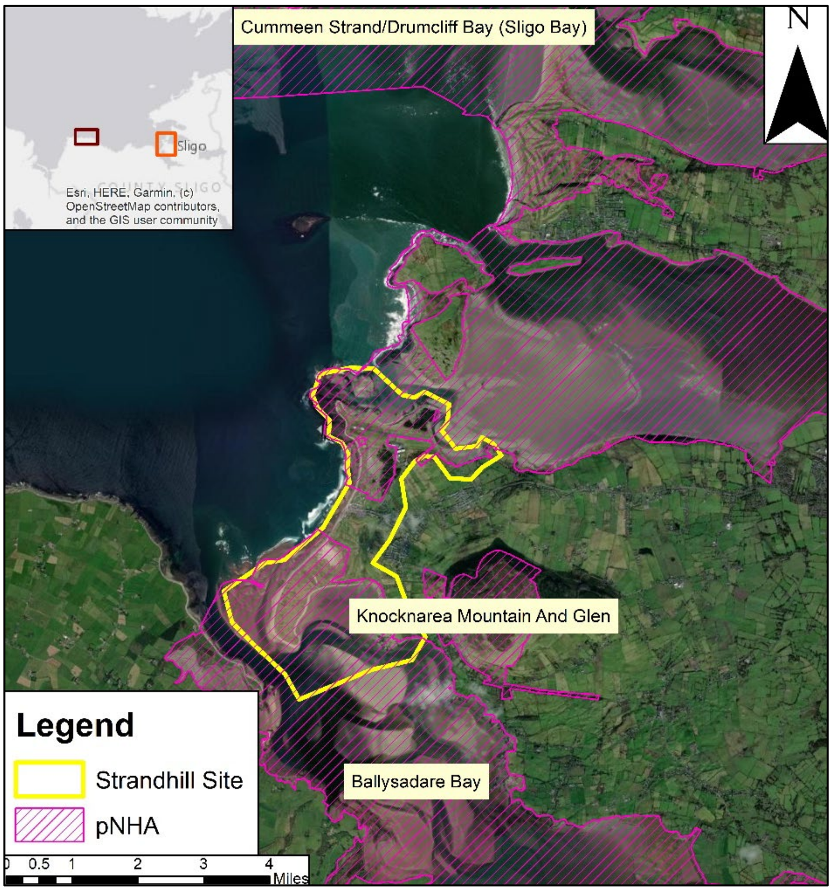


Figure 7.2 pNHA areas within the vicinity of the Strandhill study area

7.3 Water Quality Designations – The Water Framework Directive (WFD)

The 'Water Framework Directive' (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy) establishes a framework for the protection of all waters including rivers, lakes, estuaries, coastal waters and groundwater, and their dependent wildlife/habitats under one piece of environmental legislation. Specifically, the WFD aims to:

- Protect/enhance all waters (surface, ground and coastal waters)
- Achieve "good status" for all waters by 2027.
- Manage water bodies based on river basins or catchments; and
- Involve the public.

The implementation of the WFD has included the identification and establishment of eight River Basin Districts throughout Ireland. The study areas were located in the Western River Basin District (RBD) but have since been brought into the national RBD.

River Basin Management Planning takes an integrated approach to the protection, improvement, and sustainable management of the water environment. The planning process revolves around a six-year planning cycle of action and review, so that every six years a revised river basin management plan is produced. In the first cycle of River Basin Management (2009-2015) each River Basin Management Plan described the classification results for its water bodies and identified measures that can be introduced to safeguard waters and meet the environmental objectives of the WFD.

For the 2nd WFD Cycle 2015-2021, the Eastern, South-eastern, South-western, Western and Shannon River Basin Districts have been merged to form one national River Basin District with a corresponding National River Basin Plan. For the North-western and Neagh Bann International River Basin Districts (IRBDs), a single administrative area has been established in the Republic of Ireland portion of these two IRBDs for the purpose of coordinating their management with authorities in Northern Ireland. In 2021 a draft for the 3rd WFD Cycle 2021-2027 was issued with updated findings.

The recent status of rivers, lakes, transitional and coastal water bodies within the catchment area published at the end of the 2013-2018 monitoring cycle, are summarised below and shown in Figure 7.2 and Figure 7.4, similarly data displaying the "risk status" for these water bodies achieving good ecological status by the 2027 deadline presented by the 3rd cycle of the WFD is shown for both study sites in Figure 7.5 and Figure 7.6.

The coastal water bodies of Southern Donegal Bay, coinciding with the Easkey site have 'unassigned' status for this period, meaning that there is insufficient confidence in the data collected to assign a status. However, these coastal waterbodies are considered to be 'not at risk' of achieving good ecological status by the deadline. The Sligo Bay coastal body is supported by sufficient data and assigned a 'good ecological status' and is also considered to be 'not at risk' by the third cycle of the WFD River Basement Management Plan.

Most of the rivers outflowing to Sligo Bay are of good ecological status, notably the Ballysadare River which flows into the Ballysadare SAC and the Strandhill study area. However, the Garvogue River which flows into the Cummeen Strand/ Drumcliff Bay SAC and the Strandhill study area was found to be of poor ecological status and is considered to be 'at risk' by the WFD 3rd cycle. Both the Doolin River and Lugdoon Stream drain into Sligo Bay, they are labelled as being in moderate ecological status and are both considered 'at risk' under the WFD 3rd cycle. Numerous smaller rivers have an unassigned ecological status and are currently being reviewed for WFD risk.

Construction activity within the study area has the potential to impact water quality and morphological status and must therefore be sustainably managed.

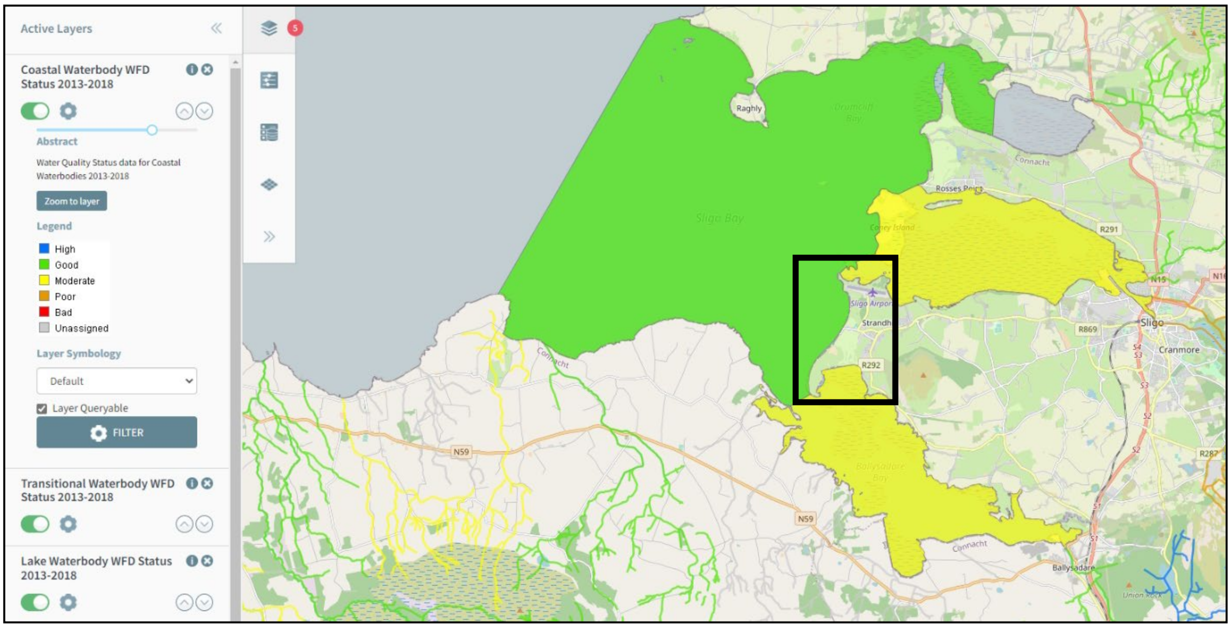


Figure 7.3 Depiction of the ecological status of riverine, lake, coastal and transitional water bodies within the vicinity of the Strandhill study area (Courtesy of https://gis.epa.ie/EPAMaps/Water)

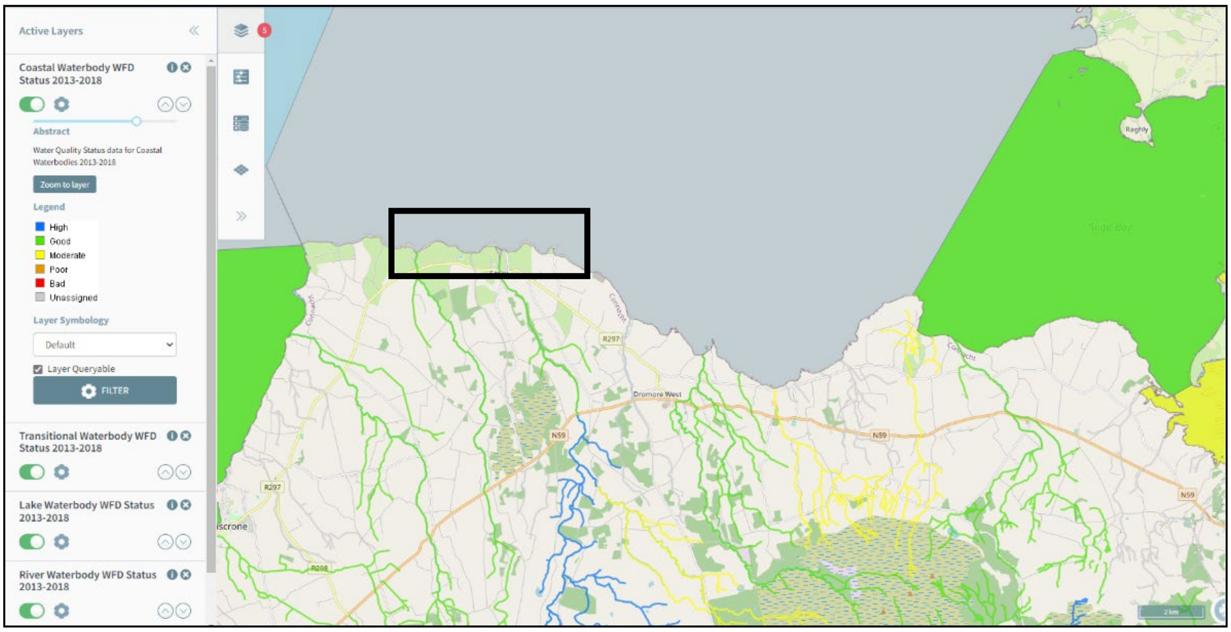


Figure 7.4 Depiction of the ecological status of riverine, lake, coastal and transitional water bodies within the vicinity of the Easkey study area (Courtesy of https://gis.epa.ie/EPAMaps/Water)

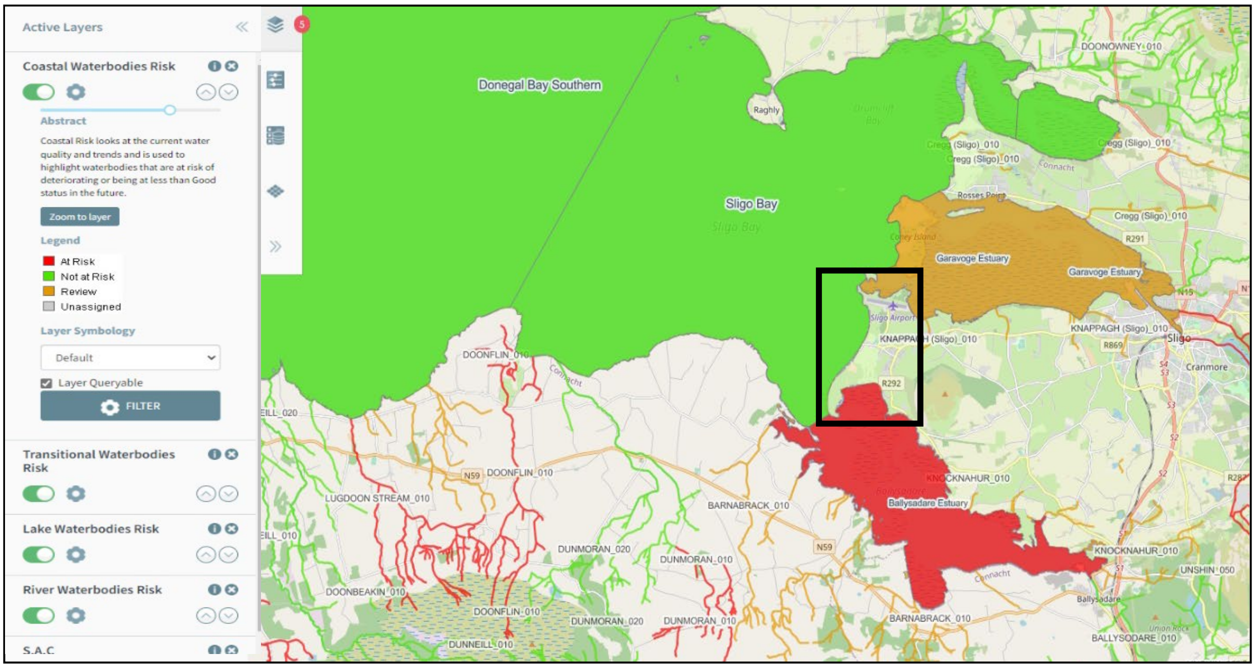


Figure 7.5 Water Framework Directive 'At Risk' status for 3rd cycle riverine, lake, coastal and transitional water bodies, Strandhill study area (Courtesy of https://gis.epa.ie)

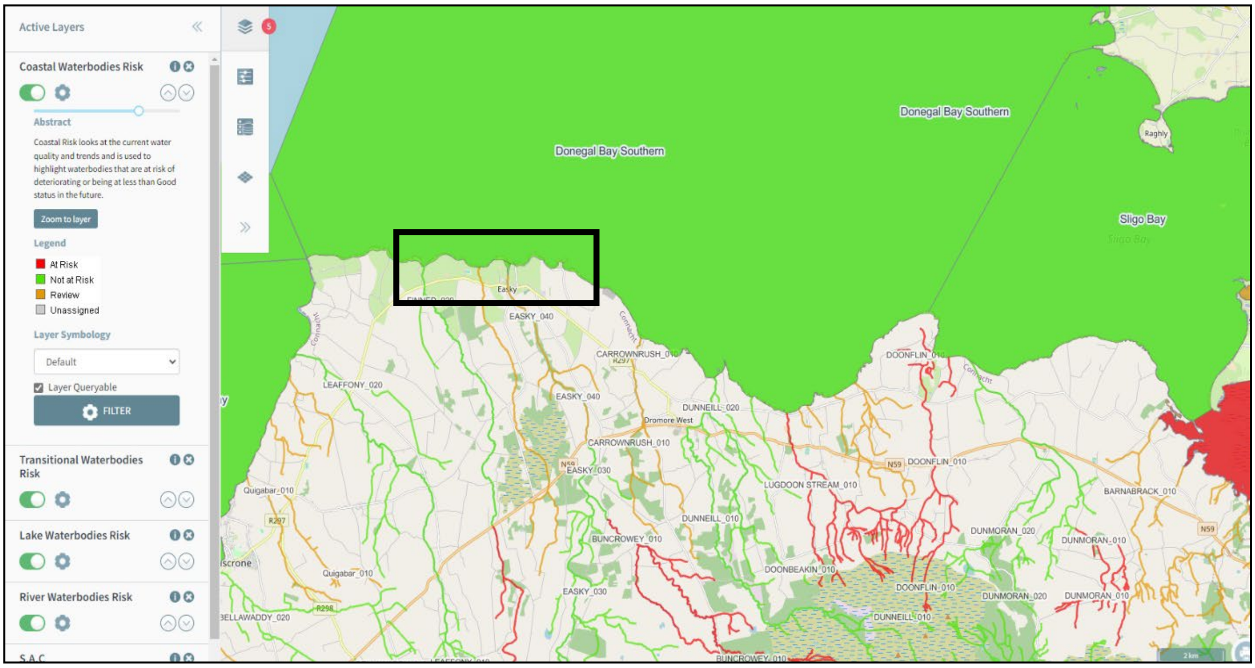


Figure 7.6 Water Framework Directive 'At Risk' status for 3rd cycle riverine, lake, coastal and transitional water bodies, Easkey study area (Courtesy of https://gis.epa.ie)

7.3.1 Register of Protected Areas (RPA)

In accordance with the requirements of the WFD and the associated national regulations, the EPA has compiled a Register of Protected Areas (RPA). The protected areas are identified as those requiring special protection under existing national or European legislation, either to protect their surface water or groundwater, or to conserve habitats or species that directly depend on those waters. The EPA is responsible for maintaining and updating the register as needed. The various categories included in the RPA are outlined in Sections 7.3.2 to 7.3.4 whilst Figure 7.7 and Figure 7.8 outline the location of RPAs surrounding study sites.

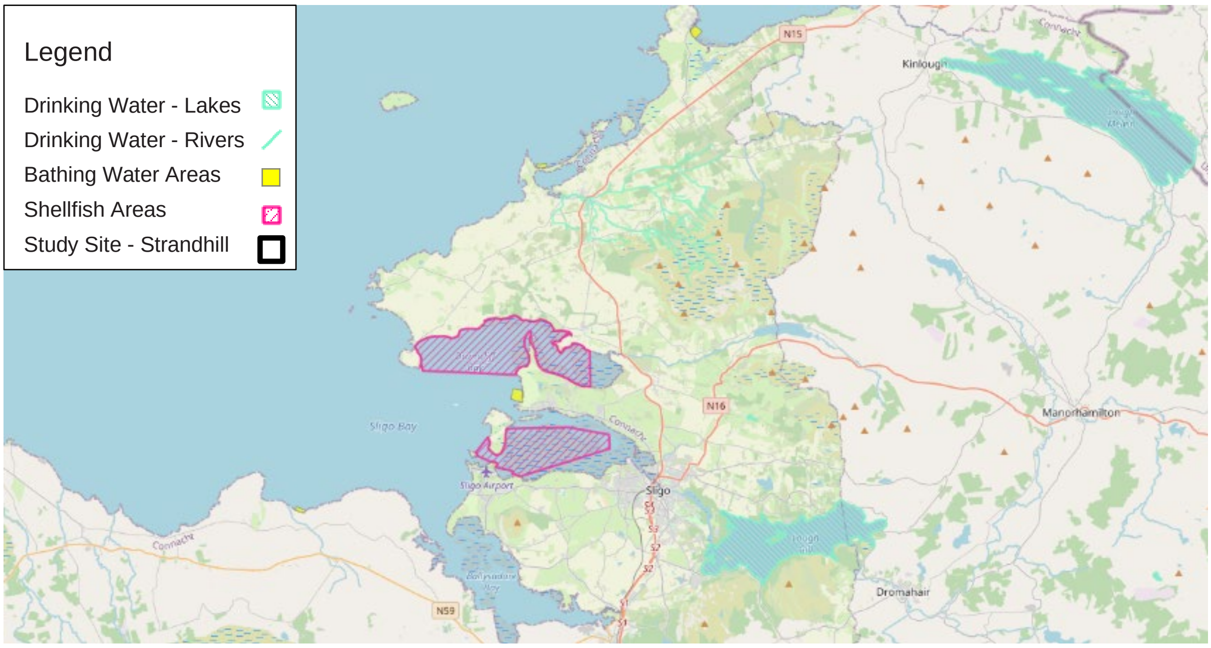


Figure 7.7 Register of Protected Areas in the vicinity of Strandhill study area (Courtesy of https://gis.epa.ie)

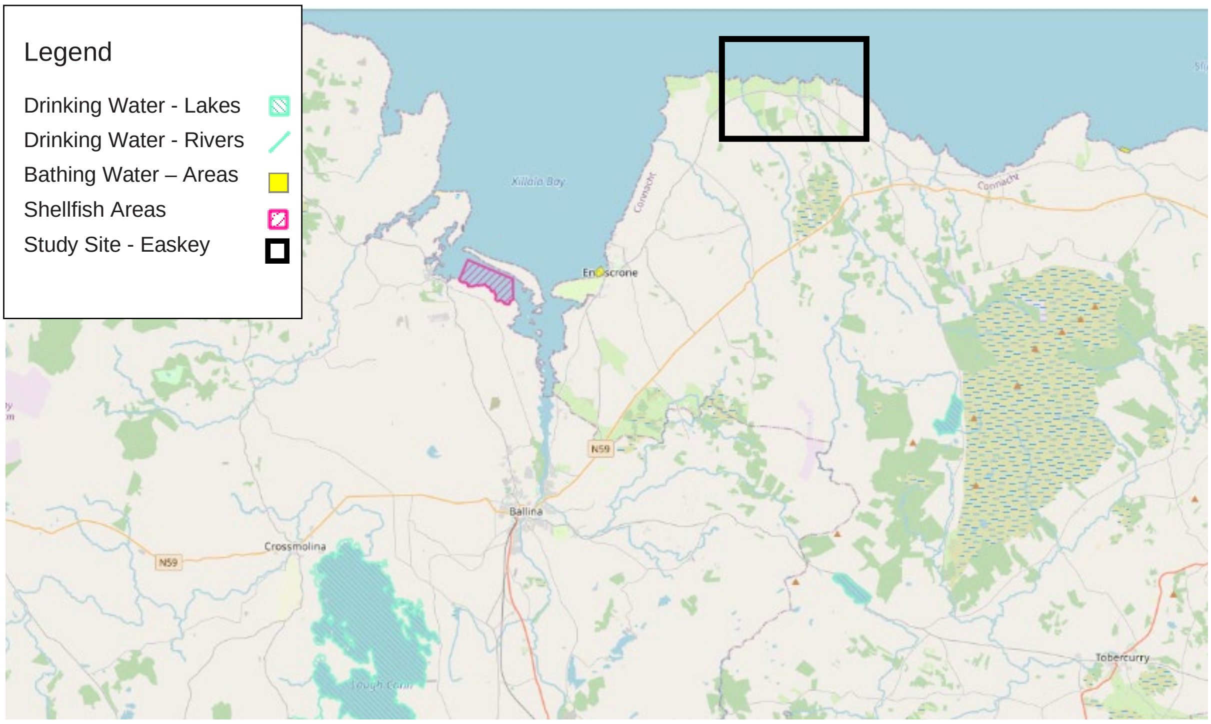


Figure 7.8 Register of Protected Areas in the vicinity of the Easkey study area (Courtesy of https://gis.epa.ie)

7.3.2 Waters used for the Abstraction of Drinking Waters

Drinking water safeguard zones are designated areas which must be carefully managed to prevent the pollution of raw water sources (including groundwater) that are used to provide drinking water. Most of the groundwater in Ireland, including the catchment of Sligo Bay and Drowse, is included in the RPA. There are no rivers in Sligo Bay on the RPA however the Strandhill site is within 15km of the Grange River which is covered in the RPA. There is one lake adjacent to Sligo Bay, Lough Gill, located approximately 10km east of the Strandhill site. The Easkey site covers no lakes or rivers within the RPA, the closest drinking water abstraction point being Easkey Lough 15km to its south.

7.3.3 Areas designated to protect Economically Significant Aquatic Species

These are protected areas established under earlier EC directives aimed at protecting shellfish (79/923/EEC) and freshwater fish (78/659/EEC).

The Directive requires Member States to designate waters that need protection to support shellfish life and growth. It also sets physical, chemical and microbiological requirements that designated shellfish waters must either comply with or endeavour to improve. There are 64 designated shellfish sites in Ireland.

The Strandhill site directly coincides with a shellfish production area in Sligo Harbour covered under the RPA. Additionally, a shellfish production area exists in the Drumcliff Bay estuary, overlapping with the Cummeen Stand/ Drumcliff Bay SAC/SPA, which is located within 5km of the site. The Easkey site has no direct overlap with Shellfish areas, however, one such area can be found in Killala Bay located approximately 15km southwest of the study area.

Certain rivers were designated under the EU Freshwater Fish Directive (78/659/EEC) (transposed into Irish law under S.I. No. 293/1988 - European Communities (Quality of Salmonid Waters) Regulations, 1988) as “salmonid waters”. The objective of this designation type was for the maintenance of water quality for salmon and trout freshwater species. The Freshwater Fish Directive has now been subsumed into the Water Framework Directive; however salmonid rivers remain on the register of protected areas. The closest river designated to support salmonoid fish is the River Moy which runs through Ballina around 20km Southwest of the Easy study area.

7.3.4 Areas designated for the Protection of Habitats or Species

These are areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection. These are designated under the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC) and have been discussed above.

7.3.5 Aquaculture and Fisheries

Several sites within Sligo Bay are licensed for aquaculture, many of which are in the vicinity of the Strandhill study area. Aquaculture sites include shellfish, predominantly focusing on oysters, finfish, and seaweed. Inshore dredge fishing focuses on cockles within the areas of Drumcliff Bay, Sligo Harbour and Ballysadare Bay. Line fishing occurring in and around the bay is predominantly associated with the catch of pollock and mackerel. Pot fishing is extensive in Sligo Bay and its surrounding coast, in this area the catch consists chiefly of crab and lobster, in the surrounding coastland the catch of shrimp is also common. Although an unpopular choice of cuisine in Ireland, periwinkles are harvested along the coasts of County Sligo for export. Gill net fishing also occurs off the coast of Sligo, with a main catch of pollock.

This fishing data was gathered by the Marine Institute in 2013 for Natura 2000 risk assessment, additionally, aquaculture data was collected at the request of the Department of Agriculture, Food and the Marine for reporting on aquaculture activities under Ireland's Marine Strategy Framework Directive article reporting. The extent and distribution of aquaculture and fishing activity in relation to both study areas can be seen in Figure 7.9 and Figure 7.10 below.

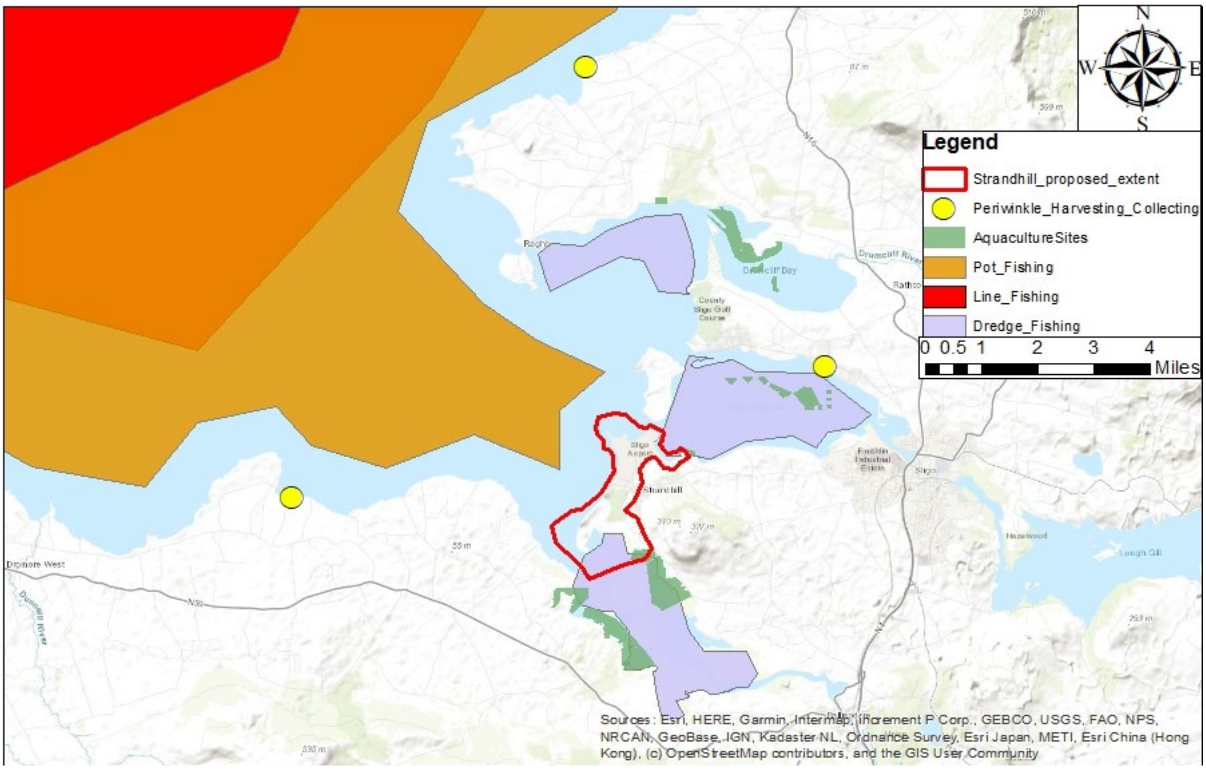


Figure 7.9 Fishing activity surrounding the Strandhill study site in Sligo Bay (Courtesy of https://atlas.marine.ie)

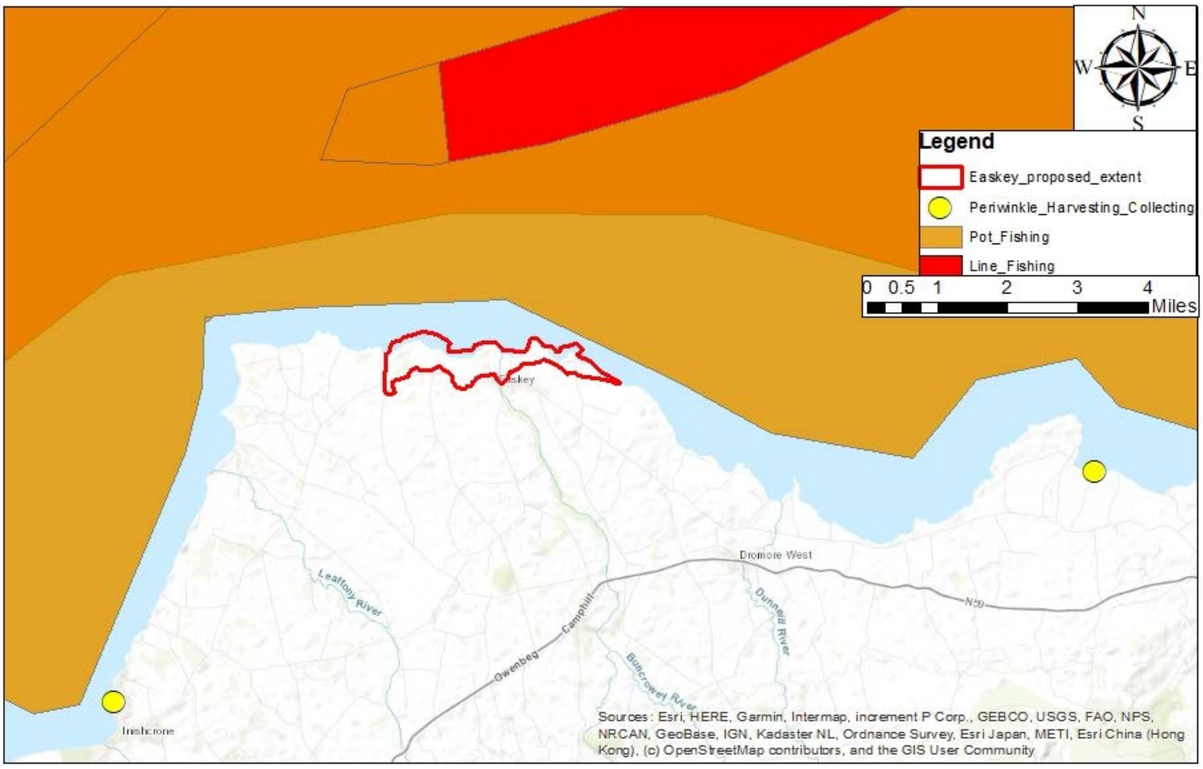


Figure 7.10 Fishing activity surrounding the Easkey study site (Courtesy of https://atlas.marine.ie)

7.4 Cultural Heritage

The implementation of coastal management measures has the potential to affect features of archaeological or architectural heritage value, e.g., altering views of ancient landscapes or causing damage to structures by collision, excavation, or vibration during construction activities.

The study areas and their surroundings host a variety of archaeological and architectural heritage sites which are afforded varying levels of protection under national legislation such as the National Monuments Acts (1930 to 2004) and the Planning and Development Act (2000) as amended.

Records of Monuments and Places (RMP) – the National Monuments Service (www.archaeology.ie) holds responsibility for maintaining this inventory of sites of archaeological significance which pre-date the 18th Century (including records of those which historically have been destroyed). These sites are established under the National Monuments Acts. The above below display the designated RMP sites in both study sites and their surrounding areas, in both cases, RMP sites are found within the study area, including sites adjacent to and on the coastline.

The National Inventory of Architectural Heritage (NIAH) – this is a record of sites of architectural heritage importance in Ireland dating from the start of the eighteenth century up to the present day which is established under the Architectural Heritage (National Inventory) and Historic Monuments (Miscellaneous Provisions) Act, 1999. The National Inventory of Architectural Heritage also maintains an inventory of historic gardens and demesnes.

Figure 7.11 and Figure 7.12 present unique records of either local or regional significance on the NIAH. The Planning and Development Act 2000 requires Local Authorities to compile a "Record of Protected Structures" as part of the County Development Plan. These are structures, or part thereof, which are considered to be of architectural value. Many of these structures also appear on the NIAH list and can be water-related features such as bridges, weirs, walls and embankments. One such structure exists in the Easkey site, a bridge constructed between 1780-1820 in the townland of Finned.

Figure 7.11 Mapped locations of RMP and NIAH sites within the vicinity of the Strandhill study area.

Figure 7.12 Mapped locations of RMP and NIAH sites within the vicinity of the Easkey study area.

Shipwrecks - Wrecks over 100 years old and archaeological objects found underwater are protected under the National Monuments (Amendment) Acts 1987 and 1994. Significant wrecks less than 100 years old can be designated by Underwater Heritage Order (UHO) on account of their historical, archaeological or artistic importance. The Shipwreck Inventory of Ireland includes all known wrecks for the years up to and including 1945 and approximately 12,000 records have been compiled and integrated into the shipwreck database thus far. An investigation of the position of wrecks located offshore of the study areas showed several wrecks (including the Molbaek, Donegal, and an unknown wreck) within 10km of Strandhill, and two wrecks (SS Thames and Potato Boat Killala Bay) within 10km of the Easkey study area.

8 OPTIONEERING PROCESS

8.1 Background

Optioneering is a process whereby measures to manage the Coastal Flood and Erosion Risk in an area are identified and evaluated before an appropriate management plan is developed. The Optioneering process is carried out through a series of individual activities as summarised in Figure 8.1 below.

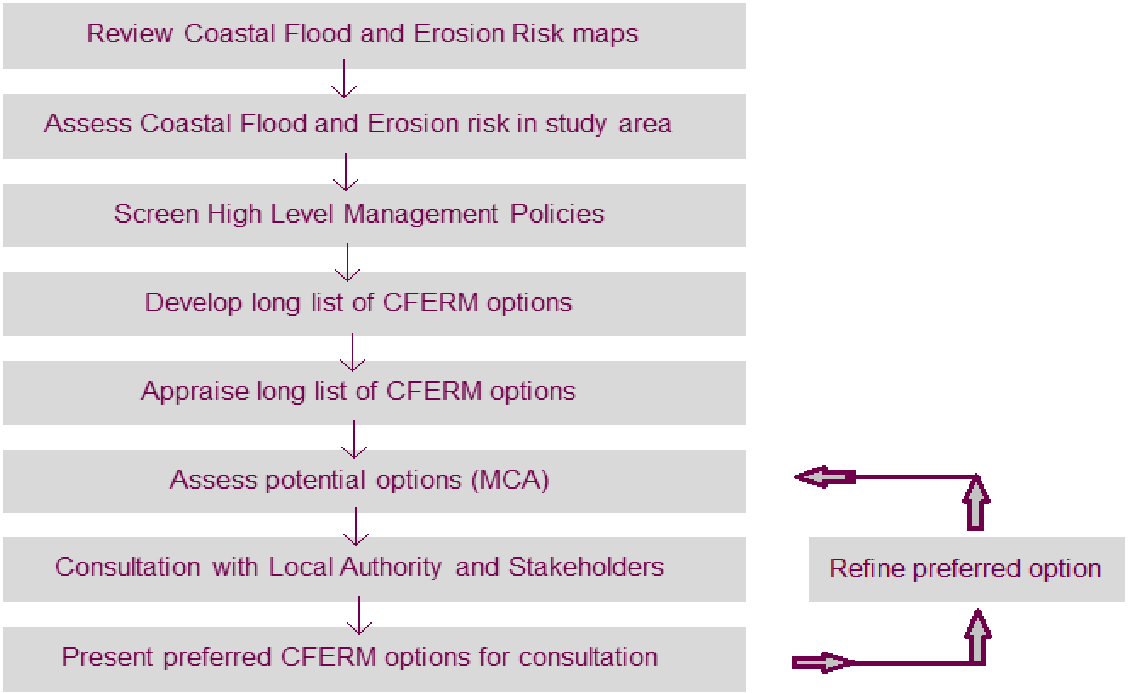


Figure 8.1: Summary of the optioneering process

The starting point in the optioneering process is to review the coastal flood and erosion hazard maps to identify the risk to be managed. The flood and erosion risk receptors are then assessed to ascertain where risk management measures will be required and to what extent. The assessment is based on the risks presented in Sections 4 and 5 and as summarised in Section 6.

After flood and erosion risks are quantified, high level policies are screened to rule out those considered unacceptable or inappropriate. The individual management measures that comprise the remaining high level policies are then used to develop a long list of potential CFERM options (see Section 9). As this long list includes options that would not be suitable or feasible, a preliminary appraisal is undertaken to produce a short list of options. This appraisal describes each option in further detail and where necessary, provides an explanation as to why it was excluded from further consideration.

The shortlist of CFERM options is then assessed against a set of criteria and objectives and scored to identify the preferred options through a process known as a Multi-Criteria Analysis (MCA). Upon completion of the MCA, the preferred options are then presented for consultation with the OPW and other relevant groups.

The preferred options identified are then taken forward to public consultation, thereby allowing the public the opportunity to comment on and influence the options. Comments from consultation with relevant stakeholders are then considered and if appropriate used to update the preferred option which in turn becomes the CFERM measure to be presented in the Coastal Flooding and Erosion Risk Management Plan (CFERMp).

8.2 CFERM Plan Objectives

Before proceeding with the optioneering process it is important to define the objectives of the proposed CFERM plan and the standard of protection any option should be designed to. To develop these objectives RPS have referred to the following documentation:

- The latest Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM) issued by the Environment Agency (EA, 2010).
- Guidance notes issued by the OPW as part of the Catchment Flood Risk Assessment Study.

In accordance with guidance issued by the OPW, this study aims to develop an appropriate management plan for the short, medium and long term epochs (i.e., periods of time). These epochs are summarised in Table 8.1 below.

Table 8.1: Summary of coastal management epochs considered for the Sligo Bay CFERM study

Epoch	Short Term	Medium Term	Long Term
Time frame	0 –10 years	10 –30 years	30 –100 years

When assessing options, it is imperative that all possible management options are considered together with their associated initial capital and ongoing maintenance costs.

In general terms, the success of the preferred CFERM plan should be measured in the context of key categories including but not limited to technical issues, economic & social risk as well as environmental impact. Each of these categories including relevant indicators by which each category can be assessed as described in Section 10.

8.3 Standard of Protection

The preferred standard of protection for coastal flood and erosion management options risk is a 0.5% AEP event (i.e., a 1 in 200 year event). Guidance issued by the OPW also recommends that a CFERM plan should have provisions to be adapted for climate change based on the Medium Range Future Scenario (MRFS) whereby sea levels are expected to rise by +0.50m by 2100. This guidance states that:

> *…. Whilst the minimum OPW recommended defence standard for coastal schemes is 1 in 200 years, consideration should be given as to how this defence standard might best be maintained into the future (e.g., to 2050), where this can be justified, having regard to the most likely (medium term) future sea level rise scenario (i.e., the MRFS) ….*

To establish the 0.5% AEP event water level for the study areas, RPS referred to the Irish Coastal Wave and Water Level Modelling Study 2018 (OPW, 2020). Based on this information the 0.5% AEP event water level within the Ballysadare Bay area was found to be circa 3.47m ODm.

By adjusting climate change projection curves from the UK Climate Programme (UKCP18) to fit the MRFS and HEFS projections as specified by the OPW, it was possible to determine potential sea level rise by 2050 and incorporate this into the standard of protection.

The adjusted MRFS and HEFS sea level rise curves for the Strandhill and Easkey area are illustrated in Figure 8.2 below.

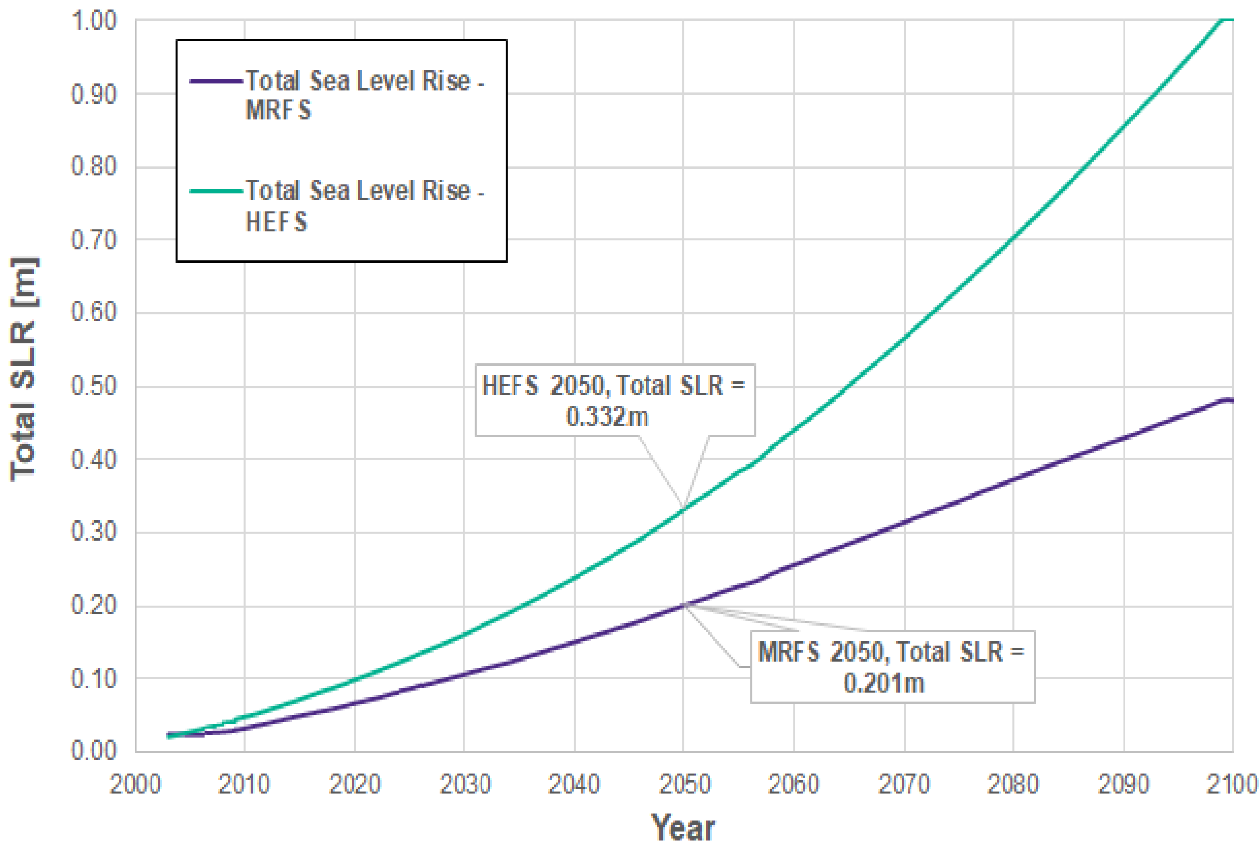


Figure 8.2: Sea level rise projection curves for the MRFS and HEFS scenario from 2007 to 2100 based on UKCP18 data

An assessment of the sea level rise projections curves presented in Figure 8.2 found that future sea level rise could be mitigated by an additional 201mm (based on the most likely medium term future sea level rise scenario). This allowance is in addition to the 300mm and 500mm freeboard recommended for hard and soft defences respectively. These design criteria are summarised in Table 8.2.

