AECOM

Balliemeanoch Pumped Storage Hydro

Environmental Impact Assessment Report

Volume 2: Main Report
Chapter 18: Marine Physical Environment and Coastal Processes

ILI (Borders PSH) Ltd

July 2024

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Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
1	July 2024	Submission	DL	David Lee	Technical Director

Distribution List

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18. Marine Physical Environment and Coastal Processes

18.1 Introduction

This chapter of the EIA Report provides an assessment of the potential effects of the Marine Facility, which forms part of the Development. The Project and Site Description *Chapter 2: Project and Site Description (Volume 2: Main Report)* provides a detailed description of the Marine Facility, a key component of the Development, consisting of a jetty to the south of Inveraray at the northern end of an extended embayment along the northern shore of Loch Fyne. The jetty will consist of a 10 m wide elevated deck supported by an open-piled structure 7 m above the local Mean High Water Springs (MHWS) level. The jetty will extend up to 180 m into Loch Fyne from the shoreline.

Potential effects, as identified in the Scoping Report, include consideration of hydrodynamic conditions and the sedimentary character across Loch Fyne and the wider area. Based on the *Source* > *Pathway* > *Receptor* model, it is noted that the physical processes topic is often concerned with pathways that have the potential to affect a specific receptor, rather than being identified as a receptor itself. For example, impacts on physical processes can result in effects on pathways that subsequently impact a receptor, as assessed separately for Aquatic Ecology *Chapter 7: Aquatic Ecology (Volume 2: Main Report)*.

This chapter is supported by *Appendix 18.1 Tidal Model Calibration (Volume 5: Appendices)*.

18.2 Legislation and Policy

A brief outline of relevant legislation and national and local planning policies relevant to the specific topic area. It will not be necessary to provide a commentary or analysis of the planning policy; this will be done within the Planning Statement which accompanies the Section 36 Application.

18.2.1 Legislation

The following national and devolved legislation is relevant to the planning and execution of projects in UK waters, including the Marine Facility:

- Marine and Coastal Access Act (MCAA) 2009 (HM Government, 2009);
- Marine (Scotland) Act 2010 (Scottish Government, 2010);
- Water Environment and Water Services (Scotland) Act 2003 (HMSO, 2003);
- The Water Environment (Controlled Activities) (Scotland) Regulations 2011. Scottish Statutory Instrument 2011 No. 209 (HMSO, 2009), as amended;
- The Environment (EU Exit) (Scotland) (Amendment etc.) Regulations 2019; and,
- The Environment (EU Exit) (Miscellaneous Amendments) (Scotland) Regulations 2019.

18.2.2 National Planning Policy

The following national and devolved policies are relevant to the planning and execution of projects in UK waters, such as the Marine Facility:

- UK Marine Policy Statement (MPS) (HM Government, 2011).
- Scottish National Marine Plan (2015) (Scottish Government, 2015).

18.2.3 Local Planning Policy

Local planning is covered by the Argyll & Bute Local Development Plan 2 (2024). It sets out a long-term vision for Argyll and Bute which aims to promote an economically diverse and successful area based on sustainable and low carbon development. The following policies within the Local Development Plan are relevant to the EIA:

- Policy 04 – Sustainable Development
- Policy 06 – Green and Blue Infrastructure

- Policy 28 – Supporting Sustainable Aquatic and Coastal Development.
- Policy 30 – The Sustainable Growth of Renewables.
- Policy 55 – Flooding
- Policy 56 – Land Erosion
- Policy 57 – Risk Appraisals
- Policy 59 – Water Quality and the Environment.
- Policy 72 – Development Impact on Areas of Wild Land
- Policy 73 – Development Impact on Habitats, Species and Biodiversity
- Policy 74 – Development Impact on sites of international importance
- Policy 75 – Development Impact on Sites of Special Scientific Interest (SSSIs) and National Nature Reserves
- Policy 76 – Development Impact on Local Nature Conservation Sites (LNCS)

18.3 Consultation

The summary of consultation comments provided in *Table 18.1 Summary of Consultation* has been prepared from responses provided from consultees on the Marine Physical Environment and Coastal Processes section of the Scoping Report (AECOM, 2022).

Table 18.1 Summary of Consultation

Consultee	Key Issue	Summary of Response	Action Taken
Argyll & Bute Council	- Suspended sediment - Siltation - Coastal morphology and sediment transport	Potential for reduced water quality from suspended sediment during dredging. Obstruction of existing and proposed sea outfalls in vicinity of proposed development due to siltation. Requirement to fully understand local processes and potential impact of the Marine Facility.	Hydrodynamic model established to simulate hydrodynamic processes and sediment dispersion, as required. Available data reviewed to understand nature and extent of potential impacts.
Marine Scotland	- Hydrodynamics - Sedimentation	Need to consider potential impacts during construction and operation taking construction methods and dredging requirements into consideration.	Hydrodynamic model established to simulate hydrodynamic processes and sediment dispersion, as required.
NatureScot	- Suspended sediment - Siltation	Need to assess and change in water quality from suspended sediment during dredging and siltation.	Hydrodynamic model established to simulate hydrodynamic processes and sediment dispersion, as required.
SEPA	- Pollution of marine waters	Pollution prevention required during all phase of the project: construction, operation, maintenance, demolition and restoration	Hydrodynamic model established to simulate hydrodynamic processes and sediment dispersion, as required.

18.4 Study Area

The extent of the study area is defined as the area of Loch Fyne below the elevation of Mean High Water Springs (MHWS) extending for a minimum distance equivalent to the flood and ebb tidal excursion on a spring tide from the location of the proposed Marine Facility.

A hydrodynamic tidal model will be used to provide a description of baseline conditions across the entire model domain which extends into the Irish Sea. The potential Zone of Influence (ZoI) for fine suspended sediments could potentially extend beyond the defined study area but will be fully contained within the defined model domain.

18.5 Methods

18.5.1 Guidance and Standards

Industry guidelines relating to the impact of marine projects on the physical environment have been taken into consideration. The following existing guidance has been used to inform this appraisal of potential effects on the physical environment, as applicable to the natures of the works associated with the proposed Marine Facility:

- Environmental Impact Assessment Handbook: Guidance for competent authorities, consultation bodies, and others involved in the Environmental Impact Assessment process in Scotland (SNH, 2018);
- Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Monitoring Requirements to Inform EIA of Major Development Projects. (NRW, 2018);
- Marine Licensing: Sediment Analysis and Sample Plans. Marine Management Organisation. (2014);
- High Level Review of Current UK Action Level Guidance: MMO Project No. 1053 (MMO, 2025);
- Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (Canadian Council of Ministers of the Environment, 1999).

18.5.2 Assessment Scope

The assessment considers the effects during the three phases of the Development lifespan, as identified in *Sections 2.16 – 2.18 of Chapter 2: Project and Site Description*. The phases include pre-construction / construction, operation and decommissioning; however, since the steel piles of the Marine Facility will be a permanent structure remaining in-situ remaining beyond the design life of the Development, the decommissioning phase has not been assessed in detail.

The assessment considers the following potential effects associated with the Marine Facility:

Pre-Construction / Construction

- Direct habitat loss from the Marine Facility deck support structures
- Fine sediment dispersion due to seabed disturbance from pile installation

Operation

- Changes to coastal morphology
- Changes to hydrodynamic conditions and sedimentary regime

18.5.3 Baseline Data

Sources of data used to establish baseline conditions for the assessment of effects on the marine physical environment include:

- A new site-specific Multi-Beam Echo-Sounder (MBES) bathymetric survey covering an area of Loch Fyne approximately 1000 m by 500 m for the location of the proposed Marine Facility;
- LiDAR topographic survey data from the Scottish Remote Sensing Portal (Scottish Government)
- Numerical hydro-dynamic (HD) model of Loch Fyne and Approaches;
- C-Map digital bathymetry;
- Measured currents from the British Oceanographic Data Centre (BODC);
- Predicted tidal water levels and currents from the Admiralty's TotalTide software;
- Extreme water levels for the Environment Agency's Coastal Flood Boundary (CFB) for the UK database;
- Wind data from ERA5's global reanalysis atmospheric model; and
- Regional mapping of seabed geology (BGS, 1988).

Following the collation and analysis of baseline data, the potential effects of the Marine Facility have been assessed using a bespoke numerical model. The modelling studies are described in detail in a separate technical appendix covering hydro-dynamic modelling of water surface elevations and current flows across the study area (*Appendix 18.1 Tidal Model Calibration (Volume 5: Appendices)*.

18.5.4 Assessment Methodology

The predicted effects arising from the construction and operation phases of the proposed Marine Facility have been assessed using the impact assessment methodology, as set out within *Chapter 4: Approach to EIA*, of this report.

The approach to the EIA studies relating to the Marine Physical Environment follows an evidence-based approach. Firstly, the (existing) baseline physical characteristics are described, through collation and analysis of a range of datasets and reports. The description of the baseline character allows any predicted effects, arising from the Development, to be placed into the context of the existing conditions, along with any natural variability evident in the physical environment.

Subsequent sections of this chapter describe the baseline Marine Physical Environment, and the predicted effects arising from the construction and operation phases of the Marine Facility. The cumulative effects arising from other relevant schemes are also outlined, as previously identified within the planning system (see *Chapter 4: Approach to EIA, Section 4.5.8.5 Cumulative Effects*).

18.5.5 Limitations And Assumptions

There is no existing source of river flow data for any of the tributaries discharging into the Loch Fyne upstream from Inveraray which includes the rivers Aray, Shira and Fyne and Kinglas Water with no gauging station at any point along these watercourses. Long-term measurements would be required to confirm the significance of flows from these sources but, given the scale of the channels relative to the Loch Fyne itself, it is assumed that these freshwater flows do not provide the dominant forcing condition driving flows within the loch.

The assessment of wind conditions makes use of hindcast wind data from the ERA5 (ECMWF Re-Analysis Version 5) global climate model where ECMWF is the European Centre for Medium-Range Weather Forecasts. This approach was used in the absence of local wind measurements since no such long-term dataset is available. It is assumed that the use of offshore hindcast wind data provides a reasonable representation of local winds given that any increase in wind speed due to landforms will be offset by the increased frictional drag of the land surface.

18.6 Baseline Environment

The description of the baseline environment covers a range of marine and coastal parameters, most of which are considered as pathways although some also behave as receptors. As an example, tidal currents have the potential to act as a pathway due to their influence on sediment transport but can also be considered as a receptor.

