ESB G&T

Green Atlantic @ Moneypoint Concept

Strategic Flood Risk Assessment

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1. Introduction and Background

1.1 Project Background

Arup was commissioned by the Electricity Supply Board (ESB) to undertake a Strategic Flood Risk Assessment (SFRA) of the Green Atlantic @ Moneypoint Concept (referred to hereafter as "the GA concept") 2025.

The aim of this concept is to enable the repurposing of the ESB Moneypoint site in County Clare into a renewable energy hub and a strategic resource for the Offshore Renewable Energy (ORE) sector, whilst also maintaining and operating Moneypoint as the strategically critical generating station that it is at present.

This SFRA has been undertaken in accordance with 'The Planning System and Flood Risk Management' guidelines for planning authorities published in November 2009, jointly by the Office of Public Works (OPW) and the then Department of Environment, Heritage, and Local Government (DEHLG).

The purpose of the SFRA is to identify and quantify the risk of flooding to the site as part of the GA Concept and, if necessary, identify a series of measures to mitigate the risk.

1.2 Scope of Study

The scope of study includes the following:

- Review of all relevant site-specific information data
- Review of the risk of fluvial, coastal, pluvial and groundwater flood risk
- Review of any available site investigation data
- Review of the GA Concept
- Propose flood risk management principles where necessary
- Assess residual risks
- Undertake the Justification Test if needed.

1.3 Summary of Data Used

In preparing this report, the following data was collated and reviewed:

- Drone survey data from the ESB Moneypoint site
- Guidelines for Planning Authorities on 'The Planning System and Flood Risk Management' published in November 2009, jointly by the OPW and the DEHLG
- Clare County Development Plan (CCDP) 2023-2029 and accompanying SFRA and maps
- Flood history of the ESB Moneypoint site from the OPW National Flood Hazard Mapping website (www.floodinfo.ie)
- Flood maps from the OPW Catchment Flood Risk Assessment and Management Studies (CFRAMS)
- Coastal flooding maps and extreme sea levels from the Irish Coastal Protection Strategy Study (ICPSS)
- Irish Coastal Wave and Water level modelling Study (ICWWS) by the OPW
- Aerial photography and mapping from Bing Maps and Google Maps.

1.4 Existing ESB Moneypoint Site

1.4.1 ESB Moneypoint Site Description

The ESB Moneypoint site, shown in Figure 1, is located on the northern shore of the Shannon Estuary in Co. Clare, approximately 3km west of Killimer and 6 km south-east of Kilrush. The extent of the ESB's current landholding in the area comprises 180 Hectares (ha) of onshore landbank and 65.24 Ha of foreshore area.

The ESB Moneypoint site relevant to this SFRA is outlined in Figure 2.

Figure 1 ESB Lands within the Shannon Estuary Region [Figure provided by the client]

1.4.2 Existing Ground levels

A Drone survey carried out in 2015 recorded the existing ground levels across the ESB Moneypoint site and was provided to Arup by the ESB. The general topographic gradient across the ESB Moneypoint site is from north to south, toward the Shannon Estuary, which forms the southern ESB Moneypoint site boundary. Across the western site area, the topographic gradient is from north-east to south-west.

The existing levels across the ESB Moneypoint site show significant variations and are described below with respect to the difference Zones as shown in Figure 2:

- The Marine Energy Zone is separated by the Industrial Energy Zone. East of the Industrial zone, the Marine Energy Zone lies above 20 mOD. West of the Industrial Zone, the Marine Energy Zone slopes from 19m AOD sloping towards Shannon Foynes Estuary, where it meets a rock revetment for wave and flood protection, which has a crest elevation of around 5.3 mOD.
- The Buffer Zone surrounds the Ash Management Zone and General Development Zone, see Figure 2. The elevation at the Buffer Zone at the northwest of the Ash Management Zone ranges from 20mOD to 27 mOD. A pond sits at a low elevation of around 3 mOD at the northeast of the Ash Management Zone. Along the seaside, the elevation at the Buffer Zone ranges from 3 mOD to 10.5mOD.

The part of the Buffer Zone in between the Ash Management Zone and the General Development Zone, is relatively flat, around 16 mOD. South of the General Development Zone, the Buffer Zone slopes towards the estuary, from 21 mOD to 3 mOD.

- The Ash Management Zone maintains elevations above 10.5 mOD, starting at 10.5 mOD in the south and gradually sloping upwards to around 17 mOD in the north.
- The General Development Zone has a mean elevation of 20 mOD.
- The Woodland Zone and Screening Zone lie between 20 mOD in the south sloping upwards to 30 mOD in the north.
- The Industrial Energy Zone slopes from 14mOD in the north to 6 mOD.
- The proposed Coastal Infrastructure Zone lies on the seaside and would require land reclamation for the development to take place. The existing levels in this zone, therefore, correspond to seabed elevation.

The properties surrounding the ESB Moneypoint site predominantly sit at higher elevations compared to the site itself.

Figure 2 The Green Atlantic @ Moneypoint Concept [Figure provided by the ESB]

1.5 GA Concept

The GA concept aims to enable the repurposing of the ESB Moneypoint site in County Clare into a renewable energy hub and a strategic resource for the ORE sector, whilst also maintaining and operating Moneypoint as the strategically critical generating station that it is at present. It has been prepared in the context of ESB's 'Net Zero by 2040' strategy and the commitment to decarbonise the Company's electricity generation activities.

The ESB's strategic objectives for Moneypoint are:

Objective 1 - To ensure Moneypoint continues to support economic development and activity in the Shannon Estuary, County Clare, the broader Region, and State by providing a reliable source of electricity while ensuring the ESB Moneypoint site is developed and operated to the highest environmental standards, in-line with ESB's Environmental Management Systems;

Objective 2 - To transition the ESB Moneypoint site to a new, lower carbon operating profile, moving progressively towards zero carbon generation with Moneypoint providing dispatchable electricity to support an increasingly renewable energy sector;

Objective 3 - To develop Moneypoint as a base for the offshore renewable energy sector, acting as a construction and deployment hub, and a manufacturing location for zero carbon fuels; and

Objective 4 - To develop and operate Moneypoint so it supports Ireland's ambitions to become a net exporter of zero carbon energy.

Given that this GA Concept envisages substantial re-development of the ESB Moneypoint site, while maintaining transitional generation and transmission activity, it is currently anticipated that the GA Concept will be developed through individual projects delivered over a number of phases. Likely landmark phases of development are:

- From 2024 to early 2030s – initiation of site remediation and phased development of energy storage and additional dispatchable low carbon generation infrastructure at Moneypoint
- 2025 – cessation of coal fuelled generation with the conversion of Moneypoint Generating Station to a lower carbon generating facility
- 2025 to 2028 – undertaking of port upgrade works and establishment of Moneypoint Hub as a construction and operations base for the ORE sector
- Post 2028 – ESB ORE project becomes operational; Moneypoint redeveloped as a lower carbon dispatchable generating facility, transitioning over time to alternative low and zero carbon fuels, such as green hydrogen and ammonia.

It is anticipated that the GA Concept will be subject of periodic reviews – particularly in the context of any significant changes to the GA Concept; changes within the receiving environment as may arise from new developments; or changes to land-use policies as may arise from a review of the CCDP, or other spatial strategies.

The GA Concept was developed to identify the optimum sites for development, to bring about the transformation and redevelopment of Moneypoint in-line with the ESB's stated objectives and broader corporate strategy. Land-use objectives as established within the GA Concept are as follows:

- **Coastal Infrastructure Zone:**

  It is expected that new infrastructure will be required for the delivery of turbine elements, deployment of substructures, assembly of turbines and limited storage, at the quayside. This may require the removal of the old jetty and the development of new quayside infrastructure including infilling / land reclamation

- **Marine Energy Zone:**

  This area will be developed to facilitate onshore development associated with the Moneypoint Hub Project and ORE developments in the maritime area. Development will be phased based on the availability of land, as existing uses e.g. coal storage, are phased out. Typical uses include:

  - Facilities utilising renewable energy in the production of alternative zero-carbon fuels such as hydrogen, ammonia, etc
  - Construction yard, area for the fabrication and assembly of fixed and floating foundations, etc
  - Turbine laydown - storage of turbine elements (blades, nacelle, tower, mooring lines / anchors etc)

- Turbine assembly and integration – quayside area for the assembly of turbines and their integration on to floating platforms
- Ancillary laydown areas and compounds.

- **Industrial Energy Zone:**

  This area will be developed to facilitate continued large scale electricity generation

- **Transmission Asset Zone:**

  This area will be maintained and developed to protect and enhance electricity transmission assets, e.g. underground export cable, substation etc.

- **General Development Zone:**

  This area will accommodate relatively small-scale development ancillary to the primary activities of the ESB Moneypoint site, such as:

  - Supporting services and infrastructure – including control buildings, modules etc.
  - Areas of external electrical plant
  - Storage facilities (open air or enclosed)
  - Lay down areas, car parking etc.

- **Buffer Zone:**

  This area will accommodate small scale, low-level development to manage the transition between industrial and greenfield lands

- **Ash Management Zone:**

  This area will continue to store ash and will be managed appropriately with any new developments having regard to the sensitivities of the area

- **Screening Zone:**

  This area will accommodate existing and proposed strategic cables, the route of these cables will be maintained

- **Woodland Zone:**

  This area will protect existing woodland and provide a visual buffer between the ESB Moneypoint site and the N67.

Land-use objectives as identified within the GA Concept are illustrated in Figure 2.

2. Planning Context

2.1 The Planning System and Flood Risk Management Guidelines

The following planning policy documents are relevant to the flood risk assessment for the GA Concept;

- The Planning System and Flood Risk Management Guidelines for Planning Authorities
- CCDP 2023-2029.

2.1.1 Introduction

In November 2009, the DEHLG and the OPW jointly published a Guidance Document for Planning Authorities entitled "the Planning System and Flood Risk Management".

The Guidelines are issued under Section 28 of the Planning and Development Act 2000 and Planning Authorities and An Bord Pleanála are therefore required to implement these Guidelines in carrying out their functions under the Planning Acts.

The aim of the Guidelines is to ensure that flood risk is neither created nor increased by inappropriate development.

The Guidelines require the Planning system to avoid development in areas at risk of flooding unless the development can be justified on wider sustainability grounds and the risk can be reduced or managed to an acceptable level.

The Guidelines require the adoption of a Sequential Approach (to Flood Risk Management) of Avoidance, Reduction, Justification and Mitigation and they require the incorporation of Flood Risk Assessment into the process of making decisions on Planning Applications and Planning Appeals.

Fundamental to the Guidelines is the introduction of flood risk zoning and the classifications of different types of development having regard to their vulnerability.

The management of flood risk is now a key element of any development proposal in an area of potential flood risk and should therefore be addressed as early as possible in the site master planning stage.

2.1.2 Definition of Flood Zones

Flood zones are geographical areas within which the likelihood of flooding is in a particular range. There are three types of flood zones defined in the Guidelines as shown in Table 1:

Table 1 Definition of flood zones (The Planning System and Flood Risk Management - Guidelines for Planning Authorities - Nov 09)

Zone	Description
Flood Zone A	Probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding).
Flood Zone B	Probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 year and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding); and
Flood Zone C	Probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.

2.1.3 Definition of Vulnerability Classes

Table 2 summarises the Vulnerability Classes defined in the Guidelines and provides a sample of the most common type of development applicable to each.

Table 2 Definition of vulnerability classes (The Planning System and Flood Risk Management - Guidelines for Planning Authorities - Nov 09)

Type of Vulnerability	Definition
Highly Vulnerable Development	Includes Garda, ambulance and fire stations, hospital, schools, residential dwellings, residential institutions. Essential infrastructure, such as primary transport and utilities distribution, including electricity generating power stations and sub-stations, water and sewage treatment, and potential significant sources of pollution (SEVESO sites, IPPC sites, etc.) in the event of flooding.
Less Vulnerable Development	Includes retail, leisure, warehousing, commercial, industrial, and non-residential institutions, etc.
Water Compatible Development	Includes Flood Control Infrastructure, docks, marinas, wharves, navigation facilities, water-based recreation facilities, amenity open spaces and outdoor sport and recreation facilities

2.1.4 Types of Vulnerability Classes Appropriate to Each Zone

Table 3 illustrates the different types of Vulnerability Class appropriate to each Zone and indicates where a Justification test will be required.

Table 3 Vulnerability class and zones (The Planning System and Flood Risk Management - Guidelines for Planning Authorities - Nov 09)

	Flood Zone A	Flood Zone B	Flood Zone C
Highly Vulnerable	Justification Test	Justification Test	Appropriate
Less Vulnerable	Justification Test	Appropriate	Appropriate
Water Compatible	Appropriate	Appropriate	Appropriate

2.2 CCDP 2023 - 2029

2.2.1 Introduction

CCDP 2023-2029 sets out an overall strategy for the planning and sustainable development of the functional area of Clare County Council (CCC) over a 6-year period. The CCDP comprises a written statement supported by maps indicating the development objectives for the area in question. The CCDP also includes a number of mandatory objectives. CCC is required to prepare and adopt a CDP every 6 years.

2.2.2 SFRA for County Clare Development Plan 2023-2029

The CCDP contains a SFRA in Volume 10. As stated in the plan, the aim of this SFRA is to provide a broad assessment of all types of flood risk to inform strategic land-use planning decisions and formulate flood risk policies. The report was prepared in accordance with the requirements of The Planning System and Flood Risk Assessment Guidelines for Planning Authorities (2009) and Circular PL02/2014 (August 2014).

A two-stage assessment of flood risk was undertaken for the area that lies within the development boundary of the Development Plan for County Clare. The first stage is to identify flood risk and is based on a variety of data sources, which have been collated into a Flood Zone map for the County. Settlements identified as requiring the Justification test were carried through to Stage 2. The ESB Moneypoint site was not screened as an area that requires the Justification Test.

The report outlines a broad overview of the requirements for a Flood Risk Assessment which should accompany planning applications including:

- All developments, including in Flood Zone C, must consider the impacts of surface water flood risks on drainage design
- Flood risk from sources other than fluvial and tidal should be reviewed, including groundwater flooding and flooding associated with stormwater deficiencies or blockages

- Use of the sequential approach and a justification test, if necessary, as per The Planning System and Flood Risk Management Guidelines for Planning Authorities (2009)
- As well as assessing the surface water management risk for a site, all development including that in Flood Zone C, should consider residual risk factors which could influence the potential mitigation measures for a site. The impacts of climate change should be considered.

It is recommended that any planning applications in flood risk areas are accompanied by a supporting appropriately detailed flood risk assessment. This is to ensure a conservative approach and that consideration is given to new development within Flood Zones where mitigation measures may still be required to ensure an appropriate level of flood protection and/or resilience. The detailed assessment should include at a minimum Stage 1 - Identification of Flood Risk. Where flood risk is identified a Stage 2 - Initial SFRA will be required and depending on the scale and nature of the risk a Stage 3, detailed FRA may be required.

The SFRA report highlights several sources of relevant flood risk information available for County Clare including:

- OPW CFRAMS. The studies mapped fluvial and coastal flood risk including benefits provided by flood defences
- Coastal flooding maps and extreme sea levels from the ICPSS (now superseded by the ICWWS)
- Historical flood events in County Clare from floodinfo.ie.

The SFRA shows certain isolated locations within the northwest section of the ESB Moneypoint site that fall within Flood Zone A, as depicted in Figure 3.

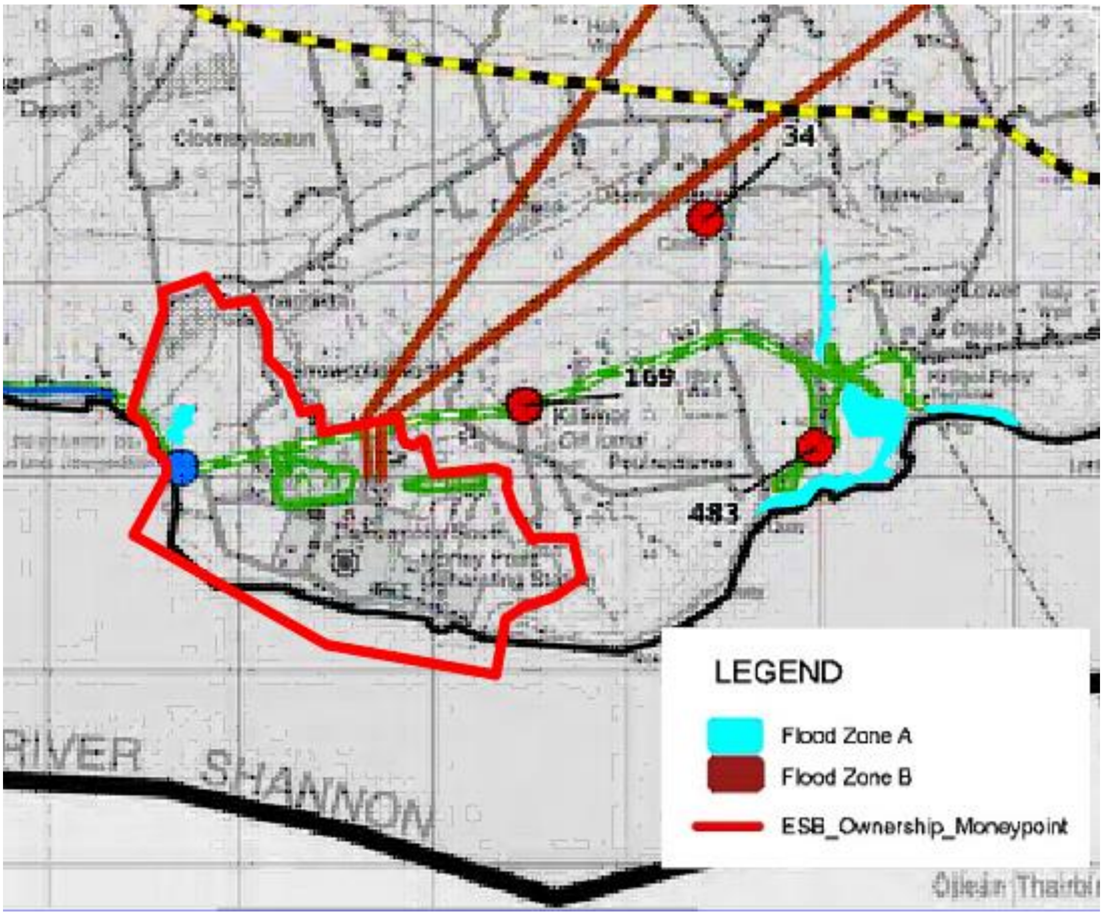

Figure 3 Flood risk zones (C. C. Council, "Volume 2 Maps - Clare County Development Plan," 2023-2029)

3. Overview of Flooding Mechanisms and Historical Flooding

3.1 Flooding Mechanisms

In broad terms, the potential sources of flooding at the ESB Moneypoint site can be categorised as:

- Fluvial flooding - This can occur when rivers overflow due to heavy rainfall
- Coastal and tidal flooding- Inundation can be caused by tidal surges, storm surges, or high waves along the coastline
- Pluvial flooding - Pluvial flooding occurs when the capacity of the local urban drainage network is exceeded during periods of intense rainfall. Water can collect at low points in the topography and cause flooding
- Groundwater flooding - Groundwater flooding can occur during lengthy periods of heavy rainfall, typically during late winter/early spring when the groundwater table is already high. If the groundwater level rises above ground level, it can pond at local low points and cause periods of flooding.

Each of the potential sources of flooding are considered in this SFRA.

3.2 Historic Flooding

3.2.1 OPW National Flood Hazard Mapping Website

The OPW National Flood Hazard Mapping summarises all recorded flood events within 2.5 km of a chosen location.

There has been only one flood event recorded at the ESB Moneypoint site which occurred on 1st January 2014- "Flooding at Carrowdotia", ID: 12970. The location of the flood event corresponds to the Buffer Zone and is presented in Figure 4. It is likely that this event was associated with Cyclone Christina which impacted Ireland in early January 2014 and was triggered by a combination of high-water level and wave action which led to flooding of a small area of the site.

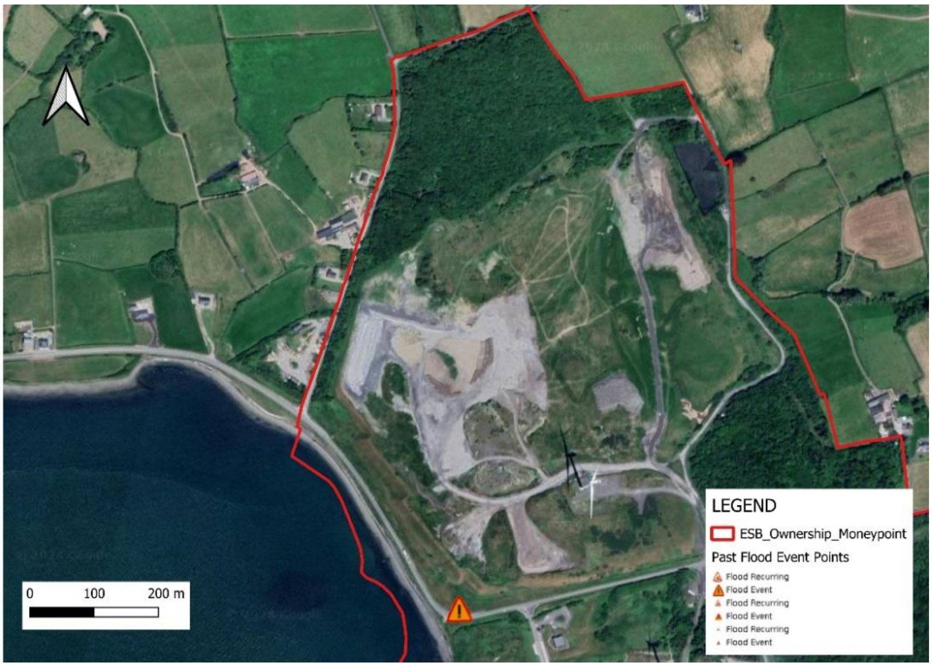

Figure 4 Historical flood record in the ESB Moneypoint Site (Source: www.floodinfo.ie)

While there is only one flood event on record, it is however possible that other unrecorded flooding events have also occurred at the site.

3.2.2 Historic maps

The National Irish Historic Maps Dashboard (https://osi.maps.arcgis.com/apps/dashboards) 6 Inch Last edition series, completed between 1830s and the 1930s, indicates the presence of a historic watercourse on the site in the area defined by the Ash Management Zone. The watercourse is defined on EPA maps as the "Molougha". The 6 and 25 Inch maps below depict the original alignment of this watercourse. Figure 5 suggests that the area in the vicinity of the river is prone to inundation from tidal springs.

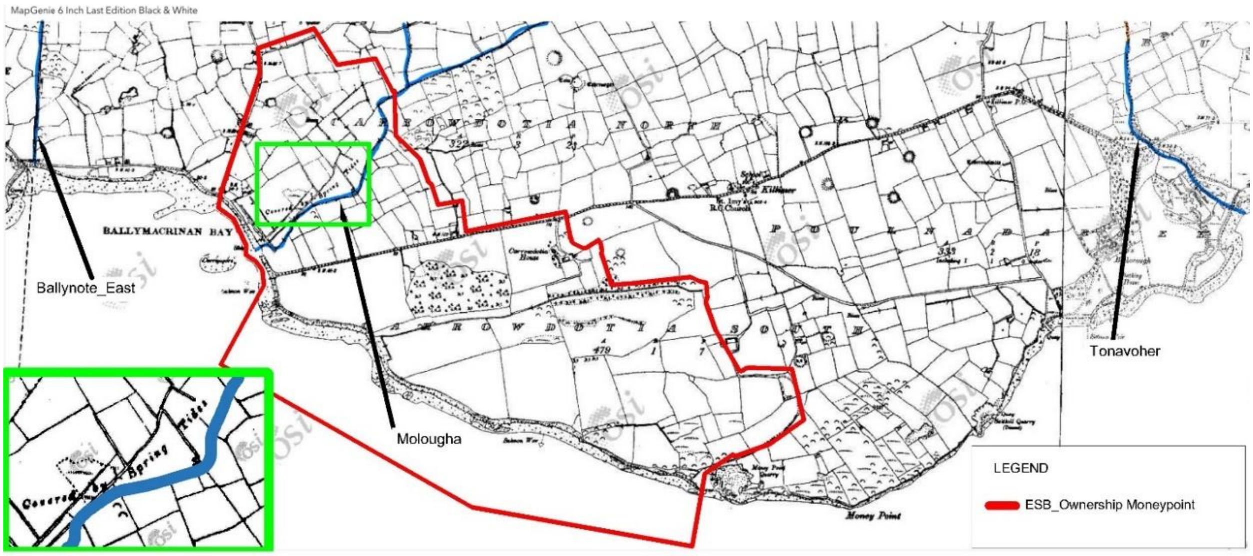

Figure 5 6-inch last edition series (1830-1930)

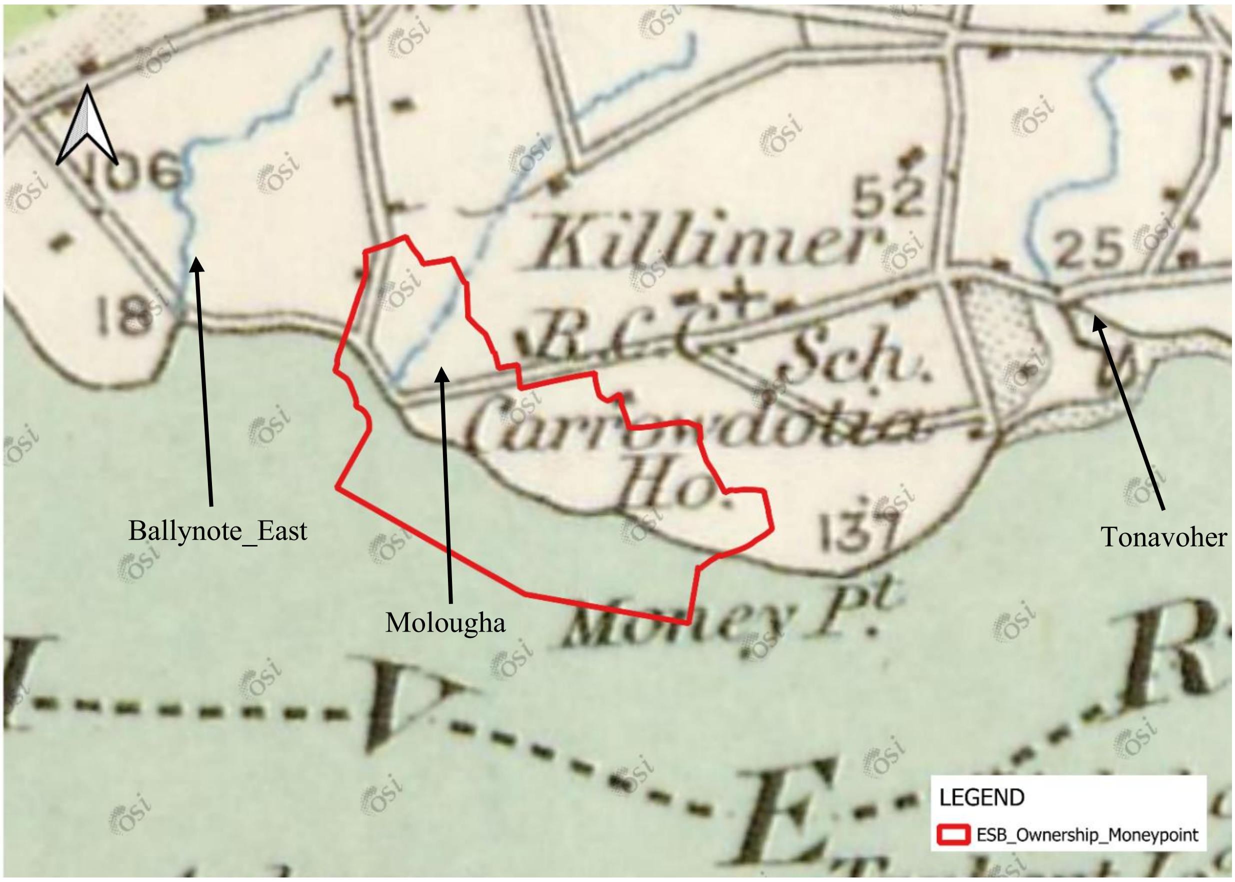

Figure 6 25-inch first edition

Since the development of the area in the 1980s in which the land was drained, bunded and landscaped, this local watercourse no longer takes an overland path as shown in Figure 5. Instead, it is culverted underneath the Ash Management Zone, the Buffer Zone and the Coastal Infrastructure Zone before discharging to the estuary. An existing pond a short distance upstream of the culvert inlet serves to attenuate flow rates and settle out solids before entering the culvert, as demonstrated in Figure 9.

3.2.3 Geological Survey Ireland (GSI) Winter 2015/2016 Surface water flood map

The GSI Winter 2015/2016 Surface Water Flooding map shows fluvial flood extents which occurred during the winter 2015/2016 flood event due to heavy rainfall. The flood extents were derived from remote sensing images and are presented in Figure 7 for the site. It can be seen that the site is not shown to be at risk as the only area inundated is a local pond on the site. It is noted however that the extents provide coverage of all sites in Ireland every 4-6 days and may not capture the peak flood extents.

Figure 7 Winter 2015/2016 Surface Water Flood extent.

4. Fluvial Flood risk

4.1 Overview

This section assesses the risk of fluvial flooding within all zones of the GA Concept.

4.2 Flood Risk from the River Shannon

The ESB Moneypoint site is located in the Shannon Estuary, a transitional zone between Shannon River and the Atlantic Ocean. The Shannon River is not considered to present a risk of fluvial flooding to the site given the expansive width of the Shannon Estuary at this location (circa 2.4km wide).

4.3 Flood Risk from the Molougha watercourse

The EPA data portal indicates the presence of a number of watercourses in the vicinity of the ESB Moneypoint site as illustrated in Figure 8. The Molougha watercourse, as referred to earlier in the report is the only watercourse of significance within the site boundary.

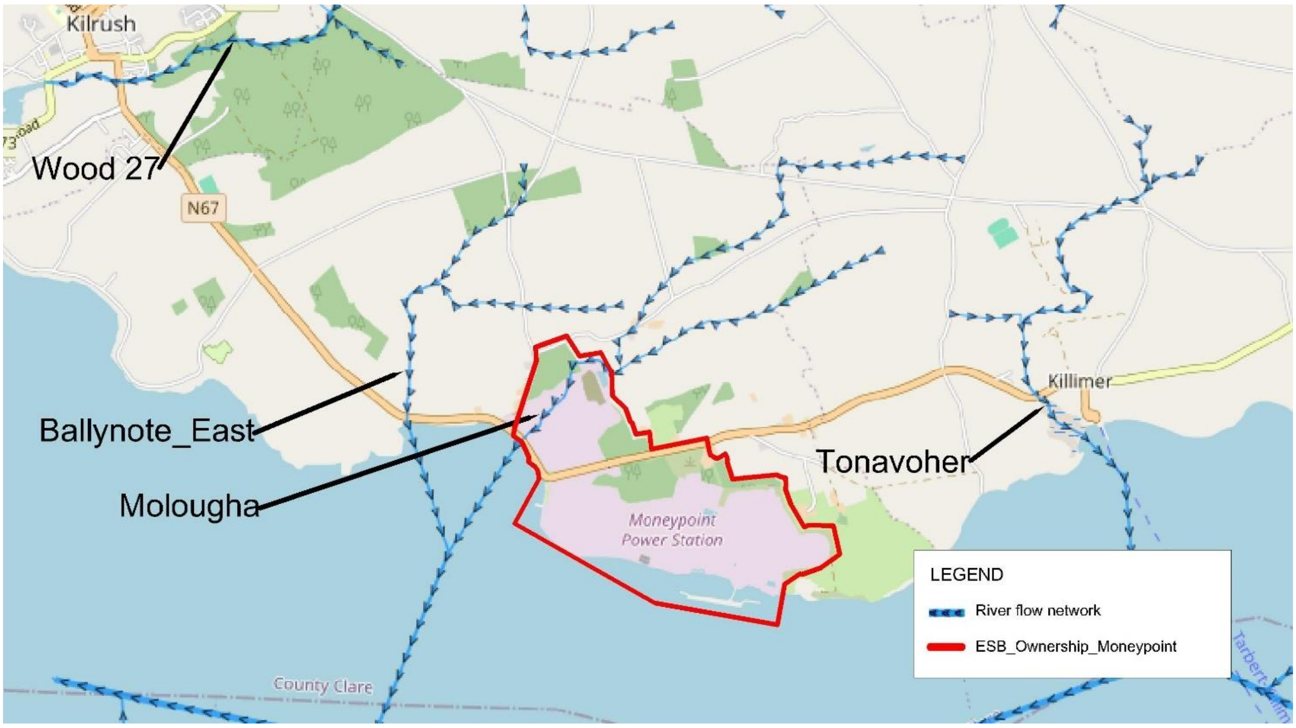

Figure 8 EPA Water features (watercourse names based on EPA records)

The alignment of the Molougha watercourse is presented in the following figure (Figure 9). It can be seen from the figure that the watercourse flows into a pond within the site before entering a culvert which conveys flow underneath the Ash Management Zone and the Buffer Zone before entering the estuary. The purpose of the pond is to attenuate flow rates in the channel and settle out solids before entering the culvert.

A large embankment runs parallel to the pond across the site as indicated by the blue line in Figure 9.

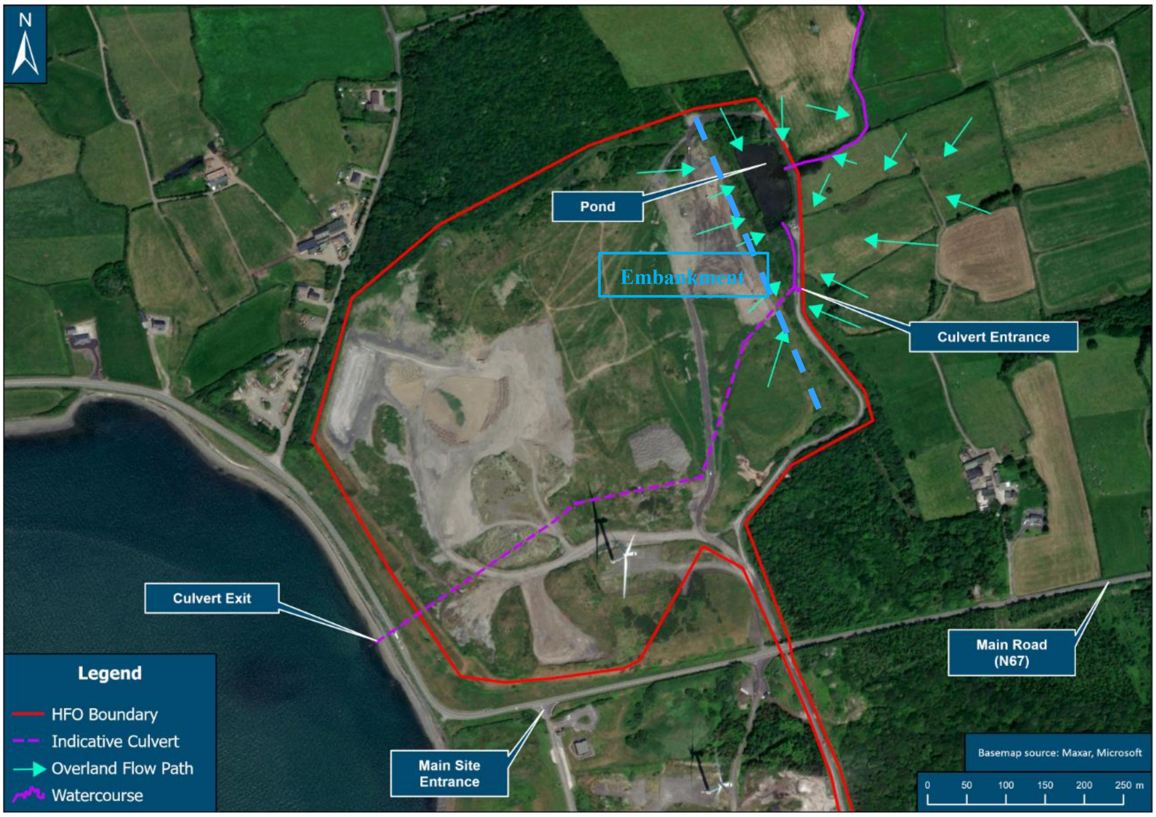

Figure 9 Indicative overland flow paths in relation to culverted watercourse [Figure provided by ESB]

Photograph 1 presents a picture of the pond. The large embankment running parallel to the pond is shown in the background of the image. Photograph 2 presents a photo of the watercourse as it enters into the pond.

