REPORT

Dundee Capital Dredge - Numerical Modelling Report

Client: Port of Dundee Limited

Reference: PC6550-RHD-XX-XX-RP-EV-0063

Status: Final/01

Date: 1 July 2025

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HASKONING UK LTD.

2nd Floor One Strawberry Lane
Newcastle
NE1 4BX
United Kingdom
Water & Maritime
VAT registration number: 792428892

Phone: +44 191 2111300
Email: info@uk.haskoning.com
Website: haskoning.com

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Author(s):	Tanja Cooper
Drafted by:	Grace Dugdale, Tanja Cooper
Checked by:	Emily Foster, Dai Xuan Luong
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1 Introduction

One of the primary uses for the Port of Dundee is to service and support the offshore renewables industry. The port already provides facilities for the transhipment and storage of components, such as wind turbine generators (WTGs) and other component parts associated with wind farm projects. Due to the increasing size of the components and vessels used by the offshore renewables industry, the Port of Dundee Limited is proposing to undertake a suite of works at the Port of Dundee and Lady Shoal approach channel in order to accommodate the increasing needs of the offshore renewables industry.

2 Capital Dredging

The capital dredging works would be carried out as follows:

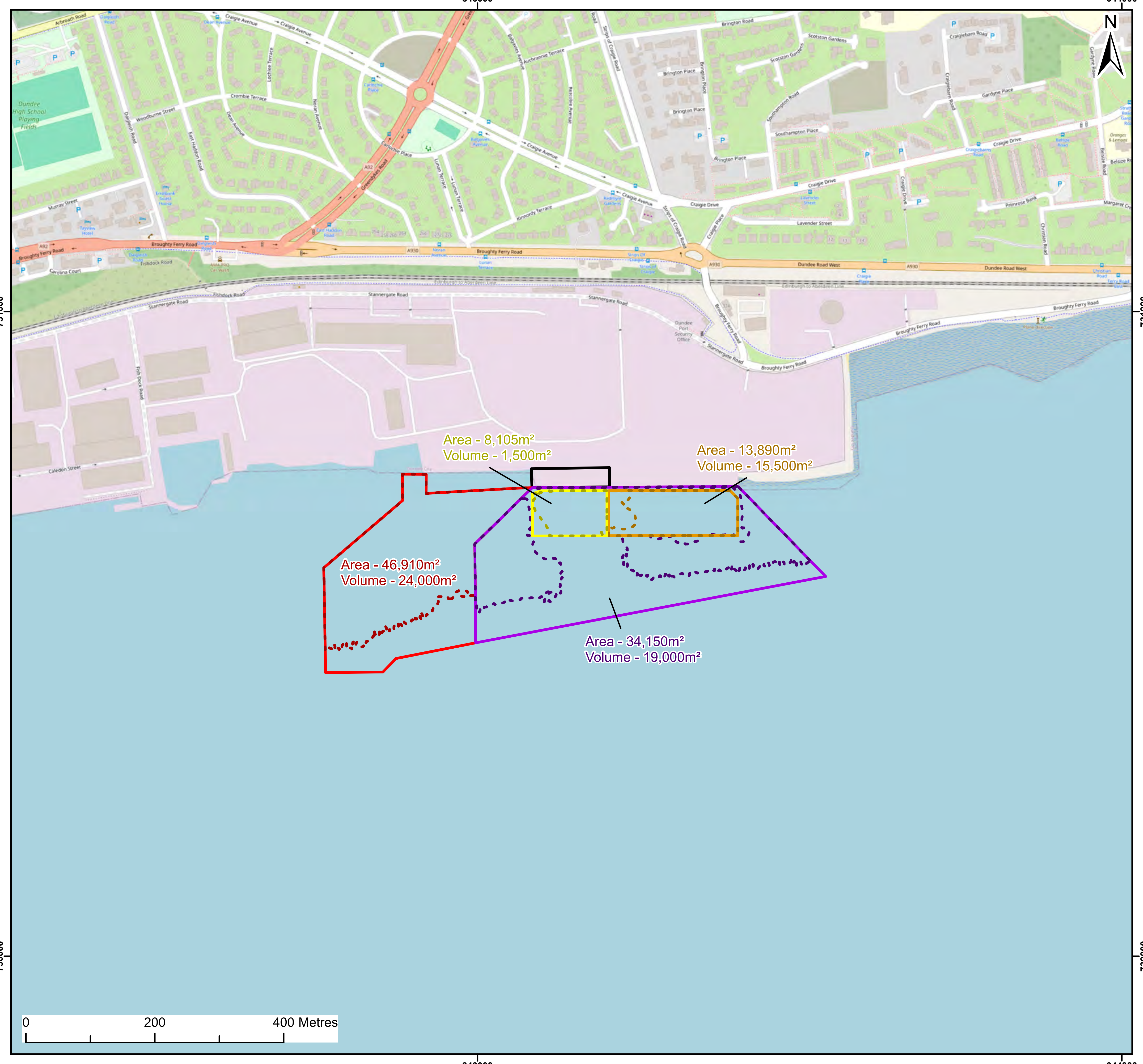
- Deepen the approach to DunEco Quay to -6m CD (red outline on **Figure 2-1**);
- Deepen the approach to the PCW to -6.5mCD (purple outline on **Figure 2-1**);
- Widen the PCW berth pocket to 70m and deepen to -9m CD (orange outline on **Figure 2-1**);
- Extend the berth pocket 200m to the east along the Prince Charles Wharf Extension (PCWE) and deepen to -10m CD (**Figure 2-1**); and
- Deepen a section of the Lady Shoal Approach channel to -6.5m CD (see **Figure 2-2**).

All dredging at the Port of Dundee, with the exception of a very small area in the south-west corner of the dredge footprint, is within the Port of Dundee Limited's licenced maintenance dredge area. The proposed dredging would generate approximately 60,000m^3 of material (105,000m^3 with an over-dredge allowance of 0.5m). The dredge depth would be between approximately 0.5m to 1m, and up to 2.5m within the berth pocket extension area. The dredge depth in the Lady Shoal Approach channel would mostly be less than 1m and would generate approximately 160,000m^3 of material (385,000m^3 with an over-dredge allowance of 0.5m). The actual dredging works would take place within the dredge footprints within thedredge areas, as shown on **Figure 1-2** and **Figure 1-3.** Total volume of dredged material would therefore be approximately 220,000m^3 (490,000m^3 with an over-dredge allowance of 0.5m). All dredging would be undertaken by back-hoe dredger, with the material being disposed of at the existing licenced Middle Bank disposal site (see **Figure 1-2**) using hopper barges. A summary of the proposed dredging can be seen in **Table 2-1**. The proposed dredging and disposal activities would take up to seven weeks to complete.

To support the assessment of potential effects, numerical modelling of tidal currents and suspended sediment transport changes caused by the construction and operation of the proposed development have been completed.

Table 2-1 Details of proposed dredge areas

Dredge location	Approximate Area (m^2)	Volume (m^3) (without over-dredge allowance)	Volume (m^3) (with 0.5m over-dredge allowance)
Approach to DunEco Quay	46,810	24,000	45,750
Approach to PCW	34,150	19,000	35,700
PCW berth pocket	8,105	1,500	1,800
PCWE berth pocket	13,890	15,500	21,750
Lady Shoal approach channel	458,500	160,000	385,000
Total	**563,955**	**220,000**	**490,000**



Legend:

Remedial Quay Works

DunEco Quay Approach Channel

Dredge Area

Dredge Footprint

Prince Charles Wharf Approach Channel

Dredge Area

Dredge Footprint

Proposed Extension to PCW Berth Pocket

Dredge Area

Dredge Footprint

Existing PCW Berth Pocket

Dredge Area

Dredge Footprint

Client:	Project:
Port of Dundee Limited	Port of Dundee Capital Dredge and Quay Improvement Works

Title:

Proposed Works at the Port of Dundee

Figure: 2-1 Drawing No: PC6550-RHD-XX-ZZ-DR-Z-0002

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	10/06/2025	JH	RG	A3	1:6,000
P01	10/12/2024	GC	RG	A3	1:6,000

Co-ordinate system: British National Grid

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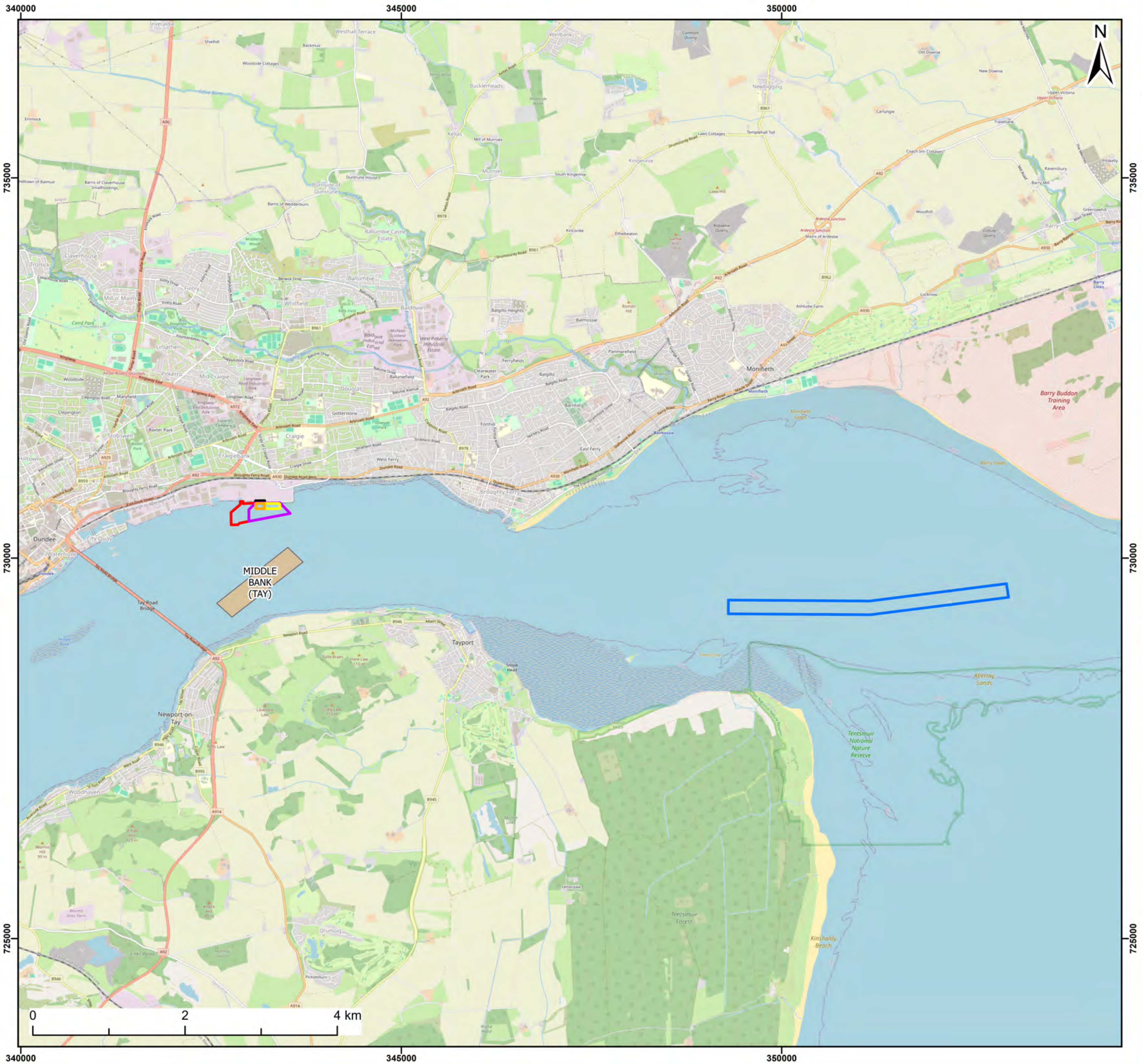

Legend:
- Prince Charles Wharf Approach Channel Dredge Area
- DunEco Quay Approach Channel Dredge Area
- Proposed Extension to PCW Berth Pocket
- Existing PCW Berth Pocket
- Lady Shoal Approach Channel Dredge Area
- Quay Improvement Works
- Disposal Site

Client:	Project:
Port of Dundee Limited	Port of Dundee Capital Dredge and Quay Improvement Works

Title:

Location Plan showing the Proposed Scheme

Figure:	2-2	Drawing No:	PC6550-RHD-XX-ZZ-D-EV-0064		
Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P01	10/07/2025	JH	JG	A3	1:50,000

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3 Approach

Haskoning utilised the MIKE software package developed by DHI, which includes the MIKE21 (2D) and MIKE3 (3D) Hydrodynamic Models (HD), for simulating water level and current speeds in response to tidal and atmospheric forcing.