It should be noted that these levels are indicative only and may vary across the study area. The actual standard of protection levels should be subject to detailed design.

Table 8.2: Summary of indicative Standard of Protection criteria for hard and soft defences at Strandhill and Easkey

Design Criteria	0.5% AEP event
Water Level	3.47m OD Malin (OSGM15)
Future climate change allowance	**Total SLR "pre-adaptation" allowance = 201mm**
Freeboard for hard defences	300mm
Freeboard for soft defences	500mm
Crest level for hard defences	3.47m + 0.20m + 0.300m **Total = 3.97m** OD Malin (OSGM15)
Crest level for soft defences	3.47m + 0.20m + 0.500m **Total = 4.17m** OD Malin (OSGM15)

8.4 Screening of High Level Policies

RPS conducted an initial screening process to review the technical feasibility and economic justification of all high level coastal management policies. These generic policy options are described below.

- **No Active Intervention (i.e., 'Do Nothing')**

  This is a policy decision not to invest in providing or maintaining any defences. Where there are presently no defences, this policy means that the shoreline will continue to evolve naturally.

  This policy can also apply to areas that do have coastal defences. In this instance, No Active Intervention means that these defences will not be maintained.

- **Hold the Line**

  This policy involves improving or maintaining the standard of protection provided by the existing defence line. Renewed defences refer to the construction of new, more robust defences. There may be some residual risk in holding the line such as a steepening of the foreshore or the loss of beach width. Such factors could make this policy unsustainable sooner than anticipated.

  This policy aims to retain the existing character and form of the coast with minimal disruption, whilst maintaining all existing assets.

- **Advance the Line**

  This policy involves building new defences on the seaward side of the original defences to reclaim land and often improve the standard of protection provided by the original defences.

- **Managed Realignment**

  When a coastline is protected with hard or soft defences, this option involves allowing the coastline to move backwards (or forwards) by realigning the position of existing defences and creating a new line of protection.

  In terms of coastal erosion, this policy can involve establishing a sacrificial buffer zone where no development is permitted (i.e., a no build zone). For coastal flooding, it will state a minimum elevation above mean sea level for development.

- **Managed Retreat**

  This policy is applicable when a coastline is not protected by coastal defences. Like the policy of **Managed Realignment,** this policy involves establishing a sacrificial buffer zone whereby no further development is permitted (i.e., a no build zone). With respect to the properties located in the buffer zone, several options can be made available including the relocation of properties, compensation schemes for landowners or the long-term abandonment of the area amongst others.

> Although similar in many respects, the key difference between **Managed Retreat** and **Managed Realignment** is that the latter involves realigning existing defences. If no coastal defences are present then realignment cannot take place.

A summary of the high level policy screening assessment is presented in Table 8.3 below.

Table 8.3: Initial review of coastal management policies

Policy	Initial Review		
	Short Term (Present day to 2032)	Medium Term (2032 – 2052)	Long Term (2052 – 2102)
No Active Intervention (NAI)	To be appraised for both Easkey and Strandhill. Will facilitate long term natural coastal processes and protect the natural environment. Potential for uncontrolled flooding & erosion in both study areas.		
Hold the Line	To be appraised for both sites. This option could mitigate the threat of flooding and erosion to the Strandhill and protect the regional road at Easkey which forms an important section of the Wild Atlantic Way. This policy could reduce beach width and impact public amenities.		
Advance the Line	No benefits at either Easkey or Strandhill Potential environmental impacts could result from the development of seaward defences. This policy was not considered further.		
Managed Realignment	To be appraised for Strandhill where there are existing defences. Cannot be appraised for Easkey as there are no defences to realign. Where implemented this option could create a buffer zone, facilitate natural coastal processes and give relevant stakeholders time to adapt.		
Managed Retreat	To be appraised for Easkey where it may be possible to re-align the regional road which forms an important section of the Wild Atlantic Way. Depending on the form of retreat, this option could potentially protect the natural environment and create natural flood & erosion defences.		

As described in Table 8.3 above, the only high level policy screened out at this stage was Advance the Line. This policy was screened out due to the lack of benefits relative to the high probability of environmental impacts. All other policies and their corresponding CFERM options were subsequently appraised in the following Sections of this report.

9 OPTIONS APPRAISAL

9.1 List of Options and Appraisal Criteria

Each high level coastal management policy described in the previous Section is comprised of several different options that could mitigate the risk of coastal flooding and erosion. A summary of potential CFERM options and the applicability of each in the context of tidal flooding wave overtopping and erosion is summarised in Table 9.1.

Table 9.1: Potential Coastal Flood and Erosion Risk Management (CFERM) options

CFERM Option	Applicability			Construction Type
	Tidal Flooding	Wave Overtopping	Erosion	Hard/Soft/Mixed
Seawalls	✓	✓	✓	Hard
Revetments		▲	✓	Hard
Embankments	✓	▲		Hard
Maintenance	▲	▲	▲	Mixed
Groynes		▲	✓	Mixed
Detached breakwaters		▲	✓	Mixed
Headlands		▲	✓	Mixed
Perched beaches	▲	▲	✓	Mixed
Cove		▲	✓	Mixed
Dune stabilisation	✓	▲	✓	Soft
Beach Nourishment	▲	▲	✓	Soft
Sand Motor	▲	▲	✓	Soft
Managed realignment	✓	✓	✓	Soft
Do nothing	▲	▲	▲	Soft

Key	
Applicable	✓
Applicable in some cases	▲
Not applicable	

It is important to ensure that options brought through the appraisal process will not result in negative environmental, social/cultural or economic impacts. To this end, each option listed above was appraised based on the following criteria:

- **The Environment -** The proposed option must not negatively impact the natural environment including the existing coastal process. Nor will the proposed option negatively impact nearby environmentally designated areas.
- **Society -** The proposed option must effectively reduce the damages/losses associated with the predicted flood and erosion risk.
- **The Economy** - The cost of constructing and maintaining the proposed option has the potential to be financially viable. I.e., the benefits of an option should outweigh the costs of an option.

An initial appraisal of each option based on these criteria is presented in the following sections of this report and summarised in Table 9.2.

9.1.1 No Active Intervention

9.1.1.1 Do Nothing

Description

Doing nothing means that the local authority does not invest in coastal defence assets or operations, i.e., there is no shoreline management activity or plan.

Initial Appraisal

From an environmental perspective, this would be favourable for Easkey and Strandhill. This option would maintain the integrity of Annexed habitats and species by avoiding potential ecological and visual impacts.

From a social perspective, this option has the potential to negatively impact local communities due to the risk of flooding and erosion that has been predicted in some study areas. In some instances, this may result in economic implications for both the local community and the Council.

Feasibility

In line with optioneering guidance, this option should be considered for all sites.

9.1.1.2 Shoreline Monitoring

Description

Although shoreline monitoring is not generally considered a management option, it is RPS' experience that monitoring, measuring and reviewing relevant coastal data provides important information. This information can be used to identify changes and trends in coastal processes. Such data is very valuable with respect to making informed and timely coastal management decisions.

Initial Appraisal

Accurate and repeatable coastal data is essential for informed and timely decision making. This is particularly true in dynamic environments such as the northwest coast of Ireland where the coastal zones can change quickly. The changes are usually driven by a range of spatially and temporarily varying factors including but not limited to storm events, coastal development and climate change.

Feasibility

This option can be implemented alongside any other management option and should be considered further for all sites.

9.1.2 Managed Realignment

Description

Managed realignment involves the landward movement of a sea defence structure and the promotion of new habitat in front of the new line of defence. The land between the old and new defences then forms a new intertidal zone that can respond to coastal processes. This reduces the effects of coastal squeeze.

This option is often implemented alongside a long-term strategy for planning land-use changes. This may include establishing no build zones etc.

Initial Appraisal

If implemented this option would be complimentary to the conservation objectives of the nearby environmentally designated areas. However, as this option involves realigning existing hard defences, it would only apply to localised sections of Strandhill.

Any form of managed realignment could result in a significant loss of land belonging to the Strandhill Camping and Caravan Park which is vital in servicing the local tourism asset. Furthermore, as the Strandhill WWTP is only *c.*40m behind the existing shoreline, it would be imperative that this important service is protected or re-situated further from the coastline. Constructing a new WWTP and de-commissioning the existing plant would be extremely costly and would require additional studies to determine the feasibility and cost of this option.

At present, the Strandhill WWTP is afforded good protection by the existing rock armour revetment. However, under future climate conditions, there is a moderate probability that this defence could be outflanked by wave action and could become detached from the shoreline.

Feasibility

This option should be considered further for some sections of Strandhill. It would not be applicable for the entire coastline as it would not be feasible to relocate the town of Strandhill. Therefore, any managed realignment option would have to tie in well with the existing defences at the town of Strandhill.

9.1.3 Managed Retreat

9.1.3.1 Setback and/or Abandonment

Description

Like managed realignment, this option involves creating a sacrificial buffer zone whereby no further development is permitted (i.e., a no build zone). However, **Managed Retreat** differs from **Managed Realignment** in that the latter involves moving existing hard defences to create a new line of defence. On the contrary, there are no defences to protect the buffer zone with the Managed Retreat option.

As opposed to establishing a fixed setback line it is possible to introduce a series of rolling easements whereby the setback line and buffer zone are adjusted over time. But this approach can postpone decision making which can result in more sustainable opportunities being missed.

The alternative **Managed Retreat** option is **Abandonment**. Long-term planned abandonment can follow the "do nothing" approach in which built assets are regarded as having a fixed life span. When these assets are at imminent risk of coastal erosion or flooding, no attempt is made to protect them.

Planned abandonment can also be achieved by prohibiting post-storm reconstruction. As with the setback approach described above, landowners directly affected by a policy of abandonment may be compensated through acquisition programmes etc. where appropriate national policies allow.

Initial Appraisal

The only site for which Managed Retreat would be applicable is Easkey. Any form of Managed Retreat is likely to be complimentary to the conservation objectives of the nearby environmentally designated sites.

As Managed Retreat does not involve defending the position of the new setback line with hard defences, the width of the buffer zone will be gradually reduced until the original setback line is of no consequence. At this point, the coastal management measures must be re-considered. As such, depending on the nature of future coastal change, this option may only buy time by delaying difficult decisions to further down the line.

At Easkey, implementing a policy of Managed Retreat would likely involve realigning localised sections of a tertiary road which forms part of the Wild Atlantic Way. From a technical perspective, this is a feasible option but would require significant engagement with local landowners to determine a suitable location for a new road and compensation for any landowners affected by this policy.

Feasibility

This option should be considered further as it is technically feasible to realign a regional road subject to agreement with local landowners affected by this policy.

9.1.4 Hold the Line

9.1.4.1 Seawalls

Description

Seawalls protect coastlines by completely separating land from water. Seawalls are primarily used to resist wave action and if designed correctly can provide effective protection to the hinterland. However, seawalls do not protect the shore in front of them. On the contrary, erosion of the seabed immediately in front of the structure will in most cases be enhanced due to increased wave reflection caused by the seawall. This usually results in a steeper seabed profile which in turn allows larger waves to reach the structure.

A seawall is usually a fixed, inflexible structure. Future sea level rise must be accounted for during the design phase. A typical sectional view of a seawall is presented in Figure 9.1 below.

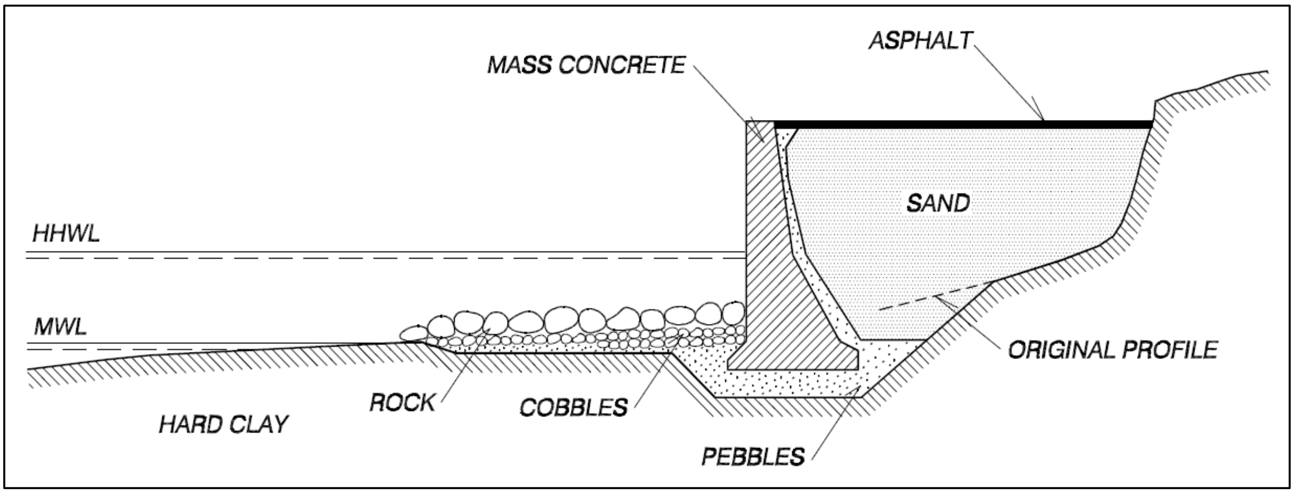


Figure 9.1: Typical section view of a vertical seawall (USACE, 2006)

Appraisal

When seawalls are used in areas with significant wave action such as the northwest coast of Ireland, they may accelerate beach erosion as much of the wave energy is redirected down toward the toe. This can reduce beach levels and result in coastal squeeze as summarised in Figure 9.2. Furthermore, seawalls will completely arrest the natural beach dune interactions and prevent the release of sediments from the section it protects. This will have a negative impact on the sediment budget along adjacent shorelines.

Due to the reasons outlined above, the construction of a seawall would be detrimental to the conservation objectives of the nearby environmentally designated areas. Furthermore, a seawall at Strandhill would likely lead to the loss of any remaining beach foreshore towards the north of Strandhill town. Based on initial consultation with local stakeholders, this is considered unacceptable as this foreshore area is crucial to local surf schools which use this amenity to access the water.

This option involves relatively high initial capital and ongoing maintenance costs. As such, seawalls are generally only feasible in areas where high value assets etc are at risk (towns, villages, roads etc).

Initial Appraisal

Other than maintaining the existing seawalls that protect Strandhill town, seawalls are unlikely to be a feasible solution at either Easkey or Strandhill as a rock armour solution which would also mitigate the risk of erosion would have less of an impact on surrounding coastal processes.

With respect to the economics of seawalls, the initial capital and ongoing maintenance costs generally more expensive than those associated with revetments.

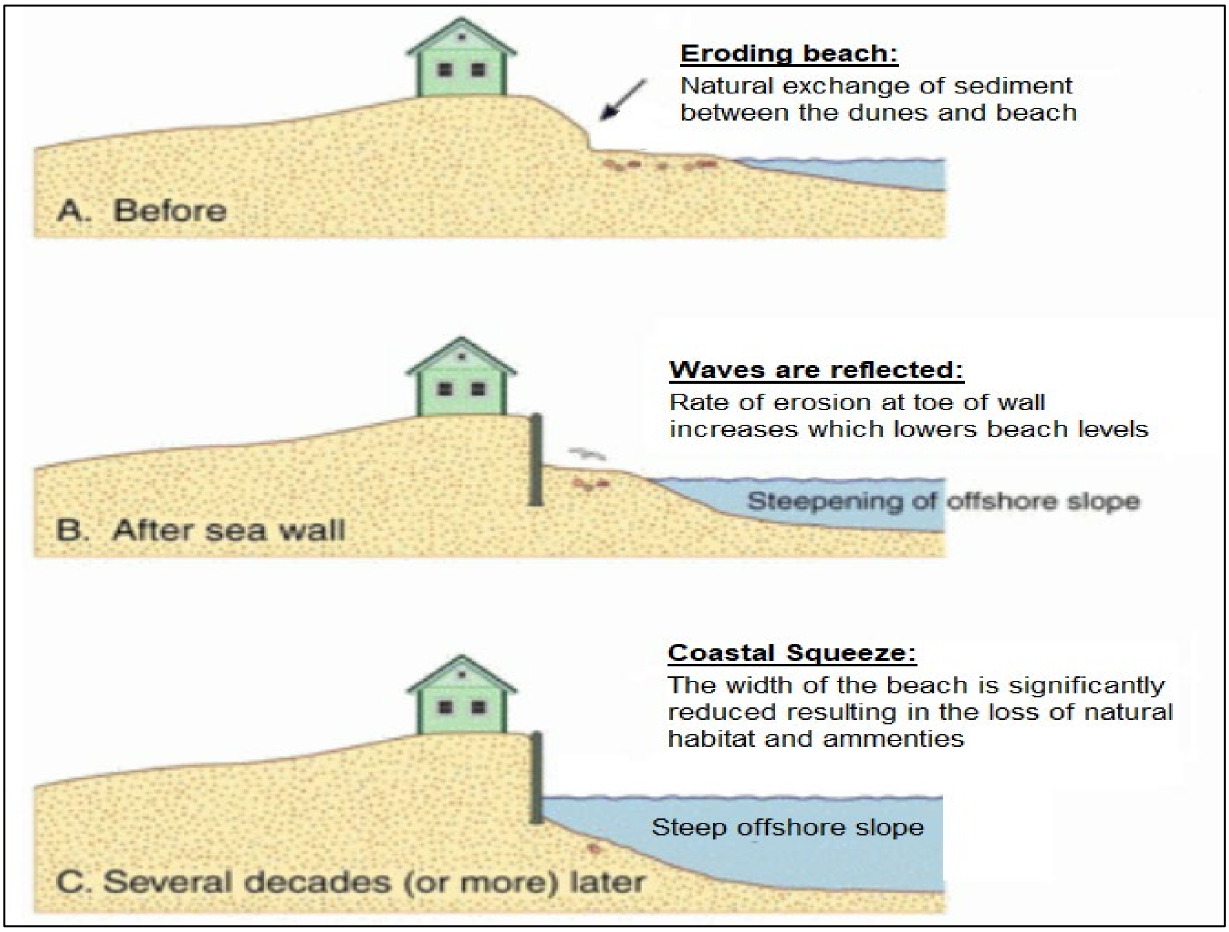


Figure 9.2: The long-term impact of a seawall (adapted from Pilkey, O.H and Dixon, K.L. 1996)

9.1.4.2 Revetments

Description

Revetments are shore parallel sloping defences that dissipate wave energy. Some modern revetments have concrete blocks laid on top of a layer of finer material while rock armour revetments consist of layers of very hard rock often weighing several tonnes. Rock armour has the advantage of good permeability which dissipates wave energy and looks more natural.

A revetment is more flexible than a seawall and is therefore easier to modify in response to future climate change. Although revetments can reduce flood risk by reducing wave overtopping (i.e., flood mechanism 2) they do not generally prevent flooding due to storm surge activity (i.e., flood mechanism 1).

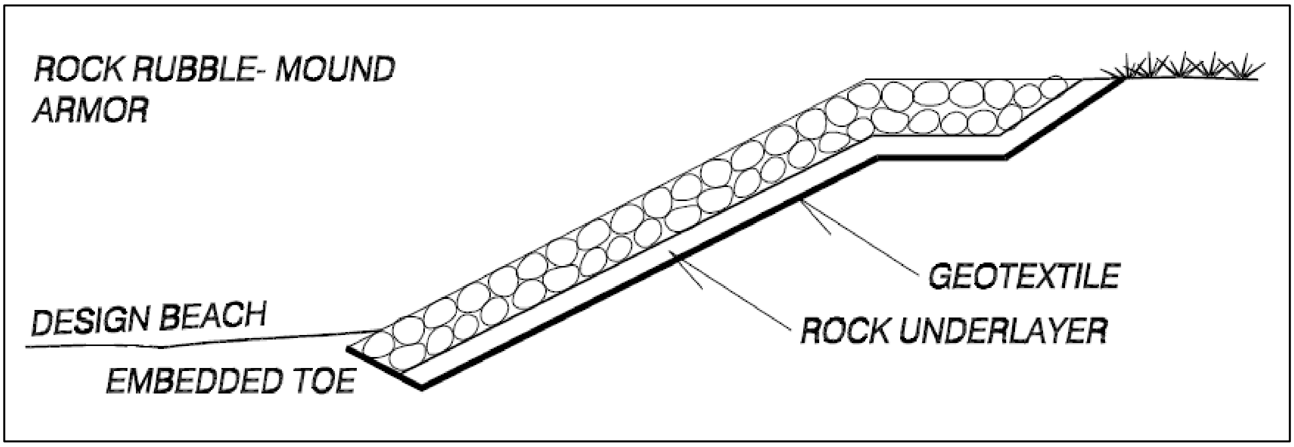


Figure 9.3: Typical section view of a rubble mound revetment (USACE, 2006)

Initial Appraisal

A revetment will fix the location of a coastline but it will not prevent erosion of the lower beach profile. Over time this results in coastal squeeze whereby the beach in front of the revetment will gradually disappear (as seen in Courtown, Co. Wexford).

A revetment interrupts the release of sediment from the section of coastline that it protects and will therefore have a negative impact on the sediment budget along adjacent shorelines. Constructing a revetment at any site could therefore be detrimental to the conversation objectives of nearby environmentally designated areas.

From a social perspective, a revetment would mitigate the risk of coastal erosion and reduce the potential for wave overtopping. This option would not mitigate the risk of coastal flooding due to tidal inundation alone (i.e., flood mechanism 1).

With respect to economics, the initial capital and on-going maintenance costs are usually cheaper than those associated with seawalls.

Feasibility

This option should be considered further for both Easkey and Strandhill whereby the primary risk is that of coastal erosion. Unlike a seawall, rock armour will not mitigate the risk of coastal flooding caused by tidal inundation, however, it may be a feasible option for sites at risk of coastal flooding caused by wave overtopping.

9.1.4.3 Groynes

Description

Groynes are narrow structures that are usually constructed perpendicular to the shoreline. A single groyne promotes the accretion of beach material on the updrift side but erosion on the downdrift side; both effects extend some distance from the structure. Consequently, a groyne system can result in a saw-tooth-shaped shoreline with different beach levels on either side of the groynes.

Groynes create very complex current and wave patterns. However, a well-designed groyne system can slow down the rate of longshore transport and by building up material in the groyne bays, provide some protection of the coastline against erosion.

Occasionally, groynes are constructed to include a specially designed “fishtail” or “Y-head” at their seaward end. The benefit of these features is that they can influence the cross-shore transport processes as well as the longshore transport element of the littoral drift regime. An example of a fishtail groyne system at Clacton-on-Sea is illustrated in Figure 9.4 and Figure 9.5.

In most cases groynes are rubble mound constructions, however, timber or sheet piling can also be used. Rock armour is generally the preferred option because of the rubble mound’s ability to withstand severe wave loads and decrease wave reflections.

Figure 9.4: Example of fishtail groynes at Clacton-on-Sea (© Google Earth)

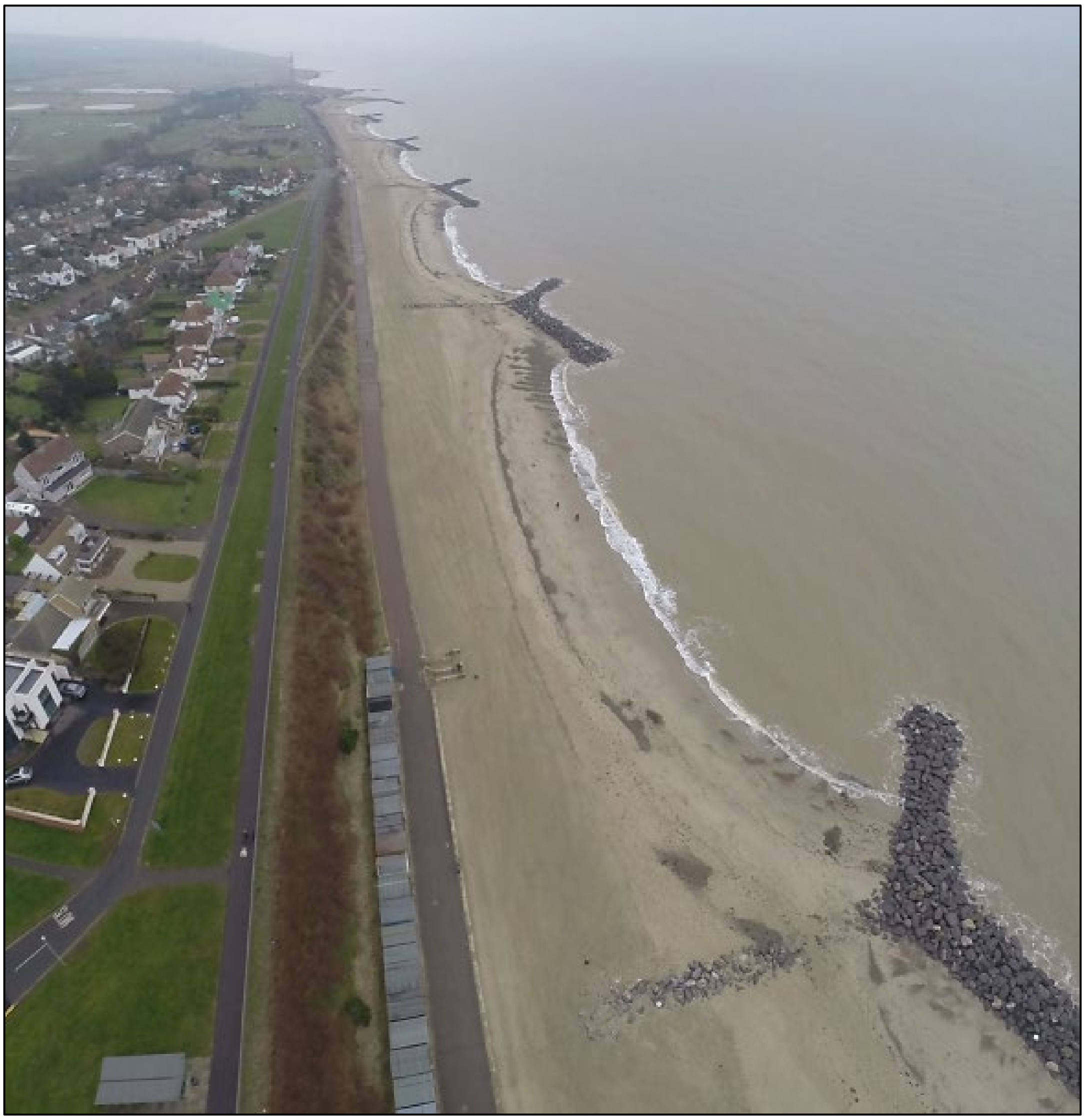


Figure 9.5: Aerial view of a fishtail groyne field at Clacton-on-Sea (VBACJV, 2019)

Initial Appraisal

Groynes work best in environments whereby sediment transport is generally dominated by longshore processes (i.e., sediment material moving parallel along the beach). However, at both sites considered in this study, sediment transport was often dominated by cross-shore processes (i.e., sediment material moving perpendicular to the beach). Groynes are not generally effective beach management solutions under cross-shore transport conditions.

The cost of constructing groynes is comparable to that of constructing rock armour revetments. However, it is the cost of the beach re-nourishment material that will influence the viability of this option. Particularly in Ireland which does not have an established offshore dredging industry, unlike the UK. As such, sourcing suitable material and obtaining the relevant permissions etc. could prove problematic and costly.

Feasibility

Whilst a groyne solution would not be a feasible solution to mitigate the risk of erosion at Easkey, it may be possible to develop a combined groyne and beach nourishment option for Strandhill. This would involve constructing a single groyne just north of Strandhill to reduce the loss of sediment to longshore sediment transport. It would be necessary to complement this scheme with a beach nourishment campaign to restore beach foreshore levels and reduce the deficit of sediment supply to the southern section of the beach.

Whilst this option could be very costly, it should be considered further.

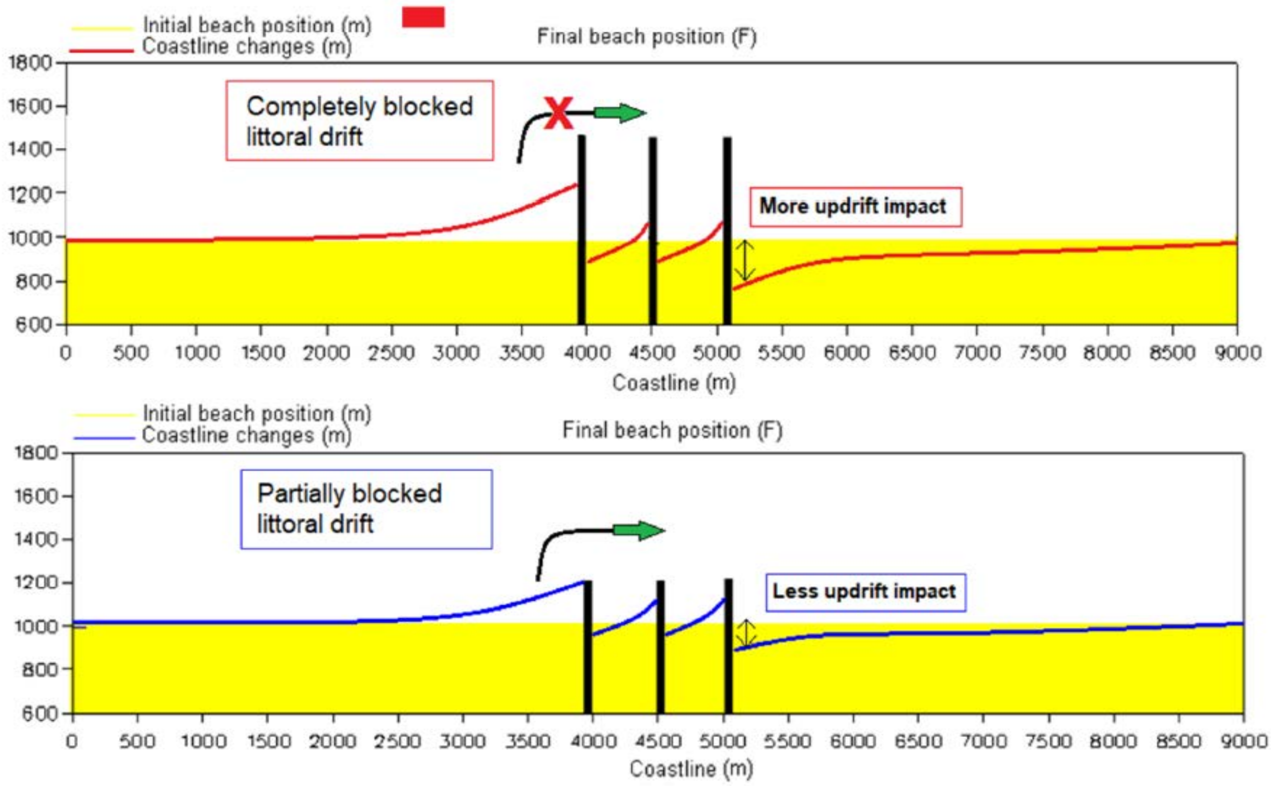


Figure 9.6: Schematic illustration of a long and short groyne field and their impact on the littoral drift regime and the adjacent coastline if not complimented with a beach nourishment programme (DHI, 2017)

9.1.4.4 Detached Breakwaters

Description

Detached breakwaters are almost always built as rubble-mound structures and are usually constructed parallel to the shoreline either inside or outside of the surf zone. These defences provide shelter from waves, whereby the sediment drift behind the breakwater is decreased and the transport pattern adjacent to the breakwater is modified.

Depending on the physical characteristics of the breakwater and the proximity of the structure to the coastline, breakwaters can result in the formation of salients or tombolos. In both instances, there is an accumulation of sand between the breakwater and coastline, but with tombolos the accumulation of sand will create an emerged beach between the breakwater and coast as summarised in Figure 9.7 below.

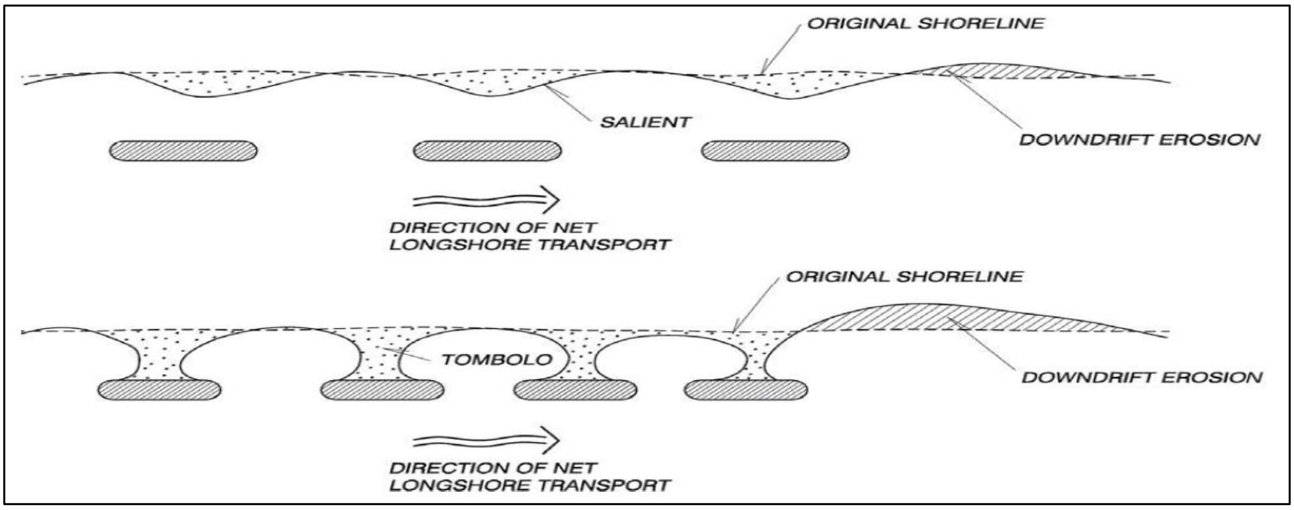


Figure 9.7: Typical beach configurations with detached nearshore breakwaters (USACE, 2006)

Initial Appraisal

The environmental impact of breakwaters is highly variable and dependent on the size and location of the structure in relation to the coastline and beach profile. Breakwaters generally have an advantage over groynes in they do not obstruct access along the beach, however, the accumulation of sand around the breakwater can be difficult to predict. Therefore, without a detailed assessment which often includes physical model testing it is difficult to assess the performance and environmental impact of a breakwater.

Breakwaters tend to work best along straight coastlines which have a dominant wave direction and a small tidal range and are therefore unlikely to be a suitable solution for either Easkey or Strandhill.

Breakwaters tend to work best along straight coastlines which have a dominant wave direction and whereby the sediment transport regime is dominated by cross-shore transport mechanisms only. This is not the case at Strandhill whereby significant volumes of sediment can be mobilised via long-shore transport mechanisms.

Whilst undesired consequences can include the formation of tombolo or salient structure behind the breakwater, it is also important to note that the primary function of a breakwater is to absorb and attenuate wave energy. This is unlikely to be acceptable given that surfing is crucial to the local economy of Strandhill. Furthermore, a breakwater can result in complex coastal processes including eddy formations and strong rip currents, both of which could present significant health and safety issues for the local surfing community.

Finally, detached breakwaters are generally very expensive to construct and maintain. Constructing a detached breakwater is generally much more expensive than implementing either a rock revetment, seawall or groyne solution (subject to the design of each option).

Feasibility

This option is not considered a feasible solution for either Easkey or Strandhill and should not be considered further.

9.1.4.5 Embankment

Description

Embankments are onshore structures with the principal function of protecting low-lying areas against flooding. These structures are usually built as a mound of fine materials like sand and clay with a gentle seaward slope that reduces wave run-up and the erosive effect of the waves. The surface of the embankment can be armoured with grass, asphalt, stones, or concrete slabs.

In most instances, embankments are constructed well above the mean high water mark which means that the structure is often fronted by a low-lying coastal platform. On an eroding shoreline, where dunes form the natural protection of the low hinterland, an embankment can be coupled with the construction of hard coastal defences as summarised in Figure 9.8 below. Revetments are generally the preferred hard defence however seawalls can also be used.

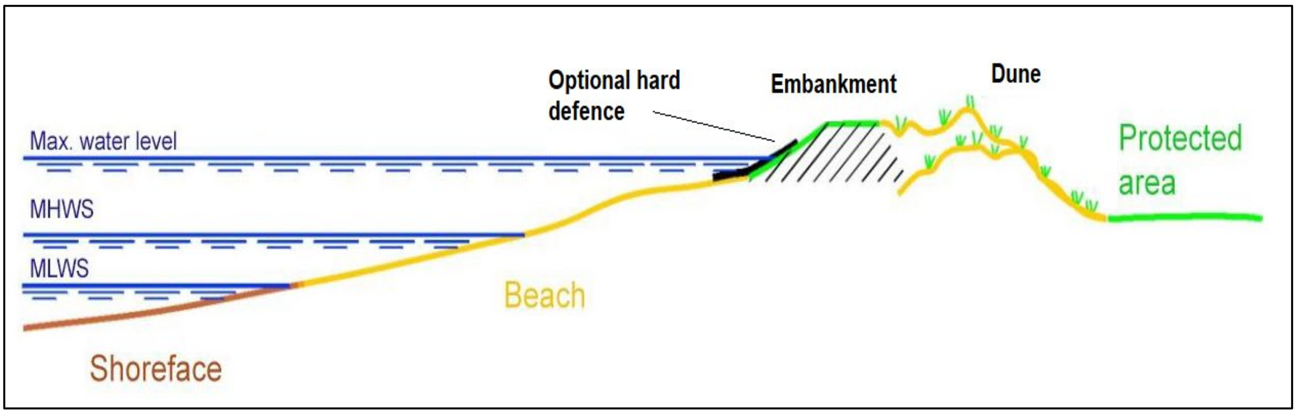


Figure 9.8: Typical section of an embankment with an optional hard defence on a sandy dune system (adapted from DHI, 2017)

Initial Appraisal

The main function of an embankment is to prevent the flooding of a low coastal hinterland, which means that the height of the embankment is the most important design parameter. However, an embankment must also be able to withstand the force of waves during extreme storm conditions.

Given that these structures are most common in areas where the frequency and magnitude of extreme storm events are low, they are best suited to mitigating the risk of flooding in low-energy environments.

Feasibility

This option could be considered further to mitigate the flood risk at Strandhill. However, given the exposure to energetic wave action from the Atlantic along the west coast of Ireland, it would be necessary to protect the face of any embankment structure with a rock armour revetment.

9.1.4.6 Beach nourishment

Description

Beach nourishment is considered a *soft engineering* solution to manage coastal erosion. Nourishment material must be of similar size and density as the natural beach otherwise it can be easily removed and lost from a coastal system.

A re-nourished beach can reduce incident wave energy and mitigate the threat of erosion. Beach nourishment can also reduce the risk of coastal flooding from wave overtopping and act as a sediment source for areas down drift of the nourishment area.

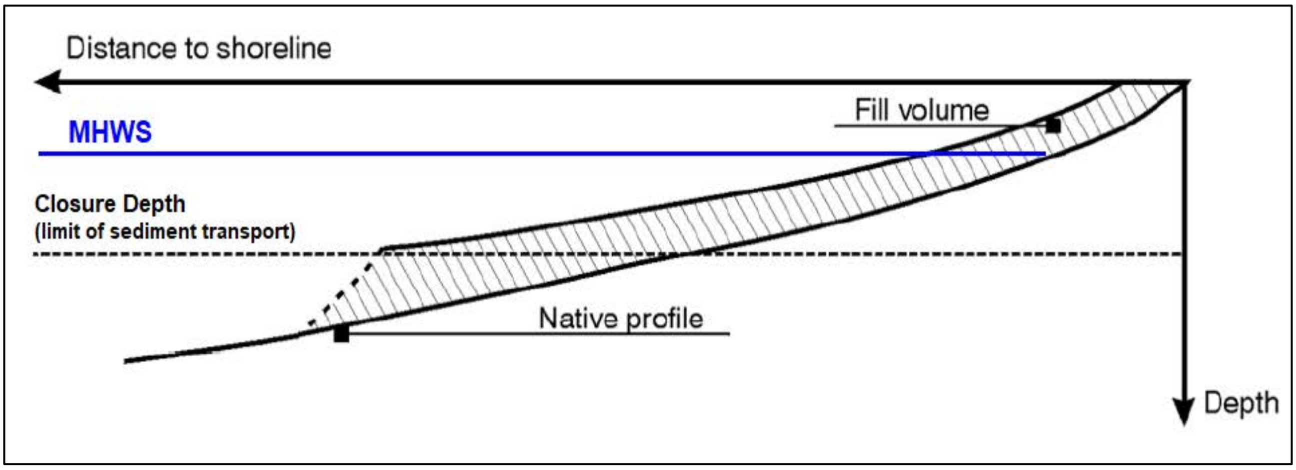


Figure 9.9: Typical section of a re-nourished beach profile (USACE, 2006)

Initial Appraisal

It is important to recognise that beach nourishment does not eliminate the cause of erosion which will continue to occur along the nourished beach section. This means that nourishment as a stand-alone method to mitigate coastal erosion requires commitment to a long-term maintenance effort. Alternatively, the success of a re-nourishment scheme could be enhanced with the construction of other sediment control structures such as a rock armour groyne,

The success of any nourishment scheme is dependent on the suitability of the nourishment material. The specification of the nourishment material such as the grain size is crucial in determining the overall shape of the coastal profile. In most instances, the volume of sand needed to re-nourish a profile increases drastically with decreasing grain size. In certain locations such as Bray in County Wicklow, sediment which is much coarser relative to native beach material can be used to minimise sediment losses and on-going maintenance requirements. The draw-back with this approach is that coarse gravel or shingle material can result in a very steep foreshore which can present difficulties regarding ingress and egress.

Despite several countries within Europe including the UK, Belgium and the Netherlands have long established practices of marine aggregate extractions for beach nourishment (amongst others), Ireland does not an established offshore dredging industry. As such, sourcing suitable material and obtaining the relevant permissions etc. could prove problematic and potentially costly.

Feasibility

Whilst establishing a beach nourishment scheme without an established sediment source could be difficult and costly, this option could maintain a useable beach foreshore which in turn could be used to support the local surfing industry at Strandhill. This option should therefore be considered further for Strandhill only.

9.1.4.7 A Sand Motor (i.e., mega nourishment)

Description

In 2011 the Dutch Government began a pilot project whereby a 1km by 2km wide hook-shaped peninsula was constructed using 21.5 million cubic metres of beach nourishment material at a cost *c.* 70 million euros (see Figure 9.10). This ongoing innovative pilot project known as the "Sand Motor" was developed to study the benefits of a mega nourishment as a more efficient, economical and environmentally friendly alternative to counteract the effects of coastal recession.

Figure 9.10: Aerial view of the Sand Motor at Ter Heijde, the Netherlands

Initial Appraisal

Early evaluations of the sand motor indicate that it has been relatively successfully achieving its main goals of increasing coastal safety, creating extra space for leisure and nature and contributing knowledge about coastal management.

Much of this success can be attributed to the fact that the 115km coastline in this region is relatively straight with very few breaks or structures to interrupt the flow of sediment. In contrast, the Irish coastline is characterised by embayments, rocky outcrops, headlands and other coastal features all of which have the potential to interrupt the longshore transport of sediment. These natural coastal features that often retain local sediment cells are also the main technical reason why a mega re-nourishment project similar to the sand motor would not work in this region.

Another important factor is that longshore sediment transport is one of the primary coastal processes along the Dutch shoreline. However, at Easkey and Strandhill it has been established that there is a significant cross-shore element to the sediment transport regime. Without any structures to control this aspect of sediment movement, large volumes of sand could be transported offshore and removed from the study coastlines.

Feasibility

A mega nourishment project similar to the sand motor is not considered a feasible solution due to the technical issues associated with this option.

This option should not be considered further for either Easkey or Strandhill.

9.1.4.8 Perched beach

Description

As illustrated in Figure 9.11 below, a perched beach is retained at an otherwise normal profile level by a submerged structure parallel to the coast. The submerged sill is usually constructed using rock armoured mound structures or commercially available pre-fabricated units.