As indicated on the image, there is a significant amount of wood debris along the watercourse, indicating a blockage risk of the gate at the entrance.

Photograph 1 Pond located upstream of the culvert inlet (image taken during a site visit on 25/03/24, after a few days of continuous rain in the area)

Photograph 2 Molougha watercourse, upstream view where it meets the pond (image taken during a site visit on 25/03/24, following several days of continuous rain in the area)

The Molougha watercourse was not modelled as part of the Catchment Flood Risk Assessment and Management (CFRAM) programme undertaken by the OPW as it was considered too small a stream to include as part of the study (www.gov.ie/en/policy-information/c04e0-cfram-programme). There is therefore no publicly available flood extent map for the watercourse.

Based on information provided by ESB and from a review of the OPW Flood Studies Update online portal, this watercourse has an upstream catchment of 3.5 km^2 and a Qmed of 1.2 m^3/s (estimated from catchment descriptors).

The key mechanisms of fluvial flooding to the site from the Molougha watercourse is when the capacity of the pond and/or culvert is exceeded during a flood event leading to water exiting the channel and collecting on site. In such an event however the risk of overland flow being generated across the site is very low as the existing embankment will contain the water to the upstream section of the site in the vicinity of the pond and culvert entrance (refer to Figure 10). When the flood event has passed any water that may have collected on the floodplain will enter back into the channel and be conveyed downstream through the culvert.

It is noted that there are no sensitive receptors in the vicinity of the pond and hence at risk of fluvial flooding. The ESB have noted that the closest properties to the area are more than 15 m above the level of the culvert inlet (i.e. >20 mOD).

If the inlet of the culvert in the pond or the gate shown in Photograph 2 was blocked, the flood risk to this area of the site would be increased. The risk however would remain low due to the influence of the embankment and the absence of any structures from the vicinity of the pond.

It is noted that the inlet screen is regularly inspected and maintained by the station as the pond serves as a monitoring point for pH and suspended solids as part of the station's EPA Industrial Emissions Licence (License Registration Number: P0605-04). Therefore, any blockage would be addressed in a matter of hours by station staff.

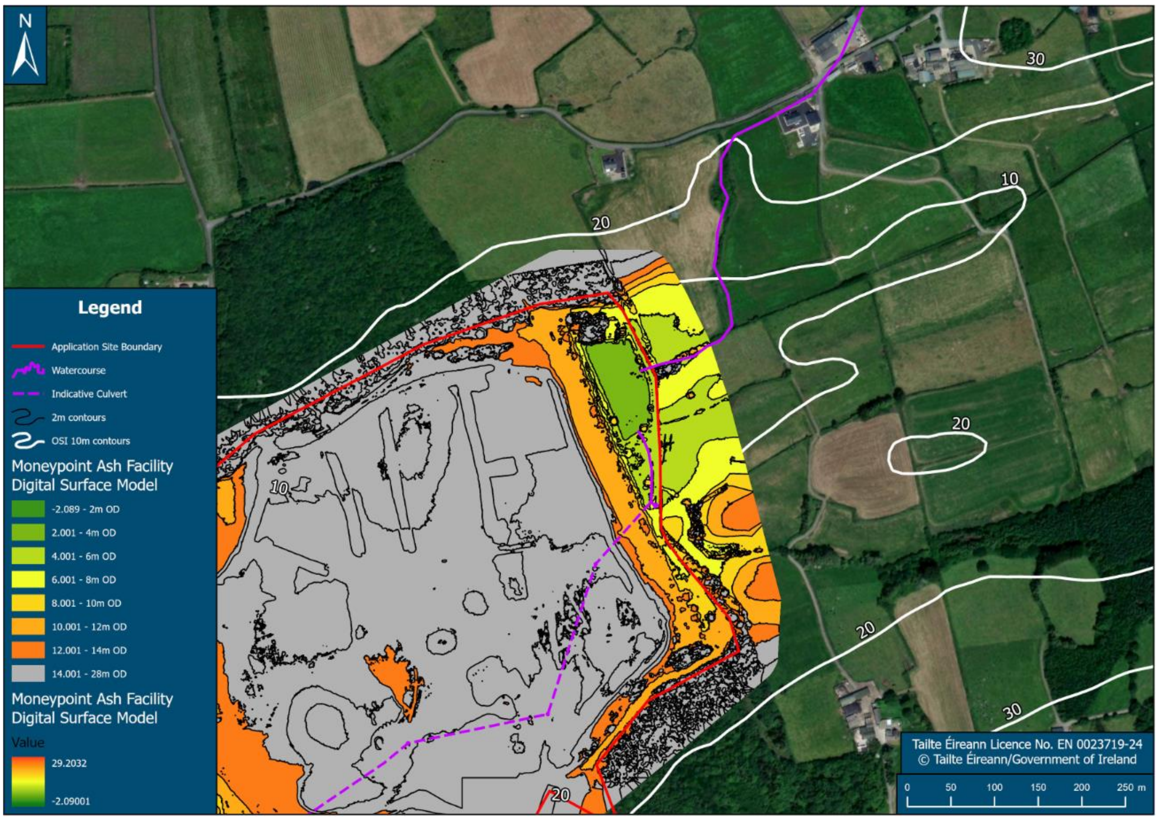

Figure 10 Surveyed levels in vicinity of Ash Management Zone [Figure provided by ESB]

4.4 Fluvial Flood Risk in a Climate Change Scenario

The impact of climate change is very unlikely to present any significant increase in the fluvial flood risk to the ESB Moneypoint site due to the small area of the Molougha catchment and the presence of the embankment in the vicinity of the pond.

4.5 Fluvial Flood Risk Summary

Fluvial flood risk is limited in the immediate vicinity of the pond within the Buffer Zone, shown in Figure 9, and there are no sensitive receptors in this location at risk of flooding. All other zones of the GA Concept are at low risk of fluvial flooding.

5. Coastal Flood Risk

5.1 Overview

This section assesses the risk of coastal flooding within all zones of the GA Concept.

5.2 Extreme Water Levels

The most reliable data for mapping coastal flooding in the ESB Moneypoint site is the National Coastal Flood Hazard Maps (NCFHM), accessible through the coastal maps section on https://www.floodinfo.ie/. These maps show the extent of land that might be flooded by the sea (coastal flooding) during the 'design' flood event with an estimated probability of occurrence. The flood extents are based on the Irish Coastal Wave and Water Level Modelling Study (ICWWS) 2018 – Phase 1 data, which has superseded the Irish Coastal Protection Strategy Study (ICPSS) 2004 – 2013 data.

The ICWWS datapoints provide an estimate of extreme water levels for the present day sea levels but also for the Mid-Range Future Scenario (MRFS), High End Future Scenario (HEFS), High+ End Future Scenario (H+EFS) and High++ End Future Scenario (H++EFS) which represent a 0.5m, 1.0m, 1.5m and 2.0m increase in sea level, respectively. The closest point to the ESB Moneypoint site is South West Point S10 and the levels for the Present day, MRFS and HEFS for the 0.5% (1 in 200 year event) and the 0.1% AEP (1 in 1000 year event) at South West Point 10 are presented in Table 4. Coastal flood maps for the site are shown in Figure 11.

Table 4 South West Point S10 Extreme Water Levels (mOD OSGM15) (www.floodinfo.ie)

AEP	Scenario		
	Present Day (m)	MRFS (m)	HEFS (m)
0.5%	3.39	3.89	4.39
0.1%	3.57	4.07	4.57

Figure 11 National Coastal Flood Hazard Mapping 2021 – Present Day (floodinfo.ie)

Elevation data collected during the Aerial drone survey in 2015 indicates that the ground levels of the Ash Management Zone generally lie at circa 10.5mOD. The flood extents for the site however show flooding in some areas of the site at this elevation – when the extreme water level of 3.57mOD (0.1% AEP) is considered it is therefore evident that the areas shown to be at risk of coastal flooding in the map are erroneous. Additionally, it is also noted that the berm that surrounds the site will protect the Ash Management Zone during an extreme coastal event such that direct tidal inundation of the site is not possible.

The ground profile of the Ash Management Zone is shown in Figure 12. The berm can be seen on the right-hand side of Figure 13.

Figure 12 Ground profile at Ash Management Zone (values shown in meters)

Figure 13 Berm around Ash Management Zone (Image taken during a site visit on 25/03/24)

This issue on the National Coastal Flood Hazard Mapping 2021 flood extents is likely due to the use of an outdated DTM dataset which informed the mapping and/or any simplifications adopted in the production of the flood extents which we note were taken on the national scale. The coastal flood extents for the site have therefore been corrected using the data from the topographic survey carried out in 2015. The updated flood extent is presented in Figure 14.

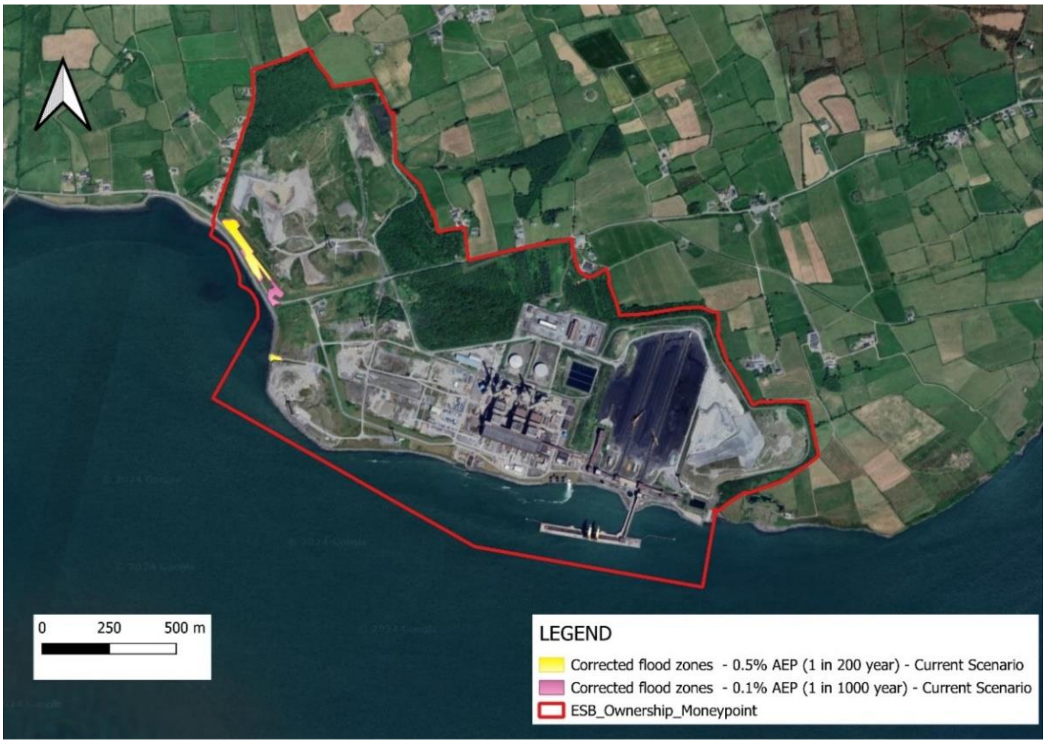

Figure 14 Corrected flood extents using updated site-specific elevation data from the 2015 drone survey

As can be seen, for the present day sea level and taking into consideration the existing defences, there are no areas at risk of coastal flooding for the 0.5% (1 in 200 year event) and the 0.1% AEP (1 in 1000 year event). The estuary side area of the Buffer Zone and the ramp within the Marine Energy Zone are however subject to flooding given that parts of these areas fall below the design flood level. This is shown in more detail in Figure 15.

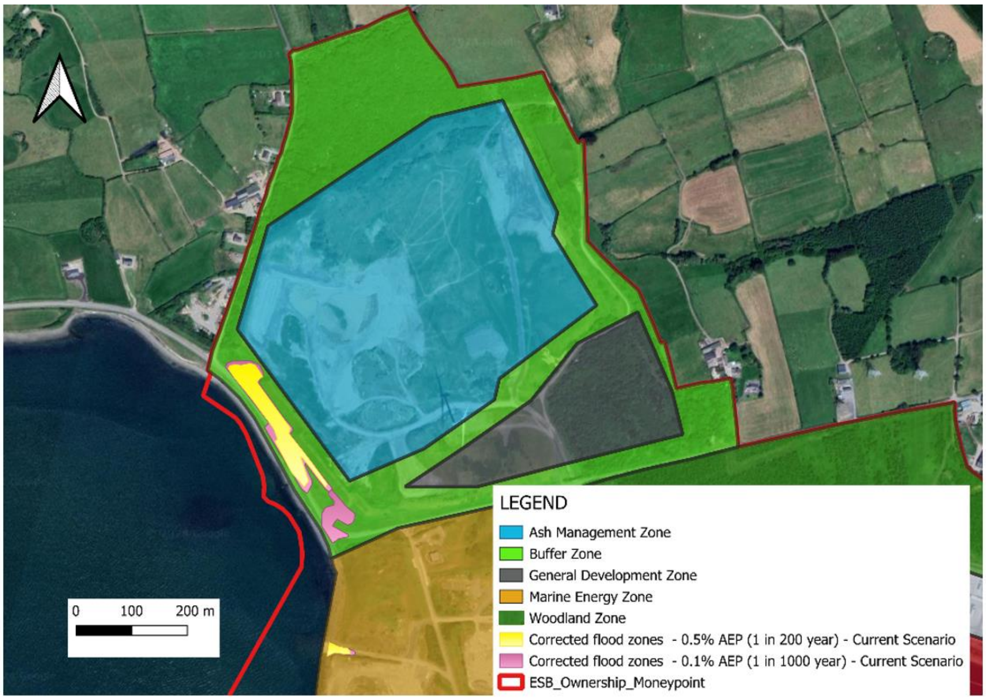

Figure 15 Corrected flood extents using updated site-specific elevation data from the 2015 drone survey (zoomed to area of interest)

The areas highlighted in yellow in Figure 15 are currently in Flood Zone A. Areas shown in pink are in Flood Zone B.

Figure 15 does not show the Coastal Infrastructure Zone. If developed as illustrated in Figure 2, the finished floor levels in this zone would be set above the 0.5% AEP tidal level (1 in 200 year event), with allowances for climate change, wave overtopping and freeboard. Consequently, the Coastal Infrastructure Zone and the areas currently at risk of coastal flooding, would be classified as Flood Zone B or C, depending on the final design levels.

5.3 Wave Conditions

A long-term site-specific wave condition assessment prepared by RPS Group on behalf of ESB is provided in Appendix A. This note assesses the wave conditions along the berthing line at Moneypoint based on the existing site layout and initial concept designs for the proposed facility. A summary of extreme wave conditions at Moneypoint for various return period events based on the existing configuration is shown in Table 5.

Table 5 Extreme wave conditions at Moneypoint

Return period [years]	Significant Wave Height [Hm0, m]	Peak Wave Period [Tp, s]	Mean Energy Wave Period [Tm10, s]
10	2.09	5.04	4.34
20	2.25	5.13	4.45
50	2.46	5.25	4.58
100	2.63	5.37	4.67
200	2.79	5.55	4.79

Table 5 indicates during the 1 in 200-year extreme event under the existing configuration, wave heights are expected to reach 2.79m. In terms of operational wave conditions, the assessment shows that monthly average significant wave heights do not generally exceed 0.2m, with corresponding peak wave periods of less than 1.5 seconds. Under very arduous conditions, wave heights may approach 1.60m with corresponding wave periods less than 10 seconds.

The values shown in Table 5 are subject to change depending on the reclamation and final configuration of the Marine Energy area. A detailed wave overtopping assessment is recommended to be performed while evaluating the various configuration options of the facility.

It is not within the scope of this SFRA report to undertake a detailed wave overtopping assessment. It is however noted that certain areas of the site are likely to be as risk of flooding from Wave overtopping, particularly the Buffer Zone and the Marine Energy Zone. If the Coastal Infrastructure Zone is developed as shown in Figure 2, this would be the main area affected by wave overtopping and would provide protection to the Buffer Zone and Marine Energy Zone from waves.

5.4 Coastal Flood Risk in a Climate Change Scenario

The impact of climate change will not result in any significant increase in the risk of coastal flooding to the site. The HEFS predicted coastal flood level of 4.57 m OD (i.e. 1m of SLR on top of the current scenario 0.1% AEP tidal level of 3.57mOD) is still lower than any areas of the site being developed. Further it is noted that the existing coastal defence has a crest level of approximately 5.3 mOD which is also above the HEFS peak water level.

5.5 Coastal Flood Risk Summary

The are two zones of the GA Concept currently at risk of coastal flooding (depicted in Figure 15):

- Along the seaside of the Buffer Zone
- The ramp within the Marine Energy Zone.

The Buffer Zone features low-level developments, serving as a transition between industrial and greenfield areas. The only affected infrastructure here is the access road which falls within Flood Zone A. However, since alternative entry/exit points exist, its disruption is not considered critical.

In the Marine Energy Zone, the ramp also lies in Flood Zone A. Yet, this ramp requires a waterside location and is suitable for this zone. Given its steepness, the ramp would not create a water pathway towards critical infrastructure within the Marine Energy Zone.

The wave conditions in the estuary could result in wave heights of 2.79m during the 1 in 200 year event. A detailed wave overtopping analysis is required to be performed once the proposals for the Coastal Infrastructure Zone are formed. Flood protection levels need to be cognisant on the wave overtopping analysis.

6. Pluvial and Groundwater Flood Risk

6.1 Overview

This section assesses the risk of pluvial and groundwater flooding within all zones of the GA Concept.

6.2 Pluvial Flood Risk

Pluvial flooding occurs when extreme rainfall overwhelms drainage systems or soil infiltration capacity, causing excess rainwater to pond above ground at low points in the topography.

In order to assess the risk of pluvial flooding to the ESB Moneypoint site, the findings of the Preliminary Flood Risk Assessment (PFRA) undertaken by the OPW have been reviewed. The Integrated flood risk PFRA map for the study area is presented in Figure 16, this map shows the flood extents for all assessed risks of flooding, including pluvial. In terms of the extents shown for coastal and fluvial, these extents have now been superseded by the CFRAM studies, as presented in section 4 and 5. As can be seen in Figure 16, several areas within the ESB Moneypoint site are prone to pluvial ponding for the 0.1% AEP (1 in 1000-year event).

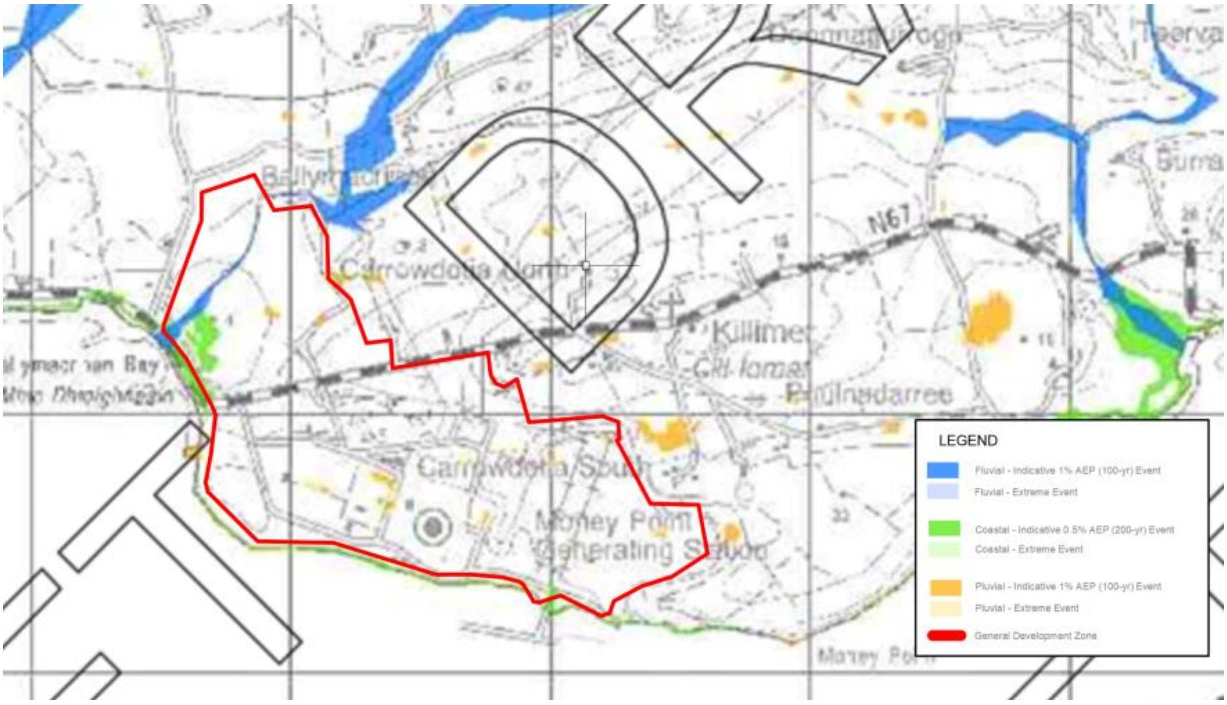

Figure 16 PFRA Integrated Flood Maps (OPW, PFRA)

The PFRA study is very high level and uses coarse terrain. The site-specific topographic survey was used to identify ponding areas with higher accuracy. The general topographic gradient across the ESB Moneypoint site area is from north to south, towards the Shannon Estuary.

Across the western site area (Ash Management Zone), the topographic gradient is north-east to south-west. The existing levels along the different development areas vary, as described in section 1.4.2.

Certain low-lying areas prone to water ponding have been identified by looking at the site-specific topographic survey, as depicted in Figure 17.

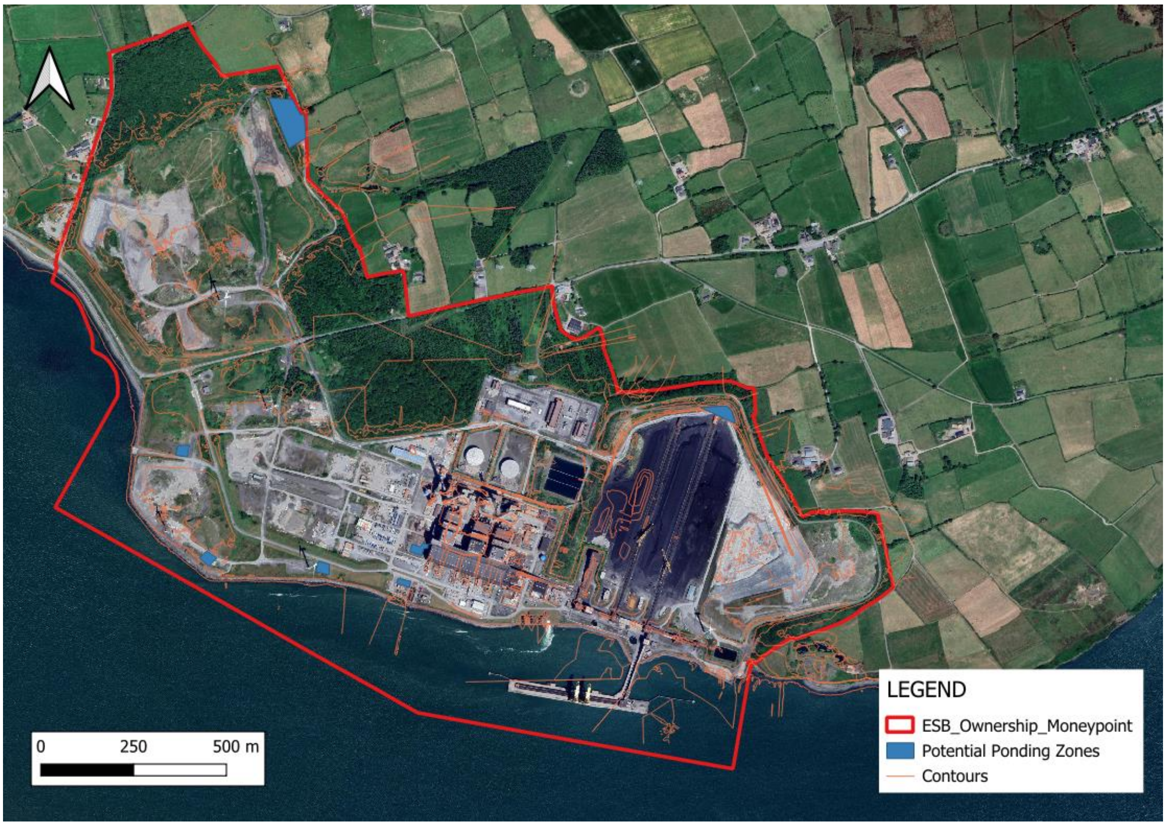

Figure 17 Low areas subject to pluvial flood risk within the ESB Moneypoint site

During a site visit undertaken on 25/03/24, which was carried out after several days of continuous rainfall, some of these ponding areas became visible, by the north-east part of the Marine Energy Zone, as shown in Figure 18.

Figure 18 Water ponding in the carbon storage area within the Marine Energy Zone (image taken during site visit on 25/03/24)

The presence of potential ponding within the facility is mainly limited to areas with no drainage system in place. It is not seen as a significant safety hazard, but it could have a negative impact on the operational efficiency of the facilities.

The risk of pluvial flooding to the ESB Moneypoint site is considered to be low.

New development as part of the GA Concept has the potential to increase the impermeable area of the ESB Moneypoint site, which could lead to an increase in surface water runoff. Without proper management, this could raise the risk of pluvial flooding.

However, as part of any new development, contemporary drainage design in line with industry standards would typically enable management and mitigation of any such risks.

6.3 Groundwater Flood Risk

Groundwater flooding can occur during lengthy periods of heavy rainfall, typically during later winter/early spring when the groundwater table is already high. If the groundwater level rises above surface level, it can pond at local points and cause flooding. Groundwater flooding tends to be very local and results from the interaction of site-specific factors such as local geology and tidal variations.

In Ireland, groundwater flooding is most commonly related to turloughs in the karstic limestone areas prevalent in particular in the west of Ireland. According to the Geological Survey of Ireland (GSI) groundwater data viewer (https://www.arcgis.com/apps/webappviewer) there are no historic groundwater flood events recorded on the ESB Moneypoint site and groundwater flooding is not expected.

To assess the risk of groundwater flooding to the ESB Moneypoint site, the GSI groundwater flooding data maps and groundwater resources (aquifers) maps were reviewed (GSI, 2019).

Groundwater flooding maps do not show any extent of groundwater flooding within the ESB Moneypoint site.

Groundwater resources (aquifers) maps show the potential of areas in Ireland to provide water supplies and this information can be used as an indication of the risk of groundwater flooding. Groundwater flooding is generally associated with regionally important aquifers, but not locally important aquifers or poor aquifers.

In the locally important aquifers or poor aquifers, the groundwater levels are generally relatively shallow (often following topography), and bedrock has a limited capacity to accept more rainwater falling on the land. In this geology, once the bedrock aquifer is “full”, the excess rainfall flows across the ground surface as water runoff. This is not considered groundwater flooding, but purely surface water runoff.

In regionally important aquifers, the network of fractures and faults which can carry the groundwater is much bigger and can carry water at greater distance. The groundwater levels may not follow the topography and they show greater fluctuation. When water falls on the ground surface and enters into the bedrock, the bedrock has more open fractures and faults to accept the water. This causes the groundwater levels to rise across an area. Where there is a depression or a low-lying area, the groundwater can emerge and cause flooding.

Since the ESB Moneypoint site is not underlain by any regionally important aquifer, only poor aquifers, and given that the GSI groundwater flood maps do not indicate any groundwater flood extents at the site, it is considered that the risk of groundwater flooding is low.

6.4 Pluvial and Groundwater Flood Risk Summary

All zones of the GA Concept are at low risk of pluvial and groundwater flooding. However, new development as part of the GA Concept has the potential to increase the impermeable area of the site, which could lead to an increase in surface water runoff. Without proper management, this could raise the risk of pluvial flooding. However, as part of any new development, contemporary drainage design in line with industry standards would typically enable management and mitigation of any such risks.

7. Flood Risk Management

7.1 Mitigation Measures

7.1.1 Avoidance and Substitution

Development in areas at risk of flooding shall be avoided. The seaside area of the Buffer Zone, directly west of the Ash Management Zone is currently at risk of coastal flooding due to low existing levels and absence of any defences. Only “Water Compatible Development” shall be permitted within Flood Zone A, as described in Table 2. Access roads are also permitted within this area if alternative emergency access and egress routes are provided.

If the Coastal Infrastructure Zone is developed as shown in Figure 2, this will contribute in reducing coastal flood risk in the Buffer Zone. As a result, developments other than "Water Compatible Development" may be permitted in accordance with Table 2 and Table 3.

7.1.2 Finished Floor Level

The majority of the ESB Moneypoint site is at low risk of flooding. Due to the proximity of the site to the coast, minimum flood protection levels are recommended below, in accordance with the SFRA of the County Clare Development Plan 2023-2029.

Although tidal flooding events are relatively short-lived compared to other types of flooding, such as fluvial flooding, it is advisable to establish a minimum level for any proposed development to safeguard against it.

The Extreme Water Level during the 1 in 200-year flood event presented in Table 4 are used as the basis for the flood risk management measures. For highly vulnerable and less vulnerable development, the Mid-Range Future Scenario (MRFS) is considered an appropriate allowance for climate change (Table 5-2 of the SFRA).

Table 6 Recommended minimum FFL as per County Clare SFRA

	Recommended minimum FFL (mOD)
Extreme Water Level - 0.5% - Present Day (ICWWS 2018 – Node S10)	3.39
Sea Level Rise (MRFS)	0.5
Freeboard (Table 5-3 of the SFRA)	0.5 (at areas at risk of wave overtopping and surge)
Total	4.39

The majority of the ESB Moneypoint site stands well above the minimum finished floor level, which will provide protection against extreme coastal flooding. Additional protection against wave action is recommended in areas within the Marine Energy Zone or the Coastal Infrastructure Zone, if it is to be developed, which would need to consider wave action and operational requirements. Therefore, a detailed wave overtopping analysis is recommended to be undertaken while evaluating the various configuration options of the facility.

The finished flood level (FFL) of any new buildings, platforms and facilities within the development shall also consider the surrounding levels and risk of surface water ingress that may occur during a rainfall exceedance event.

7.1.3 Surface Water Drainage System

At areas where buildings are proposed, a surface water drainage system shall ensure no increase in flood risk to the ESB Moneypoint site. Surface water runoff shall be managed in alignment with the principles outlined in the Greater Dublin Strategic Drainage Study. This study provides details on the process and design of Sustainable Urban Drainage Systems (SUDS). Drainage components shall be designed in line with Part H of the Building Regulations, BS EN 752 Drain and Sewer Systems outside Buildings, relevant CIRIA guidance documents and Irish Water requirements for the design of drainage systems.

The surface water drainage system for the development shall be regularly maintained. This includes undertaking regular inspections of the drains and various SuDS features by ensuring that any debris which may have accumulated is removed. This will ensure that the risk of blockage of the drains is reduced.

As part of the maintenance program, the inlet of the Molougha culvert under the Ash Management Zone and Buffer Zone shall be inspected and maintained to prevent blockages by removing wood, debris and any other objects obstructing the flow.

7.1.4 Access and Egress Routes

As shown in Figure 11, there is a section of the N67 susceptible to flooding during the present-day 0.5% coastal AEP (1 in 200-year event). Nonetheless, there are alternative routes that ensure uninterrupted access and egress to the ESB Moneypoint site, therefore avoiding the need for mitigation measures.

7.2 Residual Risk

Residual risk refers to the remaining level of risk after all mitigation measures have been put in place. In the context of the watercourse culvert beneath the Ash Management Zone, there exists a residual risk that it may become blocked. If blockage occurred, rising water levels within the pond will not pose a risk to any infrastructure inside or outside of the designated ESB Moneypoint site boundary. This is due to the local topography, which would convey any potential floodwaters to adjacent low-lying fields.

Consequently, this residual risk is considered acceptable. It is worth highlighting that any blockage would be promptly detected and addressed by station personnel within a matter of hours.

8. Application of "Flood Risk Management Guidelines"

8.1 Sequential Approach

Based on the analysis undertaken, the risk of fluvial, groundwater and pluvial flooding to the ESB Moneypoint site is considered very low.

Coastal flooding is used as the basis for the application of the Flood Risk Management Guidelines. Parts of the Marine Energy Zone and Buffer Zone currently lie within Flood Zones A and B. The rest of the development zones lie within Flood Zone C.

If the Coastal Infrastructure Zone is developed as shown in Figure 2, the finished floor levels in this zone are recommended to be set above the 0.5% AEP tidal level (1 in 200 year event), with allowances for wave overtopping, climate change and freeboard. Consequently, there will be a reduction of coastal flood risk in the Marine Energy Zone and Buffer Zone. The Coastal Infrastructure Zone and the areas currently at risk of coastal flooding, could then be raised to Flood Zones B or C, depending on the final design levels.

8.2 Vulnerability Classification and Justification Test

The anticipated new development in the Coastal Infrastructure Zone involves the installation of necessary infrastructure for turbine element delivery, substructure deployment, turbine assembly, and storage, which may also necessitate the removal of the old jetty and the establishment of a new quayside. All these activities require a waterside location and as such are considered water compatible uses, appropriate in any Flood Zone. It is however recommended that the platform level of the Zone is raised as per guidance in Section 7.

Development within Flood Zone A at the seaside of the Buffer Zone and Marine Energy Zone will be restricted to "Water Compatible" uses, if the Coastal Infrastructure Zone is not developed.

Therefore, the proposals under the GA Concept are considered appropriate within the ESB Moneypoint site and there is no need for a justification test.

9. Conclusion

This SFRA was carried out for the Green Atlantic @ Moneypoint Concept 2025. This SFRA report reviewed the risk of flooding at the nine different zones of the GA Concept.

The ESB Moneypoint site is currently at low risk of pluvial and groundwater flooding. Fluvial risk is limited in the immediate vicinity of the pond within the Buffer Zone and there are no sensitive receptors in this location at risk of flooding. The majority of the site is also at low risk of coastal flooding, located within Flood Zone C. However, there are two areas currently at risk of coastal inundation:

- The ramp within the Marine Energy Zone, which requires a waterside location
- The seaside of the Buffer Zone. This area currently consists of greenfield space, with the only existing infrastructure is a coastal road. There are other entry/exit points to the ESB Moneypoint site, and thus the road is not considered critical infrastructure

Development in Flood Zone A in the above areas shall be restricted to "Water compatible" uses. Development in Flood Zone B shall be restricted to "Less Vulnerable", or "Water Compatible" uses, in line with the Guidelines.

If the Coastal Infrastructure Zone is developed as illustrated in Figure 2, it could provide flood protection to the Buffer Zone and Marine Energy Zone, consequently removing them from Flood Zones A and B and enabling any development of these areas.

Finished floor levels of new development shall be set above the 0.5% AEP tidal level (1 in 200 year event), including allowance for climate change and freeboard. This level is calculated as 4.39mOD.

Additional protection against wave action might be desirable by the client in areas within the Marine Energy Zone or the Coastal Infrastructure Zone, if it is to be developed, which would need to consider wave action and operational requirements. Therefore, a detailed wave overtopping analysis is recommended to be undertaken while evaluating the various configuration options of the facility.

New development as part of the GA Concept has the potential to increase the impermeable area of the ESB Moneypoint site, which could lead to a slight increase in surface water runoff. Without proper management, this could raise the risk of pluvial flooding. Surface water drainage shall be designed in line with guidance provided within the Greater Dublin Strategic Drainage Study.

This SFRA demonstrated that the sources of flood risk identified within the ESB Moneypoint site can be managed to acceptable levels in accordance with The Planning System and Flood Risk Management Guidelines for Planning Authorities (2009).

Appendix A

Moneypoint Phase 2 – Hydraulic Modelling support

MONEYPOINT PHASE 2

Hydraulic Modelling Support

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31 Jan 2023

Document status

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01	Draft, for client Review	KC	AKB	MB	15/12/2022
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Approval for issue

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1 INTRODUCTION

Electricity Supply Board (ESB) desire to increase renewable energy generation capacity through 2030 and beyond. As part of this strategy ESB intends to develop a capacity to service the construction of floating offshore wind farms from its existing site at Moneypoint on the Shannon Estuary.

RPS are currently engaged by ESB to develop a preliminary design of a new facility at Moneypoint and to provide engineering to support the project's Planning Application. A fundamental objective of this commission is to complete the engineering documentation and input requirements to support the Planning Application, EIAR compilation and associated environmental survey campaigns.