The study adopted Haskoning's existing regional hydrodynamic model of the UK, which has been calibrated by water level data at numerous sites around the UK coastline. The regional model provided water level and velocity boundary conditions for the local hydrodynamic model to simulate tidal hydrodynamics and sediment plume dispersion.

The local hydrodynamic model was developed using the latest available bathymetric data at the site and calibrated by measured water levels and current speeds. This calibrated local model was used to quantify the potential effect on hydrodynamics by the proposed dredging and disposal activities. Additionally, the local hydrodynamic model was coupled with the MIKE Mud Transport (MT) module to simulate sediment plume dispersion in 3D.

4 Input Data

This section summarises the data that has been collated and utilized for the HD model setup and calibration. It also gives details of the data that was used for the MT model.

4.1 Bathymetric Data

For the regional hydrodynamic model, the bathymetry was based on EMODnet bathymetry data supplemented by more recent bathymetry data from the UK Hydrographic Office's Admiralty Maritime Data Solutions[1] (**Figure 4-1**).

The following bathymetry was collated and used in the local hydrodynamic model:

- Detailed bathymetry data surveyed in 2024 was provided by the client covering the Port of Dundee area and the Lady Shoal approach channel (**Figure 4-2**).
- Detailed bathymetry data downloaded from the UK Hydrographic Office's Admiralty Maritime Data Solutions (**Figure 4-3**), covering the deep channel of the Tay River and offshore area.
- For shallow areas where there was no detailed bathymetry available, C-MAP bathymetry data has been used. C-MAP is digital global navigational charts provided by DHI. (**Figure 4-3**).

[1] Seabed Mapping (admiralty.co.uk)

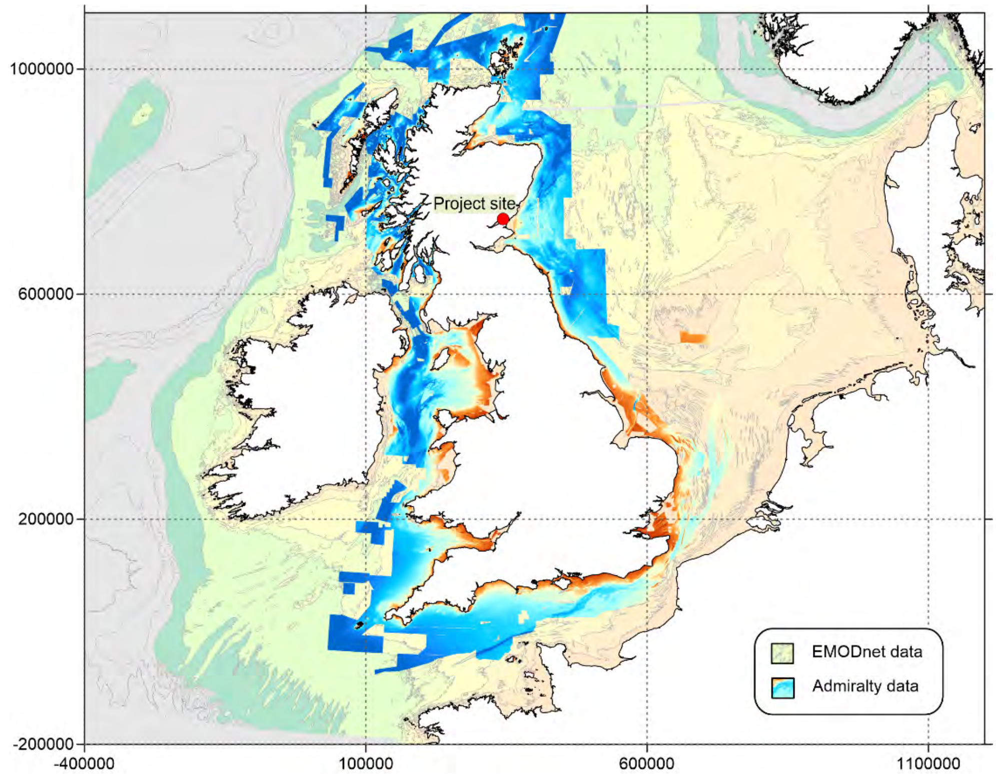


Figure 4-1 EMODnet and Admiralty Maritime Data Solutions' data for regional model

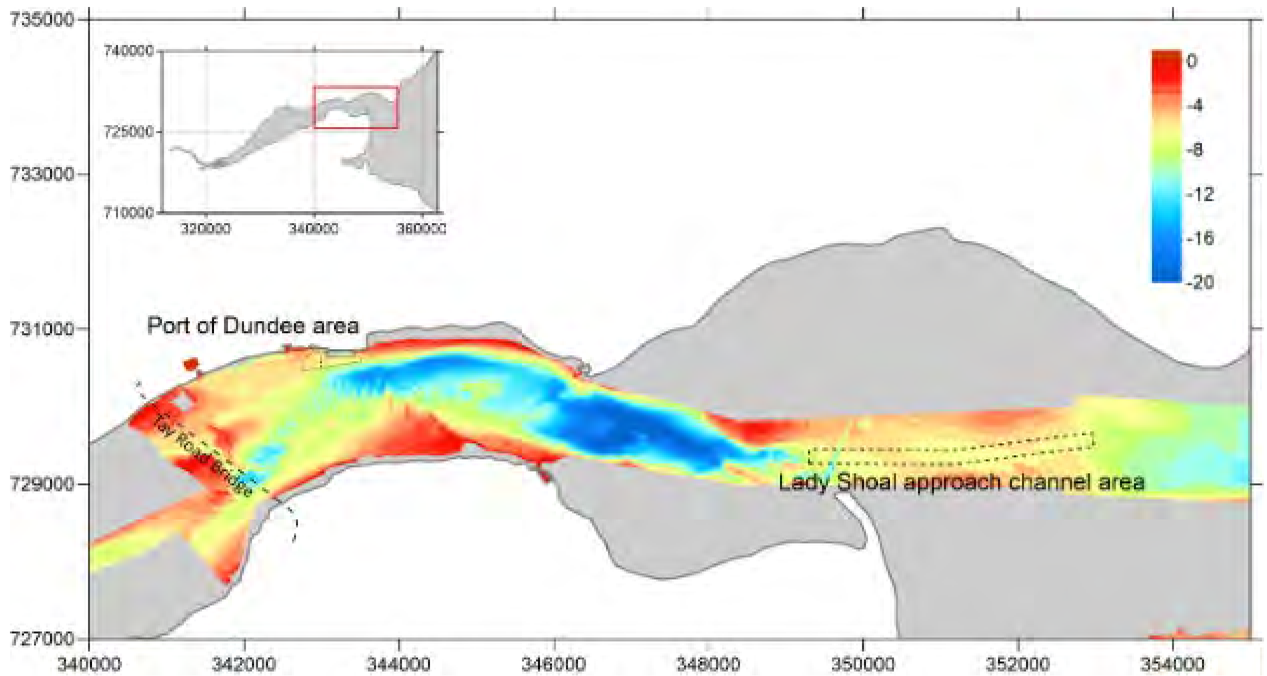


Figure 4-2 Detailed bathymetry data at and around project site

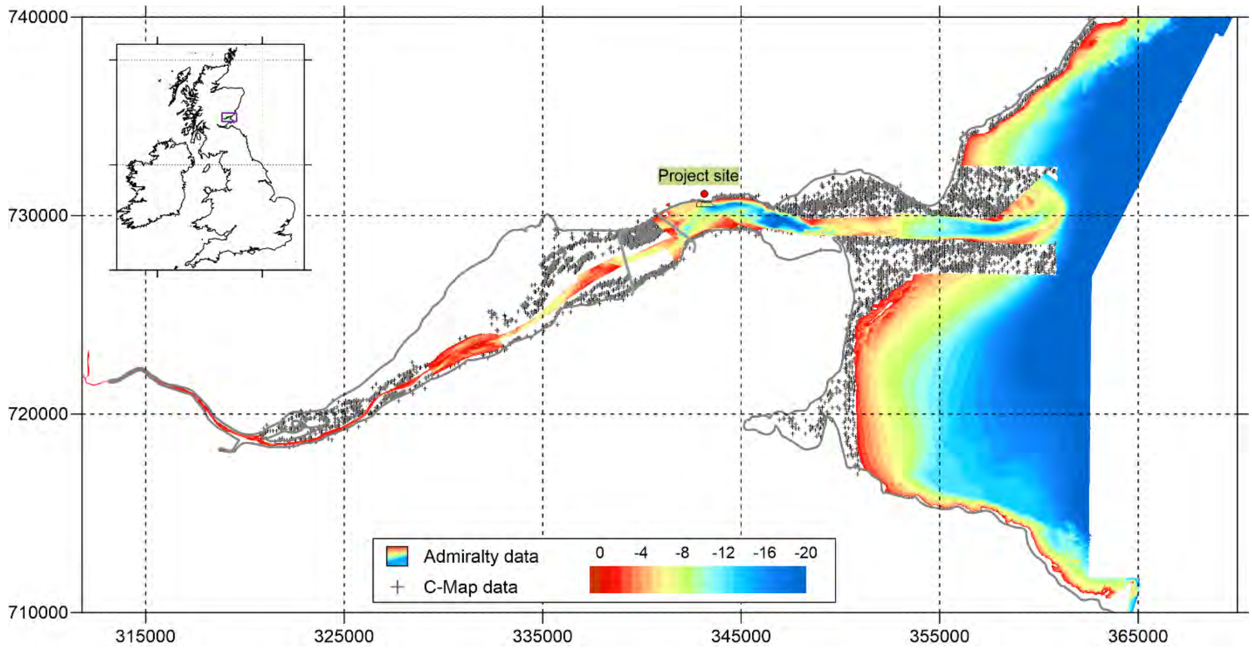


Figure 4-3 Coverage of local bathymetry data used in the local model

4.2 Water Level Data

Measured water levels from 01st January 2025 to 28th February 2024 were downloaded from British Oceanographic Data Centre (BODC)[2] recorded at three A-Class tide gauges: Aberdeen, Leith and North Shields. The locations of these three tide gauges are shown in **Figure 4-4** and the coordinates of these locations are provided in **Table 4.1**. These measured water levels were used to calibrate the regional model.

