East Coast Railway Infrastructure Protection Projects

# Phase 3 Design Report

# Merrion Gates to Seapoint Beach

## COASTAL CELL AREA 1

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# Executive summary

This report presents the Phase 3 design for coastal protection works along the Merrion Gates to Seapoint Beach section of the East Coast Railway Infrastructure Protection Projects (ECRIPP), commissioned by Iarnród Éireann (Irish Rail). The project aims to enhance the resilience of the Dublin–Wicklow railway corridor against the impacts of climate change, particularly sea level rise and coastal erosion, by providing protection against a 1-in-200-year storm event through to 2075.

The Merrion Gates to Seapoint Beach frontage (Coastal Cell Area 1), spans approximately 4.4 km of low-lying, urbanised coastline where the railway runs adjacent to the shore. The primary hazard is wave overtopping, which poses a risk to railway operations and infrastructure. The proposed works include raising and reinforcing existing seawalls, constructing new wave walls, and integrating public access and amenity features.

The design is informed by preliminary analysis, including:

- 2D spectral wave modelling and CFD analysis to assess wave overtopping and structural loading.
- Initial geotechnical investigations to evaluate ground conditions and structural stability.
- Coastal process assessments confirming low sediment transport and shoreline stability.

The preferred scheme involves:

- Raising existing seawalls using a combination of in-instu and precast reinforced concrete.
- Constructing new seawalls where existing structures are insufficient to provide the required Standard of Protection.
- Incorporating ground anchors and piles to provide the required structural stability.
- Maintaining and improving public access, footpaths, and amenity areas.
- Using textured formliners to visually integrate new structures with the existing landscape.

The scheme can be adapted for longer term climate change impacts, including potential addition of rock revetments over the existing revetments.

The project will progress to Phase 4, focusing on statutory processes including Environmental Impact Assessment (EIA), Marine Area Consent (MAC), and planning applications. Public Consultation 2 is scheduled for September 2025. Detailed design, procurement, and construction will follow in subsequent phases.

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# 1. Introduction and scope

## 1.1 Project background

The East Coast Railway Infrastructure Protection Projects (ECRIPP) were established by Iarnród Éireann Irish Rail (IÉ) to provide improved coastal protection against predicted climate change effects of sea level rise and coastal erosion on the east coast railway corridor between Merrion Gates (Co. Dublin) and Wicklow Harbour (Co. Wicklow) (Figure 1-1)

ECRIPP aims to deliver improved coastal protection measures to the railway infrastructure, addressing vulnerabilities related to coastal erosion, wave overtopping and cliff instability that are projected to worsen due to climate change. To improve resilience, the project will be designed to withstand against a 1 in 200-year return period event, for a minimum of 50 years (i.e. to year 2075).

This report presents the Phase 3 designs for Merrion Gates to Seapoint, Coastal Cell Area 1 (CCA1) (hereafter referred to as the 'Project').

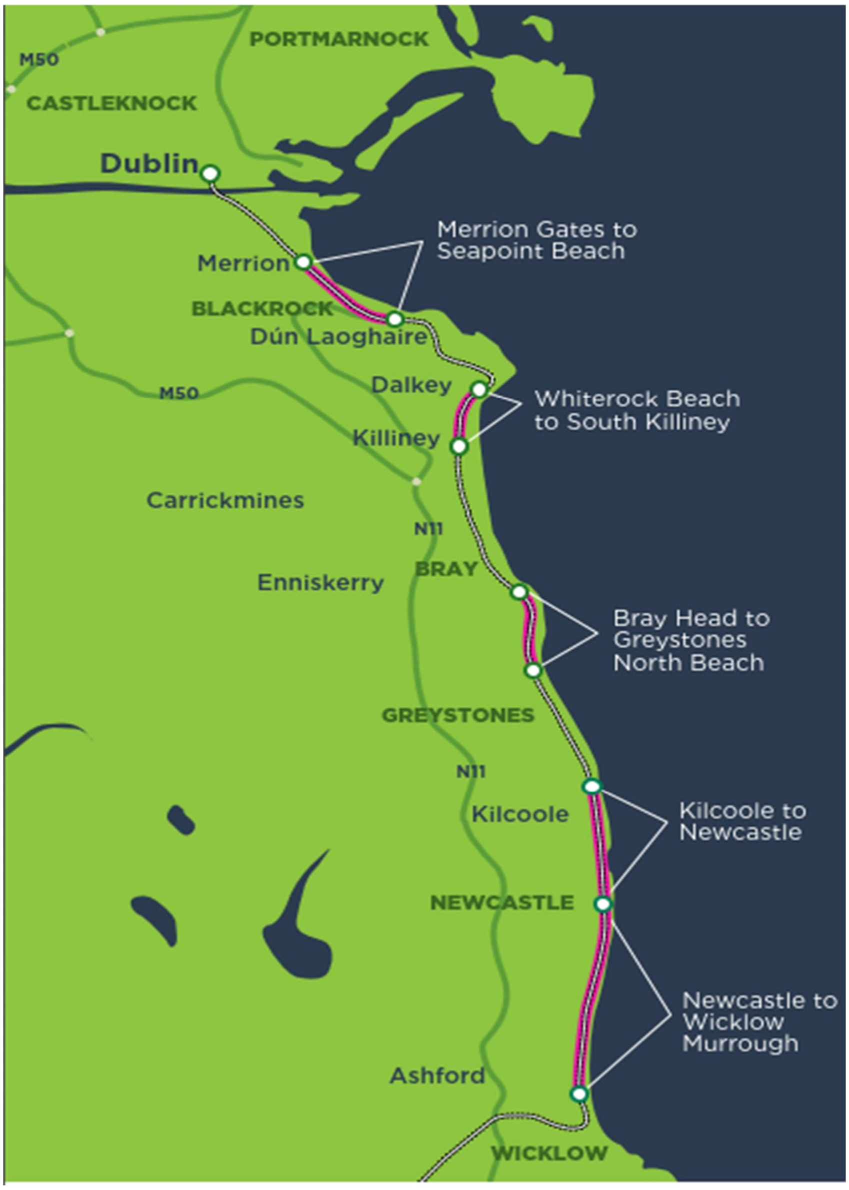


**Figure 1-1. ECRIPP Locations**

## 1.2 Project location and description

The Merrion Gates to Seapoint Beach Project is an urban frontage approximately 4.4km long with the train line running along the coastline. Much of this frontage is defended, mostly with natural stone revetments and historic seawalls. The foreshore along this frontage is soft sediment forming intertidal flats. The railway is relatively low-lying along this frontage and the main hazard is wave overtopping causing disruption and damage to the railway line.

The Project is located within a number of designated sites and due to its length and variation in existing geometries the frontage has been split into the following sections:

Merrion Gates: This section features a masonry revetment with an upstand wall (Figure 1-2) However, the area benefits from natural protection provided by a spit and higher ground levels in front of the revetment, which help mitigate the impact of larger waves.


**Figure 1-2. Example of defences at Merrion Gates showing the railway line directly behind the existing wall**

Merrion Gates to Booterstown: This stretch comprises a masonry revetment with an upstand wall. The existing wall is relatively low and in poor condition compared to other sections. It is also the most spatially constrained area, with the railway line situated extremely close to the wall, limiting available space for construction.

**Figure 1-3. Typical defences from the Spit to Booterstown with the railway line directly behind the existing wall**

Williamstown Martello Tower: This short section currently provides access to the foreshore from the landward side of the railway line. It comprises a split level walkway on the seaward side of the existing seawall with access steps down to the beach.

Booterstown to Blackrock: This section comprises a masonry revetment with upstand wall, the existing wall along here is in fair condition and the area is more heavily used for amenity purposes.

Blackrock baths and bathing area: The area in the vicinity of Blackrock station currently includes a walkway on the seaward side of the existing wave wall with access steps down to the foreshore (Figure 1-4). The existing wall along this section is relatively high (Figure 1-5) and there are opportunities to include works both seaward and landward of the existing wall.

**Figure 1-4. Blackrock bathing area with walkway and access steps**

**Figure 1-5. Existing seawall at Blackrock bathing area**

Southern Blackrock: This is the section between Vance's Barbour and Brighton Vale. The existing wall is much higher here compared to other sections and there is approximately 5.0m between the existing wall and the railway line providing an opportunity to include new works landward of the existing wall (Figure 1-6).

**Figure 1-6. Existing wall and distance to the railway line at Southern Blackrock**

Seapoint Beach: A popular amenity area with varied existing defences, including lower walkways (

**Figure 1-7**) and a footpath between the railway and the seawall (Figure 1-8). This section offers space for enhancements both seaward and landward, including improvements to existing amenity features.

**Figure 1-7. Existing lower walkway at Seapoint beach**

**Figure 1-8. Existing walkway landward of the seawall at Seapoint**

Stations: There are four stations along the Project frontage (Booterstown Station, Blackrock Station, Seapoint Station and Salthill and Monkstown Station). Each of these locations have existing wall arrangements and access provisions that differ from the intermediate defences. Site specific design solutions are proposed at these locations to accommodate these local variations and to ensure that amenity access is maintained.

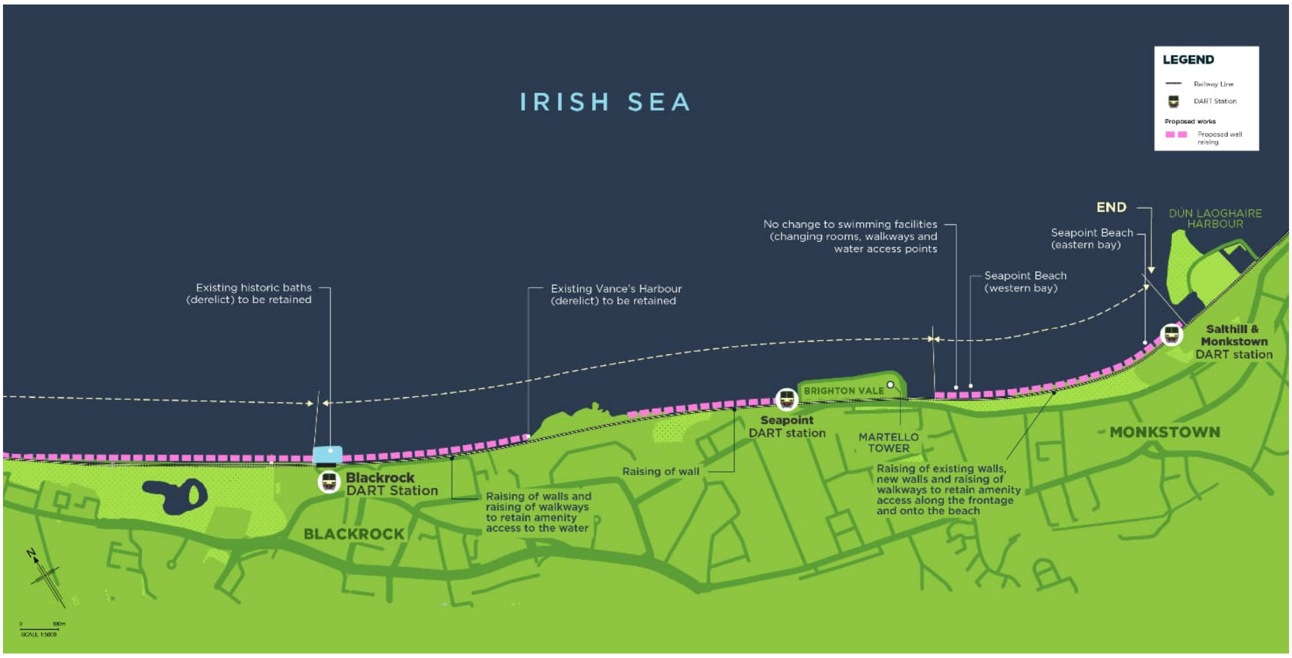


**Figure 1-9. Merrion Gates to Seapoint Beach location plan**

## 1.3 Project objectives

The objectives of engineering interventions for the Project are to manage the risk of wave overtopping disruption to the railway.

### 1.3.1 Transport benefits

The proposed works will ensure that the railway remains safe to operate over the next 50 years. Proposed works will reduce the risk of wave overtopping impacting the railway and preventing significant damage to railway infrastructure under large storms.

IE infrastructure at the site comprises a double-track railway with overhead electrification equipment (OHLE) that forms the electrified DART service that links Dublin and Greystones.

## 1.4 Project status

The project is currently in Phase 3, the Preliminary Design Stage. By integrating the proposed options (Options Selection Report) with the results of the Public Consultation 1 (Report PC1), a Phase 3 design has been developed, which considers and aims to address stakeholder feedback whilst delivering the design requirements.

The design is likely to be recalibrated, based on further technical and environmental analysis, feasibility studies and stakeholder consultation.

## 1.5 Purpose of this report

This document provides the Phase 3 Design Report for Merrion Gates to Seapoint Beach. The report defines the design that will subsequently inform detailed design.

This report should be read in conjunction with associated appendices:

- Modelling outputs (Appendix A). This describes the numerical modelling of waves and water levels that provides the inputs to overtopping calculations and design of the proposed scheme.

- Geotechnical outputs (Appendix B). The ground investigation report (GIR) presents the results of desk studies and ground investigations in an engineering ground model. The document uses the ground model to undertake geotechnical calculations for the stability and settlement potential of the proposed structures. The GIR documents the geotechnical risks arising from the scheme that feed into the designers' risk assessment (Appendix C)
- DEHERR, designers' risk assessment (Appendix C). A Design Hazard Elimination & Risk Reduction Register or DEHERR has been developed alongside the design of the preferred option at Phase 3 design. The DEHERR allows the designer to determine potential risks, and (where possible) design against the risks presented. Where the risk is not possible to eliminate at this phase of design, further evaluation of the risk will occur at detailed design stage, before the risk is transferred to the contractor for them to consider when developing their safe system of works.

# 2. Design criteria and requirements

## 2.1 Design Criteria

The design criteria are summarised in **Table 2.1**.