1.1 Purpose of Report

To inform prospective OWF developers and users of operational conditions at the Moneypoint facility, this technical note presents an assessment of long-term site-specific wave conditions along the berthing line at Moneypoint based on the existing site layout and initial concept designs for the proposed facility.

In addition, this technical note also describes the extreme inshore wave climate at Moneypoint for 1 in 10, 50, 100 and 200 year return period conditions. The output from this assessment can therefore be used to inform design conditions for the proposed facility, including determining the need for coastal protection works.

1.2 Site location and description

Located *c.* 30km from the mouth of the Shannon estuary and *c.* 5km southeast of Kilrush, the Moneypoint power station is situated on the northern side of the estuary as illustrated in Figure 1.1. The available water depths across the study area typically range from *c.*- 30m at the mouth of the estuary at Kilconly Point to *c.*-20m at Moneypoint.

As illustrated in Figure 1.2, the bathymetry at Moneypoint is particularly complex with one relatively shallow area at -16m known as the "*The Bridge*" forming an obstacle between regions of deeper water on either side. Further east, the Shannon estuary narrows to around 2 – 3km wide and is characterised by a relatively deep channel with depths ranging between - 20 and -30m up to Foynes Island.

As summarised in Table 1.1, the site is subject to a large tidal range of *c.* 5m during spring tide conditions.

Table 1.1: Tidal Levels at Tarbert Island from Admiralty Tide Tables 2022

Tidal Phase	Level (m) [Chart Datum]	Level (m) [Mean Sea Level]
Highest Astronomical Tide	+5.50	+2.77
Mean High Water Springs	+5.00	+2.27
Mean High Water Neaps	+3.70	+0.97
Mean Low Water Neaps	+1.70	-1.03
Mean Low Water Springs	+0.50	-2.23

Whilst Moneypoint is relatively well sheltered from offshore swell waves propagating in from the Atlantic, the site is fairly exposed to wind action which in turn can produce wind-generated waves. Previous studies have found that mean 1 hourly wind speeds at Moneypoint can range between 26.3 and 31.4 m/s for a 1 in 1 and 1 in 100 year return period event respectively (AkerSolutions, 2021).

Figure 1.1: Location of the Moneypoint Power Station in context of the Shannon estuary

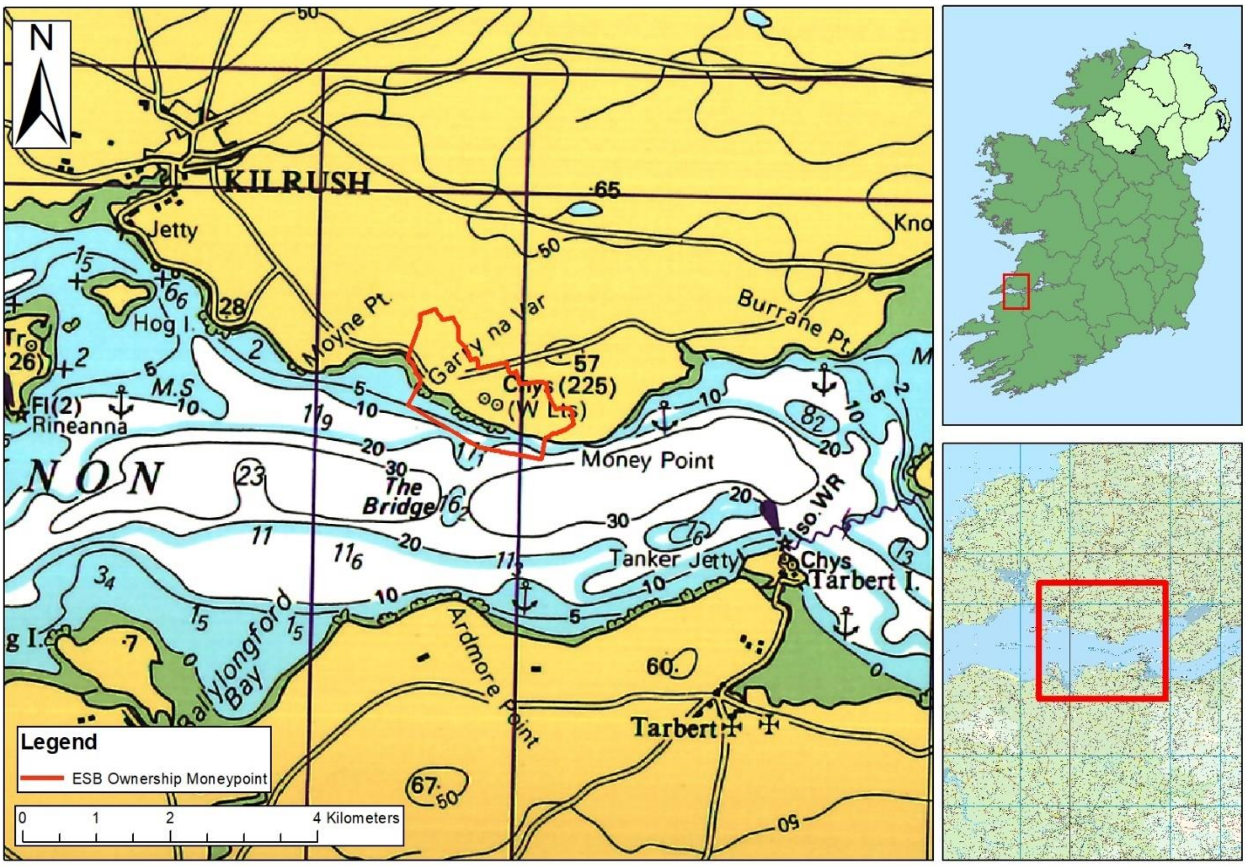


Figure 1.2: Typical depths within the vicinity of the Moneypoint Power Station, including the shallow area known as "The Bridge" directly in front of the site

2 DESCRIPTION OF CONCEPTUAL LAYOUTS

The Moneypoint Hub facility will be created to facilitate the construction (fabrication and assembly) of floating off-shore 15MW wind turbines. Each turbine will consist of a Wind Turbine Generator (WTG) (1nr Nacelle, 3nr blades and 3nr tower sections), Wind Turbine Foundation (WTF) and Anchoring components.

It is envisaged that WTF units will be fabricated and stored on-site prior to device assembly and deployment for offshore installation. WTG components will be delivered to the site by land and sea. It is a requirement of the site to facilitate the fabrication and assembly of 17nr turbine devices at any one time (half of the 500MW throughput requirement of the Hub facility).

Given the position of the existing Power Station on the site; the available land for development is split into two individual areas of ESB ownership on either side of the Power Station. Early development scenarios indicated that both Eastern and Western sites would be required to accommodate the areas required for WTFs, WTGs and ancillary equipment and storage areas.

Quayside operations, which will include mating of WTF and WTG components and deployment of assembled devices at the site, will require a large hinterland area and quay berthing face. This is required as a single quay structure connecting the Eastern and Western land side areas.

Based on these requirements, RPS' Engineering design team have developed a conceptual design for the Moneypoint Hub as detailed in drawing M0838-RPS-XX-XX-DR-C-2400 in Appendix A. To date, the design and development of the Moneypoint Hub has focused primarily on usage requirements and engineering constraints (i.e., loadings, bearing capacity etc). However, it is also imperative to ensure that the proposed development does not reduce or impinge the performance of the existing intakes or outfalls which are essential to the operation of the power station.

Working with RPS' Engineering design team, two high-level conceptual options for the Moneypoint Hub were developed based on drawing M0838-RPS-XX-XX-DR-C-2400. These options are described below and assessed in later sections of this report in respect of extreme wave conditions along the berthing line of the proposed quay edge.

2.1 Option 1 – Solid Quay solution

Demolition of the existing quay will be required to allow the construction of the new quay structure necessary to support the Hub Operations. As illustrated in Figure 2.1, the high-level schematic of Option 1, the size and geometry of the quay structure has been optimised to minimise its footprint (reclamation area) whilst still providing *c.*1,200m of a berthing face in *c.* -15m CD of water.

The structure also remains within the ESB foreshore private ownership boundary. The structure is the minimum length required to connect the East and West land sites while providing vessel berthing for Hub and Power Station operations

As illustrated in Figure 2.1, Option 1 includes for a *c.*45m and 100m pilled area in front of the existing cooling water intake and outlet respectively. It is envisaged that these open pile areas will maintain the existing hydraulic and thermal exchange properties of these cooling water assets. Based on preliminary calculations, *c.*2m diameter piles at 5m centres have been used to inform this Option.

2.2 Option 2 – Open Pile solution

This option provides the same *c.*1,200m berthing face in *c.* -15m CD of water, however, unlike Option 1, the full quay would be supported by open pile structures instead of being reclaimed. Option 2 is summarised in Figure 2.2.

In addition to describing the operational wave conditions at the existing site, the following Sections of this report describe the numerical assessment that was undertaken to assess the general hydraulic performance of these options with respect to extreme wave conditions along the proposed quay line.

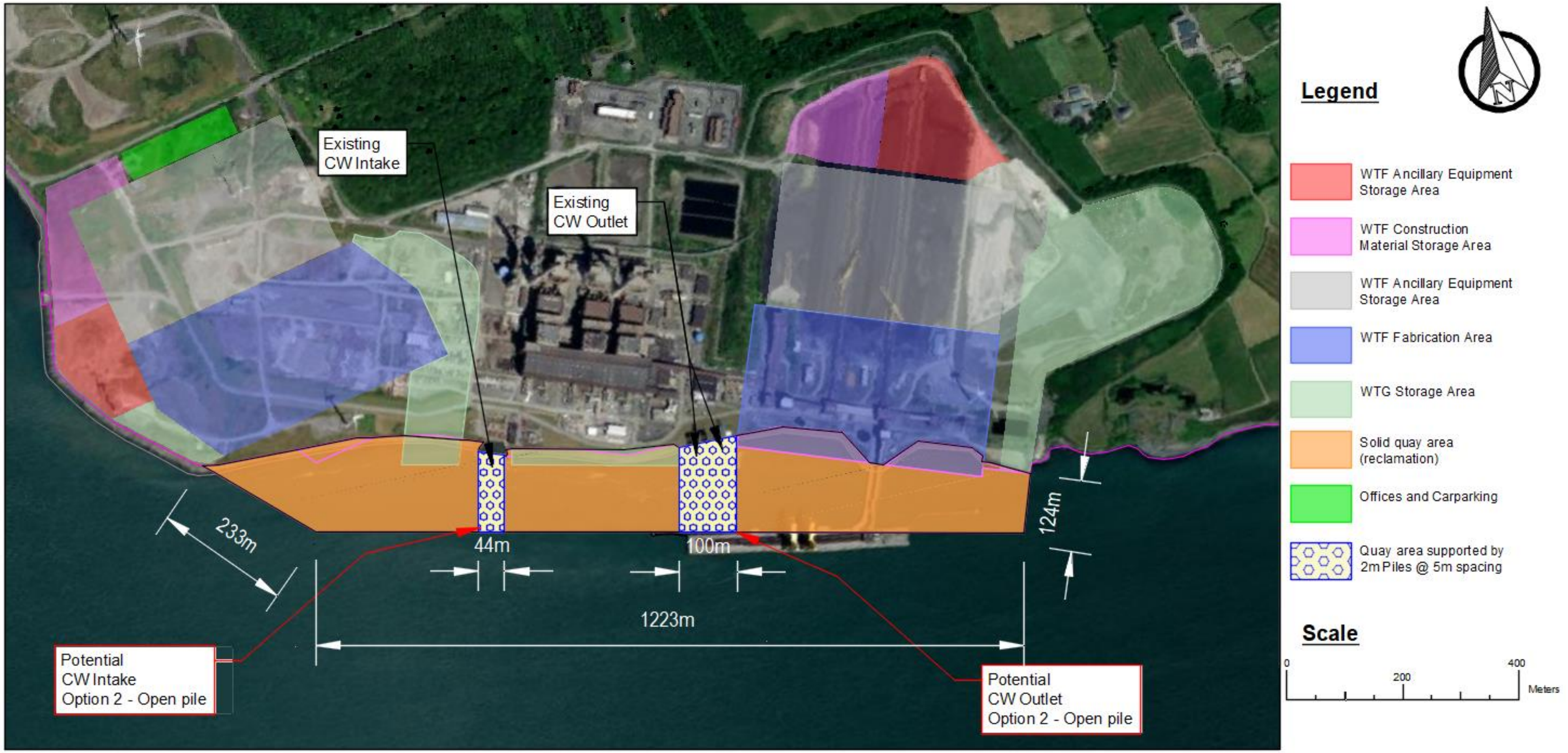


Figure 2.1: Schematic overview of Conceptual Option 1 for the Moneypoint Hub, featuring a reclaimed *c.*1,200m berthing face, with a 44m and 100m open piled section to maintain the hydraulic regime at the cooling water intake and outlet

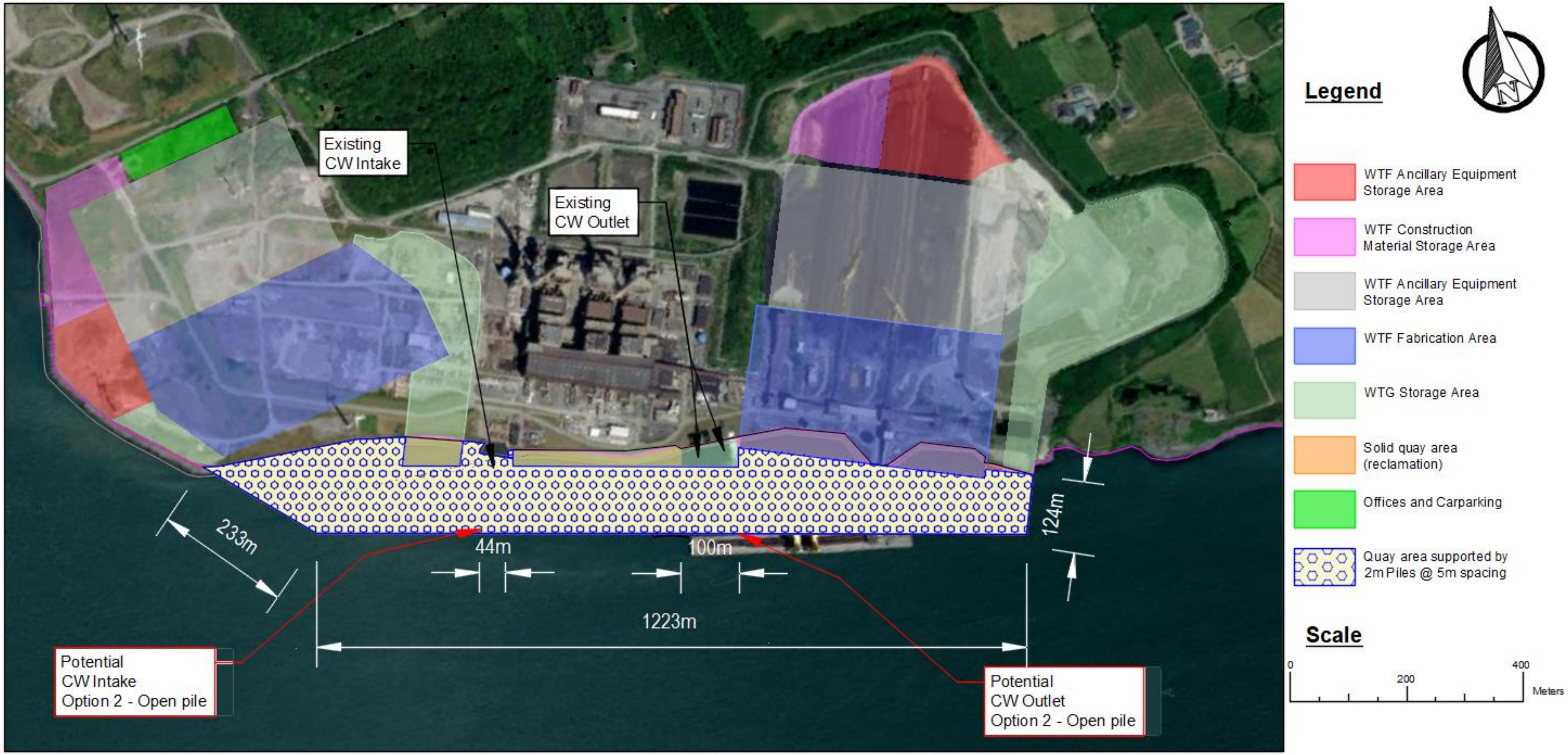


Figure 2.2: Schematic overview of Conceptual Option 2 for the Moneypoint Hub, featuring a fully open piled *c.*1,200m berthing face

3 COMPUTATIONAL MODELLING OVERVIEW

RPS has previously undertaken extensive modelling of coastal processes within the Shannon estuary and adjoining wider area. This expertise and experience were used to guide the numerical modelling programme that was undertaken to inform this study.

The detailed modelling programme for this study was developed to:

- Characterise the operational wave conditions at the existing Moneypoint site based on an assessment of the long-term wave conditions between 2000 and 2021.
- Define the extreme inshore wave climate conditions at the existing Moneypoint site for 1 in 10, 20, 50, 100 and 200 year return period conditions.
    - This analysis was then repeated using numerical models to represent conceptual Options 1 and 2 which are described in Sections 2.1 and 2.2 respectively.
- Assess the potential impact of different Moneypoint configuration options on the thermal performance of the existing cooling water intake and outlet assets which are imperative for the operation of the ESB power station at Moneypoint.

3.1 Modelling Systems

The hydraulic modelling for this study was undertaken using RPS' in-house suite of MIKE modelling systems. The MIKE modelling systems have been developed by the Danish Hydraulics Institute (DHI) and are regarded as one of the world's foremost computational modelling systems for the marine environment.

A brief synopsis of the MIKE system and modules that were used for this study are outlined below.

1. **MIKE 21 Flow Model system** – This modelling system is based on a flexible mesh approach and has been developed for applications within oceanographic, coastal, and estuarine environments. Using the MIKE 21 system it is possible to simulate the mutual interaction between waves, currents, and sediment transport by dynamically coupling the relevant modules. Hence, a full feedback of the bed level changes on the waves and flow calculation can be included.
2. **Hydrodynamic (HD) module** – This module simulates water level variations and flows in response to a variety of forcing functions in lakes, estuaries, and coastal regions. The HD Module is the basic computational component of the entire MIKE 21 Flow Model system providing the hydrodynamic basis for the Transport Module, ECO Lab/Oil Spill Module, Mud Transport Module, Sand Transport Module and Particle Tracking Module. Importantly, this module can also account for density effects caused by differences in temperatures and salinity and can therefore be used to represent and assess the performance of thermal plumes produced from outfalls and intakes like those found at Moneypoint.

   The HD Module can be used to solve both three-dimensional (3D) and two-dimensional (2D) problems. In 2D the model is based on the shallow water equations – the depth-integrated incompressible Reynolds averaged Navier-Stokes equations.
3. **Spectral Wave (SW) module** – This module simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas and accounts for key physical phenomena including wave growth by wind action, dissipation, refraction, shoaling and wave- current interaction.

A full description of these systems and modules can be found in Appendix B.

3.2 Bathymetry and Model Structure

Given that the primary objective of this study was to assess the wave climate at Moneypoint, it was imperative to consider the influence of both offshore swell waves and locally generated wind waves at the study site. To this end, RPS' developed two individual numerical models. The first "outer wave model" was developed from RPS' Irish Wave and Water level Study (IWWS) and used to propagate wave conditions from far offshore in the Atlantic Ocean to the entrance of the Shannon estuary.

As illustrated in Figure 3.1, RPS then developed a second, more detailed, model of the Shannon Estuary and Moneypoint study area. This model was created using flexible mesh technology to provide detailed information on the coastal processes at Moneypoint. The model uses mesh sizes varying from approximately 200m at the entrance to Shannon estuary to *c.* 10m at the coastline of Moneypoint. The detailed mesh structure at Moneypoint is illustrated in Figure 3.2.

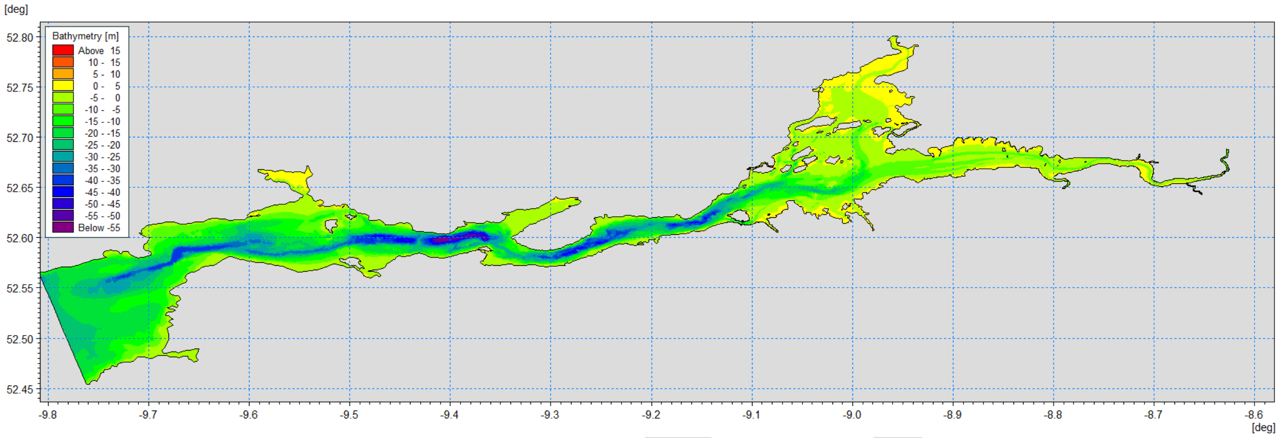


Figure 3.1: Overview of RPS' Shannon estuary model

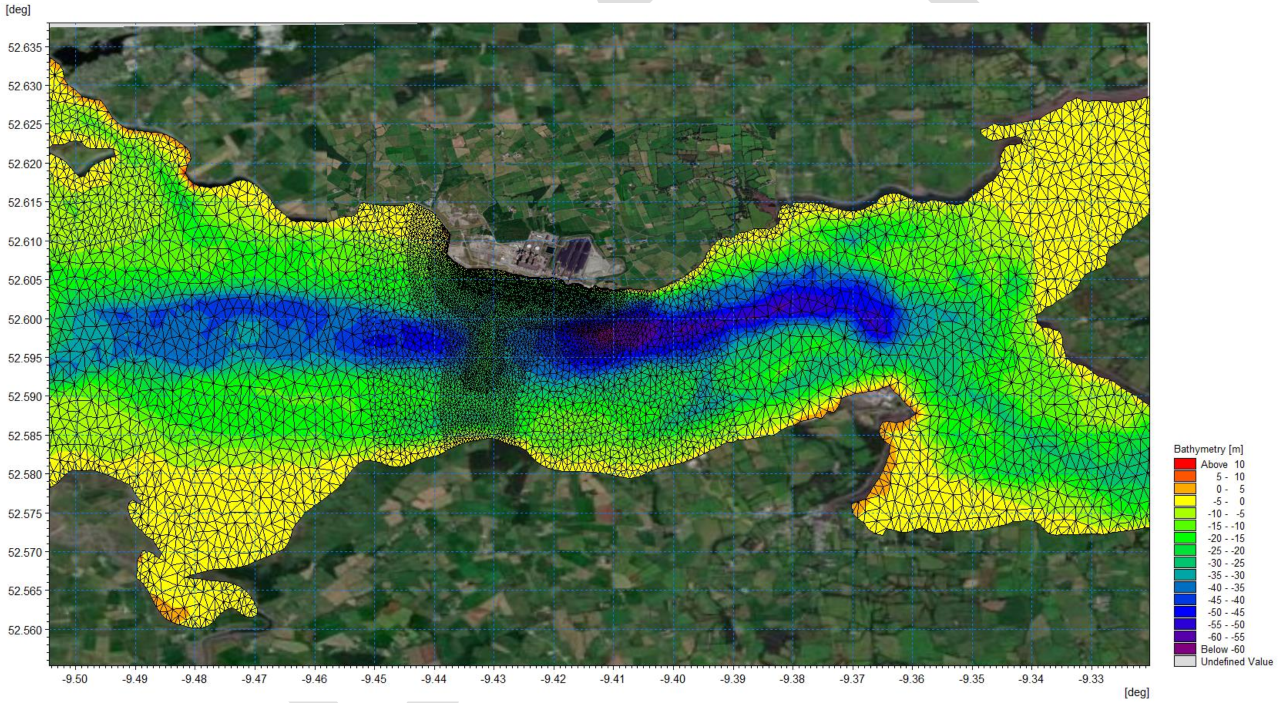


Figure 3.2: Mesh detail and structure at Moneypoint and in the surrounding area

The principal bathymetry datasets used to develop these models were derived from the INFOMAR project and other local bathymetric surveys collated by RPS as part of the Irish Coastal Protection Strategy Study (ICPSS) and the national Catchment Flood Risk Assessment and Management (CFRAM) study. The availability of his-resolution bathymetry data within the Shannon estuary and Moneypoint area is illustrated in Figure 3.3.

All bathymetry datasets were set with the depths relative to Mean Sea Level (MSL) before being input into the model.

The model illustrated in Figure 3.2 was used to represent "baseline" conditions. This model was subsequently updated to reflect the proposed development as per Options 1 and 2 described in Sections 2.1 and 2.2. The solid quay option with two open piled sections at the cooling water intakes and outlets is presented in Figure 3.4.

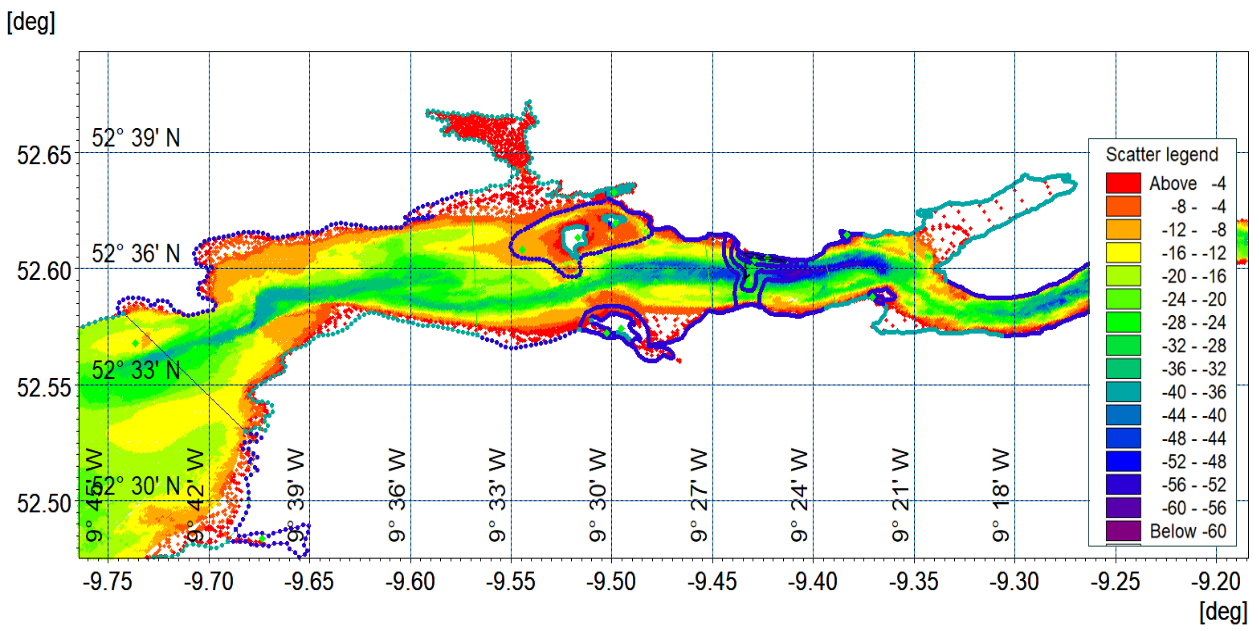


Figure 3.3: Overview of available scatter data from the INFOMAR project and other data sources used to inform the Moneypoint model

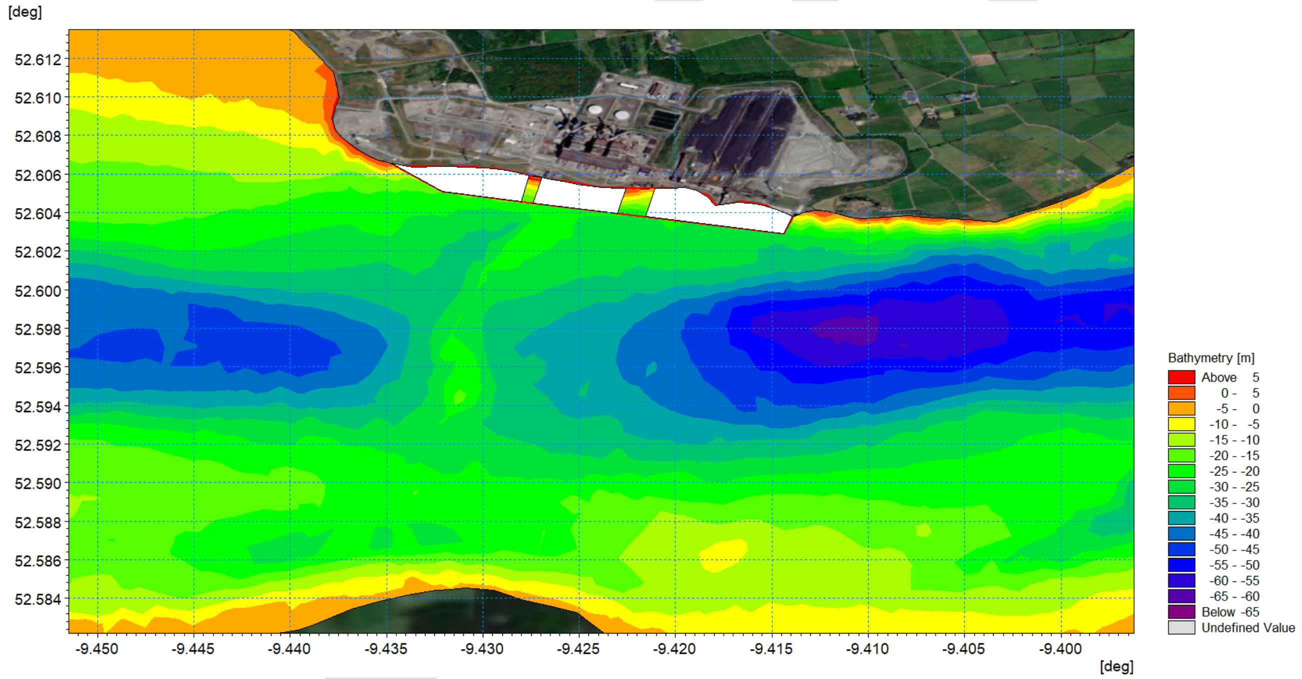


Figure 3.4: Overview of the numerical model that was developed to represent conceptual option 1

3.3 Wave and wind data

To statistically analyse the inshore wave climate at Moneypoint, it was important to first determine if offshore swell waves produced in the Atlantic Ocean could propagate through the Shannon estuary which is characterised by complex bathymetry. To this end, RPS extracted offshore wave conditions from a global wave model developed and run by the European Centre for Medium Range Forecasts (ECMWF) for the period between 2000 and 2021. These data were then used to inform the boundary conditions of RPS' outer wave model, the extent of which is illustrated in Figure 3.5.

The wave climate at the offshore location (55ºN,11ºW and shown in Figure 3.5) is illustrated in the form of a wave rose in Figure 3.6. It will be seen from this Figure that whilst waves can occur from virtually all directions at this point, waves from the westerly sectors dominate. In comparison, at the mouth of the Shannon Estuary (at 52.5ºN, 9.81ºW), the direction of the waves is much more omnidirectional. Importantly, it will be seen that owing to the process of wave dispersion and refraction, the largest occurring waves are reduced from >6.0m at the offshore location to *c.*4.0m at the mouth of the Shannon estuary. These waves generally have corresponding mean wave periods of 8 – 13 seconds.

Further assessment of the potential influence of swell waves within the Shannon estuary in respect to Moneypoint is presented in Section 5.

In addition to wave data, wind data to inform the models was extracted from the National Centres for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) global, high-resolution, coupled atmosphere-ocean-land surface-sea model for the same period, i.e., from 2000 – 2021.

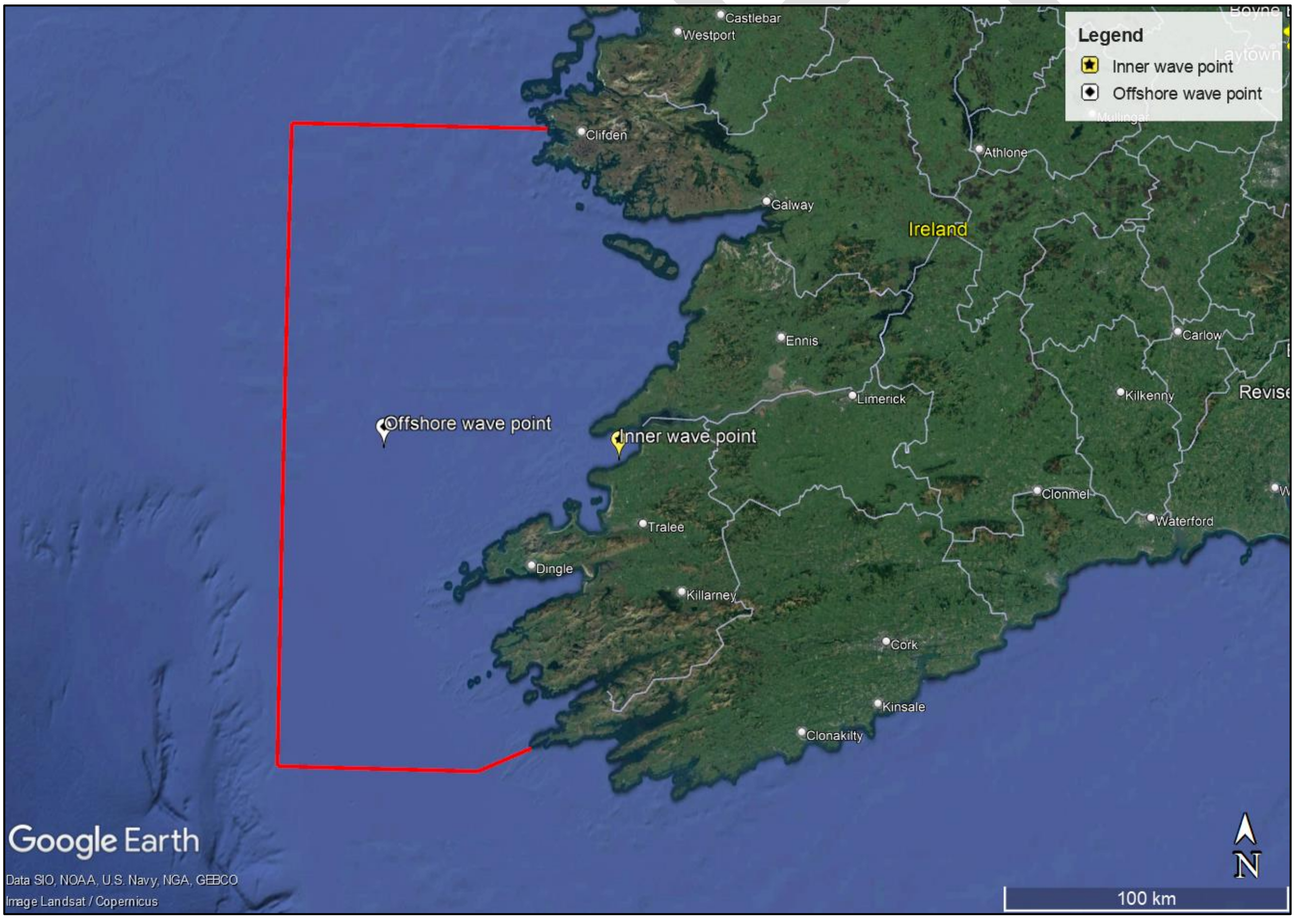


Figure 3.5: Location of RPS' outer wave model boundaries and location of offshore and inshore wave points used to produce wave roses.