18.6.1 Overview

The Marine Facility, as shown in *Figure 1. Location Of Marine Facility (Red) And Key Datasets In Loch Fyne And Firth Of Clyde*. Source: Google Earth below, is located within the Upper Loch Fyne and Lock Goil Marine Protected Area and is identified as a *Local Landscape Area* and *Garden & Designed Landscape* within the recently adopted Local Development Plan 2 (Argyll & Bute Council, 2024). Appropriate consideration therefore needs to be given due to the sensitive nature of the local and wider study area. Also presented in this figure are the datasets used to calibrate/validate the hydro-dynamic (HD) model. The location of tide gauge stations where predicted tides can be obtained using the Admiralty's TotalTide software are shown in pink, with archived current measurements from the British Oceanographic Data Centre (BODC) shown in green.

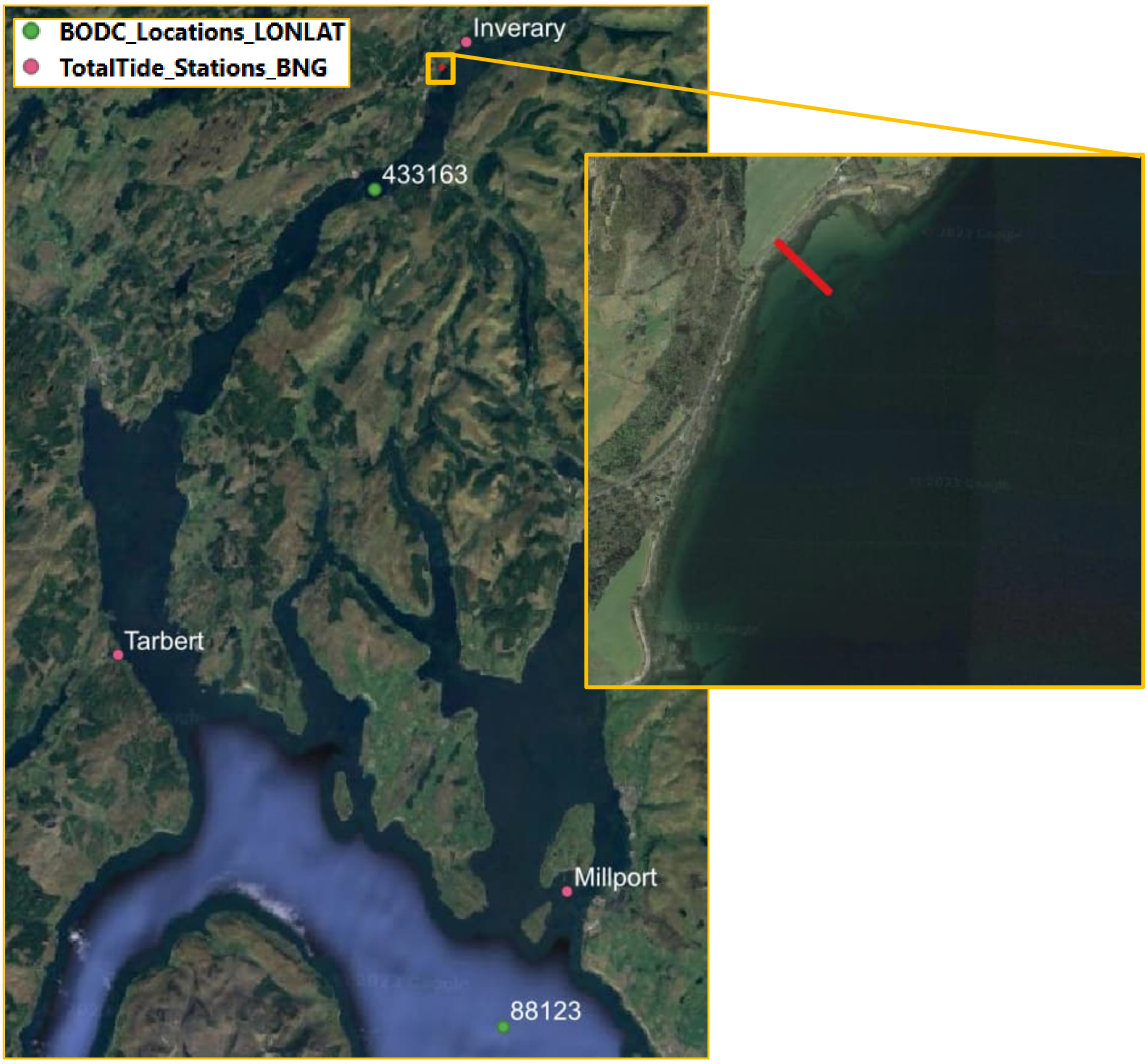

Figure 1. Location Of Marine Facility (Red) And Key Datasets In Loch Fyne And Firth Of Clyde. Source: Google Earth

18.6.2 Coastal Characterisation

The proposed Marine Facility is located on the northern shore of Loch Fyne within a small embayment to the south of Inveraray. Loch Fyne is a largely enclosed waterbody characterised by a relatively narrow water channel having a uniform width between 1.5 to 2 km along its 30 km length. Loch Fyne is connected to the open sea which is approximately 50 km from Inveraray and is therefore subject to the influence of tidal conditions. The immediate foreshore is largely made up of shingle and small pebble beaches.

The coastal character is one of a relatively developed and busy shoreline, with a focus on residential and recreation use. The section of Loch Fyne to the south of Inveraray is also an MoD exercise area used by submarines and other military vessels.

The majority of coastline, with the exception of land adjacent to Inveraray and Newton, is classified as ‘Undeveloped Coast’ (a coastal area of Sensitive Countryside) whilst land adjacent to Inveraray and Newton is classified as ‘Developed Coast’ (a coastal area of Countryside Around Settlement). Loch Shira is the inlet located approx. 3 km to the north of Inveraray.

On the land side, the majority of Inveraray is a Conservation Area and the surrounding countryside of Inveraray and Loch Shira is classified as an ‘Area of Panoramic Quality’.

In view of the above, the coastline as a receptor is considered to have a ‘High’ value and an associated ‘Medium’ sensitivity.

18.6.3 Geology & Sediments

Based on mapping of the superficial geology (*Figure 10.3 Superficial Geology (Volume 3: Figures))*, the coastal and nearshore areas around Inveraray consist of raised marine deposits comprising sand and gravel. These can be expected to extend southwards as far as the location of the proposed Marine Facility which is consistent with the description of "shingle foreshore and stony beaches for the northern shoreline of Loch Fyne", as provided for Policy Zone J in the Local Development Plan (Argyll & Bute Council, 2015).

Based on currently available information, scouring of sediment around piles is considered unlikely to be a significant issue since shingle-type material will be resistant to erosion and even if it is mobilised, is unlikely to transported more than a few metres. Also, if the piles required to support the deck structures are in relatively deep water (i.e. >20 m), the risk of scour with the relatively weak currents at this depth will be significantly reduced.

A numerical model has been developed using the MIKE21 software package. This has the intention to provide a better understanding of the hydrodynamic regime within the local study area and to assess the potential for sediment mobilisation and dispersion.

Alluvium consisting of clay, silt and sand is identified in the lower reaches of the River Shira which has the potential to be transported further downstream towards the location of the proposed Marine Facility during high flow conditions. A proportion of this fine material can therefore be expected to be found mixed together with the predominant sand and shingle type material in the vicinity of the Marine Facility.

A review of available geotechnical information indicates that fine materials (i.e. clays and silts) are present within the natural shoreline sediments. However, due to the extremely low tidal current speeds at the Marine Facility (i.e. less than 0.1 m/s), this confirms that any disturbed sediment would not be widely dispersed and modelling of sediment dispersion processes is not therefore necessary.

18.6.4 Bathymetry

A bathymetric survey of the local study area was undertaken to provide detailed information on potential constraints at the site, in particular relating to vessel access. This information has been merged with C-Map digital chart data database to provide an initial assessment of water depths close to the study area. In the central section of Loch Fyne, adjacent to the proposed Marine Facility, depths are in excess of 100 m CD (i.e. below Chart Datum) reducing to 2 m CD close to the shore.

Characteristics of vessels and barges using the Marine Facility and access requirements, in terms of required under-keel clearance, have been evaluated to assess the need for dredging. This confirms that no dredging will be required in order to provide access for work boats and barges to the Marine Facility.

18.6.5 Tides

Water level variations at the site will be dominated by tidal influences but may also be subject to surge effects due to variations in atmospheric pressure and local wind effects. Mean tidal ranges at Inveraray are approximately 2.4 m on neap and 3.2 m on spring tides, respectively, and the regime can therefore be classified as 'meso-tidal'. Fluctuations due to positive and negative surge effects are likely to be in the range ±0.75 m. Standard tidal heights for Inveraray are provided in *Table 18.2 Tidal Heights And Levels For Inveraray (Source: UKHO, 2021)*.

Table 18.2 Tidal Heights And Levels For Inveraray (Source: UKHO, 2021)

Description	Tidal Height (m CD)	Level[1] (m ODN)
Highest Astronomical Tide (HAT)	3.6	1.98
Mean High Water Springs (MHWS)	3.3	1.68
Mean High Water Neaps (MHWN)	2.9	1.28
Mean Sea Level[2] (MSL)	1.8	0.18
Mean Low Water Neaps (MHWN)	0.5	-1.12
Mean Low Water Springs (MLWS)	0.1	-1.52
Lowest Astronomical Tide[2] (LAT)	0.0	-1.62

1. Based on -1.62m CD to ODN correction (UKHO, 2021).
2. Estimated values.

18.6.6 Extreme Water Levels

Information on extreme water levels is also required as a key design parameter taking meteorological effects and elevated surge levels into consideration. A detailed study of extreme water levels was undertaken for the Environment Agency to provide a consistent dataset for use in flood studies and design referred to as the Coastal Flood Boundary (CFB) for the UK, data. AECOM has therefore extracted extreme water level data for a representative point within the study area, as provided in *Table 18.3 Extreme Sea-Levels At Entrance To Loch Fyne (Source: EA (2018))*

Table 18.3 Extreme Sea-Levels At Entrance To Loch Fyne (Source: EA (2018))

Return Period (years)	Level (m ODN)	Equivalent Surge Level[1] (m)
1	2.67	0.77
10	3.09	1.19
25	3.27	1.37
50	3.40	1.50
100	3.53	1.63

1. Relative to MHWS.

The CFB database also provides MHWS and HAT levels given as +1.90 m ODN and +2.55 m ODN, respectively, for a point close to the entrance of Loch Fyne which are consistently higher than the corresponding values for Inveraray of 1.68 m ODN and 1.98 m ODN. This suggests that the amplitude of the tidal wave is attenuated rather than amplified as it propagates into Loch Fyne as a result of energy losses and the near constant width of the channel rather than a more typical, funnel-shaped estuary.