**Table 2.1. Design criteria**

| Criteria | Description | Reference |
|---|---|---|
| Design Life | ▪ 50 years for new permanent works<br>▪ Variable for existing structures | Scope of Services |
| Proposed Standard of Protection – Damage to structures | 0.5% AEP (1 in 200RP) | Refer to technical note 7694-ZZ-P1-MMO-CV-JAC-0002 |
| Proposed Standard of Protection – Reduction of disruption to services | 10% AEP (1 in 10RP) for damage to rolling stock / lineside assets<br>100% AEP (1 in 1RP) for temporary line speed restrictions | Refer to technical note 7694-ZZ-P1-MMO-CV-JAC-0002 |
| Proposed Standard of Protection – Pedestrian Safety | 100% AEP (1 in 1RP) | Refer to technical note 7694-ZZ-P1-MMO-CV-JAC-0002 |
| Wave overtopping thresholds (refer to Table 5-3) | Design protection measures to limit wave overtopping to:<br>▪ 20 l/s/m or 2000 l/m under a 0.5% AEP storm<br>▪ 1l/s/m or 600l/m under a 100% AEP) | Refer to technical note 7694-ZZ-P1-MMO-CV-JAC-0002 |
| Maintenance requirements | For new permanent works: zero heavy maintenance for up to 25 years. | Scope of Services |

## 2.2 Design standards

The relevant design standards applicable to the Project are summarised in **Table 2.2**.

**Table 2.2. Relevant design standards and codes of practice**

| Discipline | Code/Standard | Application |
|---|---|---|
| Chief Civil Engineer (CCE), IE Requirements | PWY-1101 Requirements for Track and Structures Clearances | Geometrical constraints on proposed solutions, including installation and maintenance |
| Chief Civil Engineer (CCE), IE Requirements | CCE-TMS-389 Drawing Certification Process | All drawings produced on the project |
| Chief Civil Engineer (CCE), IE Requirements | CCE-TMS-399 Glossary of Civil and Permanent Way Engineering Term | All technical reporting relating to railway terminology |
| Chief Civil Engineer (CCE), IE Requirements | CCE-TMS-390 - Preparation of Drawings (Approval and Certification Process) | All drawings produced will follow the general guidelines in this standard. It is noted that as no track works are within scope, many of the specifics in this standard will not be applied. |
| Chief Civil Engineer (CCE), IE Requirements | CCE-TMS-410 - Civil Engineering and Structures Design Standard | Main IE standard for design (alongside Eurocode) |
| Chief Civil Engineer (CCE), IE Requirements | CCE-STR-PSD-005 - Technical Approval for Civil Engineering Structures | Main IE standard for design reporting |
| Electrification Manager, IE Requirements | I-ETR-4004 Iss1.0 Clearance Requirements for DC 1500V Electrified Lines | Assessing the hazards arising from the increased height of the sea boundary walls on the DART. Future proofing of DART extension to Wicklow should also be considered |
| Electrification Manager, IE Requirements | I-ETR-4009 Iss.2.0 Principles of Traction Bonding | Assessing the hazards arising from the increased height of the sea boundary walls on the DART. Future proofing of DART extension to Wicklow should also be considered |
| Electrification Manager, IE Requirements | I-ETR-4703 Iss1.0 Earthing and Bonding Guidelines | Assessing the hazards arising from the increased height of the sea boundary walls on the DART. Future proofing of DART extension to Wicklow should also be considered |
| Electrification Manager, IE Requirements | I-ETR-4021 Iss1.0 Maintenance Requirements for the DC 1500V DART Electric Traction System and its Interfaces | Assessing the hazards arising from the increased height of the sea boundary walls on the DART. Future proofing of DART extension to Wicklow should also be considered |
| Railway Electrification | EN 50162 :- Protection against corrosion by stray current from direct current systems | Electrical safety and installation of modified defences along the electrified railway (DART), including possible extension to Wicklow. |
| Railway Electrification | EN 50522:- Earthing of power installations exceeding 1 kV AC | Electrical safety and installation of modified defences along the electrified railway (DART), including possible extension to Wicklow. |
| Railway Electrification | EN 50562:- Railway applications. Fixed installations. Process, protective measures and demonstration of safety for electric traction systems | Electrical safety and installation of modified defences along the electrified railway (DART), including possible extension to Wicklow. |

| Discipline | Code/Standard | Application |
|---|---|---|
| Railway Electrification | EN 50122: Railway applications. Fixed installations. Electrical safety, earthing and the return circuit. Protective provisions against electric shock | Electrical safety and installation of modified defences along the electrified railway (DART), including possible extension to Wicklow. |
| Structural | EN 1990:2002 Eurocode - Basis of structural design | Principles and Requirements for the safety, serviceability and durability of structures, describes the basis for their design and verification and gives guidelines for related aspects of structural reliability |
| Structural | EN 1991 Eurocode 1 | Provides comprehensive information on all actions that should normally be considered in the design civil engineering works, including some geotechnical aspects. |
| Structural | EN 1992 Eurocode 2 | Applies to the design of civil engineering works in concrete. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design in EN 1990. |
| Structural | EN 1992 Eurocode 3 | Applies to the design of civil engineering works in structural steel. It complies with the principles and requirements for the safety and serviceability of structures, the basis of their design in EN 1990. |
| Structural | EN 1996 Eurocode 6 | Applies to the design of civil engineering works, or parts thereof, in masonry. The execution is covered to the extent that is necessary to indicate the quality of the construction materials and products that should be used and the standard of workmanship on site needed to comply with the assumptions made in the design rules |
| Structural | BS EN 206-1:2000 Concrete – Part 1: Specification, performance, production and conformity | Additional reference where Eurocode does not cover a specific topic adequately for the design of concrete structures |
| Geotechnical | Eurocode 7: Geotechnical Design | Default standard for geotechnical design, but may require other supporting documentation e.g. British Standards |
| Geotechnical | Engineers Ireland Specification and Related Documents for Ground Investigation in Ireland, 2016 | For defining approach and content of the Ground Investigation Interpretive Report |
| Coastal | The Rock Manual: The use of rock in hydraulic engineering (Ciria/CUR/CETMEF, 2007) | Design of rock structures, including: armour stability, scour, toe design |
| Coastal | BS6349 Maritime Works | Design of breakwaters, dredging, geotechnical design and materials used in maritime works |
| Coastal | Manual on wave overtopping of sea defences and related structures (EurOtop, 2018) | Wave overtopping performance assessment of defences |
| Coastal | The Coastal Engineering Manual (USACE, 2002) | Additional methods for scour, armour stability, hydrodynamic wave loading |

| Discipline | Code/Standard | Application |
|---|---|---|
| Coastal | The Beach Management Manual (Ciria, 2010) | Design of beach nourishment and management |
| Coastal | Revetment Systems against Wave Attack (McConnell, 1998) | Design of concrete blockwork and open stone asphalt |
| Coastal | The Use of Concrete in Maritime Engineering – a guide to good practice (Ciria, 2010) | Design of concrete structures |
| Coastal | Toe Structures Management Manual (Environment Agency, 2012) | Design of nearshore/offshore structures |

## 2.3 Consideration of alternatives

The Preferred Scheme being taken forward within the Project is the raising of existing seawalls with reinforced concrete and additional seawall sections and raised footpaths/pedestrian accesses to retain amenity function. The principals of this option have been developed for the Phase 3 design and assessed against wave modelling data. Refer to section 3.2 for details on wave data analysis.

Consideration of alternatives has been undertaken throughout the design process to try to maximise the efficiency of the design whilst reducing the impact on the landscape. Under Phase 2, a broad range of solutions were considered; many of these were discounted due to their inability to provide protection against future climate change or due to their impact on designated sites.

In many locations along the Project a structural arrangement of simple raising of the existing walls using granite blocks (in keeping with the existing walls) was considered. However, following analysis this was found not to be feasible. Blockwork walls have relatively low resistance to lateral loading because of low flexural strength. To enhance the flexural strength of the existing blockwork wall, the use of mechanical dowel connections and replacement of granite blocks with pre-cast concrete panels was investigated. However, due to the stability of the existing structures and its low resistance to sliding and overturning failure under applied wave forces, this option was not progressed further within the phase 3 design.

Where it has been found to be adequate to resist the design wave forces, existing walls are to remain in place supported by new concrete structures. In locations where new sea wall structures are required, the visual impact can be mitigated through the use of formliners to enhance the construction appearance and soften the impression of concrete.

## 2.4 Design elements

To meet the design criteria detailed in **Table 2.1** the raised heights of seawalls were set to limit wave overtopping discharges to acceptable levels. Consequently, significant wave forces are applied to the seawall, refer to Section 3.2. The Phase 3 design approach focuses on providing robust sea defences which resist the design wave actions and protect the railway from overtopping and subsequent flooding.

Due to the length of the study area a variety of coastal features and existing structures are present, resulting in numerous diverse constraints on the design layout of the sea defences. The Phase 3 design approach was to minimise the construction processes to provide efficiency and therefore consolidate the number of typical structural sections where possible, refer to section 5.3.1 for further details. It also needs to consider the working constraints posed by the adjacent railway line, limited working areas, access and tidal restrictions.

The Phase 3 design aims to retain the existing historical structures and features as far as reasonably practicable and enhance the heritage value of the scheme area.

In many sections of coastline, structural arrangements were developed to provide support to the existing seawall to allow as much of the structure to remain insitu as possible. In areas where significant construction constraints dictated, new concrete structures are proposed to replace the existing seawall. Additional ground support structures such as tension anchors and piles have also been proposed where required. Ground anchors are used to increase the stability of existing structures and give resistance to overturning and sliding failure. Small vertical socket holes are bored through structures into the ground, anchors are then grouted into the sockets and fixed at the head on top of the new structure. Resistance is gained by applying vertical tension which increases the weight of the structure without the need to apply additional material (i.e. mass concrete). Where the working range of ground anchors is exceeded, piles are to be installed which provide a greater resistance to sliding and overturing failure where necessary. Refer to Section 5.4 for further information on the design of ground support elements.

Refer to Section 6 for a description of the structural arrangement at each location in the Project.

## 2.5 Design assumptions and decisions

The main design assumptions relate to the condition and as-built details of existing structures and ground conditions.

The Phase 3 design has been undertaken using the results of preliminary ground investigation surveys. Further studies should be undertaken to facilitate later design phases, in particular at locations where the existing seawall is to remain insitu detailed assessments should be undertaken to confirm the structural resistance of the wall to resist direct bending and shear actions as well as the stability of the wall and its foundations to resist failure by overturning and sliding. The Phase 3 design has been completed by assuming the wall is suitable, however these assumptions will require confirmation by inspection and testing.

The design assumes precast units are to be used where possible to limit the use of in-situ concrete required on site, however due to the size of units required it may be more feasible to use in-situ concrete or a combination thereof. This will be considered further during reference design.

## 2.6 Safety certification and approval

### 2.6.1 Workplace safety: roles and responsibilities

Workplace safety in construction projects in Ireland follows the Safety, Health and Welfare at Work Act 2005 and the Safety, Health and Welfare at Work (Construction) Regulations 2013. The Safety, Health and Welfare at Work (Construction) Regulations 2013 aim to:

- Prevent accidents on construction sites.
- Define roles and responsibilities of key duty holders in a construction project.
- Ensure proper planning, coordination, and communication of health and safety throughout the construction process.

The 2013 Regulations ensure that health and safety is:

- Considered from the design stage through to completion.
- Managed by competent, clearly assigned roles.
- Proactively monitored and reviewed on all construction projects

Under these regulations, the responsibilities of duty holders are as follows:

**Clients** must:

- Appoint Project Supervisors for both the Design Process (PSDP) and Construction Stage (PSCS).

- Ensure that the PSDP and PSCS are competent and adequately resourced.
- Keep a copy of the Safety File at the end of the project.

**Project Supervisor for the Design Process** (PSDP) must:

- Identify hazards during the design stage.
- Coordinate designers to eliminate or reduce risks.
- Ensure early planning and coordination for safety.
- Prepare a Preliminary Health and Safety Plan.
- Maintain and update the Safety File.

**Project Supervisor for the Construction Stage** (PSCS) must:

- Coordinate health and safety during construction.
- Prepare and implement the Construction Stage Health and Safety Plan.
- Ensure compliance by all contractors.

**Designers** must:

- Eliminate hazards and reduce risk through design.
- Cooperate with the PSDP.
- Consider health and safety implications of their designs.

**Contractors, including subcontractors**, must:

- Comply with the Construction Stage Safety Plan.
- Provide relevant training and PPE to workers.
- Coordinate their activities with other contractors.
- Report incidents and cooperate with safety inspections.

### 2.6.2 Notification and training

Projects lasting more than 30 working days or 500 person-days must be notified to the Health and Safety Authority (HSA) before work begins. The AF1 form is used for this and is the reasonability of the client with the help of the PSDP

In relation to training and competence:

- All workers must have received Safe Pass training.
- Construction workers must be trained in manual handling, working at heights, etc., as applicable.
- Site-specific induction is required.

### 2.6.3 Iarnród Éireann safety standards

Due to the proximity to the railway line, the safety certification and approvals will be aligned with the process stated in IÉ standards and the general good practices of safety assurance and management.

Based on consultation with the stakeholders of IÉ, it has been confirmed that this project is considered non-significant in accordance with the Common Safety Method Risk Assessment (CSM-RA) and does not require Authorisation to Place in Service (APIS). In addition, the potential work will:

- Have minimal impact on the day-to-day operations and activities of Irish Rail
- Have minimal impact on the operations of trains and rail services.

With respect to this, the technical management standards CCE-TMS-391 (IÉ, 2020) will be generally followed for the safety certification and approvals, and the delivery process will be conducted through the engagement with stakeholders of IÉ.