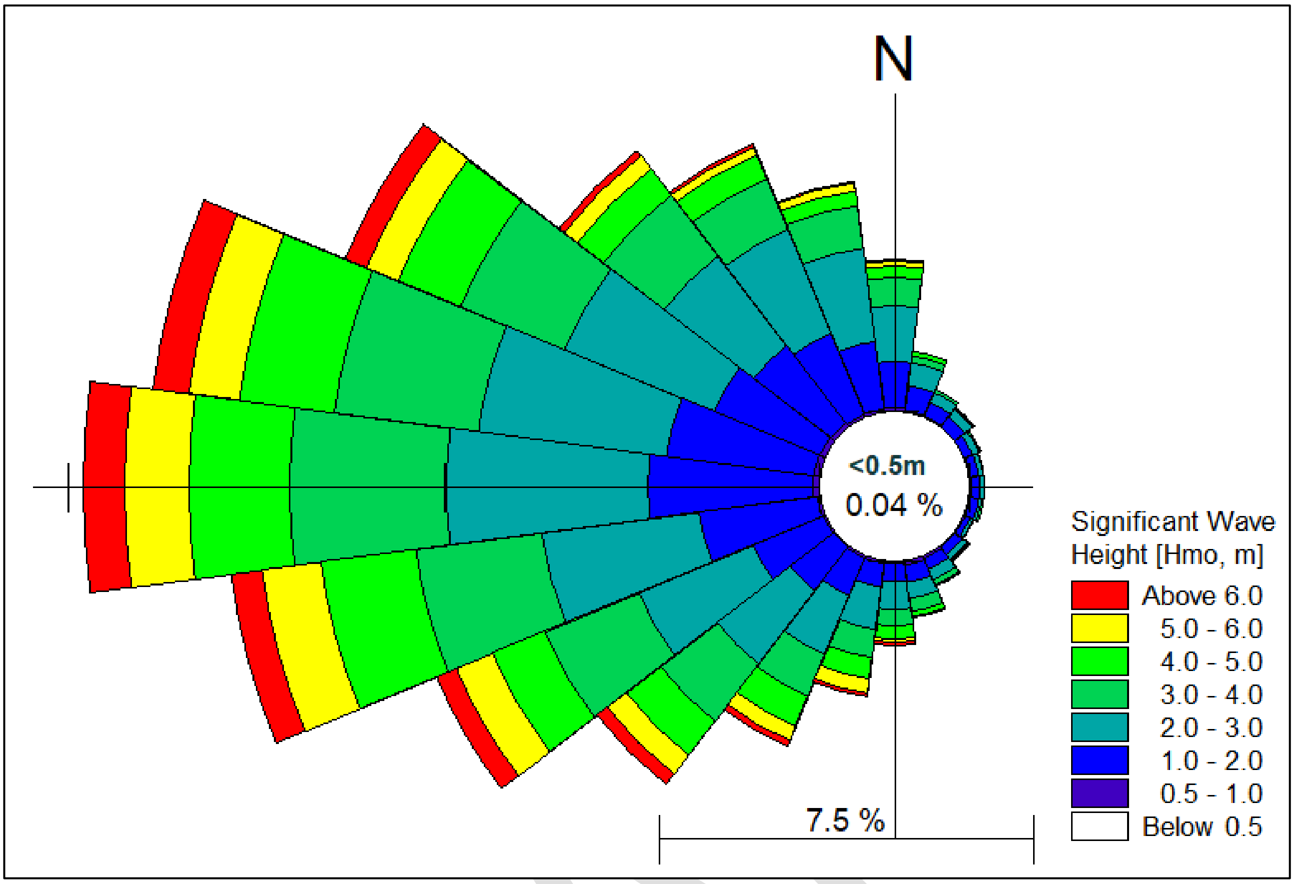


Figure 3.6: Offshore significant wave heights between 2000 and 2021 at 55ºN,11ºW

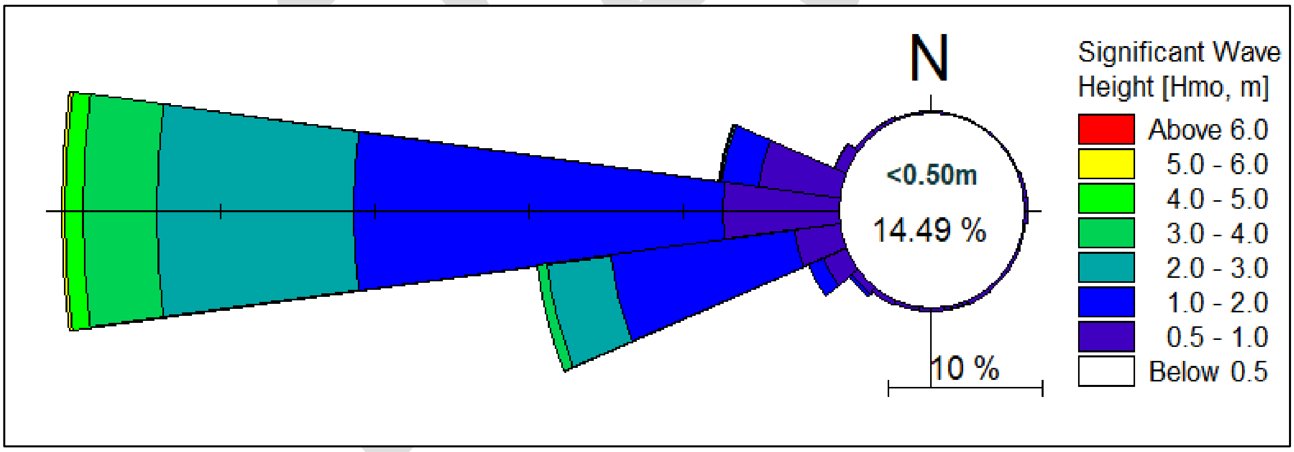


Figure 3.7: Nearshore significant wave heights between 2000 and 2021 at the mouth of the Shannon Estuary (52.5ºN, 9.81ºW)

4 WAVE SPELL ANALYSES

Port operations can be severely hampered by the effects of wave action which can induce excessive horizontal movements of the ship while at a port terminal that may disrupt loading and unloading operations and cause damages to vessels, port infrastructure and/or nearby ships. Understanding likely wave conditions at a port is therefore imperative to making informed decisions regarding effective management of marine operations and ensuring ongoing safety and efficiency.

Recognising this, RPS undertook a long-term simulation of wave conditions at Moneypoint and statistically analysed the output to produce a "spell analyses" that described the frequency occurrence of waves based on a 22 year hindcast dataset.

4.1 Modelling approach

The wave spell analysis was undertaken using the MIKE 21 Spectral Wave model in conjunction with 22 years of three hourly offshore wave and wind data which has already been described in Section 3.3. It should be noted that this wave simulation was undertaken using site specific tidal elevation data which was derived from tidal harmonics as described in the Admiralty tide tables for this area.

The wave climate at a point immediately adjacent to the existing jetty was then extracted and analysed to calculate the frequency occurrence of the varying wave conditions at this location. The location of this point is illustrated in Figure 4.1.

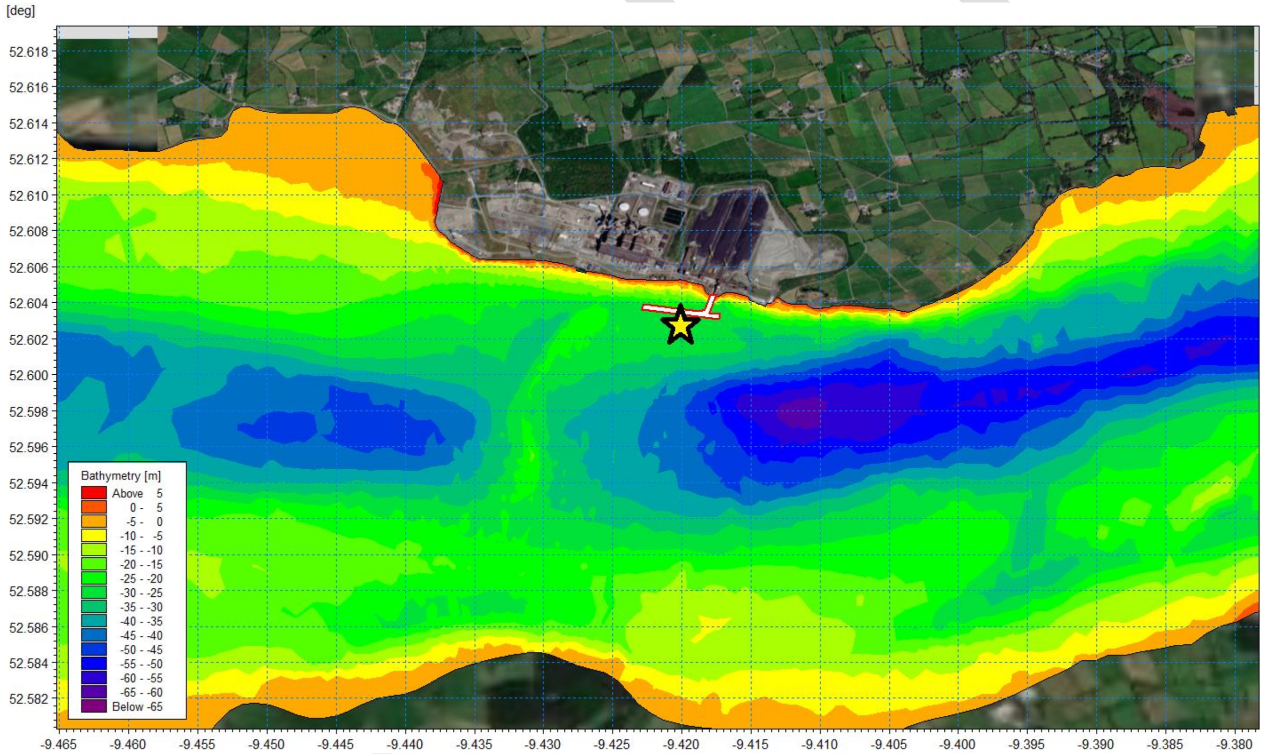


Figure 4.1: Location of the inshore wave climate point used for the spell analyses

4.2 Output of long-term wave simulation

Time series information that describes the long-term wave climate at a point immediately seaward of the existing jetty at Moneypoint is presented overleaf. In particular, the significant wave heights and peak wave periods are illustrated in Figure 4.2 & Figure 4.3 respectively. In addition, Figure 4.4 illustrates the distribution of significant wave heights vs peak wave periods between 2000 and 2021 at the existing jetty.

This information was used the undertake the spell analyses as described in the following Section of this report.

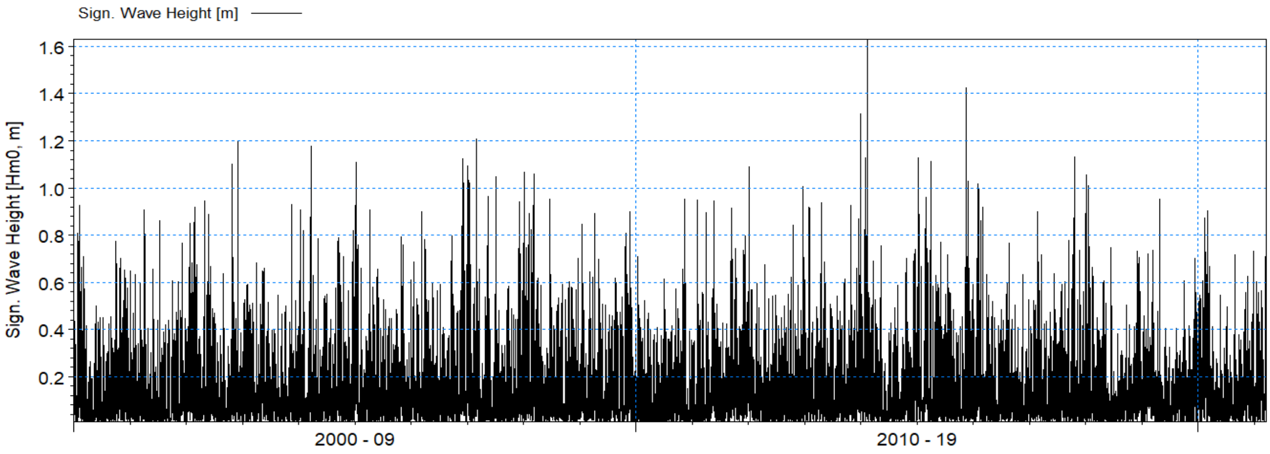


Figure 4.2: Long-term significant wave heights between 2000 and 2021 at the existing Jetty at Moneypoint

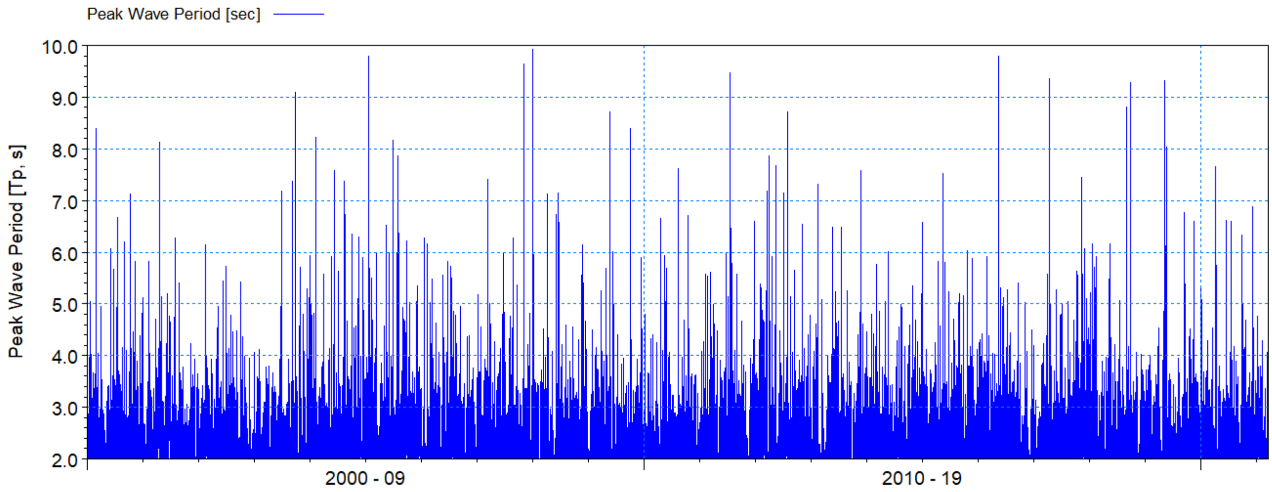


Figure 4.3: Long-term peak wave periods between 2000 and 2021 at the existing Jetty at Moneypoint

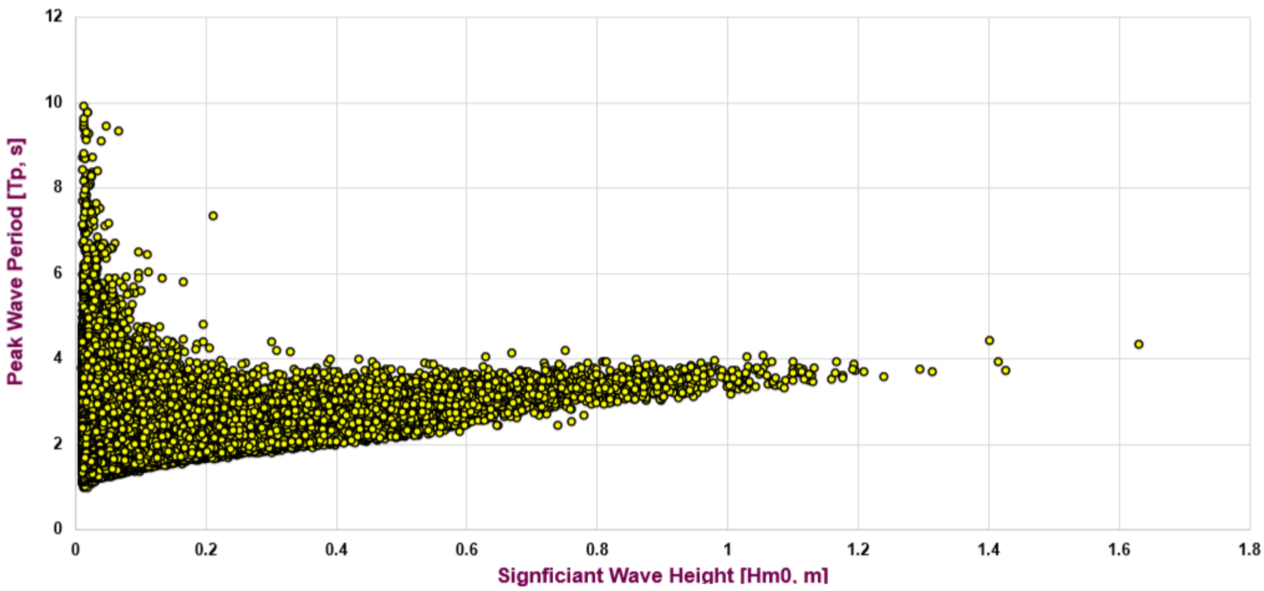


Figure 4.4: Long-term analyses of significant wave heights vs peak wave periods at the existing Jetty at Moneypoint between 2000 and 2021

4.3 Output of spell analyses

The output of the long-term wave simulation in respect of the monthly average significant wave height and peak wave periods experienced at the existing jetty at Moneypoint is summarised in Table 4.1. As would be expected, the most arduous conditions are experienced in winter months, however, even during this period, *average* significant wave heights do not typically exceed 0.20m.

The *greatest* significant wave heights and peak wave periods for the same 22-year period from 2000 and 2021 are presented in Table 4.2. These data indicate that the largest waves could be expected to approach Moneypoint during February, and that peak wave periods associated with some of these events could reach up to *c.*10 seconds.

Table 4.1: Summary of monthly average significant wave heights and peak wave periods at the existing jetty at Moneypoint

Month	Significant Wave Height [Hm0, m]	Peak Wave Period [Tp, s]
Jan	0.18	2.30
Feb	0.17	2.29
Mar	0.15	2.24
Apr	0.12	2.20
May	0.13	2.25
Jun	0.12	2.29
Jul	0.12	2.31
Aug	0.12	2.30
Sep	0.12	2.25
Oct	0.13	2.20
Nov	0.14	2.26
Dec	0.16	2.24

Table 4.2: Summary of monthly greatest significant wave heights and peak wave periods at the existing jetty at Moneypoint

Month	Significant Wave Height [Hm0, m]	Peak Wave Period [Tp, s]
Jan	1.13	9.92
Feb	1.63	8.39
Mar	1.18	7.86
Apr	0.95	9.36
May	0.97	9.79
Jun	0.95	8.17
Jul	1.05	9.47
Aug	0.76	7.86
Sep	0.91	9.29
Oct	1.13	8.40
Nov	1.43	9.64
Dec	1.31	6.87

In addition to calculating monthly averages and maximums, RPS analysed the inshore wave data to determine the frequency at which certain wave conditions occur at the existing jetty at Moneypoint. This information is presented in Table 4.3 and Table 4.4 below. It should be noted that these tables report the frequency of a condition in terms of a percentage of a typical year.

I.e., referring to Table 4.3, it is reasonable to suggest that based on this data, wave heights of between 0.2 – 0.4 metres with a corresponding peak wave period of 2 - 3 seconds could be expected to occur for 15% of the time in a typical year.

By means of another example, it can be inferred from Table 4.3 that conditions whereby wave heights of ≤0.4m and corresponding peak wave periods of ≤3s could be expected to occur for 90% of the time in a typical year.

Based on this assessment, on average, the existing jetty experiences significant wave heights <0.6m with corresponding peak wave periods of < 4s for *c.* 95% of the time during a typical year.

Figure 4.5 illustrates a long-term wave rose of significant wave heights experienced at the Moneypoint jetty between 2000 and 2021. It will be seen from this figure that the largest waves approach the existing jetty from *c.* 255ºN.

It is important to acknowledge that the wave climate statistics presented in this report are based on hindcast data (i.e., based on historical data) and that future wave conditions at Moneypoint could differ to these historical conditions.

Based on this long-term assessment, it can be concluded Moneypoint is, in general, exceptionally well sheltered from arduous waves from virtually all directions. The waves that do approach the study site are almost exclusively wind-generated over relatively short fetches of *c.*<=18km. As a result, significant wave heights do not generally exceed 0.2m with corresponding peak wave periods of < 1.5 seconds. Under very arduous conditions, wave heights may approach *c.*1.60m with corresponding wave periods of *c.* < 10 seconds.

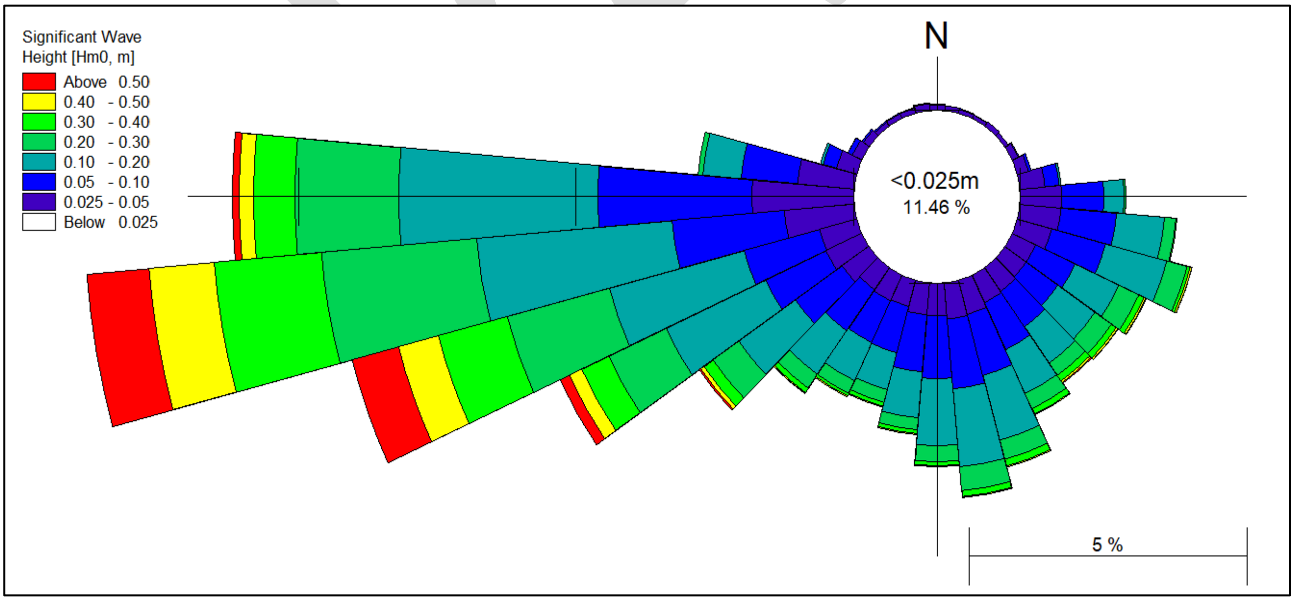


Figure 4.5: Long-term wave rose of significant wave heights experienced at the Moneypoint jetty between 2000 and 2021

Table 4.3: Percentage Frequency occurrence analyses of significant wave heights vs peak wave periods

Peak Wave Period [Tp, s]	Significant Wave Height [Hm0, m]								
	0 - 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	0.8 - 1	1 - 1.2	1.2 - 1.4	1.4 - 1.6	>1.6
0 - 1	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1 - 2	30.755	1.862	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 - 3	42.382	15.453	2.678	0.147	0.002	0.000	0.000	0.000	0.000
3 - 4	2.852	0.750	1.393	0.686	0.203	0.041	0.002	0.001	0.000
4 - 5	0.519	0.002	0.001	0.002	0.000	0.001	0.000	0.001	0.001
5 - 6	0.160	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 - 7	0.052	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7 - 8	0.034	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8 - 9	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
>9	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4.4: Percentage Frequency occurrence analyses of significant wave heights vs wave directions

Wave Direction [Deg N]	Significant Wave Height [Hm0, m]								
	0 - 0.2	0.2 - 0.4	0.4 - 0.6	0.6 - 0.8	0.8 - 1	1 - 1.2	1.2 - 1.4	1.4 - 1.6	>1.5
0 - 30	0.986	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
30 - 60	0.748	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
60 - 90	2.870	0.006	<.001	<.001	<.001	<.001	<.001	<.001	<.001
90 - 120	8.858	0.935	0.042	0.001	<.001	<.001	<.001	<.001	<.001
120 - 150	6.706	1.288	0.132	0.005	<.001	<.001	<.001	<.001	<.001
150 - 180	9.238	1.373	0.078	0.001	<.001	<.001	<.001	<.001	<.001
180 - 210	7.101	0.858	0.038	0.001	<.001	<.001	<.001	<.001	<.001
210 - 240	8.598	1.948	0.254	0.035	0.004	0.001	<.001	<.001	<.001
240 - 270	20.154	10.886	3.484	0.791	0.201	0.041	0.002	0.002	0.001
270 - 300	9.100	0.775	0.044	0.002	<.001	<.001	<.001	<.001	<.001
300 - 330	1.145	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
>330	1.271	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001

5 ANALYSES OF EXTREME WAVE CONDITIONS

In addition to characterising the long-term wave climate at Moneypoint, this study also considered extreme wave conditions. In particular, RPS assessed wave conditions for 1 in 10, 20, 50, 100 and 200 year return period events for the existing scenario and the two concept options described in Section 2.

Findings from earlier work indicated that virtually all waves that reach Moneypoint are generated by wind over local fetches. To confirm this, RPS analysed the output from the offshore wave model to undertake an Extreme Value Analyses of swell conditions approaching the Shannon Estuary entrance from the critical directional sector which in this instance was 247.50 – 262.50ºN.

The EVA was performed by fitting a theoretical probability distribution to the dataset and using a peak over threshold model to select the largest events. A Weibull probability distribution was then fitted to the dataset using a Jackknife re-sampling technique to derive a series of wave conditions for relevant return period events. The output of this assessment is illustrated in Figure 5.1 and summarised in Table 5.1.

Using this data as boundary conditions for the detailed Moneypoint model illustrated in Figure 3.2, RPS assessed how successfully swell conditions could propagate towards the study area. As demonstrated by Figure 5.2 and Figure 5.3, the offshore swell waves are highly attenuated by the complex bathymetry within the estuary and through the processes of refraction and bed friction. As such, virtually no swell waves can reach Moneypoint.

Table 5.1: Summary of extreme swell waves at the entrance to Shannon Estuary approaching from 247.5 to 262.5° sector for the period 2000 - 2021

Return Period	Significant Wave Height [Hm0, m]	Peak Wave Period [Tp, s]
10	5.92	12.85
20	6.28	13.23
50	6.73	13.70
100	7.06	14.03
200	7.39	14.35

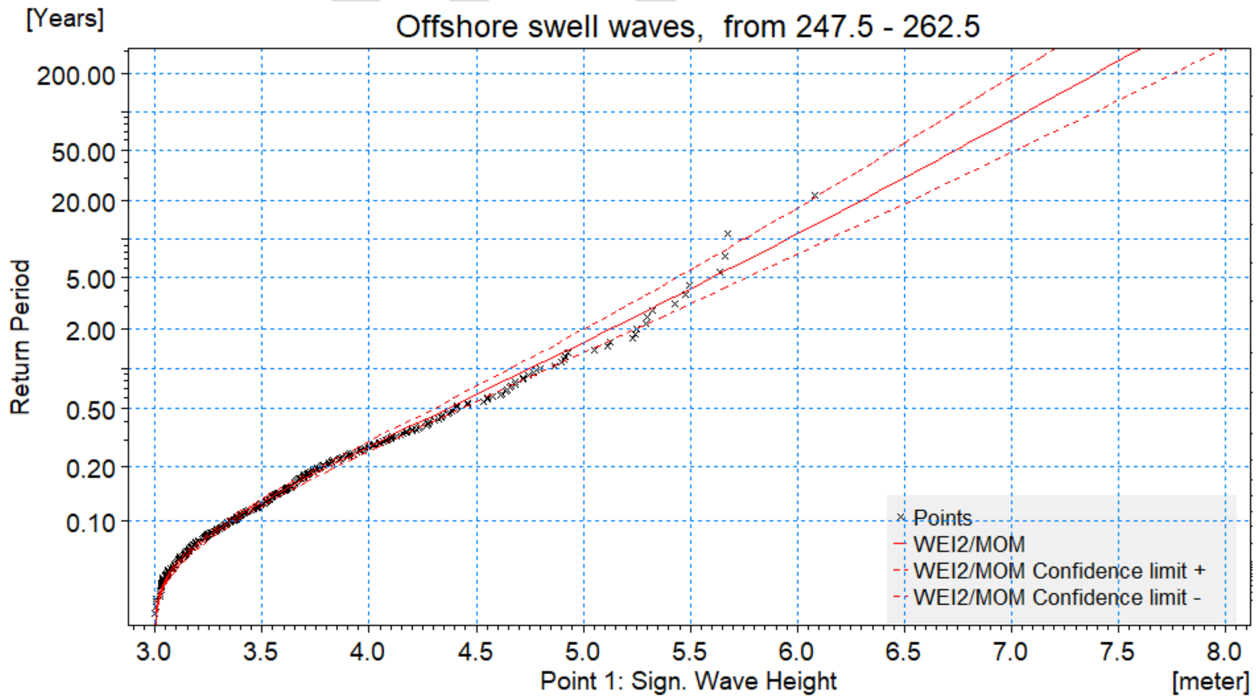


Figure 5.1: Extreme event analysis of swell waves at the entrance to Shannon Estuary approaching from 247.5 to 262.5° sector for the period 2000 - 2021

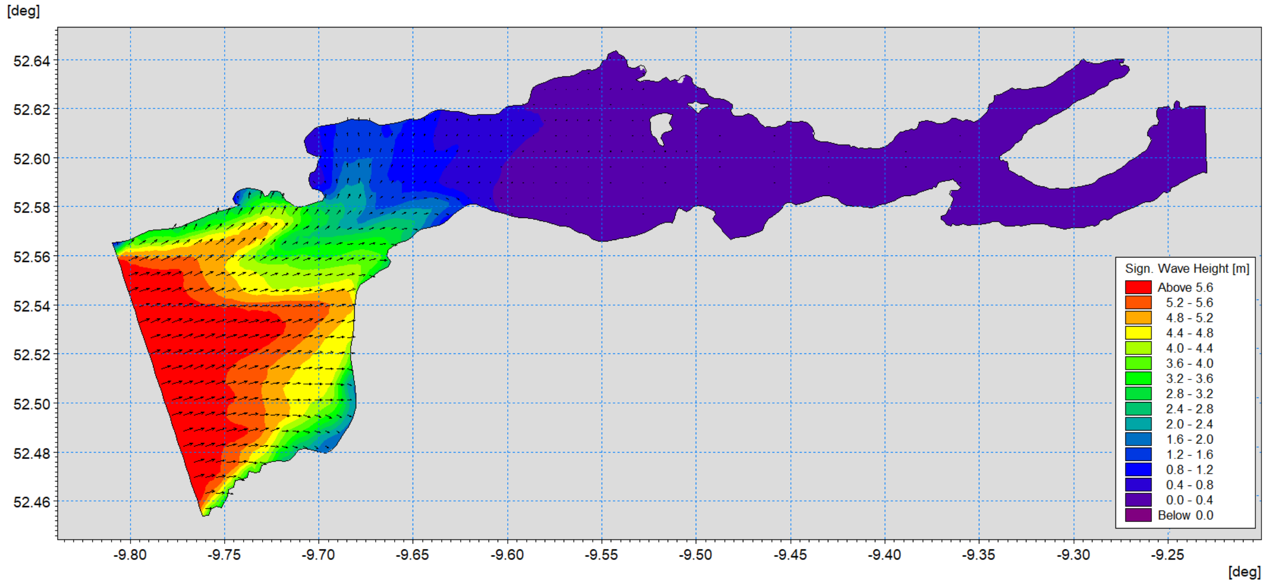


Figure 5.2: Significant wave heights in the Shannon Estuary during a 1 in 200 year offshore swell event originating from 255°

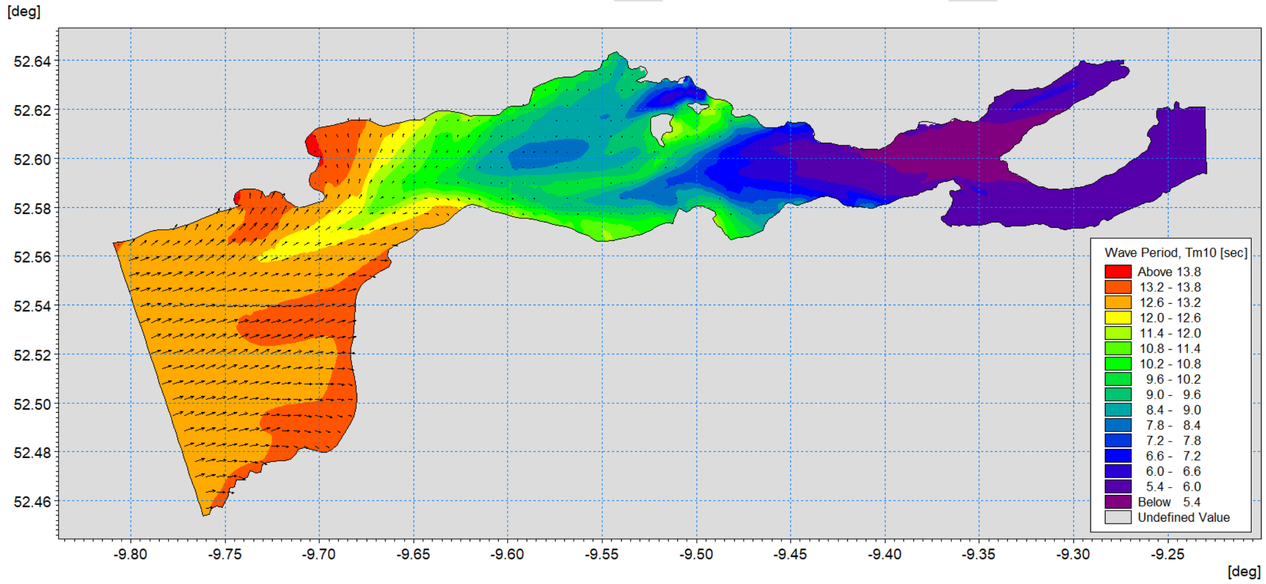


Figure 5.3: Mean energy wave periods (Tm10) in the Shannon Estuary during a 1 in 200 year offshore swell event originating from 255°

5.1 Extreme value analyses of wind conditions

Having demonstrated that swell waves do not reach Moneypoint where the wave climate is instead dominated by locally generated wind waves, it was necessary to assess the extreme wind wave climate for the baseline scenario and for the two concept options described in Section 2.

To derive boundary conditions for the detailed numerical models, RPS statistically analysed the long-term CFSR wind dataset described in Section 3.3 using the Extreme Value Analyses tool in MIKE. This EVA was performed by fitting a theoretical probability distribution to the dataset and using a peak over threshold model to select the largest events. A truncated Gumbel probability distribution was then fitted to the dataset using a Jackknife re-sampling technique to derive extreme wind conditions for relevant return period events based on an omni-directional basis (i.e., the wind data was not split into individual sectors).

An extended wind dataset from between 1979 and 2021 was used to enhance the robustness of this analysis. The output of this assessment is illustrated in Figure 5.4 and summarised in Table 5.2.

RPS used this extreme wind speed information to identify the critical direction from which the Moneypoint site could be exposed to the most arduous wave conditions. Based on this assessment it was found that wind waves generated over the *c.* 18km fetch from the *c.*255ºN sector produced the most arduous conditions at Moneypoint. The 1 in 100 year significant wave heights during events from 255º, 180º and 135ºN are illustrated in Figure 5.5 to Figure 5.7 respectively.

A summary of 1 in 100 year return period wave conditions for all relevant wind direction is summarised in Table 5.3.