Water level survey data from 23rd January 2025 to 25th February 2025 were collected by Partrac Ltd at 2 locations using Acoustic Wave and Current Profiler (AWAC) (**Appendix 1**). Site 1 is near the Port of Dundee area, and Site 2 is near the Lady Shoal approach channel area. The locations of these two tide gauges are shown in **Figure 4-5** and the coordinates of these locations are provided in **Table 4.2**. These measured water levels were used to calibrate the local model.

[2] www.bodc.ac.uk

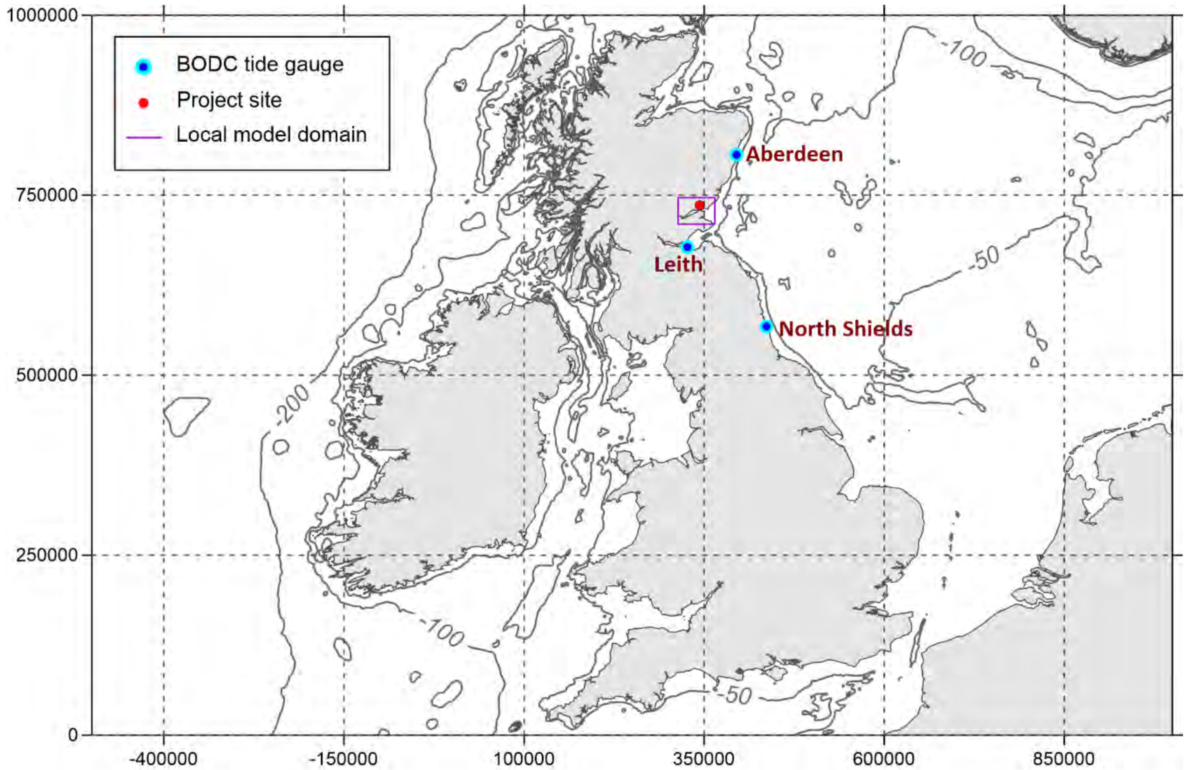


Figure 4-4 Indication of tidal gauges

Table 4.1 Measured water levels from BODC

Station name	Longitude	Latitude	Time interval (minute)	Duration	Description
Aberdeen	-2.05	57.14	15	1/1/2025 - 13/2/2025	Water level
Leith	-3.18	55.98	15	1/1/2025 - 28/2/2025	Water level
North Shields	-1.43	55.00	15	1/1/2025 - 28/2/2025	Water level

4.3 Currents

The measured current data was provided by Partrac Ltd, measured at two locations using AWAC between 23rd January 2025 and 25th February 2025. Site 1 is near the Port of Dundee area, and Site 2 is near the Lady Shoal approach channel area. Descriptions of the measured data, including locations, are provided in **Table 4.2**.

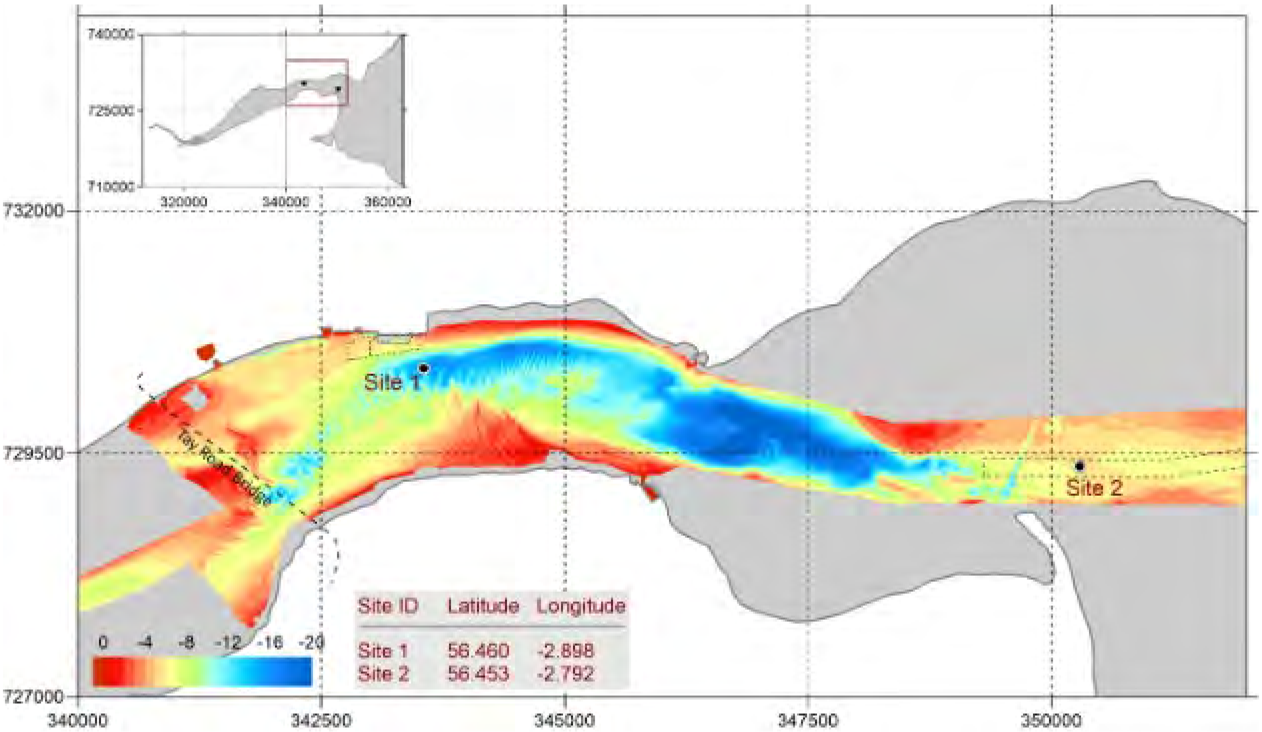


Figure 4-5 Location of current and water level measurements

Table 4.2 Locations of the measured current speed and water level.

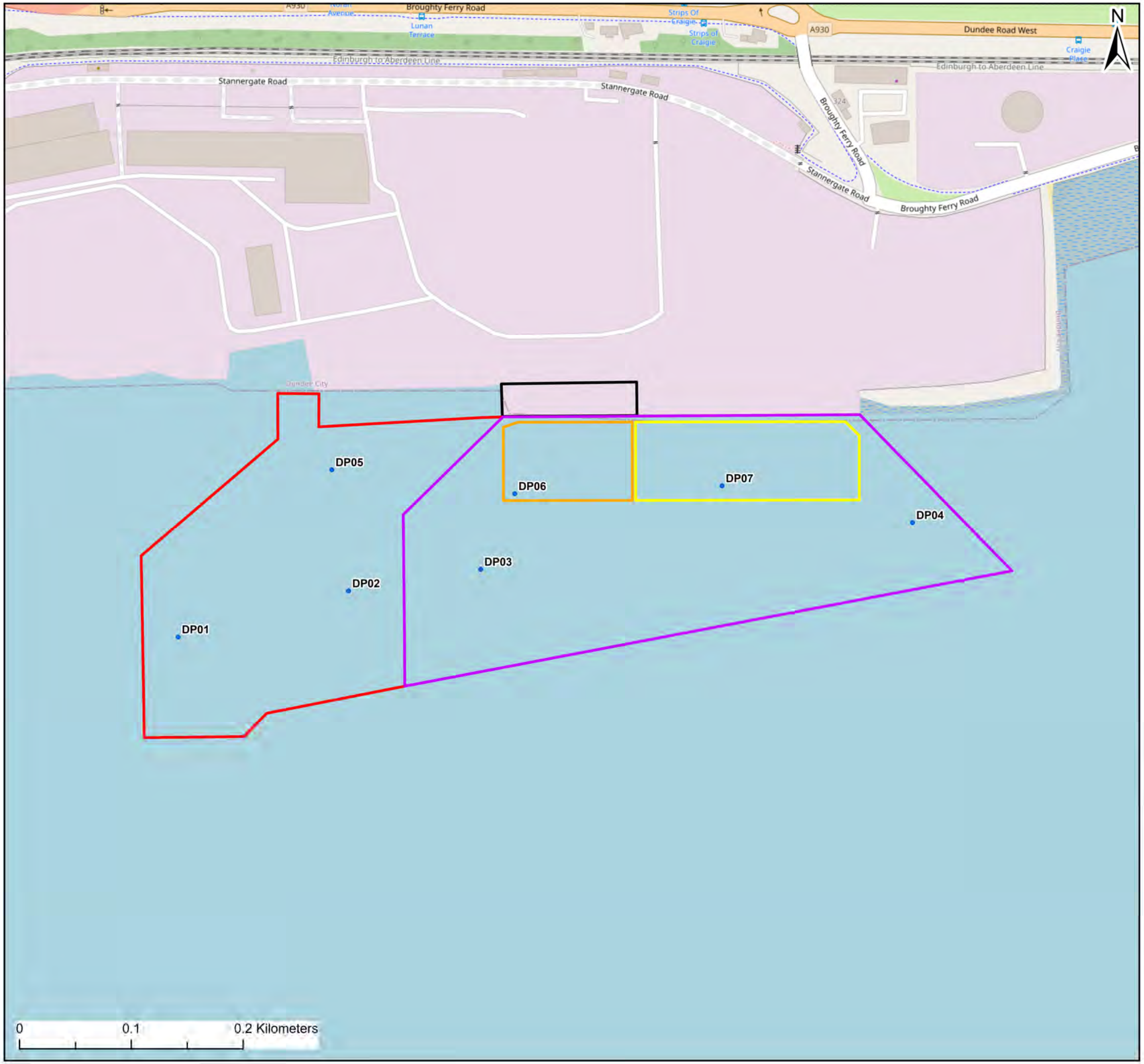
Site ID	Longitude	Latitude	Time interval (minute)	Duration	Description
Site 1	-2.898	56.460	5	23/1-25/2/2025	Current speed and Water level
Site 2	-2.792	56.453	5	23/1-25/2/2025	Current speed and Water level

4.4 Sediment Data

In line with the Marine Directorate's guidelines on pre-dredge sampling protocol[3], a site-specific sampling survey was undertaken in February 2025, during which sediment samples were collected for the following chemical and physical analyses. Sixteen vibrocores were collected from within the proposed dredge areas (**Figures 4-6** and **4-7**) (sufficient for a dredge volume of up to 600,000m^3), with sub-samples taken in accordance with Marine Directorate guidance. In total 35 samples were collected.