The objectives of the safety certification and approval are to ensure:

- The compliance with applicable legal and technical requirements;
- The credible hazards identified, and their impact assessed; and
- Safety associated with the work sufficiently controlled and managed.
- The following will be considered to support the safety certification and approval:
- The detailed definition of the change (i.e. scope of work and activities);

- Project team with the roles and responsibilities defined for project delivery and safety assurance;
- Identification of compliance requirements;
- Identification of potential affected stakeholders;
- Hazards identification and risk assessment to support the identification, assessment, control and management of safety hazards and risks; and
- Gathering evidence of demonstrating these requirements achieved.

# 3. Modelling results

A two-dimensional spectral wave model has been used to derive multi-decadal hourly time series of nearshore wave data and extreme nearshore wave and water level conditions along the East Coast of Ireland. The model includes the effects of spatially varying water levels, wind forcing, spatially varying boundary data and climate change. The model was calibrated and validated using measured nearshore wave data in the Dublin Bay. The average RMSE (Root mean Square Error) for wave height (Hm0) over the storm conditions selected for calibration is about 0.2 m with a bias of about 0.0 m.

Hourly time series of nearshore wave data are extracted at regular intervals at approximately every 1 km. The seabed level at the nearshore extraction points along the Project is approximately -6 m Mean Sea Level. Waves are mainly from ENE to SSE along this section of coast. Waves in Dublin Bay are sheltered by the island at Howth to the north and Dalkey Island to the south. The coastline close to Dun Laoghaire harbour at the south edge of Dublin Bay is sheltered from southerly waves. Similarly, the coastline close to the Dublin port in the north of Dublin Bay is sheltered from northerly waves. In the South of Dublin Bay waves are dominantly from ENE. Heading north across the bay the dominant wave direction turns clockwise so that the dominant wave direction in the north is from ESE/SE.

The hourly wave height exceeded 1% of the year is about 1.56 m (1.21m to 1.71m) and the median annual wave height is about 0.26 m (0.22m to 0.29m) for present day wave conditions (wave climate simulated for the period Jan 1988 to Dec 2021). The modelled wave heights for future conditions (including climate change) are higher. The hourly wave height exceeded 1% of the year is about 1.61 m (1.25m to 1.78m) for 2022-2055 and 1.75m (1.36m to 1.9m). The modelled hourly nearshore wave time series is used as input for the sediment transport and shoreline evolution modelling.

Joint probability analysis was carried out to determine extreme offshore wave and water level conditions for 22.5 deg wave direction sectors. Two joint probability analysis methods were used, namely: 1) Desk study method which uses correlation coefficients to determine the dependence of the two variables (wave height and water level) and 2) The simplified method which considers astronomical tide are fully independent from the wave height while surge is considered fully dependent to wave height. The results that give the more conservative joint probability pairs are used as boundary conditions for the nearshore transformation modelling. The selected joint probability pairs were transformed to the nearshore using the wave model.

Extreme nearshore wave and water level data are extracted at regular intervals at approximately every 1 km. The nearshore wave extraction points, sample nearshore wave roses and joint probability curves are shown in Appendix A. The modelled extreme wave and water level conditions are used as input for design of the coastal structures and for storm-induced cross-shore sediment transport modelling.

## 3.1 Shoreline modelling

Shoreline modelling was undertaken in Phase 2 (report 7694-CCA1-P3-ENG-CV-JAC-0004) and concluded that sediment transport rates along the frontage of the Project are very low. As the full length of the coastline along this section is protected by hard defences (revetments) there is very little impact from sediment transport. The report also concludes the risk of undermining of the existing structures due to beach drawdown is low, since the sediment transport rates are low.

## 3.2 CFD

Computational Fluid Dynamics (CFD) was used to analyse wave overtopping to determine the required wall heights to provide protection against overtopping. CFD was also used to determine wave loading forces acting on the walls to inform the structural design of the wave walls. CFD was adopted rather than empirical derived methods due to the following:

- CFD is flexible in the geometry of the structure. It can have several walls, berms, promenades and walls can be more complex, different angles, bullnoses, curved/sloped. The current empirical methods to calculated overtopping and/or wave loads are limited in their application. The formulas accounting for the influence of a wall and/or promenade on top of a slope, are limited to non-breaking waves.

- Overtopping volumes and wave forces can be measured at multiple locations within the section, e.g., at the front wall to ensure people safety and/or at the back wall to ensure railway safety.

Eight cross sections were selected along the Project, to represent the typical sections along the frontage capturing the variations in existing structure geometry. Figure 3-1 shows the location of the cross sections.

**Figure 3-1. Location of cross section modelled in CFD**

# 4. Coastal processes assessment

The Project is situated between Merrion and Dun Laoghaire harbour along the southern side of Dublin Bay. Coastal processes and sediment transport are strongly affected by shoreline developments that have formed a series of discrete units. Dun Laoghaire harbour and Dublin Port are boundaries to alongshore sediment transport. The railway forms the shoreline along most of the site. From Merrion to Blackrock, the railway is constructed on an embankment with a revetment and seawall that fronts low-lying land with marshes at Booterstown. From Blackrock to Seapoint the shoreline is rocky, with occasional pocket beaches and the railway is constructed on a low bedrock bench typically protected by a revetment and seawall.

The intertidal zone extends over a kilometre offshore, exposing sand and mud flats at low tide, with small supra-tidal accretions of sand and gravel remaining at high tide at Merrion Strand, Booterstown and Seapoint. A small sand spit is present at Booterstown, which forms an important habitat for birds. The feature is nourished by a limited supply of sediment from the east and appears to have developed and grown in the last 30 to 40 years. Historical photos of the area from the 1990s to present show formation of several similar features in the past, but these have not persisted like the Booterstown spit. The features probably originate as intertidal sand bars that have welded to the shoreline during storms, with the persistence of the Booterstown spit probably explained by the drainage outfall on its western side that limits the potential for alongshore sediment loss. No recession of the backshore has occurred in recent decades due to the continuous defences.

A two-dimensional coastal area model was used to describe potential rates and locations of sediment transport. Since there are areas of exposed bedrock and hard defences there is very limited sediment available for transport. Model results confirm observations of the coastal geomorphology. Where present, sediment moves from east to west along the frontage, with a localised drift reversal on the western side of Seapoint Beach where the shoreline alignment alters significantly. The potential transport rates are highest around Blackrock and reduce towards Booterstown Strand because the bed level increases and the duration of tidal inundation reduces. The potential sediment transport is highest in the 100m closest to the defence, however due to the general absence of available sediment, little material is moved. Where sediment is present, the calculated transport rates are low (less than 1,200m$^3$/year) and the corresponding average annual changes in bed level are also low (< 0.1 m/year). Climate change increases the transport rates as the length of time waves can act on the nearshore increases with sea level rise. However, transport rates and changes in bed level remain low.

In summary, the Project area is a low energy frontage characterised by a low rate of westwards littoral sediment transport and a stable shoreline. The small spit at Booterstown is accreting but may be sensitive to storms and sea-level rise because the low sediment supply will limit its ability to accrete in parallel with sea-level rise.

# 5. Design methodology and results

## 5.1 Design methodology and overall approach

All proposed structures are designed to a minimum of 1 in 200-year return period Standard of Protection for the year 2075 (incorporating 50-yrs of predicted sea level rise). The overall design approach is summarised below and in Figure 5-1

The waves were transformed to the proposed structure toe using the closest wave point to the structures, the bed level at the toe of the structure and nearshore slope (determined using a combination of UAV survey data, bathymetric data and recent LIDAR data). Offshore Joint Probability Analysis (JPA) used in the wave transformation was determined based on shoreline orientation and the wave direction. Shore-normal waves were used in all cases.

The cross-section was then analysed by the geotechnical team and any further changes to the design to satisfy the bearing or global stability checks were made.

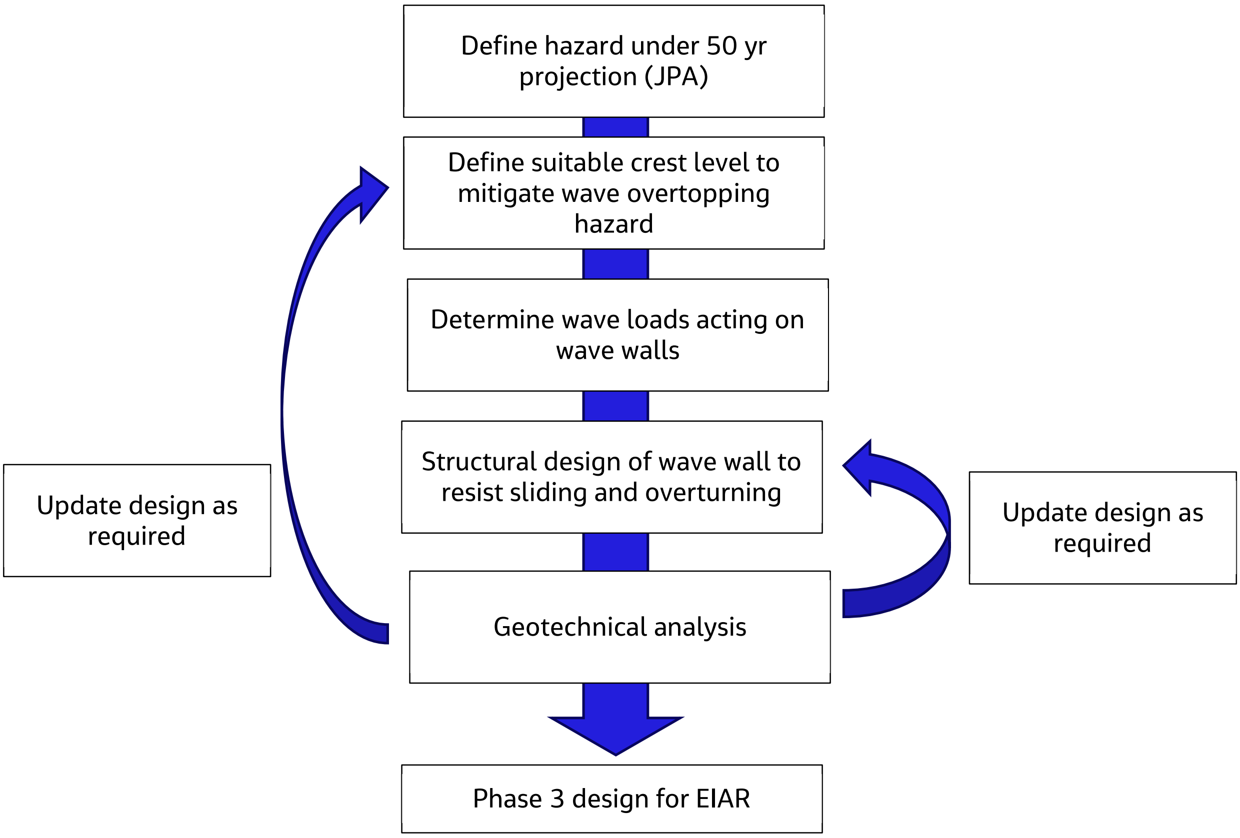


**Figure 5-1 Design methodology**

### 5.1.1 Key design parameters

All structures proposed shall be designed to recognised and proven current codes, standards, or regulations. Key design assumption used in the design of the Project are shown in Table 5-1

**Table 5-1. Key Design Parameters**

| Design Assumption | Value | Reference |
|---|---|---|
| Water Density | 1025 kg/$m^3$ | Typical values |
| Reinforced Concrete Density | 2500 kg/$m^3$ | Typical values |
| Storm Duration | 6 Hours | Typical values |
| Coefficient of Gravity | 9.81 m/$s^2$ | Typical values |
| Plunging Coefficient | 6.2 | CIRIA C683 (2007) Van Der Meer and Van Gent assessments |
| Surging Coefficient | 1.0 | CIRIA C683 (2007) Van Der Meer and Van Gent assessments |
| Wave Obliquity | 0 degrees | Assumed based on selected wave conditions for worst case results |
| Bedding material angle of friction | 30 $^o$ | |

### 5.1.2 Tide levels

Reference tide levels for Dublin North Wall and Wicklow are tabulated below.

**Table 5-2. Reference tide levels**

| Reference level | Dublin North wall (mODM) | Wicklow (mODM) |
|---|---|---|
| Highest Astronomical Tide, HAT | 1.99 | |
| Mean High Water Springs, MHWS | 1.59 | 0.19 |
| Mean High Water Neaps, MHWN | 0.89 | -0.21 |
| Mean Sea Level, MSL | -0.11 | |
| Mean Low Water Neaps, MLWN | -1.01 | -1.41 |
| Mean Low Water Springs, MLWS | -1.81 | -1.81 |
| Lowest Astronomical Tide, LAT | -2.61 | |

## 5.2 Coastal engineering design

### 5.2.1 Wave overtopping assessment

Wave overtopping analysis was undertaken using CFD to define the heights of the walls.

Wave overtopping thresholds for The Project were reviewed and proposed in Phase 1 in technical note 7694-ZZ-P1-MMO-CV-JAC-0002, these thresholds are summarised in Table 5-3.

**Table 5-3. Summary of wave overtopping thresholds (7694-ZZ-P1-MMO-CV-JAC-0002)**

| Threshold and Application | Justification |
|---|---|
| 5 to 20 l/s/m depending on incident wave height or 2000 l/m under 0.5% AEP conditions for defence structural integrity | Table 3.3 from EurOtop; depending on wave height at the defence suggests that the railway can tolerate a reasonable discharge as long as waves are not too large. |
| 1 to 2 l/s/m or 1000 l/m under 10% AEP conditions for damage to line-side assets, buildings or rolling stock | Table 3.2 from EurOtop; damage to equipment set back 5-10m and the Network Rail single-line operation (where the line closest to sea is closed) suggest that this is pragmatic choice. |
| 0.5 l/s/m or 1000 l/m under 100% AEP conditions for areas beyond platforms, resulting in need for line speed restrictions. | Network Rail amber threshold resulting in line speed restrictions. |
| 0.3 to 1 l/s/m depending on incident wave height or 600 l/m under 100% AEP conditions for pedestrian safety; we would propose to apply this along platforms and any other areas where public access is currently present. | Table 3.3 from EurOtop; depending on wave height at the defence suggests that these are appropriate thresholds for pedestrians. We consider that this would be suitable for platforms and ensure that a pedestrian would not be knocked off their feet and onto the tracks. |

Table 5-4 provides the overtopping results at each cross section.