Table 5.2: Summary of extreme wind conditions near Moneypoint for the period 1979 - 2021

Return Period	Wind speeds [m/s]
10	27.50
20	29.24
50	30.90
100	33.05
200	34.67

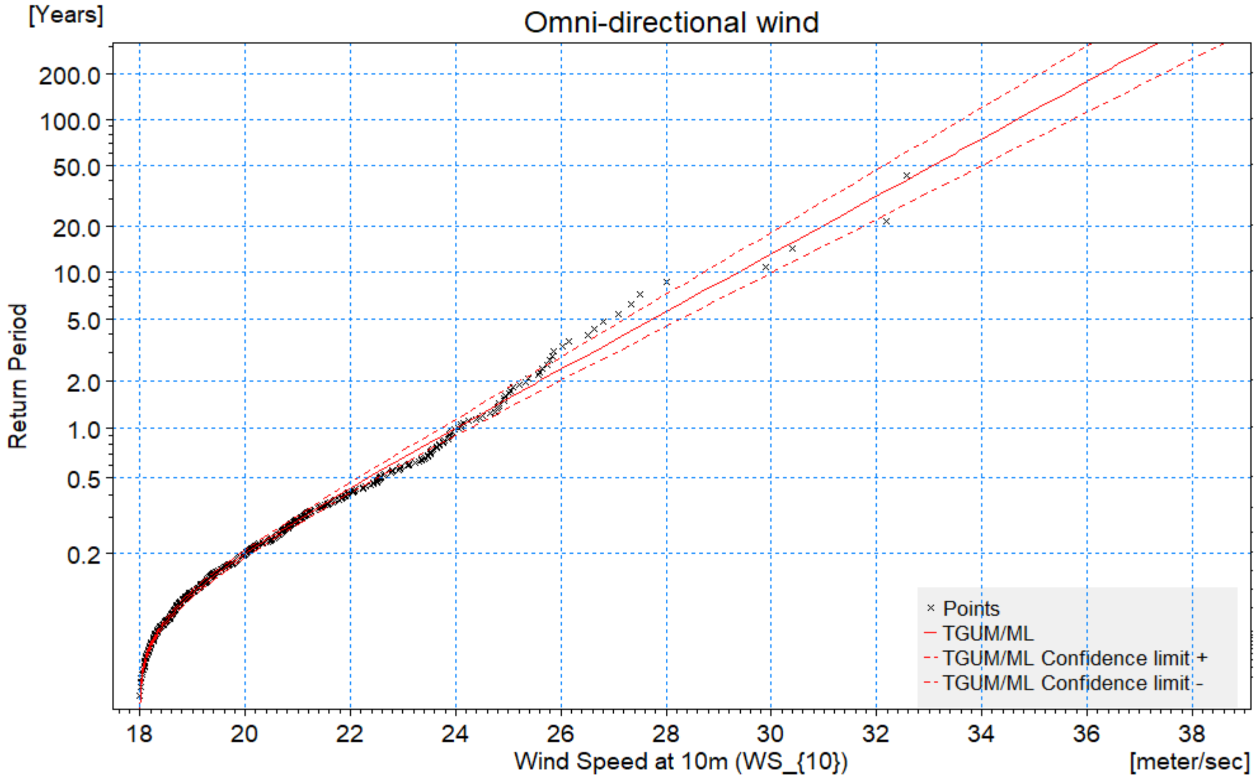


Figure 5.4: Extreme wind speeds near Moneypoint for the period 1979 - 2021

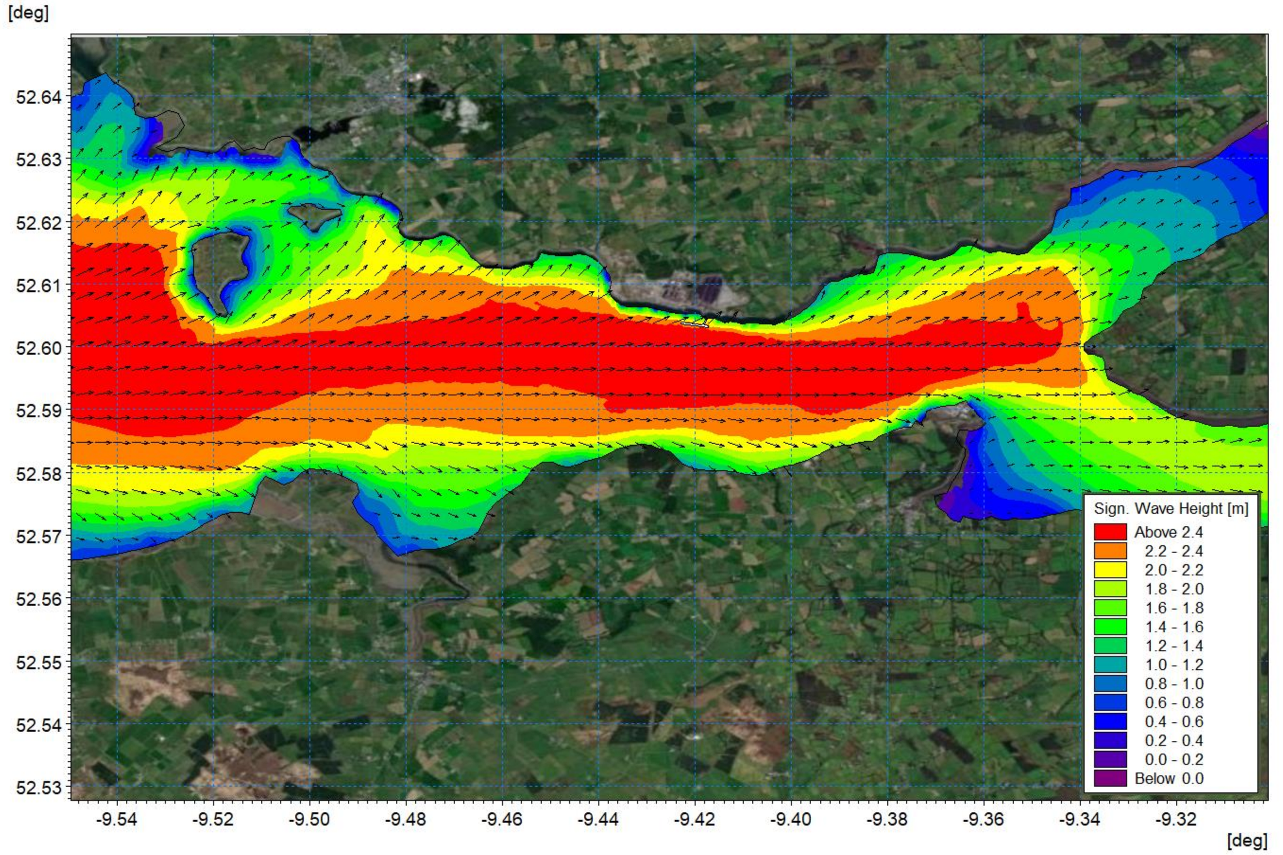


Figure 5.5: Extreme 1 in 100 significant wave heights at Moneypoint, local wind waves from 255ºN

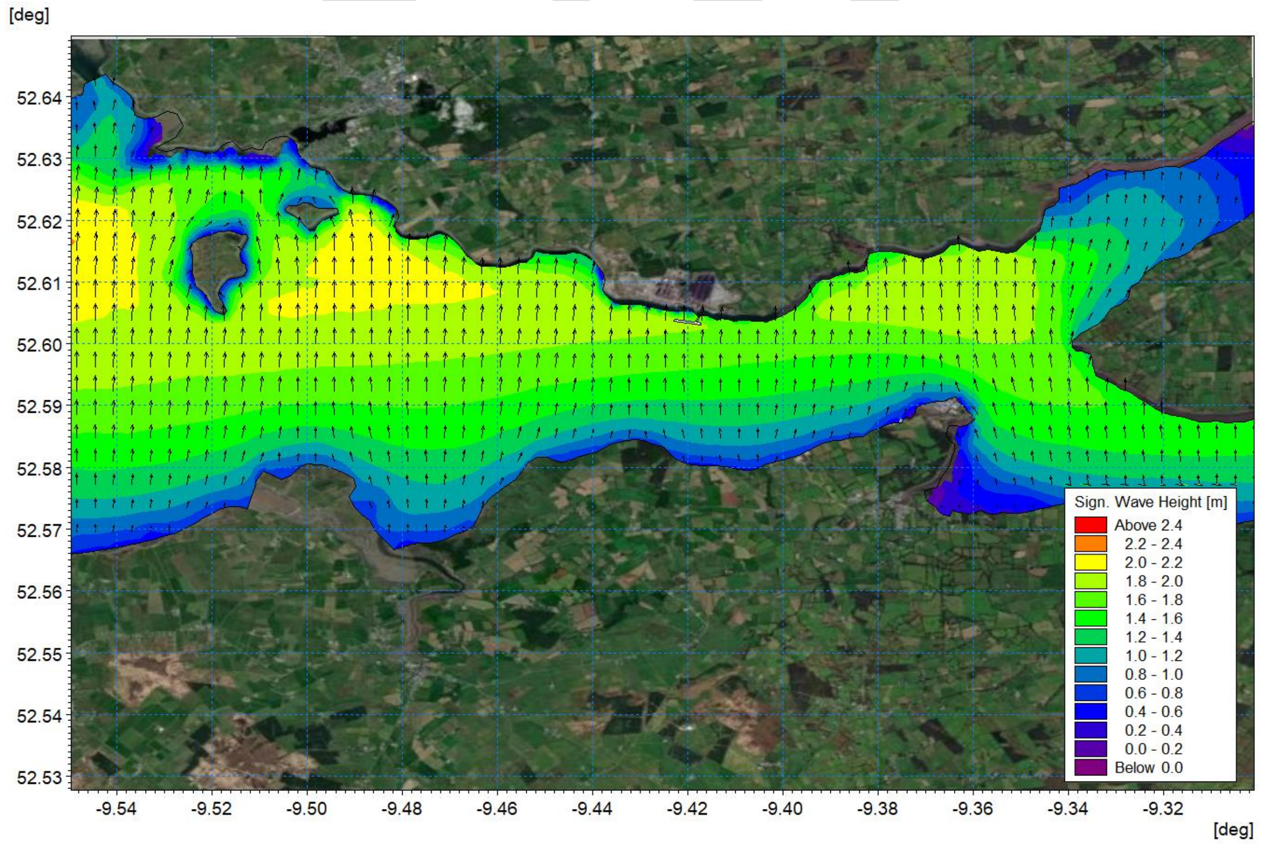


Figure 5.6: Extreme 1 in 100 significant wave heights at Moneypoint, local wind waves from 180ºN

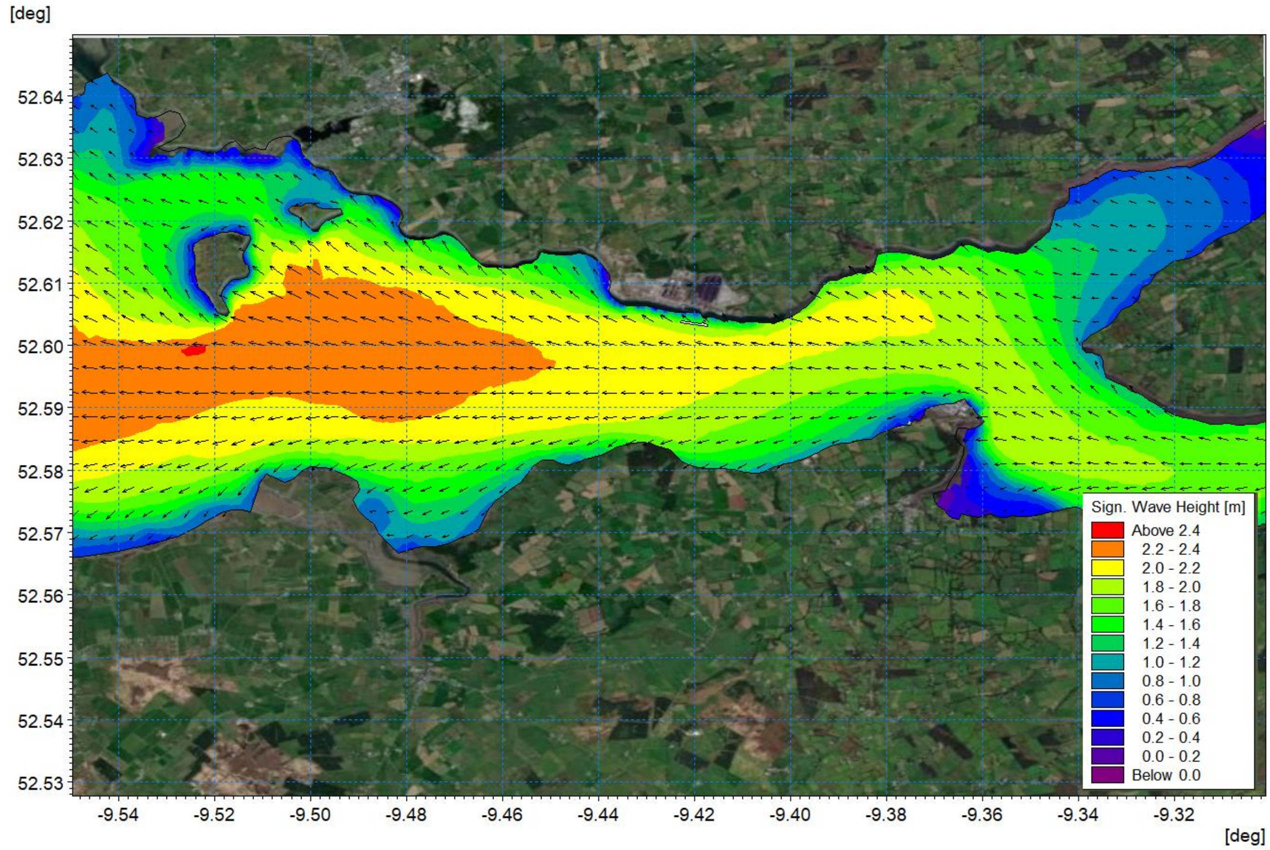


Figure 5.7: Extreme 1 in 100 significant wave heights at Moneypoint, local wind waves from 135ºN

Table 5.3: Summary of extreme 1 in 100 year wind wave conditions at the existing jetty for various wind directions

Prevailing wind direction [Deg N]	Significant Wave Height [Hm0, m]	Max Wave Height [m]	Peak Wave Period [Tp, s]	Mean Energy Wave Period [Tm10, s]
60	1.51	3.00	4.20	3.49
75	1.66	3.38	4.52	3.70
90	1.78	3.59	4.58	3.81
105	1.83	3.71	4.55	3.85
120	1.85	3.74	4.48	3.83
135	1.85	3.73	4.36	3.78
150	1.84	3.71	4.19	3.73
165	1.82	3.65	4.09	3.65
180	1.83	3.59	4.03	3.65
195	1.95	3.90	4.22	3.84
210	2.12	4.24	4.68	4.10
225	2.26	4.51	5.02	4.31
240	2.35	4.68	5.16	4.46
255	2.40	4.78	5.23	4.55
270	2.38	4.75	5.26	4.57
285	2.27	4.55	5.23	4.51
300	2.10	4.21	5.15	4.37
315	1.86	3.76	5.00	4.09

5.2 Assessment of initial concept options

The previous Section of this report demonstrated that winds from 255ºN produce the most arduous wave conditions at the existing jetty at Moneypoint. RPS therefore examined extreme wave conditions for other relevant return period events for this directional sector with the baseline and proposed conceptual options in place.

To compare the wave climate under baseline conditions with those experienced with the proposed conceptual options *in situ*, RPS extracted data from the model simulations at a point near to the proposed quay as illustrated in Figure 5.8.

Results demonstrated that the baseline wave climate experienced at Moneypoint was virtually identical to wave conditions with the open piled option in place. This can be attributed to the fact that waves continue to propagate under the deck of the proposed quay and experience limited reflection.

For brevity, RPS have not included a description of the wave climate with Option 2 in place given the insignificant difference to baseline conditions.

A summary of the extreme wave conditions experienced during various return period storm events from 255ºN under baseline conditions is presented in Table 5.4. Equivalent wave climate information at this location with initial concept option 1 in place is presented in Table 5.5.

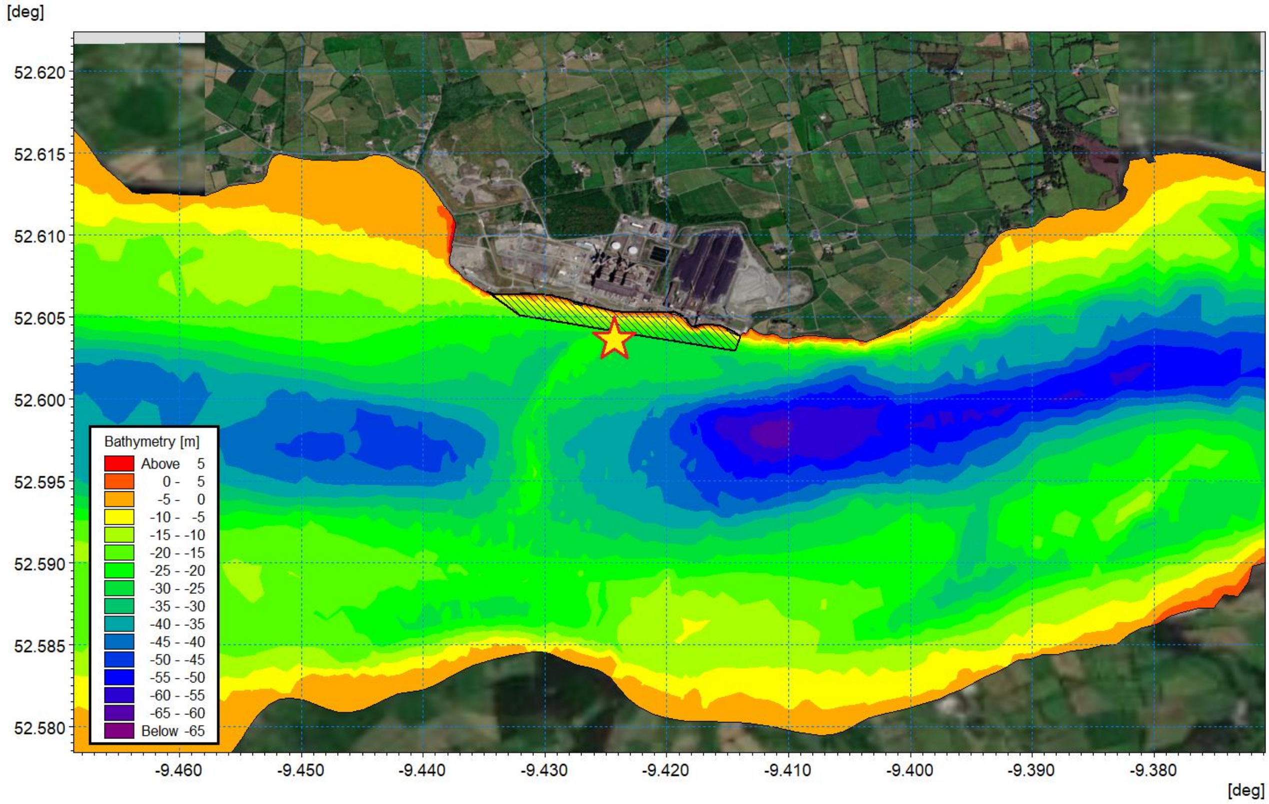


Figure 5.8: Wave climate information was extracted at a point (*yellow star*) immediately adjacent to the proposed quay

The 1 in 200 year return period wave climate during a storm from 255ºN under baseline conditions is illustrated in Figure 5.9 whilst Figure 5.10 illustrates the output from the same simulation but with the proposed solid quay option in place. Comparing these outputs demonstrates that the reflective nature of the solid quay line results in a local increase in significant wave heights immediately seaward of the berthing line.

Table 5.4: Summary of extreme wave conditions at Moneypoint for various return period events based on the existing configuration

Return Period	Significant Wave Height [Hm0, m]	Peak Wave Period [Tp, s]	Mean Energy Wave Period [Tm10, s]
10	2.09	5.04	4.34
20	2.25	5.13	4.45
50	2.46	5.25	4.58
100	2.63	5.37	4.67
200	2.79	5.55	4.79

Table 5.5 Summary of extreme wave conditions at Moneypoint for various return period events with a solid quay option *in situ*

Return Period	Significant Wave Height [Hm0, m]	Peak Wave Period [Tp, s]	Mean Energy Wave Period [Tm10, s]
10	2.54	5.09	4.55
20	2.74	5.17	4.66
50	2.99	5.30	4.81
100	3.18	5.44	4.91
200	3.38	5.61	5.01

An assessment of model results found that owing to the reflective properties of the proposed solid quay option, significant wave heights along the berthing line could increase by up to c.20% under extreme conditions. Despite this, wave heights did not generally exceed 3.40m and corresponding peak wave periods remained less than 6 seconds.

There was no noticeable difference in either peak or mean energy wave periods as a result of the installation of the proposed solid quay option.

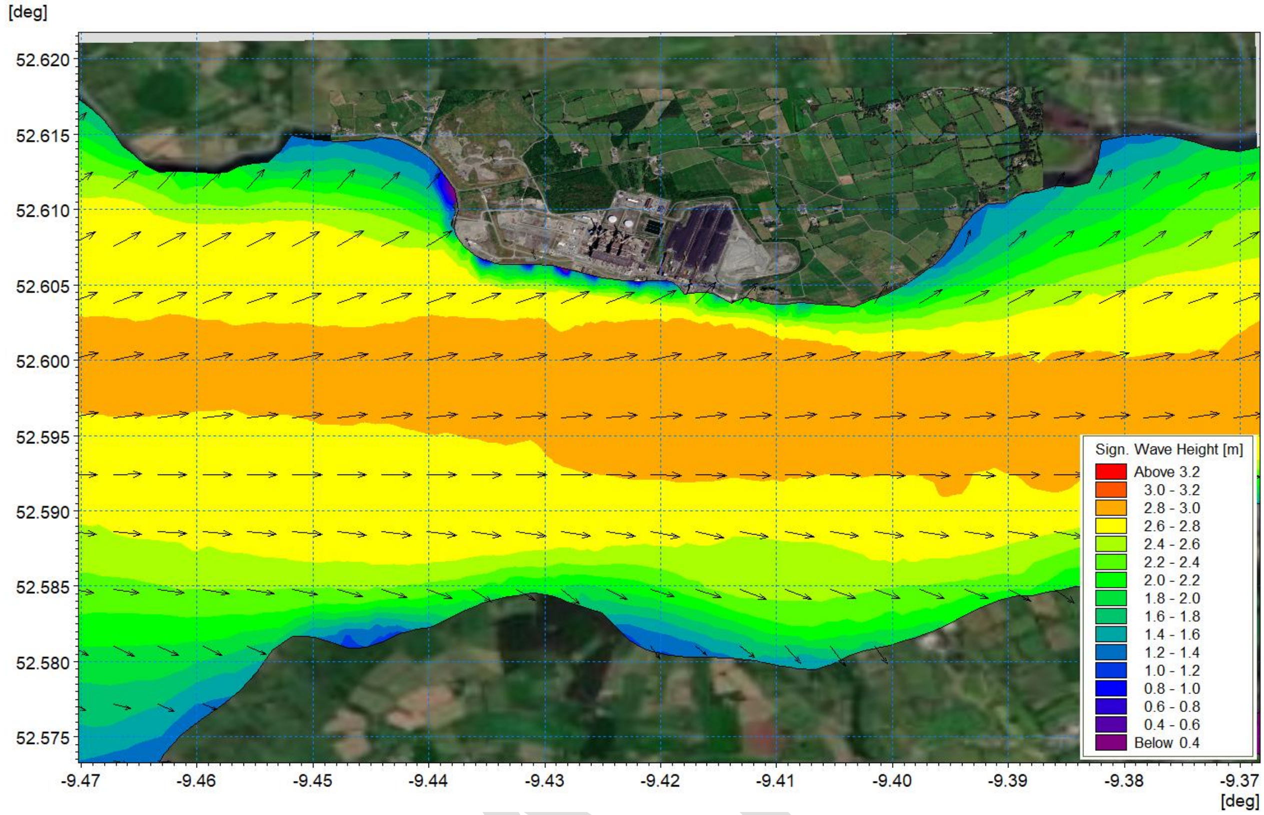


Figure 5.9: Extreme 1 in 200 significant wave heights at Moneypoint, local wind waves from 255ºN, based on the existing configuration

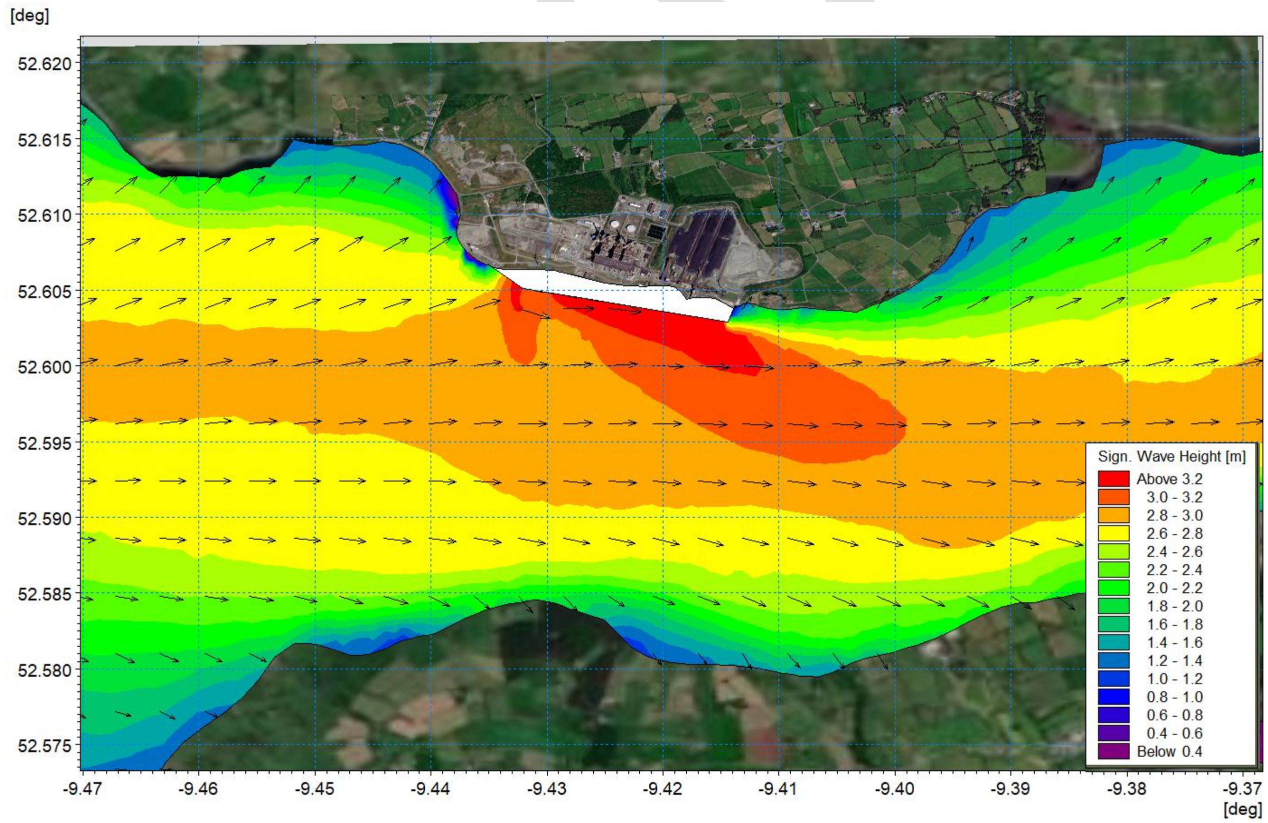


Figure 5.10: Extreme 1 in 200 significant wave heights at Moneypoint, local wind waves from 255ºN, with a solid quay option *in situ*

6 THERMAL PLUME ASSESSMENT

In addition to considering the operational and extreme wave climate at Moneypoint, it is imperative that any development at Moneypoint Hub does not impact the thermal performance of the existing cooling water intake and outlet assets which are critical to the operation of the ESB power station at Moneypoint.

According to the Integrated Pollution Prevention and Control (IPPC) / Waste License as issued by the Environmental Protection Agency (EPA), there are multiple emissions to surface waters from both process and storm/surface discharges at Moneypoint, but only one (SW8) relates to the condensing cooling water system.

6.1 Condensing cooling water operations

Cooling water is abstracted from the Shannon Estuary at the intake and is used to condense the steam generated to spin the turbine and generate electricity. Rates of flow depend on the water level in the estuary, but these are compensated for by vane control which results in a constant busmain pressure. The cooling water flows through culverts and discharges to the foreshore at SW8 as illustrated in Figure 6.1.

Measures are in place at the cooling water intake to prevent marine debris being taken into the cooling system. These comprise trash rakes and band screens. The screens, which are rotated constantly when in use, are continuously washed with water to remove any debris that has accumulated on them. The wash water is collected and discharged following removal of debris washed off the screens (SW4A).

There are five cooling water pumps, and the volume of cooling water depends on the number of units on load. Possible flows of heated water based on full load are summarised in Table 6.1 below. Conditions of maximum flow and maximum temperature rise do not coincide. Maximum flow occurs for short periods a few times a year during flushing of the cooling water system. The cooling water inlet temperature varies seasonally and historical records show a minimum of 6°C and a maximum of 17°C. The temperature at the condenser outlets has varied between 11°C and 29°C.

Table 6.1: Summary of possible flows of heated water based on full load at discharge point SW8

Conditions	98 %'ile	Maximum
Volume	92,000 m^3/hr	115,000 m^3/hr
∆ Temperature	12 °C	15 °C

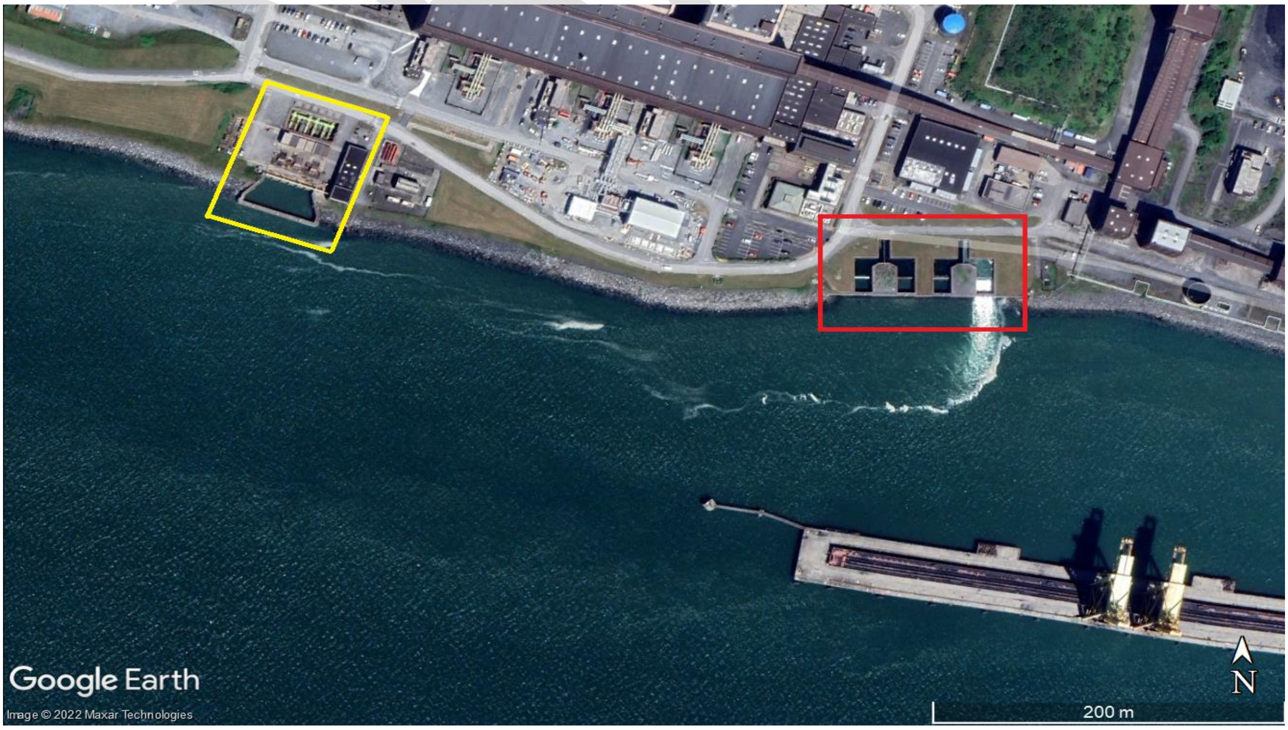


Figure 6.1: Location of the condensing cooling water system at outfall SW8 (red) and intake (yellow)

6.2 Modelling approach

To establish the potential impact of Options 1 and 2 on the thermal performance of the cooling water system at Moneypoint it was necessary to utilise a three-dimensional modelling approach. To this end, RPS utilised the baseline and proposed option models described in Section 2 to undertake a three-dimensional assessment of thermal plumes. Specifically, these models were setup to represent the vertical domain using 6 vertical layers, with layer sizes ranging from 2m at the surface to 10m along the seabed.

The cooling water intake and outlets for the cooling water system were represented using individual source terms with the inlet abstracting water from the middle of the water column and the outlet discharging into the surface layer of the model.

As summarised in Table 6.1, under maximum scenario conditions, the system can discharge up to 115,000 m^3/hr with a temperature change of 15^{o}C. Whilst it is recognised that these conditions of maximum flow and maximum temperature rise do not coincide, RPS took a conservative approach and represented the intake and outlet characteristics at maximum temperature and flow conditions for the duration of each model simulation.

The model operates by abstracting water at the intake and then discharging this water at the outlet, increasing the ambient intake by 15^{o}C. As such, the potential for water to be "re-heated" through a process of re-circulation was fully accounted for.

Based upon this approach, RPS undertook thermal plume simulations using the baseline, Option 1 and Option 2 three-dimensional models for both typical spring and neap tidal conditions. The output from these assessments is presented in the following Sections of this report.

It should be noted that the ambient temperature of the estuary water was set at 15^{o}C and that the model included for heat loss at the surface layer as a result of wind action. Wind speeds for these simulations were derived from the Shannon Airport wind gauge records. Thermal heating as a result of solar radiation was not included in these simulations owing to a lack of site specific data. This was not considered important given that this is a comparative study and the omission of solar radiation would be the same for each option.

6.3 Baseline Scenario

As summarised in Table 6.2, the output from the baseline thermal plume assessment is presented in Figure 6.2 to Figure 6.9. These plots illustrate the resulting thermal plume at various stages of typical spring and neap tidal conditions.

As demonstrated by these Figures, the extent of the thermal plume was greatest during spring tidal conditions. This is unsurprising owing to the greater tidal velocities experienced during spring tides relative to neap tides. Under spring conditions, the thermal discharge from SW8 was found to increase the ambient temperature of the surrounding water by up to 1^{o}C as far as *c.*3km to the west and *c.*3.5km to the east.

The discharge from SW8, even under maximum conditions, did not generally increase the temperate of surrounding water more than 3^{o}C beyond the immediate vicinity of the discharge point (i.e., *c.*500m). At no point during the simulations did the increase in water temperatures extend to more than *c.* 25% of the available estuary width.