PSA results show that the sediment to be dredged is highly variable and comprises mixed sediments with an average of 26.4% gravel, 43% sand and 30.7% silt.

[3] Guidance for the sampling and analysis of sediment and dredged material to be submitted in support of applications for sea disposal of dredged material.



Legend:
- Prince Charles Wharf Approach Channel Dredge Area
- DunEco Quay Approach Channel Dredge Area
- Quay Improvement Works
- Proposed Extension to PCW Berth Pocket
- Existing PCW Berth Pocket
- VC Locations

Client:	Project:
Port of Dundee Limited	Port of Dundee Capital Dredge and Improvement Works Archaeological Assessment and Protocol for Archaeological Discoveries

Title:

Location of Vibrocores - Page 1 of 2

Figure: 4-6 | Drawing No: PC6550-RHD-XX-ZZ-DR-Z-0049

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	25/06/2025	JH	VB	A3	1:3,500

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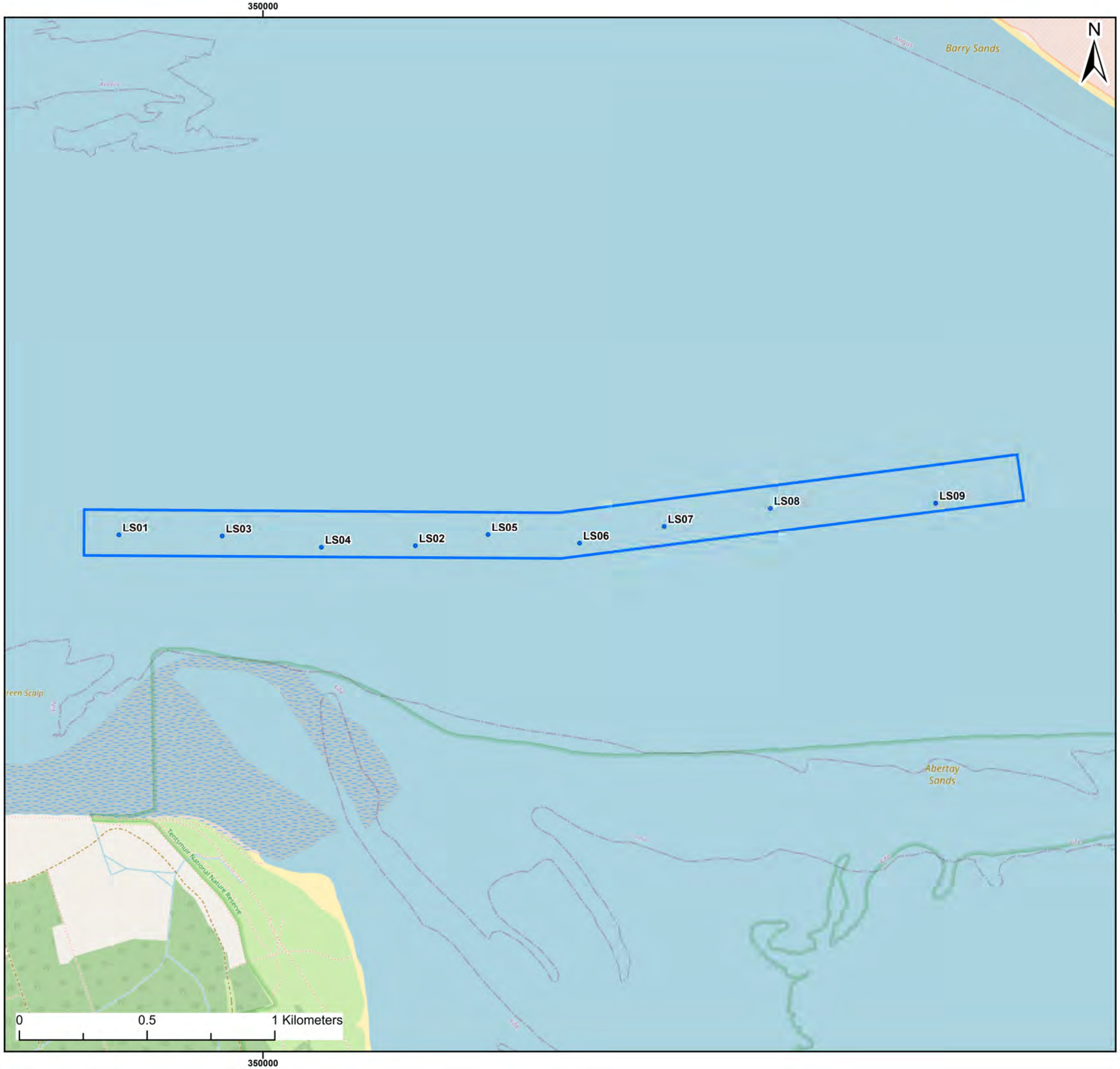

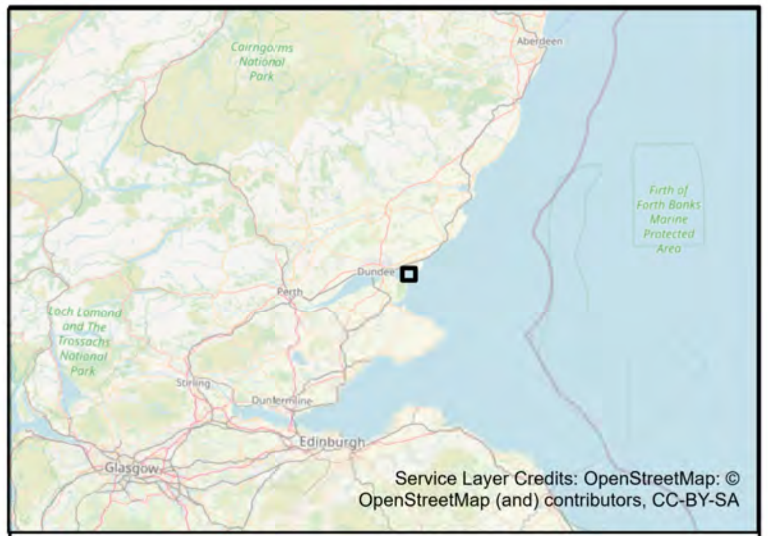

Legend:

- Lady Shoal Approach Channel Dredge Area
- VC Locations

Client:	Project:
Port of Dundee Limited	Port of Dundee Capital Dredge and Improvement Works Archaeological Assessment and Protocol for Archaeological Discoveries

Title:

Location of Vibrocores - Page 2 of 2

Figure:	4-7	Drawing No:	PC6550-RHD-XX-ZZ-DR-Z-0049

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
P02	25/06/2025	JH	VB	A3	1:15,000

Co-ordinate system: British National Grid

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5 Hydrodynamic Model

5.1 Computational Mesh and Bathymetry

5.1.1 Regional model

The computational mesh consists of 292,000 elements and 143,000 nodes. As the regional model was developed for simulation of large-scale circulation patterns, the mesh resolution is relatively coarse, ranging from 1km to 5km. In general, the grid resolution increases towards the coastline to capture the nearshore shallow water effects (**Figure 5-1**).

The model bathymetry and grid were developed using EMODnet bathymetry data and Admiralty Maritime Data Solutions' data, with coastline positions digitised from Google Earth. This combined model bathymetry, shown in Figure 5.2, was then used to generate the model bathymetry.