18.6.7 Tidal Currents

Measured tidal current data (Location 443163) has been obtained from the British Oceanographic Data Centre (BODC) for a location within Loch Fyne close to the proposed Marine Facility near Inveraray (see *Figure 2. Location Of The BODC Dataset (443163) Relative To Inveraray*, below). The data covers the period from 20/11/1994 to 25/2/1995 with measurements made at a level 11 m below the surface in a water depth of approximately 35 m at the location shown in *Figure 3. Measured Current Speeds Near Inveraray* and *Figure 4. Measured Current Directions Near Inveraray*, below. Although the measured data was collected almost 30 years ago, there have been no major developments within the loch and the channel morphology is very stable therefore this information is still representative of present-day conditions. The measured current speed and direction values are provided in Figure 3. and Figure 4. respectively.

This measured dataset was processed using harmonic analysis to identify the tidal constituents, also enabling tidal currents to be predicted for any timeframe. The M2 and S2 constituents derived from the analysis were used to calculate the tidal excursion distance resulting from tidal processes. Specifically, the tidal excursion has been calculated for a mean spring tide associated with stronger than average tidal currents to provide an indication of the maximum tidal excursion. At the BODC location (see *Figure 2. Location Of The BODC Dataset (443163) Relative To Inveraray*, below), the water depths allow for faster current speeds when compared to the location of the Marine Facility due to the reduced influence of bottom friction. Here the peak mean spring tidal currents provide a tidal excursion distance of 700 m on the flood or ebb tide thus the major axis of the tidal ellipse is 1.4 km for this mean spring tide. For the weaker currents near the Marine Facility, the tidal excursion distance is estimated to be approximately 300 m for the flood or ebb tide resulting in a dimension of 600 m for the major axis of the tidal ellipse.

Figure 2. Location Of The BODC Dataset (443163) Relative To Inveraray

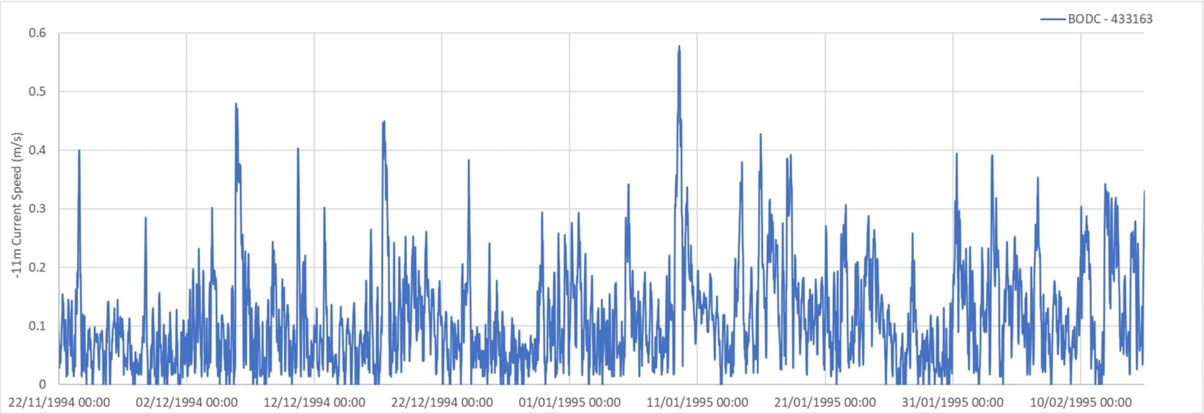

Figure 3. Measured Current Speeds Near Inveraray

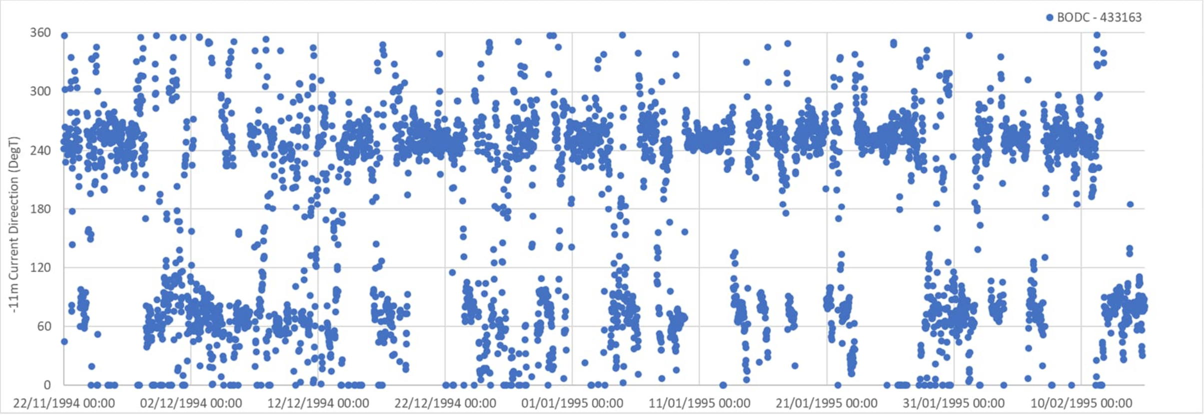

Figure 4. Measured Current Directions Near Inveraray

At this location near the centre of the loch, tidal currents are weak with speeds generally less than 0.2 m/s, close to the lower limit that can be measured using an impeller type current meter. During storm conditions surface currents will be enhanced by the action of strong winds acting on the water surface, particularly when the wind is blowing in the same direction as the ambient currents. Surface water flows will also have an influence on local currents, mainly at the surface due to the lower density of freshwater relative to the saline water in the loch.

The high density of data points around directions in the range 50-90°N and 230-270°N correspond to the alignment of the channel which in turn dictates the direction of flood and ebb tidal currents. However, there are also periods when the current direction does not reverse but instead remains constant. During these periods currents are therefore dominated by non-tidal processes, primarily winds that are funnelled along the axis of Loch Fyne driving currents towards the north-east or south-west.

Further detail of tidal current patterns is provided in *Figure 5. Modelled Hydrodynamics For A Mean Spring Tide At The Proposed Marine Facility*, below which shows output from the HD model for peak flood and ebb flow conditions during a mean spring tide at the proposed Marine Facility location. At this location, close to the head of the loch, both the ebb and flood current speeds are shown to be very low reaching peak values of approximately 0.025 m/s.

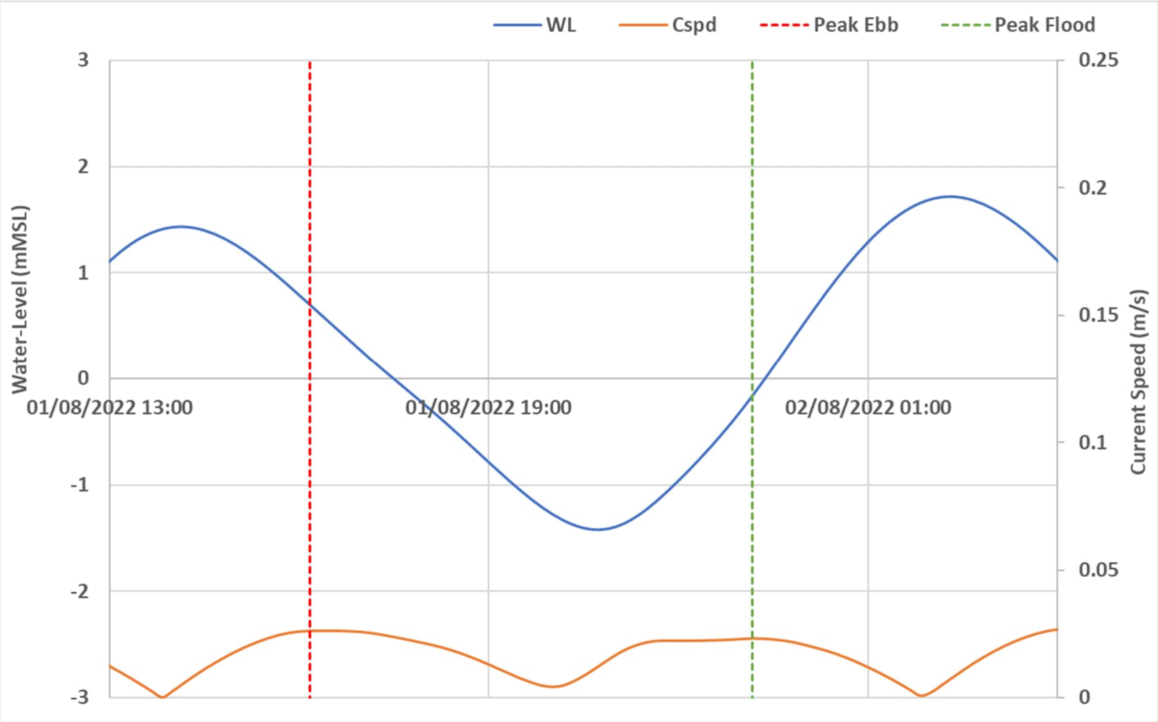

Figure 5. Modelled Hydrodynamics For A Mean Spring Tide At The Proposed Marine Facility

Sensitivity tests were undertaken to assess the influence of wind on the flow field, with winds applied from both the SSW and NE directional sectors, as shown in *Figure 6. Tidal Currents Over A Tidal Cycle For A 1 In 1 Year Wind Condition From SSW* and *Figure 7. Tidal Currents Over A Tidal Cycle For A 1-In-1 Year Wind Condition From NE,* below, respectively. These results show that for a 1 in 1 year return period, the wind causes an increase in current speeds, with the SSW direction resulting in the largest increase. This is due to an overall faster wind speed and a longer stretch of open water over which the wind can be influential on the waterbody. Despite this magnification under ‘extreme’ conditions, peak spring tide currents are still below 0.15 m/s and can therefore be classified as very weak, with limited potential to affect sediment transport since the near-bed currents will be less affected by surface wind effects. It is noted that the inclusion of wind effects also causes a slight phase shift in the tidal signal and consequently the timing of the peak ebb and flood current is also modified although this is of no consequence in terms of sediment transport.