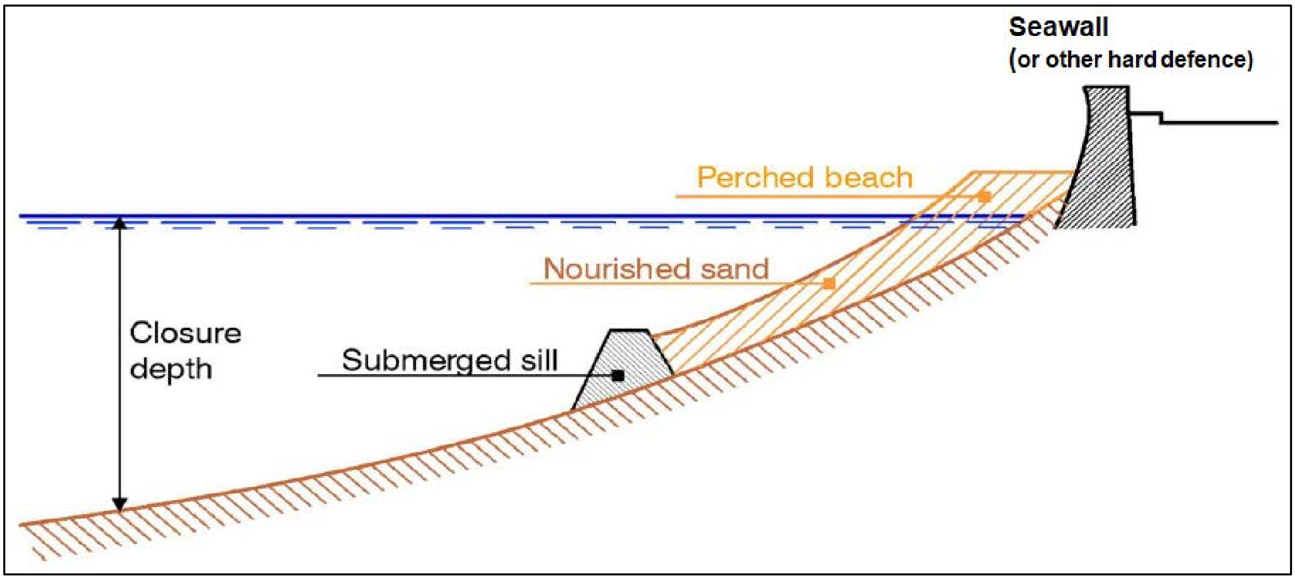


Figure 9.11: A typical section of a perched beach consisting of beach fill supported by a submerged sill (DHI, 2017).

Initial Appraisal

In principle, a perched beach is a simple concept in that the submerged sill structure prevents sand from moving offshore during active wave conditions. However, high waves combined with low tides can result in waves breaking over the sill. This can create strong undertow currents that lead to the permanent loss of sand material over the sill.

The concept of a perched beach is most applicable to coastal environments with steep and eroded coastal profiles. On the contrary, perched beaches are not well suited for coasts with oblique wave attack and at locations with large tidal regimes.

From a public safety perspective, strong undertow currents at the sill structure can present a significant non-visible hazard to bathers. In addition to this, stagnant water trapped on the lee side of the sill can result in poor water quality conditions during calm conditions.

Feasibility

Given that the Sligo Bay study areas experience relatively large tidal ranges (i.e., the difference between high and low tides) and are subjected to oblique wave attack (i.e., waves that approach from different angles), a perched beach solution is not considered a feasible solution.

This option should not be considered further for Easkey or Strandhill.

9.1.4.9 Dune stabilisation

Description

Dune stabilisation is a collection of *soft engineering* methods aimed at protecting, preserving and enhancing the natural protection afforded by a beach and its dune systems. These methods include the construction of sand trap fencing, planting of marram grass and re-grading steep dune faces as shown in Figure 9.12.

The effect of installing sand-trap fencing is to trap wind-blown sand and the build-up of dunes. Vulnerable fore dunes can also be protected by encouraging the seasonal development of embryo dunes using sand trap fencing. Although dunes will be eroded during winter conditions a useful measure of protection will nonetheless have been afforded to the fore dune and net losses will be reduced.

Figure 9.12: Sand trap fencing at a beach in Co. Clare

Where dune faces have become over-steepened through toe erosion or a continual lowering of beach levels it can be difficult to acquire and retain a reasonable vegetation cover. Steep dunes will be continuously vulnerable to undercutting by wave action; resulting in failure and slumping of the upper dune face as illustrated in Figure 9.13.

Re-profiling the dune to a more stable slope angle (usually around 1 in 2.5) will reduce the extent of damage caused if the toe of the dune is eroded by wave action. The success of dune re-profiling can be enhanced by the planting of marram, seeding, sand trap fencing or preferably a combination of all three.

The aim of adopting these dune stabilisation techniques is to build up the foredune overtime before an extreme event. The built-up foredune can then act as a reservoir to feed sand onto the beach during future extreme storm events. Where erosion is active, this buffer provides a short-term defence to assets behind the dunes, possibly only lasting through a single storm event.

In addition to encouraging the natural formation of embryo dunes and building up sand dunes, sand trap fencing also reduces pedestrian traffic through sand dunes which in turn reduces damage to the dunes and marram grass.

Figure 9.13: Over steepened dune faces along the Burrow, Portrane

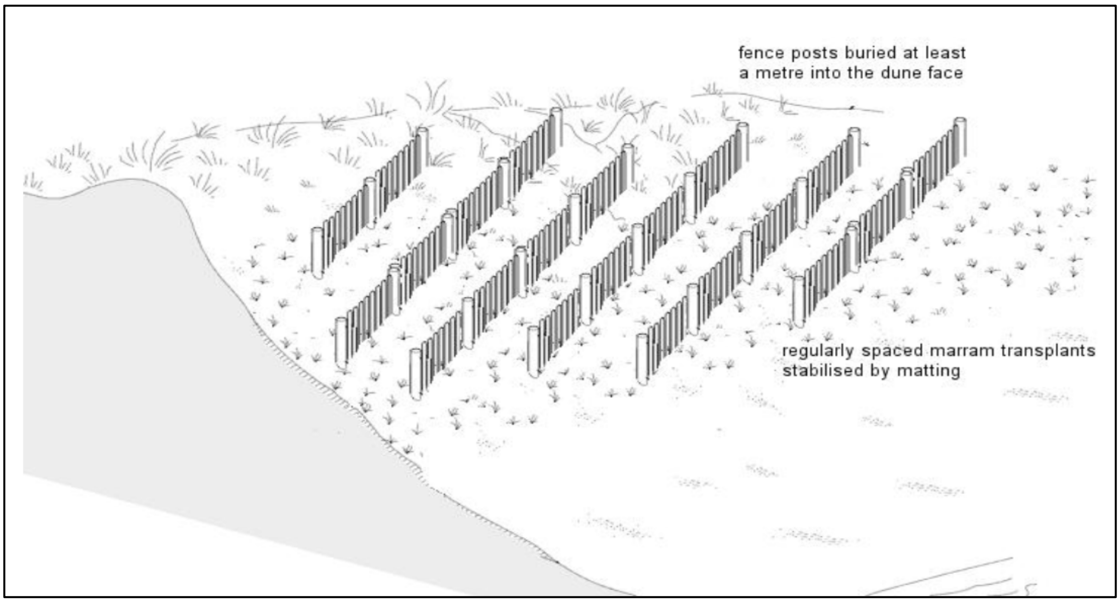


Figure 9.14: Typical section of a re-profiled dune face stabilised with sand trap fencing and the planting of marram grass

Initial Appraisal

Dune stabilisation is applicable in any location where natural dunes occur. This is particularly the case on moderately exposed to exposed sandy coasts with perpendicular or oblique wave and wind attack like at Strandhill.

The flexibility of dune systems makes them well suited to accommodate future sea-level rise. However, it is important to accept that some setback of the coastline will occur during extreme storm events and with future climate change. If such setbacks are considered unacceptable dune stabilisation can be supplemented with beach nourishment campaigns.

Feasibility

Whilst most soft engineering methods are considered sacrificial and will require a commitment to regular maintenance or replacement, particularly after extreme storm events, valuable protection will nevertheless have been provided by working with the natural environment to reduce the risk of coastal erosion and flooding

Soft engineering measures should be considered for Strandhill.

9.2 Outcome of the Preliminary Options Appraisal

RPS undertook a preliminary appraisal of the long list of CFERM options described in Section 9 based on several different criteria. These criteria considered the environmental, social and economic viability of each option at a high level. The outcome of this preliminary assessment and the management options for each study area that were brought forward to the Multi-Criteria Assessment (MCA) is summarised in Table 9.2 below.

Table 9.2: CFERM options shortlisted for further consideration across the Study areas

High Level Policy	CFERM option	Study Area			
		Easkey	North Strandhill	Strandhill town	South Strandhill
No Active Intervention	Do Nothing	✓	✓	✓	✓
	Shoreline Monitoring	✓	✓	x	✓
Managed Realignment		✓	✓	x	✓
Managed Retreat		x	✓	x	x
Hold The Line	Seawalls	x	x	✓	x
	Revetments	✓	✓	✓	✓
	Groynes	x	✓	x	✓
	Detached Breakwaters	x	x	x	x
	Embankments	x	x	x	x
	Beach Nourishment	x	✓	x	x
	Perched Beach	x	x	x	x
	Dune Stabilisation (soft engineering methods)	x	✓	x	✓

10 MULTI-CRITERIA ANALYSIS OF CFERM OPTIONS

10.1 Background

The CFERM options that progressed to this stage were considered relatively feasible (based on a high-level assessment and professional judgement). To appraise this list of options in greater detail, RPS undertook a Multi-Criteria Assessment (MCA) to objectively and systematically score each CFERM option.

The MCA is based on a numeric but non-monetarised assessment of options using a range of objectives. Indicators are used to assign scores for each objective based on how well each option meets the requirement for that objective. Weightings are applied globally for each objective, with local weightings applied to reflect the local importance of that objective. Scores for each option are then adjusted according to these weightings.

The sums of the weighted scores represent the preference for a given option. The total weighted scores can be used to inform the decision on the selection of preferred option(s) for a given location and the prioritisation of potential schemes between locations. However it is important to note that a favourable outcome from this process does not mean that a solution can be economically justified.

10.2 Criteria, Objectives and Weightings

Each option is assessed against four criteria: Technical, Economic, Social and Environmental. These criteria were developed by the OPW as part of the national Catchment-based Flood Risk Assessment and Management (CFRAM) Programme to help achieve cost-effective and sustainable management of existing and potential future flood and erosion risks.

A set of objectives are associated with each criterion and are an expansion on the requirements of the National Flood Policy Review and the EU Floods Directive. The degree to which an option achieves each objective is an indication of the success of the option; the more the option achieves across all the objectives, the greater preference it will be given.

Each objective focuses on a receptor type and how the risk is to be reduced except for the technical objectives which focus on how the options would be constructed and operated during their lifetime. In some cases, the receptor type is wide reaching, and sub-objectives are required to focus on a specific group within the receptor type. Table 10.1 overleaf describes the objectives and sub-objectives set for each of the criteria in the MCA.

The **Global Weightings** assigned to each objective in Table 10.1 reflect the importance of the objective in the context of the overall assessment of the suitability of the CFERM option. Global Weightings are fixed nationally to ensure a consistent approach and basis for prioritisation and are intended to represent the 'societal value' for the objective relative to the others, i.e., with those of most weight representing the most important objectives.

The **Local Weightings** assigned to each objective represent the local importance of that objective within the local context. They are very important as they provide scale to the process, whereby if the subject of a given objective is of much greater significance than another in the same location and should have a greater influence on the choice of option, then this can be provided for using appropriate Local Weightings.

Further information on the MCA process, global and local weightings as well as the scoring system can be found in the technical note "Option Appraisal and the Multi-Criteria Analysis (MCA) Framework" which was issued by the OPW in 2018.

All options with a positive MCA percentage score were carried forward to the final stage of the process - the identification of the preferred options.

Table 10.1: Coastal Flood and Erosion Risk Management objectives and global weightings

Criteria	Objective	Global Weighting
Technical Effectiveness	Ensure option is operationally robust	20
	Minimise health and safety risks associated with the construction and operation of CFERM option	20
	Ensure CFERM option is adaptable to future climate change	20
Economic	Minimise economic risk	27
	Minimise risk to transport infrastructure	10
	Minimise risk to utility infrastructure	14
Social	Minimise risk to health and life including properties	27
	Minimise risk to high vulnerability properties	17
	Minimise risk to social infrastructure and amenity. Amenities can include but may not be limited to beaches, coastal walks, public parks etc).	9
Environmental	Support the objectives of the Habitats and Birds Directives	10
	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	5
	Protect, and where possible enhance, landscape character and visual amenity within the zone of influence.	13
	Avoid damage to or loss of features, institutions and collections of cultural heritage importance and their setting, and improve their protection	4

Table 10.2: Multi-Criteria Analysis (MCA) of the Coastal Flooding and Erosion Risk Management options for Easkey

Criteria	Objective	Global Weight	Local Weighting	Do Nothing		Shoreline Monitoring		Managed Realignment		Revetments	
				Score	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*
Technical Effectiveness	Ensure option is operationally robust	**20**	**5**	-3	-300	1	100	-1	-100	4	400
	Minimise health and safety risks associated with the construction and operation of CFERM option	**20**	**5**	0	0	-1	-100	-3	-300	-3	-300
	Ensure CFERM option is adaptable to future climate change	**20**	**5**	5	500	5	500	1	100	3	300
Economic	Minimise economic risk	**27**	**5**	0	0	0	0	3	405	3	405
	Minimise risk to transport infrastructure	**10**	**2**	0	0	0	0	5	50	5	50
	Minimise risk to utility infrastructure	**14**	**0**	0	0	0	0	0	0	0	0
Social	Minimise risk to health and life including properties	**27**	**5**	0	0	0	0	3	405	3	405
	Minimise risk to high vulnerability properties	**17**	**0**	0	0	0	0	0	0	0	0
	Minimise risk to social infrastructure and amenity.	**9**	**0**	0	0	0	0	3	27	3	27
Environmental	Support the objectives of the Habitats and Birds Directives	**10**	**5**	0	0	0	0	0	0	0	0
	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	**5**	**1**	0	0	0	0	0	0	0	0
	Protect, and where possible enhance, landscape character and visual amenity within the zone of influence.	**13**	**4**	0	0	0	0	-1	-26	-1	-26
	Avoid damage to or loss of features, institutions and collections of cultural heritage importance and their setting, and improve their protection	**4**	**3**	0	0	0	0	0	0	1	8
					200		500		561		1269

Table 10.3: Multi-Criteria Analysis (MCA) of the Coastal Flooding and Erosion Risk Management options for North Strandhill, Pt1

Criteria	Objective	Global Weight	Local Weighting	Do Nothing		Shoreline Monitoring		Managed Realignment		Managed Retreat		Revetments		Groynes	
				Score	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*
Technical Effectiveness	Ensure option is operationally robust	**20**	**5**	-3	-300	1	100	-1	-100	-1	-100	3	300	1	100
	Minimise health and safety risks associated with the construction and operation of CFERM option	**20**	**5**	0	0	-1	-100	-3	-300	-3	-300	-3	-300	-3	-300
	Ensure CFERM option is adaptable to future climate change	**20**	**5**	5	500	5	500	1	100	1	100	2	200	2	200
Economic	Minimise economic risk	**27**	**5**	0	0	0	0	1	135	1	135	5	675	1	135
	Minimise risk to transport infrastructure	**10**	**2**	0	0	0	0	1	20	1	20	5	100	1	20
	Minimise risk to utility infrastructure	**14**	**2**	0	0	0	0	1	28	1	28	4	112	1	28
Social	Minimise risk to health and life including properties	**27**	**5**	0	0	0	0	0	0	0	0	4	540	1	135
	Minimise risk to high vulnerability properties	**17**	**1**	0	0	0	0	0	0	0	0	4	68	1	17
	Minimise risk to social infrastructure and amenity.	**9**	**2**	0	0	0	0	0	0	0	0	4	72	1	18
Environmental	Support the objectives of the Habitats and Birds Directives	**10**	**5**	0	0	0	0	1	50	1	50	-1	-50	0	0
	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	**5**	**1**	0	0	0	0	-1	-5	-1	-5	0	0	1	5
	Protect, and where possible enhance, landscape character and visual amenity within the zone of influence.	**13**	**5**	0	0	0	0	-1	-65	-1	-65	0	0	-3	-195
	Avoid damage to or loss of features, institutions and collections of cultural heritage importance and their setting, and improve their protection	**4**	**2**	0	0	0	0	0	0	0	0	5	40	0	0
					200		***500***		***-137***		***-137***		***1757***		***163***

Table 10.4: Multi-Criteria Analysis (MCA) of the Coastal Flooding and Erosion Risk Management options for North Strandhill, Pt2

Criteria	Objective	Global Weight	Local Weighting	Beach Nourishment		Groyne & Nourishment		Seawalls		Soft Engineering	
				Score	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*
Technical Effectiveness	Ensure option is operationally robust	**20**	**5**	-3	-300	-3	-300	3	300	-1	-100
	Minimise health and safety risks associated with the construction and operation of CFERM option	**20**	**5**	-3	-300	-3	-300	-3	-300	-3	-300
	Ensure CFERM option is adaptable to future climate change	**20**	**5**	1	100	1	100	1	100	4	400
Economic	Minimise economic risk	**27**	**5**	2	270	3	405	5	675	1	135
	Minimise risk to transport infrastructure	**10**	**2**	2	40	3	60	5	100	1	20
	Minimise risk to utility infrastructure	**14**	**2**	2	56	3	84	4	112	1	28
Social	Minimise risk to health and life including properties	**27**	**5**	2	270	3	405	4	540	1	135
	Minimise risk to high vulnerability properties	**17**	**1**	2	34	3	51	4	68	1	17
	Minimise risk to social infrastructure and amenity.	**9**	**2**	2	36	3	54	4	72	1	18
Environmental	Support the objectives of the Habitats and Birds Directives	**10**	**5**	1	50	1	50	-1	-50	1	50
	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	**5**	**1**	3	15	3	15	0	0	3	15
	Protect, and where possible enhance, landscape character and visual amenity within the zone of influence.	**13**	**5**	3	195	3	195	0	0	3	195
	Avoid damage to or loss of features, institutions and collections of cultural heritage importance and their setting, and improve their protection	**4**	**2**	0	0	0	0	5	40	0	0
					466		***819***		***1657***		***613***

Table 10.5: Multi-Criteria Analysis (MCA) of the Coastal Flooding and Erosion Risk Management options for South Strandhill

Criteria	Objective	Global Weight	Local Weighting	Do Nothing		Shoreline Monitoring		Revetments		Groynes		Soft Engineering	
				Score	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*	*Score*	*Weighted Score*
Technical Effectiveness	Ensure option is operationally robust	**20**	**5**	-3	-300	1	100	3	300	1	100	-1	-100
	Minimise health and safety risks associated with the construction and operation of CFERM option	**20**	**5**	0	0	-1	-100	-3	-300	-3	-300	-3	-300
	Ensure CFERM option is adaptable to future climate change	**20**	**5**	5	500	5	500	2	200	2	200	4	400
Economic	Minimise economic risk	**27**	**5**	0	0	0	0	0	0	0	0	0	0
	Minimise risk to transport infrastructure	**10**	**0**	0	0	0	0	0	0	0	0	0	0
	Minimise risk to utility infrastructure	**14**	**0**	0	0	0	0	0	0	0	0	0	0
Social	Minimise risk to health and life including properties	**27**	**5**	0	0	0	0	0	0	0	0	0	0
	Minimise risk to high vulnerability properties	**17**	**0**	0	0	0	0	0	0	0	0	0	0
	Minimise risk to social infrastructure and amenity.	**9**	**1**	0	0	0	0	1	9	1	9	1	9
Environmental	Support the objectives of the Habitats and Birds Directives	**10**	**5**	0	0	0	0	-1	-50	-1	-50	1	50
	Avoid damage to, and where possible enhance, the flora and fauna of the catchment	**5**	**1**	0	0	0	0	-2	-10	-2	-10	3	15
	Protect, and where possible enhance, landscape character and visual amenity within the zone of influence.	**13**	**5**	0	0	0	0	-3	-195	-3	-195	3	195
	Avoid damage to or loss of features, institutions and collections of cultural heritage importance and their setting, and improve their protection	**4**	**1**	0	0	0	0	0	0	0	0	0	0
					200		500		-46		-246		269

10.3 Development of MCA Options - Easkey

As summarised in Table 10.6 below, all options that passed the initial options appraisal scored positively in the MCA and were therefore considered potentially viable options that would likely result in various degrees of success in respect of managing coastal flooding and erosion risk at Easkey. However, it is important to note that the highest scoring option is not necessarily the best or preferred coastal management strategy. Instead, positive scoring options represent viable methods from which a sustainable solution be developed.

Table 10.6: Summary output of MCA process for Easkey

Option	Score
Revetments	1269
Managed Realignment	561
Shoreline Monitoring	500
No Active Intervention	200

A summary of the main factors that affected the MCA scoring of options for Easkey is presented in Table 10.7below. Using these CFERM options, RPS developed two management plans for Easkey as described overleaf.

Table 10.7: Summary of main factors that affected the MCA scoring of CFERM options for Easkey

Option	Advantage	Disadvantages
Revetments	• This option would effectively mitigate future coastal erosion. • This would safeguard a popular section of the Wild Atlantic Way which is an important regional economic driver.	• Potential to constrain the coastline's ability to respond naturally to a change in coastal processes because of coastal climate change. • Potential to impact the important surfing recreational amenity in this area. • Initial capital and future maintenance costs may be more expensive relative to other options.
Managed realignment	• This option would provide sufficient space to allow the coastline to respond naturally to a change in coastal processes. • This would safeguard a popular section of the Wild Atlantic Way which is an important regional economic driver. • Likely to be complimentary to maintaining the surfing recreational amenity • Significantly less maintenance costs relative to rock armour revetments	• A parcel of land would have to be "sacrificed" to facilitate the re-alignment of the Wild Atlantic Way. • Local landowners may be affected by this policy and should be suitably compensated in line with government policy. • This section of the Wild Atlantic Way would be set back from the coastline and may therefore impact the existing visual amenity associated with this road.
Shoreline Monitoring	• Information from a monitoring programme can be used to identify changes and trends in coastal processes. • This data can be used to assist timely and informed coastal management decisions.	• This option will not mitigate the risk of coastal erosion in this area or the subsequent economic impact associated with the potential loss or closure of this section of the Wild Atlantic Way.
No Active Intervention	• This option would maintain the integrity of existing coastal processes, habitats and visual amenities.	

10.3.1 Easkey CFERM Option 1 – Rock Revetment

The first option developed to mitigate the potential risk of erosion at Easkey would involve protecting *c.*1,650m of the coastline by constructing a rock armour revetment. The extent of this option in relation to the vulnerable section of the Wild Atlantic Way is illustrated in Figure 10.1 below.

It is well established that rock armour effectively dissipates wave energy and in turn mitigates the risk of coastal erosion. Whilst this option would provide effective protection to the Wild Atlantic Way, this area of the coast is recognised as being a popular location for local and travelling surfers. Installing >1.5km of rock armour could therefore present significant difficulties for surfers accessing the foreshore area and create a health and safety risk for surfers approaching an otherwise natural coastline.

Installing a hard defence on a coastline also has the potential to increase terminal erosion at adjacent soft coastlines that are not protected. In these areas, it is not uncommon for deflected wave energy to exacerbate coastal erosion. Whilst it is unlikely to be a significant issue at Easkey given the predominantly rocky nature of the foreshore, in other softer environments, rock armour can also contribute to the loss of the foreshore area, otherwise known as beach squeeze.

Fixing the position of the coastline by means of a hard engineered solution also constrains the ability of a coastline to naturally respond to increased coastal pressures and/or climate change. Thus, it is likely that rock armour installed now would need to be regularly maintained and even upgraded if predicted sea level rises increase wave energy at the foreshore.

In summary, a rock revetment solution is likely to effectively mitigate the risk of erosion at Easkey. However, this option has the potential to impact the existing surfing recreational amenity, accelerate erosion at adjacent coastlines that are not defended and require significant maintenance and upgrading in the future. Given the potential for change in coastal processes, this option has the potential to impact the natural environment.

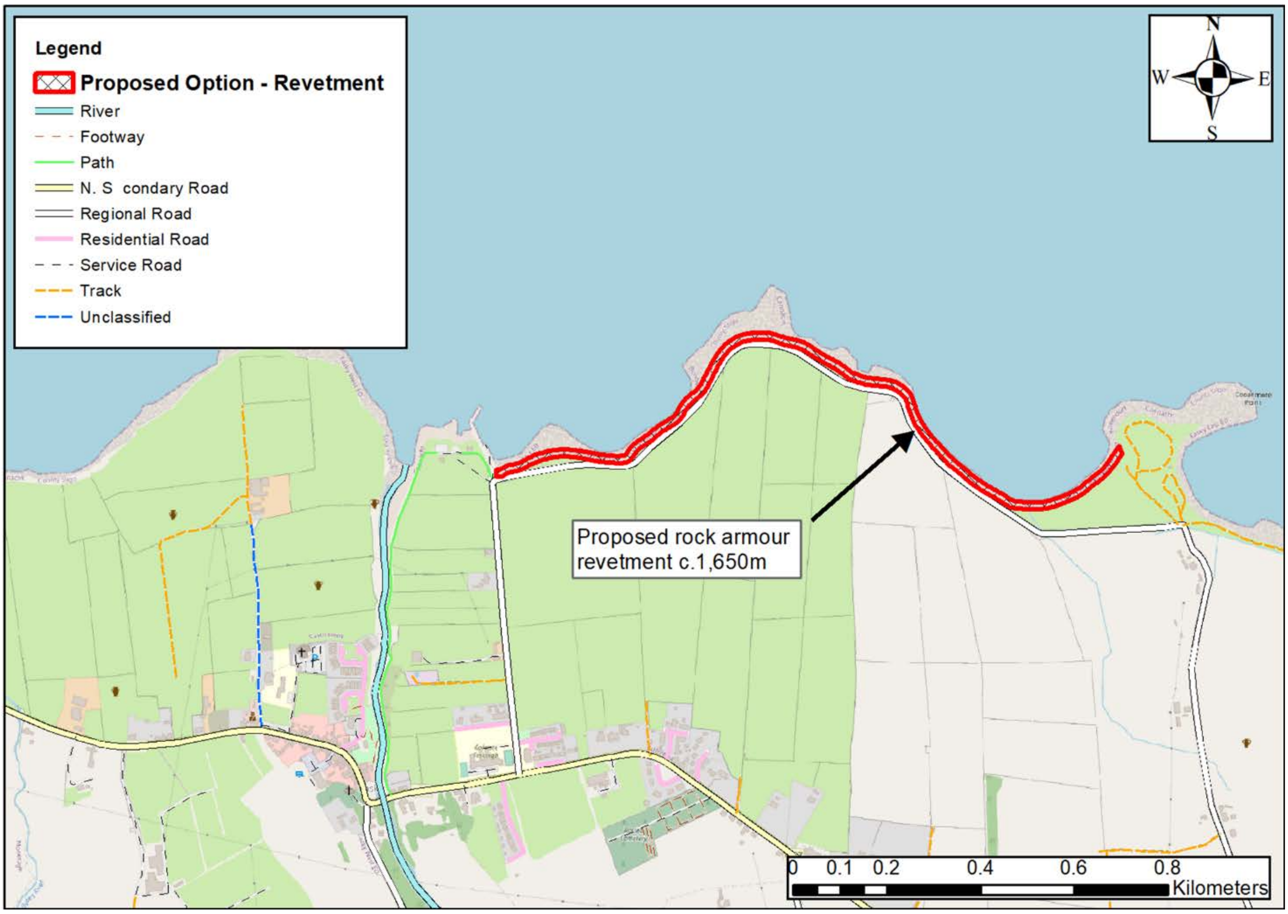


Figure 10.1: Location and extent of proposed CFERM option 1 at Easkey – a rock revetment solution

10.3.2 Easkey CFERM Option 2 – Road re-alignment

Given that the only risk identified at Easkey was the potential loss of a localised section of the Wild Atlantic Way, the second option developed for this area was the re-alignment of *c.*1,450m of the regional road which in some areas is located less than 5m from the existing coastline.

Based on this assessment, this option is considered to be the most sustainable given that it balances the social, economic and environmental considerations most effectively. Importantly, re-aligning this road by 40 - 50 m inland would in effect create a “sacrificial” parcel of land which would enable the coastline to respond naturally to any change in coastal processes and pressures as a result of climate change.

As well as maintaining an important section of the Wild Atlantic Way which is an important economic driver for the region, this option would have minimal impact on the surfing recreational amenity. Indeed, enabling the coastline to respond naturally to pressures has the potential to distribute soft till material eroded from the coast onto the foreshore area which could improve access and egress to the water.

Given that a road is not exposed to the same arduous wave energy as a rock armour revetment would be, maintenance associated with this option would be significantly less relative to Option 1. Maintenance of this asset would instead be primarily governed by traffic usage.

This option would affect approximately 6.55 hectares of privately owned land. It would therefore be imperative to liaise with relevant stakeholders to ensure affected landowners are adequately compensated in line with relevant guidance.

It should be noted that the location of the re-alignment as illustrated in Figure 10.2 is indicative only and that the actual location of the realigned road would be subject to detailed design, ground conditions and discussions with relevant stakeholder, primarily landowners who would be affected by this option.

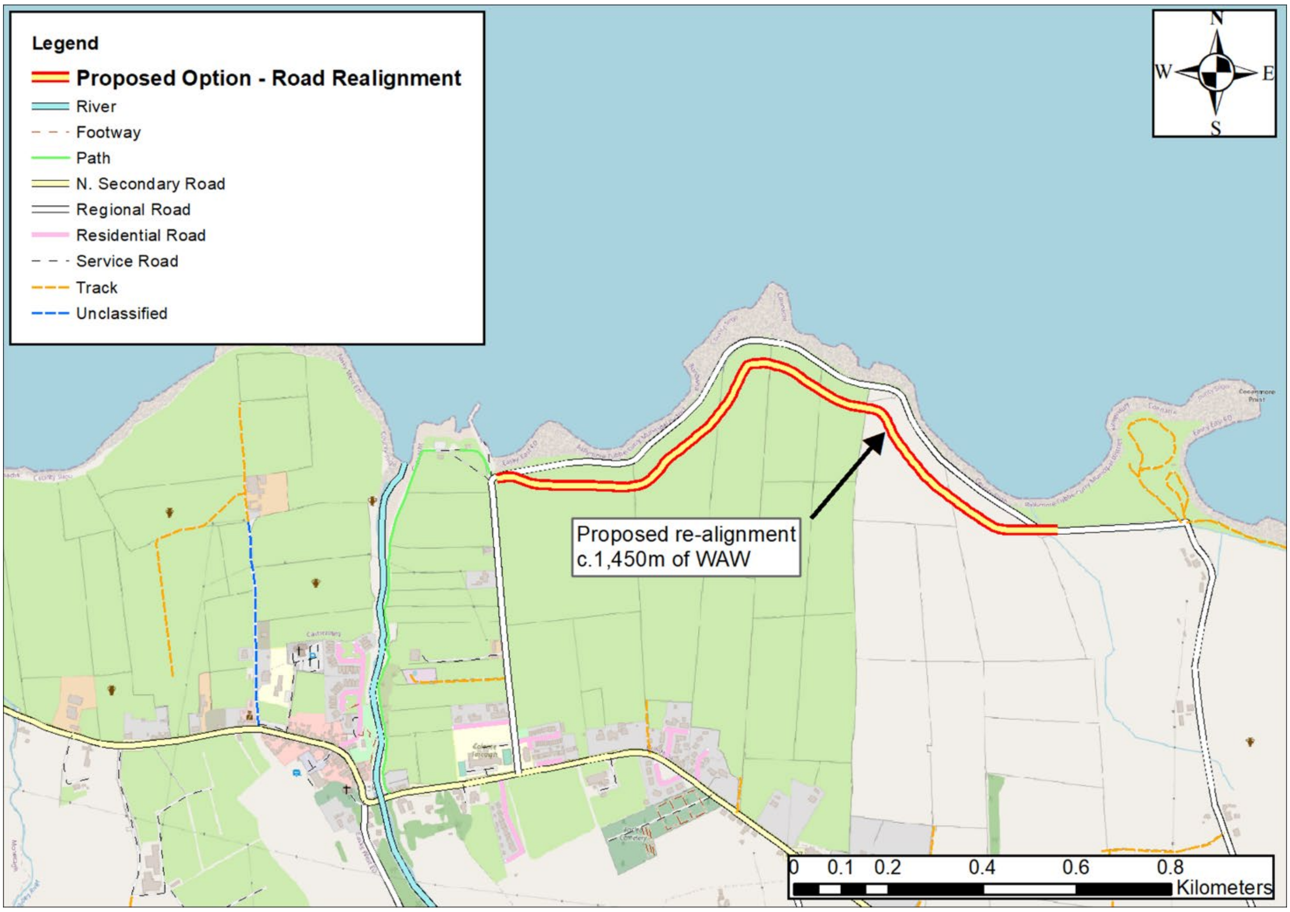


Figure 10.2: Location and extent of proposed CFERM option 2 at Easkey – road re-alignment solution

10.4 Development of MCA Options – North Strandhill and Strandhill Town

The output of the MCA for all options that passed the initial options appraisal for Strandhill is presented in Table 10.8 below. As before, the highest scoring option does not necessarily represent the best or preferred coastal management strategy. Instead, options that score more than zero represent options that should be considered future in the context of expert knowledge of the site.

Table 10.8: Summary output of MCA process for North Strandhill and Strandhill Town

Option	Score
Revetments	1757
Seawalls	1657
Groyne & Nourishment	819
Soft Engineering	613
Shoreline Monitoring	500
Beach Nourishment	466
No Active Intervention	200
Groynes	163
Managed Realignment	-137
Managed Retreat	-137

A summary of the main factors that affected the MCA scoring of options for this study area that scored more than zero is presented in Table 10.9 below. Using these CFERM options, RPS developed two management plans for this area as described in the following sections of this report.

Table 10.9: Summary of main factors that affected the MCA scoring of CFERM options for North Strandhill and Strandhill Town

Option	Advantage	Disadvantages
Revetments	• To the north, this option would effectively mitigate future coastal erosion. • This would prevent any further loss of land including at Strandhill Camping and Caravan Park and also the partial loss of Cummeen Strand/Drumcliff Bay (Sligo Bay) SAC • Rock armour could be installed to prevent the undermining of the existing seawall which protects the Kilasprugbone Graveyard • Repairing, maintaining or upgrading the rock armour at Strandhill town would continue to provide effective and essential protection to the town of Strandhill	• Potential to constrain the coastline's ability to respond naturally to a change in coastal processes because of coastal climate change. • Rock armour defences cut the natural exchange of sediment between and beach and dune system. Over time this results in beach drawdown and a narrowing of the foreshore, otherwise known as *beach squeeze.* • Extensive rock armouring can there eventually lead to the complete loss of beach as seen in Courtown, Co. Wexford. • Potential to impact the important surfing recreational amenity in this area. • Initial capital and future maintenance costs may be more expensive relative to other options.
Seawalls	• Seawalls scored highly owing to the crucial protection and thus economic benefit afforded to Strandhill town. This defence should be maintained as necessary.	• None at Strandhill town, as the existing rock armour revetment at Strandhill town mitigates the risk of wave reflection and drawdown at this asset.

Groynes & Beach nourishment	• A groyne structure along the north shore would reduce longshore sediment transport and in turn retain a storm beach. • The effectiveness of this option could be further enhanced by re-charging the currently depleted beach with suitable sand or gravel material. • This would provide a useable foreshore area for recreational purposes including surfing. • The retention of a storm beach would enhance the natural protection afforded to this coastline during storm events.	• Coastal processes along the northern section of Strandhill are complex and consist of both longshore and cross-shore transport mechanisms. • A storm beach could quickly be depleted by a single or a series of storm events which would leave an otherwise undefended coastline vulnerable to erosion. • Owing to a lack of an established marine aggregate industry in Ireland, it could prove difficult and costly to source and procure suitable material to recharge the foreshore.
Soft Engineering	• Soft engineering measures work with natural coastal processes to stabilise and enhance a natural dune system. These measures can also be used to facilitate the recovery of a dune following an arduous storm event. • In certain cases, soft engineering measures can enhance flora and fauna and are therefore often considered complimentary to environmentally designated areas or sensitive habitats.	• In high energy wave climates like that at Strandhill, soft engineering methods will not prevent coastal erosion. However, valuable protection may still have been afforded by these *“sacrificial”* measures.
Shoreline Monitoring	• Information from a monitoring programme can be used to identify changes and trends in coastal processes. • This data can be used to assist timely and informed coastal management decisions.	• This option will not mitigate the risk of coastal erosion in this area or the subsequent economic impact associated with the potential loss of important amenities such as surfing, camping and tourism.
Beach nourishment	• Beach nourishment can be used to restore depleted beach levels and in turn enhance the natural protection afforded to this coastline during storm events. • This would likely result in significant benefits to important amenities such as surfing, camping and tourism.	• Without sediment control structures such as groynes, beach nourishment could quickly be depleted by a single or a series of storm events which would leave an otherwise undefended coastline vulnerable to erosion. • Owing to a lack of an established marine aggregate industry in Ireland, it could prove difficult and costly to source and procure suitable material to recharge the foreshore.
No Active Intervention	• This option would maintain the integrity of existing coastal processes, habitats and visual amenities.	• This option will not mitigate the risk of coastal erosion in this area or the subsequent economic impact associated with the potential loss of important amenities such as surfing, camping and tourism.
Groynes	• A groyne structure along the north shore would reduce longshore sediment transport and in turn retain a storm beach. • This would assist in retaining a useable foreshore area for recreational purposes including surfing and also enhance the natural storm protection afforded by the beach.	• Coastal processes along the northern section of Strandhill are complex and consist of both longshore and cross-shore transport mechanisms. • A storm beach could quickly be depleted and leave an otherwise undefended coastline vulnerable to erosion.

10.4.1 North Strandhill and Strandhill Town CFERM Option 1 – Rock Revetment

North Strandhill and Strandhill town are at risk of coastal erosion and flooding respectively. Option 1 for Strandhill would involve protecting Kilaspugbone Graveyard by installing approximately 175m of rock armour revetment as illustrated in Figure 10.3. This rock armour would in effect provide toe protection which would prevent the existing seawall from being undermined by local wave action and mitigate the risk of erosion in this area. Given that the existing foreshore area is already comprised of coarse gravel material, installing rock armour in this location is highly unlikely to result be beach draw down from wave reflection.

In option 1, the unprotected section of the coastline between Strandhill town and the existing rock armour at the WWTP would be fully protected by installing *c.* 875m of rock armour as illustrated in Figure 10.3 and Figure 10.4. Whilst this rock armour would effectively mitigate the risk of coastal erosion in this area, it is possible that this defence would effectively cut the natural exchange of sediment between the dune system and the foreshore area. Over time, this could result in beach drawdown and a narrowing of the foreshore, otherwise known as "beach squeeze". This may have the potential to impact the local surfing amenity.

Given that the beach would effectively be cut off from the foreshore, it would be important to install a new ramp to provide access to the beach. This concrete ramp could be installed at the southern extent of the existing WWTP rock armour as illustrated in Figure 10.3.

At Strandhill town, it would be essential to immediately repair or replace the northern half of the existing rock armour (*c.*80m) given that this defence plays an important role in reducing wave overtopping and protecting the seawall which is imperative to Strandhill town.

Whilst the southern section of this defence is presently in good condition, this c.200m section of revetment would likely require either upgrading or replacing in the future. Whilst the deterioration of this defence would be gradual and subject to the frequency and magnitude of prevailing storm conditions, for the purposes of the economic assessment presented in Section 11, it has been assumed that this defence would be replaced / upgraded in during the medium term (i.e., *c.*30years).

The existing stormwater manhole would also be repaired and set back into the proposed rock armour.

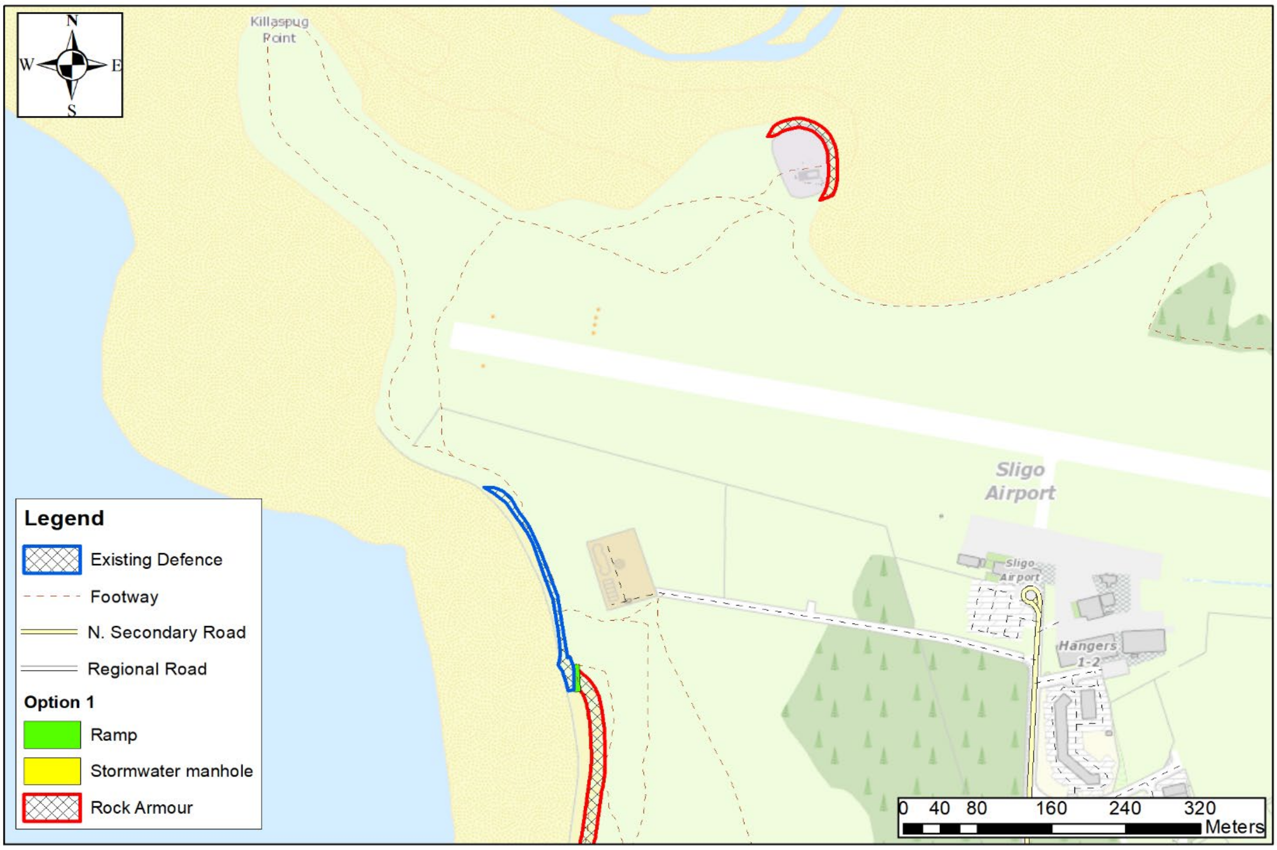


Figure 10.3: Location and extent of proposed CFERM option 1 at North Strandhill – a rock revetment solution

Figure 10.4: Location and extent of proposed CFERM option 1 at Strandhill town – a rock revetment solution

10.4.2 North Strandhill and Strandhill town CFERM Option 2 – Rock revetment and groyne

As illustrated in Figure 10.5 and Figure 10.6, option 2 would also involve protecting Kilaspugbone Graveyard by installing approximately 175m of rock armour revetment. This rock armour would in effect provide toe protection which would prevent the existing seawall from being undermined by local wave action and mitigate the risk of erosion in this area. Given that the existing foreshore area is already comprised of coarse gravel material, installing rock armour in this location is highly unlikely to result be beach draw down from wave reflection.