**Table 5-4. Overtopping Results for all CCA1 cross sections**

| Cross Section (refer to Figure 3-1) | Description | Return Period | Front Wall | | Back Wall | |
|---|---|---|---|---|---|---|
| | | | Qmean (l/s/m) | Vmax (l/m) | Qmean (l/s/m) | Vmax (l/m) |
| Merrion Gates to Booterstown (CCA1-B) | Existing wall 1.3m raising with bullnose | 200 | - | - | 6 | 6,700 |
| Booterstown to Blackrock (CCA1-C) | Existing wall 1.3m raising with bullnose | 200 | - | - | 8.5 | 4,100 |
| Blackrock station north (CCA1-D2a) | Front wall 0.75m raising with bullnose and new back wall | 1 | 8 | 3,215 | 0.4 | 700 |
| | | 200 | 40 | 4,500 | 5 | 1,700 |
| Blackrock station south (CCA1-D2b) | New front wall with bullnose, new back wall with glass on top | 1 | 9 | 1,900 | 0.7 | 400 |
| | | 200 | 48 | 4,000 | 4.5 | 1,150 |
| Blackrock amenity area (CCA1-D3) | Front wall 1m raising with bullnose and new back wall | 1 | 26 | 3,500 | 3 | 1,000 |
| | | 200 | 113 | 6,750 | 21 | 2,700 |
| South of Blackrock (CCA1-D5) | Existing wall 0.75m raising with bullnose | 200 | - | - | 8 | 3,200 |
| Seapoint beach west (CCA1-E1) | New front wall with bullnose, new back wall | 1 | 0 | 160 | 0 | 0 |
| | | 200 | 66 | 5,000 | 8 | 2,000 |
| Seapoint beach east (CCA1-E3) | Front wall 1.1m raising with bullnose and new back wall | 1 | 16 | 4,300 | 1.1 | 600 |
| | | 200 | 80 | 5,500 | 12 | 2,600 |

Notes:
- Where there are three walls, the first wall results are not shown here, due to the path being behind the second wall.
- Where there is only one wall, the results are provided for the back wall.

It is noted that in some locations the Vmax threshold of 2,000l/s is exceeded. However, unlike the mean overtopping discharge (Qmean), the maximum overtopping volume (Vmax) does not consistently follow the expected pattern of worse conditions resulting in higher Vmax. This is due to factors including:

- **Vmax is based in one single overtopping event**: the CFD model is run for at least 500 waves and Qmean averages the overtopping of all 500 waves, where smaller waves counterbalance higher waves. Vmax is only based on one wave event within the minimum 500 waves modelled.
- **Wave grouping and sequencing**: the sequence of average height waves can cause larger overtopping volume than a small wave followed by a high wave.
- **The randomness of the wave timeseries**: the same wave conditions result in different timeseries due to the randomness of the wave components phasing.

Therefore, Qmean provides a better indication of the impact of layout changes, such as raising or adding walls, than Vmax. Qmean accounts for all the waves reaching the structure and a change in the layout, wall raising for example, may lead to a reduction in the number of waves overtopping and reduction in overall volume overtopped, that is not captured by Vmax. At detailed design, additional analysis of the Vmax values can be undertaken to gain a better understanding of the potential risk of damage to the structures from the maximum overtopping volumes.

### 5.2.2 Wave loading assessment

Wave loading was derived from a Computational Fluid Dynamics (CFD) model, following the determination of an appropriate crest level and overall structural configuration. These parameters were selected to mitigate wave overtopping hazards by limiting discharge volumes to predefined thresholds, as detailed in Section 5.2.1

The CFD model was developed to resolve forces on individual structural elements within each section. For example, the seaward and landward walls were modelled as separate elements. The model outputs a time series of force data for each component for both horizontal and vertical wave forces under worst-case Joint Probability Analysis (JPA) conditions. These were then subsequently analysed to determine live wave impact loading. Due to the presence of isolated extreme events that could disproportionately influence design outcomes, the live load was characterised by averaging the peak values from the most significant force events within the time series.

A partial factor of 1.5 was applied to the live wave impact loading in accordance with I.S. EN 1997-1, reflecting the recommended design approach for ultimate limit state verification. In specific sections where isolated extreme wave events were observed which might significantly influence the force time series, an additional accidental load case was defined. This case was based on the average of the dominant peak loads, with a partial factor of 1.0 applied, consistent with the treatment of accidental actions under the Irish standard.

In addition to evaluating individual wall elements, the global stability assessment of the structure as a whole was also assessed.  In this analysis the force time series from each component were combined to provide a more representative and accurate loading scenario for structural analysis. This approach accounts for the phase differences between impact forces, acknowledging that peak loads on separate walls are unlikely to occur simultaneously.

## 5.3 Structural design

The proposed works consist of new concrete seawalls or new support structures for existing seawalls.. The structural design approach focuses on withstanding wave-induced pressures on these walls, which serve to protect the railway. The design also aims to optimise material use, particularly by minimising the quantity of concrete and other construction materials. A structural stability assessment of each section of seawall has been completed to confirm resistance to sliding and overturning failure from applied design wave forces. Whilst the seawall must resist other environmental design actions such as wind, current and thermal actions and other variable actions from maintenance and pedestrians; storm wave loading is the main design load case due to the magnitude for the applied force. The design does not consider accidental actions such as strike by train or boat or impact from waterborne debris as this scenario would be too onerous.

The primary function of the seawall is to protect the railway from overtopping by storm wave action. A secondary function in some locations is to provide a pedestrian walkway with occasional access points for the pedestrians. At certain locations along the seaward side, access steps have been integrated to enable public access to and from the beach to replace existing access points where required.

Wave forces were assessed using CFD analysis as described in Section 5.2.2. This was used to undertake stability checks, including sliding and overturning assessments. These analyses will be further refined during the detailed design phase.

To ensure compliance with Eurocode requirements and achieve efficient structural utilisation under the anticipated wave pressures, the Phase 3 design has been configured accordingly. In addition, the following factors were considered during the design process, where applicable:

- Retaining wall analysis has been undertaken in accordance with EN 1992-1-1 for concrete design and EN 1997-1 for geotechnical design. The Irish National Annex was used for defining the design factors.
- The design of access steps and ramps is in accordance with Technical Guidance Document M (Access and Use) or equivalent standard.

A range of sequential construction scenarios will need to be evaluated to ensure that precast units can be cast, stored, lifted, and installed without compromising the stability of the slope or the integrity of individual units prior to completion. A summary of the various design conditions will be agreed upon before the commencement of detailed design and will be reviewed for constructability constraints, such as transport and lifting limits and handling requirements.

The layout and geometry of the structure will be further optimised during the detailed design phase, informed by refined wave modelling and analysis.

### 5.3.1 Geometry and Composition

As discussed in Section1.2, the Project has been split into different sections based on the geometry and condition of the existing structures. The proposed works can be split into four typical cross sections based on the form of constructions. These are discussed in more detail in the following sections.

#### 5.3.1.1 Supporting structures

In locations where a high wall currently exists, it will be retained due to its heritage significance but structurally supported from behind with an L-wall. This addition will enhance the wall's capacity to withstand wave loading and improve its overall resistance to sliding and overturning. For sections where the existing crest level is insufficient based on overtopping criteria, a bullnose profile will be added to the wall to achieve the required top level. New concrete elements shall be precast reinforced concrete where possible to reduce installation time and avoid issues with concrete curing during an incoming tidal cycle. Insitu concrete shall also be used where necessary to accommodate connections to existing structures.

To provide additional stability, micro-piles have been implemented in paired rows, allowing them to function as a couple - one pile resisting tension forces while the other handles compression. This design approach provides the necessary structural stability while avoiding the need for large plant equipment. It was chosen specifically to suit site constraints.

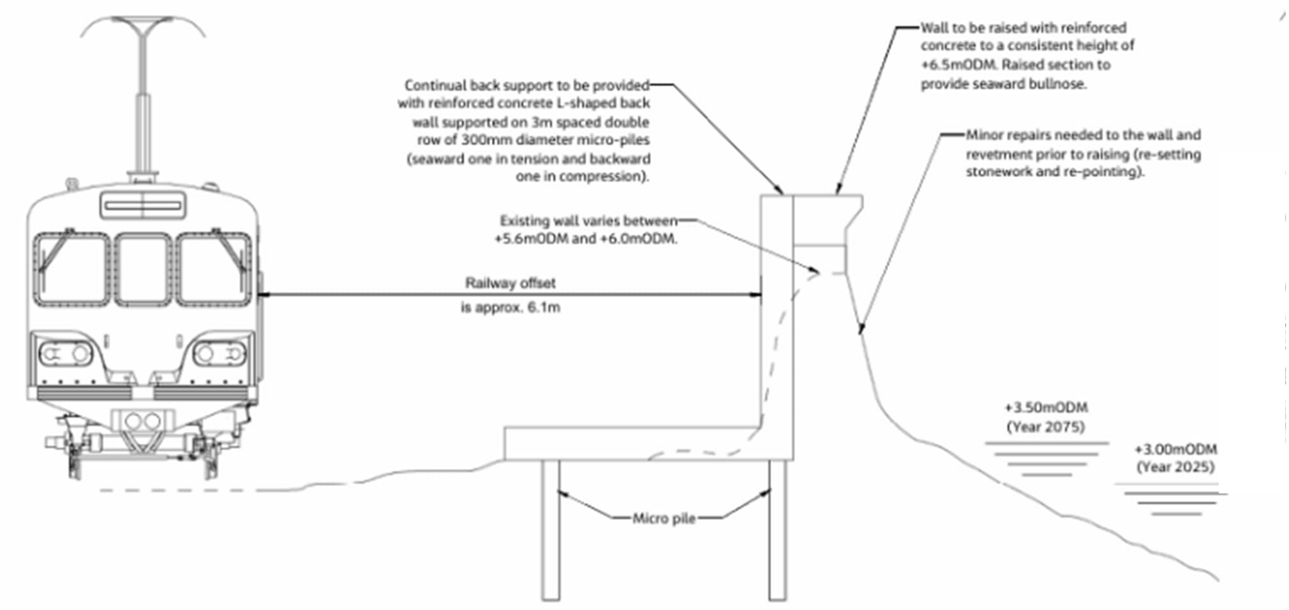


**Figure 5-2 Typical section: Existing wall raising with support structure**

### 5.3.1.2 Limited construction space areas

In locations where the existing wall is situated close to the railway, new seawalls will be constructed to meet the required Standard of Protection, equivalent to a 1-in-200-year storm event. Due to the significant wave forces identified through CFD modelling, fixing a bullnose extension on top of the existing wall using dowelled or anchored connections was found to be unfeasible. As a result, two alternative primary cross-section types have been developed to effectively resist these wave loads.

Where the existing wall is in poor condition it will be demolished down to ground level and a new seawall constructed to the required crest elevation. Where feasible, new structural elements will be precast reinforced concrete, with in-situ concrete used as needed for connections and tie-ins to existing infrastructure. Additional stability is provided through ground anchors, which apply tension between the structure and the underlying ground. This technique effectively increases the structure's self-weight, enhancing its resistance to sliding and overturning without the need for large volumes of concrete. Due to spatial constraints imposed by the adjacent railway, using sufficient concrete to meet stability requirements was not viable, leading to the adoption of alternative solutions.

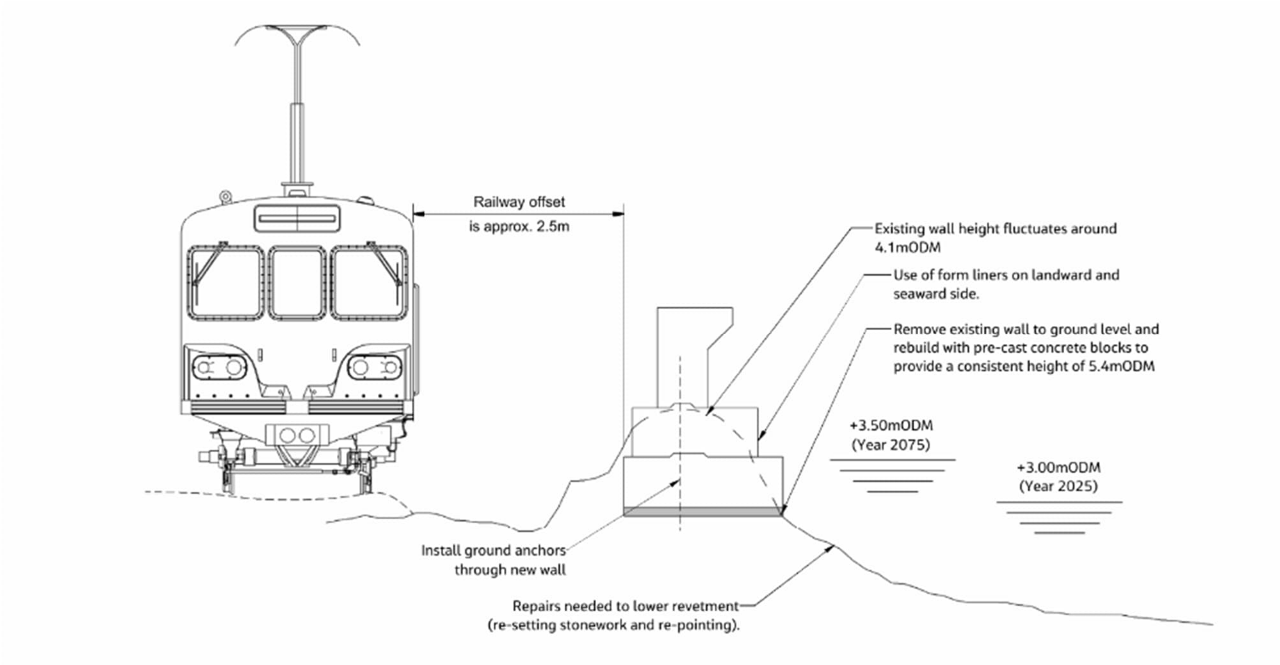


**Figure 5-3 Typical section: Wall on existing concrete base with existing wall demolished**

Where the existing wall is in fair condition a new seawall will be constructed seaward of it, retaining the existing seawall. Structural stability is achieved through the use of ground anchors and a shear key, which work together to resist wave forces and achieve stability.