Table 6.2: Summary of thermal plume figures for the baseline scenario

Tidal phase	Figure
Spring, mid flood	Figure 6.2
Spring, high water	Figure 6.3
Spring, mid-ebb	Figure 6.4
Spring, low water	Figure 6.5
Neap, mid flood	Figure 6.6
Neap, high water	Figure 6.7
Neap, mid-ebb	Figure 6.8
Neap, low water	Figure 6.9

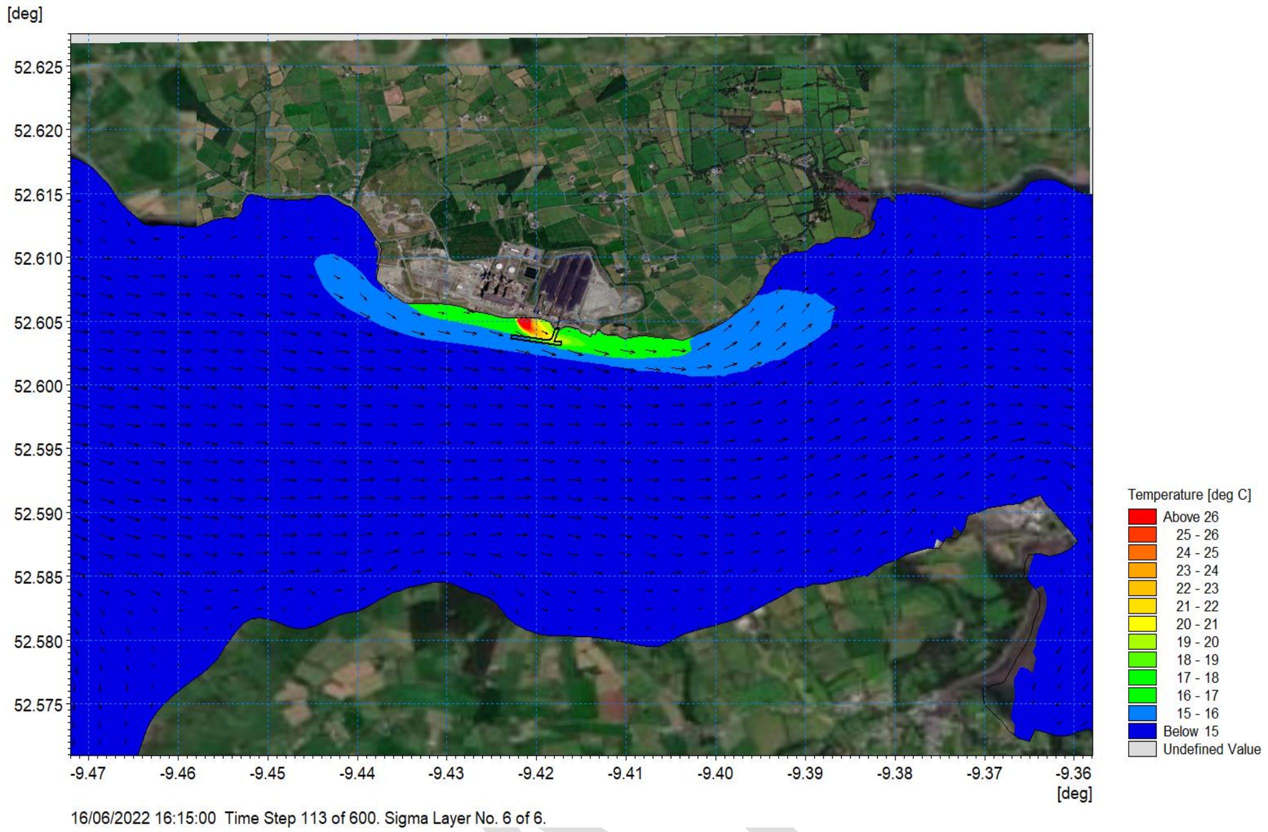


Figure 6.2: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring mid-flood

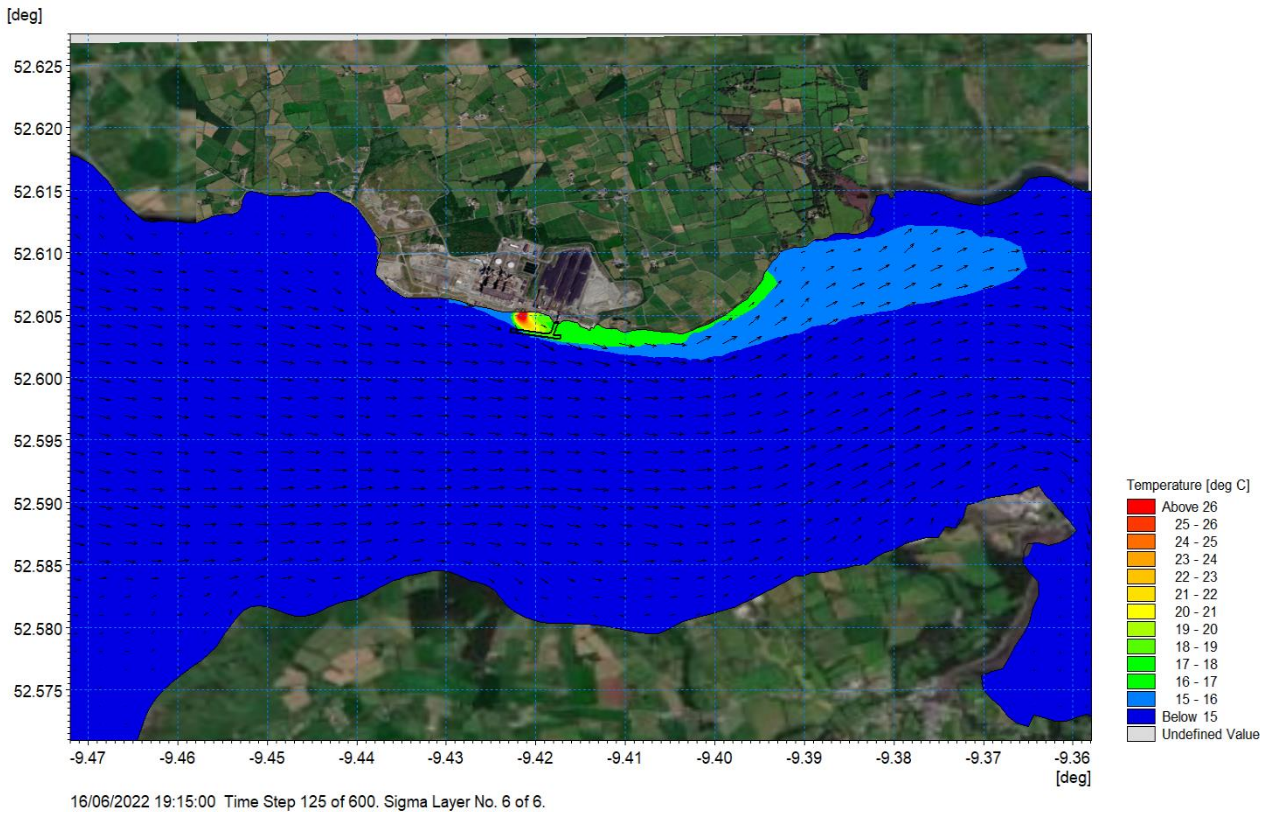


Figure 6.3: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring high water

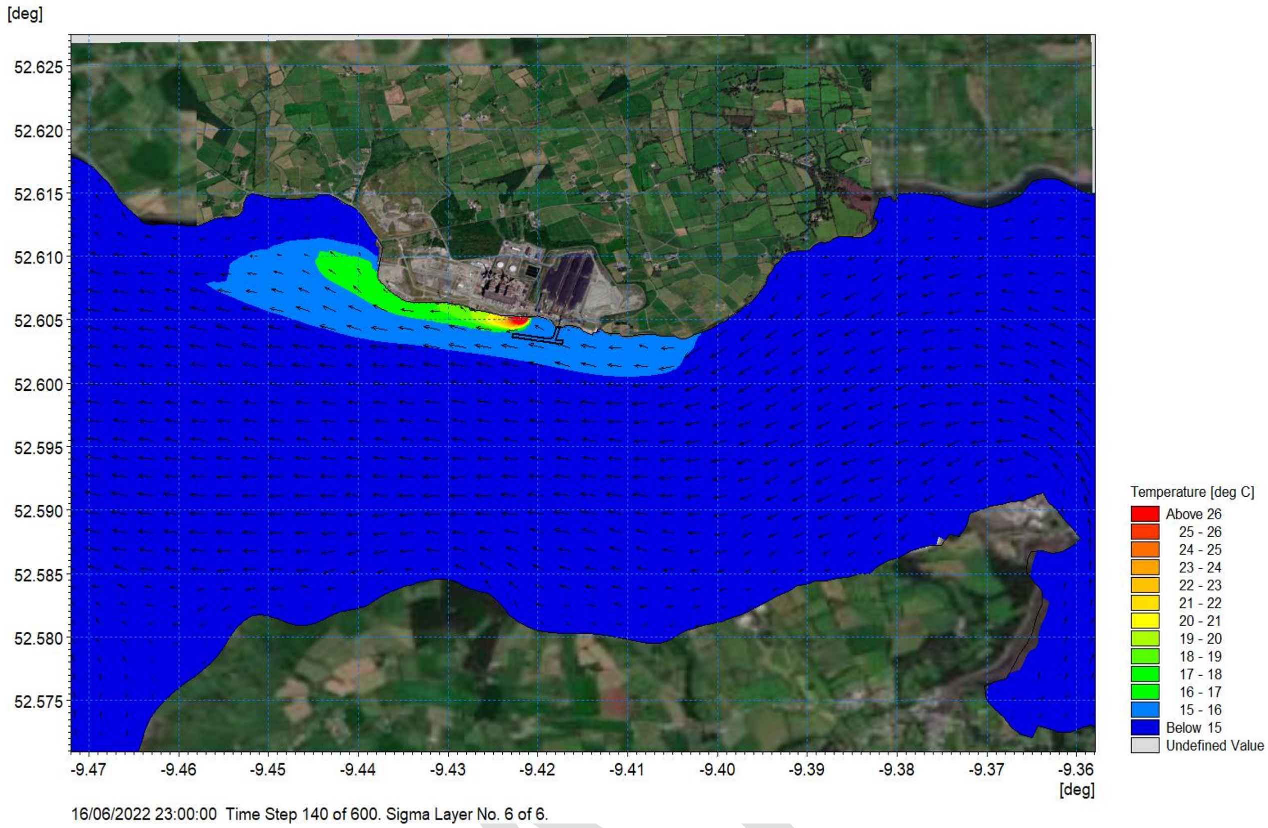


Figure 6.4: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring mid-ebb

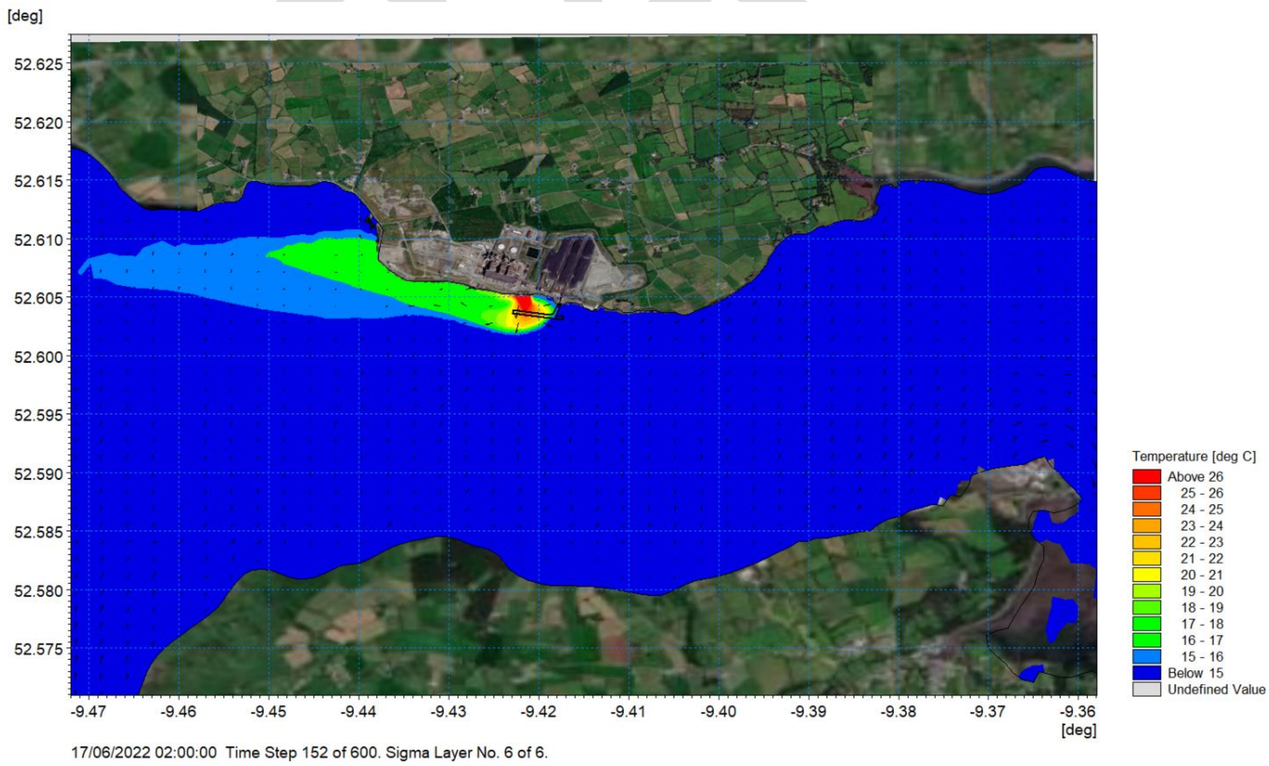


Figure 6.5: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring low water

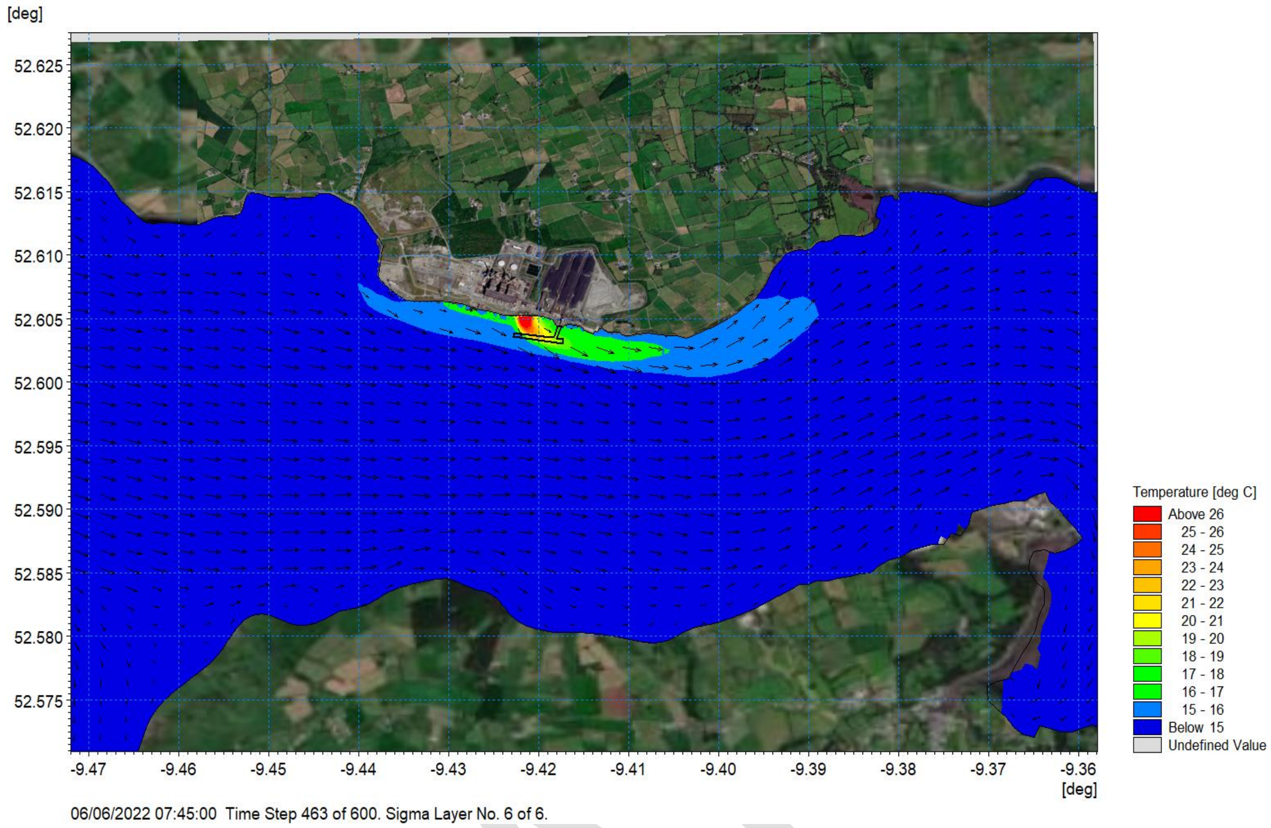


Figure 6.6: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap mid-flood

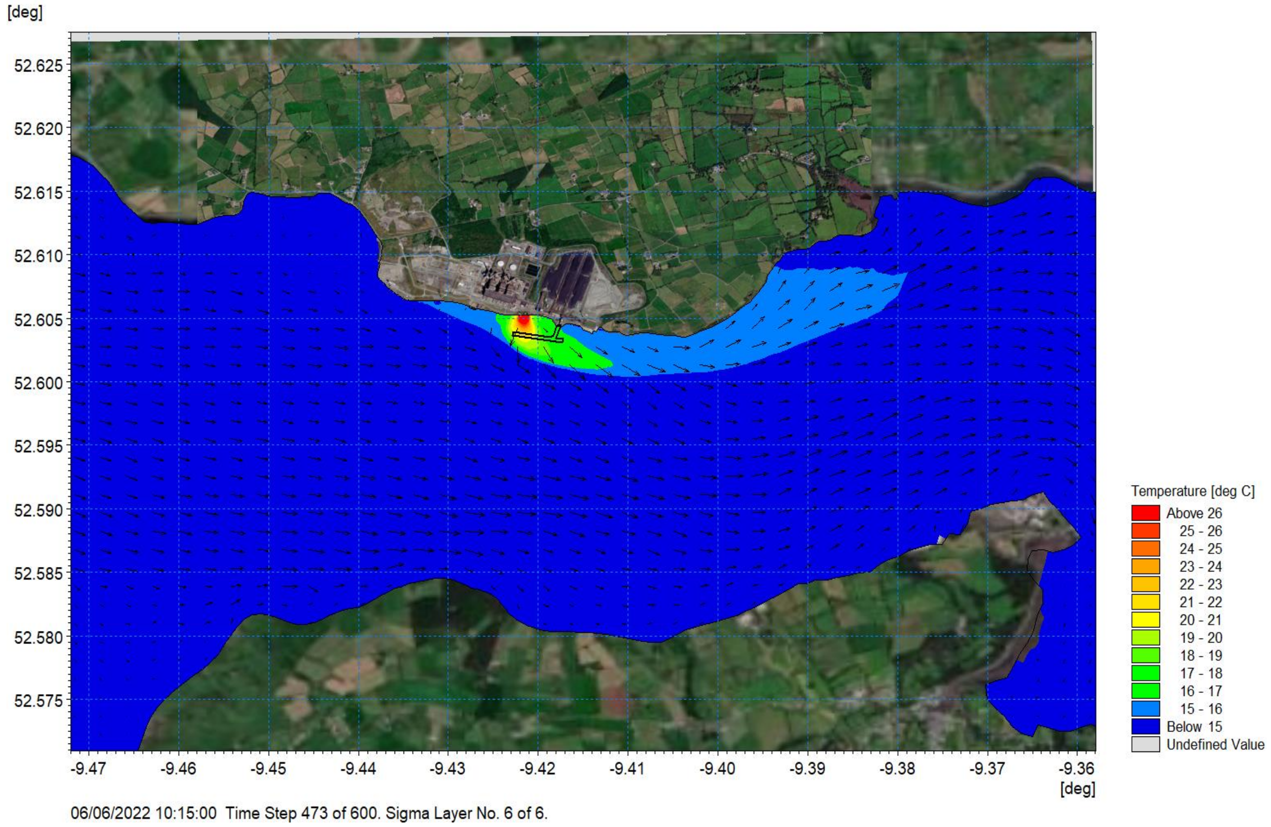


Figure 6.7: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap high water

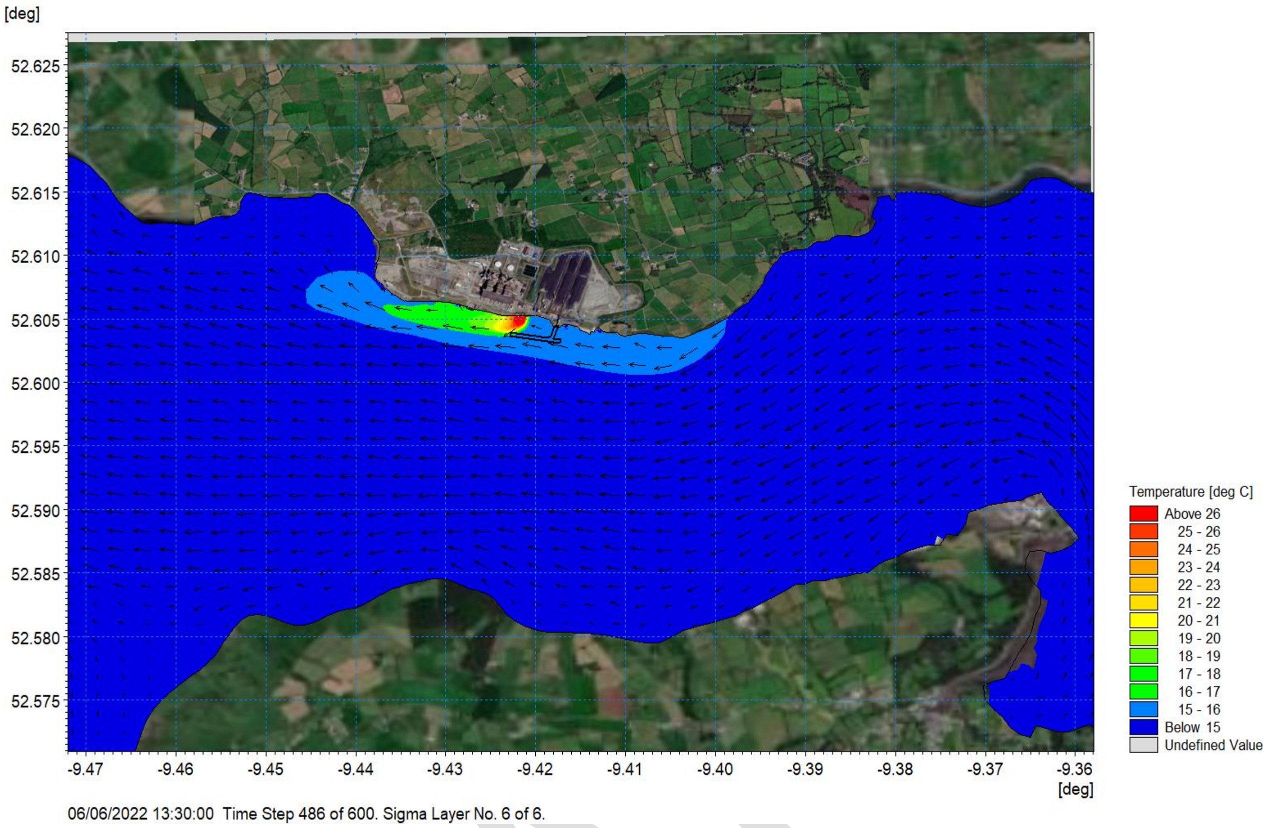


Figure 6.8: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap mid-ebb

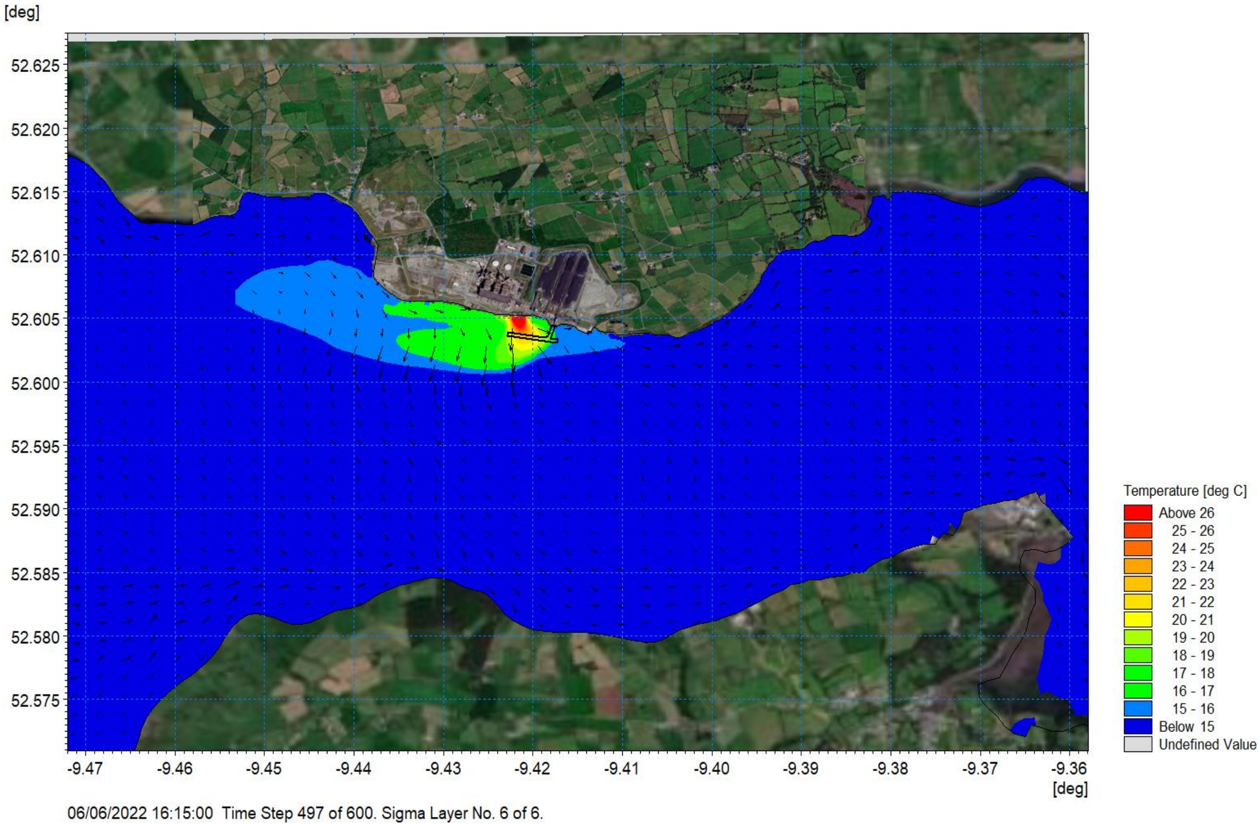


Figure 6.9: Existing scenario - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap low water

6.4 Option 1 – Solid Quay

The output from the thermal plume assessment with the solid quay option *in situ* is presented in Figure 6.10 to Figure 6.17. A description of the corresponding tidal phases for these figures is provided in Table 6.3.

Based on the output of these simulations, it was found that whilst similar, the thermal plume arising from the discharge at SW8 did not extend as far east or west relative to baseline conditions. This can be attributed to the fact that the discharge water is effectively diverted into deeper waters by the adjacent solid quays, where there is a modest drop in current velocities. Furthermore, the diversion into deeper water effectively "dilutes" the thermal discharge meaning the extent over which water is increased by 3°C is also reduced.

By assessing these 3D thermal plume plots it is evident that the proposed structures do not result in the discharged water from SW8 being re-circulated and "re-heated" to increase ambient temperatures above what is observed under baseline conditions.

At no point during the simulations did the increase in water temperatures extend to more than *c.* 25% of the available estuary width.

A further assessment and comparison of water temperatures at both the inlet and outlets is presented in Section 6.6.

Table 6.3: Summary of thermal plume figures with Option 1, the solid quay option *in situ*

Tidal phase	Figure
Spring, mid flood	Figure 6.10
Spring, high water	Figure 6.11
Spring, mid-ebb	Figure 6.12
Spring, low water	Figure 6.13
Neap, mid flood	Figure 6.14
Neap, high water	Figure 6.15
Neap, mid-ebb	Figure 6.16
Neap, low water	Figure 6.17