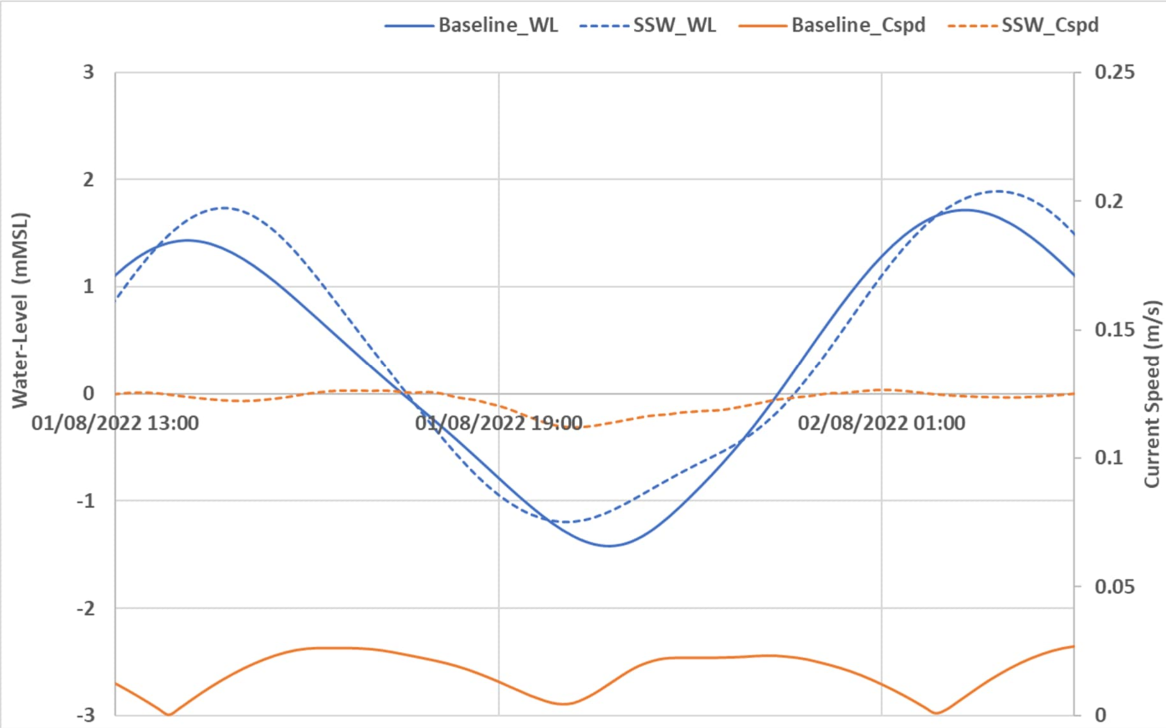

Figure 6. Tidal Currents Over A Tidal Cycle For A 1 In 1 Year Wind Condition From SSW

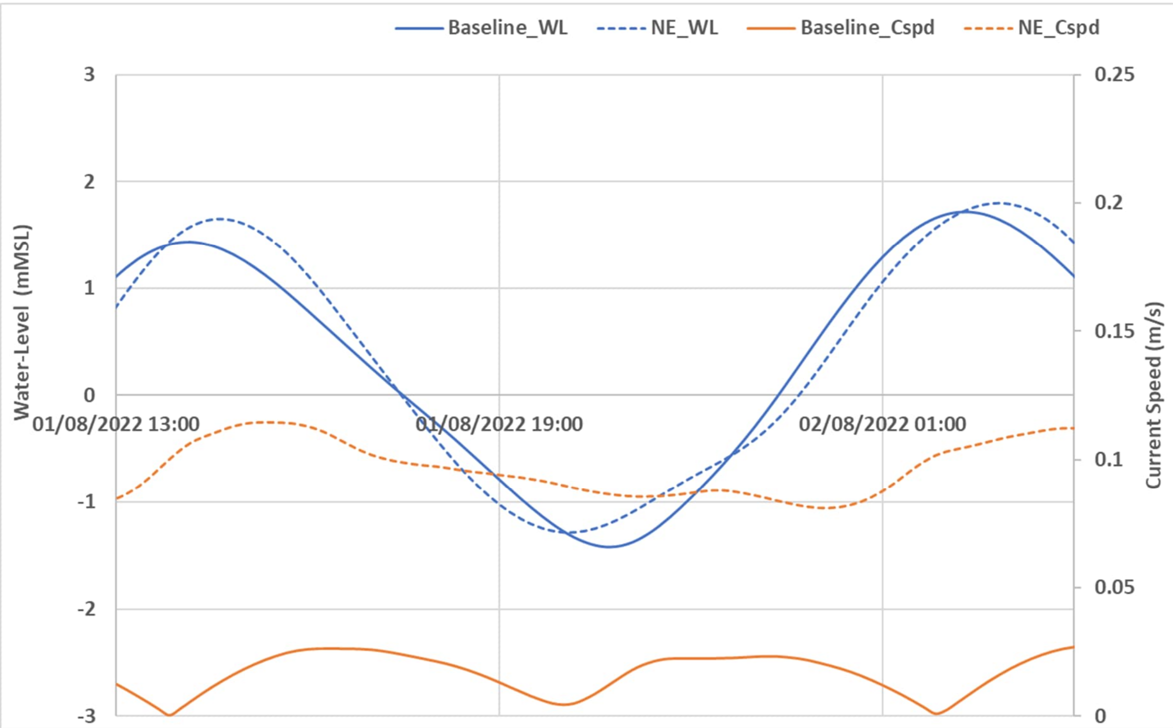

Figure 7. Tidal Currents Over A Tidal Cycle For A 1-In-1 Year Wind Condition From NE

Further details of results from this and other model sensitivity tests can be found in *Appendix 18.1 Tidal Model Calibration (Volume 5: Appendices)*.

18.6.8 Waves

In terms of local wave conditions, Inveraray is approximately 50 km from the open sea and therefore beyond the limit of offshore swell wave penetration. Only locally generated wind waves reach the location of the proposed Marine Facility and are limited by the available fetch lengths within Loch Fyne which are less than 10 km. However, Loch Fyne has a south-west to north-east alignment which coincides with the strongest winds from the predominant south-westerly direction. Using a fetch-based approach to estimate wave conditions from the SSW (which provides the largest magnification in current speeds out of the directions assessed), the 1 in 1 year return period wind speed of 11.6 m/s and fetch length of 10 km can result in a significant wave height in the range 1-2 m, which would have a relatively short period of less than 5s. Under such conditions, loading/unloading operations at the Marine Facility would most likely need to be restricted until the storm has abated.

18.6.9 Wind

No record of measured wind data near Inveraray was identified and therefore wind data was obtained for the closest location (-5.0973' W, 56.19332' N) from the ERA5 (2024) global re-analysis atmospheric model at 10 m elevation, see *Figure 8. ERA5 Wind Data Extraction Location. Source: Google Earth*. The model data is assumed to be representative of conditions along Loch Fyne.

Tidal modelling undertaken for the project has demonstrated that at Inveraray, whilst water levels vary in response to tidal forcing, the local currents are still very weak, typically less than 0.15 m/s. This has been shown to be due to the position of Inveraray within Loch Fyne and the shape of the channel. Local currents within Loch Fyne near the proposed Marine Facility are therefore likely to be dominated by the influence of surface winds during storms and, to a lesser extent, by surface run-off during periods of heavy rainfall.

Figure 8. ERA5 Wind Data Extraction Location. Source: Google Earth

18.6.10 Coastal Processes

The shoreline adjacent to the proposed Marine Facility is considered as a receptor that could be affected by changes in tidal and/or wave conditions during the operational phase. It is therefore important to establish baseline conditions in terms of coastal processes from the inspection of beach materials and indicators of active sediment transport along the shoreline.

The predominant sediments identified along the shoreline were found to be a mixture of gravel, sand and mud, with the majority classified as a sand-mud mixture with a median grain size ($D_{50)}$ in the range 0.041 – 0.59 mm as a result of the varying proportion of sand and mud. The three sampling locations closest to the proposed Marine Facility give a mean sediment grain size of 0.35 mm. As previously established, currents in the main channel of Loch Fyne are very weak (approximately 0.2 m/s) and would be even weaker along the margins of the Loch due to frictional effects. Waves are therefore expected to provide the primary mechanism for mobilising sediment which is subsequently transported by the ambient currents. Wakes from larger vessels navigating within the loch could also contribute to the suspension of sediment but will not influence sediment pathways.

The main channel is relatively narrow (approximately 2 km), thus the most severe waves will propagate along the channel either from the north-east or south-west where the maximum fetch length is approximately 10 km with any corresponding transport of sediment directed along the shoreline. To evaluate the level of transport, inspection of foreshore levels either side of obstacles, such as slipways, was undertaken to identify any differential levels that would indicate the direction of net transport. It was concluded that there is no evidence to suggest there are significant levels of transport in either direction along the coastline adjacent to the proposed Marine Facility. The expectation is therefore that the modelling studies would support this conclusion.

A review of coastal monitoring data (Dynamic Coast, 2022) also confirmed that the coastal frontage along the northern shore of Loch Fyne is predicted to be generally stable up to the year 2100, even under a high emissions scenario (i.e. RCP8.5 95th percentile), with negligible landward retreat. The only exception is a 100 m section of the south-facing coastline, as shown on *Figure 9. Predicted Future Shoreline Position For The Study Area (Source: Dynamic Coast, 2022)*, below, which is predicted to advance inland a distance of 60 m by 2100, based on a sea level rise of 0.91 m over this period.

Figure 9. Predicted Future Shoreline Position For The Study Area (Source: Dynamic Coast, 2022)

The progressive landward movement of the shoreline is not due to coastal erosion but is instead due to the predicted future rise in local sea levels leading to a landward migration of the shoreline based on the existing topography.

The predicted response to future sea level rise shows that the sensitivity of this particular location as a receptor is High and the value is Very High on the basis that permanent inundation of the coastal road with the associated loss of access would be a major issue.

Raising land levels or providing defences to mitigate the predicted future realignment of the coastline in this area is therefore likely to be required in the future to maintain access along the A83 road to Inveraray.

18.6.11 Existing Outfalls

Four sea outfalls have been identified adjacent to the location of the proposed Marine Facility with two commercial outfalls at Lùib lomaire Mhóir, a consented SEPA discharge south of Creagan nan Caorach and a local authority-maintained outfall at Newton which discharges from the Inveraray sewage works.

Concerns regarding the outfalls were highlighted by Argyll & Bute Council during the scoping stage which it is assumed relates to the adjacent Shellfish Protected Area referred to as the Loch Fyne Coastal Strip by the Scottish Government which is currently classified as ‘Not Achieving Guideline Standards’. Any additional adverse impact can therefore be expected to exacerbate this issue.