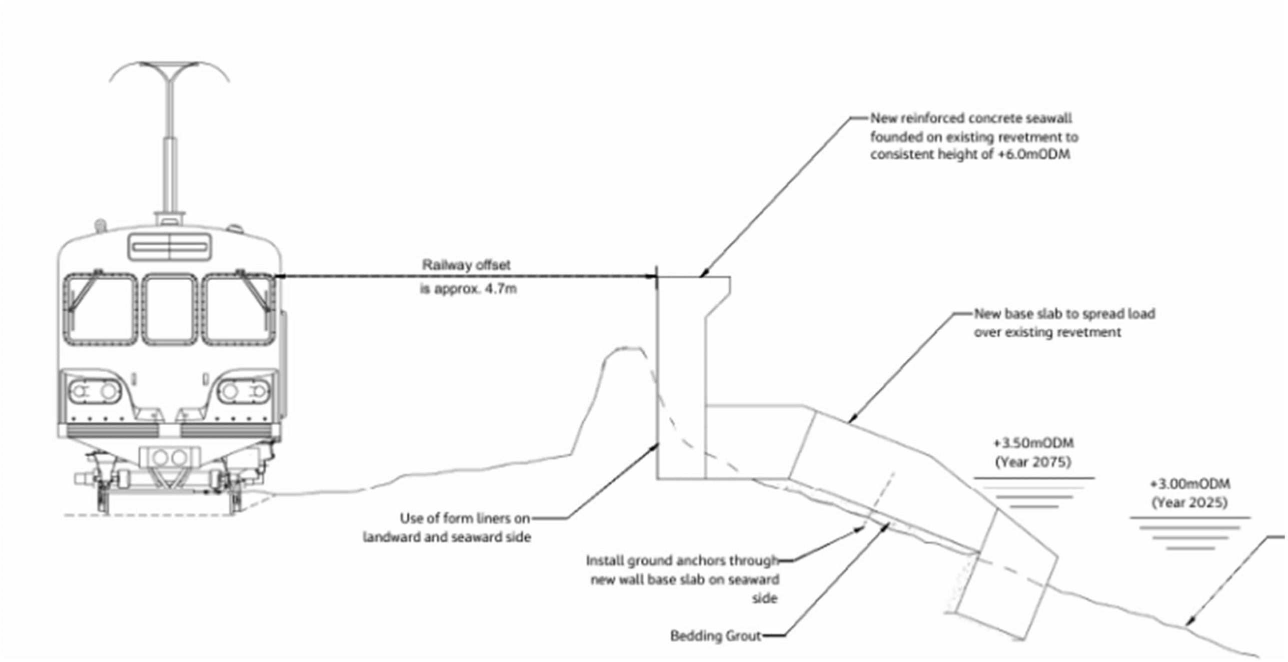


**Figure 5-4 Typical section: Seaward wall on existing stone revetment base**

### 5.3.1.3 Footpaths

In areas where footpaths run adjacent to existing sea defences, these will be preserved. New or upgraded seawalls will incorporate a raised walkway constructed above the existing footpath, maintaining clear views out to sea for users. Small sections of the existing wall will be removed down to ground level to accommodate the new structure. The footpath will be protected by a seawall featuring a bullnose profile to deflect wave energy seaward. Existing access points will be retained and integrated into the new design.

To ensure structural stability under extreme wave loading conditions, ground anchors are installed in areas where geotechnical investigations indicate poor subgrade conditions. In contrast, where a solid foundation has been confirmed, dowelled connections are utilised to achieve adequate load transfer.

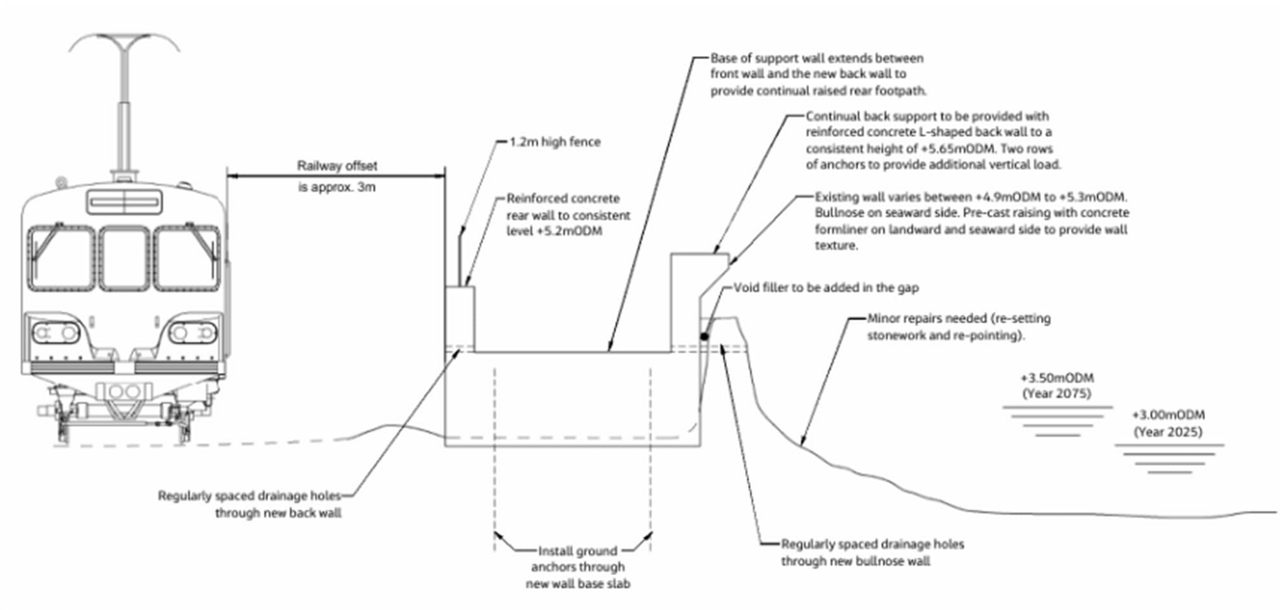


Figure 5-5 Typical section: New raised footpath

#### 5.3.1.4 Amenity areas

Numerous amenity areas along the coastline provide public access to the beach, including a prominent location south of Blackrock. These areas will be preserved as part of the proposed works. Similar to the footpaths, they will be protected by new seawalls featuring a bullnose crest to deflect wave energy seaward. The existing ground levels of these amenity spaces will be raised to support the new coastal defence structures, while ensuring full public access is maintained. Structural stability is achieved by providing doweled connections and ground anchors through the existing concrete structure, enabling effective load transfer and ensuring monolithic behaviour under wave-induced forces.

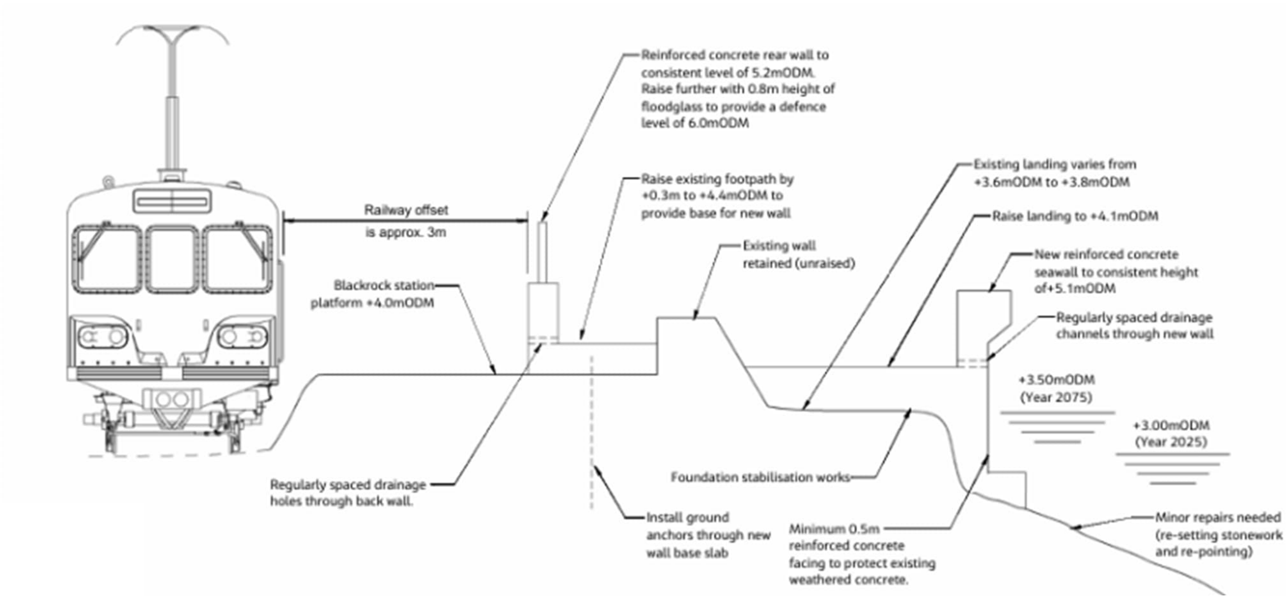


**Figure 5-6 Typical section: New amenity area**

## 5.4 Geotechnical design

The geology in the area is characterized by superficial deposits primarily comprising estuarine silts and clays, as well as marine beach sands and till derived from limestones, with bedrock outcrops present seaward of the railway. Marine sands and gravels become increasingly common closer to the coast, while glacial tills become more prevalent landward of the railway. The solid deposits predominantly consist of limestone from the Lucan Formation, located north of the frontage and north of Blackrock Station. From Blackrock Station southwards, granite of Caledonian age was encountered. Additionally, two normal faults intersect the frontage, approximately at the northern and southern boundaries of Blackrock Park, dipping at an angle of 60 to 70 degrees to the northwest.

From December 2023 to February 2025, ground investigations were conducted to gather information on soil, rock, and groundwater for designing coastal defences. Jacobs supervised the work to promote accurate data collection and reporting. A factual report (Causeway Geotech Ltd, 2025) summarised the methods and results.

An engineering ground model for the site has been developed in the Geotechnical Interpretive Report (GIR) for this Project. This is supported by boreholes, dynamic probes at track level and on the beach. For interpretation of ground conditions and soil/rock parameters refer to CCA1- Geotechnical Interpretive Report, Doc No 7694-CCA1-P3-ENG-CV-JAC-0002.

The geotechnical design comprised of assessment of sea walls founded on Made Ground or Engineered Fill for Ultimate Limit States (ULS) of bearing and sliding. The new wall utilises the existing structures and will be structurally connected. The conducted geotechnical analysis resulted either in the required width of the sea walls so that ULS design cases are satisfied, or in the inclusion of mini piles and/or prestressed anchors so the required protection (for a 1 in 200-year storm event) for bearing, sliding is provided. Section 5.4.1 to 5.4.4

below include summary of geotechnical results. For details of the geotechnical analyses undertaken, refer to Section 6 of the GIR.

The geotechnical risks identified at this stage of the project have been included in Section 9 of the GIR. The major risks include variable or unforeseen ground conditions at all proposed structures, limited information pertaining to the size and depth of the existing sea walls foundations, large wave forces.

The geoenvironmental risks associated with the construction phase are generally considered to be 'moderate/low' based on the information available. Risks to future site users are also considered to be generally 'low'. However a potential risk of unidentified contamination remains in areas not subject to GI. For details about assessment of potential site contamination refer to Section 7 of the GIR.

For geotechnical recommendations refer to Section 8 of the GIR.

### 5.4.1 Sliding assessment

A sliding assessment was carried out for the sea walls determine the necessary base width. The analysis indicated a minimum base width requirements of 1.9 meters and 3.3 meters at Merrion Gates to the Spit and The Spit to Booterstown respectively. To supplement the structural weight and introduce an additional vertical resisting force, the use of ground anchors may be necessary (see Section 5.4.4 below).

South of Blackrock the stability of the proposed structure against sliding was acceptable.

For details of the sliding assessment undertaken, refer to Section 6 of the GIR.

### 5.4.2 Bearing capacity

The bearing capacity was checked for the sea walls underlain by founding stratum such as Made Ground or Engineered Fill. Surcharge from structure self-weight was considered as unfavourable permanent loading. Vertical loading from wave action (uplift) was considered as favourable variable loading. Bearing capacity analysis confirms that the bearing capacity of the founding stratum are acceptable. For details of the undertaken bearing capacity analysis, refer to Section 6 of the GIR.

### 5.4.3 Pile assessment

A piled foundation solution is proposed around Seapoint Station to ensure structural stability under wave loading associated with a 1 in 200-year storm event. The design includes two rows of bored piles supporting the base of the new wall, with lateral spacing of 1.5 meters and longitudinal spacing of 3 meters. The ground profile comprising Made Ground over Alluvium, underlain by Limestone (anticipated at -3m OD or 6m below ground level) indicates that rock sockets are necessary to achieve adequate axial capacity. The minimum axial capacity achieved per pile is 4900kN.

An assessment of pile capacity was carried out for an individual bored pile, and the following pile characteristics were determined:

- Pile diameter 450mm
- Total pile length 9m
- Rock socket 3m

For details about pile assessment refer to Section 6 of the GIR.