Unlike option 1, option 2 would involve only installing *c.*475m of rock armour between Strandhill town and the existing stormwater manhole. This would protect important protection to Strandhill Camping and Caravan Park and partially protect the Cummeen Strand/Drumcliff Bay (Sligo Bay) SAC. At the northern terminal of this new rock armour, a *c.*75m groyne would be installed. The purpose of this structure would be to partially interrupt the longshore transport of sediment along this section and thus encourage the retention of a storm beach along the remaining *c.*400m of coastline to the north.

The benefit of retaining a natural storm beach in this area would be twofold. Firstly, this storm beach would *reduce* coastal erosion of the foredune and secondly, provide surfers with a natural point of ingress and egress from the water. It should be noted that although the rate of erosion along this unprotected section of coastline would be reduced, natural erosion would still likely occur. However, this would partially maintain the exchange of sediment between the foredune and beach and thus the dynamics within the local sediment cell.

As described previously for option 1, this option would also involve the immediate repair or upgrading of c.80m of the existing rock revetment at Strandhill. The remaining *c.*200m section of revetment would require either upgrading or replacing in the future. Whilst the deterioration of this defence would be gradual and subject to the frequency and magnitude of prevailing storm conditions, it is likely action would be required in the medium term (i.e., *c.*30years).

The existing stormwater manhole would also be repaired and set back into the proposed rock armour. It is proposed that the groyne would be constructed immediately adjacent to this structure to provide additional protection during storm conditions.

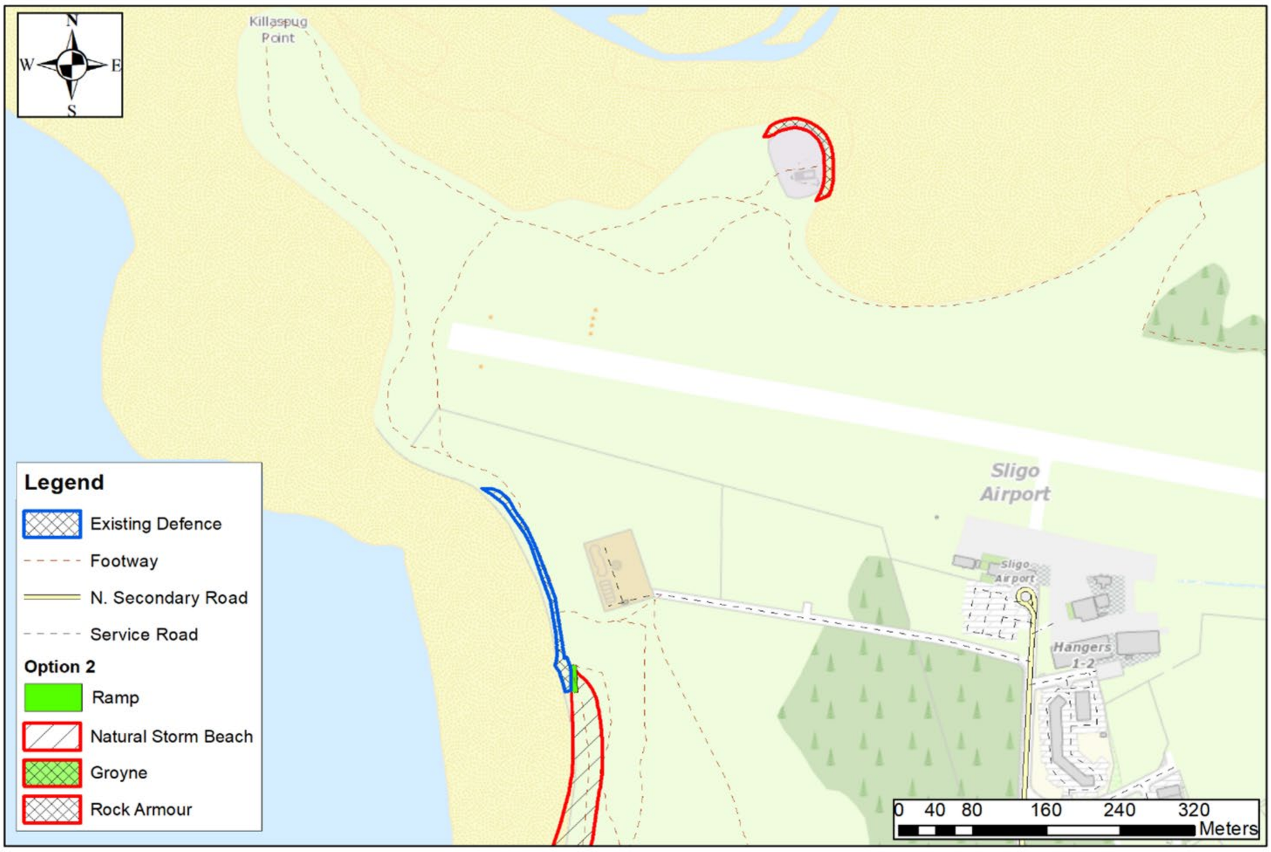


Figure 10.5: Location and extent of proposed CFERM option 2 at North Strandhill – a rock revetment and groyne solution

As with all options discussed in this study, it should be noted that the extent and location of the groyne proposed for option 2 and illustrated in Figure 10.6 is only indicative and would require further detailed design to ensure that the existing dangerous tidal currents are not exacerbated.

In summary, it is envisaged that option 2 provides the “best of both worlds” in that it provides critical protection to Strandhill Camping and Caravan Park, maintains and enhances a useable beach area for surfers and walkers alike whilst also minimising the potential impact to the Cummeen Strand/Drumcliff Bay (Sligo Bay) SAC by working with natural coastal processes. This option also addresses the potential flood risk to Strandhill town by recommending the replacement or upgrading of the existing rock armour which provides critical protection to Strandhill town. As illustrated in Figure 10.6, this option would also include the installation of a new ramp to provide access to the beach at the southern extent of the existing WWTP rock armour.

Figure 10.6: Location and extent of proposed CFERM option 2 at Strandhill town – a rock revetment and groyne solution

10.4.3 Consideration of alternative options

During the option development process, RPS also considered a third option for Strandhill which was a variation of Option 2 whereby the rock armour proposed between Strandhill town and stormwater manhole chamber was replaced by a series of groynes.

However, this alternative option was quickly ruled out given the proximity of high value assets near the coast that would still be at risk of erosion, even with groyne structures in place. These assets including the Strandhill Camping and Caravan Park and coastal path are key economic drivers for Strandhill and imperative to the tourism hub in the wider area.

As such, this alternative option was not considered further.

10.5 Development of MCA Options – South Strandhill

The output of the MCA for all options that passed the initial options appraisal for Strandhill is presented in Table 10.10 below. As before, the highest scoring option does not necessarily represent the best or preferred coastal management strategy. Instead, options that score more than zero represent options that should be considered future in the context of expert knowledge of the site.

Table 10.10: Summary output of MCA process for South Strandhill

Option	Score
Shoreline Monitoring	500
Soft Engineering	269
Do Nothing	200
Revetments	-46
Groynes	-246

A summary of the main factors that affected the MCA scoring of options for South Strandhill is presented in Table 10.11 below. The proposed management option for this area based on the output in Table 10.11 is presented in the following section of this report.

Table 10.11: Summary of main factors that affected the MCA scoring of CFERM options for South Strandhill

Option	Advantage	Disadvantages
Shoreline Monitoring	• Information from a monitoring programme can be used to identify changes and trends in coastal processes. • This data can be used to assist timely and informed coastal management decisions.	• This option will not completely mitigate the risk of coastal erosion in this area.
Soft Engineering	• Soft engineering measures work with natural coastal processes to stabilise and enhance a natural dune system. These measures can also be used to facilitate the recovery of a dune following an arduous storm event. • In certain cases, soft engineering measures can enhance flora and fauna and are therefore often considered complimentary to environmentally designated areas or sensitive habitats.	• In high energy wave climates like that at Strandhill, soft engineering methods will not prevent coastal erosion. However, valuable protection may still have been afforded by these *“sacrificial”* measures. • Soft engineering measures may have to be replaced following extreme storm events and can therefore often be short-lived.
No Active Intervention	• This option would maintain the integrity of existing coastal processes, habitats and visual amenities.	• This option will not mitigate the risk of coastal erosion in this area and may limit ingress and egress to the beach area following severe storm events.
Revetments or Groynes	• Implementing hard defences would fix the current position of the coastline.	• Hard defences can interrupt longshore drift, leading to beach starvation and increased rates of erosion • The unpredictable impact of hard defences on fore-dune habitats in this area is considered “Unfavourable-Inadequate“ in the Ballysadare Bay SAC (site code 622) Conservation objectives supporting document.

10.5.1 South Strandhill CFERM Option 1 – Soft Engineering

The dune system at Strandhill is subject to occasional severe weather and sea conditions. This can result in large, sudden erosion events which can result in localised damage to the foredune which in turn can impact ingress and egress to the beach (see Section 4.2). Historically, Sligo County Council has been very proactive in repairing this localised damaged by regrading beach levels and implementing soft engineering measures to restore this important local amenity.

Given that there are no built assets at risk of either coastal flooding or erosion in this area, and that the dunes form a well-developed system with considerable habitat diversity with seven Annex I sand dune habitats being listed in the Ballysadare Bay SAC (SAC 000622), RPS recommend that no additional hard defences are constructed in this area.

Instead, Option 1 for South Strandhill would involve protecting, preserving, and enhancing the natural protection afforded by a beach and its dune systems by implementing soft engineering methods along *c.*80m of the coastline as illustrated in Figure 10.8. This would include the construction of sand trap fencing; planting of marram grass and re-grading steep dune faces as summarised in Figure 10.7.

The aim of adopting these dune stabilisation techniques is to build up the foredune overtime before an extreme event. The built-up foredune can then act as a reservoir to feed sand onto the beach during future extreme storm events. Where erosion is active, this buffer provides a short-term defence to assets behind the dunes, possibly only lasting through a single storm event. As such, it may be necessary to replace or repair these soft engineering measures following arduous storm events, subject to magnitude of the storm and subsequent damage.

In addition to encouraging the natural formation of embryo dunes and building up sand dunes, sand trap fencing also reduces pedestrian traffic through sand dunes which in turn reduces damage to the dunes and marram grass.

RPS also recommend implementing a shoreline monitoring programme in this area. Information gathered from this programme could subsequently be used to identify changes and trends in coastal processes. This data could be used to inform any future change in coastal management strategies if coastal pressures changed significantly because of future climate change.

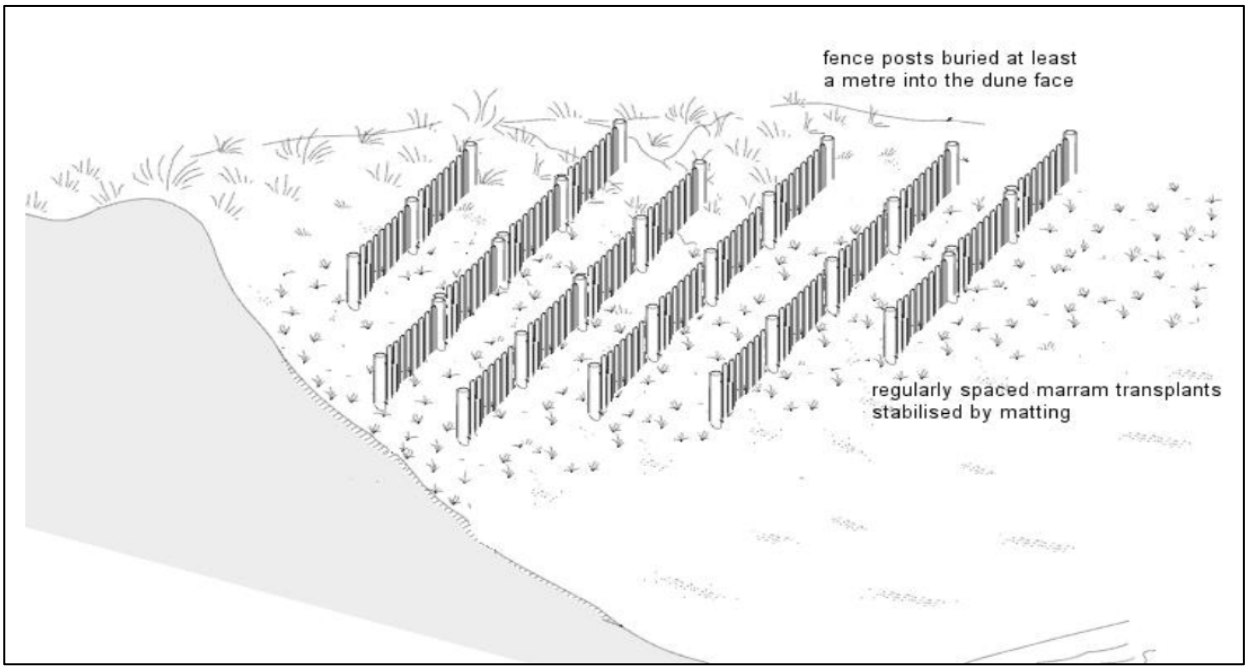


Figure 10.7: Typical section of a re-profiled dune face stabilised with sand trap fencing and the planting of marram grass

Figure 10.8: Location and extent of proposed CFERM option 1 at South Strandhill – soft engineering

11 ECONOMIC ASSESSMENT OF BENEFITS & COSTS

Economic appraisal is a technique used to aid and improve decisions in terms of flood and erosion risk management. The appraisal process involves quantifying, as far as possible, the benefits of avoiding damages/losses caused by flooding or erosion and comparing these benefits with the cost of a scheme.

The appraisal process, therefore, indicates if a scheme represents good value for money and if it can be justified from an economic perspective.

11.1 Flood Damage Assessment Guidelines

The damage assessment methodology for this study followed the guidance presented in "The Benefits of Flood and Coastal Defence: A Manual of Assessment Techniques" (Middlesex University, 2005). This document is often referred to as the Multi-Coloured Manual (MCM).

Depending on the assessment type, a range of different data can be used to quantify potential damages. If available, individual property information including property type and floor levels in combination with flood depths can be used to appraise damages. In the absence of detailed survey information, RPS have instead followed MCM guidance and assigned properties a direct damage of €34,000 when flooded, irrelevant of property type, flood depth or duration.

It will be seen from Table 11.1 that an average direct damage of €34,000 is proportionate to direct damages recommended by the MCM for flood levels similar to those experienced across Sligo Bay under various storm events. Furthermore, within the OPW's guidance for assessing benefits under the Minor Works Scheme, homes that have been flooded should be assigned a value of €30,000 – €39,000.

It is accepted that guidance issued to support Minor Work Scheme assessments should not generally be used for this type of assessment. However, given the lack of property-specific survey data, it is RPS' opinion, based upon professional experience of undertaking similar flood studies, that the direct damages used for this study are representative and fit for purpose.

Table 11.1: MCM Direct damage data for short duration major flood storms with no Warning (Sterling rates have been converted to Euro @ £1 = €1.15)

MCM code	Property Type	Flood depth in metres (m)					
		0.1	0.2	0.3	0.6	0.9	1.2
0	Residential Sector Average	13,195	22,266	27,175	33,554	36,562	40,395
11	Detached	17,871	30,818	38,290	46,485	51,325	56,797
12	Semi-detached	12,167	20,465	24,980	30,884	33,481	37,145
13	Terrace	11,079	18,824	22,849	28,375	30,680	33,887
14	Bungalow	18,531	29,814	35,962	44,126	48,820	54,388
	Average (€)	14,569	24,438	29,851	36,685	40,173	44,522

11.3 Damage to Properties Due to Flooding

To gain an appreciation of the potential economic impact of coastal flooding as described in previous Sections of this report, the associated flood damages were calculated. This involved assessing the likelihood of eachflood event occurring in any given year and applying this as a percentage to the damage; this is known as the Annual Average Damage (AAD). The AAD was then taken over the lifetime of the study (+100years) and discounted back to present-day costs; this is known as the present value damage (PVD).

The AAD can best be described by considering the graph shown in Figure 11.1 The points shown represent the various design flood events where the event damage is calculated. Their position on the graph is dictated by the damage caused and the frequency of the event occurring in any given year. These points are joined together to create a damage curve. The area under the curve is therefore a function of the damage and the frequency and gives the AAD.

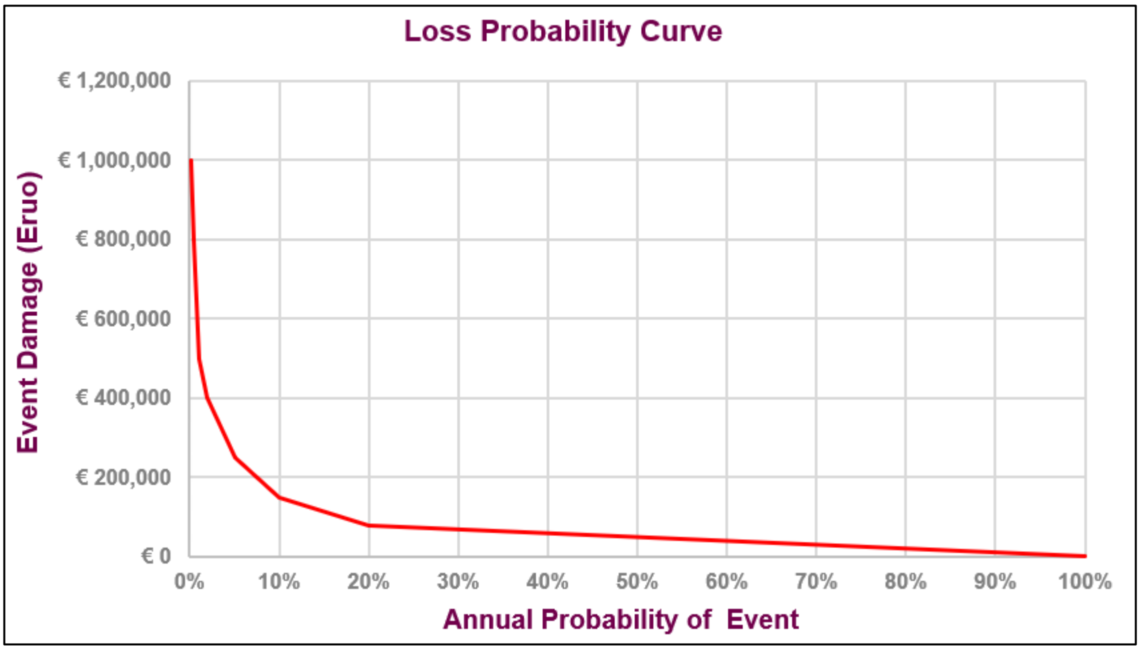


Figure 11.1: Example Loss Probability Curve

Once the AAD is calculated the present value damage can be determined. The present value damage calculation sums the AAD that is expected to occur for each year considered by the study. For the damage values in each year to be comparable with each other they are discounted to represent the equivalent present damage value.

Discounting damage values in the future is based on the principle that generally people prefer to receive goods or services now rather than later. This is known as time preference. The cost therefore of providing a flood management option will also be discounted to present-day values. A discount rate of 4% is considered, in accordance with OPW Cost Benefit Assessment (CBA) methodology.

11.3.1 Damage Assessment Data

Damage assessments are carried out to quantify the economic risk to the study area. These assessments often rely on a range of data including, but not limited to, categorisation of residential and non-residential properties, estimation of damage incurred to utilities and public infrastructure as well as finished floor levels of properties which in turn can be used to determine property threshold levels.

Using the direct damages value of €34,000 per property (see Section 11.1) in conjunction with the flood risk projections presented in Section 6, it was possible to calculate the Average Annual Damages for property and other assets at risk in Strandhill and Easkey using the equation presented in Table 11.2 whilst the damage curve for Strandhill is presented overleaf in Figure 11.2. These AADs were used in the economic assessment of potential CFERM options as described in the following sections of this report.

Table 11.2: Equation used to calculate the Average Annual Damage for Strandhill and Easkey.

Data type	Attribute name	Data details
Annual Average Damage for direct damages	AAD	The equation to calculate the AAD is as follows: (([Q2_EvDam]+[Q5_EvDam])/2*(0.5-0.2)+ ([Q5_EvDam]+[Q10_EvDam])/2*(0.2-0.1)+ ([Q10_EvDam]+[Q20_EvDam])/2*(0.1-0.05)+ ([Q20_EvDam]+[Q50_EvDam])/2*(0.05-0.02)+ ([Q50_EvDam]+[Q100_EvDam])/2*(0.02-0.01)+ ([Q100_EvDam]+[Q200_EvDam])/2*(0.01-0.005)+ ([Q200_EvDam]+[Q1000_EvDam])/2*(0.005-0.001))

Table 11.3: Calculated Average Annual Damages for Strandhill based on the current climate scenario.

Area	Climate Scenario	Average Annual Damages
Strandhill	Existing	€46,104
Easkey	Existing	No built assets at risk

11.3.2 Intangible Damages, Utility and Emergency Costs

Apart from the direct damages to buildings and the goods inside the property, it is recognised that there are monetary damages associated with clean-up costs, temporary accommodation, stress, etc. To account for this, it is OPW policy to assign intangible damages to all residential properties equal to the direct damages.

A cost will also be associated with emergency services dealing with flood events. Following the MCM guidance, the OPW have set the emergency costs at 8.1% of the principal direct damages and this has been adopted in this study.

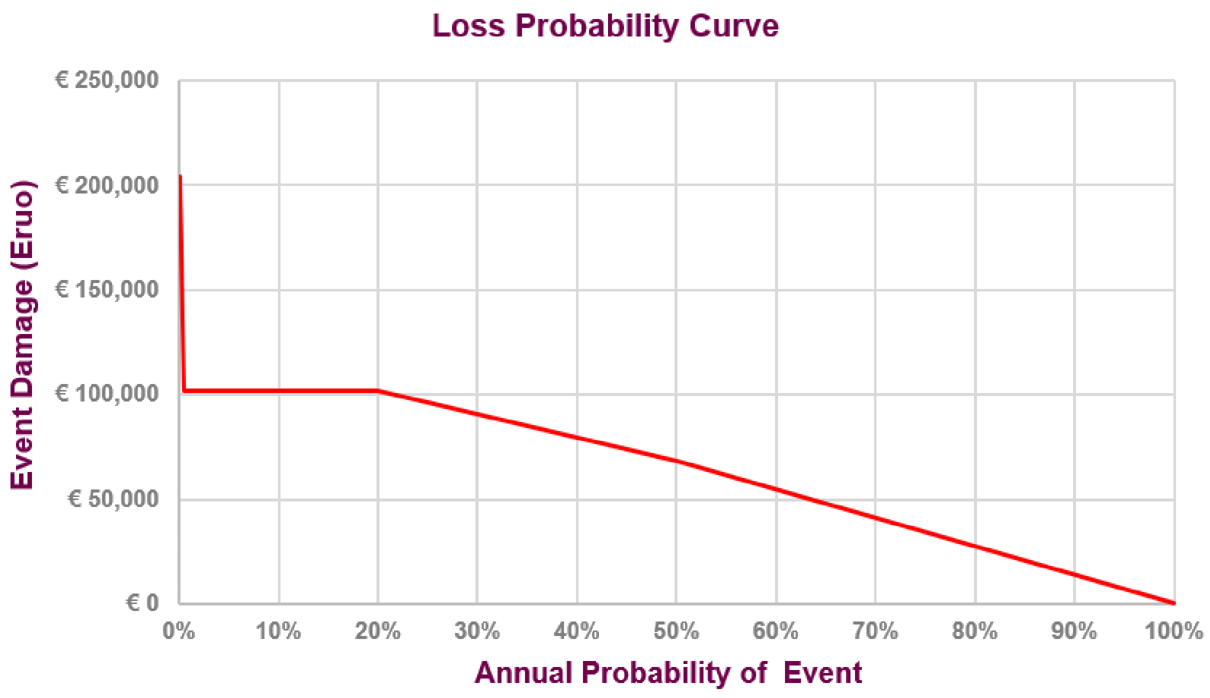


Figure 11.2: Average Annual Damages at Strandhill under existing climate scenario

11.4 Loss of Land Due to Erosion

At both Easkey and Strandhill, the coastline is expected to retreat over the next +100years as a result of ongoing erosion and climate change. Without intervention, this will result in the irreversible loss of land. To derive a valuation for land expected to be lost over the long term, RPS referred to the Annual SCSI/TEAGASC Agricultural Land Market and Review and & Outlook publication which provides values for residential and non-residential land sales and rental prices for all counties in Ireland.

Based on this information, the average value per acre of non-residential farmland in Sligo varies between €3,900 and €10,000 for poor and good quality land respectively. For the purposes of this assessment, RPS has therefore assumed an average cost of €6,950 per acre of land lost to coastal erosion.

11.5 Recreational Gains and Benefits

Both Strandhill and Easkey are recognised important economic drivers of the local and national economy. At Easkey, the small section of the Wild Atlantic Way identified as being at risk from coastal erosion attracts significant visitors on a daily basis.

Across the Bay, Strandhill is recognised for a wide variety of recreational usage and is described as "*the jewel of the Wild Atlantic Way's surf coast, an energetic village with bustling cafes and eateries, and new adventures around every corner*". The village has multiple hostels including the Ocean Wave Lodge, The Dunes Tavern and Surf'n'Stay Lodge and Hostel. There is also the Strandhill Lodge and Suites which was awarded the third best hotel in Ireland by Tripadvisor.

Furthermore, Strandhill is nationally recognised as a prime surfing location and recently received funding from Sligo County Council, Failte Ireland, and the Department of Rural Community and Development for a €2.7m National Surf Centre of Excellence. The new facility will be used by local, national and international surfers, and will cater for those providing advanced surfing training up to international standards - including video analysis equipment, training rooms and virtual surfing experience. It is envisaged that this facility will promote Sligo as a key tourism hub and provide a significant economic boost to the community of Strandhill and the Sligo region.

Thus, in addition to direct damages associated with flooding at Strandhill, coastal erosion and continual loss of sand from the beach would reduce the attractiveness of Strandhill, impact the surfing tourism asset and result in the partial loss of Strandhill Camping and Caravan Park. Collectively, these impacts are expected to result in a significant downturn in a downturn in recreational gains and benefits to Strandhill and the wider Sligo region.

At Easkey, given that much of the existing *c.*1.8km stretch of Wild Atlantic Way is less than 5m from the coastline, it is estimated that this section of road could be lost to erosion in the short term (i.e., within +10 years). This would be expected to result in an almost immediate and complete loss of recreational gain or benefit associated with this amenity.

The MCM recommends a methodology for evaluating the recreational losses and gains between the 'Do Nothing' scenario and a proposed option and determining the resultant benefit. Owing to the specialist nature of this work RPS engaged John Chatterton Associates (JCA) (a contributing author to the MCM guidance) to undertake this assessment. Whilst the full Recreational Benefits work undertaken by JCA is provided separate to this report, the following sections of this report summarise the main findings of the assessment.

11.5.1 Outline Methodology for evaluating Recreational benefits

The methodology used by JCA is derived from the Flood Hazard Research Centre's Multi-Coloured Handbook (Chapter 8), adapted as agreed with officers from Sligo County Council, RPS and the Office of Public Works.

In brief, the benefits of using a beach facility and its environs for recreation (or losses, if the beach is lost to coastal processes) are considered as the difference between the Value of Enjoyment (VoE) derived from the current asset (i.e., beach/shoreline) and the VoE of visiting an equivalent beach (or enjoying an alternative activity).

Those enjoying the beach and its facilities (unless permanent nearby residents) must travel to enjoy the beach, thus, an additional benefit from maintaining the asset (or losses, if the beach is lost to coastal processes, under the Do-Nothing scenario) relates to the difference in cost of travel between a home base and the beach and the cost of visiting an alternative site. It is noted that both VoE and costs maybe negative.

The following formula summarises the above:

$$L = (Eo - Ea) + (Ca - Co)$$

Where:

L is the benefit per person

Eo is the VoE of a visit to the site now (before erosion)

Ea is VoE of a visit to an alternative equivalent site after loss

Ca is the cost incurred in visiting an alternative site after a loss

Co is the cost incurred in visiting the site now

These are recognised as legitimate National resource costs. However, in line with advice from the OPW in the preparation of similar studies, the benefits of foregone beach recreation are divided as:

- Losses to Strandhill and Easkey – the local economy (with alternative activities transferred within County Sligo)
- Losses to County Sligo (with alternative activities transferred outside the county)
- Losses to the Republic of Ireland (with alternative activities abroad or in Northern Ireland)

National losses refer to scenario 3; County Sligo losses refer to scenario 2 and local losses refer to scenario 1.

To inform this assessment and derive robust Value of Enjoyment figures, interview surveys were conducted with 3 distinct groups of visitors during the summer of 2022 with counts as summarised in Table 11.4

Table 11.4: Summary of VoE questionnaire responses at Strandhill and Easkey

Survey type	Strandhill	Easkey
	Responses	
Day Visitors	82	74
Staying visitors	71	60
Permanent Residents	87	63

11.5.2 Summary of VoE questionnaire results at Strandhill

Based on the 82 responses from day visitors at Strandhill, it was found that:

- Just over half of Day visitors visit Strandhill once per month or more frequently.
- Over 85% of Day visitors have visited Strandhill on multiple previous occasions with over 40% having visited more than 20 times.
- Around 70% of Day visitors visit as part of a group.
- Over 90% of Day visitors rate the beach =>9 out of 10.
- Approximately 70% of Day visitors come to Strandhill for beach activities and almost 90% for walking/cycling.
- Rosses Point would be the favourite alternative site for day visitors.
- Over two-thirds of Day Visitors would remain within Sligo County as an alternative outing with a further quarter choosing other mainly coastal Irish counties.
- 28% of day visitors came from within Sligo County but over 40% drove more than 1 hour to visit Strandhill.

Based on the 71 responses from staying visitors at Strandhill, it was found that:

- Almost two-thirds of staying visitors come to Strandhill less than once per year.
- Over two thirds of staying visitors have visited 5 times or less.

- Over 90% of Staying visitors visit in Groups.
- Almost 85% of staying visitors spend between 2 and 7 nights in Strandhill.
- Almost 90% of Staying visitors rate the beach as => 9 out of 10.
- Two thirds of staying visitors indicated that beach activities were the reason for visiting Strandhill whilst over 90% suggested walking and cycling with over three quarters indicating hotel-based activities were also important.
- Only 40% of staying visitors would stay on vacation in Sligo if Strandhill facilities were compromised by erosion with a further almost 50% staying within the Republic of Ireland.
- Three quarters of Staying visitors were from the island of Ireland with almost a quarter originating from overseas.

Based on the 87 responses from permanent residents at Strandhill, it was found that:

- Almost three quarters of Permanent residents visit the beach daily.
- Almost all Permanent residents engage in walking/cycling or social activities.
- Around 60% of Permanent Residents stay on the beach for less than one hour.
- Around 95% of permanent residents feel that coastal erosion is a risk at Strandhill.
- Almost 80% of permanent residents rate the beach as =>9 out of 10

11.5.3 Summary of VoE questionnaire results at Easkey

Based on the 74 responses from day visitors at Easkey, it was found that:

- 50% of coast road users visit less than once per year.
- Almost a quarter of day visitors have used the coast road more than 20 times with over half visiting up to 20 times.
- Some 70% of day visitors travel the coast road in Groups.
- Over 85% of day visitors think the coast road is rated at 9 or10 out of 10.
- Over 50% of Day visitors would still visit the Easkey area if the coast road was not available.
- Two thirds of day visitors indicated that walking/cycling were the main reasons for visiting Easkey/coast road with only around 10% citing hotel and facilities
- Enniscrone was the single most favourable alternative location.
- Almost 50% of day visitors suggested they would travel more than an hour from their home location to the Easkey area.
- Over half of day visitors were undecided as to where to take an alternative visit but over a quarter citing staying within Sligo.

Based on the 60 responses from day visitors at Easkey it was found that:

- Some 60% of staying visitors had previously visited Easkey between 5 and 20 times.
- 90% of Staying visitors come in groups.
- Three quarters of staying visitors spend between 2 and 7 nights away.
- Over 85% rated the coast road as 10 out of 10.
- Beach based activities were mentioned as the main attraction for staying visitors.
- Almost two thirds of staying visitors were unsure about alternative locations though only 2 interviewees said they would go away from Ireland.
- Over 70% of staying visitors came from the island of Ireland with around a quarter coming from abroad.

Based on the 63 responses from permanent residents at Easkey, it was found that:

- 95% of permanent residents visit either daily or at least once or twice a week.

- Nearly two thirds of permanent visitors visit for walking/cycling.
- Just less than 60% of permanent residents spend less than an hour on the coast.
- Almost 97% of permanent residents felt that coastal erosion is a significant risk.
- Over 90% of permanent residents rated the coast road as =>9 out of 10.

11.5.4 Quantifying Do Nothing Losses

For Day visitors the questionnaire was designed to quantify their willingness to pay for a visit to either Strandhill or Easkey against the willingness to pay for a visit to an alternative site providing the same level of enjoyment. The difference between these two monetary estimates is known as the Value of Enjoyment (VoE).

11.5.4.1 Day Visitors

Day visitors were asked how much they spent at either Strandhill or Easkey per visit, how often they visited and how much they would spend at an alternative site. A value was computed for the mean and the median value ascribed to the visit for each person or group interviewed as summarised in Table 11.5.

Table 11.5: Summary of Value of Enjoyment figures for Day Visitors at Strandhill and Easkey

Parameter	Strandhill	Easkey
Mean expected daily spend at primary study area	€35.00	€45.00
Mean expected daily spend at alternative	€79.00	€115.00
Median expected daily spend at primary study area	€27.50	€20.00
Median expected daily spend at alternative	€55.00	€50.00

Based on the information summarised in Table 11.5, the median ***extra*** value Day Visitors were willing to spend at Strandhill and Easkey equated to €27.50 and €30.00 respectively.

Estimates of difference in travel resource costs were not included in this analysis as apart from journeys by Strandhill day visitors, all distances and times are marginally shorter to selected alternative locations. Furthermore, as Strandhill/Easkey were destinations of choice it would be inappropriate to suggest adjusting the losses to account for improvements in travel distance and time.

11.5.4.2 Present Value of Average Annual Benefits at Strandhill

Staying visitors spend money at their accommodation and in nearby pubs, shops and restaurants. A very conservative estimate of €100 per staying group per day was used as an approximate marker of expenditure by JCA for this assessment.

If in extreme circumstances hotel and recreational facilities in Strandhill or Easkey/coast road were unavailable or increasingly more unattractive because of either coastal flooding or erosion, then alternatives might be chosen.

In this case, losses incurred would be threefold affecting:

1. The local economy i.e., Strandhill or Easkey
2. The Sligo County economy (visitors go to other Irish counties as alternative locations)
3. The National economy (visitors go abroad, including Northern Ireland as alternative locations).

Staying visitors will either stay in the hotels or B&B establishments or in the caravan park or surf school accommodations. JCA undertook a basic analysis of the number of visitors based on these types of accommodation in the absence of detailed statistics regarding visitor numbers for the study areas.

Strandhill has one 4-star hotel with 22 rooms and a second hotel with 11 bedrooms (along with an undetermined number of B&Bs etc.). Conservatively, JCA assumed 100%[1] occupancy in the main four summer months. Assuming an average occupancy of visitors per room per night, this equates to 66 visitors staying in hotels per night and a total of 7,920 hotel visitors during this 4 month summer period alone. JCA made a conservative assumption that this figure would be closer to 10,000 staying visitors once B&B stays were factored in.

In addition to hotel and B&B stays, communications with local business owners indicate that caravan parks accommodate a further *c.* 75,000 visitor nights per year.

In respect of revenue generated from local surf schools, communications with relevant businesses indicated that for 3-4 days per week, 20-40 surfers visit Strandhill to surf, check the surf or have coffee/snack or a short day trip/overnight trip. When there are no waves, poor weather or unsuitable conditions, there are a negligible number of surfers visiting Strandhill seafront. Conversely, there are 5 to 10 days over the summer when sunny weather or good surf conditions cause the number of visiting surfers to increase up to 100 per day.

Taking 3.5 days on average for 30 surfers per week for 52 weeks gives 5,460 surfers. This is higher than the 2,600 customers that the Sligo surf experience would expect to cater for. As such, JCA assumed that the minimum and a maximum number of surfers to Strandhill in a typical year would equate to 2,600 and 5,460 respectively, to give an average annual number of surfers of 4,060.

Based on the information presented above, JCA estimated the annual recreational benefits as described in Table 11.6.

Table 11.6: Summary of Present Value of Average Annual Benefits associated with various recreational activities at Strandhill

Receptor	Assumption	Present Value of Average Annual Benefits
Hotel and B&B visitors	(10,000 visitors per year) * (An average spends per **couple** of €100)	(10,000 / 2) * €100 **= €500,000**
Caravan Site Visitors	(75,000 visitor nights per year) * (Median value additional VoE Strandhill of €27.50)	75,000 * €27.50 **= €2,062,500**
Surfing revenue	(4,060 annual surfers) * (Median value additional VoE Strandhill of €27.50)	4,060 * €27.50 **= €111,650**

11.5.4.3 Present Value of Average Annual Benefits at Easkey

As with Strandhill, JCA was unable to procure visitor number data from which monetary losses could be estimated. However, Sligo County Council were able to supply robust traffic count data for the localised section of the Wild Atlantic Way at risk of coastal erosion.

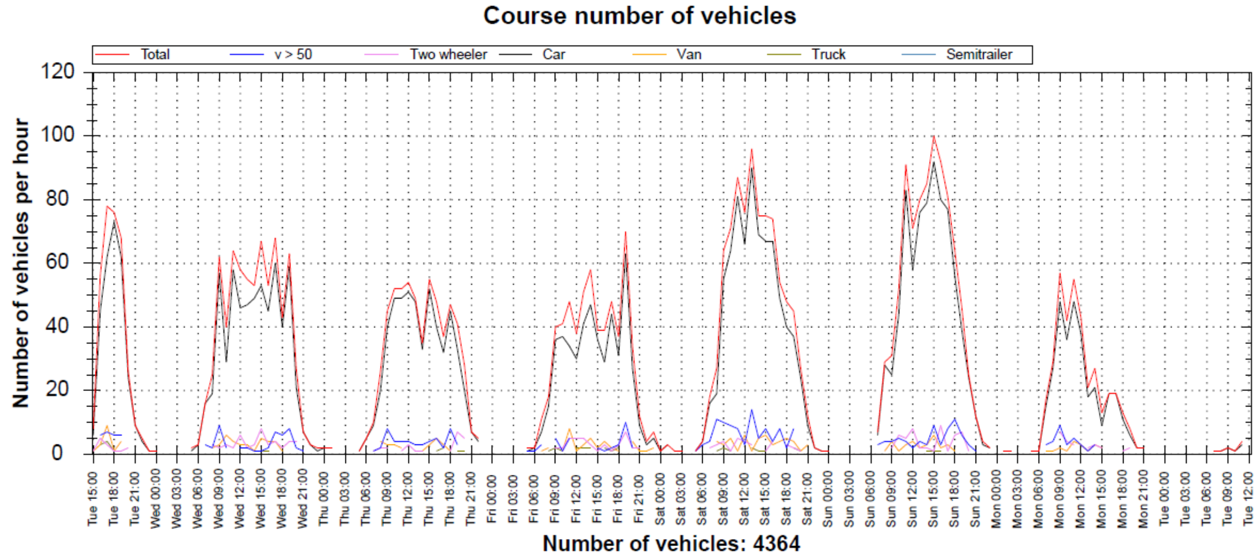
Based on two individual traffic surveys between September and November as illustrated in Figure 11.3 and Figure 11.4, the average daily number of cars using the coast road equated to 546 and 227 respectively, or an average of 386 per day based on all available data.

Applying the median value ***additional*** VoE for Easkey of €30.00 (see Section 11.5.4.1), it can be assumed that 386 daily cars would equate to a minimum value of enjoyment of €11,580 per day or *c.* €4.2mill per year.

Whilst not all cars using this route are likely to be tourists, given that there are only a few residential properties on this closed route, JCA concluded that most car users are likely to be tourists or people availing of recreational amenities on this route.

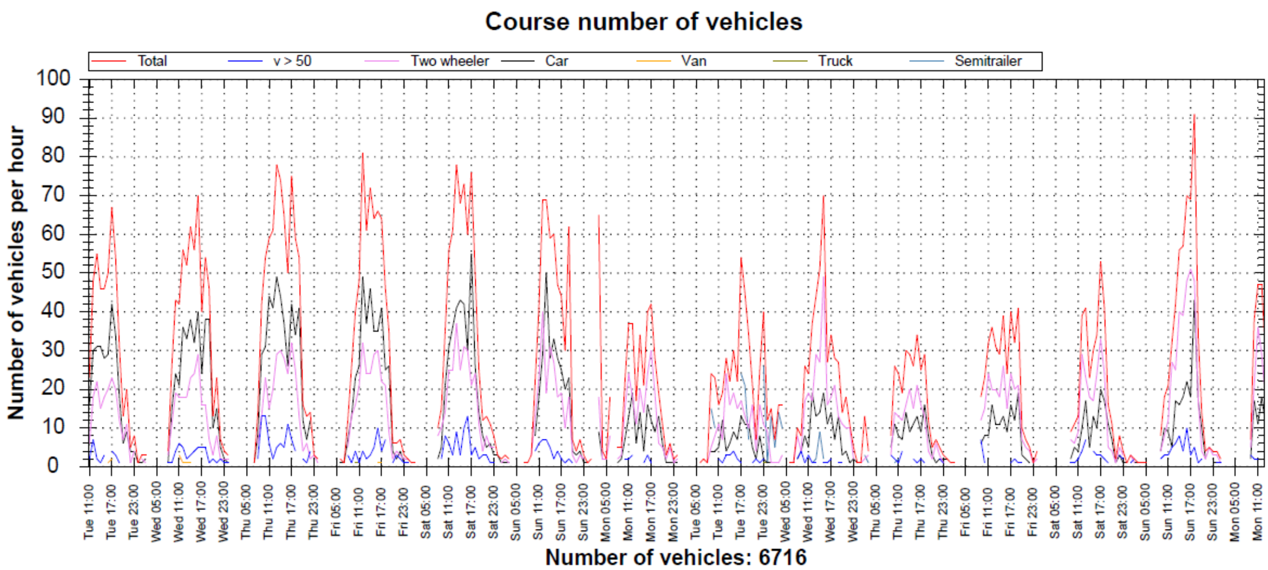
[1] Accommodation was fully occupied in August 2021 but this may have been skewed because of restrictions on foreign travel due to the COVID 19 pandemic

It is expected that virtually all of this **€4.2mill Average Annual Benefits (present value)** would be lost if this section of the Wild Atlantic Way was lost to coastal erosion.



Evaluation time	Tuesday 14 September 2021,14:50 till Tuesday 21 September 2021,12:17						
Speed limit	50	km/h		Number	Vd[km/h]	Vmax[km/h]	V85[km/h]
Speed violations:	8.59	%	**Two wheeler**	246	15.83	62	28
Average gap time:	136.40	s	**Car**	3826	38.80	76	48
Queue traffic:	4.38	%	**Van**	224	35.50	55	44
ADT (Av. daily traffic):	633		**Truck**	64	30.64	49	41
LGV traffic share:	1.60	%	**Semitrailer**	4	22.00	38	38
Measurement location: Easkey Coast Road			**Total**	4364	37.20	76	47

Figure 11.3: Summary of traffic count data on the WAW section at Easkey between 14th and 21st September 2021



Evaluation time	Tuesday 26 October 2021,10:41 till Monday 8 November 2021,12:33						
Speed limit	80	km/h		Number	Vd[km/h]	Vmax[km/h]	V85[km/h]
Speed violations:	7.71	%	**Two wheeler**	3234	35.90	70	47
Average gap time:	155.53	s	**Car**	3184	37.11	68	47
Queue traffic:	6.57	%	**Van**	42	29.98	53	38
ADT (Av. daily traffic):	514		**Truck**	39	28.51	42	38
LGV traffic share:	3.83	%	**Semitrailer**	217	31.24	50	39
Measurement location: Easkey Coast Road			**Total**	6716	36.24	70	47

Figure 11.4: Summary of traffic count data on the WAW section at Easkey between 26th Oct. and 08th Nov. 2021

11.6 Summary of Net Present Value of Scheme Benefits

The economic benefit derived from a CFERM option is the difference in present value losses before and after the measure is put in place. Therefore, to calculate the net present value of benefits, the scheme options should be compared with the "Do Nothing" scenario in terms of the amount of mitigation they provide. This includes mitigating "direct damages" from flooding and erosion as discussed in Sections 11.3 and 11.4 together with mitigating the loss of recreational benefits as described in Section 11.5.