On the basis of the above, the sensitivity and value of the outfalls as a receptor are assessed to be High.

18.7 Future Baseline

It is important to recognise that present-day baseline conditions are not stationary and will change over the lifetime of the proposed Marine Facility.

18.7.1 Water Levels

Table 18.4 Sea Level Rise Allowances provides sea level rise (SLR) allowances for 2023 and 2053 relative to a base year of 2017 and therefore the difference between these values represents the SLR allowance for the two defined percentiles and thus represents the likely range in variability.

Table 18.4 Sea Level Rise Allowances

Year	SLR relative to base year		Comment
Year	*50th percentile*	*95th percentile*	
2023	*0.068*	*0.103*	Present day
2053	*0.208*	*0.322*	End of Marine Facility Design Life[1]
-	***0.140***	***0.219***	Increase in MSL 2023 to 2053

Note. 1. Estimated values.

18.7.2 Currents

As previously noted, surface water run-off into local watercourses will influence near-surface currents within Loch Fyne which are associated with periods of heavy rainfall. Current guidance[1] suggests an allowance for peak river flows of 59% to the year 2100 for the Argyll region. However, the effect of any increased river discharge into Loch Fyne will be highly localised and at the location of the Marine Facility such increases will be less than 10% of the peak tidal currents and unlikely to be measurable and of no consequence in terms of potential sediment transport.

18.7.3 Wind

Coastal flood studies typically apply a 5% uplift to wind speeds to allow for future climate change within the epoch 2023 to 2053 (GOV.UK, 2023). This increased wind speed would have a direct influence on surface currents, particularly for winds from south-westerly directions that are aligned with the axis of the loch. Increased wind speeds are unlikely to result in increased extreme wave conditions within Loch Fyne due to the limited length of fetch available over which waves are generated.

18.8 Assessment of Effects

This section presents the findings of the assessment for the pre-construction / construction and operational phases. Given that the Marine Facility is intended to be a permanent structure with the steel piles remaining in-situ, decommissioning effects do not need to be considered. If decommissioning were required, these effects would be very similar to those described in here which relate to construction effects.

18.8.1 Construction Effects

18.8.1.1 Direct Loss of Intertidal and Subtidal Habitats

There is a direct impact of the installed piles due to the plan area of seabed that these structures occupy. Based on the project design information provided, the Marine Facility will require the installation of 15 piles in the intertidal zone (i.e. below MHWS and above MLWS) with 57 piles in the subtidal zone (i.e. below MLWS). For a pile diameter of 600 mm, the loss of habitat in the intertidal zone would be approx. 4.2 m^2 and 16.1 m^2 in the subtidal which is considered to be negligible relative to the corresponding total areas for Loch Fyne. The loss of intertidal area is approximately 0.0002% of the equivalent total area available within Loch Fyne, which is negligible, and the area of subtidal loss is even smaller in percentage terms.

The sensitivity of both intertidal and subtidal habitats is considered to **High** although the magnitude of the effect is considered to be **Negligible** and consequently the overall effect is assessed as being **Minor**.

[1] SEPA (2023) Climate change allowances for flood risk assessment in land use planning (Version 3).

18.8.1.2 Sediment Scouring

During installation of the piles there is potential for disturbance of the local seabed due to the local acceleration of tidal flows as they are diverted around the physical obstruction created by each pile. This potential acceleration could be up to an increase of 0.005 m/s as highlighted in *,Figure 10. Difference In Tidal Current Speed With The Marine Facility Included In The Model During Mean Spring Peak Ebb Flow* and *Figure 11. Difference In Tidal Current Speed With The Marine Facility Included In The Model During Mean Spring Peak Flood Flow*, below. This effect will be most noticeable in the intertidal zone due to the presence of potentially mobile sediments. This local scour process cannot be assessed using standard modelling techniques and has therefore been assessed using expert judgement to determine the likely response. A localised lowering of the seabed adjacent to the pile is expected to occur soon after installation reaching an equilibrium state following exposure to the strongest spring tide currents. The depth will reduce linearly to the natural seabed level at a distance of half the pile diameter from the outer face of the pile. The maximum depth of scour at the pile face would have a similar dimension of approx. 350 mm. In reality the extent of scour is expected to be much less due to the presence of coarser, gravel-sized material on the seabed surface which will have an armouring effect.

18.8.1.3 Coarse Suspended Sediment

Sediment samples obtained at two of the three locations closest to the proposed Marine Facility show that the bed material can be classified as coarse sand with the third location in deeper water as fine sand. The coarse sand will therefore rapidly settle back onto the seabed within a few metres of the pile location whereas the fine sand has the potential to travel further due to it having a much lower settling velocity of approx. 2 mm/s. Even with this low settling velocity, the sediment is unlikely to fall more than 1 m before reaching the bed suggesting a travel distance of less than 100 m from the pile location in the direction of the flood or ebb currents under peak flow conditions.

18.8.1.4 Fine Suspended Sediment

The proportion of fine sediment (i.e. mud, clay and silt with a D_{50} of less than 63 µm) within the two sediment samples closest to the shore is less than 10% with this material being mobilised by natural tide and wave processes. However, in the deeper water the proportion of mud in the sample was found to be nearly 40%. If any of this material is brought into suspension during pile installation, or soon after, it has the potential to travel further since it will remain in suspension for longer. Based on the estimated dimension of the tidal excursion ellipse, this fine material could result in elevated suspended sediment concentrations over a distance 300 m from the Marine Facility although this effect will gradually reduce due to the finite supply which will cease as soon as the developed scour hole has reached an equilibrium state. Any sediment in suspension will be rapidly diluted with distance from the Marine Facility and elevated concentrations along the shoreline (i.e. where there are existing outfalls) will be negligible.

Taking Water Quality as the primary receptor affected by coarse and fine suspended sediment concentrations, with the sensitivity of this parameter considered to be **High** and the magnitude of the effect considered to be **Negligible** (due to the temporary, localised and transient nature of this effect), the overall sensitivity is assessed as **Minor**.

18.8.2 Operational Effects

18.8.2.1 Hydrodynamic Conditions and Sedimentary Regime

The analysis of tidal currents described above demonstrates that the presence of the Marine Facility will result in highly localised and undetectable changes in terms of tidal hydrodynamic conditions. A similar, but even lesser magnitude effect can be expected with respect to near-bed, wave-induced currents during storm conditions. Consequently, during the operational phase of the development, there will be negligible change related to sediment transport processes, both locally around individual pile structures and further afield, along adjacent sections of the coast.

A series of model simulations were carried out to address how the operational Marine Facility can be expected to modify baseline hydrodynamic conditions. The piles supporting the deck of the Marine Facility structure will impede tidal currents as the tide floods and ebbs, and to a lesser extent the propagation of waves. This is anticipated to impact the velocity of the near-bed currents, which in turn has the potential to impact the Bed Shear-Stress (BSS) within the water column and potentially interfere with local sedimentary processes.

The magnitude of this impact has been assessed by creating difference maps by comparing the present-day (**Baseline**) model output against and the model run with inclusion of the Marine Facility (**Development**). *Figure 10.* and *Figure 11. Difference In Tidal Current Speed With The Marine Facility Included In The Model During Mean Spring Peak Flood Flow* represent the changes in current speed and demonstrate the model's ability to capture minor changes that the presence of the Marine Facility induces (note the very small magnitude of values applied to the colour-scale of the figures). The changes presented in these plots present very insignificant to the flow regime that will only be detectable by the accuracy of a numerical model, with maximum offsets in the region of 0.001 m/s, with areas of both deceleration (blue) and acceleration (red). This is coupled with the differences presented to the BSS (*Figure 12. Difference In BSS With The Marine Facility Included In The Model During Mean Spring Peak Ebb Flow* and *Figure 13.*), which indicate even smaller changes to levels of BSS.

Time-series of both parameters have been extracted in the centre of the modelled differences (see *Figure 10*). This quantifies how marginal the maximum expected changes are during a mean spring tide within the highlighted areas. These are presented in *Figure 14. Peak Flood Extraction Differences In Cspd (Top) And Bss (Bottom) With The Inclusion Of The Marine Facility (Development)* and *Figure 15. Peak Ebb Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development).*

A threshold BSS value of 0.205 (N/m^2) is also presented (red line) in the plots presented. This value has been calculated using established methods (Soulsby, 1994) using a representative sediment size (0.35 mm) for the seabed close to the proposed Marine Facility. This represents the BSS required to mobilise sediment on the seabed at this location.

Peak offsets in current speeds at the flood and ebb extraction locations and equally almost indistinguishable within the time-series for both parameters. With no significant changes shown to occur during the flood and ebb phases in both current speed and BSS following the installation of the Marine Facility, with both the Baseline and Development model runs indicating BSS levels well below the site sediment threshold. This illudes to the conclusion that the Marine Facility will not alter local hydrodynamics or the sediment pathways under normal circumstances.

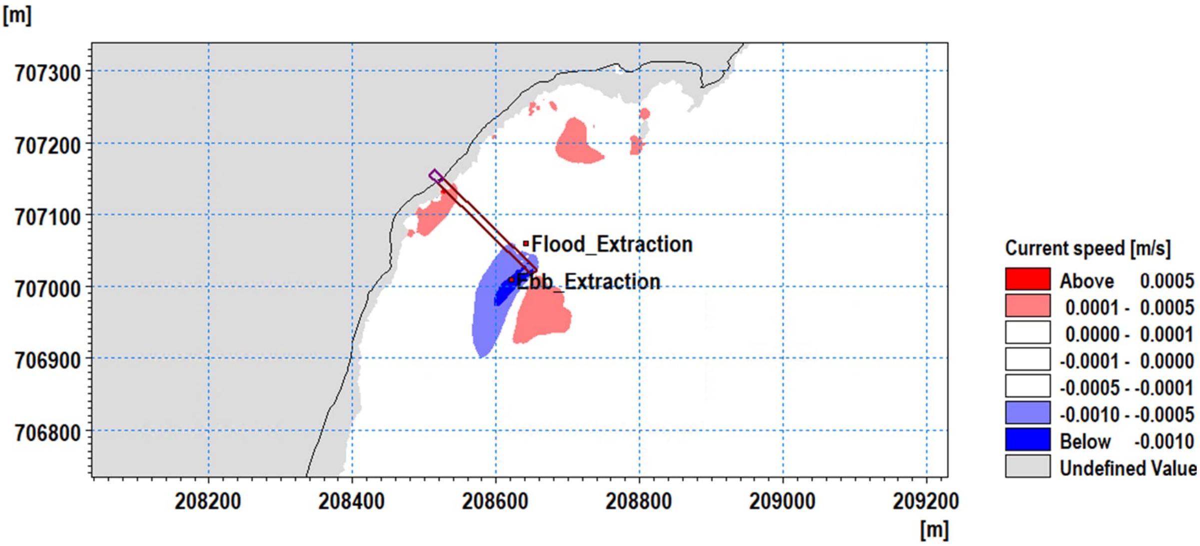

Figure 10. Difference In Tidal Current Speed With The Marine Facility Included In The Model During Mean Spring Peak Ebb Flow