### 5.4.4 Ground Anchor assessment

Sliding assessment has shown that the self-weight of the sea walls was insufficient to resist sliding at Blackrock and Seapoint. Moreover, the self-weight of the walls is potentially insufficient to provide enough resistance against sliding at Merrion Gates to Booterstown. Therefore, to provide additional vertical resistance, prestressed ground anchors are proposed (refer to Section 6 of the GIR).

## 5.5 Landscape design

Merrion Gates to Seapoint Beach is an urban location with heritage walls protecting the railway line and numerous amenity areas. Whilst the proposed works will maintain, and in many cases improve, the amenity offerings it is noted that the use of precast concrete is in contrast to the existing structures. The use of formliners in the pre-cast concrete mould will be used to add texture to the walls to soften the impact of the concrete against the existing landscape. Figure 5-7 to Figure 5-11 provide artistic sketches of the proposed works along the Project.

During Phase 4 further design work will be undertaken by landscape architects, in collaboration with heritage consultants, to explore material choices and enhancements that will help integrate these coastal defences into the landscape.

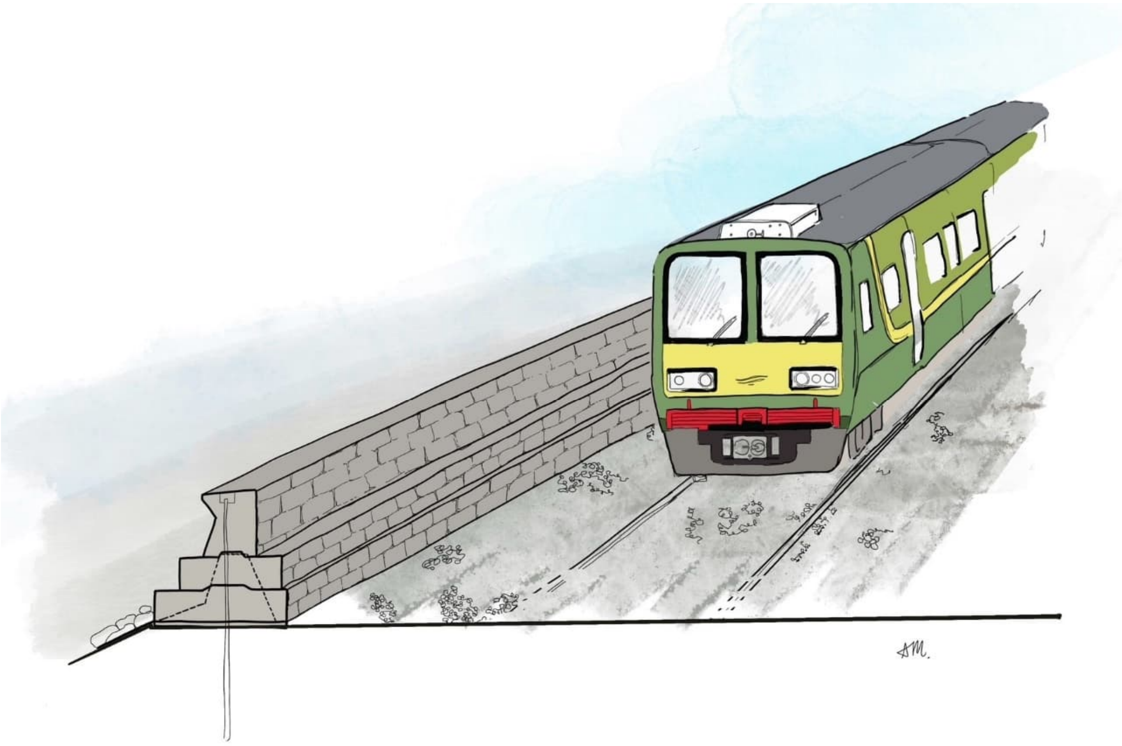

**Figure 5-7. Illustrative sketch of the new concrete wave wall at Merrion**

**Figure 5-8. Illustrative view of the proposed works at Booterstown Station**

**Figure 5-9. Illustrative view of the proposed works at Blackrock Station**

**Figure 5-10. Illustrative view of the proposed works at Seapoint (looking south)**

**Figure 5-11. Illustrative view of the proposed works at Seapoint (looking north)**

## 5.6 Access

All existing access to and from the foreshore and the stations will be maintained as part of the Project. No additional access is proposed.

## 5.7 Environmental enhancement/biodiversity design

The Phase 3 design will be further modified at detailed design having regard to the potential for environmental effects as identified by the Environmental Impact Assessment Report (EIAR) which will be produced in Phase 4 of the Project.

# 6. Preferred scheme

## 6.1 Description of preferred scheme design solution

Throughout the whole of the Project frontage the existing walls are not high enough to provide the required overtopping protection for the next 50 years. Therefore, the preferred scheme taken forward to Phase 3 comprises raising and strengthening the defences along the majority of the frontage. The approach to raising the height of the defences differs by location due to the variation in the existing shoreline geometry, the variation in the available space for construction and the complexities around maintaining amenity provision.

### 6.1.1 Design at Merrion to Booterstown

The existing wall here is in poor condition and not suitable to be raised when wave loading over the next 50 years is considered. This location also has very limited space between the existing wall and the railway line. The existing wall will be taken down to ground level (top of the existing revetment) and rebuilt. The new wall will be constructed from pre-cast concrete units with ground anchors (these will not be visible) installed to provide the required stability. The new wall will be approximately 1.3m higher than the existing wall. Formliners can be used to create a textured finish to the precast wall units to be more in keeping with the existing structures. This can be used on both the seaward and landward face of the walls.

### 6.1.2 Design at Booterstown to Martello Tower

This area is also space constrained, however the existing wall is in fair condition and can be left in place. A new reinforced concrete wall will be constructed seaward of the existing wall over the existing revetment, ground anchors through the new wall base slab on the seaward side will be installed to provide stability and support. The new wall will be approximately 1.3m higher than the existing wall. Formliners can be used to create a textured finish to the precast wall units to be more in keeping with the existing structures

### 6.1.3 Design at Williamstown Martello Tower

Just south of the Martello Tower, along a short section of approximately 19m, the existing wall is already at a sufficient height to protect the railway from overtopping for 50 years. Therefore, no works are proposed to the existing wall here. The existing amenity access step seaward of the existing seawall will be raised and a new 1.0m high reinforced concrete upstand wall added to the front of the raised step with a bullnose on the seaward side. New steps down to existing walkways to the south and to the foreshore to the north will also be included to preserve public foreshore access.

### 6.1.4 Design at Martello Tower to Blackrock

The existing wall here is in fair condition and can be left in place. A new reinforced concrete wall will be constructed seaward of the existing wall over the existing revetment. A new walkway will be constructed in place of the existing walkway. Ground anchors will be installed through the base slab of the new wall to provide stability and support.

The new wall will be approximately 1.2m higher than the existing wall.

### 6.1.5 Design at Blackrock to Seapoint Beach

At the Blackrock bathing area, the existing seawall will be retained. A new reinforced concrete wall will be built over the revetment seaward of a raised amenity platform. To provide additional coastal protection to wave overtopping, a new 1.8m high wall (L-shaped reinforced concrete lower section, which is raised further with floodglass) will be constructed alongside the railway corridor (replacing the existing railway fence). South of this location, where a high wall is present, a supporting structure will be introduced to ensure the existing wall meets structural requirements, with localised crest raising implemented where necessary. Floodgates will be installed at existing wall openings to maintain flood resilience. Further south, the existing footpath will be preserved and raised to maintain sea views for pedestrians, with protection provided by a seaward bullnose and a secondary wall landward.

### 6.1.6 Design at Seapoint Beach

At central Seapoint Beach a new concrete seaward wall will be constructed over a raised and improved walkway over the revetment. New amenity steps will be provided seaward of the walkway. The existing fence alongside the railway will be replaced with a 1.3m concrete wall (with a security fence on top). No works will be undertaken to the existing wall but the footpath between the existing wall and the new rear wall will be raised.

At southeast Seapoint Beach the existing seawall will be raised by approximately 0.9m and a new rear wall will be constructed alongside the platform (1.4m high L-shaped reinforced concrete lower section, which is raised further with 0.9m of floodglass). The footpath between the two walls will be raised to retain views.

### 6.1.7 Design at Stations

At Booterstown Station protection against wave overtopping will be provided whilst maintaining the existing access and amenity features. The existing walkway on the seaward side of the seawall will be raised and improved. A new concrete wall on the seaward side of the walkway will be constructed and access to the foreshore maintained. The fence alongside the platform will be replaced with a 1.35m high concrete wall, raised further with 0.9m high flood glass.

At Blackrock Station North, to preserve public foreshore access, a new concrete wall will be built seaward of a raised and improved walkway. Along the platform edge a new 0.5m concrete wall will be constructed with a further 0.8m of floodglass installed on top of the wall

At Blackrock Station new walls will be constructed landward and seaward of the existing wall to avoid any impacts on the public access provision and existing masonry wall. The existing walkway along the seaward side of the seawall will be raised and a new wall will be installed on the seaward face of the raised and improved walkway to provide overtopping protection. A new backwall will be constructed along the line of the existing fence, raised further with floodglass alongside the station platform.

At Seapoint Station the existing wall will be raised by up to 0.9m and supported at the back by a new concrete retaining wall.

## 6.2 Future Adaptability of preferred scheme design solution

The future long term adaptability for the Project will be the addition of rock revetments overlaying the existing masonry revetments. This will provide the additional protection required to manage the overtopping risk to the railway against longer term climate change. The rock revetments will also reduce the wave impact forces on the wave walls thereby extending the design life of these structures. It should be noted that prior to the longer term rock works being implemented, the overall standard of protection of the coastal defences will rely on maintaining the structural integrity of the existing exposed stone revetment (and exposed masonry walls). This will necessitate ongoing inspection and maintenance.

## 6.3 Drawing list

Drawings prepared for the Project are summarised in Table 6-1.

**Table 6-1. Drawing list for Merrion Gates to Seapoint Beach Phase 3**

| Drawing No. | Title | Description |
|---|---|---|
| 7694-CCA1-P3-DWG-CV-JAC-0010 | SITE LOCATION PLAN | Overview of frontages between Merrion Gates and Seapoint Beach |

| Drawing No. | Title | Description |
|---|---|---|
| 7694-CCA1-P3-DWG-CV-JAC-0100 | LOCATION PLAN | Location of proposed works between Merrion Gates and Seapoint Beach |
| 7694-CCA1-P3-DWG-CV-JAC-0200 | GENERAL ARRANGEMENT PLAN 1 OF 7 | Location of proposed works |
| 7694-CCA1-P3-DWG-CV-JAC-0201 | GENERAL ARRANGEMENT PLAN 2 OF 7 | Location of proposed works |
| 7694-CCA1-P3-DWG-CV-JAC-0202 | GENERAL ARRANGEMENT PLAN 3 OF 7 | Location of proposed works |
| 7694-CCA1-P3-DWG-CV-JAC-0203 | GENERAL ARRANGEMENT PLAN 4 OF 7 | Location of proposed works |
| 7694-CCA1-P3-DWG-CV-JAC-0204 | GENERAL ARRANGEMENT PLAN 5 OF 7 | Location of proposed works |
| 7694-CCA1-P3-DWG-CV-JAC-0205 | GENERAL ARRANGEMENT PLAN 6 OF 7 | Location of proposed works |
| 7694-CCA1-P3-DWG-CV-JAC-0206 | GENERAL ARRANGEMENT PLAN 7 OF 7 | Location of proposed works |
| 7694-CCA1-P3-DWG-CV-JAC-0300 | GENERAL ARRANGEMENT CROSS SECTIONS 1 OF 3 | Proposed cross-sections |
| 7694-CCA1-P3-DWG-CV-JAC-0301 | GENERAL ARRANGEMENT CROSS SECTIONS 2 OF 3 | Proposed cross-sections |
| 7694-CCA1-P3-DWG-CV-JAC-0302 | GENERAL ARRANGEMENT CROSS SECTIONS 3 OF 3 | Proposed cross-sections |

## 6.4 Buildability / Constructability

The use of construction staging areas will likely be required for the Project. These areas will contain site compounds, laydown areas and material load out points for works using the railway. The expectation is that during the construction phase there will be at least one main site compound which will contain the site welfare, offices, laydown areas, car parking etc. There may also be smaller satellite compounds closer to the works locations for activities such as material load out points and welfare closer to the works.

Some material import and construction works are likely to be undertaken from the trackside, therefore having a compound/staging area remote from the work area would support this. There is a small area at the northern end of the Project that could be used for material load out. This area could be used to position a small crane to lift precast units, load out concrete materials and plant. It has good transport links for HGV to deliver materials but is too small to store large volumes of material. Careful planning of material import will be needed along with delivering materials on a 'just in time' basis which can carry more risk. This area is close to residential properties and may not be suitable due to noise impacts.

Alternatively, there is an area South of Merrion Strands in an existing car park which could be suitable. This hardstanding is close to the railway and has good transport links into it. This location would provide sufficient area for positioning a mobile crane, provide site welfare and offer sizeable laydown areas close to the railway.

The assumption at this stage is that the precast units will be fabricated locally, brought to a staging area adjacent to the railway, loaded onto the railway and delivered via rail bogeys to the work area. Overnight possessions of the railway will be required to transport materials, equipment and labour to the work area.

In addition to using the railway line during night shutdown periods, access for materials, plant and labour will be required from the seaward side of the railway line boundary where there may also be the requirement to construct some temporary working platforms and access routes that support construction activities during the railway operational periods. There are a number of access points along the frontage such as Merrion Gates, Seapoint and Salthill & Monkstown available for access.

For Merrion Gates to Booterstown, the existing wall will need to be removed and a new wall built up in sections. The wall will be made up of precast sections with a ground anchor through the centre to provide lateral restraint from wave action. From Booterstown to Blackrock, there will be an apron constructed over the upper part of the existing revetement and a new vertical seawall constructed from a combination of precast and insitu elements, with a ground anchor installed through the centre of the apron section.