Whilst the "direct damages" from flooding and erosion are relatively straightforward to quantify, it is more difficult to determine how the gradual impact of coastal erosion and/or flooding will impact recreational gains and benefits. In this respect, RPS used information gathered from the VoE questionnaire and liaised with JCA, Sligo County Council and other stakeholders regarding how the present value of recreational gains and benefits would likely be impacted over the long term. To this end, the following assumptions were made for the purposes of this assessment:

For Easkey

- At Easkey, given that much of the existing *c.*1.8km stretch of Wild Atlantic Way road is less than 5m from the coastline, it is estimated that this section of road could be lost to erosion in the short term (i.e., within +10 years).
- Therefore, in +10yrs the Average Annual Benefit (AAD) of €4.2mill (present value) would be lost. However, to take a very conservative approach, RPS assumed that the AAD was just €2.0mill.

For Strandhill

- Initially, coastal erosion or flooding is unlikely to impact visitors to Strandhill. However, the continued loss of the dune system and beach under a "Do Nothing" scenario would result in a gradual but significant loss of visitors to Strandhill.
- For the purposes of this assessment and based on the feedback from questionnaires, it has been assumed that staying visitors would gradually be reduced by 50% over the long term (i.e., +100years). As illustrated in Figure 11.5 , the present value of annual average benefits for the main receptors at Strandhill would therefore be impacted as follows:
    - The present value of annual average benefits for **Hotel and B&B visitors** would reduce from €500,000 to €250,000 in +100years.
    - The present value of annual average benefits **Caravan Site visitors** would reduce from €2,062,500 to €1,031,250 in +100years.
    - The present value of annual average benefits **Surfing Revenue** would reduce from €111,650 to €55,825 in +100years.

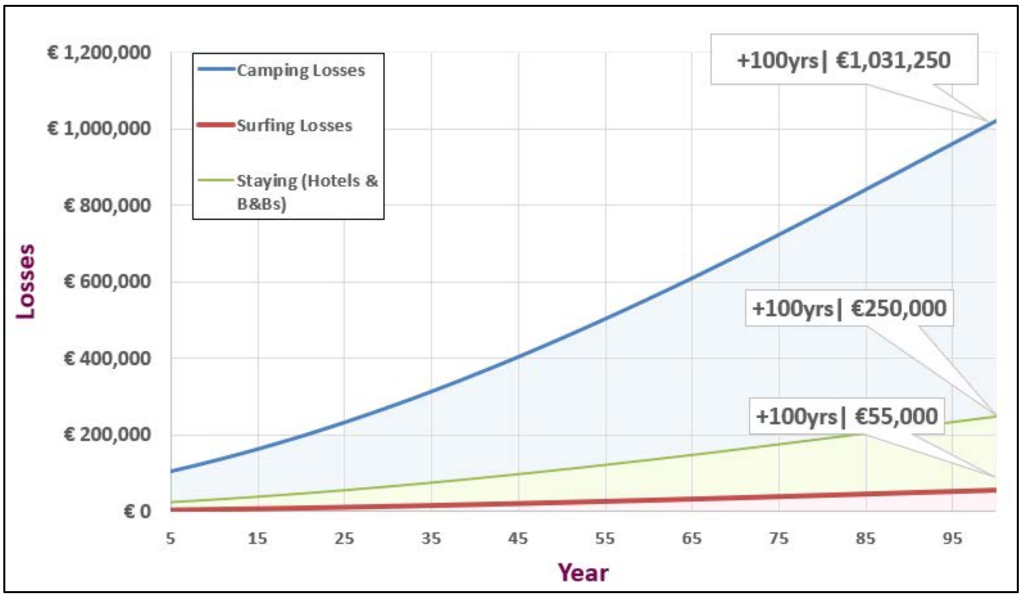


Figure 11.5: Summary of gradual loss of main recreational gains and benefits at Strandhill over +100years as a result of future coastal erosion

For each economic assessment, the damages incurred each year were discounted back to present day costs, to obtain a present value damage (PVd). For the purposes of this type of analysis, OPW guidelines specify a Discount Rate of 4% for use in determining the present value of the benefit.

The total present value of benefits of an effective coastal scheme with a design life of +100 years which effectively mitigates losses incurred from direct flood or erosion damages and losses to existing recreational gains and benefits is presented in Table 11.7 below.

Table 11.7: A summary of the Total PV benefits (i.e., potential damages/losses avoided) for coastal schemes at Easkey and Strandhill

Area	Climate Scenario	Total PV benefits based on a 100 scheme life
Easkey	Existing	€40,109,054
Strandhill	Existing	€11,394,545

11.7 Option Costing for Easkey

11.7.1 Option 1 – Rock Armour

Option 1 for Easkey involves protecting *c.* 1650m of the coastline by installing an appropriately designed rock armour revetment. Whilst a rock armour revetment for Easkey would be significantly less substantial than that required for Strandhill owing to the lower crest level and overall volume of rock required per linear metre, RPS took a conservative approach and utilised unit cost of €6,200 per linear metre given that these costs were developed based on current knowledge of experienced Irish contractors.

The total capital cost associated with this option therefore equated to €10,230,000 ex.VAT which in accordance with MCM guidance and recommendations from the OPW, included for a 40% adjustment to account for optimism bias.

Once discounted, the total Present Value cost associated with the initial construction and maintenance of Option 1 for Easkey as described in Section 10.3.1 equates to €11,676,268 euro ex. VAT (subject to further detailed design and other market pressures including but not limited to inflation).

11.7.2 Option 2 –Road Realignment

Option 2 for Easkey involves re-aligning approximately *c.* 1450m of the Wild Atlantic Way landward by *c.*40 - 50m. Using costs that were recently developed by RPS for a similar road re-alignment scheme at Liscannor and adjusted for inflation, it is expected that the cost of re-aligning this section of road would equate to *c.* €1.9mill euro ex.VAT.

Given that *c*. 6.5ha of privately owned land would effectively be "sacrificed" to facilitate the future response of the coastline to climate change, affected landowners would have to be compensated for this loss. This could be achieved by means of a Compulsory Purchase Order. Based on a current land valuation of €123,548 per hectare ex.VAT, this could cost approximately €809,239 euro ex.VAT.

Once discounted, the total Present Value cost associated with the initial construction and maintenance of Option 1 for Easkey as described in Section 10.3.2 equates to €2,848,948 euro ex. VAT (subject to further detailed design, consultation with affected landowners and other market pressures including but not limited to inflation).

11.8 Option Costing for Strandhill

11.8.1 Option 1 - Complete Rock Armour Solution

The costs for Option 1 which includes a complete rock armour solution for North Strandhill and Strandhill town are summarised in Table 11.8. These costs have been based on discussions with experienced contractors with knowledge of the Irish market (as of July 2022) and a review of available cost data from previous coastal revetment schemes in this area.

In accordance with MCM guidance and recommendations from the OPW, option costs include an adjustment of 40% to account for optimism bias.

Assuming maintenance costs equivalent to *c.* 10% of initial capital costs every 15 years, the total non-discounted cost of maintenance is expected to equate to *c.*€4.5mill euros. However, when this value is adjusted by 4% over the +100year design life of a scheme, this is reduced to a present value cost of *c.* €1mill euros. In addition, it is envisaged that the remaining 130m section of the revetment at Strandhill town will require upgrading in the medium term (+30yrs). This would equate to a present day cost of €806,000 euro ex. VAT.

In summary, the total Present Value cost associated with the initial construction and maintenance of Option 1 for Strandhill as described in Section 10.4.1 equates to €7,798,138 euro ex. VAT (subject to further detailed design and other market pressures including but not limited to inflation).

Table 11.8: Initial capital costs (inclusive of design & contingencies) associated with Option 1 for Strandhill

Element	Cost per unit	Unit/Length	Total Cost (€)
Rock Armour	€6,200	875m	5,425,000
Ramp Access	€50,000	1	50,000
Reinstate WWTP Manhole	€75,000	1	75,000
Immediate Repair of Rock Armour	€6,200	80m	496,000
Graveyard Rock Armour	€4,000	175m	700,000
		Initial Capital Cost (€)	**6,746,000**

11.8.2 Option 2 - Rock revetment and groyne

The costs for Option 2 which includes a rock armour and groyne solution for North Strandhill and Strandhill town are summarised in Table 11.9. These costs have been based on discussions with experienced contractors with knowledge of the Irish market (as of July 2022) and a review of available cost data from previous coastal revetment schemes in this area.

In accordance with MCM guidance and recommendations from the OPW, option costs include an adjustment of 40% to account for optimism bias.

Assuming maintenance costs equivalent to *c.* 10% of initial capital costs every 15 years, the total non-discounted cost of maintenance is expected to equate to *c.*€3.0mill euros. However, when this value is adjusted by 4% over the +100year design life of a scheme, this is reduced to a present value cost of *c.* €0.75mill euros. In addition, it is envisaged that the remaining 130m section of the revetment at Strandhill town will require upgrading in the medium term (+30yrs). This would equate to a present day cost of €806,000 euro ex. VAT.

In summary, the total Present Value cost associated with the initial construction and maintenance of Option 2 for Strandhill as described in Section 10.4.2 equates to €5,653,272 euro ex. VAT (subject to further detailed design and other market pressures including but not limited to inflation).

Table 11.9: Initial capital costs (inclusive of design & contingencies) associated with Option 2 for Strandhill

Element	Cost per unit	Unit/Length	Total Cost (€)
Rock Armour	€6,200	475m	2,945,000
Groyne	€6,200	75m	465,000
Ramp Access	€50,000	1	50,000
Reinstate WWTP Manhole	€75,000	1	75,000
Immediate Repair of Rock Armour	€6,200	80m	496,000
Graveyard Rock Armour	€4,000	175 m	700,000
		Initial Capital Cost (€)	**4,731,000**

11.9 Summary of Economic Appraisal

The Net Present Value (NPV) was calculated for both options at Easkey and Strandhill and is presented in the FCDPAG3 spreadsheets in Appendix D and summarised in Table 11.10 and Table 11.11 respectively.

Table 11.10: Summary of economic appraisal for Options 1 and 2 at Easkey

Costs and benefits of options	Do Nothing	Option 1 Rock Revetment	Option 2 Road Re-alignment
Total PV Cost of Option	-	€ 11,676,269	€ 2,848,949
Total PV Damages	€ 40,109,504	€ 40,109,055	€ 40,109,055
PV Benefits	-	€ 40,109,055	€ 40,109,055
Net Present Value	-	€ 28,432,786	€ 37,260,106
Benefit Cost Ratio (BCR)	**-**	**3.44**	**14.08**

Table 11.11: Summary of economic appraisal for Options 1 and 2 at Strandhill

Costs and benefits of options	Do Nothing	Option 1 Complete Rock Amour Revetment	Option 2 Rock Armour Revetment and Groyne
Total PV Cost of Option		€ 7,991,128	€ 5,653,273
Total PV Damages	€11,394,995	€ 11,394,546	€ 11,394,546
PV Benefits		€ 11,394,546	€ 11,394,546
Net Present Value		€ 3,403,418	€ 5,741,273
Benefit Cost Ratio (BCR)		**1.43**	**2.02**

This economic appraisal has therefore demonstrated the Benefit Cost Ratio is robustly greater than unity for both proposed coastal protection options at Easkey and Strandhill. At Easkey, it was Option 2 which involves re-aligning a section of the WAW that produced the best BCR of 14.08. At Strandhill, Option 2 which involves the construction of a new rock revetment and a groyne to encourage the natural retention of a storm beach scored best, producing a BCR of 2.02.

In both instances, these schemes score significantly more than the BCR of 1.0 – 1.5 as required by the OPW for funding under the Minor Flood Mitigation Works and Coastal Protection Scheme. Furthermore, these options are compatible with the desire of Sligo County Council, local businesses, local residents and visitors to maintain the unique tourist facility offered by Easkey and Strandhill for the foreseeable future.

11.9.1 Consideration of soft engineering at Strandhill south

As there are no built assets at risk and to mitigate potential impacts to the seven Annex I sand dune habitats listed in the Ballysadare Bay SAC (SAC 000622), RPS has recommended a policy of soft engineering for *c.*80m of the coastline immediately south of the existing hard defences. Given the difficulty in establishing any direct economic benefits of these works, RPS undertook a sensitivity test whereby the cost of this work was included in the economic appraisal for the Strandhill options discussed in previous Sections.

Based on recent estimations (2022), the costs of installing three rows of sand trap fencing in the area illustrated in Figure 10.8, with a total length of *c.* 250m of sand trap fencing would amount to approximately €12,000 ex. VAT. Other measures such as the transplanting of marram grass from healthy parts of the dune system to this area and re-grading the seaward face of the dune system would also be relatively inexpensive and quick operations. Given costs of labour and plant, it is expected re-grading the dune and transplanting marram in this area could cost up to €4,000 ex. VAT.

In total, the soft engineering works for this area are expected to cost €16,000 ex. VAT. Given the "sacrificial" nature of these defences, it may be necessary to replace these soft engineering measures following extreme or arduous winter periods.

Over a 100 year period, these soft engineering works would increase the present value costs of a scheme by *c.*€0.45mill euros. When considered in context of the economic assessment summarised in Table 11.11, it was found that these soft engineering measures reduced the BCR of option 1 from 1.43 to 1.35 and the BCR of Option 2 from 2.02 to 1.86. As such, it can be concluded that both options remain economically viable with the soft engineered options included.

12 COASTAL EROSION RISK MANAGEMENT PLANS

12.1 Preferred CFERM Option - Strandhill

The preferred option identified for Strandhill was Option 2. Whilst a full description of this scheme is provided in Section 10.4.2, the main features and supporting rationale for this option are summarised in Table 12.1 below.

Table 12.1: Summary of key features of the preferred CFERM option for Strandhill

Feature	Rationale
Protecting Kilaspugbone Graveyard by installing approximately 175m of rock armour revetment.	This rock armour would prevent the existing seawall from being undermined and mitigate the risk of erosion in this area. The foreshore area in this area is comprised of coarse gravel material and therefore unlikely to be affected by beach drawdown.
Installing c.475m of rock armour between Strandhill town and the existing stormwater manhole.	This rock armour would provide important protection to Strandhill Camping and Caravan Park and partial protection to Cummeen Strand/Drumcliff Bay (Sligo Bay) SAC, thus protecting the economic benefits associated with both.
Constructing a c.75m groyne to encourage the retention of a storm beach along the remaining c.400m of coastline.	This structure would encourage the retention of a storm beach along the remaining c.400m of coastline. This storm beach would reduce coastal erosion of the foredune and secondly, provide surfers with a natural point of ingress and egress from the water.
Repair of existing storm water manhole	This would ensure the ongoing operation of this structure
The immediate repair or upgrading of c.80m of the existing rock revetment at Strandhill.	This would consolidate the existing wave protection afforded to Strandhill town
Upgrading the remaining c.200m section of revetment in the medium term (i.e., c. 30 years).	

Whilst most recommendations summarised in Table 12.1 involves the construction or repair of hard defences over the short to medium term, it is envisaged that these measures would be maintained, repaired, and upgraded as necessary to ensure effective protection over the long term.

Based on discussions with experienced contractors with knowledge of the Irish market (as of July 2022) and a review of available cost data from previous coastal revetment schemes in this area, it is estimated that the present value cost of this scheme would equate to €5,653,272 euro ex. VAT (subject to further detailed design and other market pressures including but not limited to inflation). This includes initial construction and future maintenance costs (assuming maintenance costs equivalent to *c.* 10% of initial capital costs every 15 years). An economic appraisal for this scheme demonstrated a robust Benefit Cost Ratio of 2.02.

To the south of Strandhill town, a series of soft engineering measures have been proposed given the lack of risk to any built assets or infrastructure and the close proximity of the Ballysadare Bay SAC (SAC 000622). However, given the difficulty in establishing any direct economic benefits of these works, RPS included the cost of these measures in the main Strandhill scheme described above and found that this reduced the BCR from 2.02 to 1.86, thus indicating that this scheme remains economically viable.

In summary, the preferred option described above balances the interests of many stakeholders by providing partial coastal protection to key assets whilst maintaining a soft natural coastline to support various recreational amenities. This is imperative given that Strandhill is nationally recognised as a prime surfing location and recently received funding from Sligo County Council, Failte Ireland, and the Department of Rural Community and Development for a €2.7m National Surf Centre of Excellence.

In all, this option reflects the desire of Sligo County Council, local businesses, residents and visitors to maintain the unique tourist facility offered at Strandhill for the foreseeable future.

12.2 Preferred CFERM Option - Easkey

The preferred option identified for Easkey was Option 2. In summary, this scheme would involve re-aligning *c.*1,450m of a regional road which forms a popular section of the Wild Atlantic Way which in some areas is located less than 5m from the existing coastline.

As well as maintaining an important section of the Wild Atlantic Way which is an important economic driver for the region, this option would have minimal impact on the surfing recreational amenity. Indeed, enabling the coastline to respond naturally to pressures has the potential to distribute soft till material eroded from the coast onto the foreshore area which could improve access and egress to the water.

Subject to detailed design, this option would affect approximately 6.55 hectares of privately owned land. It would therefore be imperative to liaise with relevant stakeholders to ensure affected landowners are adequately compensated in line with relevant guidance.

Based on costs that were recently developed by RPS for a similar road re-alignment scheme in County Clare, it is expected that the cost of re-aligning this section of road would equate to *c.* €1.9mill euros ex.VAT. Compensating affected landowners could cost an additional €809,239 euro ex.VAT. An economical appraisal demonstrated an extremely robust Benefit Cost Ratio (BCR) for this option of 14.08.

The indicative extent and location of option is illustrated in Figure 12.2. it should be noted that the actual location this re-alignment scheme would be subject, ground conditions and discussions with relevant stakeholder, primarily landowners who would be affected by this option.

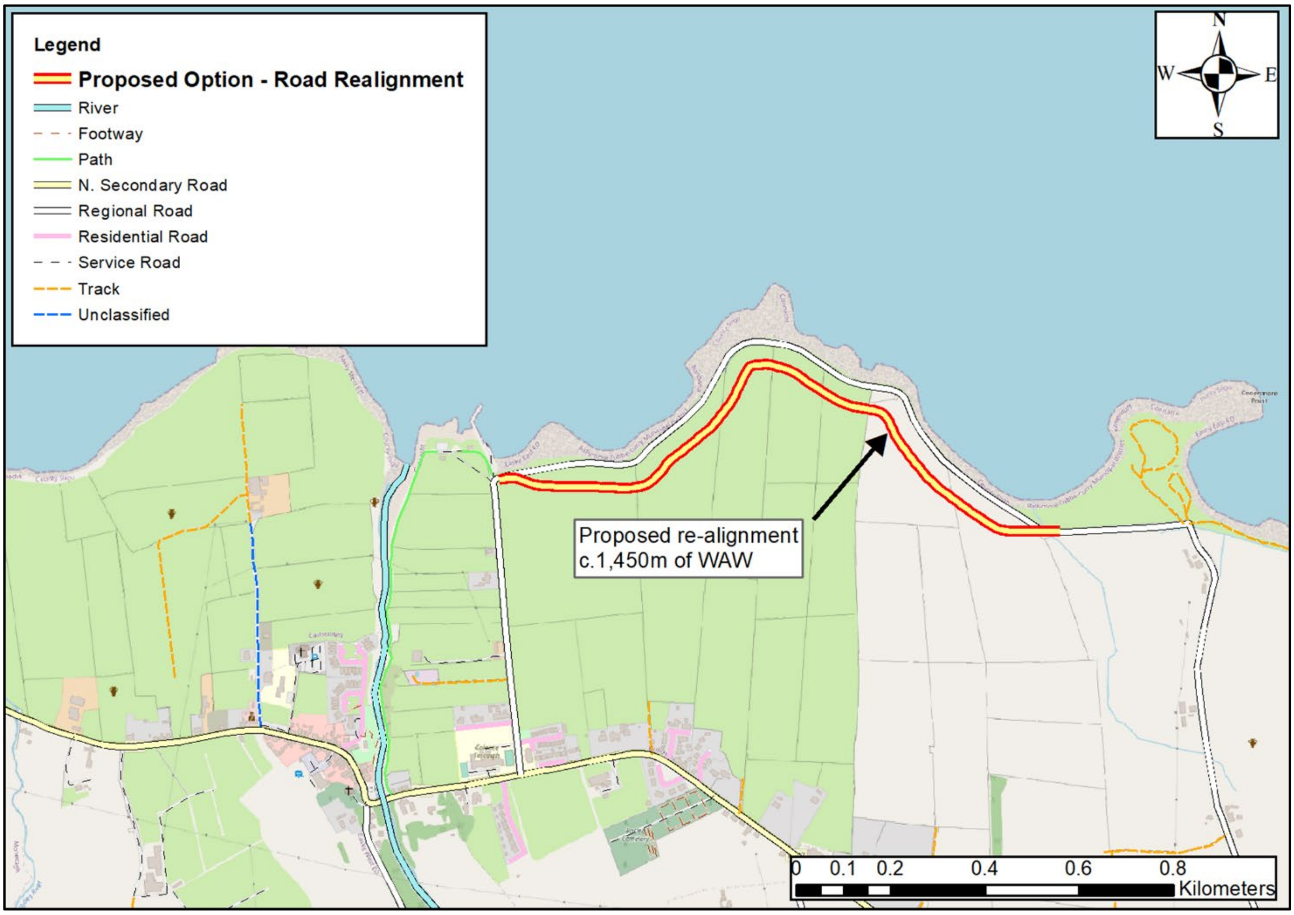


Figure 12.1: Location and extent of proposed CFERM option 2 at Easkey – road re-alignment solution

13 CONCLUSIONS

RPS was commissioned by Sligo County Council (SCC) to undertake a Coastal Flood Erosion Risk Management (CFERM) study at Strandhill and Easkey. The purpose of this study was to identify and quantify the coastal erosion and flooding risk to these areas and to develop a sustainable coastal management plan that would mitigate these risks.

Background

At Strandhill, coastal processes around the beach are complex with almost continuous and often extreme swell waves approaching from the Atlantic. These unique conditions have resulted in Strandhill becoming a prime surfing location in Ireland which in-turn provides a significant economic boost to the community of Strandhill and the Sligo region.

However, the exposed and energetic nature of this region has contributed to long-standing issues with coastal erosion at Strandhill. In response, different hard engineered schemes have been constructed to mitigate this risk. Despite these measures, much of Strandhill is still affected by on-going erosion, raising concerns regarding potential knock-on impacts upon beach and coastal activities including surfing, walking, cycling and camping, all of which are crucial economic drivers for this major tourism resort.

Easkey village is also an important surfing destination in County Sligo with the rugged coastline east of the village being particularly popular with more experienced surfers. The coast road in this same area forms an integral and very scenic part of 'Wild Atlantic Way' with a 2km stretch of the road running right beside the ocean. However, many sections of this stretch of road are less than 5m from the existing coastline and therefore at significant risk of erosion. This has raised concerns regarding the potential impact to the tourism asset for Easkey and wider Sligo region.

Coastal Flooding and Erosion Risk Assessment

Using a series of methods including complex computer models to assess coastal processes and reviewing historical aerial imagery for each site, RPS assessed and quantified the erosion and flood risk at both sites. This assessment found that:

At Easkey

- The long-term *average rate* of coastal retreat in this area was *c.*0.01m per year. However, there was low confidence associated with this assessment due to a lack of long-term high-resolution data.
- The coastline could retreat by up to 24m over the next 100 years, depending on the rate and magnitude of future climate change.
- It is estimated that some sections of this road could be lost to erosion in the short term (i.e., within +10 years). This would be expected to result in an almost immediate and complete loss of recreational gain or benefit associated with this amenity.
- Owing to the local topography the risk of coastal flooding in this area is minimal. Even under future climate conditions whereby sea levels could rise by +0.5m by 2100, only two properties were expected to be affected by flooding.

At Strandhill

- Historical data indicated that the long-term *average rate* of coastal retreat along the northern section of Strandhill equated to *c.*0.94m per year. There was significant variability in erosion rates along the coast, with the highest rates having been observed south of the revetment at the WWTP. The rate of erosion in this area has since reduced closer to the average rate.
- Based on historical rates, the coastline between Strandhill and the WWTP revetment could retreat by up to *c.*94m over the long term. Future climate change and rising sea levels could result in an *additional* 15 – 50m of coastal retreat over the long-term.
- Erosion of this magnitude could result in the partial but significant loss of the Cummeen Strand/ Drumcliff Bay SAC, Strandhill Camping and Caravan Park and potentially threaten the Strandhill WWTP if the existing rock revetment was not maintained.
- It is imperative that the existing coastal defences at Strandhill are maintained to mitigate any risk of erosion to the town.

- The coastline along the southern section of the coast is considered relatively stable and at little risk of erosion. However, localised sections can erode in response to extreme events.
- Areas of Strandhill are also at risk of coastal flooding from both tidal inundation and wave overtopping.
- In the south at Ballysadare Bay, coastal flooding during extreme events could propagate into the Strandhill Golf Course. Similarly, tidal inundation during a 1 in 200 year MRFS flood event was found to impact the runway at Strandhill airport, Strandhill WWTP and Kilasprugbone church .
- No main roads or buildings were found to be at risk from flooding caused by tidal inundation.
- Strandhill town is relatively well elevated and therefore naturally protected against tidal inundation. However, wave overtopping of the existing revetment resulted in the flooding of between 2 and18 properties depending on the magnitude of storm event and climate scenario considered.

Options and Feasibility Assessment

An options and feasibility assessment was undertaken for each of the study sites. This included an initial screening of high level management policies and a Multi-Criteria Assessment of a long list of potential management options.

The only options that scored positively for Easkey other than “No Active Intervention” and “Shoreline Monitoring” were rock revetments and managed re-alignment. Option 1 involved mitigating the risk of coastal erosion by installing rock armour, however the significant disadvantages with this option were the continued high maintenance requirements and potential impact to the surfing amenity tin this area.

It was Option 2 which involved re-aligning c.1,450m of the vulnerable regional road that was identified as the most sustainable solution given as it best balanced all social, economic and environmental issues.

At Strandhill, the options assessment identified multiple coastal management solutions. Based on this output, RPS developed two different options. Option 1 involved continuing the revetment at Strandhill town further north to link with the existing revetment at the WWTP. Other features of this option included improved defences at Strandhill town and Kilasprugbone Graveyard and improved access to the beach by means of a new ramp.

Option 2 for Strandhill was similar but involved leaving *c.* 400m of the coastline “undefended” to facilitate important coastal and beach recreational amenities that underpin the tourism asset offered by Strandhill. Instead, a 75m groyne structure is proposed at the existing stormwater manhole to encourage the retention of a storm beach along the remaining c.400m of coastline. This storm beach would reduce erosion of the foredune and secondly, provide surfers a natural point of ingress and egress from the water.

Economic Assessment

The fundamental basis of all economic assessments is that the cost and benefits of an option can be defined in monetary terms. An option is considered to be economically justifiable if the benefits outweigh the costs. To help identify the preferred scheme RPS undertook an economic assessment of options as per the industry standard guidance.

This assessment which also accounted for recreational gains and benefits at both Easkey and Strandhill found that the preferred schemes for both sites produced a Benefit Cost Ratio (BCR) robustly greater than unity. In particular, the preferred scheme at Easkey produced a BCR of 14.08 whilst the scheme at Strandhill which also included soft engineering works south of the town produced a BCR of 1.86.

Statutory Planning & Consents

Relevant statutory regulations and legislation have been reviewed to determine what consents may be required in relation to the proposed option. Planning Permission will be required for both the preferred schemes at Easkey and Strandhill, however, the latter will also likely require Foreshore License/Lease.

In addition, an Appropriate Assessment Screening should be undertaken to confirm there will be no significant adverse impact on any nearby Natura 2000 sites. Whilst the proposed works at Strandhill do not exceed the 1km threshold for coastal works as defined in the Planning and Development Regulations 2001 – 2018, further work should be undertaken to establish if the proposed scheme should be considered in the context of discretionary or sub-threshold EIA as per Article 92 (Part 10) of the Planning and Development Regulations 2001 – 2018.

14 BIBLIOGRAPHY

Baatsen M, Haarsma R.J and Van Delden A.J. et al. Severe Autumn storms in future Western Europe with a warmer Atlantic Ocean [Journal] // Climate Dynamics. - 2005. - Vol. 45.

Border Regional Authority Border Regional Planning Guidelines (2010-2022) [Online]. - 2010. - August 2021. - https://www.nwra.ie/wp-content/uploads/Planning-Guidelines-for-the-Border-Region.pdf.

Bruun P. Sea-level rise as a cause of shoreline erosion [Journal]. - [s.l.] : Journal of the Waterways and Harbors Division, 1962. - 1 : Vol. 88.

Cooper W., Saulter A. and Hodgetts P. Guidelines for the Use of Metocean Data Through the Lifecycle of a Marine Renewable Energy Development [Book]. - [s.l.] : Construction Industry Research & Information Association (CIRIA), 2008.

Davidson-Arnott Conceptual Model of the Effects of Sea Level Rise on Sandy Coasts [Journal] // Journal of Coastal Research. - 2005. - 6 : Vol. 21.

DHI Shoreline Management Guidelines [Report]. - 2017.

DHPLG Department Housing, Planning and Local Government National Marine Planning Framework [Report]. - 2021.

EA Environment Agency Flood and Coastal Erosion Risk Management appraisal guidance [Report]. - 2010.

EurOtop Manual on wave overtopping of sea defences and related structures [Journal]. - 2018.

Geological Survey Ireland [Online]. - 2022. - February 2022. - https://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228.

KMM Strandhill Coastal Study [Report]. - 2000.

Knight J, Burningham H and Barrett-Mold C The geomorphology and controls on development of a boulder-strewn rock platform, NW Ireland [Report]. - 2009.

Middlesex University Flood Hazard Research Centre The Benefits of Flood and Coastal Defence: A Manual of Assessment Techniques [Book]. - 2005.

OPW ICPSS (Irish Coastal Protection Strategy Study) [Online]. - 2012. - August 2021. - ttps://www.gov.ie/en/collection/d23916-irish-coastal-protection-strategy-study-phase-5-north-west-coast/#appendix-4-erosion-mapping.

OPW Irish Coastal Wave and Water Level Modelling Study [Report]. - 2020.

OPW Office of Public Works rish Coastal Wave and Water Level Modelling Study 2018 Phase 1 Technical Report [Report]. - 2020.

Pilkey O.H and Cooper J.A.G. Society and sea level rise [Journal]. - [s.l.] : Science, 2004. - 5665 : Vol. 303.

Riddel K and Green C FCDPAG3: Flood and Coastal Defence Project Appraisal Guidance. Economic Appraisal Guidance [Book]. - 1999.

RPS IBE1907 Sligo Bay CFERM: Data review [Report]. - 2021.

RPS Sligo Bay CFERM Assessment Report [Report]. - 2022.

RPS Strandhill Beach - Coastal Erosion Report [Report]. - 2012.

RPS Strandhill WWTW – Coastal Protection Scheme [Report]. - [s.l.] : Unpublished, 2015.

Sligo County Council Project Briefing Document - Coastal Flooding and Erosion Risk Management Study [Report]. - 2021.

Sligo County Council Sligo County Development Plan 2017-2023 [Online]. - 2017. - August 2021. - https://www.sligococo.ie/cdp/Volume1_MainWrittenStatement.pdf.

Thieler Robert [et al.] The use of mathematical models to predict beach behaviour for US Coastal Engineering: a critical review [Journal]. - [s.l.] : Journal of Coastal Research, 2000. - 1 : Vol. 16.

USACE U.S. Army Corps of Engineers Coastal engineering manual [Book]. - 2006.

USGS U.S Geological Survey Digital Shoreline Analysis System (DSAS) [Book]. - 2018.

Appendix A Extreme Value & Joint Probability Analyses

A.1 Extreme Value Analysis

To assess the return period extreme wave climate in the study area RPS undertook an Extreme Value Analysis (EVA) of the offshore wave dataset. Given the location of the study site the offshore wave and wind, the climate was divided into three 30° sectors from the south through to the north-west. Extreme Value Analysis was undertaken for each of the 30° sectors and all wave directions (omnidirectional) for the period 1979 to 2021.

The EVA was performed by fitting a theoretical probability distribution to the dataset and using a peak over threshold model to select the largest events. A Truncated Gumbel probability distribution was then fitted to the dataset using a Jackknife re-sampling technique to derive a series of return period wave heights for each relevant directional sector.

The analysis found that the waves with the largest significant wave heights affecting the Sligo CFERM study areas originated from the westerly sector Figure A. 1 to Figure A. 3 show the extreme value plots output from the EVA for each of the three 30° sectors from the period between 1979 and 2021. Table A 1 and Table A 2 the significant wave heights and wind speeds for the three 30° directional sectors at point 54.5°N, 9.5°W.

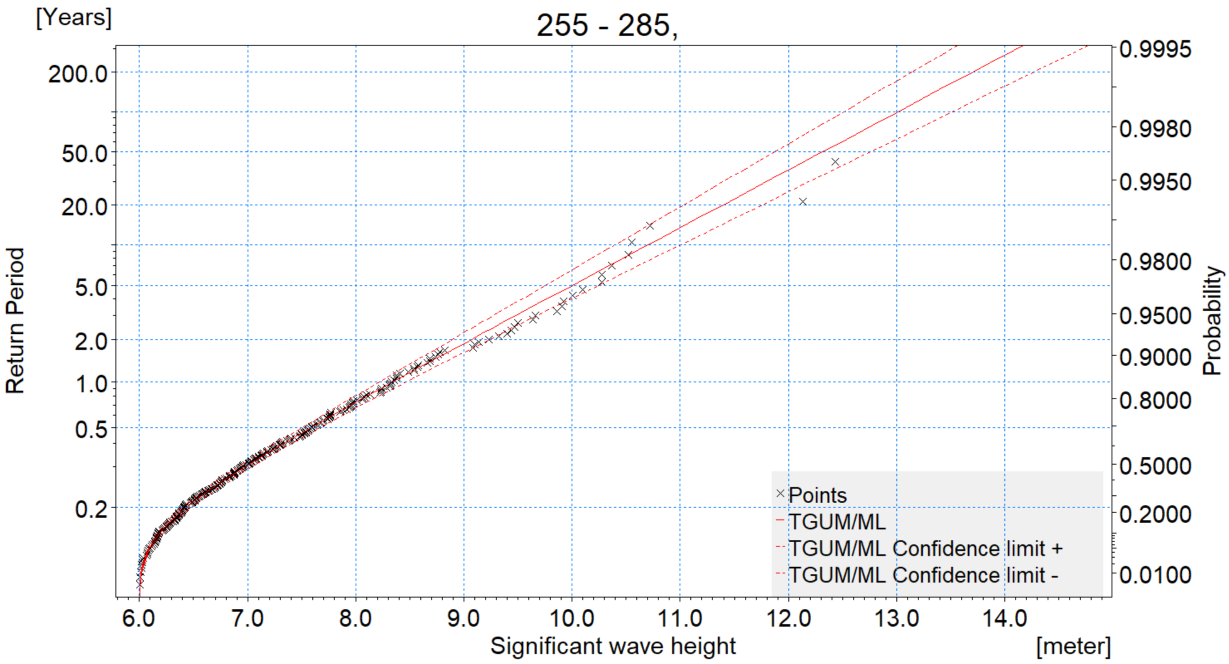


Figure A. 1: Extreme event analysis of offshore waves from the 255° - 285° sector for the period 1979 to 2021

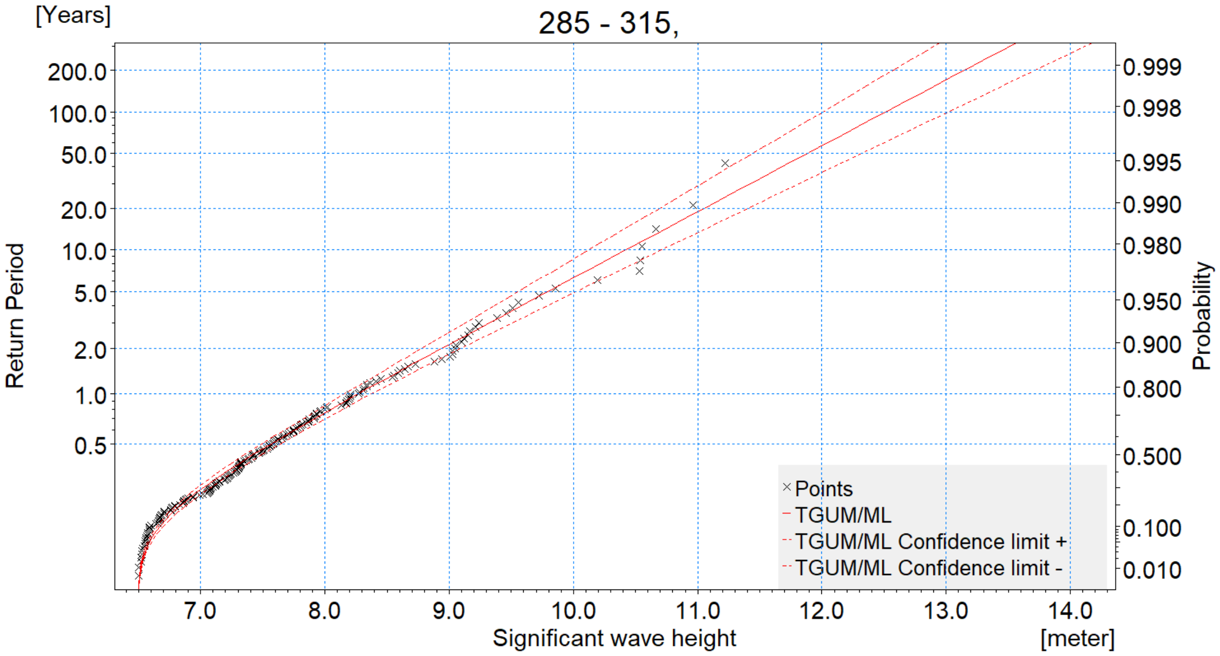


Figure A. 2: Extreme event analysis of offshore waves from the 285° - 315° sector for the period 1979 to 2021

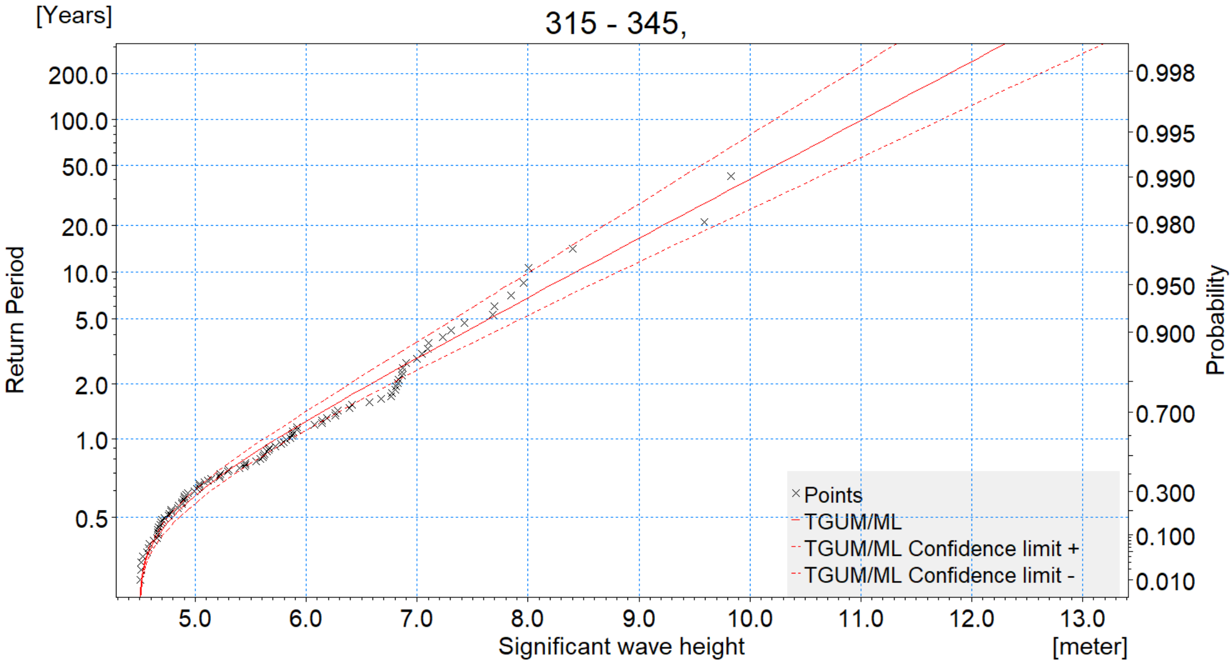


Figure A. 3: Extreme event analysis of offshore waves from the 315° - 345° sector for the period 1979 to 2021

Table A 1: Extreme significant wave heights for 1979-2021 at an offshore point (54.5°N, 9.5°W)

	Significant Wave Height [m]		
Return Period [years]	**255° - 285°**	**285° - 315°**	**315° - 345°**
2	9.06	8.93	6.57
5	10.00	9.78	7.63
10	10.70	10.42	8.41
20	11.39	11.05	9.19
50	12.31	11.88	10.21
100	13.01	12.51	10.98
200	13.71	13.14	11.75

Table A 2: Extreme wind speeds for 1979-2019 at an offshore point (54.45°N, 9.15°W)

	Wind Speed [m/s]		
Return Period [years]	**225° - 255°**	**255° - 285°**	**285° - 315°**
2	26.33	27.01	23.72
5	28.06	29.02	25.04
10	29.35	30.54	26.03
20	30.63	32.05	27.01
50	32.31	34.05	28.31
100	33.59	35.57	29.29
200	34.86	37.08	30.27

A.2 Joint Probability Analysis

The level of exposure of any shoreline to wave action is governed primarily by the local tidal regime as the maximum height of any incident wave is a function of water depth. As incident waves are limited by water depth larger waves tend to break further offshore. However, beaches often experience large irregular increases in water levels called surges. These surge events increase the local water depth allowing larger waves to reach the shore and expose more landward sections of the shore to wave attack. It is the combination of high waves with high water levels that is particularly important in causing the erosion of shorelines and dune systems.

A joint probability analysis of wave heights with water levels and wind speeds with water levels was undertaken using techniques and methods derived during the JOIN-SEA project (Defra /Environment Agency, 2005). This method involves selecting a correlation coefficient between each pair of variables and using the associated tools to derive matched combinations of known Annual Exceedance Probability (AEP) events.

Once an appropriate correlation coefficient was selected, the relevant set of AEP water levels and wind speeds or wave heights derived during the EVA stage of this study, were input into the JOIN-SEA spreadsheet for analysis. Combinations of wave heights and water levels for joint AEPs of 50%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% were derived for each relevant directional sector at an appropriate offshore location.

Typical joint exceedance probability curves for the three directional sectors considered are presented in Figure A. 4 to Figure A. 6 while the resulting combinations of sea level and wave height for the same sectors are presented in Table A 3 and Table A 4 respectively.