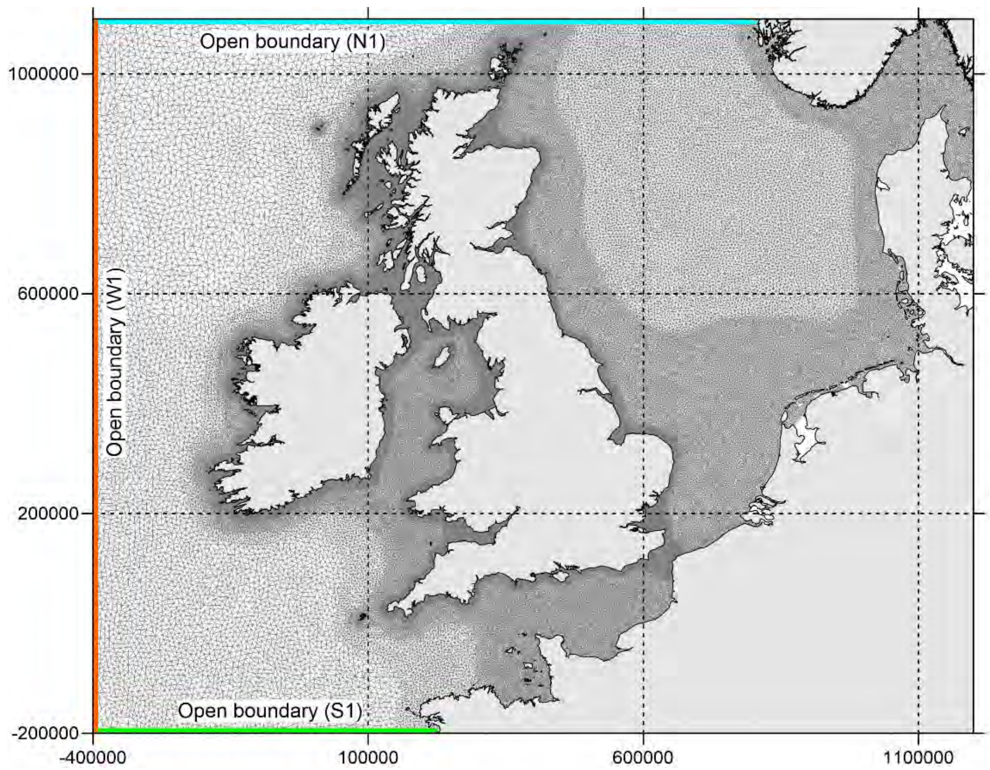

Figure 5-1 Computational mesh of the regional HD model

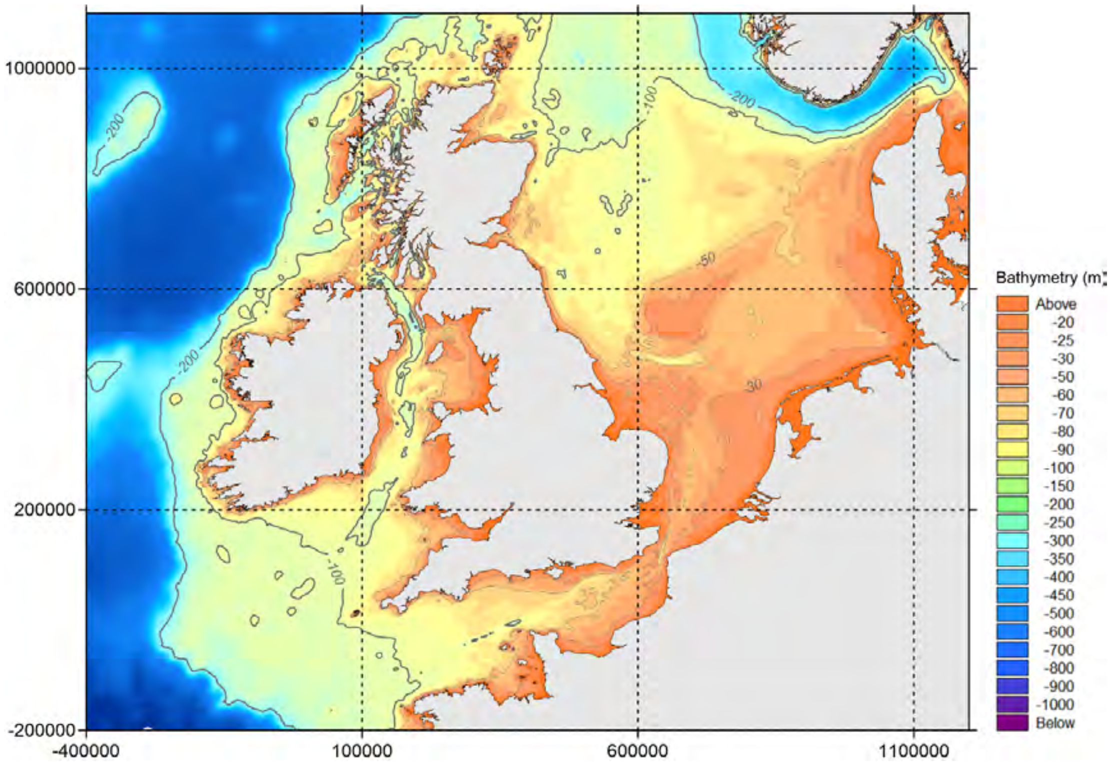

Figure 5-2 Regional HD model bathymetry

5.1.2 Local model

The bathymetry of the existing layout was generated using combined data from the client, UKHO and C-MAP.

The bathymetry of the Option layout detailed below was modified to reflect the two dredged areas at the Port of Dundee Area and the Lady Shoal approach channel (see **Figure 5-3** and **Figure 5-4**). The target dredge depths of each dredge area that were incorporated into the computation bathymetry are outlined in **Table 5.1**.

Table 5.1: Target dredge depths of each dredge area incorporated into the bathymetry for the Option layout

Dredge Area	Target Dredge Depth [mCD]
DunEco Quay Approach	6
Prince Charles Wharf Approach	6.5
Berth Area 2 (PCW)	9
Berth Area 1 (PCWE)	10
Lady Shoal	6.5

Like the regional model, a flexible mesh was adopted in the local model. A coarser grid (100-250m) was used in peripheral areas and a finer grid (5-6m) in the areas of interest. The computational mesh for the local model consists of 100,434 elements and 51,581 nodes (see **Figure 5-6**).

The model bathymetry for the Existing and Option layouts are shown in **Figure 5-7 - Figure 5-11**.