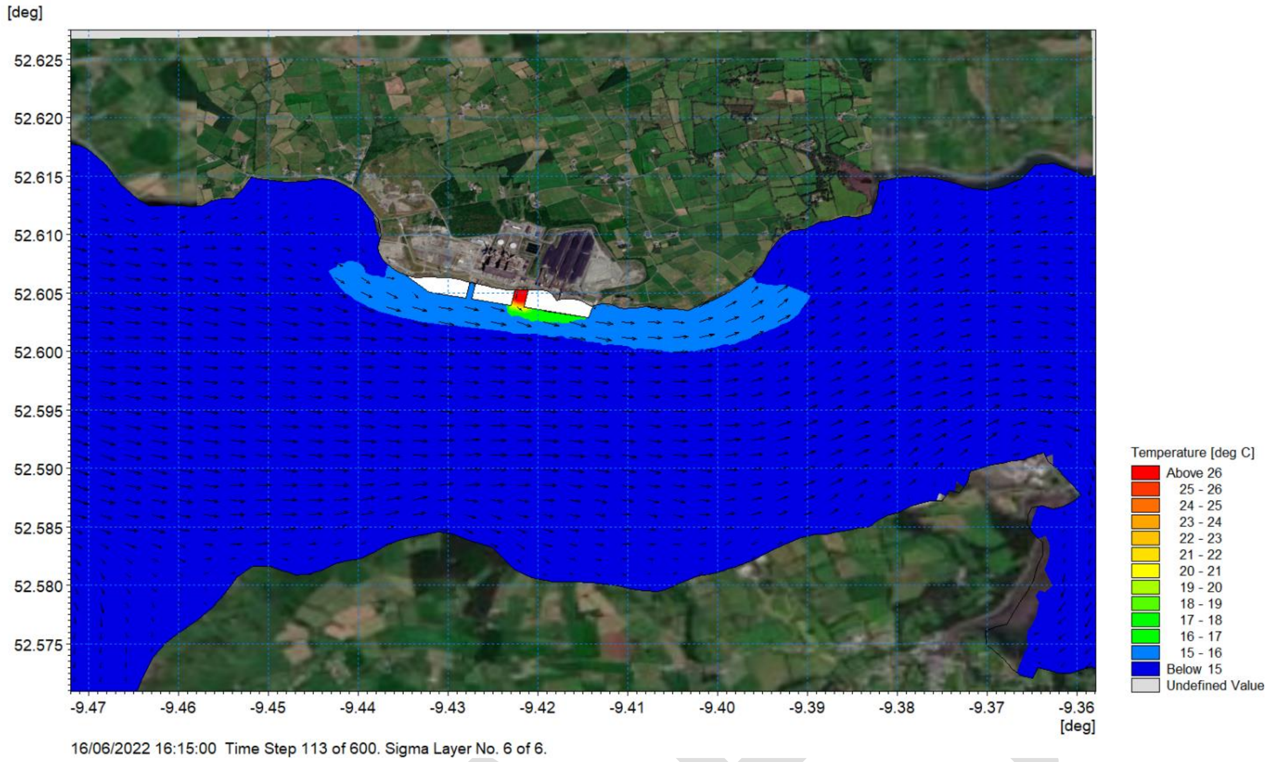


Figure 6.10: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring mid-flood

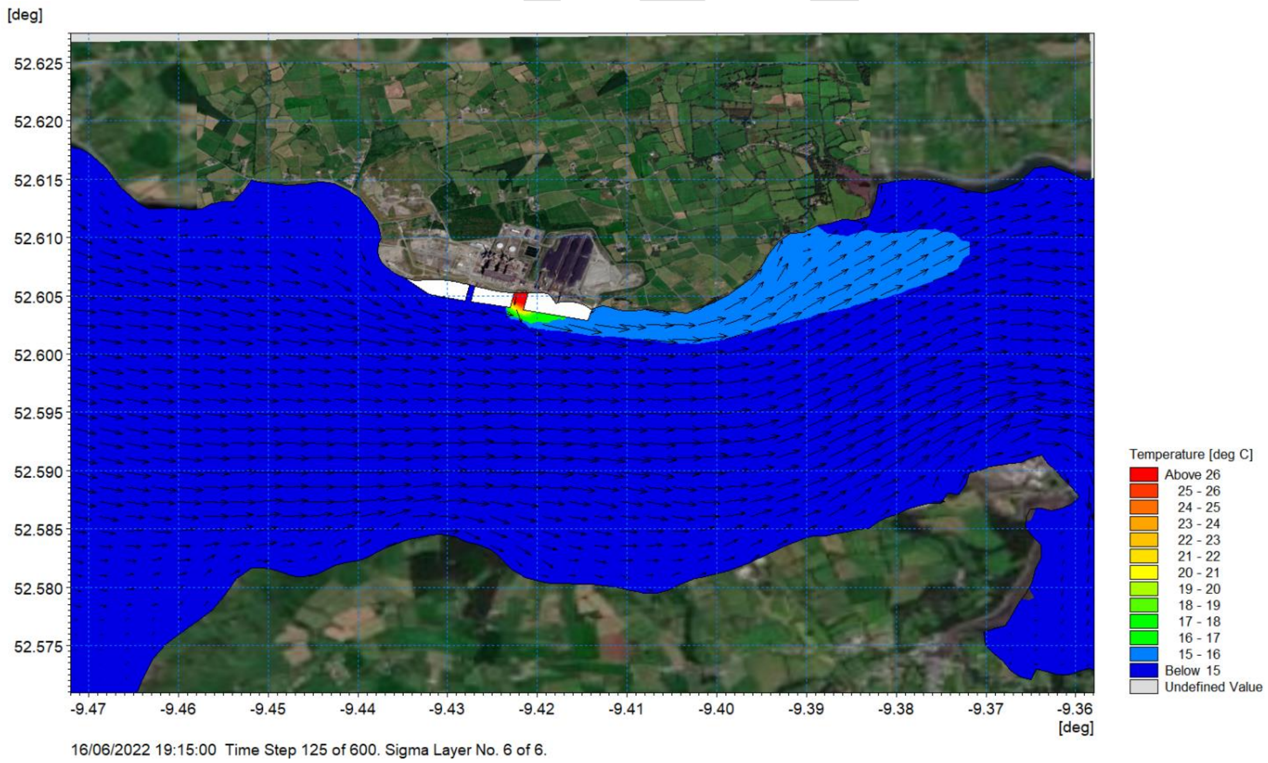


Figure 6.11: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring high water

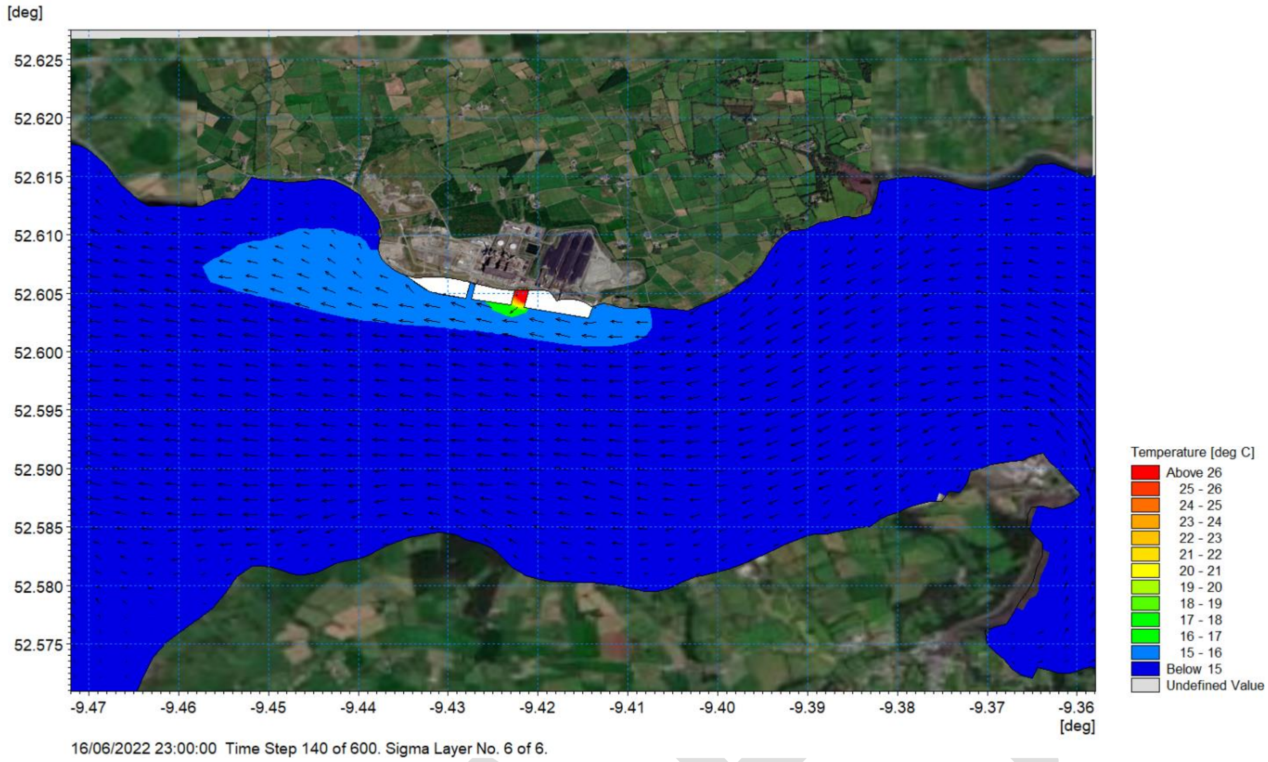


Figure 6.12: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring mid-ebb

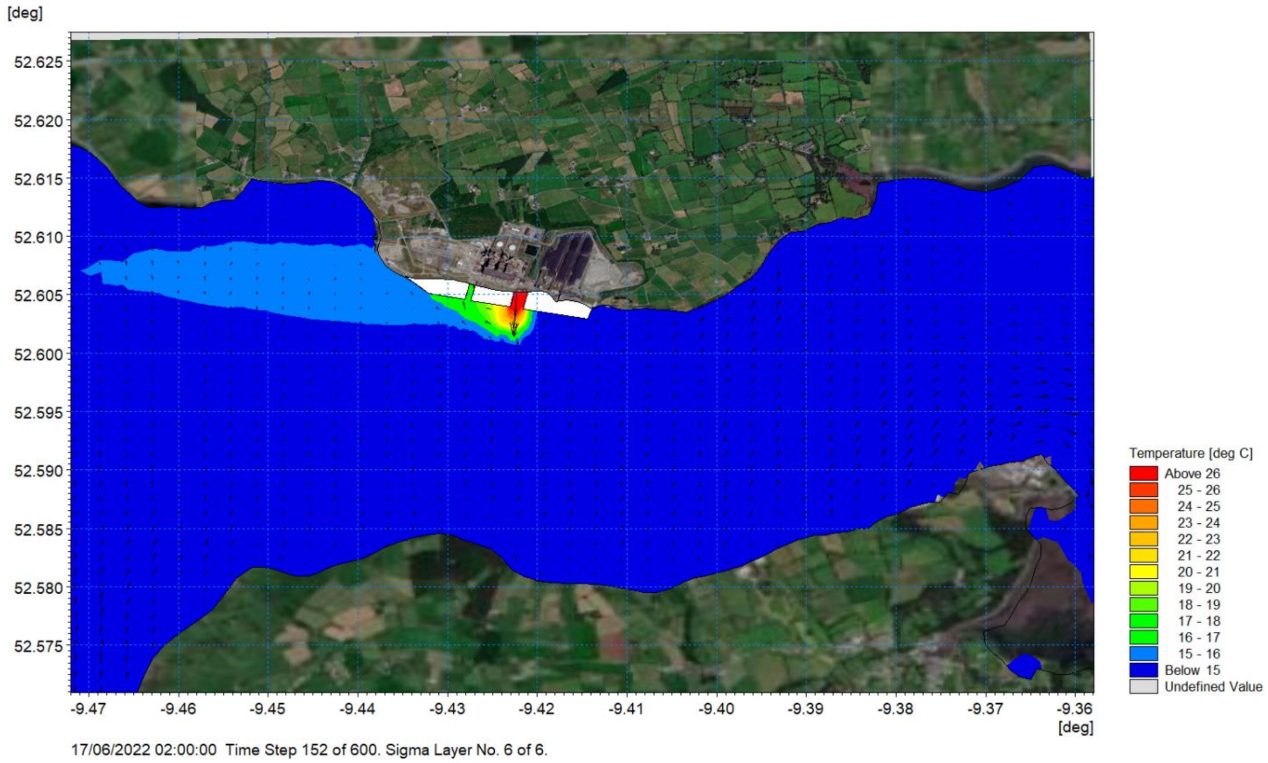


Figure 6.13: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring low water

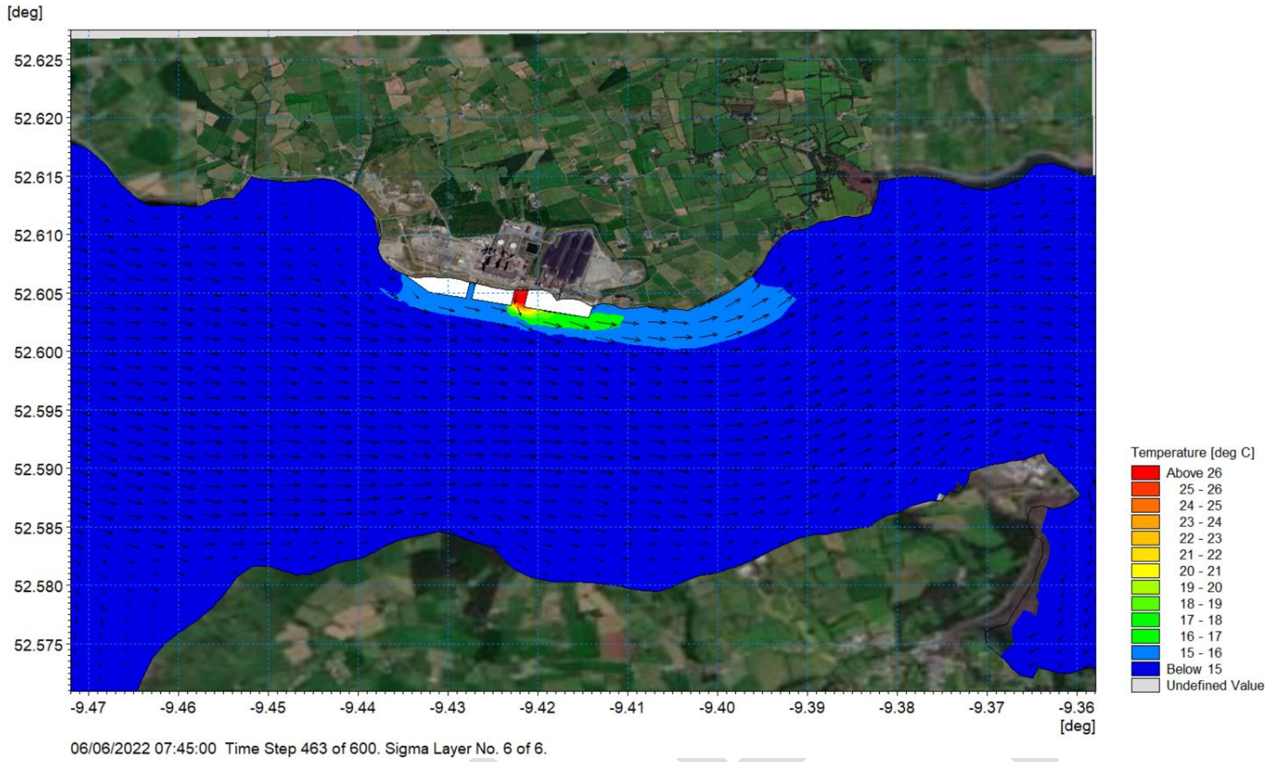


Figure 6.14: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap mid-flood

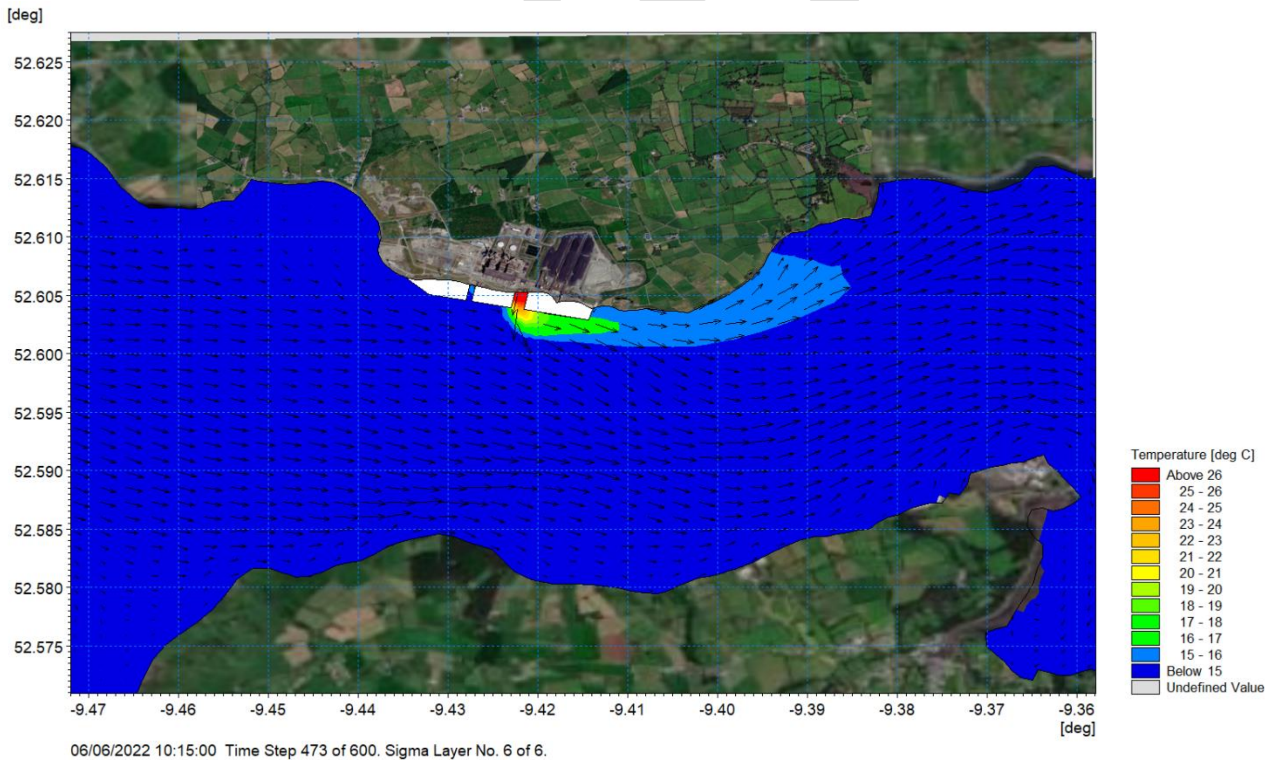


Figure 6.15: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap high water

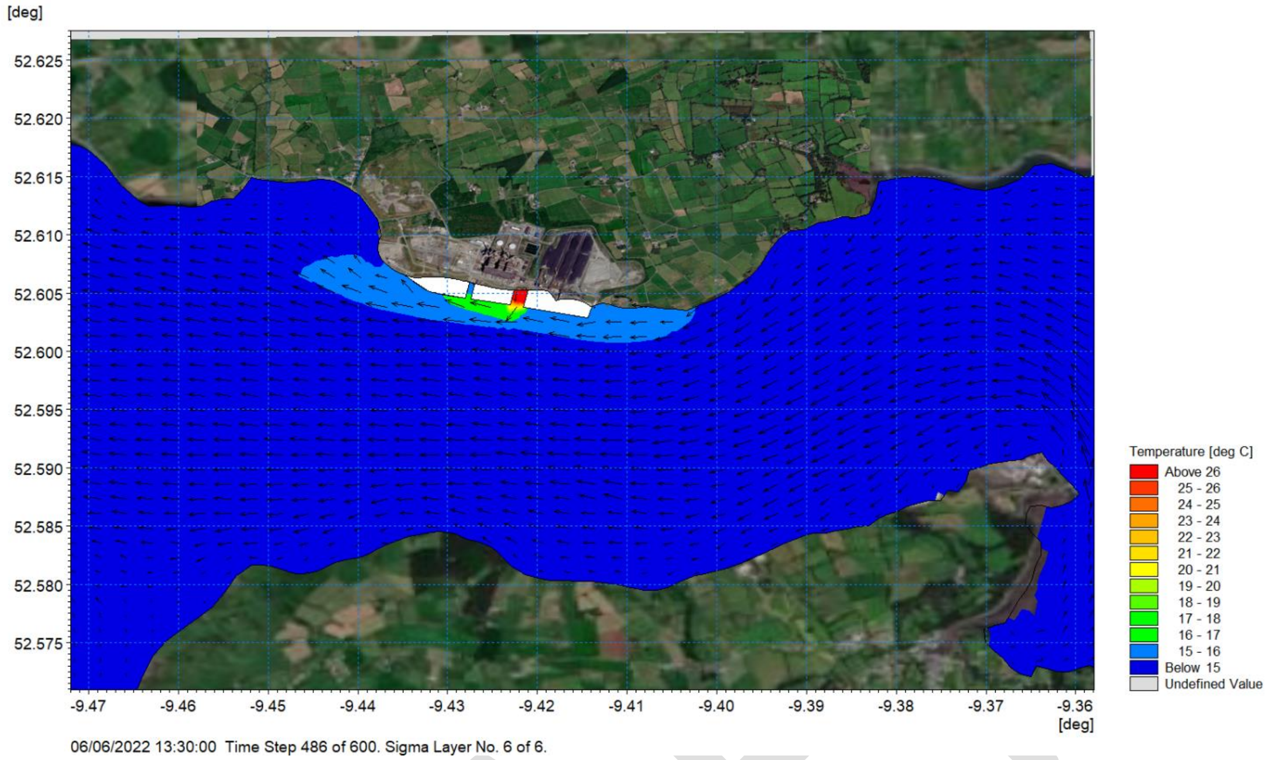


Figure 6.16: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typica neap mid-ebb

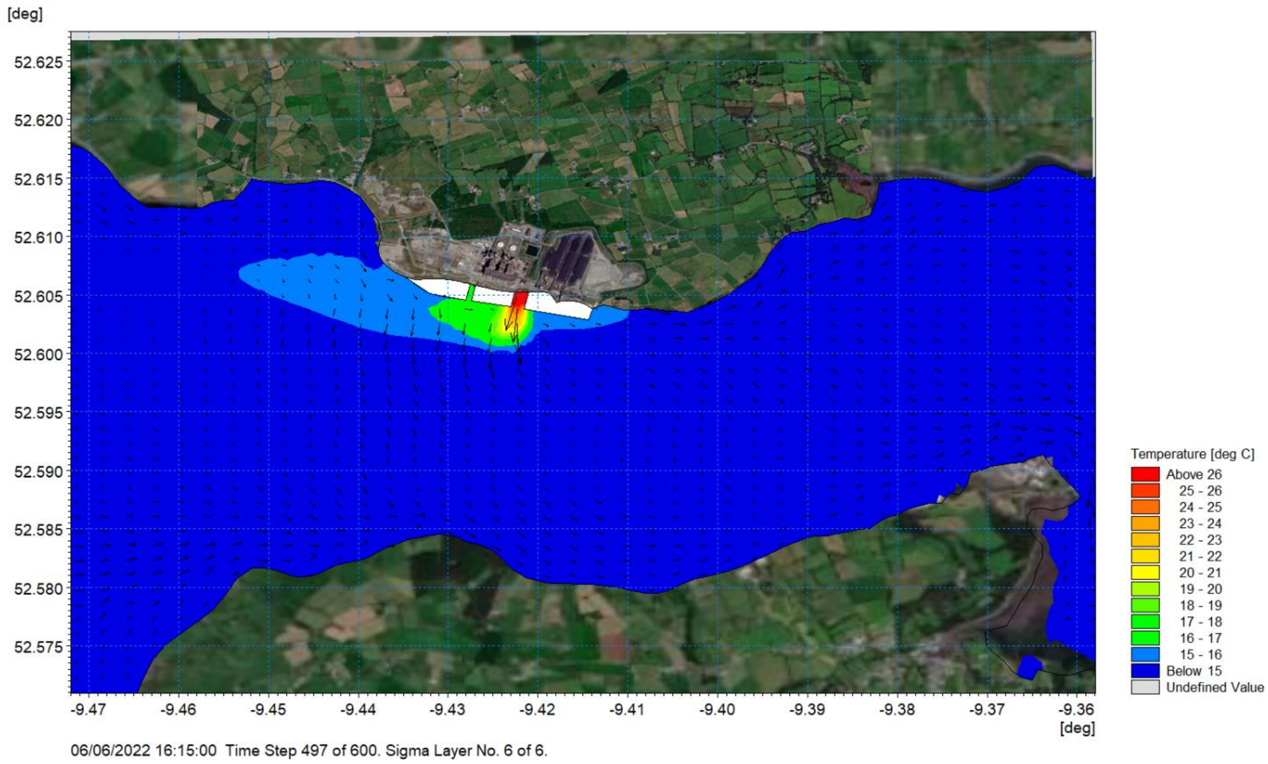


Figure 6.17: Option 1, Solid Quay Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap low water

6.5 Option 2 – Open Piled

As summarised in Table 6.4, the output from the thermal plume with the open piled option *in situ* is presented in Figure 6.18 to Figure 6.25. These plots illustrate the resulting thermal at various stages of typical spring and neap tidal conditions.

By comparing the output of this simulation with baseline conditions it was found that there was an almost imperceptible difference in thermal plume extents or heating of the surrounding water body at Moneypoint. This is unsurprising given that the proposed piled structures had only a very limited impact on the underlying hydrodynamics, including current speeds and directions.

As with baseline conditions, Option 2 was found to increase the ambient temperature of the surrounding water by up to 1^{o}C as far as *c.*3km to the west and *c.*3.5km to the east under typical spring tidal conditions. The discharge from SW8, even under maximum conditions, did not generally increase the temperate of surrounding water more than 3^{o}C beyond the immediate vicinity of the discharge point (i.e., *c.*500m).

At no point during the simulations did the increase in water temperatures extend to more than *c.* 25% of the available estuary width.

A further assessment and comparison of water temperatures at both the inlet and outlets is presented in Section 6.6.

Table 6.4: Summary of thermal plume figures with Option 2, the open piled option *in situ*

Tidal phase	Figure
Spring, mid flood	Figure 6.18
Spring, high water	Figure 6.19
Spring, mid-ebb	Figure 6.20
Spring, low water	Figure 6.21
Neap, mid flood	Figure 6.22
Neap, high water	Figure 6.23
Neap, mid-ebb	Figure 6.24
Neap, low water	Figure 6.25

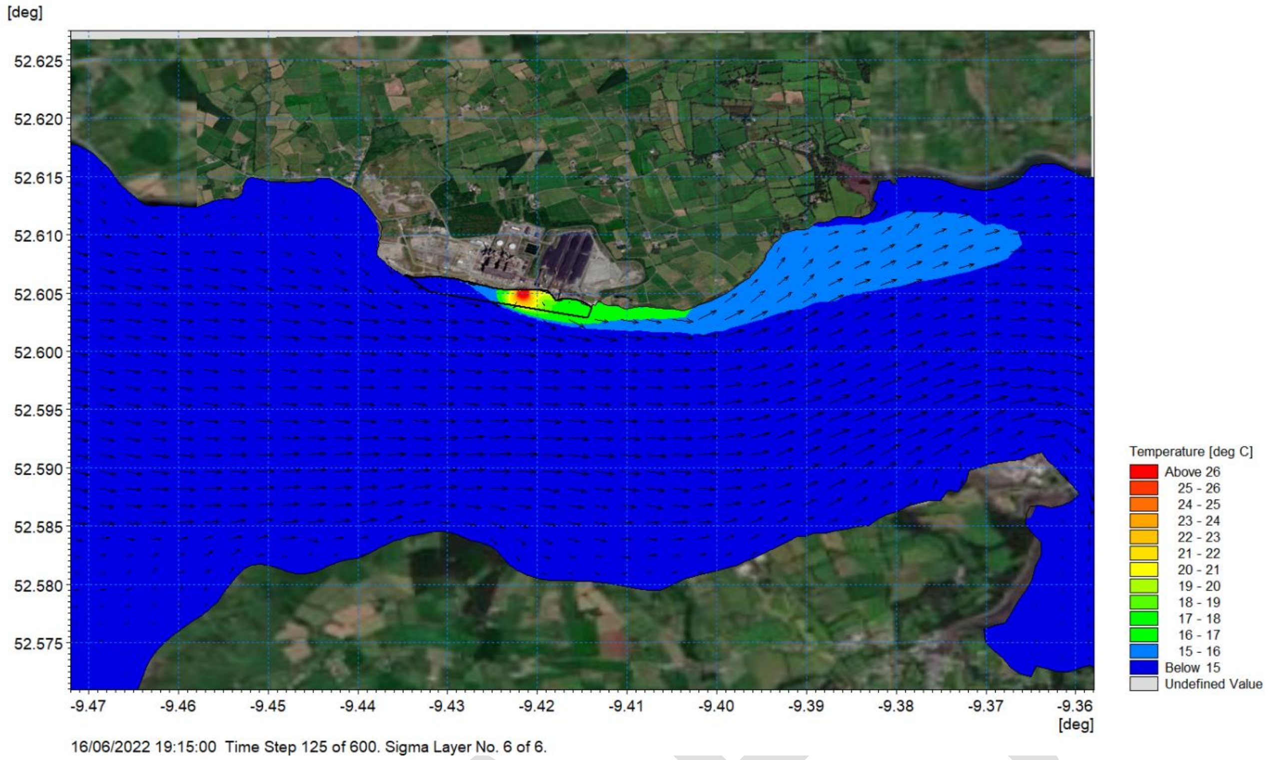


Figure 6.18: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring mid-flood

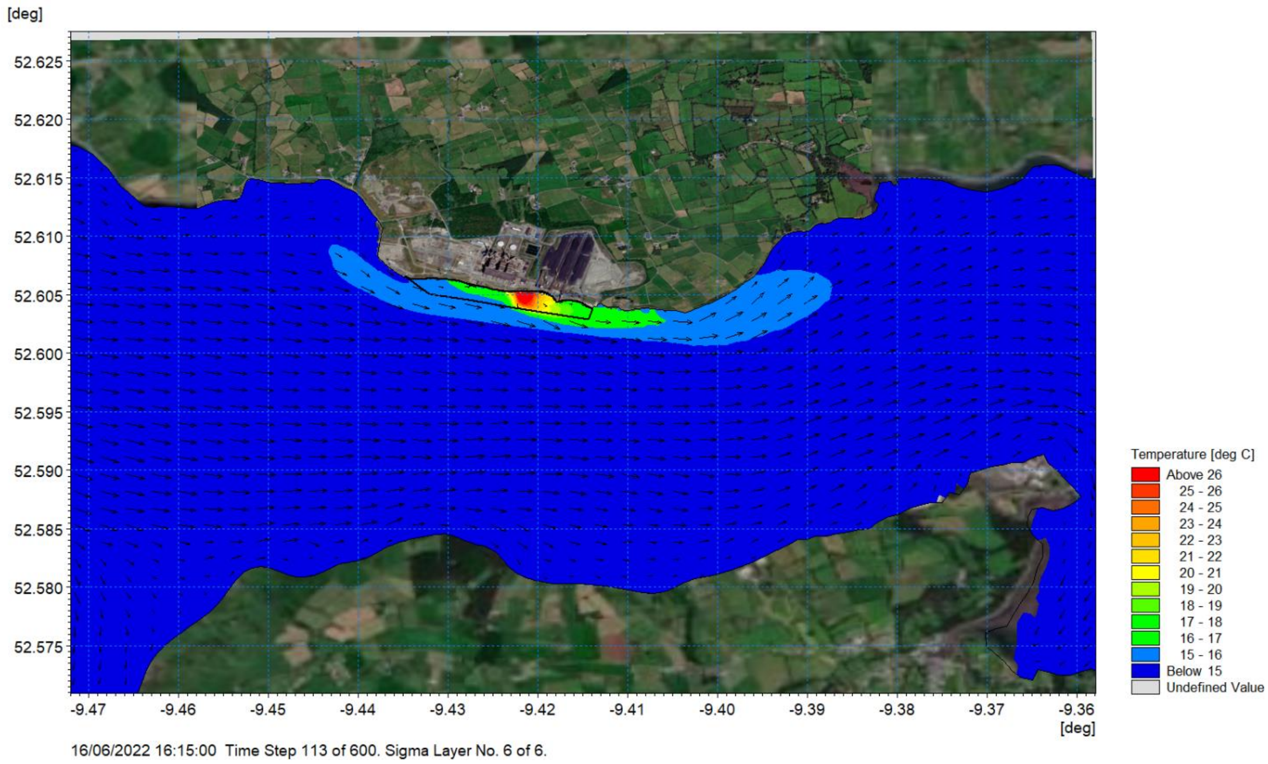


Figure 6.19: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring high water

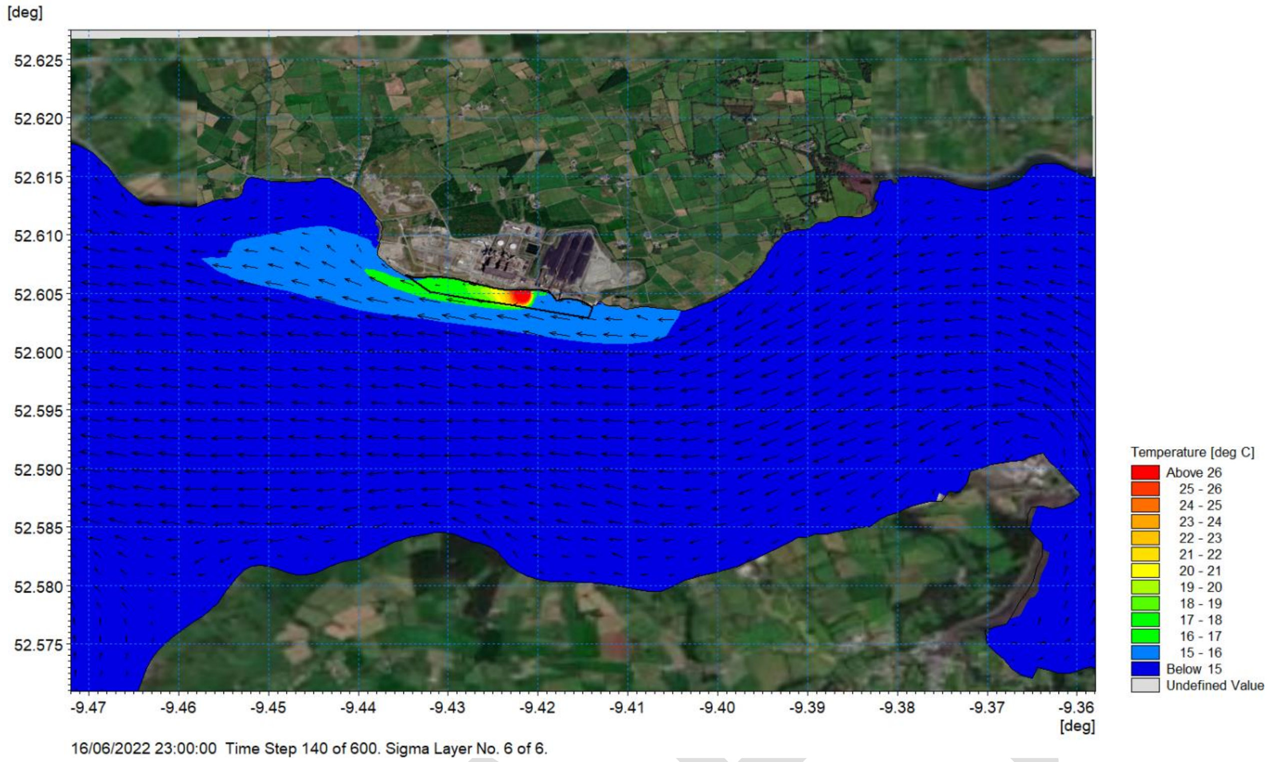


Figure 6.20: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring mid-ebb

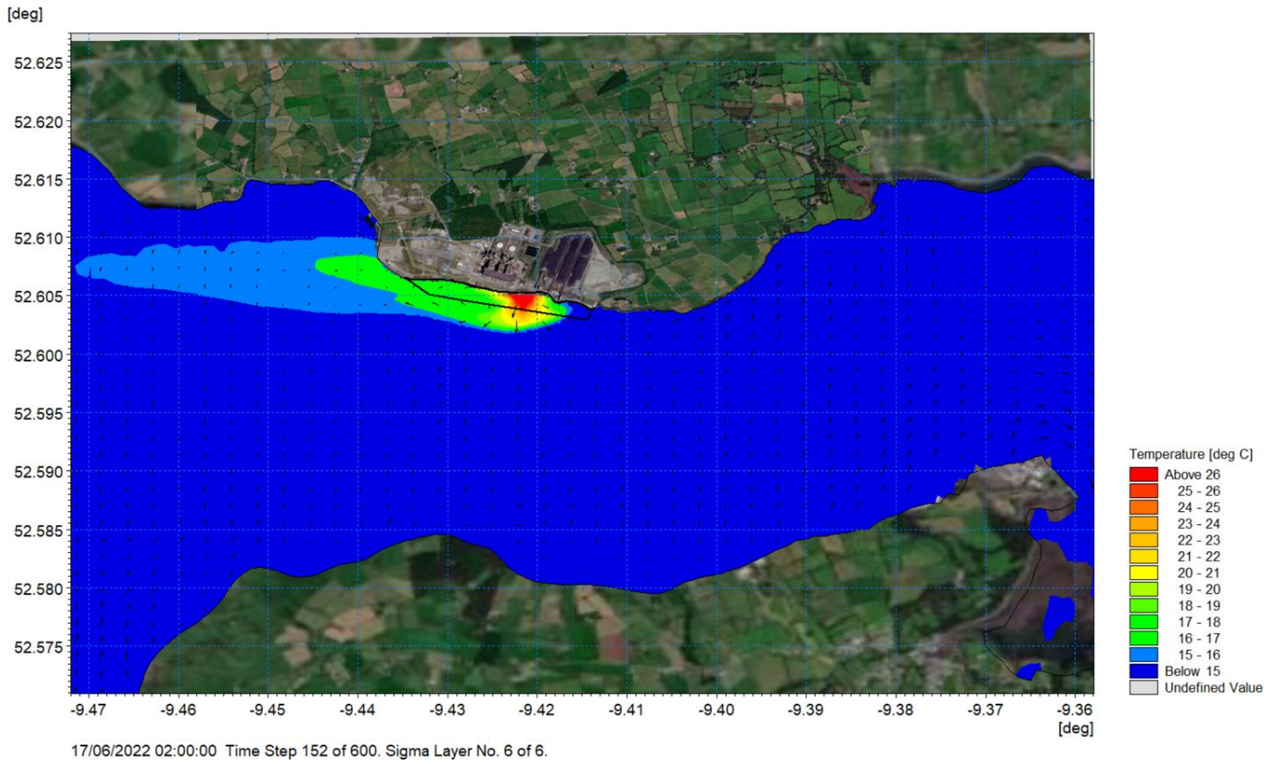


Figure 6.21: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical spring low water

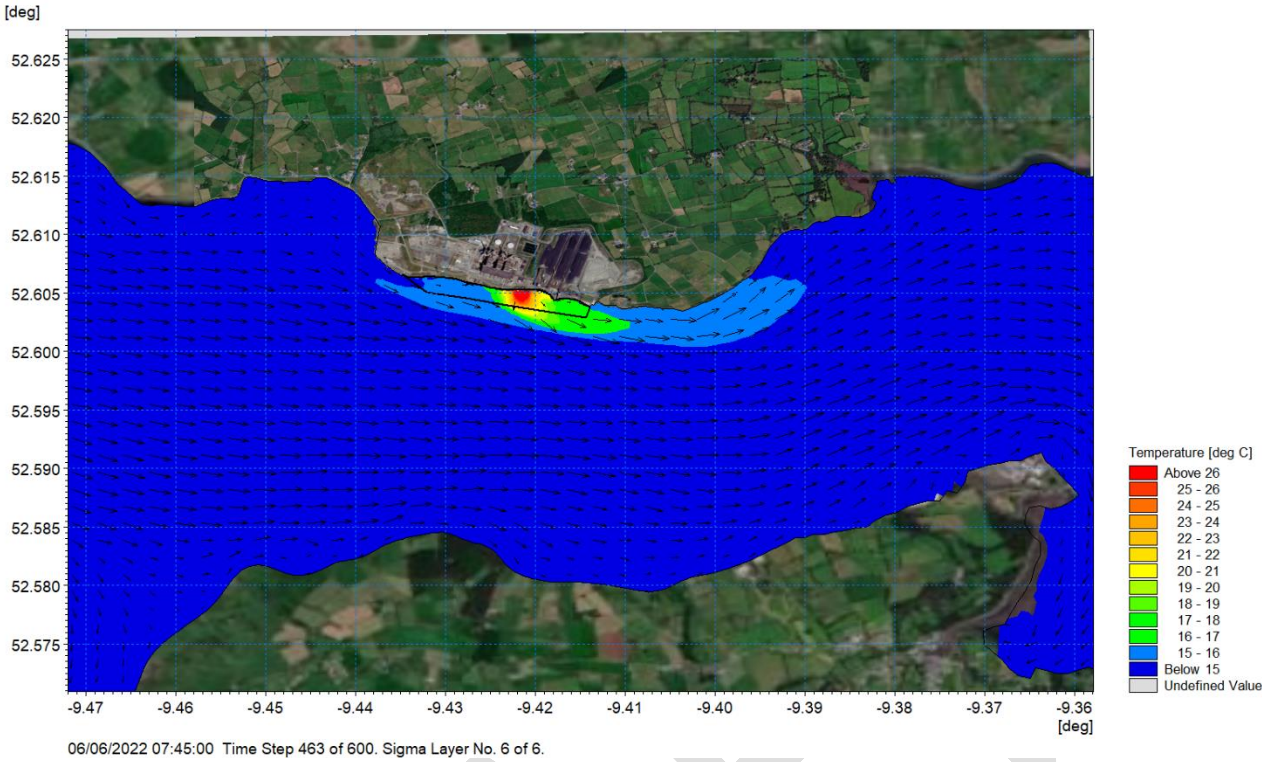


Figure 6.22: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap mid-flood

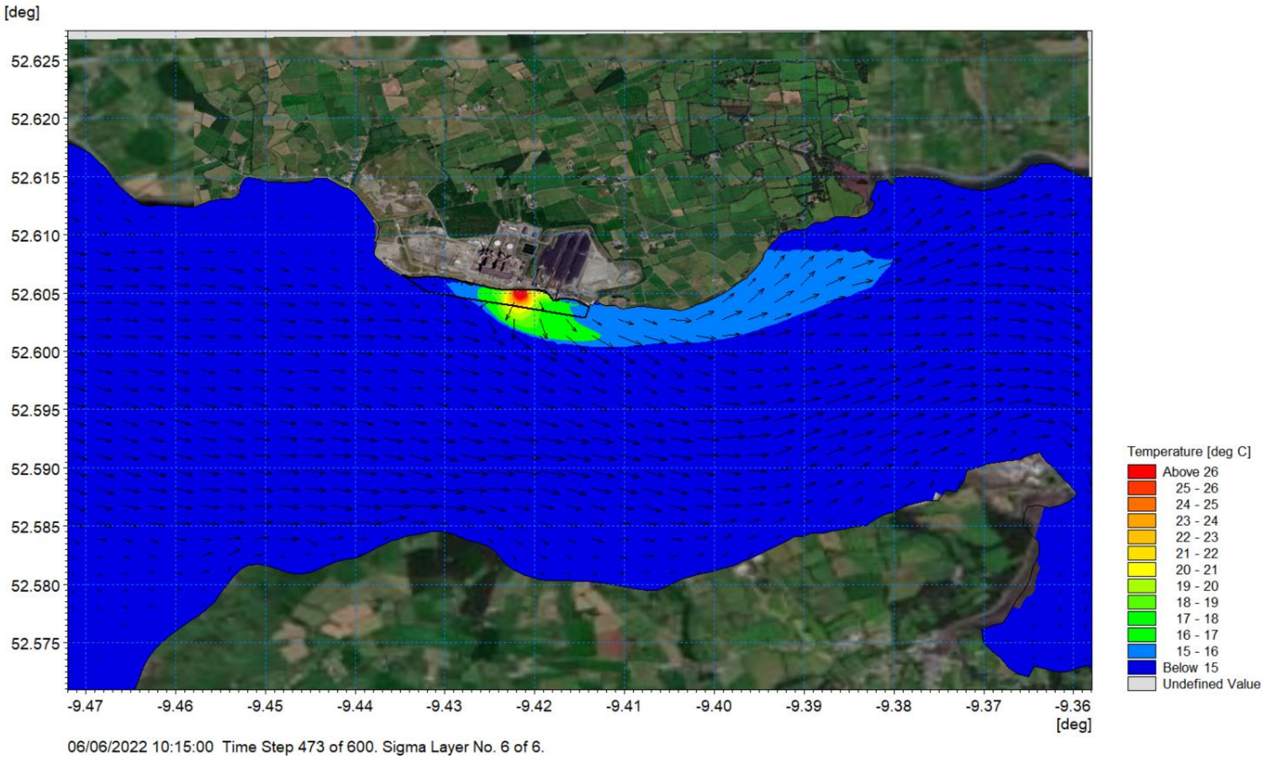


Figure 6.23: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap high water

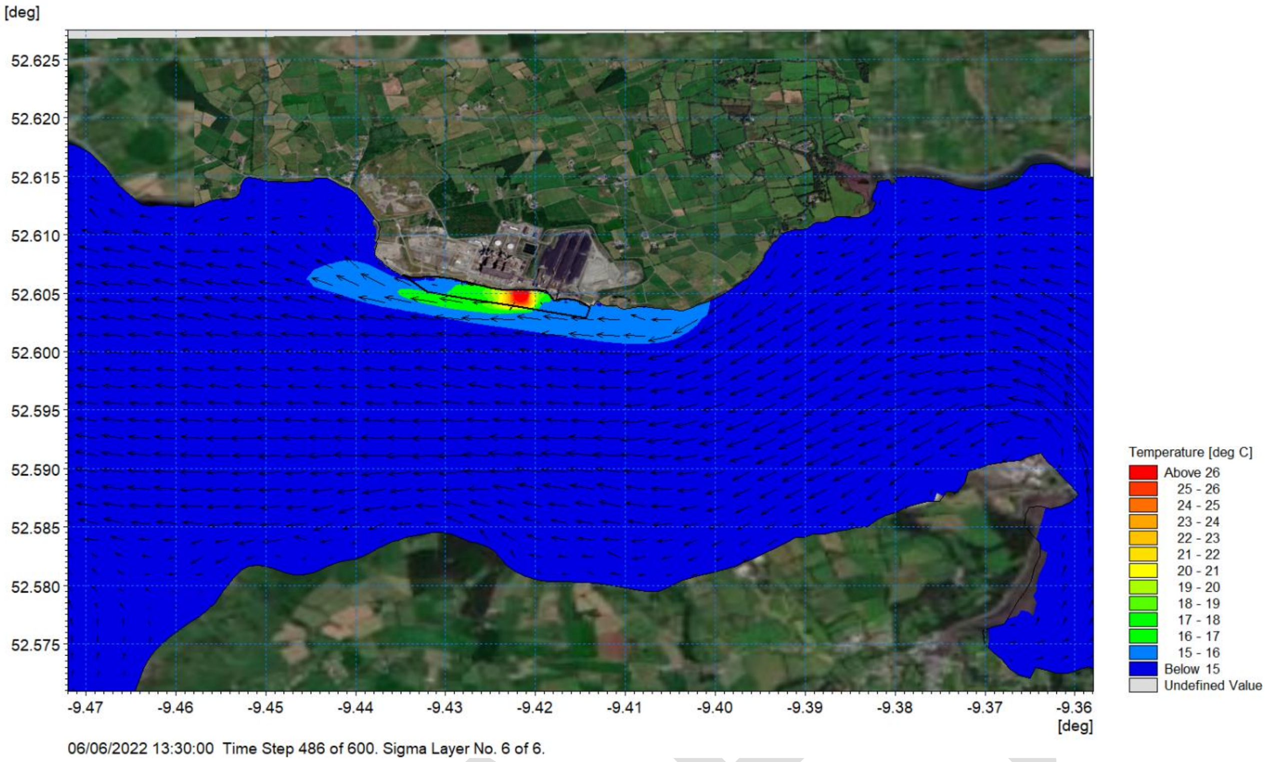


Figure 6.24: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap mid-ebb

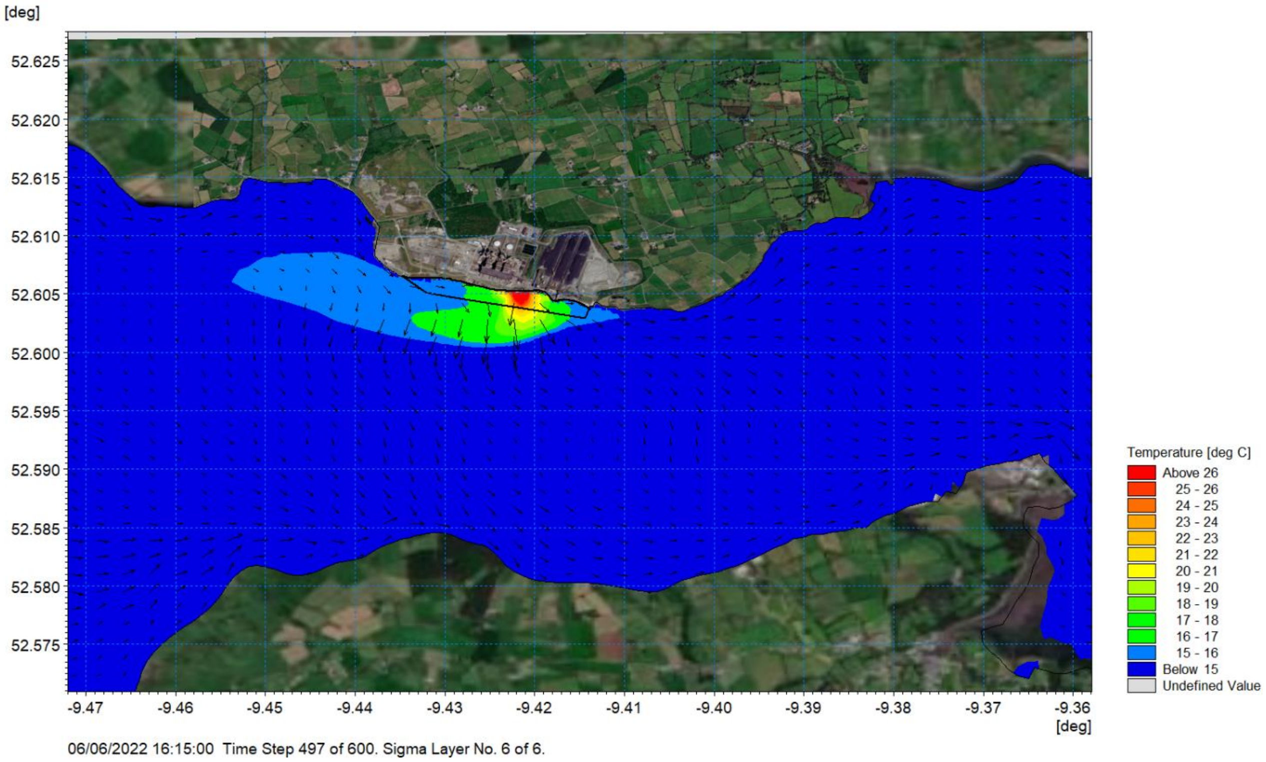


Figure 6.25: Option 2, Open Pile Option - Distribution of thermal plumes in the upper water column at Moneypoint outfall during a typical neap low water