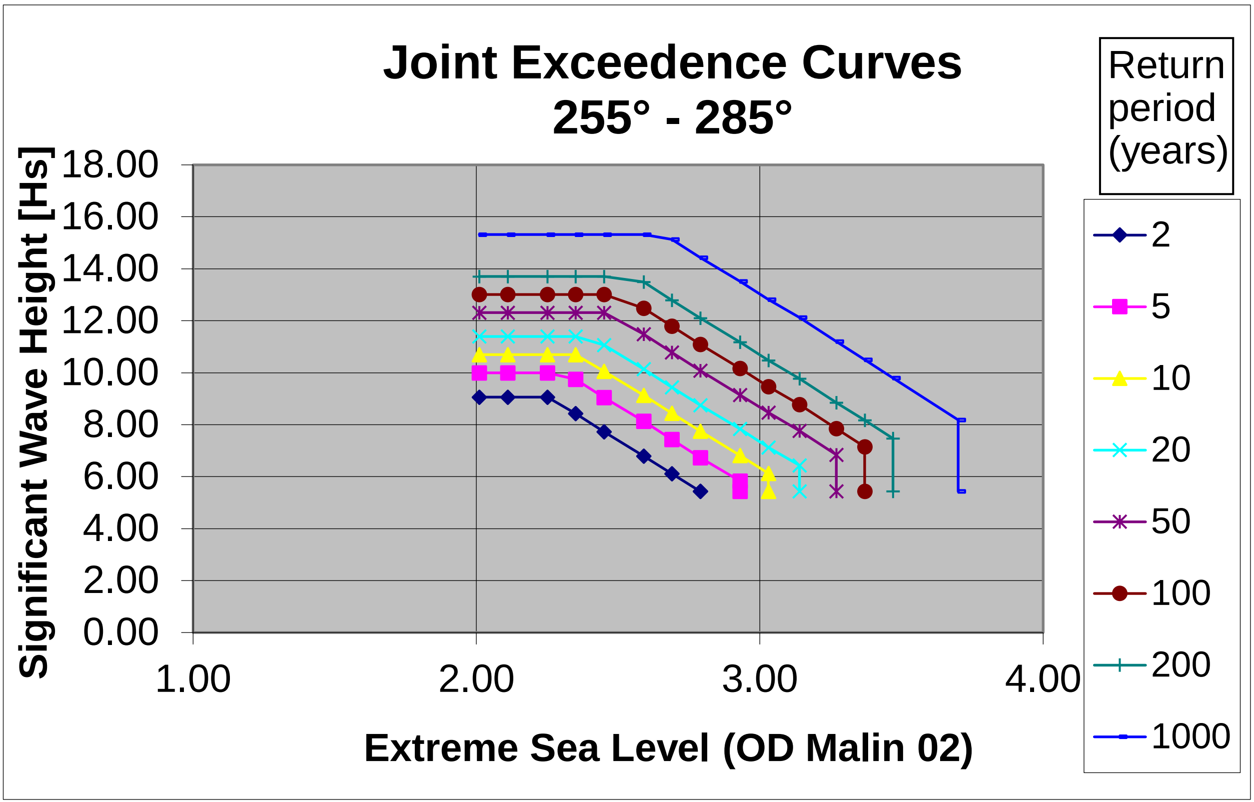


Figure A. 4: Joint exceedance curves – West (255° - 285°) sector wave heights and water levels 54.5°N 9.5°W

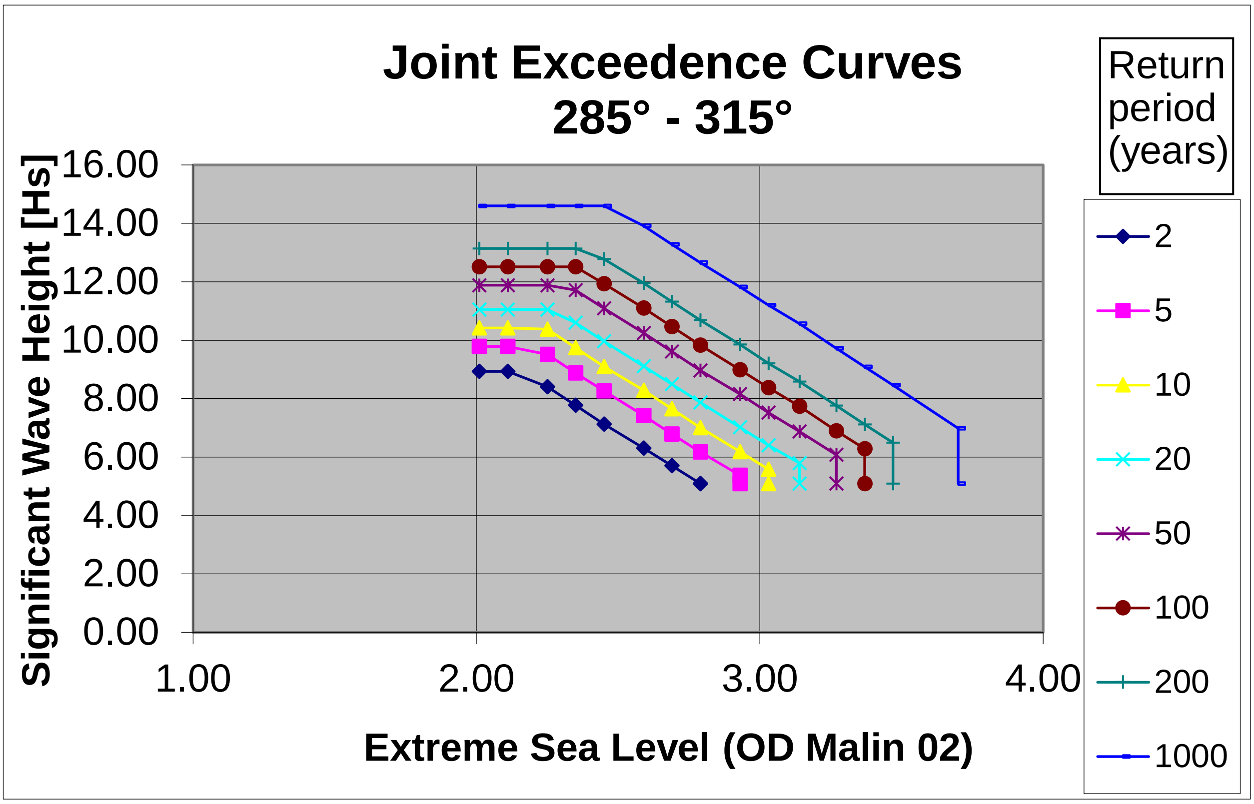


Figure A. 5: Joint exceedance curves – 285° - 315° sector wave heights and water levels 54.5°N 9.5°W

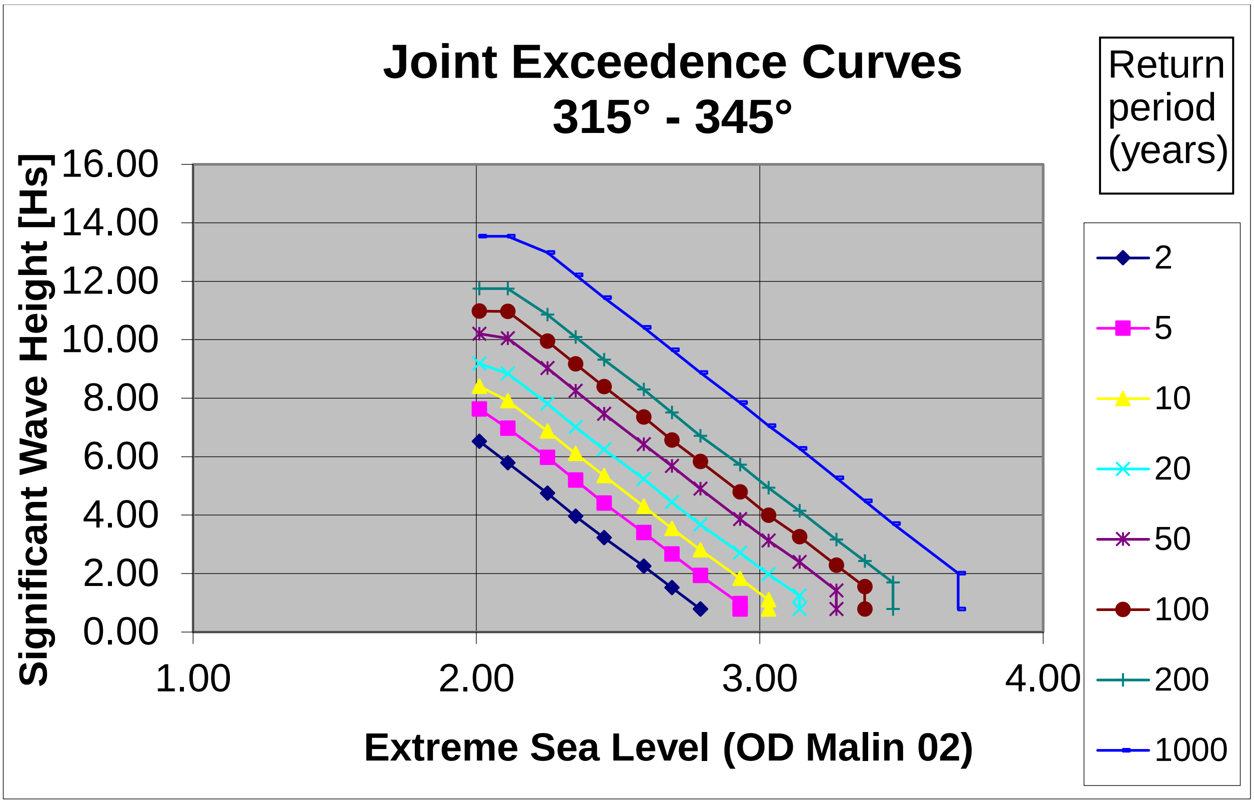


Figure A. 6: Joint exceedance curves – 315° - 345° sector wave heights and water levels 54.5°N 9.5°W

Table A 3: Joint exceedance return period (inverse of AEP) values for wave heights and water levels - 255° - 285° sector at 54.5°N 9.5°W

Value of first variable: Present Day Extreme Sea Level (mOD OSGM15)	Joint exceedance return period (years) 2	5	10	20	50	100	200	1000
	Value of second variable: Significant wave height (m)							
2.01	9.06	10.00	10.70	11.39	12.31	13.01	13.71	15.32
2.11	9.06	10.00	10.70	11.39	12.31	13.01	13.71	15.32
2.25	9.06	10.00	10.70	11.39	12.31	13.01	13.71	15.32
2.35	8.42	9.75	10.70	11.39	12.31	13.01	13.71	15.32
2.45	7.73	9.04	10.06	11.07	12.31	13.01	13.71	15.32
2.59	6.79	8.14	9.13	10.15	11.48	12.49	13.49	15.32
2.69	6.11	7.43	8.45	9.44	10.78	11.79	12.80	15.13
2.79	5.43	6.73	7.75	8.75	10.08	11.09	12.10	14.43
2.93	#N/A	5.83	6.81	7.83	9.15	10.17	11.18	13.51
3.03	#N/A	#N/A	6.13	7.13	8.47	9.46	10.48	12.82
3.14	#N/A	#N/A	#N/A	6.43	7.77	8.77	9.78	12.12
3.27	#N/A	#N/A	#N/A	#N/A	6.84	7.86	8.85	11.20
3.37	#N/A	#N/A	#N/A	#N/A	#N/A	7.15	8.17	10.50
3.47	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	7.46	9.80
3.70	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	8.19

Table A 4: Joint exceedance return period (inverse of AEP) values for wave heights and water levels - 285° - 315° sector at 54.5°N 9.5°W

Value of first variable:	Joint exceedance return period (years)							
	2	5	10	20	50	100	200	1000
Present Day Extreme Sea Level (mOD OSGM15)	Value of second variable:		Significant wave height (m)					
2.01	8.93	9.78	10.42	11.05	11.88	12.51	13.14	14.60
2.11	8.93	9.78	10.42	11.05	11.88	12.51	13.14	14.60
2.25	8.40	9.52	10.38	11.05	11.88	12.51	13.14	14.60
2.35	7.77	8.88	9.74	10.59	11.72	12.51	13.14	14.60
2.45	7.13	8.27	9.10	9.96	11.09	11.94	12.78	14.60
2.59	6.31	7.42	8.28	9.11	10.25	11.10	11.95	13.91
2.69	5.70	6.78	7.65	8.49	9.61	10.47	11.32	13.29
2.79	5.09	6.18	7.00	7.87	8.97	9.84	10.69	12.66
2.93	#N/A	5.37	6.19	7.02	8.16	8.99	9.85	11.83
3.03	#N/A	#N/A	5.58	6.40	7.52	8.37	9.21	11.20
3.14	#N/A	#N/A	#N/A	5.79	6.88	7.74	8.58	10.56
3.27	#N/A	#N/A	#N/A	#N/A	6.07	6.89	7.76	9.72
3.37	#N/A	#N/A	#N/A	#N/A	#N/A	6.28	7.11	9.08
3.47	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	6.49	8.46
3.70	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	6.99

Appendix B Flood Maps

Appendix C Outline Recreational Benefits Study

C.1 Introduction

J Chatterton and Associates were commissioned by RPS, on behalf of Sligo County Council (SCC) to study the benefits associated with improved coastal management options at Strandhill and Easkey. This report looks at the broad, speculative annual recreational losses under the baseline "Do Nothing" scenario, using questionnaire analysis for day visitors, staying visitors, and permanent residents using broad assessments of visitor numbers.

Strandhill is described as "the jewel of the Wild Atlantic Way's surf coast, an energetic village with bustling cafes and eateries, and new adventures around every corner".[2] Its population in 2016 was 1,753. The village has multiple hostels, the Ocean Wave Lodge, The Dunes Tavern and Surf'n'Stay Lodge and Hostel. Additionally, there is the Strandhill Lodge and Suites, awarded by Tripadvisor as the third best hotel in Ireland [3]. A premier surfing location, Strandhill is a vast beach break capable of holding huge waves in the right conditions.

Easkey or Easky is located in the centre of West Sligo, at the estuary of the Easkey river with a coastal road to the east of the village on the Wild Atlantic Way. People visit for the "*spectacular scenery, great surfing, and the pleasure of staying in a picturesque, traditional village environment with all the facilities of modern life*"[4]. The population in 2016 was 239.

Atlantic storms over recent years continue to pressure the coastline in these regions, placing both coastal protection assets and future tourism in jeopardy. As both locations have a well-established history of tourism, it is likely that recreational tourism together with the local economy of Sligo will suffer without suitable coastal management intervention.

C.2 Outline Methodology for evaluating Recreational benefits

The methodology used in this assessment is derived largely from the Flood Hazard Research Centre's Multi Coloured Handbook (Chapter 8)[5], adapted as agreed with officers from Sligo County Council, RPS and the Office of Public Works.

In brief, the benefits of using a beach facility and its environs for recreation (or losses, if the beach is lost to coastal processes) are considered as the difference between the Value of Enjoyment (VoE) derived from the current asset (i.e., beach/shoreline) and the VoE of visiting an equivalent beach (or enjoying an alternative activity). Those enjoying the beach and its facilities (unless permanent nearby residents) must travel to enjoy the beach. Thus, an additional benefit from maintaining the asset (or losses, if the beach is lost to coastal processes, under the Do-Nothing scenario) relates to the difference in cost of travel between home base and the beach and the cost of visiting an alternative site. It is noted that both VoE and costs maybe negative.

[2] https://gostrandhill.com/

[3] https://en.wikipedia.org/wiki/Strandhill

[4] http://easkey.ie/

[5] Flood and Coastal Erosion Risk management: Handbook for Economic Appraisal, 2019. Flood Hazard Research Centre, Middlesex University, London. co-authored by Dr Chatterton

The following formula summarises the above:

$$L = (Eo - Ea) + (Ca - Co)$$

Where:

- L is the benefit per person
- Eo is the VoE of a visit to the site now (before erosion)
- Ea is VoE of a visit to an alternative equivalent site after loss
- Ca is the cost incurred in visiting an alternative site after loss
- Co is cost incurred in visiting the site now

These are recognised as legitimate National resource costs. However, in line with advice from the OPW in the preparation of similar studies, the benefits of foregone beach recreation are divided as:

1. Losses to Strandhill and Easkey – the local economy (with alternative activities transferred within County Sligo)
2. Losses to County Sligo (with alternative activities transferred outside the county)
3. Losses to the Republic of Ireland (with alternative activities abroad or in Northern Ireland)

National losses refer to scenario 3; County Sligo losses refer to scenario 2 and local losses refer to scenario 1.

Interview surveys were conducted with 3 distinct groups of visitors between August and November 2021 in both communities with counts as follows:

Strandhill

- Day Visitors (82 interviews)
- Staying visitors (71 interviews)
- Permanent Residents (87 interviews)

Easkey

- Day Visitors (74 interviews)
- Staying visitors (60 interviews)
- Permanent Residents (63 interviews)

C.2.1 Qualitative conclusions from Strandhill interviews

C.2.1.1 Day Visitors (Strandhill)

Frequency of visits (Strandhill)	Day visits	
	%	no.
Daily	4.9	4
Once or twice per week	20.7	17
once per month	28.0	23
Less than once per year	41.5	34
First Time	4.9	4
Total sample	100.0	82

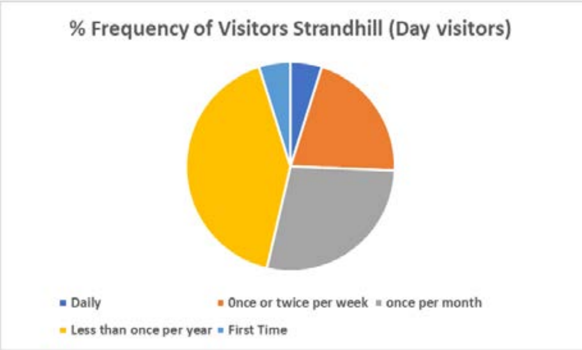


Figure A. 7: just over half of Day visitors visit Strandhill once per month or more frequently.

Number of Previous Visits Strandhill	Day visits	
	%	no.
Never	9.8	8
2 to 5	30.5	25
6 to 20	12.2	10
More than 20	43.9	36
Unknown	3.7	3
Total Sample	100.0	82

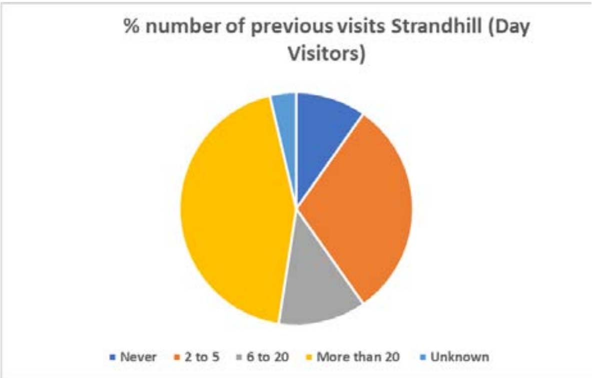


Figure A. 8: Shows that over 85% of Day visitors have visited Strandhill on multiple previous occasions with over 40% having visited more than 20 times.

Alone or Group?	Day visits	
	%	no.
Alone	29.3	24
Group	70.7	58
Total sample	100.0	82
Mean adults per group	*1.7*	
men children per group	*0.4*	

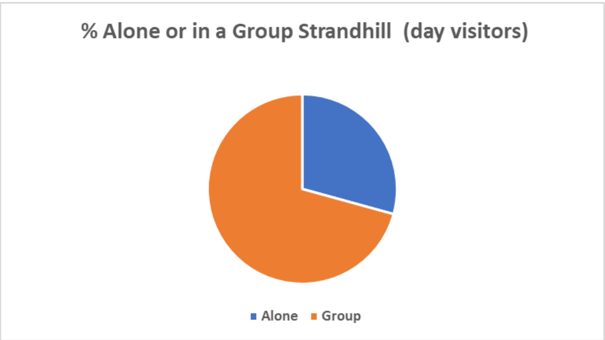


Figure A. 9: Shows that around 70% of Day visitors visit as part of a group.

Rating of Beach Strandhill	Day Visits	
	%	*no.*
10 (Highest)	78.0	64
9 or 9/10	12.2	10
8 or 8/9	6.1	5
7	2.4	2
5	1.2	1
Total sample	100.0	82

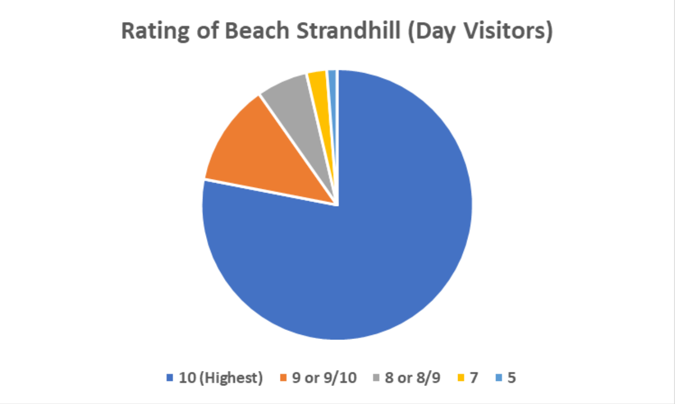


Figure A. 10: Shows that over 90% of Day visitors rate the beach 9 or 10 out of 10.

Reason for visiting Strandhill	Day Visits	
	%	*no.*
Beach based activities	59.8	49
Hotel based activities	64.6	53
Walking and Cycling	89.0	73
Sports and recreation away from beach	34.1	28
Visiting the Graveyard at Killlaspurghbone	22.0	18
Visiting Shelley Valley	32.9	27
Other (Golf, Business, Scenery, Photography)	9.8	8
Activity or multiple activity mentioned		

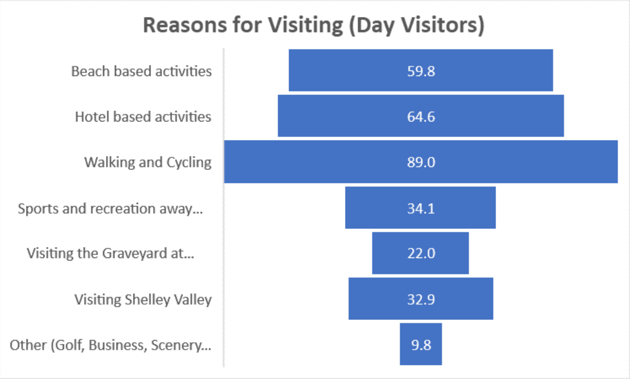


Figure A. 11: Shows approximately 70% of Day visitors visit for beach activities and almost 90% for walking/cycling.

Choice of Alternative Sites Strandhill	Day Visits
	no.
Rosses Point	19
Mullaghmore	4
Bundoran, Co Donegal	5
Donegal	6
Galway/Salthill	5
Spain/Portugal	4
Other locations (single or double mentions) within Ireland	19
Abroad (single mentions)	5

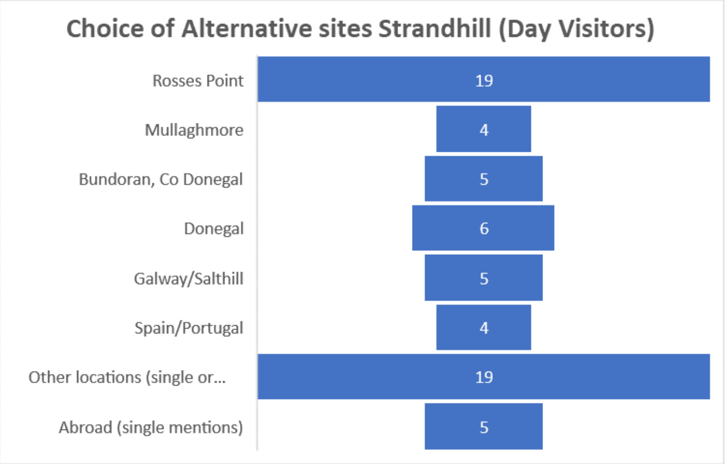


Figure A. 12: Shows that Rosses Point would be the favourite alternative site for day visitors.

	Day Visits	
Alternative Destinations Strandhill	**%**	**no.**
Sligo	68.3	56
Rest of Ireland	26.8	22
Abroad excluding Northern Ireland	0.0	0
Northern Ireland	0.0	0
Unknown	4.9	4
	100.0	82

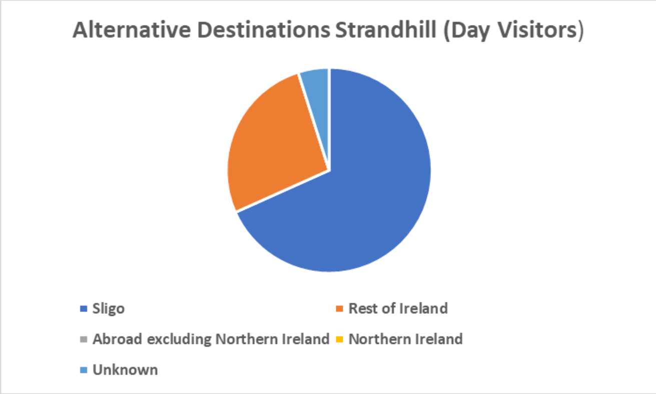


Figure A. 13: Shows over two thirds of Day Visitors would remain within Sligo County as an alternative outing with a further quarter choosing other mainly coastal Irish counties.

Visitor Origin	**Day Visits**	
	%	no.
Sligo	28.0	23
Rest of Ireland (within 1 hour)	15.9	13
Rest of Ireland (more than 1 hour)	41.5	34
Abroad excluding Northern Ireland	7.3	6
Northern Ireland	4.9	4
Unknown	2.4	2
	100.0	82

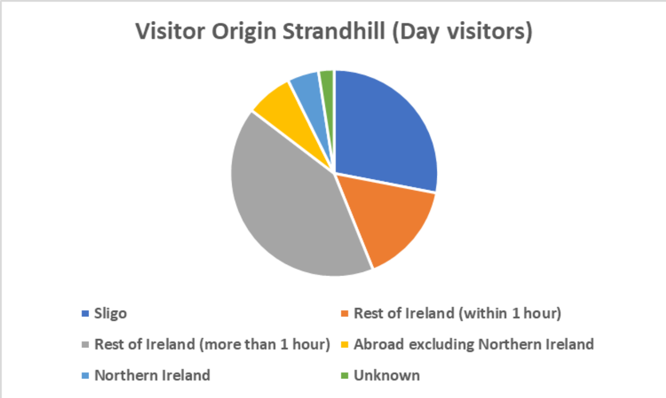


Figure A. 14: Shows 28% of day visitors came from within Sligo County but over 40% drove more than 1 hour to visit Strandhill[6].

C.2.1.2 Staying Visitors (Strandhill)

Frequency of visits (Strandhill)	**Staying Visitors**	
	%	***no.***
Daily	2.8	2
Once or twice per week	1.4	1
once per month	18.3	13
Less than once per year	63.4	45
First Time	12.7	9
No answer	1.4	1
		71

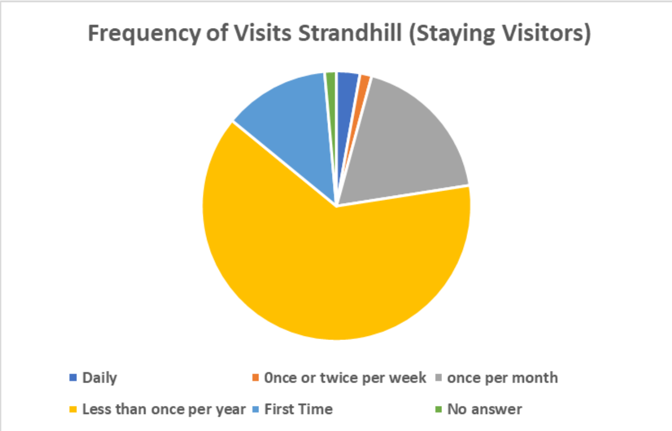


Figure A. 15: Shows that almost two thirds of staying visitors come to Strandhill less than once per year.

[6] The questionnaire did not distinguish between day visitors not staying in Strandhill but on vacation elsewhere and visiting Strandhill for a day. This explains the day visitors from abroad.

Number of Previous Visits Strandhill	Staying Visitors	
	%	*no.*
First time	35.2	25
1 to 5	36.6	26
6 to 20	9.9	7
20 or more	18.3	13
	100.0	71

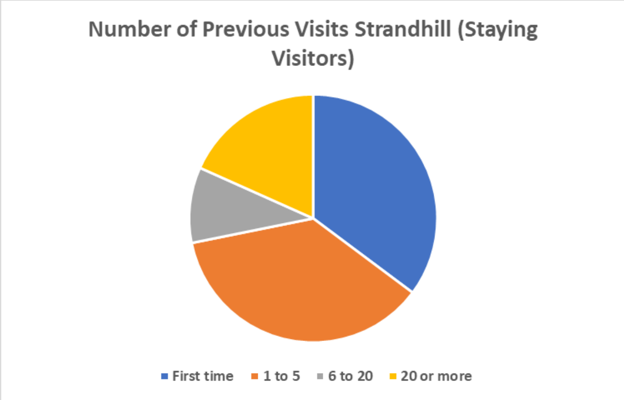


Figure A. 16: Shows over two thirds of staying visitors have visited 5 times or less.

Alone or Group? Strandhill	Staying Visits	
	%	*no.*
Alone	8.5	6
Group	91.5	65
	100.0	71
Mean Adults	***2.1***	
Mean Children	***0.5***	

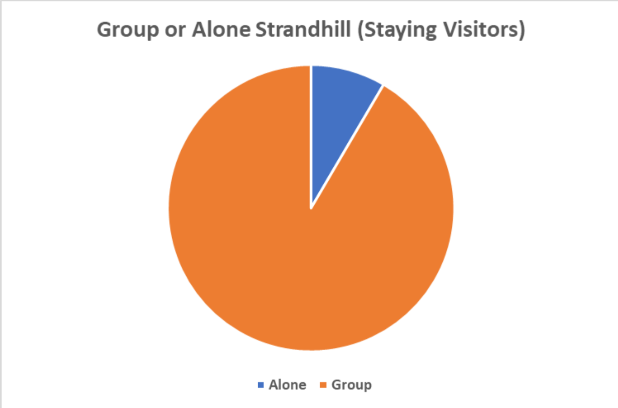


Figure A. 17: Shows that over 90% of Staying visitors visit in Groups.

Nights away from home Strandhill	%	no.
1 night	4.2	3
2-3 nights	46.5	33
4 to 7 nights	38.0	27
8-14 nights	7.0	5
More than 2 weeks	4.2	3
	100.0	71

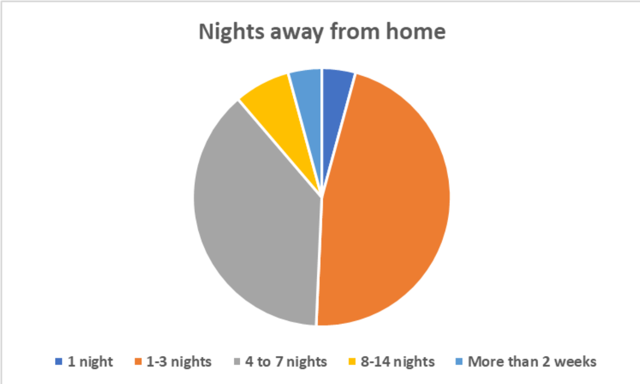


Figure A. 18: Shows that almost 85% of staying visitors spend between 2 and 7 nights in Strandhill.

Rating of Beach Strandhill	Staying Visits	
	%	*no.*
10 (Highest)	80.3	57
9	8.5	6
8	7.0	5
7	1.4	1
6	1.4	1
5	1.4	1
	100.0	71

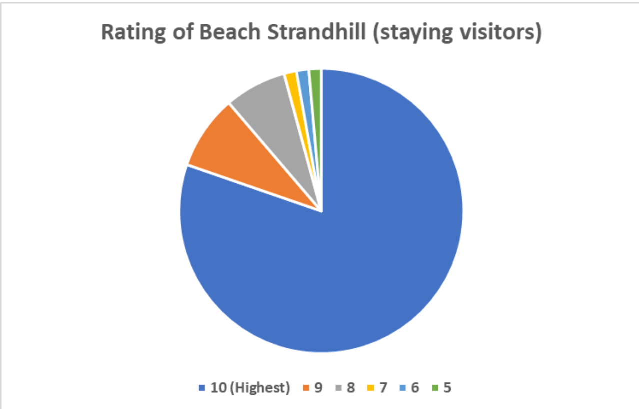


Figure A. 19: Shows almost 90% of Staying visitors rate the beach as => 9 out of 10.

Reason for visiting Strandhill	Day Visits	
	%	***no.***
Beach based activities	66.2	47
Hotel based activities	78.9	56
Walking and Cycling	91.5	65
Sports and recreation away from beach	33.8	24
Visiting the Graveyard at Killlaspurghbone	22.5	16
Visiting Shelley Valley	43.7	31
Other (Golf, Photography)	5.6	4
Activity or multiple activity mentioned		

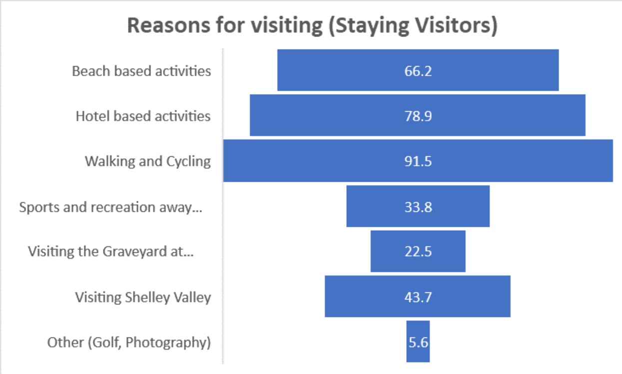


Figure A. 20: Shows that two thirds of staying visitors indicated that beach activities were the reason for visiting Strandhill whilst over 90% suggested walking and cycling with over three quarters indicating hotel based activities were also important.

Choice of Alternative Sites Strandhill	Staying Visits	
	%	**no.**
County Sligo	39.4	28
Other Irish Counties	49.3	35
Abroad	1.4	1
Northern Ireland	1.4	1
Unknown	8.5	6
	100.0	71

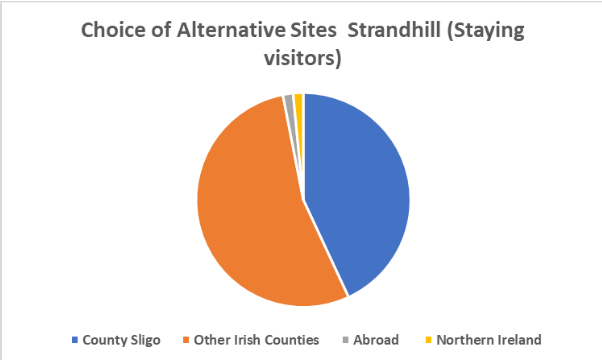


Figure A. 21: Shows nearly 40% of staying visitors would stay on vacation in Sligo if Strandhill facilities were compromised by erosion with a further almost 50% staying within the Republic of Ireland. Only 1 interviewee suggested they would go out of the island of Ireland.

County Sligo	0.0	0
Rest of RoI	57.7	41
Northern Ireland	18.3	13
Abroad	22.5	16
Unknown	1.4	1
	100.0	71

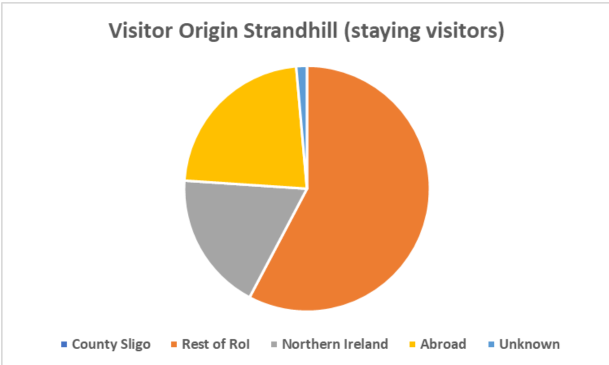


Figure A. 22: Shows three quarters of Staying visitors were from the island of Ireland with almost a quarter originated from overseas.

C.2.2 Permanent Residents

Frequency of visits Strandhill	Permanent Residents	
	%	*no.*
At Least Daily	72.4	63
Once or twice per week	25.3	22
At least once per month	2.3	2
Less than once per year	0.0	0
	100.0	87

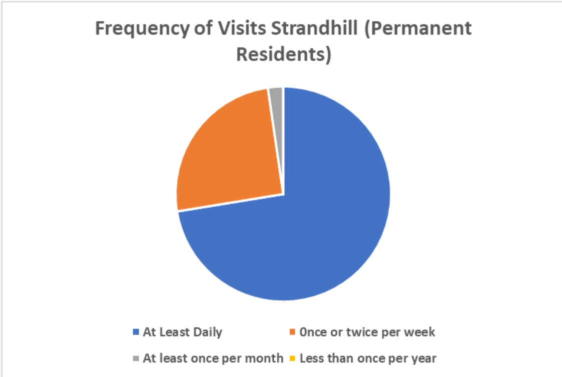


Figure A. : Shows that almost three quarters of Permanent residents visit the beach daily.

Length of residency in Strandhill	permanent Residents	
	%	no.
5 years or less	20.7	18
6 to 20 years	26.4	23
Greater than 20 years	52.9	46
	100	87

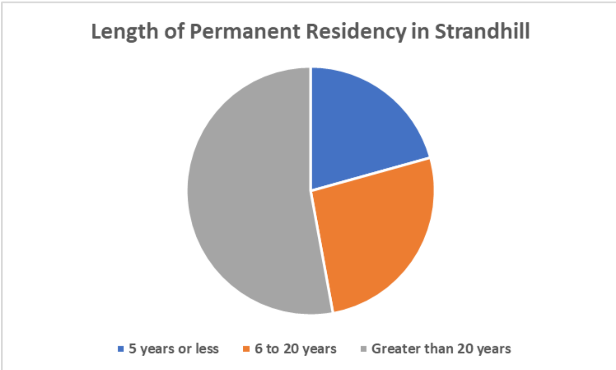


Figure A. 23: Shows that over half of permanent residents in Strandhill have lived there for more than 20 years.

Reason for visiting Permanent residents		
	% of sample	*no.*
Beach-based activities	48.3%	42
Sport and recreation outside beach area	46.0%	40
Walking / Cycling	95.4%	83
Café/Restaurant/Pub	93.1%	81
Visiting the Graveyard at Killasprughbone	49.4%	43
Visiting the Shelley Valley area	49.4%	43
Other (Running, Golf, Surf, Work)	11.5%	10
Multiple activities mentioned		

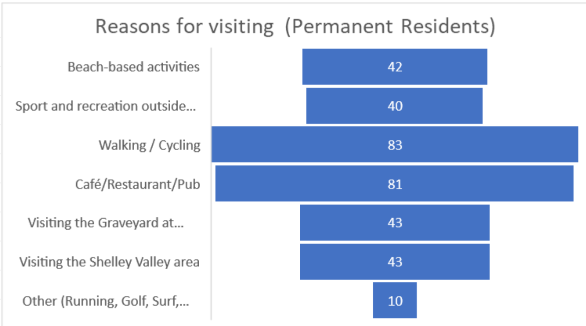


Figure A. 24: Shows almost all the permanent residents engage in walking/cycling or social activities.

Length of Stay on Beach Strandhill	Permanent Residents	
	%	*no.*
Full Day	8.0	7
Half Day	29.9	26
Less than 1 hour	59.8	52
n/a	2.3	2
	100.0	87

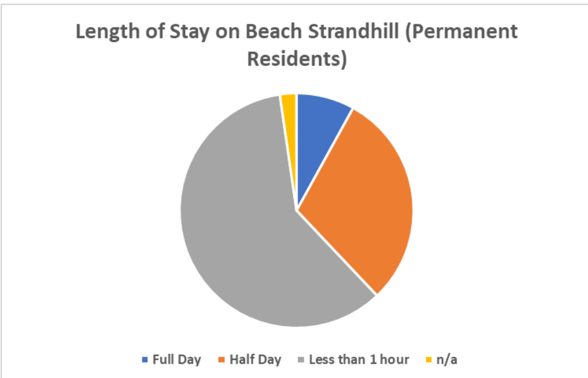


Figure A. 25: Shows around 60% of Permanent Residents stay on the beach for less than one hour.

Is Coastal erosion a significant risk at Strandhill?		
	%	no.
No	1.1	1
Maybe/possibly	2.3	2
Partly	1.1	1
Yes	92.0	80
Extremely	2.3	2
No reponse	1.1	1
	100	87

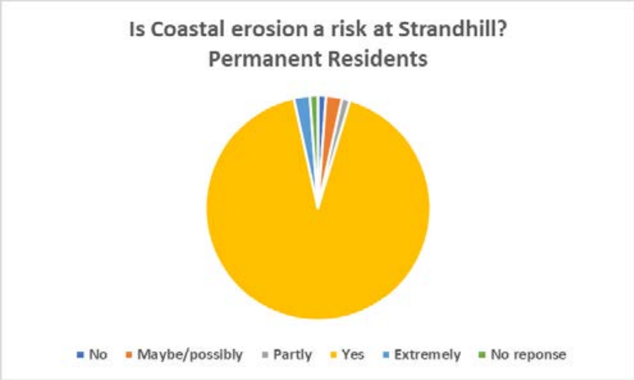


Figure A. 26: Shows around 95% of permanent residents feel that coastal erosion is a risk at Strandhill.

Rating of Beach at Strandhill	Permanent Residents	
	%	*no.*
10 (Highest)	69.0	60
At least 9	10.3	9
At least 8	11.5	10
At least 7	4.6	4
6	3.4	3
5	1.1	1
	100.0	87

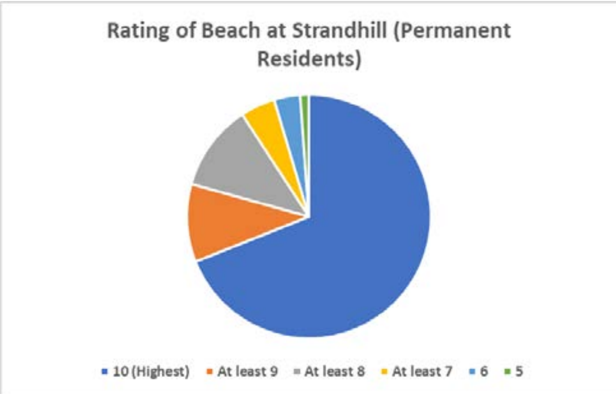


Figure A. 27: Shows almost 80% of permanent residents rate the beach as =>9 out of 10

C.2.3 Qualitative conclusions from Easkey interviews

C.2.3.1 Day Visitors

Frequency of visits - Coast road	Day visits	
	%	*no.*
Daily	2.7	2
0nce or twice per week	10.8	8
once per month	28.4	21
Less than once per year	50.0	37
First Time	5.4	4
no answer	2.7	2
Total sample	100.0	74

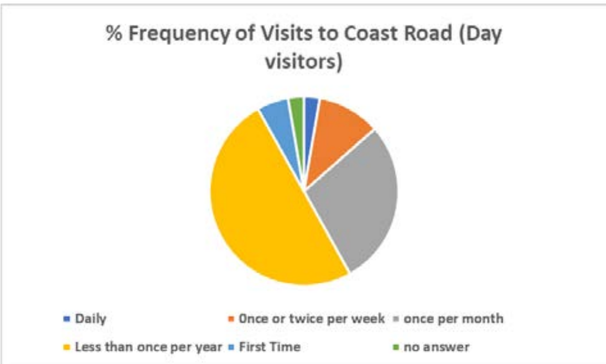


Figure A. 28: Shows that 50% of coast road users visit less than once per year.

Number of Previous Visits to Coast Road	Day visits	
	%	*no.*
First Time	10.8	8
2 to 5	28.4	21
6 to 20	28.4	21
More than 20	23.0	17
Unknown	9.5	7
Total Sample	100.0	74

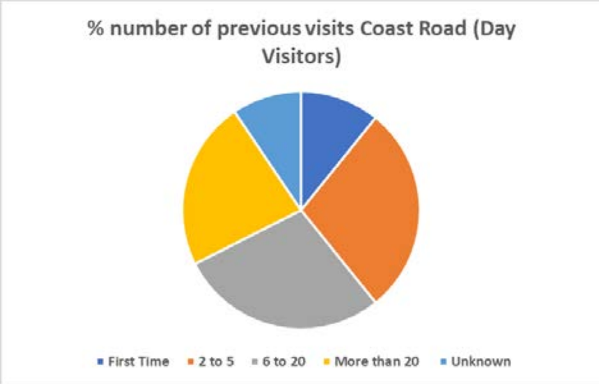


Figure A. 29: Shows that almost a quarter of day visitors have used the coast road more than 20 times with over half visiting up to 20 times.