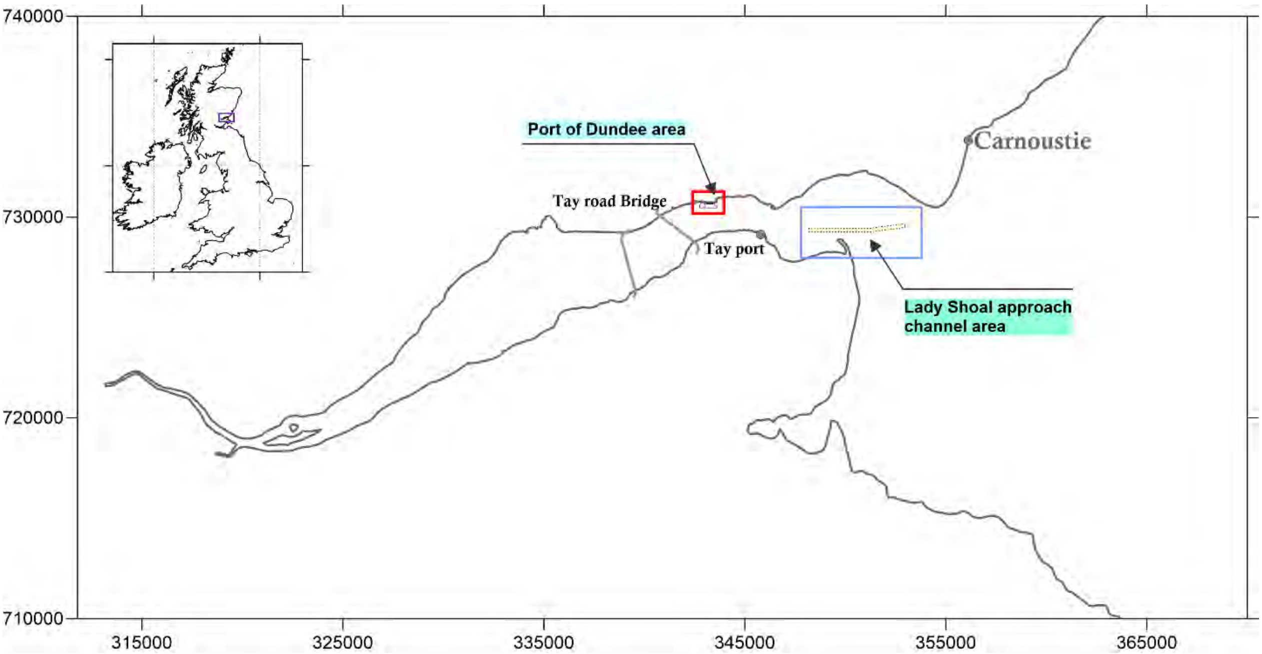

Figure 5-3 Dredging locations

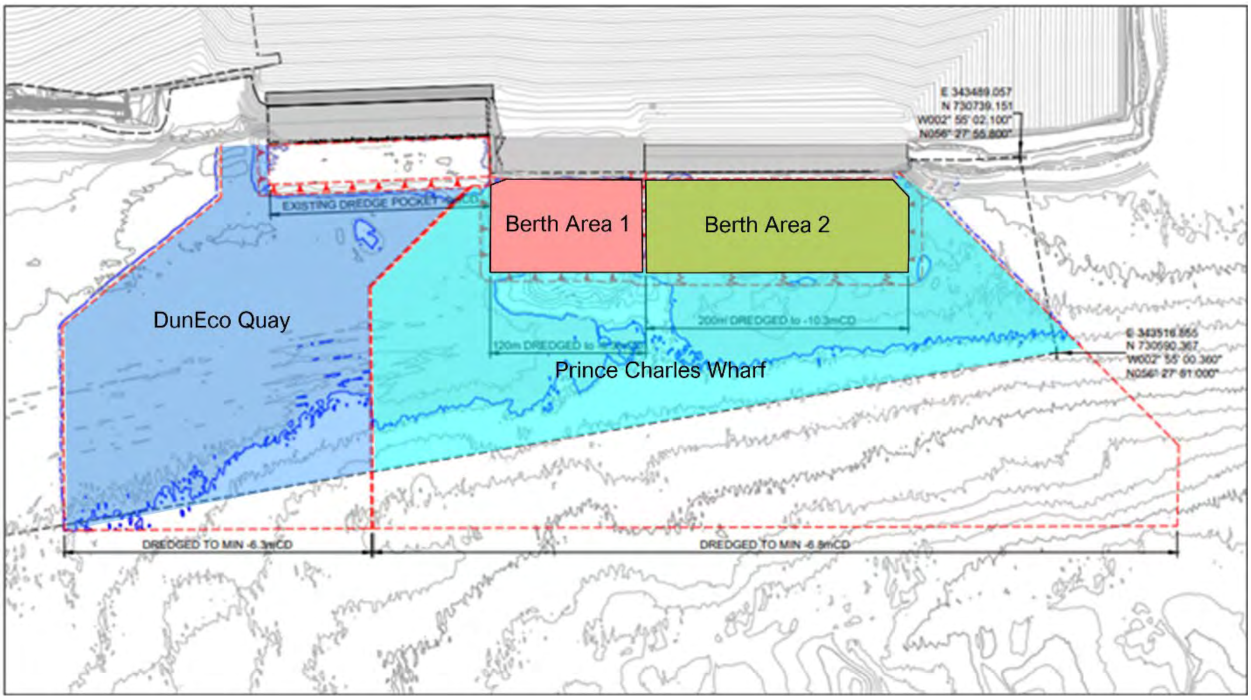

Figure 5-4 Port of Dundee expansion – dredging plan

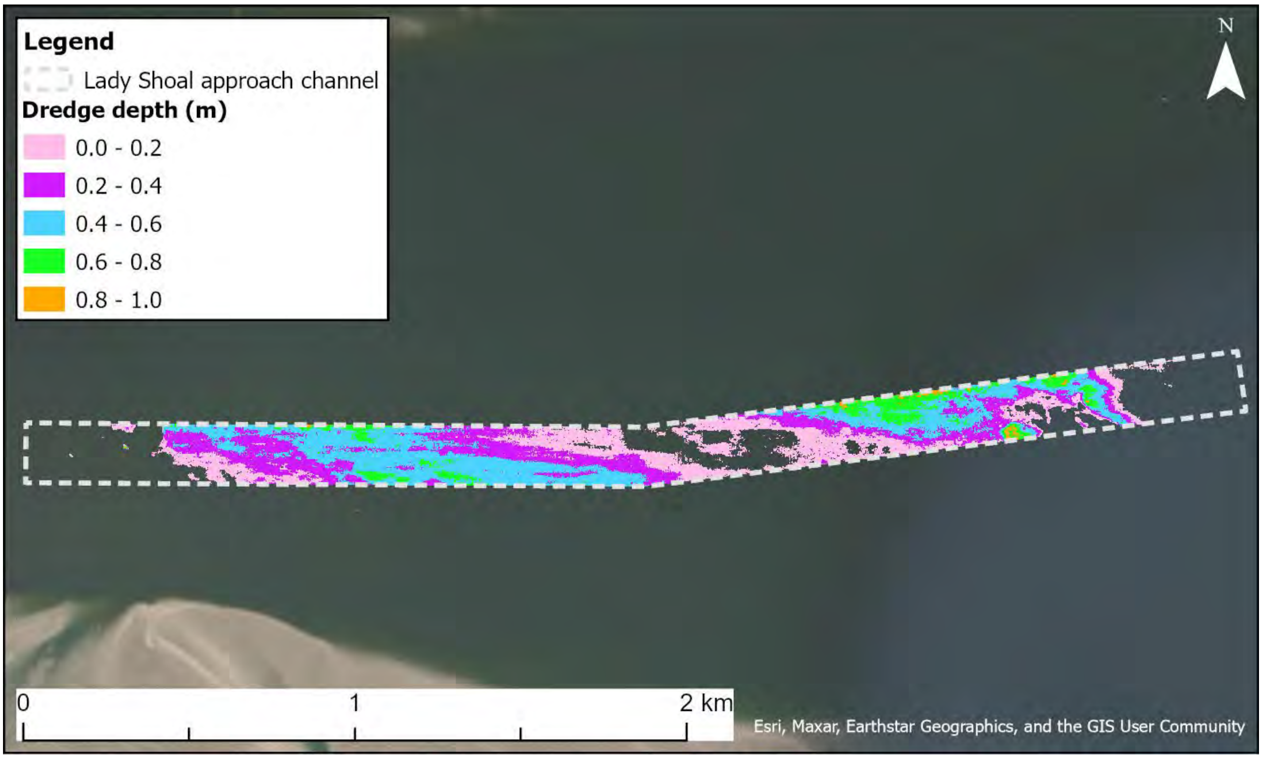

Figure 5-5 Lady Shoal approach channel – dredging plan

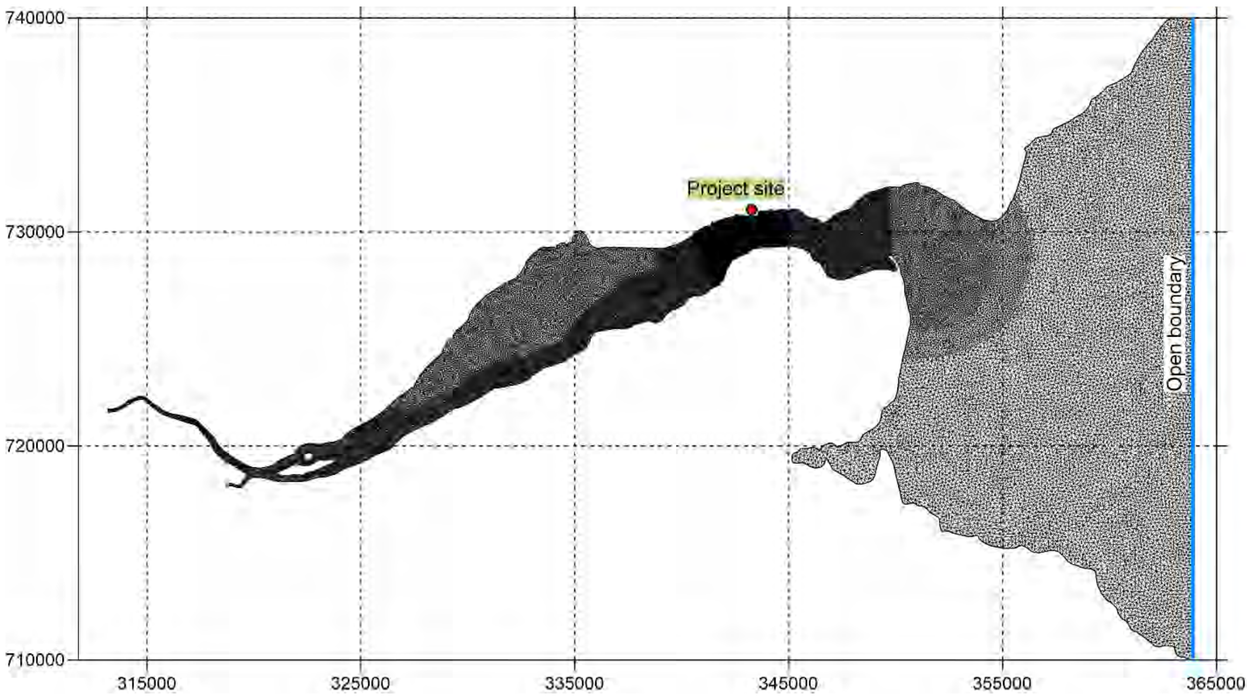

Figure 5-6 Local model computational mesh

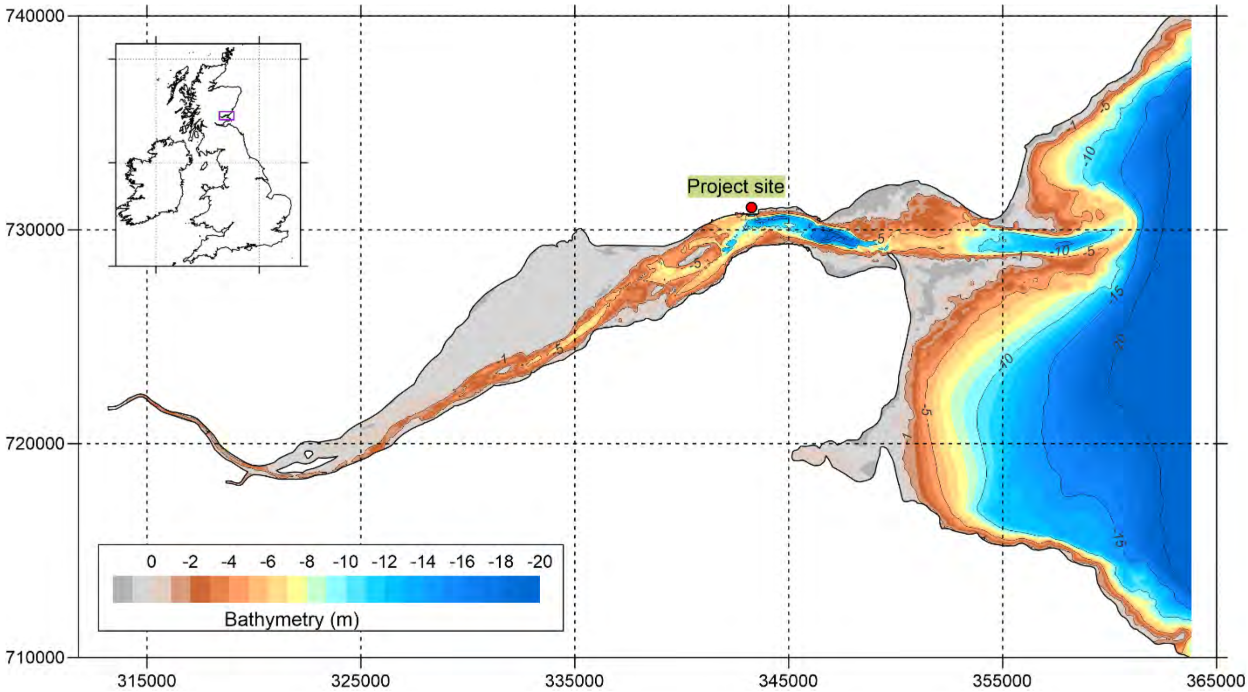

Figure 5-7 Bathymetry of the local model domain (Existing layout)

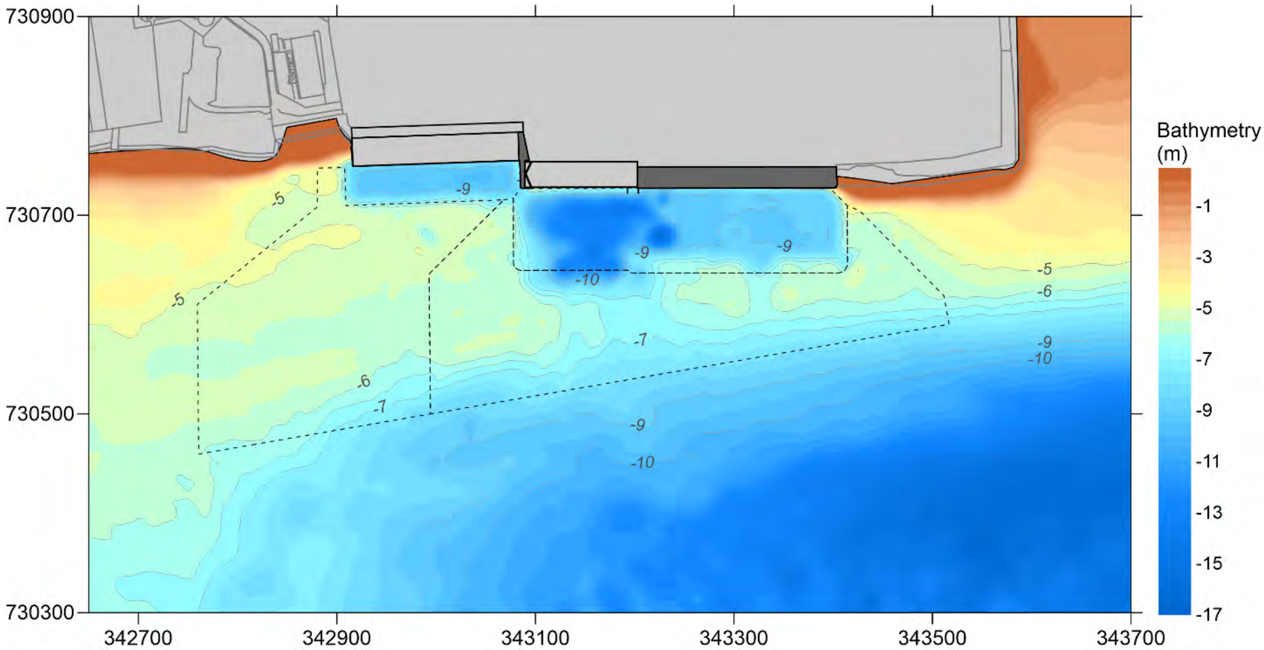

Figure 5-8 Detailed bathymetry of the Existing layout of the local model at and around the Port of Dundee area

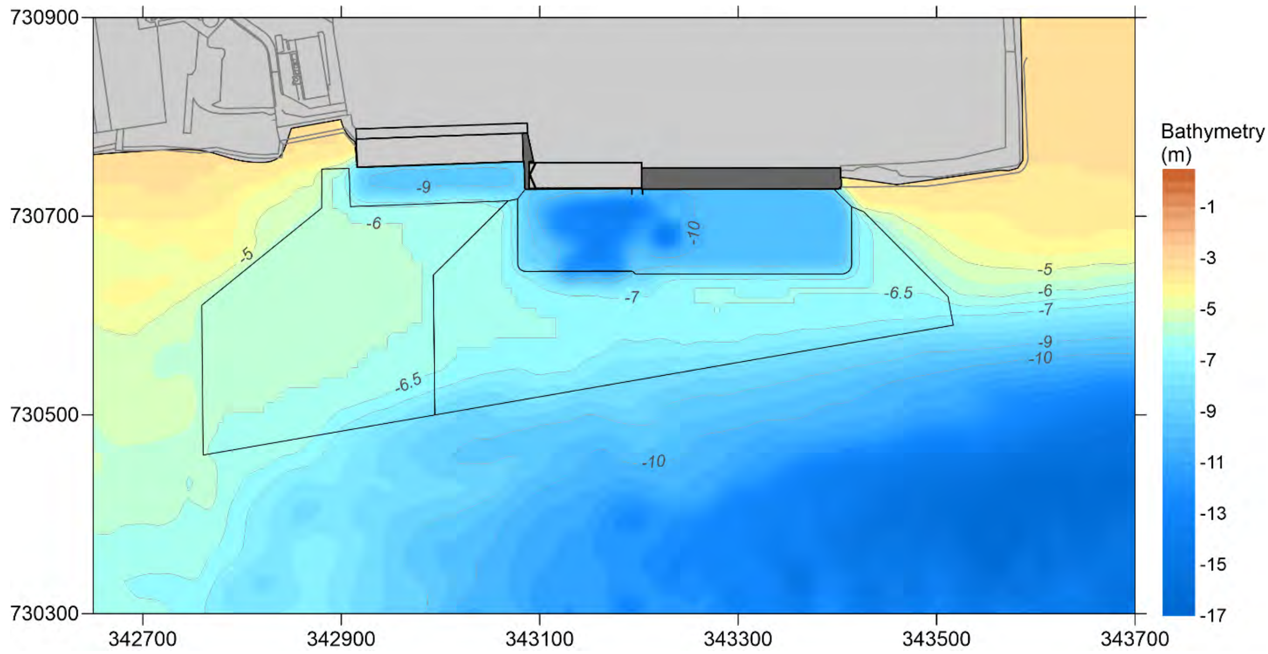

Figure 5-9 Detailed bathymetry of the Option layout of the local model at and around the Port of Dundee area