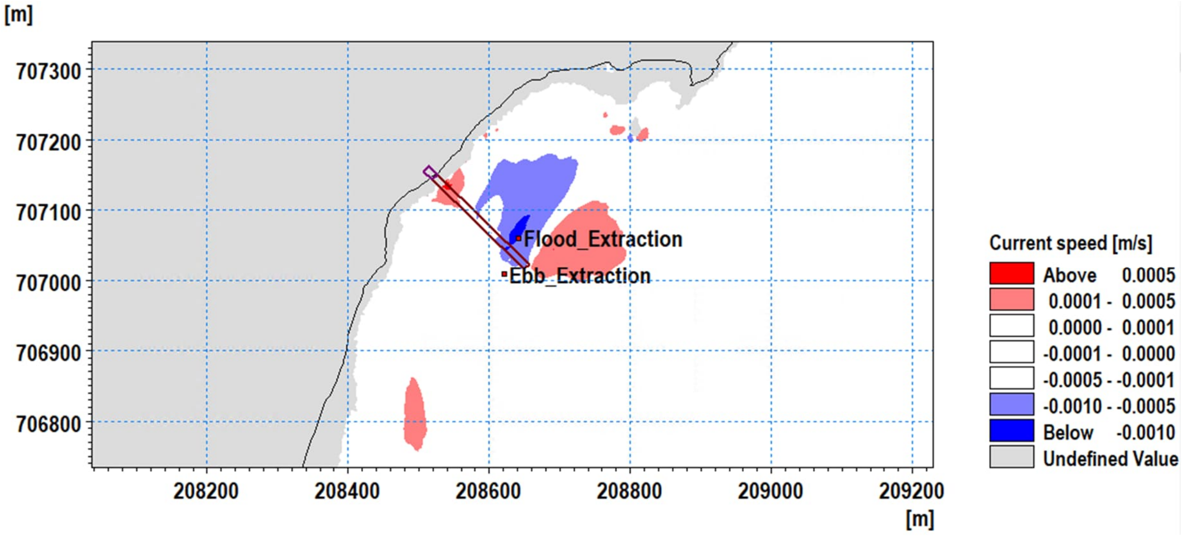

Figure 11. Difference In Tidal Current Speed With The Marine Facility Included In The Model During Mean Spring Peak Flood Flow

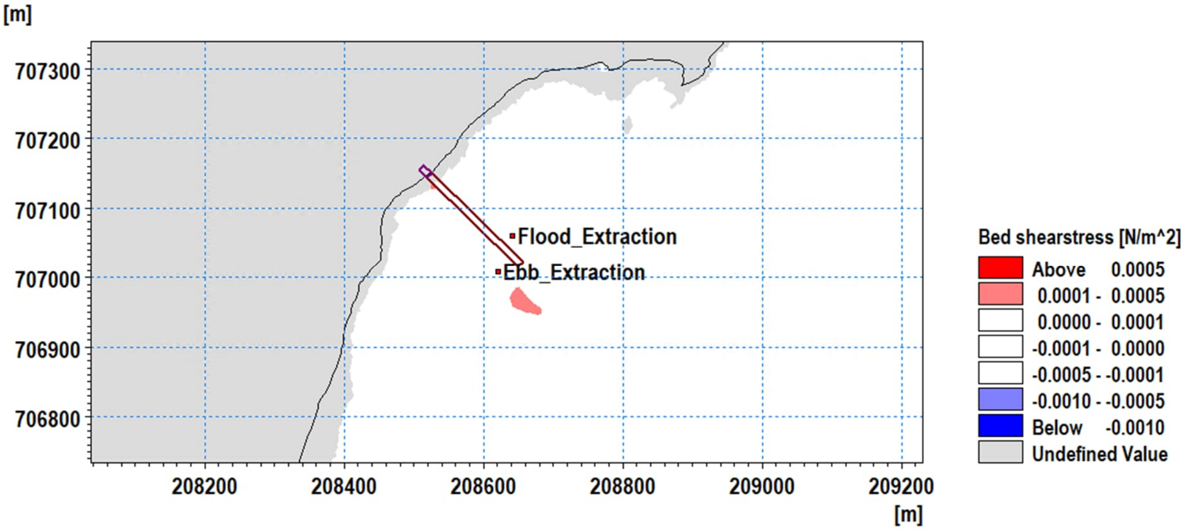

Figure 12. Difference In BSS With The Marine Facility Included In The Model During Mean Spring Peak Ebb Flow

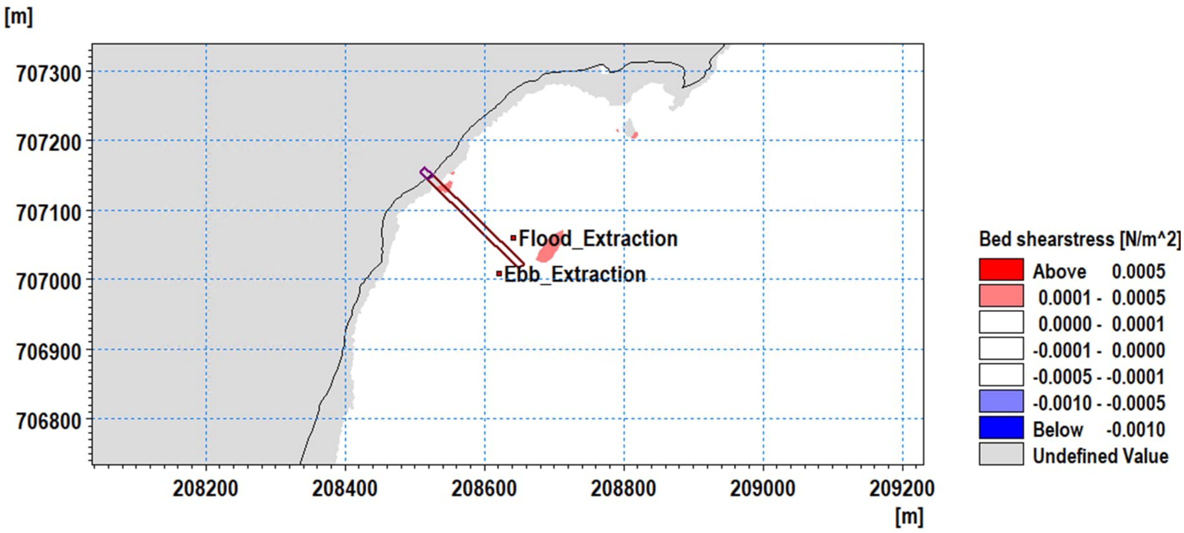

Figure 13. Difference In BSS With The Marine Facility Included In The Model During Mean Spring Peak Flood Flow

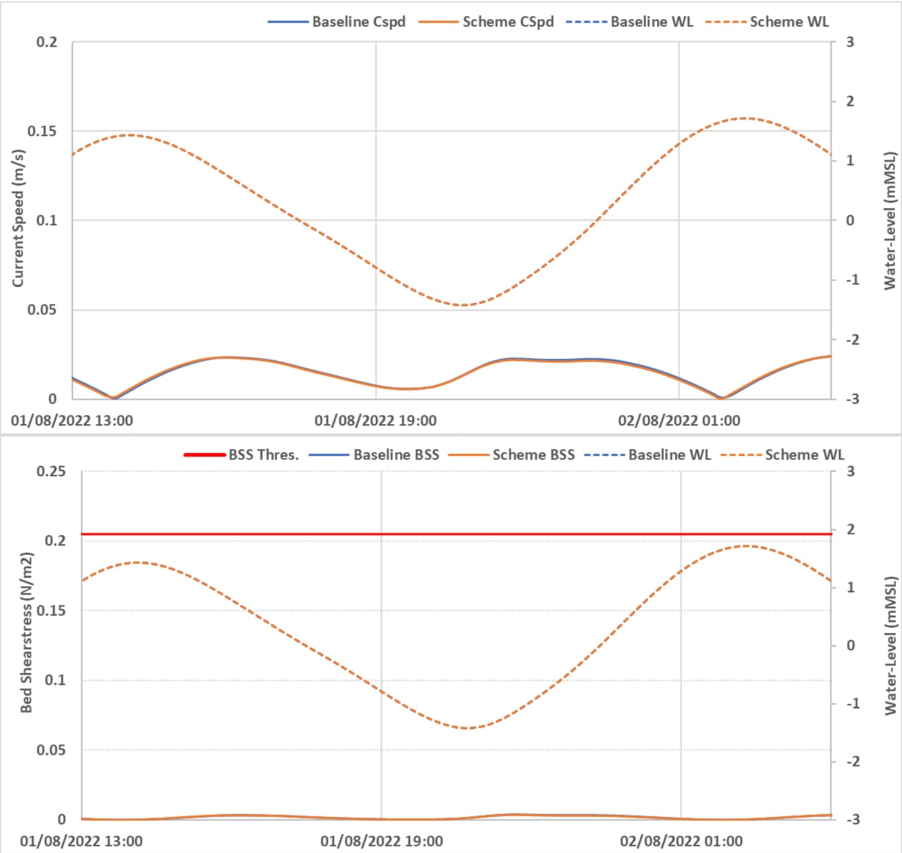

Figure 14. Peak Flood Extraction Differences In Cspd (Top) And Bss (Bottom) With The Inclusion Of The Marine Facility (Development)