Alone or Group to coast road?	Day visits	
	%	*no.*
Alone	29.7	22
Group	70.3	52
Total sample	100.0	74
Mean adults per group	*2.3*	
men children per group	*0.2*	

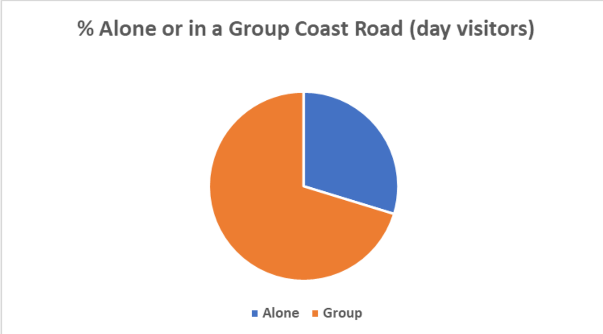


Figure A. 30*: Shows that70% of day visitors travel the coast road in Groups.

Importance of Coast Road to visit	Day Visits	
	%	*no.*
10 (Highest)	83.8	62
9	2.7	2
8	4.1	3
7	2.7	2
5	5.4	4
3	1.4	1
	100.0	74

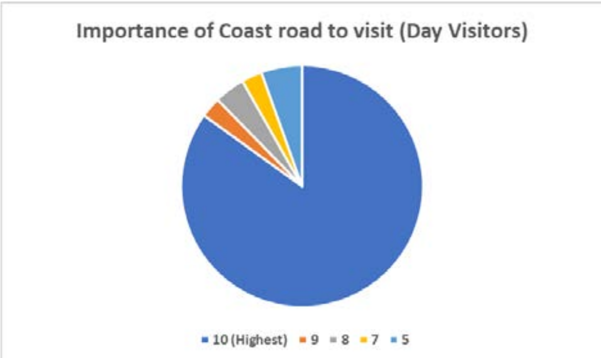


Figure A. 31: Shows over 85% of day visitors think the coast road is rated at 9 or10 out of 10.

Still visit if coast road not available	Day visits	
	%	no.
Yes	54.1	40
No	39.2	29
Uncertain	6.8	5
	100.0	74

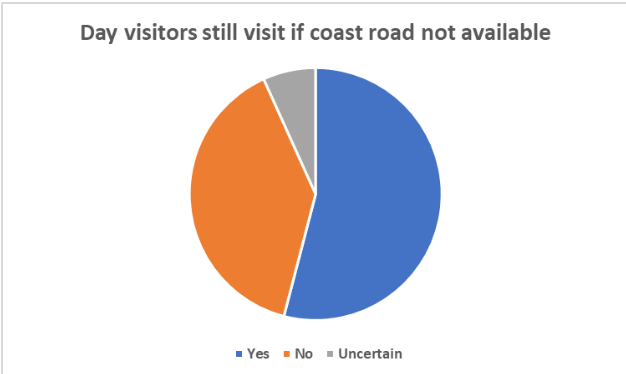


Figure A. 32: Shows that over 50% of Day visitors would visit Easkey area if coast road was not available.

Reason for visiting Easkey/Coast Road	Day Visits	
	%	*no.*
Hotel and facilities	10.8	8
Beach-based activities (including surfing)	58.5	48
Sports and Recreation outside beach	31.7	26
Walking and cycling	67.1	55
Other Scenery, photography, work)	32.9	27
Activity or multiple activity mentioned		

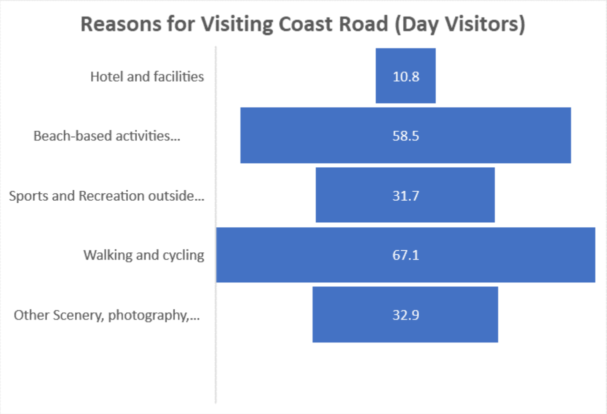


Figure A. 33: Two thirds of day visitors indicated that walking/cycling were main reasons for visiting Easkey/coast road with only around 10% citing hotel and facilities

Choice of Alternative Sites to Coast Road	Day Visits
	no.
Enniscrone	14
Clare	3
Other locations (single or double mentions) within Ireland	16

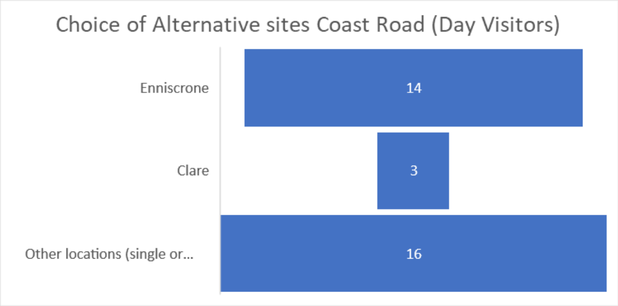


Figure A. 34: Shows that Enniscrone was the single most favourable alternative location.

Visitor Origin Coast Road	Day Visits	
	%	no.
Sligo	14.9	11
Rest of Ireland (within 1 hour)	16.2	12
Rest of Ireland (more than 1 hour)	48.6	36
Abroad excluding Northern Ireland	6.8	5
Northern Ireland	4.1	3
Unknown	9.5	7
	100.0	74

Figure A. 35: Shows that almost 50% of day visitors suggested they would travel more than an hour from their home location to Easkey area[7].

Alternative Destination Coast Road	Day Visits	
	%	no.
Sligo	27.0	20
Rest of Ireland	14.9	11
Unknown	58.1	43
	100.0	74

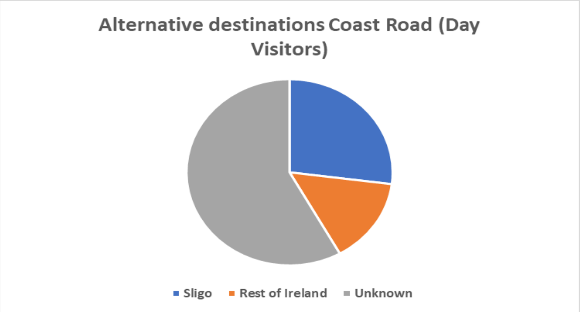


Figure A. 36: Shows over half of day visitors were undecided as to where to take an alternative visit but over a quarter citing staying within Sligo.

[7] The questionnaire did not distinguish between day visitors not staying in Easkey area but on vacation elsewhere and visiting Easkey/coast road for a day. This explains the day visitors from abroad.

C.2.3.2 Staying Visitors Easkey

Frequency of visits to Coast Road	Staying Visitors	
	%	*no.*
At least daily	6.7	4
Once or Twice a week	0.0	0
At least once a month	15.0	9
Less than once a year	71.7	43
First Time	3.3	2
No Answer	3.3	2
	100.0	60

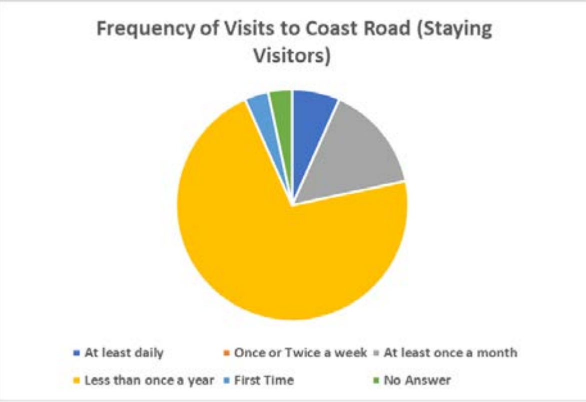


Figure A. 37: Shows almost three quarters of staying visitors used the coast road less than once per year.

Number of Previous Visits to Easkey	Staying Visitors	
	%	*no.*
First time	10.0	6
Up to 5	35.0	21
6 to 20	25.0	15
20 or more	23.3	14
No answer	6.7	4
	100.0	60

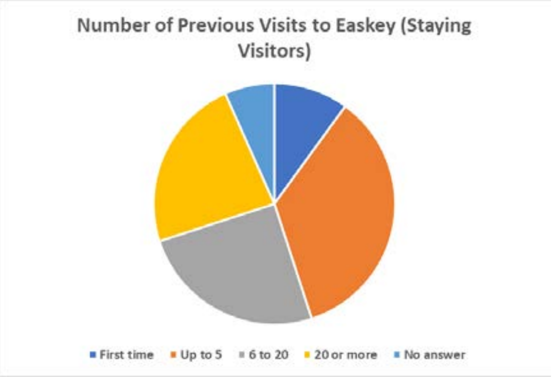


Figure A. 38: Shows that 60% of staying visitors had previously visited Easkey between 5 and 20 times.

Alone or Group?	Staying Visits	
	%	*no.*
Alone	8.3	5
Group	90.0	54
Group	1.7	1
	100.0	60
Mean Adults	***2.8***	
Mean Children	***0.7***	

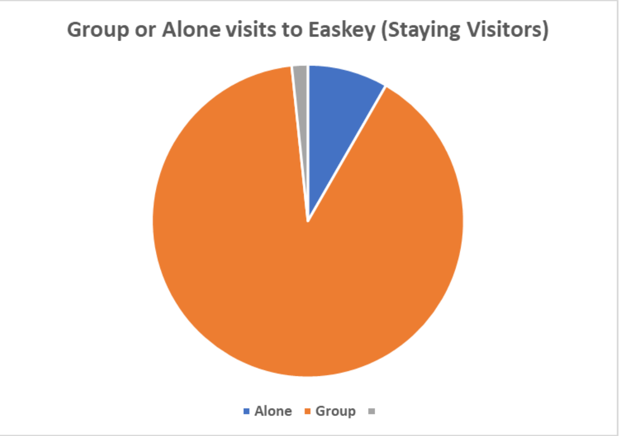


Figure A. 39: Shows that 90% of Staying visitors come in groups.

Nights away from home	%	no.
1 night	5.0	3
2-3 nights	38.3	23
4 to 7 nights	36.7	22
8-14 nights	11.7	7
More than 2 weeks	5.0	3
unknown	3.3	2
	100.0	60

Figure A. 40: Shows three quarters of staying visitors spend between 2 and 7 nights away.

Rating of Coast Road	Staying Visits	
	%	*no.*
10 (Highest)	86.7	52
8	6.7	4
5,6,7	5.0	3
Unknown	1.7	1
	100.0	60

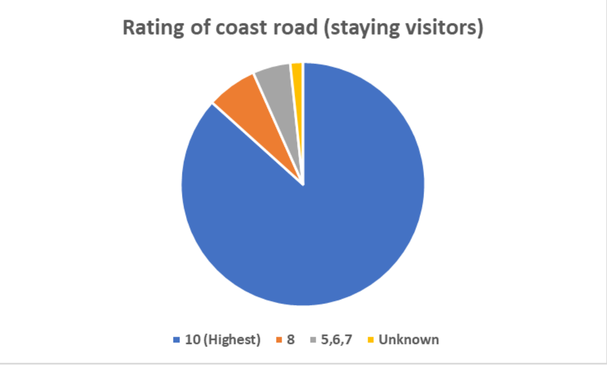


Figure A. 41: Shows over 85% rated the coast road as 10 out of 10.

Visit if coast road was closed due to erosion?	Staying visitors	
	%	no.
Yes	63.3	38
No	25.0	15
Not certain	11.7	7
	100.0	60

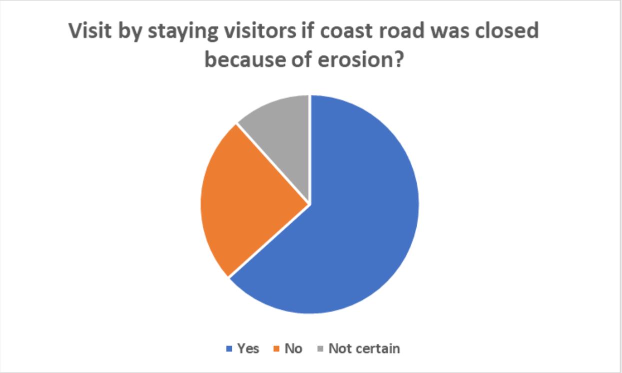


Figure A. 42: Shows almost two thirds of staying visitors said they would still visit the area if the coast road was closed.

Reason for visiting Coast Road	Staying visitors
	no.
Hotel and facilities	13
Beach-based activities (including surfing)	51
Sports and Recreation outside beach	20
Walking and cycling	44
Other (swimming, scenery, WAW, fishing, outdoors)	22
Activity or multiple activity mentioned	

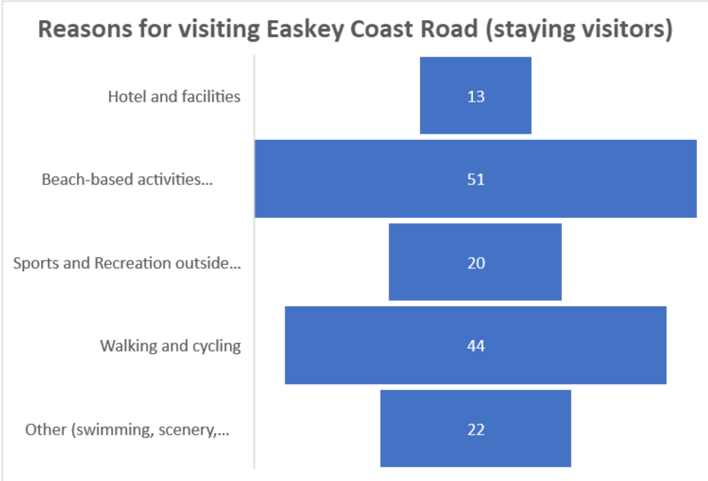


Figure A. 43: Shows that beach based activities were mentioned as the main attraction for staying visitors.

Choice of Alternative Sites	Staying Visits	
	%	no.
Within County Sligo	16.7	10
Other Irish Counties	18.3	11
Abroad (incl. N. ireland)	3.3	2
Not given	61.7	37
	100	60

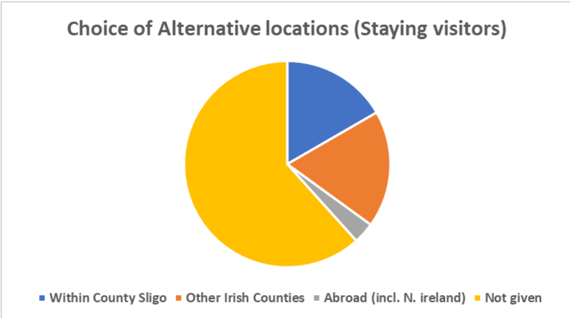


Figure A. : Almost two thirds of staying visitors were unsure about alternative locations though only 2 interviewees said they would go away from Ireland.

Visitor Origin Coast Road	Staying Visits	
	%	
Sligo	0.0	1
Rest of RoI	56.7	34
Northern Ireland	15.0	9
Abroad	26.7	16
	100.0	60

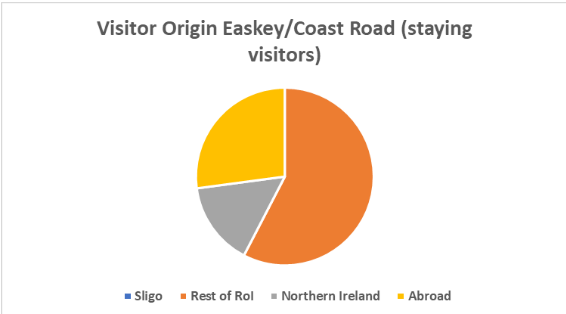


Figure A. 44: Shows that over 70% of staying visitors came from the island of Ireland with around a quarter coming from abroad.

C.2.3.3 Permanent visitors to Easkey

Frequency of visits to coast road	Permanent Residents	
	%	*no.*
At Least Daily	71.4	45
Once or twice per week	23.8	15
At least once per month	4.8	3
Less than once per year	0.0	0
	100.0	63

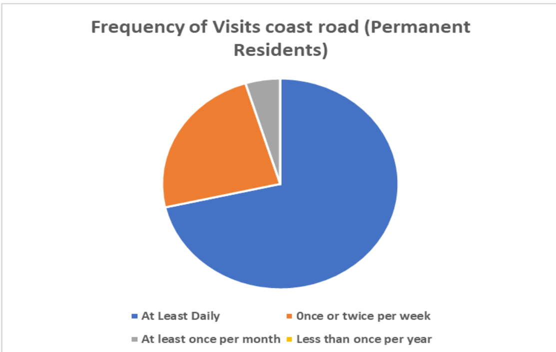


Figure A. 45: Shows that 95% of permanent residents visit either daily or at least once or twice a week.

Length of residency in Easkey	permanent Residents	
	%	no.
5 years or less	11.1	7
6 to 20 years	23.8	15
Greater than 20 years	63.5	40
Unknown	1.6	1
	100.0	63

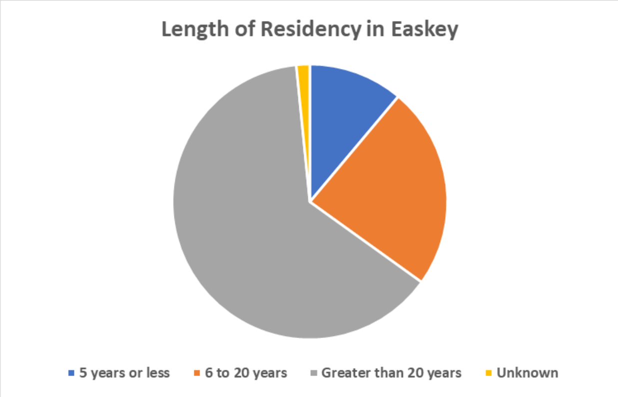


Figure A. 46: Shows that nearly two thirds of permanent residents have lived in Easkey for more than 20 years.

Reason for visiting coast road	Permanent Residents	
	% of sample	*no.*
Beach-based activities (Including Surfing)	33.3%	29
Sport and recreation outside beach area	25.3%	22
Walking / Cycling	62.1%	54
Café/Restaurant/Pub	31.0%	27
Other (work, Swimming)	23.0%	20
Multiple activities mentioned		

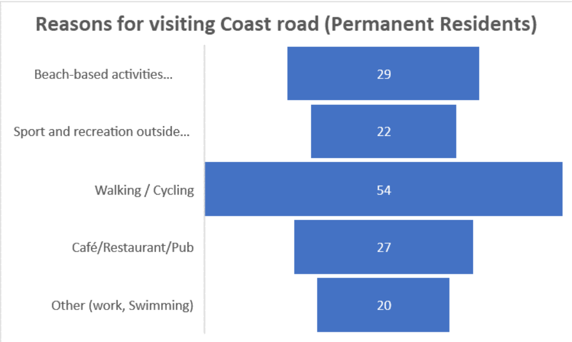


Figure A. 47: Shows nearly two thirds of permanent visitors visit for walking/cycling.

Length of Stay on coast	Permanent Residents	
	%	*no.*
Full Day	4.8	3
Half Day	31.7	20
Less than 1 hour	58.7	37
n/a	4.8	3
	100.0	63

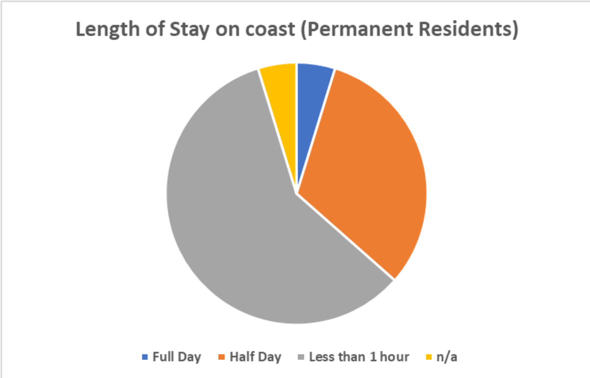


Figure A. 48: Shows just less than 60% of permanent residents spend less than an hour on the coast.

Is Coastal erosion at Easkey a significant risk?		
	%	no.
No	1.6	1
Not Sure	1.6	1
Yes	95.2	60
Yes - drastically	1.6	1
	100.0	63

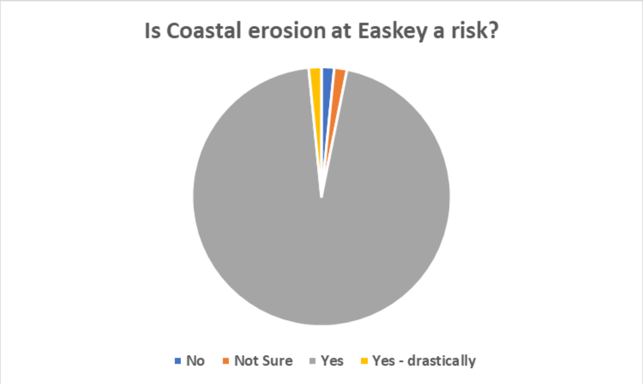


Figure A. 49: Shows that almost 97% of permanent residents felt that coastal erosion is a significant risk.

Rating of Coast Road	Permanent Residents	
	%	no.
10 (Highest)	85.7	54
9	4.8	3
8	4.8	3
5,6,7	4.8	3
	100.0	63

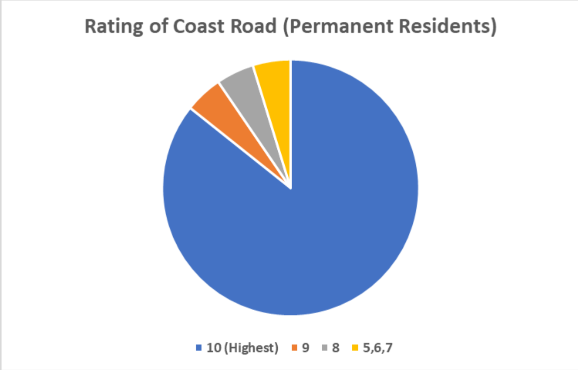


Figure A. 50: Shows that over 90% of permanent residents rated the coast road as =>9 out of 10.

C.2.4 Interviewee Type/Location Comparison

Frequency of Visits	Daily or once or twice per week
	%
Day Visitors (Strandhill)	25.61
Day Visitors (Easkey)	13.51
Staying Visitors (Strandhill)	4.23
Staying Visitors (Easkey)	6.67
Permanent Visitors (Strandhill)	97.70
Permanent Visitors (Easkey)	95.24

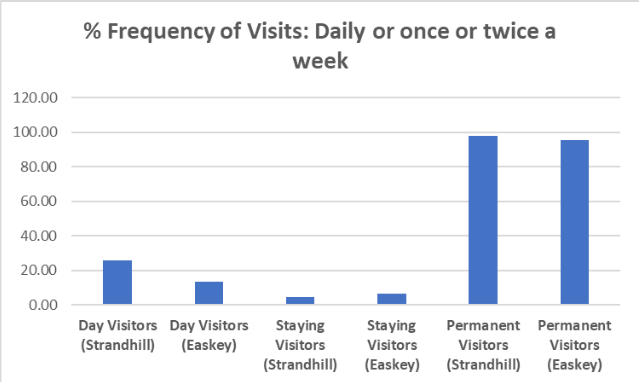


Figure A. 51: Shows, as is to be expected, permanent residents are the most frequent visitors in both Strandhill and Easkey.

Number of Previous Visits	20 or more
	%
Day Visitors (Strandhill)	43.9
Day Visitors (Easkey)	23.0
Staying Visitors (Strandhill)	18.3
Staying Visitors (Easkey)	23.3

Figure A. 52: Shows that day visitors to Strandhill make the most visits.

Beach/Coast Rating	9 and 10
	%
Day Visitors (Strandhill)	90.2
Day Visitors (Easkey)	86.5
Staying Visitors (Strandhill)	88.7
Staying Visitors (Easkey)	86.7
Permanent Visitors (Strandhill)	79.3
Permanent Visitors (Easkey)	90.5

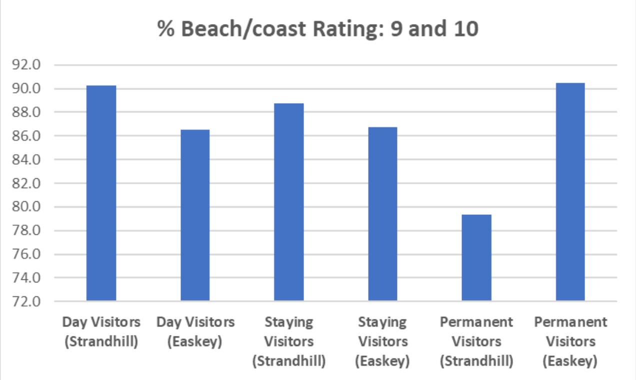


Figure A. 53: Shows all types of visitors rate the beach/coast at almost 80% or greater.

Reasons for Visiting	Beach/coast based
	%
Day Visitors (Strandhill)	59.8
Day Visitors (Easkey)	58.5
Staying Visitors (Strandhill)	66.2
Staying Visitors (Easkey)	51.0
Permanent Visitors (Strandhill)	48.3
Permanent Visitors (Easkey)	33.3

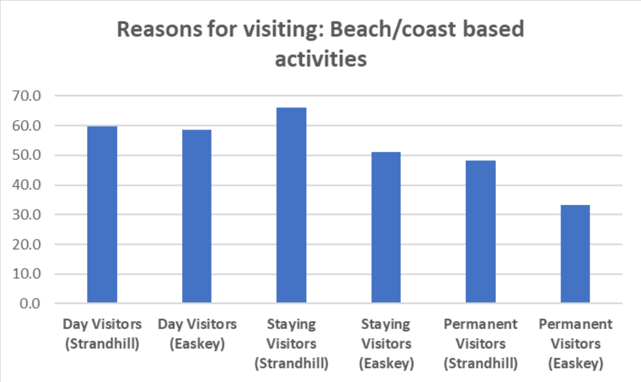


Figure A. 54: Shows the percent of beach/coast-based activities varies with two thirds of staying visitors at Strandhill nominating beach based activities as their primary interest with only one third of Easkey permanent visitors mentioning beach based activities as a key interest.

Choice of alternative sites/holidays	County Sligo
	%
Day Visitors (Strandhill)	68.3
Day Visitors (Easkey)	27.0
Staying Visitors (Strandhill)	39.4
Staying Visitors (Easkey)	16.7

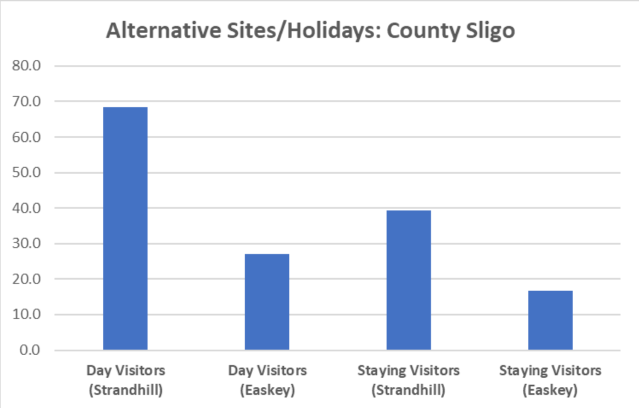


Figure A. 55: Shows that whilst two thirds of day visitors to Strandhill wish to stay in County Sligo as an alternative Easkey visitors are more likely to leave the county.

Visitor origin	From Other Irish Counties
	%
Day Visitors (Strandhill)	57.4
Day Visitors (Easkey)	62.8
Staying Visitors (Strandhill)	57.7
Staying Visitors (Easkey)	56.7

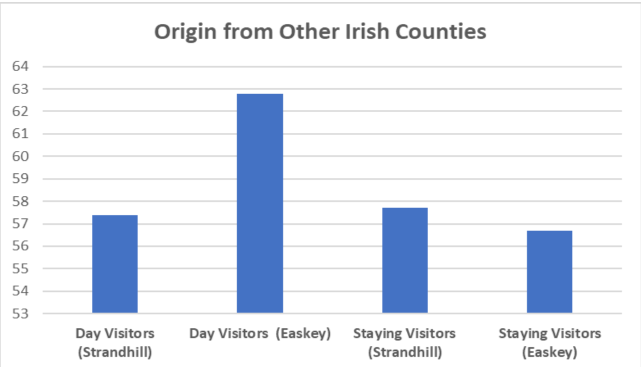


Figure A. 56: Shows most day and staying visitors originate from other Irish counties.

C.2.5 Quantifying Do Nothing Losses

A broad analysis of losses as a result of beach erosion (the “Do Nothing” scenario) follows.

C.2.5.1 Day Visitors

The questionnaire for day visitors was designed to quantify a willingness to pay for a visit to either Strandhill or Easkey against willingness to pay for a visit to an alternative site providing the same level of enjoyment. The difference between these two monetary estimates is considered as the Value of Enjoyment (VoE).

Choosing a suitable/acceptable alternative location may cost more in time and driving costs and this additional cost (or reduced cost) might also be included in the assessment.

Willingness to Pay (Value of Enjoyment)

Day visitors were asked how much they spent at either Strandhill or Easkey per visit, how often they visited, and how much they would spend at an alternative site. A value was computed for the mean and the median[8] value ascribed to the visit for each person or group interviewed:

- Mean expected daily spend at **Strandhill** per interview = **€35.00**
- Mean expected daily spend at alternative site per interview = **€79.00**
- Median expected daily spend at **Strandhill** per interview = **€27.50**
- Median expected daily spend at alternative site per interview = **€55.00**

- Mean expected daily spend at **Easkey** per interview = **€45.00**
- Mean expected daily spend at alternative site per interview = **€115.00**
- Median expected daily spend at **Easkey** per interview = **€20.00**
- Median expected daily spend at alternative site per interview = **€50.00**

The median value Visitors to **Strandhill** were willing to pay ***extra*** per visit was **€27.50**.

The median value Visitors to **Easkey** were willing to pay **extra** per visit was **€30.00.**

Additional Travel costs (car journey value of time (VoT) and Vehicle Operating Costs (VOC))

Table A. 1summarises the additional mean distances from home locations to Strandhill and Easkey and from home locations to a chosen primary alternative (some responses suggested more than one preferred alternative location)[9].

[8] The median value is more representative as this excludes extreme values (both low and high) when using a mean value. It is the 50th percentile of a data array

[9] Travellers originating from overseas were assumed to fly to Dublin with onwards journey by road

Table A. 1: Distances and Time differences between travelling from home base to either Easkey/Strandhill and their preferred alternatives

	Mean distance travelled (km)	Mean Time (hours-minutes)	Km distance difference Alternative to Strandhill/ Easkey)	Time minutes difference
Strandhill day visitors[10]	32	30.7 minutes	2km	-2.3 minutes
Alternative day visitors	34	28.4 minutes		
Strandhill Staying Visitors	181.3	2hrs 28min	-19.9km	-17 minutes
Alternative day visitors	161.4	2 hrs 11 min		
Easkey day visitors	35	33 minutes	-7km	-6 minutes
Alternative day visitors	28	27 minutes		
Easkey staying visitors	195	2hrs 33min	-7km	-4 minutes
Alternative staying visitors	188	2 hrs 29min		

A value of €0.39/km[11] could be used to estimate the per car resource costs of travel (i.e., costs excluding tax and insurance which are financial rather than economic costs). However, apart from journeys by Strandhill day visitors, all distances and times are marginally shorter to selected alternative locations. Furthermore, as Strandhill/Easkey were destinations of choice it would be inappropriate to suggest adjusting the losses to account for improvements in travel distance and time. Estimates of difference in travel resource costs were therefore not included in the loss analysis.

The following quantifications of loss were used in the analysis:

Day Visitors

Value of Enjoyment gained from Strandhill or Easkey was compared with alternative visitor experiences, as per guidance in the MCM Manual; these are legitimate economic benefits and thus the Value of Enjoyment applies to all visitors irrespective of their origin.

To complete this analysis estimates of annual visitors from tourism authorities or similar are required. As the VoE data relates to interviews for day visitors only, it is assumed that visitor numbers are divided by the mean group size in the questionnaire surveys (Table A. 2):

Table A. 2: Day visitor group sizes for Strandhill and Easkey

Location	Type of visitor	Mean Adults/group	Mean children/group	Mean group size
Strandhill	Day	1.7	0.4	2.1
Easkey	Day	2.3	0.2	2.5

Staying visitors

Staying visitors spend money at their accommodation and in nearby pubs, shops, and restaurants. A cautious estimate of €100 per staying group per day was used as an approximate marker of expenditure.

If in extreme circumstances hotel and recreational facilities in Strandhill or Easkey/coast road were unavailable or increasingly more unattractive because of either coastal flooding or erosion, then alternatives might be chosen.

In this case losses incurred would be threefold affecting:

---

[10] Day travellers to both locations were 'cut off assuming a 1 hour drive each way

[11] MCM Online Chapter 6 Table 6.11 Total resource costs of travel as a function of speed (pence/km) (updated to 2020 prices) assuming car speed at average of 50km per hour (0.43 cents per km – updated from £ sterling at 1.20 exchange rate.

1. The local economy i.e., Strandhill or Easkey
2. The Sligo County economy (visitors go to other Irish counties as alternative locations)
3. The National economy (visitors go abroad, including Northern Ireland as alternative locations).

Classical national resource losses to be included in a benefit assessment relate only to scenario 3 but the OPW will accept losses to the Sligo economy where costs of mitigation are funded (partly) by the local authority. Table A. 3 summarises alternative locations to Strandhill for Staying visitors:

Table A. 3: Choice of alternative sites, Strandhill, staying visitors

Choice of Alternative Sites Strandhill	Staying Visits	
	%	no.
County Sligo	39.4	28
Other Irish Counties	49.3	35
Abroad	1.4	1
Northern Ireland	1.4	1
Unknown	8.5	6
	100.0	71

In summary,

- 100% of visitors will be lost to Strandhill (theoretically in worst case scenario)
- 58.8 % of visitors will be lost to County Sligo (including unknown)
- 2.8% of visitors will be lost to the Republic of Ireland.

Table A. 4 summarises alternative locations to Easkey for Staying visitors:

Table A. 4: Alternative choices, Easkey, Staying visitors

Choice of Alternative Sites	Staying Visits	
	%	no.
Within County Sligo	16.7	10
Other Irish Counties	18.3	11
Abroad (incl. N. ireland)	3.3	2
Not given	61.7	37
	100	60

In summary,

- 100% of visitors will be lost to Easkey (theoretically in worst case scenario).
- 83.3% of visitors will be lost to County Sligo (including the 6 locations recorded as unknown)
- 3.3% of visitors will be lost to the Republic of Ireland

Unfortunately, conclusions will be volatile, with 61.7% of staying visitors unsure of their preferred locations.

However, taking a straw poll of where/what those interviewed suggested gave them equal pleasure to the two locations (222 replies) suggested the following (more than 4 times mentioned) **Table A. 5**:

Table A. 5: Top replies when asked which places or activities gave similar enjoyment

Mullaghmore	14
Hiking/walking	11
Donegal	8
Salthill	8
Bundoran	7
Enniscrone	7
Lahinch	7
Kerry	6
Portrush	6
Portugal	6
Restaurant/socialising	6
Rosses Point	6
Tramore	6
Houth	5
Jersey	5
Spain	5

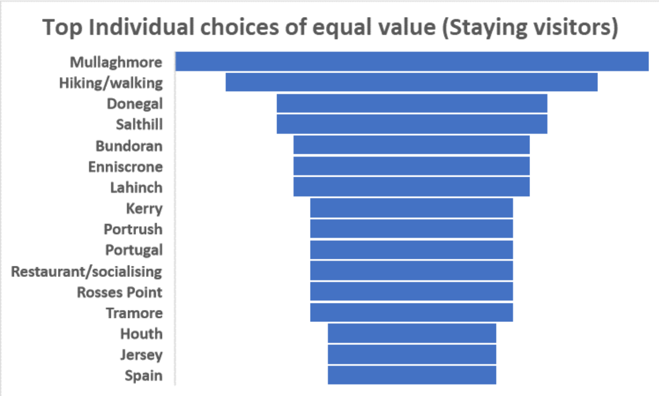
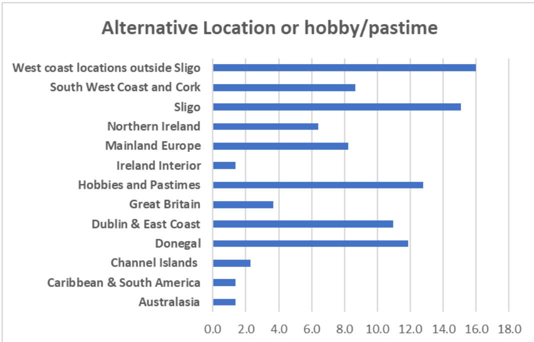


Table A. 6Clusters the replies by activity or destination:

Table A. 6: Destination/activity clusters for alternative locations

Alternative location or hobby/pastime	%	no.
Australasia	1.4	3
Caribbean & South America	1.4	3
Channel Islands	2.3	5
Donegal	11.9	26
Dublin & East Coast	11.0	24
Great Britain	3.7	8
Hobbies and Pastimes	12.8	28
Ireland Interior	1.4	3
Mainland Europe	8.2	18
Northern Ireland	6.4	14
Sligo	15.1	33
South West Coast and Cork	8.7	19
West coast locations outside Sligo	16.0	35
	100.0	219



Filtering location clusters and removing hobbies and pastimes resulted in just the frequency of alternative geographical locations, Table A. 7.

Table A. 7: Clustered alternative geographical locations

Sligo	17.3	33
Other Irish Counties	56.0	107
Northern Ireland	7.3	14
GB and Abroad	19.4	37
	100.0	191

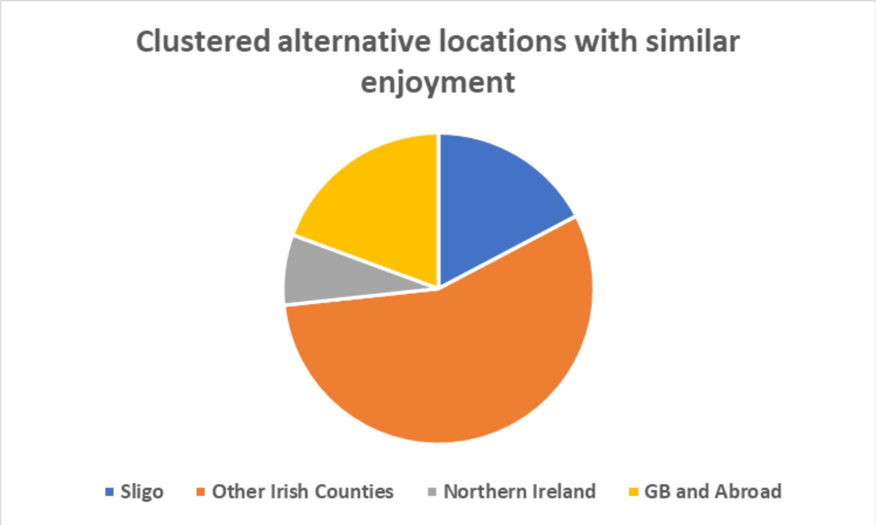


Figure A. 57: Using this data:

- 100% (theoretically in worst case scenario) of visitors will be lost locally
- 82.7% of visitors will be lost to County Sligo
- 26.7% of visitors will be lost to the Republic of Ireland

C.2.6 Monetary losses (Strandhill or Easkey, County Sligo or Republic of Ireland-RoI)

C.2.6.1 Strandhill Visitors

From the Health check report[12] it is clear that 'beach front' is top of the list of what people like most about Strandhill.

In answering the question *"What do you like most about Strandhill?"* the word cloud below illustrates the words used most frequently by respondents. The number of times each word, or term, is mentioned ranged from 9 to 83.

[12] Strandhill Health Check Public survey 2020 commissioned by Strandhill Development Association and Sligo County Council

The word cloud analysis taken from the report demonstrates how many interviewees (83+) mention the Beach front as a prime motivation for visits.

Staying visitors will either stay in the hotels, B&B establishments, in the caravan park, or surf school accommodation. A basic analysis of numbers of visitors using these types of accommodation is required in the absence of detailed statistics.

Strandhill has a 4-star hotel with 22 rooms and a further hotel with 11 bedrooms (besides an undetermined number of B&B's etc.) Conservatively it is assumed 100%[13] occupancy in the 4 summer months which allows for any shortfall in occupancy. This is enhanced by B&B trade (that is if actually only 25 rooms are booked on average there will also be 8 B&B rooms fully occupied, though this is pure conjecture without any detailed survey). With an occupancy of 2 on average, which equates to 66 people for 4 months or 7,920 maybe rounding up conservatively to 10,000 people annually. There will clearly be some all-round occupancy associated with the Wild Atlantic Way and other tourist attractions.

Based on communications with local business owners and Sligo County Council, it is estimated that caravan parks and camping sites etc within the vicinity cater for approximately 75,000 visitor nights.

In respect of other recreational amenities, discussions with one local surf school demonstrated the following typical customer basis:

- May ~ 50 customers per month
- June ~ 500 customers per month
- July ~ 900 customers per month
- August ~ 750 customers per month
- September ~ 130 customers per month
- October ~ 240 customers per month
- November ~ 70 customers per month
- December ~ 20 customers per month

This equates to 2,660 customers per year.

In respect of the other surf schools, it is estimated that for 3-4 days per week, 20-40 surfers visit Strandhill to surf, check the surf or have coffee/snack or a short day trip/overnight trip. When there are no waves, poor weather or unsuitable conditions, there are a negligible number of surfers visiting Strandhill seafront. Conversely, there are 5 to 10 days over the summer when sunny weather or good surf conditions cause the number of visiting surfers to rise to perhaps 100 per day.

Taking 3.5 days on average for 30 surfers per week for 52 weeks gives 5,460 surfers or their followers, but there will statistically be more bad days than good summer days, so the minimum are Sligo surf school estimated numbers and the maximum assuming no poor weather of 5,460. The annual figure for debate would be the mean i.e., 4,060.

As for spending foregone under a "Do Nothing" scenario when the beach front is unsafe or unattractive then:

a) The number of guests staying in hotels at Strandhill could (speculatively) diminish by half, with at €100 per day expenditure foregone per couple in Strandhill then this equates to 2,500 times €100 or €250,000 per year. This is not all lost to Sligo or the RoI but to Strandhill.

b) The caravan site by the same logic would reduce to 37,500 nights per year though some would still relocate to within Sligo or other parts of RoI. All campers (if Strandhill is their first choice of holiday attraction) could be assumed to have forfeited the €27.50 median value additional VoE Strandhill provides for day visitors (as against other locations) or around 1 million Euros.

c) As Strandhill is the premier surf beach in Sligo the application of the €27.50 seems appropriate for the estimated 4,060 annual surfers or €111,650 per year.

It is complicated to separate day visitors from staying visitors as the questionnaire did not define that day visitors were not staying at other locations but just visiting Strandhill for the day.

[13] Accommodation was fully occupied in August 2021, but this may have been skewed because of restrictions of foreign travel due to the COVID 19 pandemic

In summary, it is suggested as a high level estimate without further financial and visitor numbers the following summary of losses is possible per year:

- Staying visitors in Hotel/B&B accommodation = €250,000 per year
- Camping visitors = €1 million per year
- Surfing fraternity = €111,650 per year

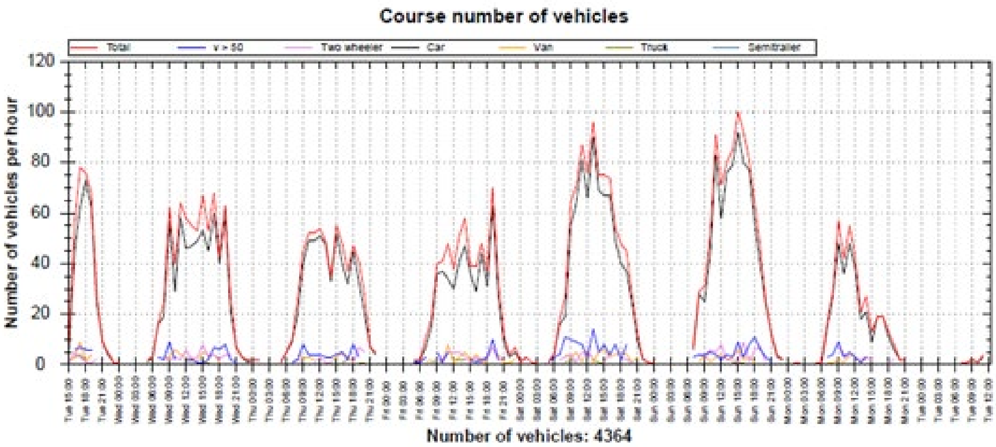
As the coastline degrades, then modest losses initially would increase commensurate to the degradation, and these escalating annual losses (as above) should be reflected in the cost benefit cash flows.