These precast units could be loaded onto rail bogeys, transported to site via rail bogeys and lifted directly from the rail bogeys into the work area.

Consideration should also be given to the sections of the railway line that has overhead power lines (OHLE). The areas with OHLE may limit the use of certain railway mounted equipment

The overall construction approach would be to have the first work spread working independently for a number of shifts; this would then create sufficient gap between the next work spread starting. This approach creates a rolling production line with appropriate separation between each work spread such that if one spread gets delayed it doesn't delay subsequent work spreads. This gap may be one week or more depending on how much work is needed along the route. The overnight possession window (assumed as a minimum working time of 3 hours) will dictate the durations for the works. This logic allows for curing time between pours. It has also been assumed that daytime works will continue without impact to the railway line based on unhindered access being available along the seaward side of the railway line boundary.

Due to the location and limited working window, it is envisaged that, where possible, the concrete structures will be constructed as precast concrete units. The size and length of the units will be agreed and set to lifting limits set by the Contractor. Therefore, precast units will be connected, either by in-situ concrete sections or other mechanical means, to minimise the risk of lateral movement due to wave action or vertical movement due to settlement. Movement and construction joints are to be placed at regular intervals to allow the structure to accomodate effects of thermal actions and other sources of movement.

## 6.5 Environmental assessment

The EIA screening and scoping documents are currently being prepared. The EIA screening report will determine whether the proposed project is of the nature and scale that requires an EIA. The EIA scoping report will outline the proposed assessment to be undertaken to generate an Environmental Impact Assessment Report (EIAR) for the proposed project including details of the environmental topics to be scoped in/out, the assessment methodology and the surveys, consultation and data required for the assessment.

The Phase 3 design will inform the environmental assessment under Phase 4 of the Project

## 6.6 Health and Safety

A Design Hazard Elimination & Risk Reduction Register or DEHERR, has been developed alongside the Phase 3 design. The DEHERR is presented in Appendix C and allows the designer to determine potential risks and, where possible, design against the risks presented. Where the risk is not possible to eliminate at this stage of design, further evaluation of the risk will occur at detailed design, before the risk is transferred to the contractor to consider when developing their safe system of works. A table presenting the principal identified risks is provided **Table 6-2**.

**Table 6-2. Top five risks identified in the DEHERR**

| Risk ID. | Activity | Potential Hazard | Design to Reduce Risk | Residual Risk | Action By | Comments |
|---|---|---|---|---|---|---|
| 1 | Transportation of precast units | Striking of live services overhead rail cables causing electrocution, and/or explosion. | Known services identified on drawings | Striking of live services overhead rail cables causing electrocution, and/or explosion. | Designer / Contractor | Client to agree procedures for cable isolation.<br>Contractor to provide thorough method statement and safe system of work. |
| 2 | Existing Services | Damage to existing services during construction leading to death or injury to site personnel. | Full services survey to be undertaken during detailed design development. | Damage to existing services during construction leading to death or injury to site personnel. | Designer / Contractor | Full services search to be undertaken at detailed design stage.<br>Contractor to survey location prior to excavation works, where reasonable. |
| 3 | Unforeseen services present | Striking of live services causing electrocution, explosion, flooding and / or disruption of services. | Full services survey to be undertaken during design development. | Striking of live services causing electrocution, explosion, flooding and / or disruption of services. | Designer / Contractor | Full services search to be undertaken at detailed design stage.<br>Contractor to survey location prior to excavation works, where reasonable. Working methods for excavations to be developed to detect, locate and identify services. |

| Risk ID. | Activity | Potential Hazard | Design to Reduce Risk | Residual Risk | Action By | Comments |
|---|---|---|---|---|---|---|
| 4 | Unstable ground conditions | Potential for site operatives or plant to become stuck in pockets of soft or lose ground. Instability of plant working in area of low soil strength. Risk of suffocation, crash injuries from sinking into ground/loss or damage to plant. | Inform contractor of risk of soft ground from GI and geotechnical analysis in detailed design. | Potential for site operatives or plant to become stuck in pockets of soft ground. Instability of plant working in area of low soil strength. Risk of suffocation, crash injuries from sinking into ground/loss or damage to plant. | Designer / Contractor | Contractor to prepare method statement and safe systems of work. Risk to be updated following completion GI and geotechnical analysis. |
| 10 | Managing public access to works | Potential for public to become injured if gaining access to site works while heavy plant etc are working. | At detailed design stage, contractor to address public access concerns as part of method statement. | Risk of injury to public due to access gained to site. | Designer / Contractor | Contractor to prepare method statement and safe systems of work. These will ensure that the chance of public access to the site is limited as much as practically possible. |

### 6.6.1 Safety and maintenance plan

The safety and maintenance plan will be developed during detailed design.

The safety certification and approvals will be aligned with the process stated in Iarnród Éireann (IÉ) standards and the general good practices of safety assurance and management. However, based on the consultation with IÉ stakeholders, it has been confirmed that the scoped works are non-significant in accordance with the Common Safety Method Risk Assessment (CSM-RA) and does not require Authorisation to Place in Service (APIS).

Ongoing routine inspection of all coastal assets will be required (as per the current IE requirements). Inspection and maintenance repairs to the exposed existing lower masonry revetment and masonry walls will be particularly important prior to the future installation of a rock revetment.

In addition to the routine maintenance works undertaken by IE, it is recommended that inspections of the railway are undertaken following significant storms to assess any potential damage. The concrete structures may require some patch repairs during the design life.

## 6.7 Recommendations for refinement at detailed design

At detailed design the following additional studies and analyses are recommended to refine and confirm the Phase 3 designs.

- Full topographic survey
- CFD analysis of wave loading and overtopping at additional cross sections, in particular at the stations
- Interfaces between cross sections and existing structures;
- Location of construction assess points and review of construction options;
- Confirmation of lifting limits to size precast concrete and other prefabricated elements;
- Structural inspections/condition assessment of all elements due to remain in place for the permanent works;
- Health and Safety requirements such as the need for handrails and edging kerbs (Public Safety Risk Assessment);
- Materials and finishes for the concrete structures;
- Reinforcement design of concrete elements;
- Ground investigation to confirm:
  - existing foundations width and underside level of foundations of existing walls
  - founding stratum make up and its geotechnical properties underneath the existing sea walls
  - presence and thickness of estuarine silts/clays (Merrion Gates to the Spit and The Spit to Booterstown) and alluvium (Booterstown to Blackrock, south of Blackrock) to inform anchor and pile design
  - top of rock levels at Blackrock to inform anchor and pile design
  - piezometers to monitor ground water level and fluctuations with tide
- Following receipt of additional information about existing foundations and ground conditions at detailed design stage, optimisation of the proposed piled and anchored solutions is recommended;
- Seek to further minimise the removal of the existing historical upstand wall elements and explore mitigation measures with heritage specialists where this this not possible.

# 7. Conclusions and Next Steps

The Project phases to deliver the Preferred Scheme are summarised below:

- Phase 1 – Project Scope and Approval (completed);
- Phase 2 – Concept, Feasibility and Options (completed);
- **Phase 3 – Preliminary Design (current phase);**
- Phase 4 – Statutory Process (next phase);
- Phase 5a- Detailed Design and Tender Issue (future phase);
- Phase 5b - Contract Award (future phase);
- Phase 6 – Construction; and,
- Phase 7 – Close out.

This Phase 3 Design Report is the principal deliverable for this stage.

## 7.1 Design development

The next phase of design covers Statutory Process that is focussed on preparation of the environmental impact assessment report (EIAR) AA Screening reports, Natura Impact Statements and associated documentation required for a planning application.

## 7.2 Opportunities for consultation and engagement

The Phase 3 Design has been informed by Public Consultation 1 (PC1) undertaken in Nov/Dec 2024. The findings are summarised in the PC1 report (7694-CCA2_3-P2-PLA-EV-JAC-0010. A second round of consultation (PC2) will be undertaken in September 2025.

The Project will now undertake an environmental assessment which will be reported in the EIAR and other documentation in support of the statutory planning process for the Project. Stakeholders will be afforded the opportunity to engage on the Project again at this point through the statutory stakeholder engagement process. Outputs from this consultation process will be taken into consideration by the planning authority.

## 7.3 Consenting

The significant work streams undertaken during this phase of the project comprise the preparation of all documentation leading to a Marine Area Consent application and Planning Consent application.

An application(s) will be made to MARA for the Marine Area Consent (MAC). On receipt of a MAC a planning consent application will be made. At this stage it is considered that the application for planning will be made under the Seventh Schedule Strategic Infrastructure Development (SID) under the Planning and Development (Strategic Infrastructure) Act 2006 and Planning and Development Act, 2000 (as amended). However, the application will be made under the Planning and Development Act 2024 if the relevant sections are enacted at the time of the application.

## 7.4 Procurement and programme

The construction procurement will commence following the granting of the necessary consents..

A high-level indicative programme of the next phases is as follows:

- Phase 3 completion autumn 2025; and
- Phase 4 programmed for winter 2025 and throughout 2026.

The programme for phases after planning submission (Phase 5 onwards) is subject to application durations.

# 8. Glossary

| Term | Description |
|---|---|
| Annual exceedance probability | The probability that a given event will be equalled or exceeded in any one year |
| Antecedent rainfall | Cumulative rainfall totals over a given period |
| Beach lowering | Reduction in beach surface elevation over a timescale due to cross-shore and longshore sediment transport. |
| Beach nourishment | Supplementing the existing beach periodically with suitable material to increase beach volumes, reduce erosion and toe scour at flood defences and/or soft cliffs. |
| Breakwater | Offshore structure which dissipates wave energy due to their size, roughness and presence of voids. This reduces the wave heights at the shoreline defences |
| Caisson | A watertight retaining structure used as a foundation |
| Capital expenditure | Funds used to acquire, upgrade and maintain physical assets (e.g., construction costs) |
| Capping beam | Steel structures that join pile foundations together to increase their rigidity and reduce movement |
| Carbon management | An approach to mitigate or reduce carbon (or other greenhouse gas) emissions |
| Catch fence | A fence designed to catch falling debris and absorb impact |
| Circular economy | A system which reduces material use, redesigns materials, products, and services to be less resource intensive, and recaptures “waste” as a resource |
| Cliff recession | Landward retreat of the cliff profile (from cliff toe to cliff top) in response to cliff instability and erosion processes |
| Climate adaption plan | A plan which sets out measures that protect a community or ecosystem from the effects of climate change, while also building long-term resilience to evolving environmental conditions |
| Climate change | A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide |

| Term | Description |
|---|---|
| Climate resilience | Climate resilience is the capacity of social, economic and ecosystems to cope with a hazardous event or trend or disturbance caused by climate change |
| Coastal Cell Area | A spatial model which subdivides the coast based on the variation in physical characteristics, including the geology, geomorphology, shoreline topography and orientation, and existing defence type |
| Coastal erosion | Loss or displacement of land, or long-term removal of rocks and sediment along the coastline due natural impact of waves, wind, rain and tides |
| Coastal flooding | Submergence of normally dry and low-lying land by seawater |
| Coastal protection | Measures aimed at protecting the coast, assets and inhabitants from coastal flooding and erosion. Coastal protection may involve structural, non-structural or nature-based solutions |
| Coastal spit | A coastal landform, whereby a stretch of beach material projects out to the sea and is connected to the mainland at one end |
| Concept level design | Foundational phase of the design process which lays the groundwork for the entire project. The design work undertaken for the concept design is sufficient to confirm that the options will work from a technical perspective and will meet the Project objectives. |
| Concrete armour | Precast concrete units placed to form breakwaters or revetments to dissipate wave energy |
| Constructability | Also known as buildability. The extent to which a design facilitates the each and efficiency of construction |
| Design horizon | The period of time over which the scheme provides the required Standard of Protection (SoP) to the railway line. |
| Design life | The service life intended by the designer, which is the period of time after installation during which the structure meets or exceeds the performance requirements. |
| Dilapidation survey | A detailed survey that examines the existing state of the coastal structure |
| Dune regeneration | Stabilisation and enhancement of existing dune systems to deliver additional resilience |

| Term | Description |
|---|---|
| Embankment | Linear grassed earth structure providing flood protection; typically used along riverbanks |
| Emergency works | Works in response to an event that is unexpected and serious such that it presents a significant risk to human life, health and property or the natural environment and involves the need for immediate action to manage the risk |
| Feasibility study | An assessment of the practicality of a proposed project plan or method. |
| Flood proofing | Structural, and non-structural, solutions that can prevent or reduce flood damages to a property or its content. |
| Flood warning and preparedness | Measures undertaken to better prepare, respond and cope with the immediate aftermath of a flood event |
| Foreshore | The part of a shore between high- and low-water marks |
| Freeze-thaw weathering | Form of mechanical weathering whereby water enters cracks in rocks, freezes and expands, widening the cracks. Repetition of this cycle causes gradual break down of the rock. |
| Gabions | A basket or container filled with earth, stones, or other material |
| Geomorphology | The interaction between Earth's natural landforms, processes and materials |
| Geotextile | Permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain |
| Geotubes/ Geotextile Tubes | Tube shaped bags made of porous, weather-resistant geotextile and filled with sand slurry, to form artificial coastal structures such as breakwaters or levees |
| Groyne | Linear structure constructed perpendicular to the shoreline which helps retain beach material in place. |
| Hazard | A process or material that has the potential to cause harm. |
| High tide mark | A point that represents the maximum rise of a body of water over land |
| Hydrodynamic modelling | Used in the analysis of coastal hydrodynamic processes, it is employed to simulate major physical phenomena in the coastal region |