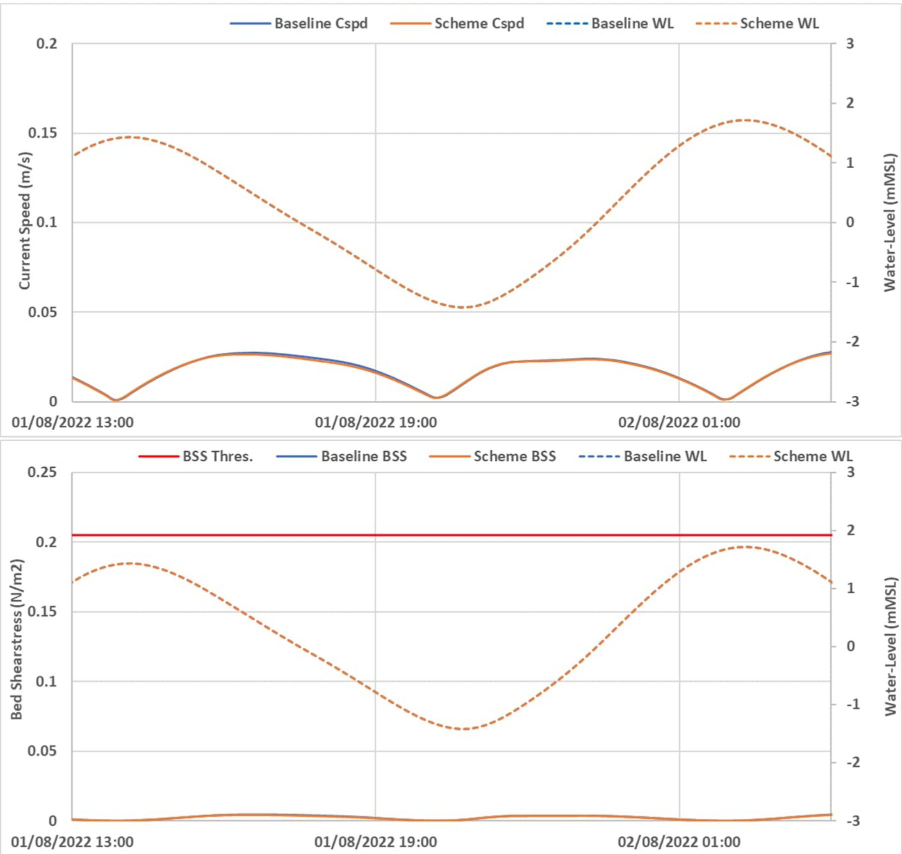

Figure 15. Peak Ebb Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development)

The same extraction locations as presented in *Figure 10.* have been used to extract data comparing baseline against development model runs but with the inclusion of 1:1 wind event from SSW and NE direction sectors. Again, addressing changes north and south of the Marine Facility during peak flows of a mean spring tide. Comparative time-series plots covering a mean spring tide during the representative SSW wind event are presented in *Figure 16. Peak Flood Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An SSW Wind 1:1-Year Event* and *Figure 17. Peak Ebb Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An SSW Wind 1:1-Year Event*, with the NE equivalents in *Figure 18. Peak Flood Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An NE Wind 1:1-Year Event* and *Figure 19. Peak Ebb Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An NE Wind 1 In 1 Year Event.*

These figures both indicate that despite faster current speeds being present due to the inclusion of the wind field, the offsets are still negligible with the inclusion of the Marine Facility. The largest modelled differences occur during the SSW wind event and are in the region of 0.01 m/s for current speeds and 0.03 N/m^2 for BSS. During this event the BSS is momentarily shown to exceed the BSS threshold (by 0.004 N/m^2), but this is reduced to below the threshold following the inclusion of the Development. However, this offset is negligible and only notable through the numerical model.

Even under wind events from direction sectors that will lead to the greatest magnification of current speeds, the installation of the Marine Facility will have minimal influence of both the flow regime and consequentially BSS. Any changes that are caused by the presence of the structure, will be rapidly dissipated.

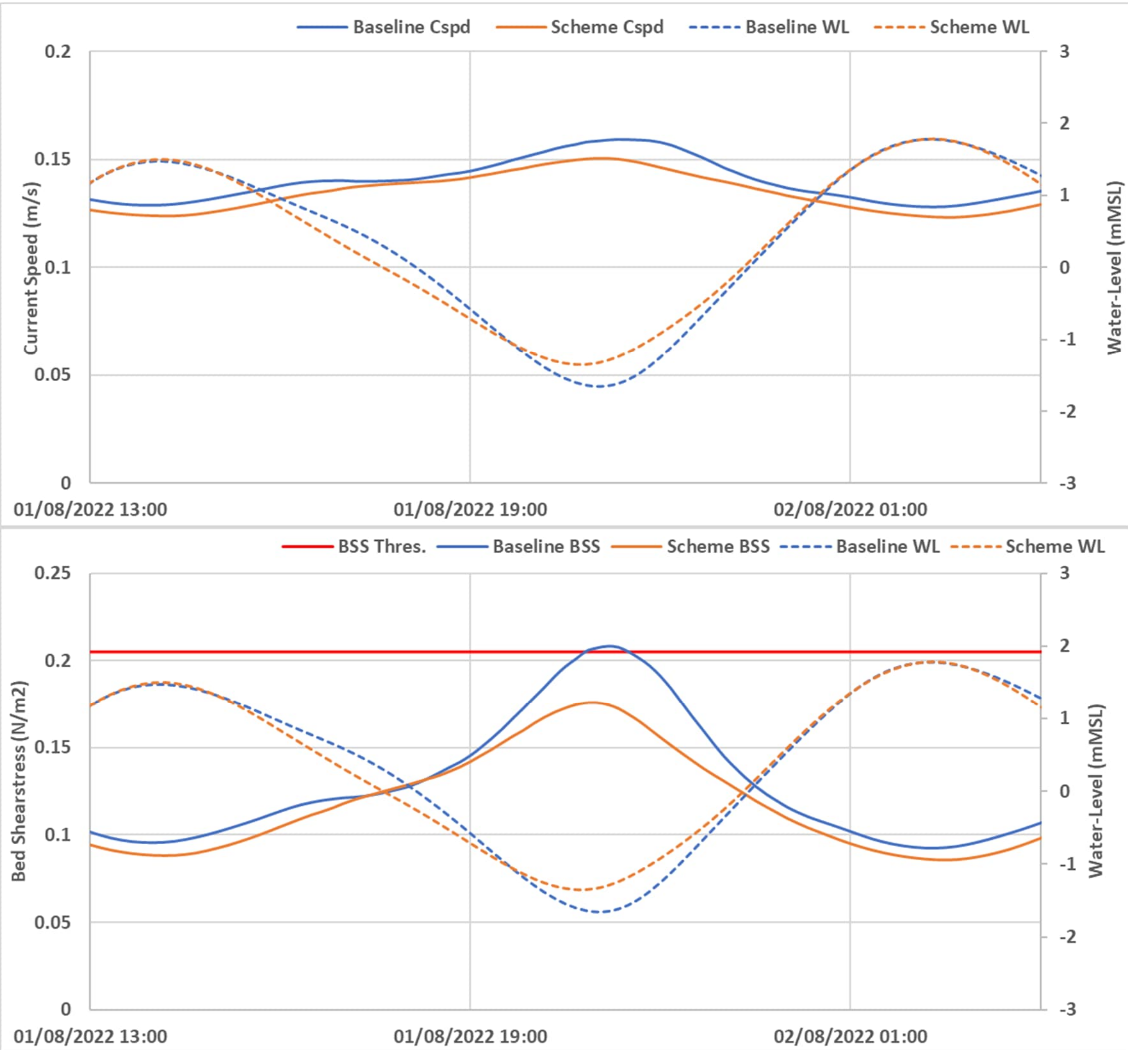

Figure 16. Peak Flood Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An SSW Wind 1:1-Year Event

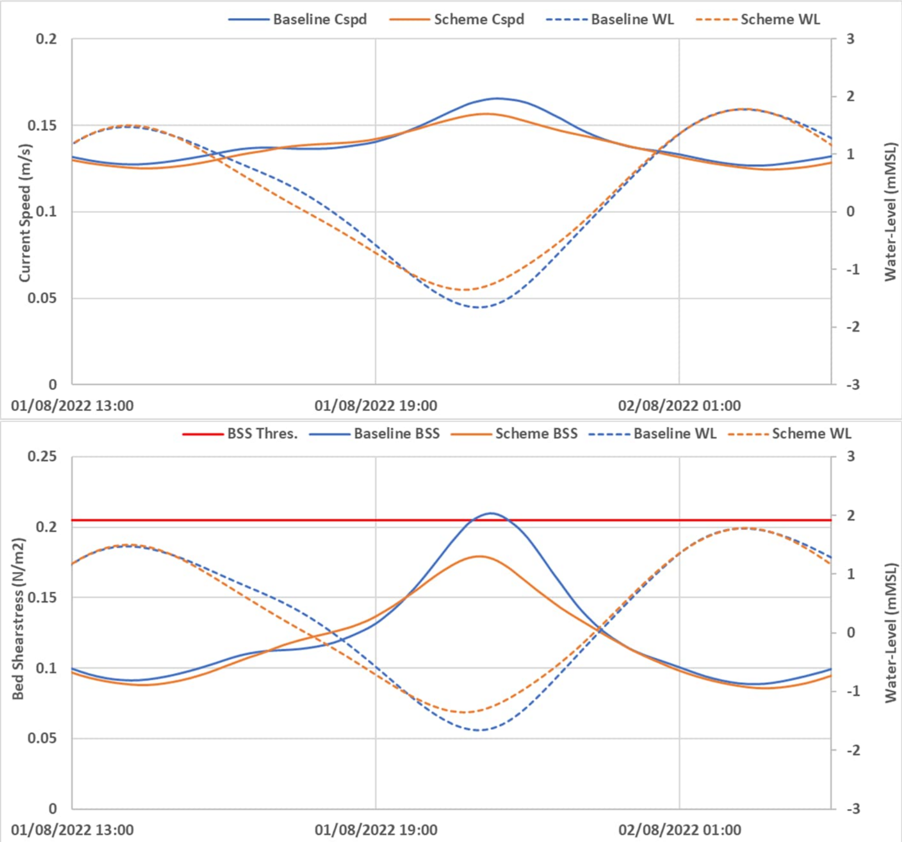

Figure 17. Peak Ebb Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An SSW Wind 1:1-Year Event