Though a speculative loss of circa €1.3 million to Strandhill per year based on lost income and reduction in the VoE is suggested this would not be a loss to Sligo County or RoI as (see Table 8) 61.1% would relocate to other locations within Sligo and 2.8% to other parts of RoI. It is further expected that post pandemic alternative second choice locations might be outside RoI should the degradation of the coast continue at the current pace.

C.2.6.2 Easkey visitors

As with Strandhill, no firm data of visitor numbers from which estimate monetary losses could be estimated was available. There was however data on vehicle numbers using the coast road:

A 7-day total of traffic using the coast road totals 3,826 cars out of 4,364 in total including 246 2-wheelers) between 14 hours 50 14/9/21 and 12 hours 17 21/9/21 equivalent to 546 cars a day, as can be seen in Figure A. 58



Evaluation time	Tuesday 14 September 2021,14:50 till Tuesday 21 September 2021,12:17						
Speed limit	50	km/h		Number	Vd[km/h]	Vmax[km/h]	V85[km/h]
Speed violations:	8.59	%	Two wheeler	246	15.83	62	28
Average gap time:	136.40	s	Car	3826	38.80	76	48
Queue traffic:	4.38	%	Van	224	35.50	55	44
ADT (Av. daily traffic):	633		Truck	64	30.64	49	41
LGV traffic share:	1.60	%	Semitrailer	4	22.00	38	38
Measurement location:	L-2401-0 50m from Secondary scho ol		Total	4364	37.20	76	47

Figure A. 58:Summary of 7 day traffic survey conducted on coastal roads at Easkey.

A 14-day total of traffic using coast road (3184/6716 in total with an extraordinary high 2-wheeler count of 3284) between 10 hours 41 26/10/21 and 8/11/21 equivalent to 227 per day or less than half of September totals, as presented in the Figure.

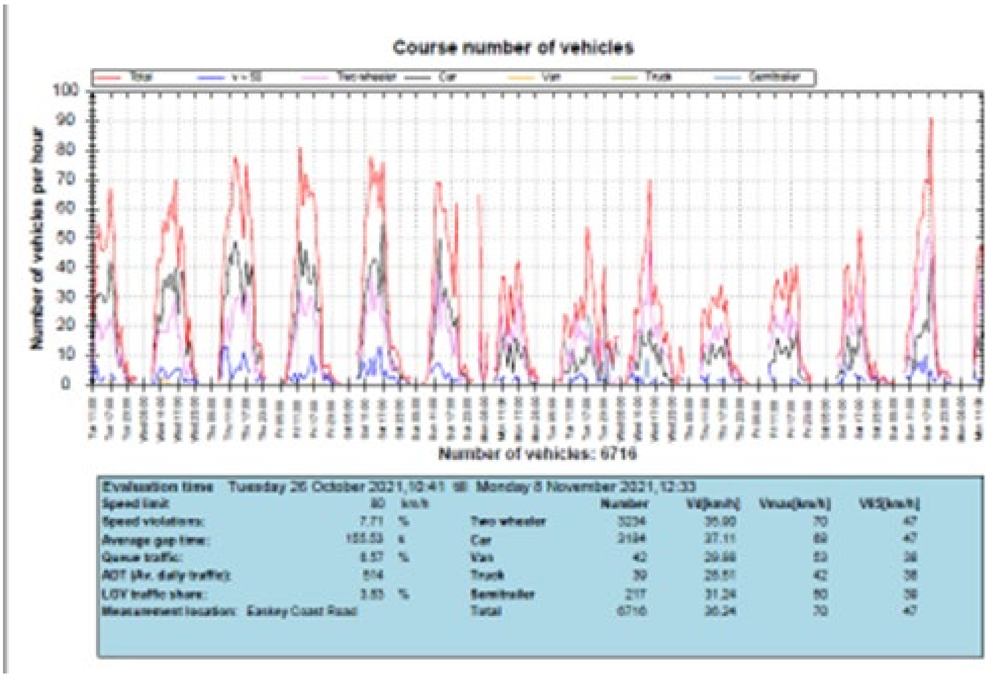


Figure A. 59: Summary of 14 day traffic survey conducted on coastal roads at Easkey.

With no information to differentiate staying and day visitors at Easkey, traffic count data has instead been used to derive a value of enjoyment based on an average of 386 cars per day.

Assuming the estimated €30 median figure for VoE, then restricting this route as coastal degradation progresses will incur losses of €23,190 per day or €4.2 million per year. It is unclear how much of this traffic is tourist traffic and how much is local traffic, but continued coastal degradation would have impact, and thus must be reflected in the cost benefit cash flows, as also suggested for Strandhill. Using an annual VoE lost to Easkey as €2 million is regarded as conservative.

It should be noted that this value could readily be doubled to €8.4 million per year if it is assumed that on average, two people travel in every car instead of just one, i.e.:

- 1 person per car * 386 cars * €30 * 365 = €4.2 million per year
- 2 person per car * 386 cars * €30 euros * 365 = €8.4 million per year

C.2.7 Conclusions

It is clear from the questionnaire analysis that ratings of the beach and coast road as reasons for visiting both locations are high, with more 90% of all visitors suggesting that erosion is a significant risk. Further degradation of the coast will create problems for those either involved in enjoying the Wild Atlantic Way at Easkey or using the beach for surfing and recreation in the popular Strandhill resort. This will have an economic effect on the two locations especially Strandhill whose hotels and cafes and restaurants will suffer. These costs are estimated by both reduction in spending at Strandhill and loss of the value of enjoyment in both locations.

In turn, Hotels, cafes and restaurants would suffer loss of trade but financial losses which can be transferred to other parts of Sligo or RoI cannot be considered as monetary losses. Only losses to RoI (i.e., national losses) are allowable in coastal management cost benefit analysis. However, VoE is an economic loss as recognised in the MCM Handbook and acceptable in appraisals submitted to OPW. The differential in VoE in both Strandhill and Easkey is therefore a part of the legitimate losses suffered progressively as beach and coast degradation continues apace. The pace of these losses as Atlantic storms continue to attack the coast under a “Do Nothing” scenario are speculative and must in some way be reflected in the Cost Benefit Analysis.

This study is an overview with commensurate resources and the visitor numbers applied to the unit losses of differential VoE and income from accommodation and catering are speculative. Where possible, survey information and visitor numbers should be confirmed with tourist authorities.

JB Chatterton, J Chatterton Associates 18th May 2022

Appendix D Cost Benefit Analysis

D.1 Easkey Cost Benefit Analyses (FCDPAG3)

D.1.1 Easkey project summary sheet

Project Summary Sheet

Client/Authority		Prepared (date)	
Sligo County Council		Printed	15/09/2022
Project name		Prepared by	KC
Sligo Bay CFERM Assessment		Checked by	MB
Project reference	IBE1902	Checked date	
Base date for estimates (year 0)	Sep-2022		
Scaling factor (e.g. £m, £k, £)	€	(used for all costs, losses and benefits)	
Principle land use band	C	(A to E)	
Discount rate	4%		

Costs and benefits of options

	Costs and benefits €				
	Do nothing	Option 1	Option 2		
PV costs PVc	-	11,676,268.73	2,848,948.84	-	-
PV damage PVd	40,130,123.11	1,110.73	1,110.73	-	-
PV damage avoided		40,129,012.38	40,129,012.38		
PV assets Pva	-	-	-	-	-
PV asset protection benefits		-	-		
Total PV benefits PVb		40,129,012.38	40,129,012.38		
Net Present Value NPV		28,452,743.65	37,280,063.54		
Average benefit/cost ratio		3.44	14.09		
Incremental benefit/cost ratio			-		
		-	Highest b/c		

Brief description of options:

Do nothing	Do nothing
Opt. 1 Rock Armour	Rock armour along entire cost
Opt. 2 Road re-alignment	Road re-alignment

Notes:

1) Benefits will normally be expressed either in terms of damage avoided or asset values protected. Care is needed to avoid double counting
2) PV damage avoided is calculated as PV damage (No Project) - PV damage (Option)
PV asset protection benefits are calculated as PVa (Option) - PVa (No Project)
PV benefits calculated as PV damage avoided + PV asset protection benefits
3) Incremental benefit/cost ratio is calculated as:
(PVb(current option) - PVb(previous option))/(PVc(current option) - PVc(previous option))

D.1.2 Easkey PV loses

Client/Authority
Sligo County Council
Project name
Sligo Bay CFERM Assessment

Project reference	IBE1902	
Base date for estimates (year 0)	Sep-2022	
Scaling factor (e.g. £m, £k, £)	€	
Discount rate	4%	

year	Discount Factor	Do nothing Recreation	Flooding - AAD		TOTALS	PV
	cash sum	82,000,000.00	0.00	0.00	182,000,000.00	40,095,477.79
0	1.000	0			0.00	0.00
1	0.966	0			0.00	0.00
2	0.934	0			0.00	0.00
3	0.902	0			0.00	0.00
4	0.871	0			0.00	0.00
5	0.842	0			0.00	0.00
6	0.814	0			0.00	0.00
7	0.786	0			0.00	0.00
8	0.759	0			0.00	0.00
9	0.734	0			0.00	0.00
10	0.709	2000000			2000000.00	1417837.63
11	0.685	2000000			2000000.00	1369891.43
12	0.662	2000000			2000000.00	1323566.60
13	0.639	2000000			2000000.00	1278808.31
14	0.618	2000000			2000000.00	1235563.58
15	0.597	2000000			2000000.00	1193781.24
16	0.577	2000000			2000000.00	1153411.82
17	0.557	2000000			2000000.00	1114407.56
18	0.538	2000000			2000000.00	1076722.28
19	0.520	2000000			2000000.00	1040311.38
20	0.503	2000000			2000000.00	1005131.77
21	0.486	2000000			2000000.00	971141.81
22	0.469	2000000			2000000.00	938301.26
23	0.453	2000000			2000000.00	906571.27
24	0.438	2000000			2000000.00	875914.27
25	0.423	2000000			2000000.00	846293.98
26	0.409	2000000			2000000.00	817675.34
27	0.395	2000000			2000000.00	790024.48
28	0.382	2000000			2000000.00	763308.68
29	0.369	2000000			2000000.00	737496.31
30	0.356	2000000			2000000.00	712556.82
31	0.344	2000000			2000000.00	688460.70
32	0.333	2000000			2000000.00	665179.42
33	0.321	2000000			2000000.00	642685.43
34	0.310	2000000			2000000.00	620952.10
35	0.300	2000000			2000000.00	599953.72
36	0.290	2000000			2000000.00	579665.43
37	0.280	2000000			2000000.00	560063.22
38	0.271	2000000			2000000.00	541123.88
39	0.261	2000000			2000000.00	522825.01
40	0.253	2000000			2000000.00	505144.94
41	0.244	2000000			2000000.00	488062.74
42	0.236	2000000			2000000.00	471558.20
43	0.228	2000000			2000000.00	455611.79
44	0.220	2000000			2000000.00	440204.63
45	0.213	2000000			2000000.00	425318.48
46	0.205	2000000			2000000.00	410935.73
47	0.199	2000000			2000000.00	397039.35
48	0.192	2000000			2000000.00	383612.90
49	0.185	2000000			2000000.00	370640.49
50	0.179	2000000			2000000.00	358106.75

Client/Authority
Sligo County Council
Project name
Sligo Bay CFERM Assessment

Project reference	IBE1902	
Base date for estimates (year 0)	Sep-2022	
Scaling factor (e.g. £m, £k, £)	€	
Discount rate	4%	

year	Discount Factor	Do nothing Recreation	Flooding - AAD		TOTALS	PV
	cash sum	82,000,000.00	0.00	0.00	182,000,000.00	40,095,477.79
50	0.179	2000000			2000000.00	358106.75
51	0.173	2000000			2000000.00	345996.86
52	0.167	2000000			2000000.00	334296.48
53	0.161	2000000			2000000.00	322991.77
54	0.156	2000000			2000000.00	312069.34
55	0.151	2000000			2000000.00	301516.27
56	0.146	2000000			2000000.00	291320.07
57	0.141	2000000			2000000.00	281468.67
58	0.136	2000000			2000000.00	271950.40
59	0.131	2000000			2000000.00	262754.01
60	0.127	2000000			2000000.00	253868.61
61	0.123	2000000			2000000.00	245283.68
62	0.118	2000000			2000000.00	236989.07
63	0.114	2000000			2000000.00	228974.94
64	0.111	2000000			2000000.00	221231.83
65	0.107	2000000			2000000.00	213750.56
66	0.103	2000000			2000000.00	206522.28
67	0.100	2000000			2000000.00	199538.43
68	0.096	2000000			2000000.00	192790.76
69	0.093	2000000			2000000.00	186271.26
70	0.090	2000000			2000000.00	179972.24
71	0.087	2000000			2000000.00	173886.22
72	0.084	2000000			2000000.00	168006.01
73	0.081	2000000			2000000.00	162324.64
74	0.078	2000000			2000000.00	156835.41
75	0.076	2000000			2000000.00	151531.79
76	0.073	2000000			2000000.00	146407.53
77	0.071	2000000			2000000.00	141456.55
78	0.068	2000000			2000000.00	136673.00
79	0.066	2000000			2000000.00	132051.20
80	0.064	2000000			2000000.00	127585.70
81	0.062	2000000			2000000.00	123271.21
82	0.060	2000000			2000000.00	119102.62
83	0.058	2000000			2000000.00	115074.99
84	0.056	2000000			2000000.00	111183.57
85	0.054	2000000			2000000.00	107423.74
86	0.052	2000000			2000000.00	103791.05
87	0.050	2000000			2000000.00	100281.21
88	0.048	2000000			2000000.00	96890.06
89	0.047	2000000			2000000.00	93613.58
90	0.045	2000000			2000000.00	90447.91
91	0.044	2000000			2000000.00	87389.28
92	0.042	2000000			2000000.00	84434.09
93	0.041	2000000			2000000.00	81578.83
94	0.039	2000000			2000000.00	78820.12
95	0.038	2000000			2000000.00	76154.71
96	0.037	2000000			2000000.00	73579.43
97	0.036	2000000			2000000.00	71091.24
98	0.034	2000000			2000000.00	68687.18
99	0.033	2000000			2000000.00	66364.43
100	0.032	2000000			2000000.00	64120.22

D.1.3 Easkey PV costs

Present Value Costs for all options

Sheet Nr.

Client/Authority		Prepared (date)	
Sligo County Council		Printed	15/09/2022
Project name		Prepared by	
Sligo Bay CFERM Assessment		Checked by	
Project reference	IBE1902	Checked date	
Base date for estimates (year (	Sep-2022		
Scaling factor (e.g. £m, £k, £)	€		
Discount rate	4%		

Results €

	Do nothing	Opt. 1 Rock Armour	Opt. 2 Road re-alignment	0
PV total costs	0.00	11676268.73	2848948.84	0.00

		Do nothing			TOTALS:		Opt. 1 Rock Armour			TOTALS:		Opt. 2 Road re-alignment			TOTALS:				0	TOTALS:	
		Capital	Maint.	Other	Cash	PV	Capital	other	Other	Cash	PV	Capital	other	Other	Cash	PV	Capital	Maint.	Other	Cash	PV
	cash sum	0	0	0	0.00	0.00	16368000	0	0	16368000.00	11676268.73	2476560.13	809239.4	0	3285799.53	2848948.84	0	0	0	0.00	0.00
year	Discount Factor																				
0	1.000				0.00	0.00	10230000			10230000.00	10230000.00	1905046.25	809239.4		2714285.65	2714285.65				0.00	0.00
1	0.966				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
2	0.934				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
3	0.902				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
4	0.871				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
5	0.842				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
6	0.814				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
7	0.786				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
8	0.759				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
9	0.734				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
10	0.709				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
11	0.685				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
12	0.662				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
13	0.639				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
14	0.618				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
15	0.597				0.00	0.00	1023000			1023000.00	610619.10	95252.3125			95252.31	56855.21				0.00	0.00
16	0.577				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
17	0.557				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
18	0.538				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
19	0.520				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
20	0.503				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
21	0.486				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
22	0.469				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
23	0.453				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
24	0.438				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
25	0.423				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
26	0.409				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
27	0.395				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
28	0.382				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
29	0.369				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
30	0.356				0.00	0.00	1023000			1023000.00	364472.81	95252.3125			95252.31	33936.34				0.00	0.00
31	0.344				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
32	0.333				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
33	0.321				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
34	0.310				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
35	0.300				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
36	0.290				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
37	0.280				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
38	0.271				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
39	0.261				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
40	0.253				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
41	0.244				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
42	0.236				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
43	0.228				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
44	0.220				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
45	0.213				0.00	0.00	1023000			1023000.00	217550.40	95252.3125			95252.31	20256.28				0.00	0.00
46	0.205				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
47	0.199				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
48	0.192				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
49	0.185				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
50	0.179				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
51	0.173				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
52	0.167				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
53	0.161				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
54	0.156				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
55	0.151				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
56	0.146				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
57	0.141				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
58	0.136				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
59	0.131				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
60	0.127				0.00	0.00	1023000			1023000.00	129853.79	95252.3125			95252.31	12090.79				0.00	0.00
61	0.123				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
62	0.118				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
63	0.114				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
64	0.111				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
65	0.107				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
66	0.103				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
67	0.100				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
68	0.096				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
69	0.093				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
70	0.090				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
71	0.087				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
72	0.084				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
73	0.081				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
74	0.078				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
75	0.076				0.00	0.00	1023000			1023000.00	77508.51	95252.3125			95252.31	7216.88				0.00	0.00
76	0.073				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
77	0.071				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
78	0.068				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
79	0.066				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
80	0.064				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
81	0.062				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
82	0.060				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
83	0.058				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
84	0.056				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
85	0.054				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
86	0.052				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
87	0.050				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
88	0.048				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
89	0.047				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
90	0.045				0.00	0.00	1023000			1023000.00	46264.10	95252.3125			95252.31	4307.69				0.00	0.00
91	0.044				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
92	0.042				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
93	0.041				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
94	0.039				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
95	0.038				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
96	0.037				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
97	0.036				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
98	0.034				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
99	0.033				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00
100	0.032				0.00	0.00				0.00	0.00				0.00	0.00				0.00	0.00

D.1.4 Easkey PV erosion loses

Erosion Loss Calculation Sheet with delay options

Sheet Nr.

Client/Authority				
Sligo County Council				
Project name		**Option:**	**Delay (yrs)**	Prepared (date)
Sligo Bay CFERM Assessment		Opt. 1 Rock Armour	100	Printed 15/09/2022
Project reference	**IBE1902**		0	Prepared by
Base date for estimates (year 0)	**Sep-2022**		0	Checked by
Scaling factor (e.g. £m, £k, £)	**€**		0	Checked date
Discount rate	**4%**			

Ref	Asset Description	MV €	Year	Prob of loss without project in year	Expected value of asset losses € Without Project	Opt. 1 Rock Armour
0	Land lost to erosion, *c.* 0.85ha	**14696.50**	10	1	10,418.63	334.02
1	Land lost to erosion, *c.* 0.85ha	**14696.50**	20	1	7,385.96	236.79
2	Land lost to erosion, *c.* 0.85ha	**14696.50**	30	1	5,236.05	167.87
3	Land lost to erosion, *c.* 0.85ha	**14696.50**	40	1	3,711.93	119.00
4	Land lost to erosion, *c.* 0.85ha	**14696.50**	50	1	2,631.46	84.36
5	Land lost to erosion, *c.* 0.85ha	**14696.50**	60	1	1,865.49	59.81
6	Land lost to erosion, *c.* 0.85ha	**14696.50**	70	1	1,322.48	42.40
7	Land lost to erosion, *c.* 0.85ha	**14696.50**	80	1	937.53	30.06
8	Land lost to erosion, *c.* 0.85ha	**14696.50**	90	1	664.63	21.31
9	Land lost to erosion, *c.* 0.85ha	**14696.50**	100	1	471.17	15.11
Totals		58786.00			34645.33	1110.73

Notes
Make one entry in the description column for each property (or group of properties) as this determines subsequent calculation
MV = risk free market value at base date for estimate - must be entered on each line when probaility distribution is used
Equivalent annual value = MV x discount rate (assumes infinite life)
Year is year in which there is the probability of loss shown, years must be entered consecutively for each property or group
If no distribution is used enter year of expected year of loss and enter 1.0 in probability column
Columns G to K show expected values of asset losses with each option, assuming extensions of life entered above
The loss is calculated using the formula PV loss = MV * Prob of loss * (1 - (1 - 1/((1+r)^(Year of loss))) = MV * Prob of loss / ((1+r)^(Year of loss))
Additional properties can be entered by inserting lines above line 62 and copying all formulae, including hidden calculation in column C

Net Present Value over time

Sheet Nr.

Client/Authority			
Sligo County Council		Prepared (date)	
Project name		Printed	15/09/2022
Sligo Bay CFERM Assessment		Prepared by	
Project reference	IBE1902	Checked by	
Base date for estimates (year 0)	Sep-2022	Checked date	
Scaling factor (e.g. £m, £k, £)	€		
Discount rate	4%		

D.2 Strandhill Cost Benefit Analyses (FCDPAG3)

D.2.1 Strandhill project summary sheet

Project Summary Sheet

Client/Authority		Prepared (date)	
Sligo County Council		Printed	15/09/2022
Project name		Prepared by	KC
Sligo Bay CFERM Assessment		Checked by	MB
Project reference	IBE1907	Checked date	
Base date for estimates (year 0)	Sep-2022		
Scaling factor (e.g. £m, £k, £)	€	(used for all costs, losses and benefits)	
Principle land use band	C	(A to E)	
Discount rate	4%		

Costs and benefits of options

	Costs and benefits €				
	Do nothing	Opt. 1 Rock armour	Opt. 2 Rock armour & Groyne		
PV costs PVc	-	7,991,127.74	5,653,272.55	-	-
PV damage PVd	11,415,614.54	1,110.73	1,110.73	-	-
PV damage avoided		11,414,503.81	11,414,503.81		
PV assets Pva	-	-	-	-	-
PV asset protection benefits		-	-		
Total PV benefits PVb		11,414,503.81	11,414,503.81		
Net Present Value NPV		3,423,376.07	5,761,231.26		
Average benefit/cost ratio		1.43	2.02		
Incremental benefit/cost ratio			-		
		-	Highest b/c		

Brief description of options:

Do nothing	Do nothing
Opt. 1 Rock armour	Complete rock armour solution
Opt. 2 Rock armour & Groyne	Rock armour, groyne and nourishmnet

Notes:

1) Benefits will normally be expressed either in terms of damage avoided or asset values protected. Care is needed to avoid double counting

2) PV damage avoided is calculated as PV damage (No Project) - PV damage (Option)
PV asset protection benefits are calculated as PVa (Option) - PVa (No Project)
PV benefits calculated as PV damage avoided + PV asset protection benefits

3) Incremental benefit/cost ratio is calculated as:
(PVb(current option) - PVb(previous option))/(PVc(current option) - PVc(previous option))

D.2.2 Strandhill PV loses

Client/Authority	
Sligo County Council	
Project name	
Sligo Bay CFERM Assessment	
Project reference	IBE1907
Base date for estimates (year 0)	Sep-2022
Scaling factor (e.g. £m, £k, £)	€
Discount rate	4%

		Do nothing						
		Camping	Staying Visitors	Recreation - Surfing	Flood AAD	Emergency	TOTALS	PV
	cash sum	12859773.21	3005426.981	671111.845	2305200		69957362.27	11380969.21
year	Discount Factor							
0	1.000	85119	20635	4608	46104	3734	160200.71	160200.71
1	0.966	89997	21817	4872	46104	3734	166524.72	160893.45
2	0.934	95014	23034	5143	46104	3734	173029.82	161525.19
3	0.902	100100	24267	5419	46104	3734	179623.96	162010.52
4	0.871	105272	25521	5699	46104	3734	186329.86	162375.71
5	0.842	110610	26814	5988	46104	3734	193250.13	162711.43
6	0.814	115999	28121	6279	46104	3734	200237.26	162893.14
7	0.786	121483	29450	6576	46104	3734	207348.27	162973.86
8	0.759	127123	30818	6882	46104	3734	214660.51	163015.67
9	0.734	132844	32205	7191	46104	3734	222078.18	162945.64
10	0.709	138681	33620	7507	46104	3734	229646.72	162800.88
11	0.685	144687	35076	7832	46104	3734	237433.44	162629.02
12	0.662	150780	36553	8162	46104	3734	245333.45	162357.58
13	0.639	156980	38056	8498	46104	3734	253371.68	162006.90
14	0.618	163285	39584	8839	46104	3734	261546.38	161578.59
15	0.597	169729	41146	9188	46104	3734	269901.47	161101.65
16	0.577	176292	42738	9543	46104	3734	278411.52	160561.57
17	0.557	182997	44363	9906	46104	3734	287104.81	159975.88
18	0.538	189766	46004	10273	46104	3734	295881.16	159290.92
19	0.520	196621	47666	10644	46104	3734	304768.34	158526.99
20	0.503	203683	49378	11026	46104	3734	313924.67	157767.83
21	0.486	210869	51120	11415	46104	3734	323242.43	156957.12
22	0.469	218096	52872	11806	46104	3734	332612.57	156045.39
23	0.453	225470	54660	12205	46104	3734	342173.85	155102.49
24	0.438	232963	56476	12611	46104	3734	351888.41	154112.04
25	0.423	240558	58317	13022	46104	3734	361736.03	153067.51
26	0.409	248285	60190	13440	46104	3734	371754.02	151987.05
27	0.395	256066	62077	13862	46104	3734	381842.21	150832.35
28	0.382	263939	63985	14288	46104	3734	392050.78	149627.88
29	0.369	271958	65929	14722	46104	3734	402447.77	148401.87
30	0.356	280025	67885	15159	46104	3734	412907.11	147109.89
31	0.344	288222	69872	15602	46104	3734	423534.51	145793.43
32	0.333	296561	71894	16054	46104	3734	434347.19	144459.41
33	0.321	304952	73928	16508	46104	3734	445226.20	143070.19
34	0.310	313472	75993	16969	46104	3734	456272.70	141661.75
35	0.300	322109	78087	17437	46104	3734	467470.77	140230.41
36	0.290	330816	80198	17908	46104	3734	478760.25	138760.38
37	0.280	339614	82331	18384	46104	3734	490167.27	137262.33
38	0.271	348595	84508	18871	46104	3734	501811.55	135771.11
39	0.261	357668	86707	19362	46104	3734	513576.11	134255.22
40	0.253	366732	88905	19852	46104	3734	525328.03	132683.40
41	0.244	375813	91106	20344	46104	3734	537101.23	131069.55
42	0.236	385045	93344	20844	46104	3734	549070.90	129459.44
43	0.228	394425	95618	21352	46104	3734	561233.35	127852.27
44	0.220	403885	97912	21864	46104	3734	573499.20	126228.50
45	0.213	413452	100231	22382	46104	3734	585903.13	124597.71
46	0.205	423010	102548	22899	46104	3734	598295.17	122930.43
47	0.199	432694	104896	23423	46104	3734	610851.35	121266.01
48	0.192	442572	107290	23958	46104	3734	623658.76	119621.77
49	0.185	452458	109687	24493	46104	3734	636476.42	117951.96
50	0.179	462387	112094	25031	46104	3734	649349.68	116268.25

Client/Authority	
Sligo County Council	
Project name	
Sligo Bay CFERM Assessment	
Project reference	IBE1907
Base date for estimates (year 0)	Sep-2022
Scaling factor (e.g. £m, £k, £)	€
Discount rate	4%

		Do nothing						
		Camping	Staying Visitors	Recreation - Surfing	Flood AAD	Emergency	TOTALS	PV
	cash sum	12859773.21	3005426.981	671111.845	2305200		69957362.27	11380969.21
year	Discount Factor							
50	0.179	462387	112094	25031	46104	3734	649349.68	116268.25
51	0.173	472388	114518	25572	46104	3734	662316.69	114579.75
52	0.167	482535	116978	26121	46104	3734	675472.78	112904.09
53	0.161	492716	119446	26672	46104	3734	688672.83	111217.83
54	0.156	503002	121940	27229	46104	3734	702009.98	109537.90
55	0.151	513298	124436	27787	46104	3734	715359.22	107846.22
56	0.146	523705	126959	28350	46104	3734	728852.07	106164.62
57	0.141	534159	129493	28916	46104	3734	742405.93	104482.00
58	0.136	544696	132048	29486	46104	3734	756068.48	102806.56
59	0.131	555337	134627	30062	46104	3734	769864.90	101142.55
60	0.127	565992	137210	30639	46104	3734	783679.15	99475.77
61	0.123	576675	139800	31217	46104	3734	797530.84	97810.65
62	0.118	587431	142407	31800	46104	3734	811476.26	96155.50
63	0.114	598374	145060	32392	46104	3734	825664.82	94528.28
64	0.111	609176	147679	32977	46104	3734	839670.38	92880.91
65	0.107	620242	150362	33576	46104	3734	854018.05	91273.42
66	0.103	631298	153042	34174	46104	3734	868352.49	89667.07
67	0.100	642488	155755	34780	46104	3734	882861.36	88082.39
68	0.096	653809	158499	35393	46104	3734	897539.37	86518.65
69	0.093	665077	161231	36003	46104	3734	912148.67	84953.54
70	0.090	676542	164010	36623	46104	3734	927014.49	83418.43
71	0.087	687983	166784	37243	46104	3734	941847.63	81887.16
72	0.084	699570	169593	37870	46104	3734	956871.21	80380.06
73	0.081	711150	172400	38497	46104	3734	971885.78	78880.51
74	0.078	722638	175185	39119	46104	3734	986779.56	77380.99
75	0.076	734330	178019	39752	46104	3734	1001939.57	75912.85
76	0.073	746018	180853	40384	46104	3734	1017093.23	74455.05
77	0.071	757768	183701	41021	46104	3734	1032328.32	73014.80
78	0.068	769366	186513	41648	46104	3734	1047365.51	71573.29
79	0.066	781176	189376	42288	46104	3734	1062678.13	70163.96
80	0.064	793013	192246	42928	46104	3734	1078026.05	68770.36
81	0.062	804762	195094	43564	46104	3734	1093258.26	67383.63
82	0.060	816621	197969	44206	46104	3734	1108635.02	66020.67
83	0.058	828477	200843	44848	46104	3734	1124005.97	64672.49
84	0.056	840499	203757	45499	46104	3734	1139593.98	63352.06
85	0.054	852441	206652	46145	46104	3734	1155077.48	62041.37
86	0.052	864354	209540	46790	46104	3734	1170523.04	60744.91
87	0.050	876316	212440	47438	46104	3734	1186032.83	59468.40
88	0.048	888219	215326	48082	46104	3734	1201465.33	58205.02
89	0.047	900298	218254	48736	46104	3734	1217126.36	56969.78
90	0.045	912237	221148	49382	46104	3734	1232605.67	55743.30
91	0.044	924266	224065	50034	46104	3734	1248202.88	54539.78
92	0.042	936261	226972	50683	46104	3734	1263755.26	53352.01
93	0.041	948080	229838	51323	46104	3734	1279078.74	52172.87
94	0.039	959967	232719	51966	46104	3734	1294490.67	51015.96
95	0.038	971830	235595	52608	46104	3734	1309872.42	49876.48
96	0.037	983658	238463	53249	46104	3734	1325207.61	48754.01
97	0.036	995607	241359	53896	46104	3734	1340700.25	47656.02
98	0.034	1007585	244263	54544	46104	3734	1356230.18	46577.82
99	0.033	1019437	247136	55186	46104	3734	1371597.21	45512.63
100	0.032	1031250	250000	55825	46104	3734	1386913.42	44464.60

D.2.3 Strandhill PV costs

Present Value Costs for all options

Client/Authority
Sligo County Council
Project name
Sligo Bay CFERM Assessment
Project reference IBE1907
Base date for estimates (year (Sep-2022
Scaling factor (e.g. £m, £k, £) €
Discount rate 4%

Results €

	Do nothing	Opt. 1 Rock armour	Opt. 2 Rock armour & Groyne	0
PV total costs	0.00	7991127.74	5653272.55	0.00

year	Discount Factor	Do nothing: Capital	Do nothing: Maint.	Do nothing: Other	TOTALS: Cash	TOTALS: PV	Opt. 1 Rock armour: New Armour	Ramp	Re-instate WWTP	Immediate Repair / Upgrade existing armour	Future Upgrade existing armour	Graveyard Rock Armour	TOTALS: Cash	TOTALS: PV	Opt. 2 Rock armour & Groyne: New Armou	Ramp	Groyne	Re-instate WWTP	Immediate Repair / Upgrade existing armour	Future Upgrade existing armour	Graveyard Rock Armour	TOTALS: Cash	TOTALS: PV
	cash sum	0	0	0	0.00	0.00	8680000	80000	75000	942400	671539	1330000	11778939	7991128	4712000	80000	511500	75000	942400	671539	1330000	8322439	5653273
0	1.000				0.00	0.00	5425000	50000	75000	496000		700000	6746000.00	6746000.00	2945000	50000	465000	75000	496000		700000	4731000.00	4731000.00
1	0.966				0.00	0.00							0.00	0.00								0.00	0.00
2	0.934				0.00	0.00							0.00	0.00								0.00	0.00
3	0.902				0.00	0.00							0.00	0.00								0.00	0.00
4	0.871				0.00	0.00							0.00	0.00								0.00	0.00
5	0.842				0.00	0.00							0.00	0.00								0.00	0.00
6	0.814				0.00	0.00							0.00	0.00								0.00	0.00
7	0.786				0.00	0.00							0.00	0.00								0.00	0.00
8	0.759				0.00	0.00							0.00	0.00								0.00	0.00
9	0.734				0.00	0.00							0.00	0.00								0.00	0.00
10	0.709				0.00	0.00				49600		70000	119600.00	84786.69					49600		70000	119600.00	84786.69
11	0.685				0.00	0.00							0.00	0.00								0.00	0.00
12	0.662				0.00	0.00							0.00	0.00								0.00	0.00
13	0.639				0.00	0.00							0.00	0.00								0.00	0.00
14	0.618				0.00	0.00							0.00	0.00								0.00	0.00
15	0.597				0.00	0.00	542500	5000					547500.00	326797.61	294500	5000	46500					346000.00	206524.15
16	0.577				0.00	0.00							0.00	0.00								0.00	0.00
17	0.557				0.00	0.00							0.00	0.00								0.00	0.00
18	0.538				0.00	0.00							0.00	0.00								0.00	0.00
19	0.520				0.00	0.00							0.00	0.00								0.00	0.00
20	0.503				0.00	0.00				49600		70000	119600.00	60106.88					49600		70000	119600.00	60106.88
21	0.486				0.00	0.00							0.00	0.00								0.00	0.00
22	0.469				0.00	0.00							0.00	0.00								0.00	0.00
23	0.453				0.00	0.00							0.00	0.00								0.00	0.00
24	0.438				0.00	0.00							0.00	0.00								0.00	0.00
25	0.423				0.00	0.00							0.00	0.00								0.00	0.00
26	0.409				0.00	0.00							0.00	0.00								0.00	0.00
27	0.395				0.00	0.00							0.00	0.00								0.00	0.00
28	0.382				0.00	0.00							0.00	0.00								0.00	0.00
29	0.369				0.00	0.00							0.00	0.00								0.00	0.00
30	0.356				0.00	0.00	542500	5000		49600	479671	70000	1146771.00	408569.75	294500	5000			49600	479671	70000	898771.00	320212.70
31	0.344				0.00	0.00							0.00	0.00								0.00	0.00
32	0.333				0.00	0.00							0.00	0.00								0.00	0.00
33	0.321				0.00	0.00							0.00	0.00								0.00	0.00
34	0.310				0.00	0.00							0.00	0.00								0.00	0.00
35	0.300				0.00	0.00							0.00	0.00								0.00	0.00
36	0.290				0.00	0.00							0.00	0.00								0.00	0.00
37	0.280				0.00	0.00							0.00	0.00								0.00	0.00
38	0.271				0.00	0.00							0.00	0.00								0.00	0.00
39	0.261				0.00	0.00							0.00	0.00								0.00	0.00
40	0.253				0.00	0.00				49600		70000	119600.00	30207.67					49600		70000	119600.00	30207.67
41	0.244				0.00	0.00							0.00	0.00								0.00	0.00
42	0.236				0.00	0.00							0.00	0.00								0.00	0.00
43	0.228				0.00	0.00							0.00	0.00								0.00	0.00
44	0.220				0.00	0.00							0.00	0.00								0.00	0.00
45	0.213				0.00	0.00	542500	5000			47967.1		595467.10	126631.58	294500	5000				47967.1		347467.10	73892.09
46	0.205				0.00	0.00							0.00	0.00								0.00	0.00
47	0.199				0.00	0.00							0.00	0.00								0.00	0.00
48	0.192				0.00	0.00							0.00	0.00								0.00	0.00
49	0.185				0.00	0.00							0.00	0.00								0.00	0.00
50	0.179				0.00	0.00				49600		70000	119600.00	21414.78					49600		70000	119600.00	21414.78
51	0.173				0.00	0.00							0.00	0.00								0.00	0.00
52	0.167				0.00	0.00							0.00	0.00								0.00	0.00
53	0.161				0.00	0.00							0.00	0.00								0.00	0.00
54	0.156				0.00	0.00							0.00	0.00								0.00	0.00
55	0.151				0.00	0.00							0.00	0.00								0.00	0.00
56	0.146				0.00	0.00							0.00	0.00								0.00	0.00
57	0.141				0.00	0.00							0.00	0.00								0.00	0.00
58	0.136				0.00	0.00							0.00	0.00								0.00	0.00
59	0.131				0.00	0.00							0.00	0.00								0.00	0.00
60	0.127				0.00	0.00	542500	5000		49600	47967.1	70000	715067.10	90766.55	294500	5000			49600	47967.1	70000	467067.10	59286.84
61	0.123				0.00	0.00							0.00	0.00								0.00	0.00
62	0.118				0.00	0.00							0.00	0.00								0.00	0.00
63	0.114				0.00	0.00							0.00	0.00								0.00	0.00
64	0.111				0.00	0.00							0.00	0.00								0.00	0.00
65	0.107				0.00	0.00							0.00	0.00								0.00	0.00
66	0.103				0.00	0.00							0.00	0.00								0.00	0.00
67	0.100				0.00	0.00							0.00	0.00								0.00	0.00
68	0.096				0.00	0.00							0.00	0.00								0.00	0.00
69	0.093				0.00	0.00							0.00	0.00								0.00	0.00
70	0.090				0.00	0.00				49600		70000	119600.00	10762.34					49600		70000	119600.00	10762.34
71	0.087				0.00	0.00							0.00	0.00								0.00	0.00
72	0.084				0.00	0.00							0.00	0.00								0.00	0.00
73	0.081				0.00	0.00							0.00	0.00								0.00	0.00
74	0.078				0.00	0.00							0.00	0.00								0.00	0.00
75	0.076				0.00	0.00	542500	5000			47967.1		595467.10	45116.10	294500	5000				47967.1		347467.10	26326.16
76	0.073				0.00	0.00							0.00	0.00								0.00	0.00
77	0.071				0.00	0.00							0.00	0.00								0.00	0.00
78	0.068				0.00	0.00							0.00	0.00								0.00	0.00
79	0.066				0.00	0.00							0.00	0.00								0.00	0.00
80	0.064				0.00	0.00				49600		70000	119600.00	7629.63					49600		70000	119600.00	7629.63
81	0.062				0.00	0.00							0.00	0.00								0.00	0.00
82	0.060				0.00	0.00							0.00	0.00								0.00	0.00
83	0.058				0.00	0.00							0.00	0.00								0.00	0.00
84	0.056				0.00	0.00							0.00	0.00								0.00	0.00
85	0.054				0.00	0.00							0.00	0.00								0.00	0.00
86	0.052				0.00	0.00							0.00	0.00								0.00	0.00
87	0.050				0.00	0.00							0.00	0.00								0.00	0.00
88	0.048				0.00	0.00							0.00	0.00								0.00	0.00
89	0.047				0.00	0.00							0.00	0.00								0.00	0.00
90	0.045				0.00	0.00	542500	5000		49600	47967.1	70000	715067.10	32338.16	294500	5000			49600	47967.1	70000	467067.10	21122.62
91	0.044				0.00	0.00							0.00	0.00								0.00	0.00
92	0.042				0.00	0.00							0.00	0.00								0.00	0.00
93	0.041				0.00	0.00							0.00	0.00								0.00	0.00
94	0.039				0.00	0.00							0.00	0.00								0.00	0.00
95	0.038				0.00	0.00							0.00	0.00								0.00	0.00
96	0.037				0.00	0.00							0.00	0.00								0.00	0.00
97	0.036				0.00	0.00							0.00	0.00								0.00	0.00
98	0.034				0.00	0.00							0.00	0.00								0.00	0.00
99	0.033				0.00	0.00							0.00	0.00								0.00	0.00
100	0.032				0.00	0.00							0.00	0.00								0.00	0.00

D.2.4 Strandhill PV erosion loses

Erosion Loss Calculation Sheet with delay options

Sheet Nr.

Client/Authority
Sligo County Council

Project name		**Option:**	**Delay (yrs)**
Sligo Bay CFERM Assessment		Opt. 1 Rock Armour	100
Project reference	IBE1902		0
Base date for estimates (year 0)	Sep-2022		0
Scaling factor (e.g. £m, £k, £)	€		0
Discount rate	4%		

Prepared (date)	
Printed	15/09/2022
Prepared by	
Checked by	
Checked date	

Ref	Asset Description	MV €	Year	Prob of loss without project in year	Expected value of asset losses € Without Project	Opt. 1 Rock Armour
0	Land lost to erosion, *c.* 0.85ha	14696.50	10	1	10,418.63	334.02
1	Land lost to erosion, *c.* 0.85ha	14696.50	20	1	7,385.96	236.79
2	Land lost to erosion, *c.* 0.85ha	14696.50	30	1	5,236.05	167.87
3	Land lost to erosion, *c.* 0.85ha	14696.50	40	1	3,711.93	119.00
4	Land lost to erosion, *c.* 0.85ha	14696.50	50	1	2,631.46	84.36
5	Land lost to erosion, *c.* 0.85ha	14696.50	60	1	1,865.49	59.81
6	Land lost to erosion, *c.* 0.85ha	14696.50	70	1	1,322.48	42.40
7	Land lost to erosion, *c.* 0.85ha	14696.50	80	1	937.53	30.06
8	Land lost to erosion, *c.* 0.85ha	14696.50	90	1	664.63	21.31
9	Land lost to erosion, *c.* 0.85ha	14696.50	100	1	471.17	15.11
Totals		58786.00			34645.33	1110.73

Notes
Make one entry in the description column for each property (or group of properties) as this determines subsequent calculation
MV = risk free market value at base date for estimate - must be entered on each line when probaility distribution is used
Equivalent annual value = MV x discount rate (assumes infinite life)
Year is year in which there is the probability of loss shown, years must be entered consecutively for each property or group
If no distribution is used enter year of expected year of loss and enter 1.0 in probability column
Columns G to K show expected values of asset losses with each option, assuming extensions of life entered above
The loss is calculated using the formula PV loss = MV * Prob of loss * (1 - (1 - 1/((1+r)^(Year of loss))) = MV * Prob of loss / ((1+r)^(Year of loss))
Additional properties can be entered by inserting lines above line 62 and copying all formulae, including hidden calculation in column C

Net Present Value over time

Sheet Nr.

Client/Authority
Sligo County Council
Project name
Sligo Bay CFERM Assessment

Project reference	IBE1907
Base date for estimates (year 0)	Sep-2022
Scaling factor (e.g. £m, £k, £)	€
Discount rate	4%

Prepared (date)	
Printed	15/09/2022
Prepared by	
Checked by	
Checked date