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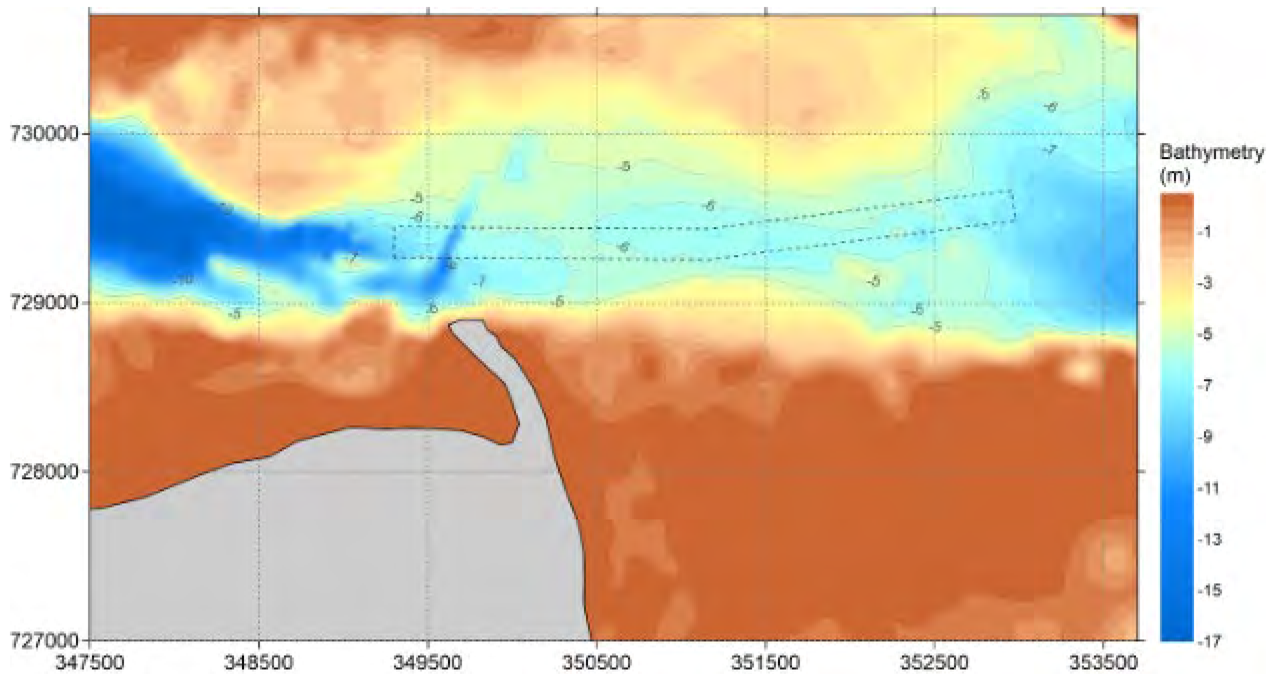

Figure 5-10 Detailed bathymetry of the Existing layout of the local model at and around the Lady Shoal approach channel

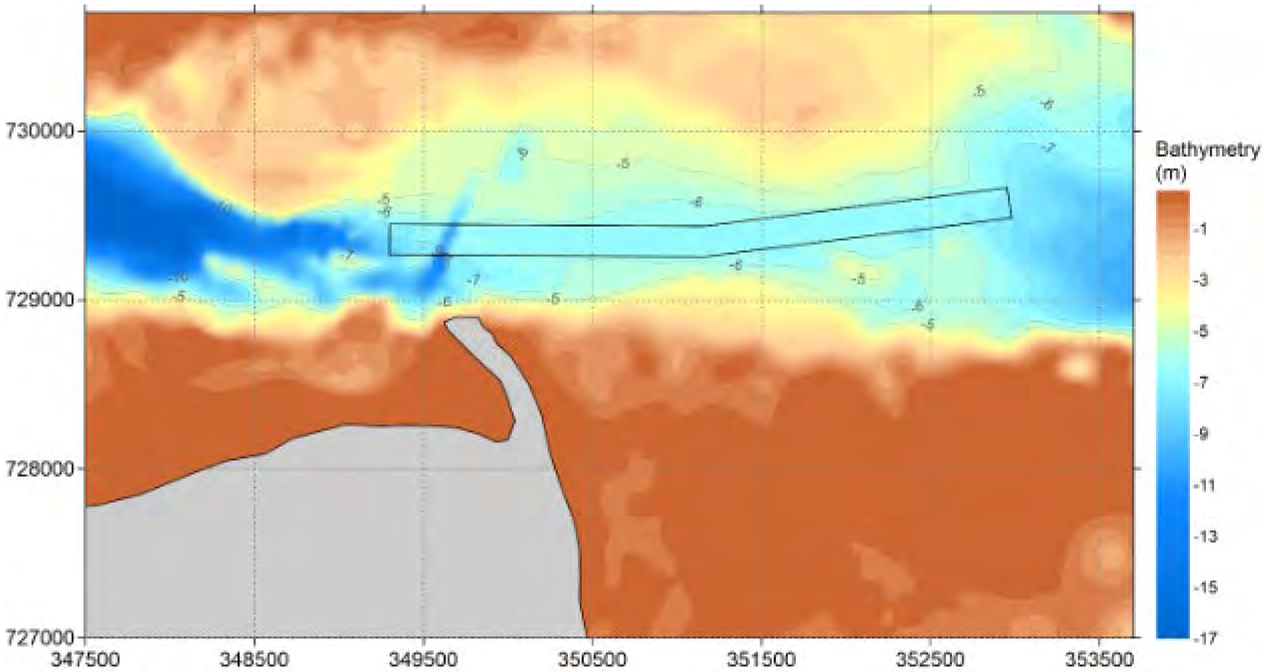

Figure 5-11 Detailed bathymetry of the Option layout of the local model at and around the Lady Shoal approach channel

5.2 Boundary Conditions

Spatially and temporally varying water levels were used at the open boundaries of the regional model. The water level input data for these boundaries were extracted (at locations N1, S1 and W1 as in **Figure 5-1**) from the Global Tidal Model of DHI with a spatial resolution of 0.25° × 0.25°. The data represents the major diurnal (K1, O1, P1 and Q1) and semidiurnal tidal constituents (M2, S2, N2 and K2) based on OPEX/POSEIDON altimetry data.

The open boundary of the local model, as shown in **Figure 5-6**, utilised temporally varying water levels and velocities. The inputs for velocity and water levels at the local model's open boundary were provided from the regional model.

5.3 Model Calibration

5.3.1 Regional model calibration (water level)

For this study, the regional model was re-calibrated using measured water levels recorded at Aberdeen and Leith from 15 January 2025 to 16 February 2025. Re-calibration performance was assessed by both visual comparison and quantifying errors using statistical parameters, including Correlation Coefficient and Mean Absolute Error. **Figure 5-12** and **Figure 5-13** show the modelled and measured water levels, and **Table 5.2** presents quantified errors. The model errors in predicted water level are minimal, with a Mean Absolute Error of no more than 0.15m. Both visual comparison and error statistics show reasonably good agreement between the measured and modelled water levels.

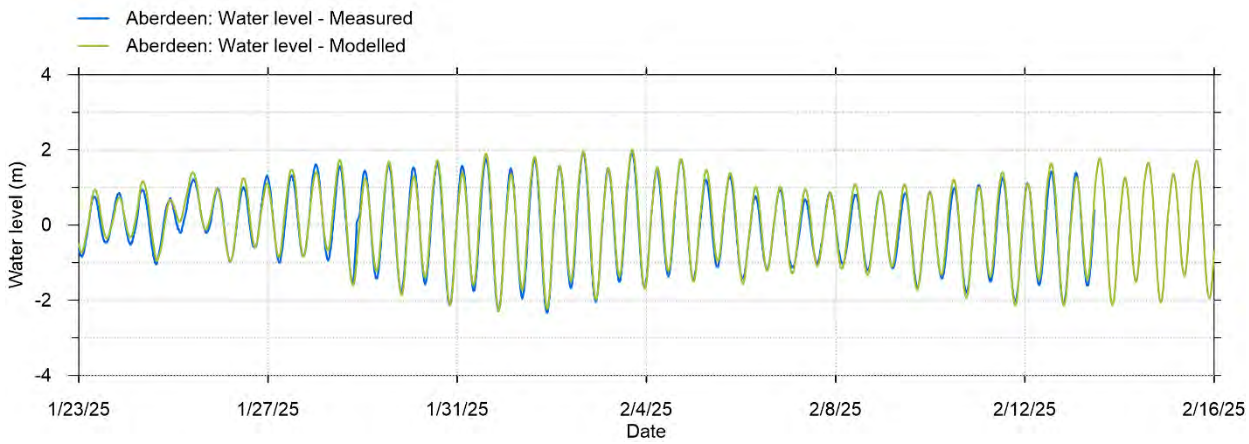

Figure 5-12 Time series comparison between simulated vs observed water levels at Aberdeen from 23/1 to 13/2/2025 (Regional model)

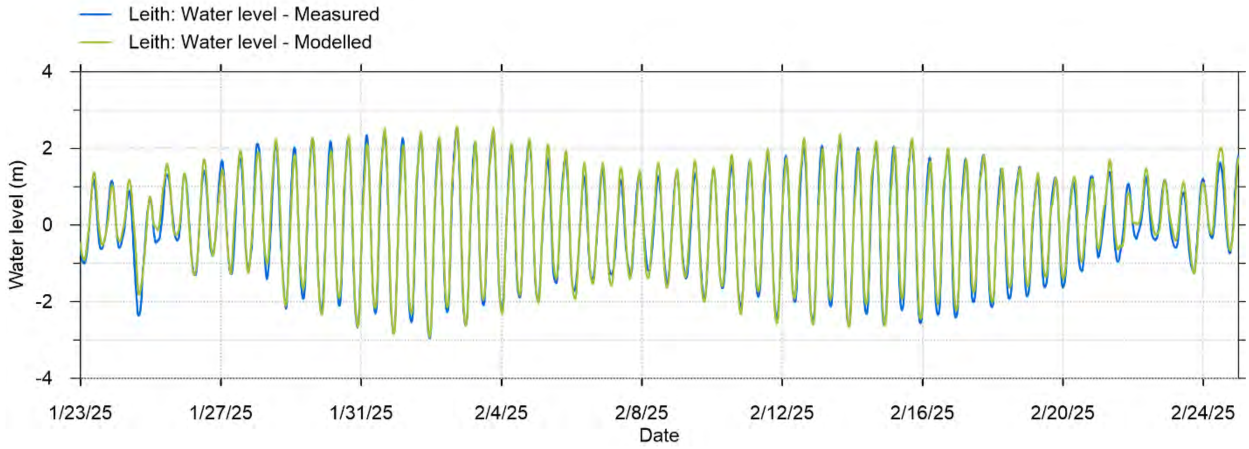

Figure 5-13 Time series comparison between simulated vs observed water levels at Leith from 23/1 to 25/2/2025 (Regional model)