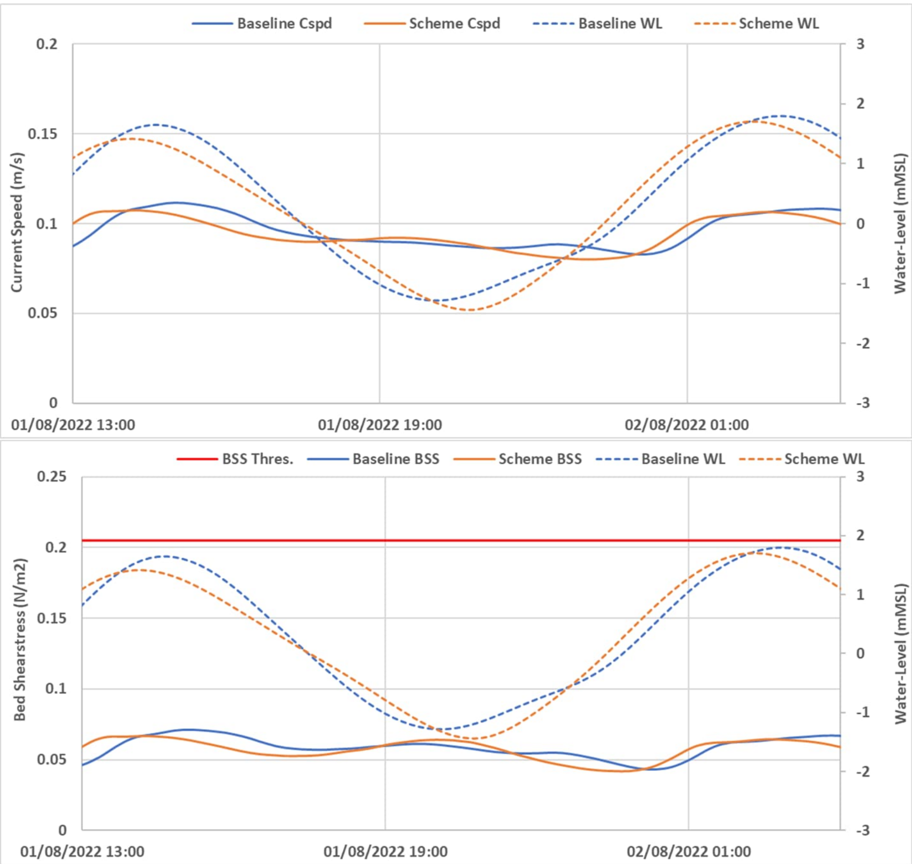

Figure 18. Peak Flood Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An NE Wind 1:1-Year Event

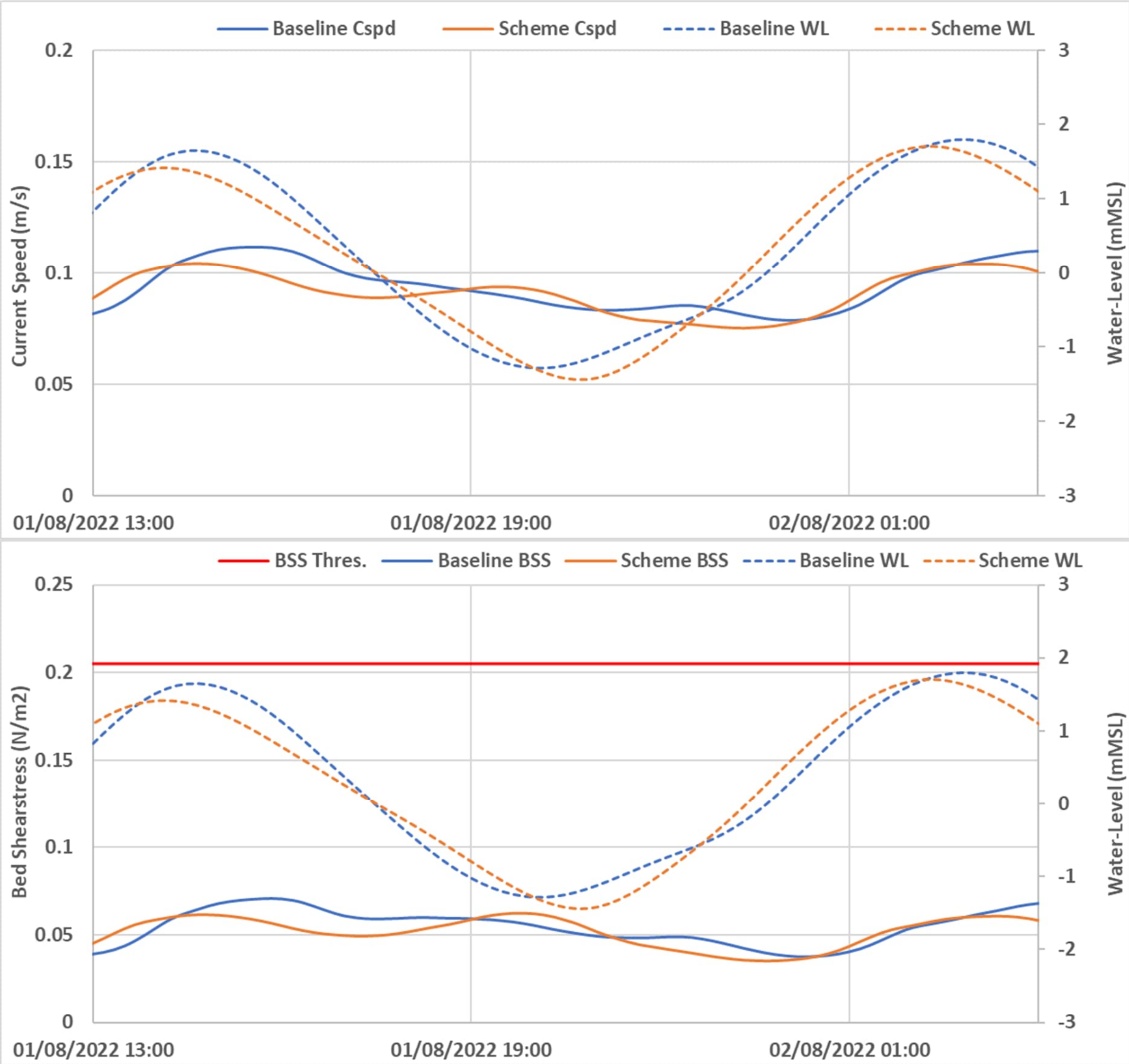

Figure 19. Peak Ebb Extraction Differences In Cspd (Top) And BSS (Bottom) With The Inclusion Of The Marine Facility (Development) During An NE Wind 1 In 1 Year Event

In terms of hydrodynamic conditions and the general sedimentary regime, the sensitivity in both cases is considered to be **High** but due to the **Negligible** magnitude of the effect, the overall significance is assessed as **Minor**.

18.8.2.2 Coastal Morphology and Outfalls

The analysis described above provides a description of changes to the underlying physical processes which drive sediment transport and ultimately dictate potential changes in coastal morphology during the operational phase of the Marine Facility. The predicted changes to hydrodynamic conditions, including both typical tidal conditions and a relatively extreme storm wave condition, demonstrate that there is limited potential for any changes to either the local or wider-scale coastal morphology. Even under more extreme conditions where the threshold BSS is exceeded due to the presence of the Marine Facility structures, this occurs for a very short duration and the associated magnitude is therefore **Negligible**.

Taking the **High** sensitivity of these two receptors (i.e. Coastal morphology and Outfalls) into consideration, the significance of the effect is still assessed as **Minor** in both cases.

18.9 Cumulative Effects

18.9.1 Inter-Cumulative Effects

There are no identified developments in the marine environment that have the potential to interact with the proposed Marine Facility. On this basis there are considered to be no potential inter-cumulative effects affecting the Development.

18.9.2 Intra-Cumulative Effects

There are no identified effects in the marine environment that have the potential for interaction. There are therefore no potential intra-cumulative effects due to the proposed Marine Facility.

18.10 Mitigation and Monitoring

18.10.1 Embedded Mitigation

The embedded mitigation that reduces the impact of the Marine Facility includes the following:

- Piled foundations will be used to support the deck of the Marine Facility. This provides minimal blockage to tidal currents and wave propagation relative to alternative construction options. This will minimise the impact of the Marine Facility on the local flows during the operational phase.
- The avoidance of dredging means there will be minimal disturbance to sediments on the seabed during the construction phase. The potential requirement for maintenance dredging and spoil disposal is also avoided.

18.10.2 Additional Mitigation, Compensation and Enhancement

Due to the negligible effect that the Marine Facility is shown to have on the physical marine environment, no additional mitigation, compensation, or enhancement measures are presented.

18.10.3 Monitoring

Although the effects summarised in *Table 18.5 Summary of Effects: Construction* and *Table 18.6 Summary of Effects: Operation are* limited to having a **Minor** significance, a limited scope of post-construction monitoring is recommended as a precautionary measure, as outlined below:

- Visual inspection of outfalls to check for accretion of sediment (monthly)
- Visual inspection of coastline 500 m either side of the Marine Facility to check for any localised erosion or accretion (monthly)

If after 5 years it is found from the monthly inspections that there is no change in local accretion and/or erosion, there would be no requirement for continued monitoring.

18.11 Residual Effects

Due to the 'Negligible' classification of the various potential impacts identified, no requirement for additional mitigation has been identified in which case the residual effects remain as assessed, minor adverse..

Table 18.5 Summary of Effects: Construction provides a summary of construction effects, as determined from the impact assessment presented above with operation effects provided in *Table 18.6 Summary of Effects: Operation*.

Table 18.5 Summary of Effects: Construction

Receptor	Description of Effect	Effect	Additional Mitigation	Residual Effects	Significance
Intertidal habitat	Direct loss of 6m^2 of intertidal area due to footprint of pile structures	Habitat no longer available. Minor adverse.	None	Minor adverse	Minor **Not Significant**
Subtidal habitat	Direct loss of 22m^2 of subtidal area due to footprint of pile structures	Habitat no longer available. Minor adverse	None	Minor adverse	Minor **Not Significant**
Water quality	Short-term disturbance of bed material due to installation of piles	Transient elevated suspended sediment concentrations in close proximity to the structure. Minor adverse	None	Minor adverse	Minor **Not Significant**

Table 18.6 Summary of Effects: Operation

Receptor	Description of Effect	Effect	Additional Mitigation	Residual Effects	Significance
Hydrodynamic conditions	Change in currents or water levels	Navigation and/or flood issues. Minor adverse.	None	Minor adverse	Minor **Not Significant**
Sedimentary regime	Change in sediment transport	Modified seabed morphology. Minor adverse	None	Minor adverse	Minor **Not Significant**
Coastal morphology	Erosion or accretion of sediment unrelated to natural processes	Unnatural accumulation of sediments along the coast. Minor adverse	None	Minor adverse	Minor **Not Significant**
Coastal outfalls	Local sediment accumulation	Blockage of outfall structure. Minor adverse	None	Minor adverse	Minor **Not Significant**

18.12 References

Flood risk assessments: Climate change allowances GOV.UK. Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#offshore-wind-speed-and-extreme-wave-height-allowance (Accessed: 12 October 2023).

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