| Term | Description |
|---|---|
| Maintenance burden | The level of maintenance (repair, monitoring, rebuilding) required over the design life of the structure to retain the Standard of Protection of the coastal defence structure |
| Managed realignment | A coastal management strategy that involves setting back the line of actively maintained defences to a new line inland and creating inter-tidal habitat between the old and new defences |
| Mudslides | Mass of saturated sediment that moves downslope. Typically comprises distinct source, transport and debris accumulation zones |
| Multi criteria analysis (MCA) | A structured approach to determine overall preferences among alternative options, where the options should accomplish multiple objectives. |
| Nature-based solutions | The use of natural materials and processes to reduce erosion and flood risk to coastal infrastructure |
| Pore water pressure | The pressure of groundwater within voids between sediment particles. High pore water pressures push particles part, reducing the shear strength which may trigger slope failure. |
| Risk | The adverse consequence of a hazard event. Risk is typically described in financial terms, but may consider human harm, environment impact, programme delays or reputational damage. |
| Residual risk | The risk that cannot be completely eliminated by engineered mitigation measures. It is generally agreed to be at an acceptable level by the client. |
| Revetment | Sloping or stepped structure built parallel along the shoreline between the low lying beach and higher mainland to protect the coast from erosion and wave overtopping. The revetment may have a smooth or rough surface |
| Rock netting | A drapery system designed to control rockfall movement by guiding falling debris to a collection point at the toe of the slope |
| Saltmarsh | Coastal grassland that is regularly flooded by seawater |
| Sea level rise | An increase in the level of the oceans due to the effects of climate change and/or land-level change |
| Seagrass bed | Intertidal or sub-tidal beds of sea grass. Provides ecosystem benefits including carbon sequestration. |

| Term | Description |
| --- | --- |
| Seawall | Vertical or near-vertical impermeable structure designed to withstand high wave forces and protect the coast from erosion and/or flooding |
| Shellfish reefs | Sub-tidal or intertidal reefs formed of suitable material for settlement by oysters or mussels. |
| Sill | A low rock structure in front of existing eroding banks to retain sediment behind. |
| Standard of Protection | The expected frequency or chance of an event of a certain size occurring. Defined for this project as being a 0.5% Annual Exceedance Probability, also known as a 1 in 200-year storm protection level. |
| Storm surge | A temporary change in sea level that is caused by a storm event, which can lead to coastal flooding |
| Toe scour | Occurs when the toe (bottom) of the defence is worn away by the waves and can cause defences to fail. |
| Wave exposure | The degree to which a coast is exposed to wave energy |
| Wave overtopping | The average quantity of water that is discharged per linear meter by waves over a protection structure (e.g., breakwater) whose crest is higher than the still water level |

# Appendix A. Modelling outputs

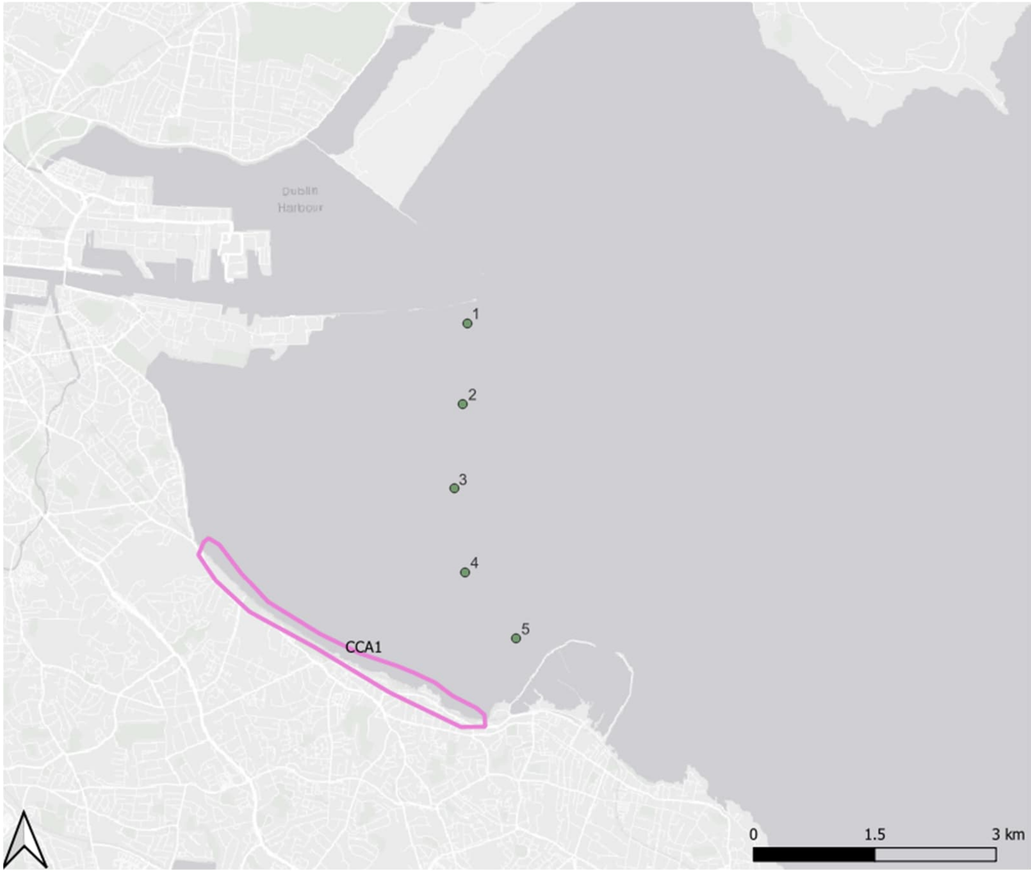


**Figure A-1. Wave model extraction locations along CCA1.**

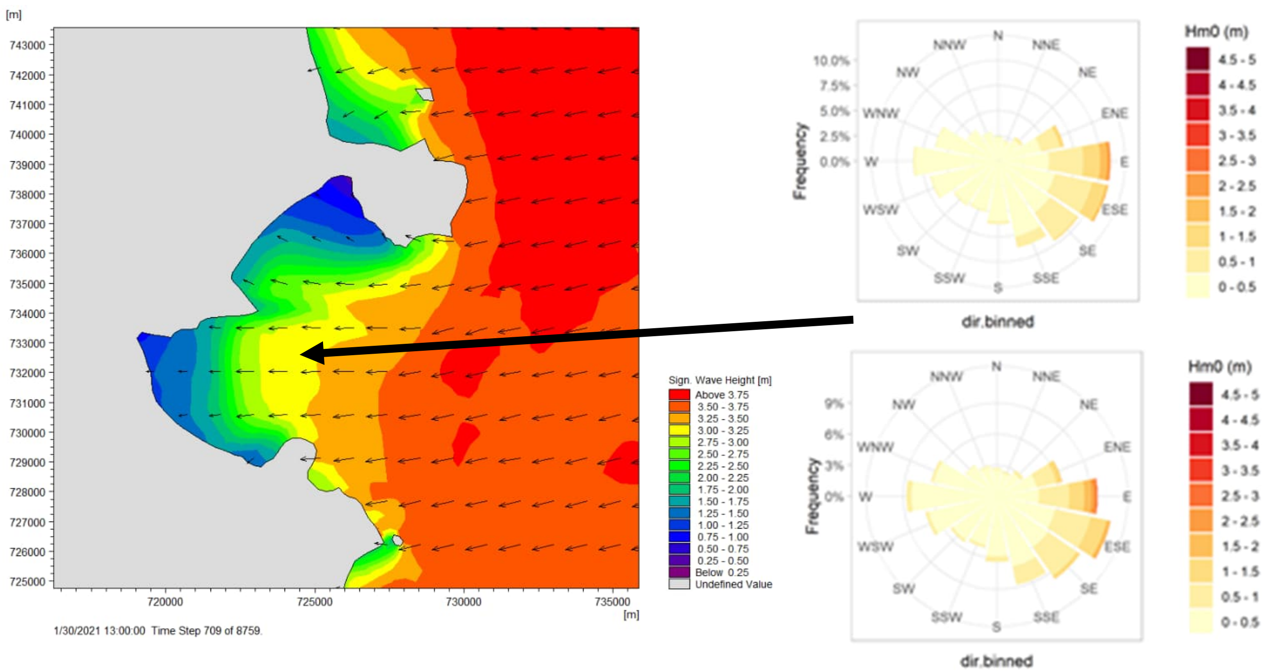

**Figure A-2. CCA1: Contour plot showing event of 3rd March 2018 (left), wave height roses - Jan/1988-Dec/2021 (top right) & Jan/2056-Dec/2100 (bottom right)**

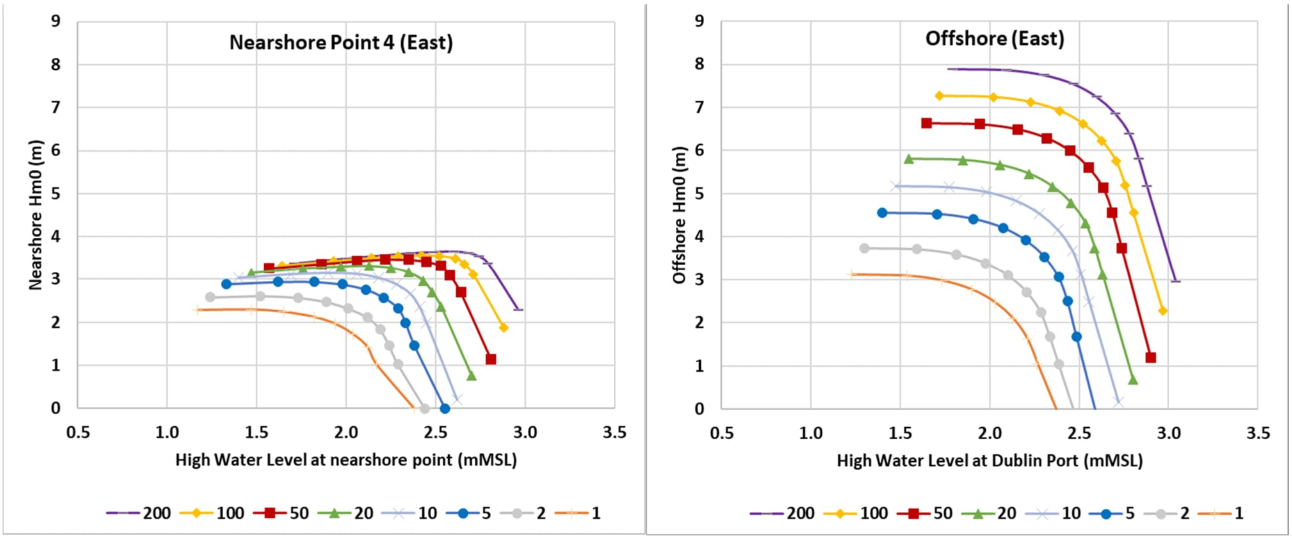


**Figure A-3. Joint probability curve at nearshore point 4 in CCA1 (left) compared to offshore (right) for waves from the East. Nearshore wave extracted at depth of -5.80 mMSL. Note any changes in the high water levels from Dublin to the nearshore point is due to 2D variations in water level.**

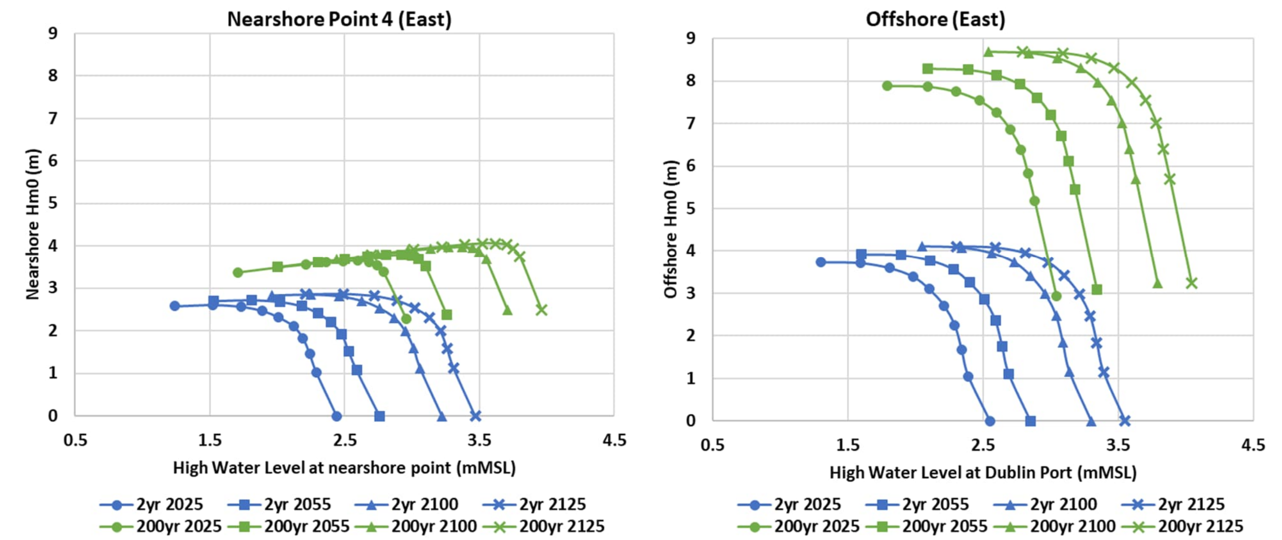


**Figure A-4. Impact of climate change on joint probability curves for 1 in 2 year and 1in 200 year return periods at nearshore point 4 in CCA1 (left) and Offshore (right) for waves from East. Nearshore wave extracted at depth of -5.80 mMSL. Note any changes in the high water levels from Dublin to the nearshore point is due to 2D variations in water level.**

# Appendix B. Geotechnical outputs

| Document Number | Document Title |
|---|---|
| 7694-CCA1-P3-ENG-CV-JAC-0002 | Geotechnical Interpretive Report |

# Appendix C. DEHERR – (designers risk assessment)

| Document Number | Document Title |
|---|---|
| 7694-CCA1-P3-REG-CV-JAC-0002 | Design Hazard Elimination Risk Register |