6.6 Comparison of inlet and outlet water temperatures

In addition to assessing the spatial extent of thermal plumes and the increase in ambient water temperatures based on different model scenarios (i.e., different Moneypoint development configurations), RPS also examined one-dimensional time series data at a point near both the inlet and outlet structures.

6.6.1 Assessment of water temperatures at the cooling water outlet

It will be seen from Figure 6.26 which illustrates the variation of water temperature immediately seaward of the SW8 outlet that during maximum operating conditions, that with the existing jetty the water temperatures generally range between 15 and 17°C, despite discharging at approximately 30°C (i.e., 15°C above background). This apparent discrepancy is explained by the initial dilution of the discharge effluent within the immediate water column which significantly reduces water temperatures, even close to the outlet.

As would be expected, there is no significant difference in temperature characteristics with open piled solution in place (i.e., option 2) during either spring or neap tidal conditions. This is because despite the pile structures this option does not significantly change the flow regime or available water in this area.

However, as illustrated in Figure 6.26, the solid piled option does result in a significant difference in temperature characteristics near the existing SW8 outlet. On average, Option 1 increases water temperature at the outlet by *c.* 3°C, however during certain phases of the tidal regime, this increase can be as much as *c*. 8.5°C.

Whilst at first sight this appears to be a significant increase and a potential design constraint; it is clearly demonstrated in Section 6.4 and Figure 6.10 to Figure 6.17 that any increase in water temperatures at this location is extremely localised. Analysing the three-dimensional thermal plumes, this localised increase in water temperatures is quickly diluted by the deeper water available at the edge on the proposed solid quay line.

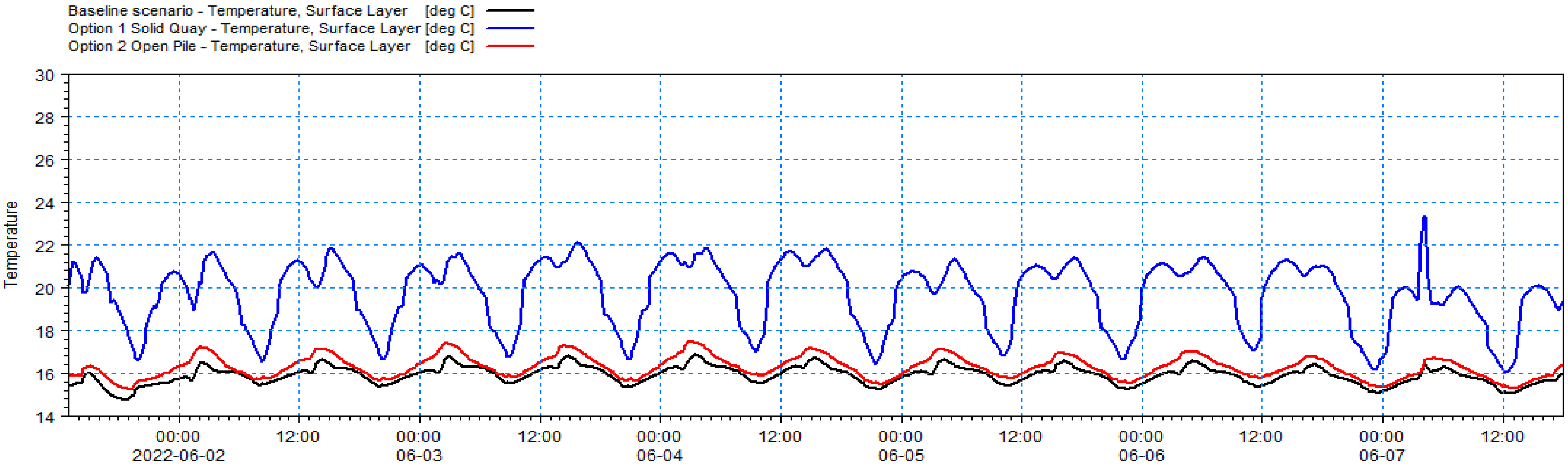
> It can therefore be concluded that even under maximum flow rates and operating temperatures, there is no significant increase in water temperatures from the outlet point SW8 as a result of either Option 1 or Option 2 during typical spring or neap tidal conditions.

6.6.2 Assessment of water temperatures at the cooling water intake

Figure 6.27 illustrates the variation of water temperature near to the cooling water intake based on different model scenarios.

As demonstrated by Figure 6.27, both Options 1 and 2 actually improve the performance of this intake asset by reducing the re-circulation of water between the intake and outlet. As a result, the water temperature at the intake is on average 1.0 and 0.2°C cooler with Options 1 and 2 in place respectively, relative to the baseline scenario.

> The solid quay option (i.e., Option 1), was found to be significantly more effective in reducing water temperatures near the existing cooling water intake, relative to Option 2.



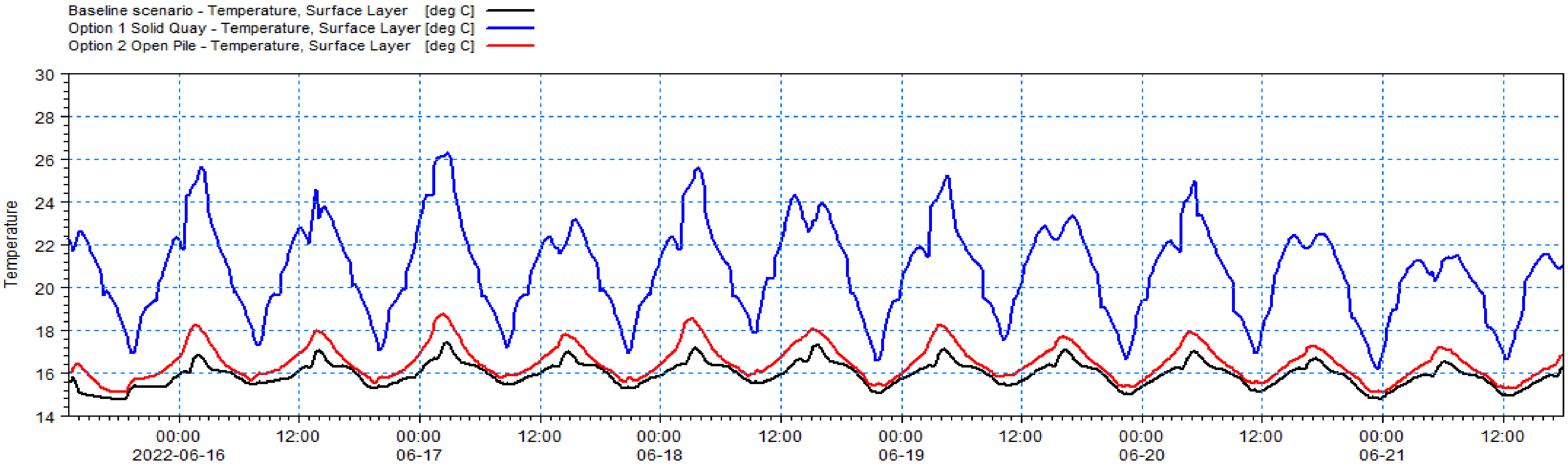
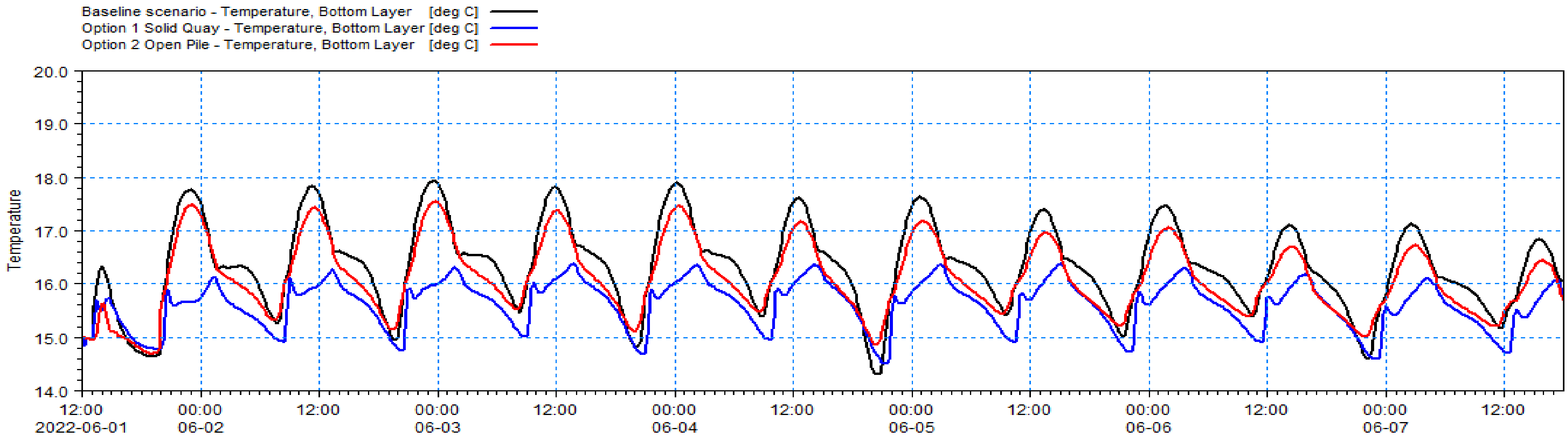


Figure 6.26: Water temperature near to the cooling water outlet based on baseline, option 1 and option 2 scenarios during spring (upper) and neap (lower) tidal conditions



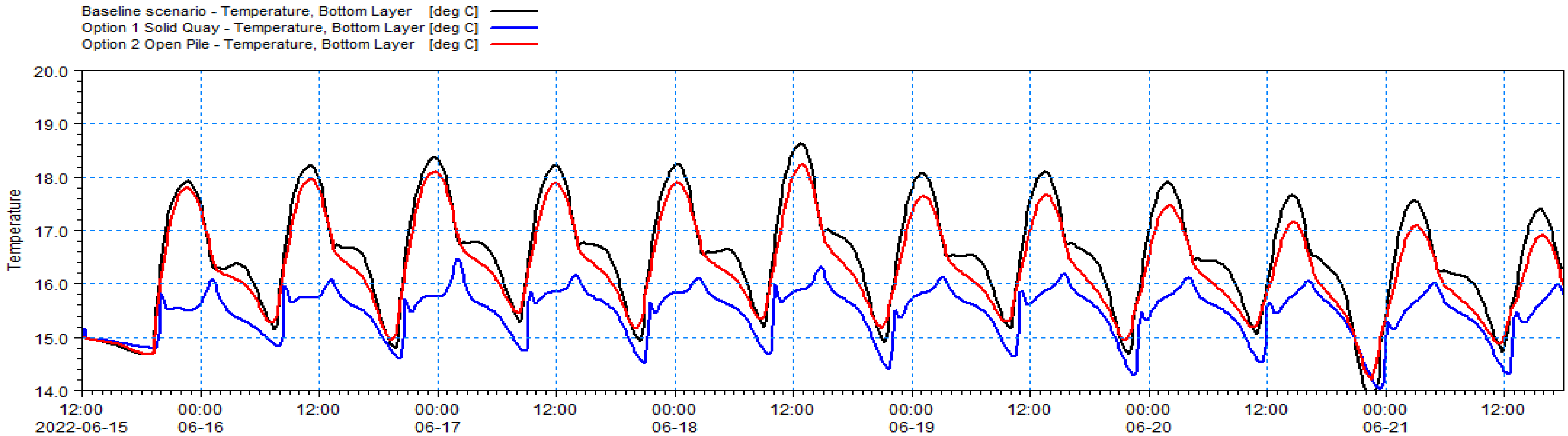


Figure 6.27: Water temperature near to the cooling water inlet based on baseline, option 1 and option 2 scenarios during spring (upper) and neap (lower) tidal conditions

7 CONCLUSION

To assist with the preliminary design of the Moneypoint Hub facility, RPS were commissioned to undertake a numerical modelling study to:

- Characterise the operational wave conditions at the existing Moneypoint site based on an assessment of the long-term wave conditions between 2000 and 2021.
- Define the extreme inshore wave climate conditions at the existing Moneypoint site for 1 in 10, 20, 50, 100 and 200 year return period conditions.
    - This analysis was then repeated using numerical models to represent an open piled and solid quay development options for the Moneypoint Hub.
- Assess the potential impact of different Moneypoint configuration options on the thermal performance of the existing cooling water intake and outlet assets which are imperative for the operation of the ESB power station at Moneypoint.

7.1 Operational wave conditions

Recognising that port operations can be severely hampered by the effects of wave action, RPS undertook a “spell analyses” that described the frequency occurrence of waves at Moneypoint based on a 22 year hindcast dataset.

Based on this long-term assessment, it was found that Moneypoint is, in general, exceptionally well sheltered from arduous waves from virtually all directions. The waves that do approach the study site are almost exclusively wind-generated over relatively short fetches of *c.*<=18km. As a result, monthly average significant wave heights do not generally exceed 0.2m with corresponding peak wave periods of < 1.5 seconds. Under very arduous conditions, wave heights may approach *c.*1.60m with corresponding wave periods of *c.* < 10 seconds.

7.2 Analyses of extreme conditions

In addition to characterising the long-term wave climate at Moneypoint, this study also considered extreme wave conditions. In particular, RPS assessed wave conditions for 1 in 10, 20, 50, 100 and 200 year return period events for the existing scenario, as well as for an open piled and a solid quay development options. This assessment considered both swell waves approaching from the Atlantic Ocean and locally generated wind waves within the Shannon estuary. It was demonstrated that owing to the complex bathymetry, amongst other factors, swell waves do not reach Moneypoint even under extreme wave conditions.

The assessment of extreme wind waves found that significant wave heights along the berthing line could increase by up to c.20% under extreme conditions with a solid quay solution *in situ*. However, wave heights did not generally exceed 3.40m and corresponding peak wave periods remained less than 6 seconds even under extreme 1 in 200 year return period conditions. There was no significant difference in either peak or mean energy wave periods as a result of the proposed solid quay option.

7.3 Thermal plume assessment

It is imperative that any development does not impact the thermal performance of the existing cooling water intake and outlet assets which are critical for the operation of the ESB power station at Moneypoint. To examine this potential impact, RPS undertook three-dimensional model simulations to assess the dispersion and potential of re-circulation with open piled and solid quay developments *in situ*. RPS took a conservative approach and represented the intake and outlet characteristics at maximum temperature and flow conditions for the duration of each model simulation.

Based on this work, it was found that even under maximum flow rates and operating temperatures, there is no significant increase in water temperatures from the outlet point SW8 as a result of either Option 1 or Option 2 during typical spring or neap tidal conditions. Furthermore, both development options were found to improve the performance of the cooling water intake asset by reducing the re-circulation of water between the intake and outlet. The solid quay option was found to reduce water temperatures near the existing cooling water intake by an average of 1.0^{o}C during typical spring and neap tidal conditions.

Appendix A

A.1 Drawing M0838-RPS-XX-XX-DR-C-2400

Appendix B

B.1 Numerical Modelling Systems

B.1.1 Mike Modelling Modules

B.1.1.1 MIKE 21 Coupled System

The MIKE 21 Coupled Modelling modules which are 2D numerical modelling systems respectively were used to simulate the coastal processes in the Moneypoint study area. The MIKE 21 is a truly dynamic modelling system for application within coastal and estuarine environments and can be used for investigating the morphological evolution of the nearshore bathymetry due to the impact of engineering works (coastal structures, dredging works etc.). The engineering works may include breakwaters (surface-piercing and submerged), groynes, shoreface nourishment, harbours etc. The MIKE 21 Model FM can also be used to study the morphological evolution of tidal inlets.

MIKE 21 Coupled Model FM is composed of the following modules:

- Hydrodynamic Module
- Transport Module
- ECO Lab Module
- Mud Transport Module
- Sand Transport Module
- Particle Tracking Module
- Spectral Wave Module

The Hydrodynamic Module and the Spectral Wave Module are the basic computational components of the modelling system. Using MIKE 21 Coupled Model FM it is possible to simulate the mutual interaction between waves and currents using a dynamic coupling between the Hydrodynamic Module and the Spectral Wave Module. The MIKE 21 Coupled Model FM also includes a dynamic coupling between the Mud Transport, Particle Tracking and the Sand Transport models and the Hydrodynamic Module and the Spectral Wave Module. Hence, a full feedback of the bed level changes on the waves and flow calculations can be included.

- The main features of the MIKE 21 Coupled Model FM are as follows:
- Dynamic coupling of flow and wave calculations
- Full feedback of bed level changes on flow and wave calculations
- Easy switch between 2D and 3D calculations (hydrodynamic module and process modules)
- Optimal degree of flexibility in describing bathymetry and ambient flow and wave conditions using depth-adaptive and boundary-fitted unstructured mesh

B.1.1.2 Hydrodynamic Module

The Hydrodynamic Module simulates water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions. The effects and facilities include:

- Flooding and drying
- Momentum dispersion
- Bottom shear stress
- Coriolis force
- Wind shear stress
- Barometric pressure gradients
- Ice coverage
- Tidal potential
- Precipitation/evaporation
- Wave radiation stresses
- Sources and sinks

The Hydrodynamic Module can be used to solve both three-dimensional (3D) and two-dimensional (2D) problems. In 2D the model is based on the shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations.

B.1.1.3 Mike21 FM Flexible Mesh Spectral Wave Modelling System

Modelling the wave transformation from the offshore boundary of the Shannon Estuary model to the sites of interest was undertaken using the MIKE 21 Spectral Wave (SW) model which is a new generation spectral wind-wave model based on unstructured meshes. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas. MIKE 21 SW accounts for the following physical phenomena:

- Wave growth by wind action
- Non-linear wave-wave interaction
- Dissipation due to white-capping
- Dissipation due to bottom friction
- Dissipation due to depth-induced wave breaking
- Refraction and shoaling due to depth variations
- Diffraction
- Wave-current interaction
- Effect of time-varying depth and flooding and drying

The discretisation of the governing equation in geographical and spectral is performed using a cell-centred finite volume method. In the geographical domain, an unstructured mesh technique is used. The time integration is performed using a fractional step approach where a multi-sequence explicit method is applied for the propagation of wave action.

The MIKE 21 SW includes two different formulations:

- Directional decoupled parametric formulation
- Fully spectral formulation

The directional decoupled parametric formulation is based on a parameterization of the wave action conservation equation. The parameterization is made in the frequency domain by introducing the zeroth and first moment of the wave action spectrum as dependent variables following Holthuijsen (1989).

B.1.1.4 Bed Roughness

When using the two-dimensional hydrodynamic models, the bed resistance was specified using the Manning number. According to the MIKE 21 manual, the relationship between the Manning number,M, and the Nikuradse roughness length, k_s can be estimated using

$$M = \frac{25.4}{k_s^{1/6}}$$

Using one of the several relationships recommended by Soulsby (1997), over flat beds of sediment, k_s is related to the median grain diameter (D_50) as approximately

$$k_s = 2.5\ D_{50}$$

It was therefore possible to impose a uniform bed resistance coefficient at the seabed for both the two and three dimensional models - the value of which was determined using the simple relationships presented above and by calibrating of the Shannon Estuary model.

Appendix C

C.1 Typical tidal current information

In addition to providing output describing the dispersion of thermal plumes, the numerical modelling approach described in Section 6.2 also provided detailed tidal current information in respect of velocities and directions.

Given that this information is likely to be of interest to prospective developers, RPS have presented tidal current plots for the baseline scenario. Figure 7.1 to Figure 7.4 illustrate tidal current velocities and directions during mid-flood, high water, mid-ebb and low water phases of a typical spring tidal regime respectively when tidal current velocities are greatest (relative to neap tides).

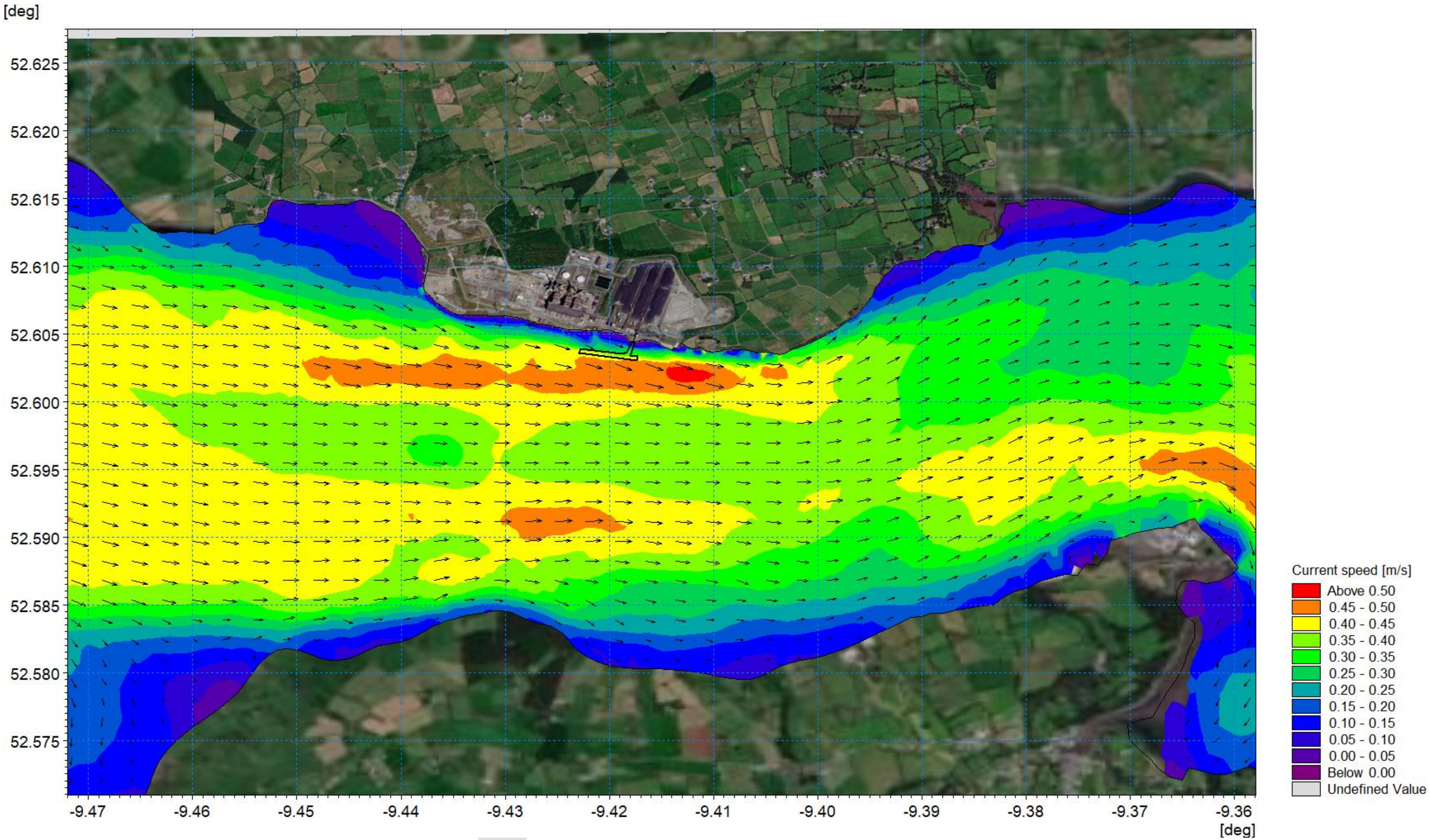


Figure 7.1: Baseline scenario - Distribution of current speeds in the upper water column at Moneypoint outfall during a typical spring mid-flood

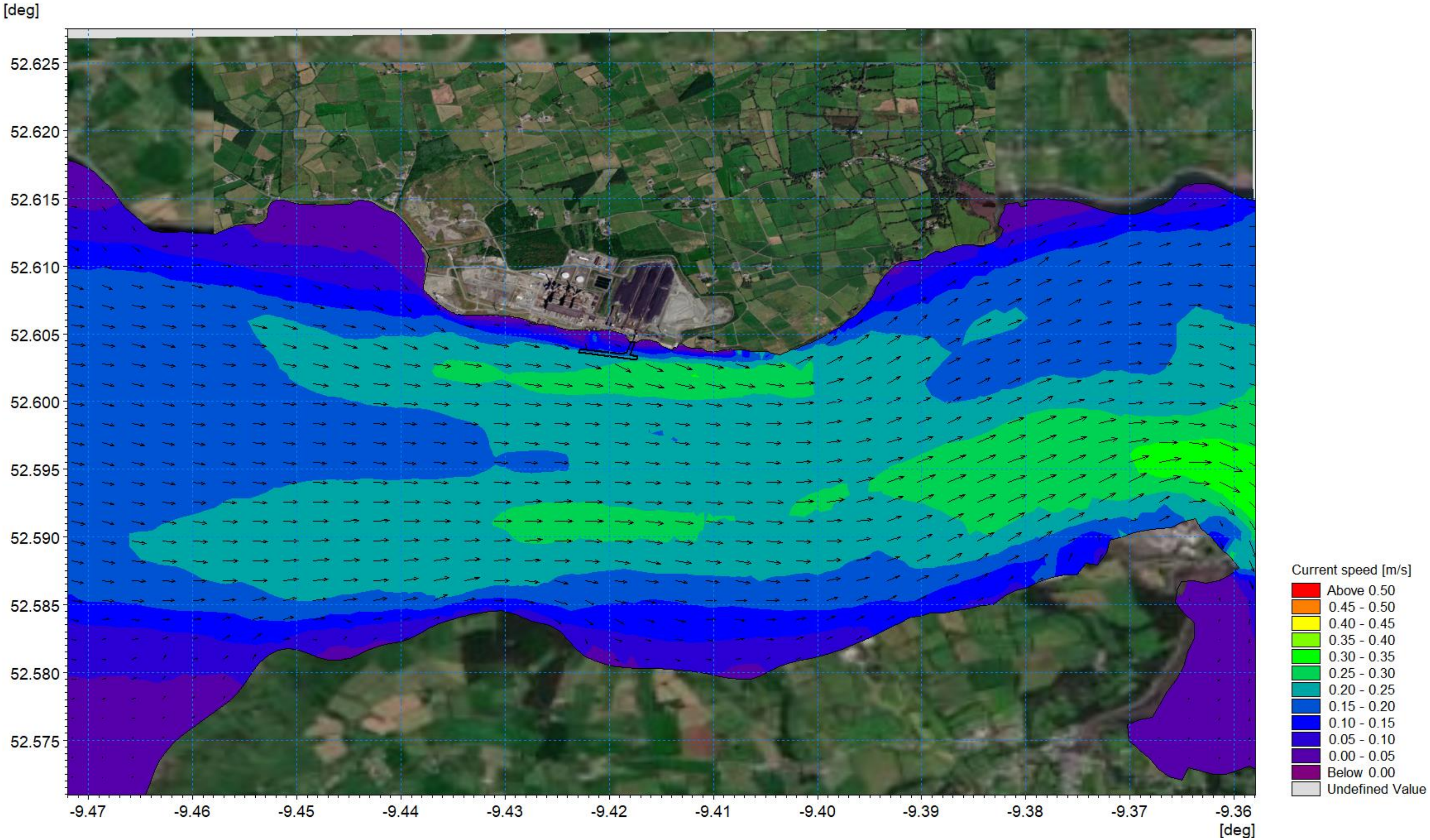


Figure 7.2: Baseline scenario - Distribution of current speeds in the upper water column at Moneypoint outfall during a typical spring high-water

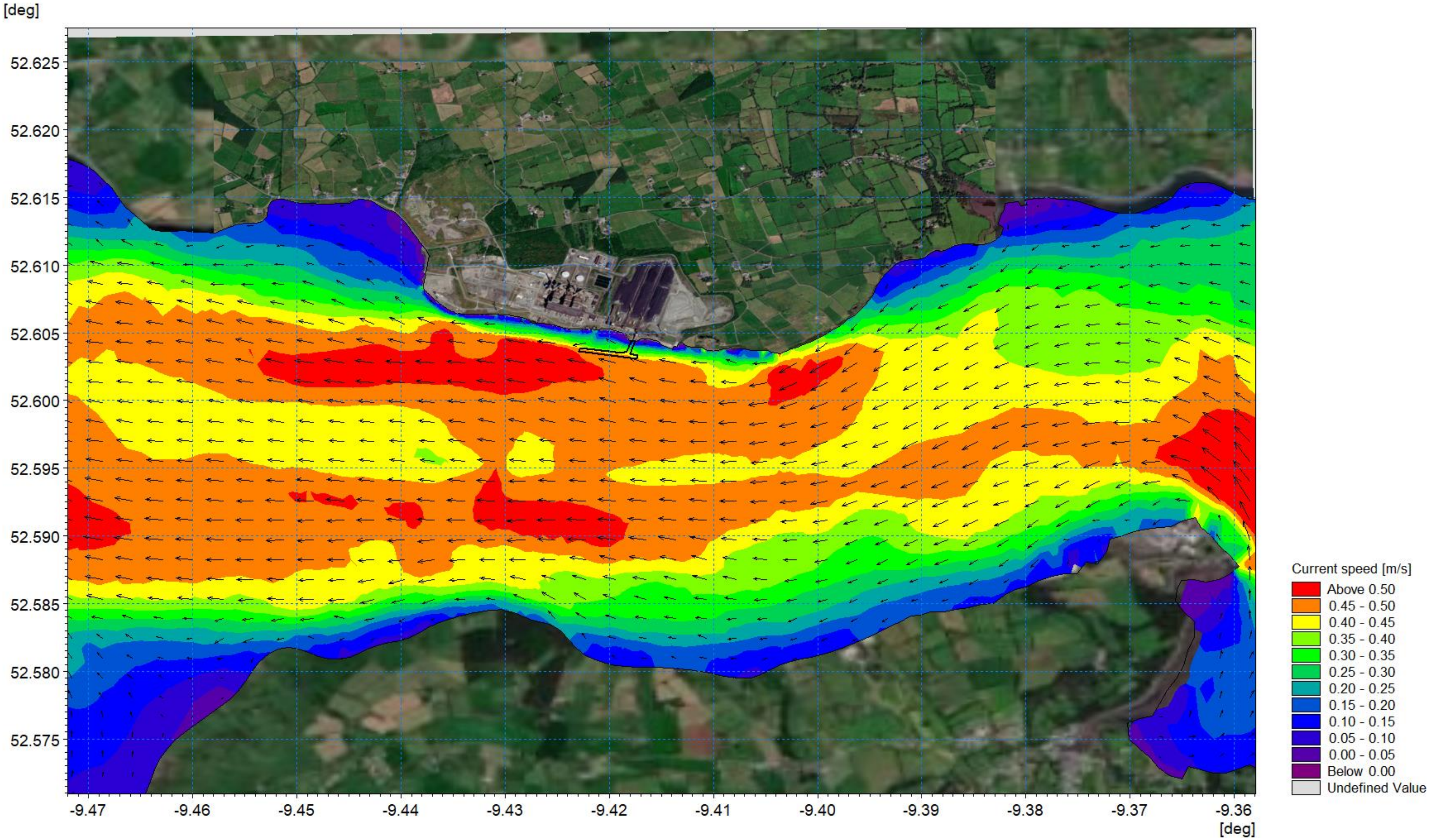


Figure 7.3: Baseline scenario - Distribution of current speeds in the upper water column at Moneypoint outfall during a typical spring mid-ebb

Figure 7.4: Baseline scenario - Distribution of current speeds in the upper water column at Moneypoint outfall during a typical spring low-water