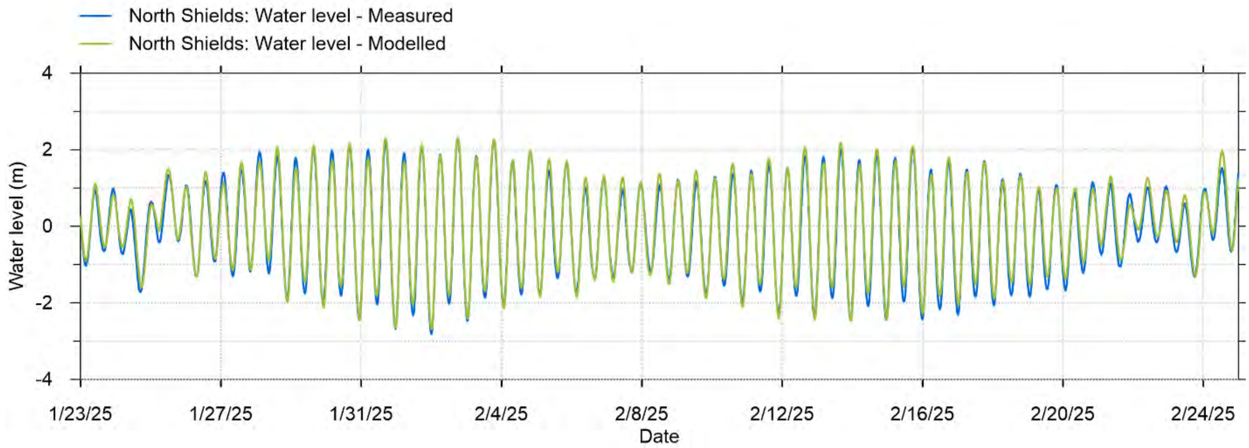

Figure 5-14 Time series comparison between simulated vs observed water levels at North Shields from 23/1 to 13/2/2025 (Regional model)

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Table 5.2 Model errors in water level (Regional model)

Name of station	ME (m)	MAE (m)	Std (m)	R
Aberdeen	-0.06	0.12	0.15	0.98
Leith	-0.06	0.15	0.18	0.98
North Shields	-0.04	0.11	0.13	0.98

Note: *ME: Mean Error; MAE: Mean Absolute Error; Std: Std. dev of Residuals; R: Coefficient of Determination*

5.3.2 Local model calibration (water level)

The local model has been calibrated using measured water levels recorded at Site 1 and Site 2 from 23 January 2025 to 25 February 2025. Model calibration performance is assessed by both visual comparison and quantifying errors using statistical parameters including Correlation Coefficient and Mean Absolute Error. **Figure 5-15** and **Figure 5-16** show the modelled and measured water levels, and **Table 5.3** presents quantified errors. The model errors in predicted water level are minimal, with a Mean Absolute Error of no more than 0.17m. Both visual comparison and error statistics show reasonably good agreement between measured and modelled water levels.

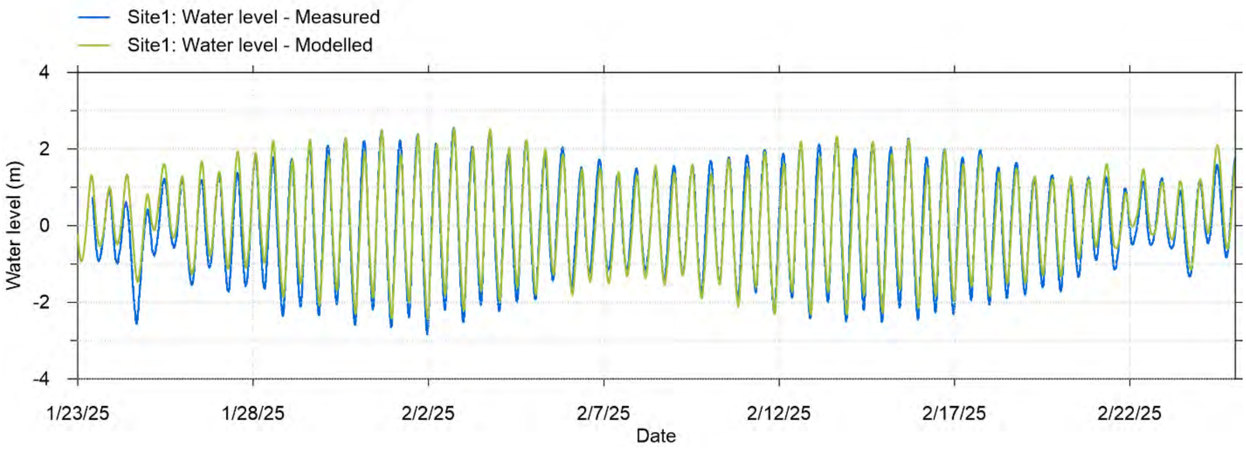

Figure 5-15 Time series comparison between simulated vs observed water levels at Site 1 from 23/1 to 25/2/2025 (Local model)

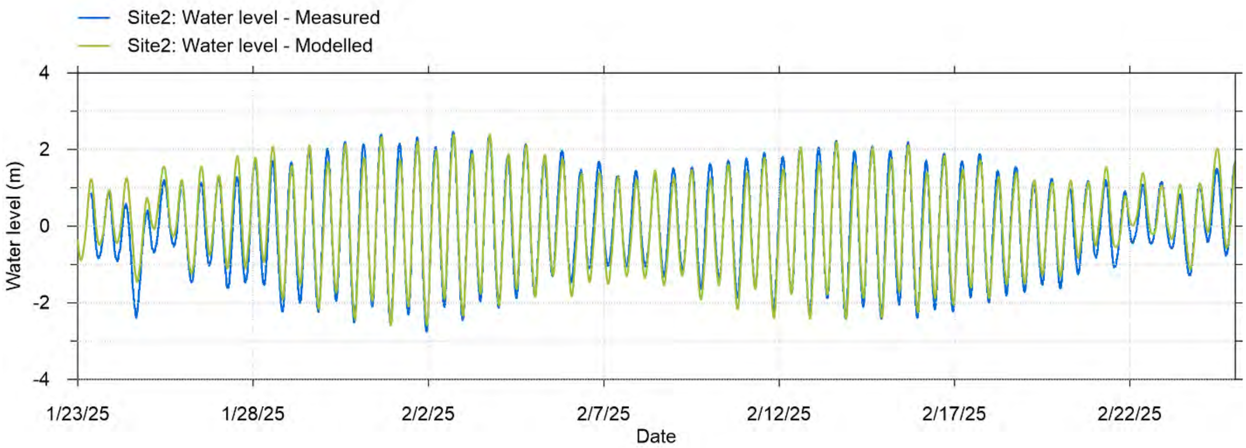

Figure 5-16 Time series comparison between simulated vs observed water levels at Site 2 from 23/1 to 25/2/2025 (Local model)

Table 5.3 Model errors in water level (Local model)

Site ID	ME (m)	MAE (m)	Std (m)	R
Site 1	0.04	0.17	0.19	0.96
Site 2	0.09	0.15	0.18	0.97

Note: *ME: Mean Error; MAE: Mean Absolute Error; Std: Std. dev of Residuals; R: Coefficient of Determination*

5.3.3 Local model calibration (current)

The local model has additionally been calibrated using measured current data recorded at 2 locations. The model calibration performance is assessed by both visual comparison and quantifying errors using statistical parameters, including Correlation Coefficient and Mean Absolute Error. **Figure 5-17** to **Figure 5-20** illustrate the modelled and measured current speed and direction, while **Table 5.4** presents quantified errors. The model errors in predicted current speed are minimal, with a maximum Mean Absolute Error of 0.14m/s. This low error provides confidence in using the model to assess potential impacts on tidal currents and associated bed shear stress.

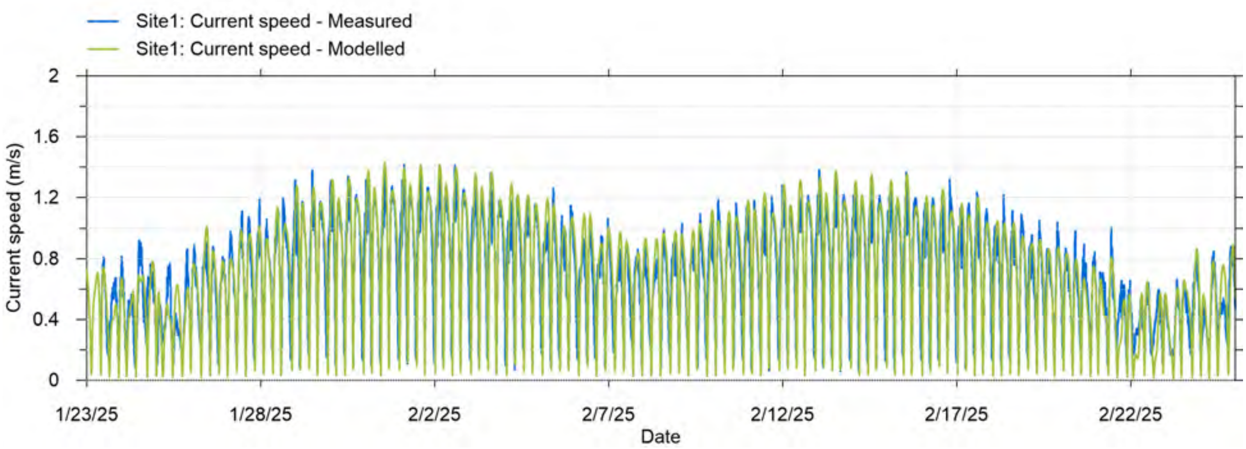

Figure 5-17 Time series comparison between simulated vs observed current speeds at Site 1 (Local model)

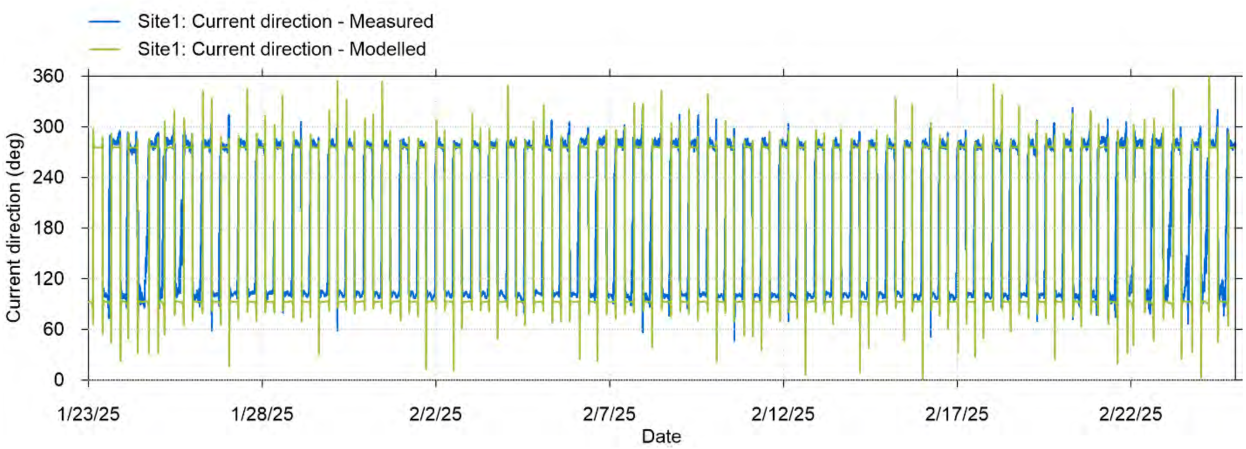

Figure 5-18 Time series comparison between simulated vs observed current directions at Site 1 (Local model)

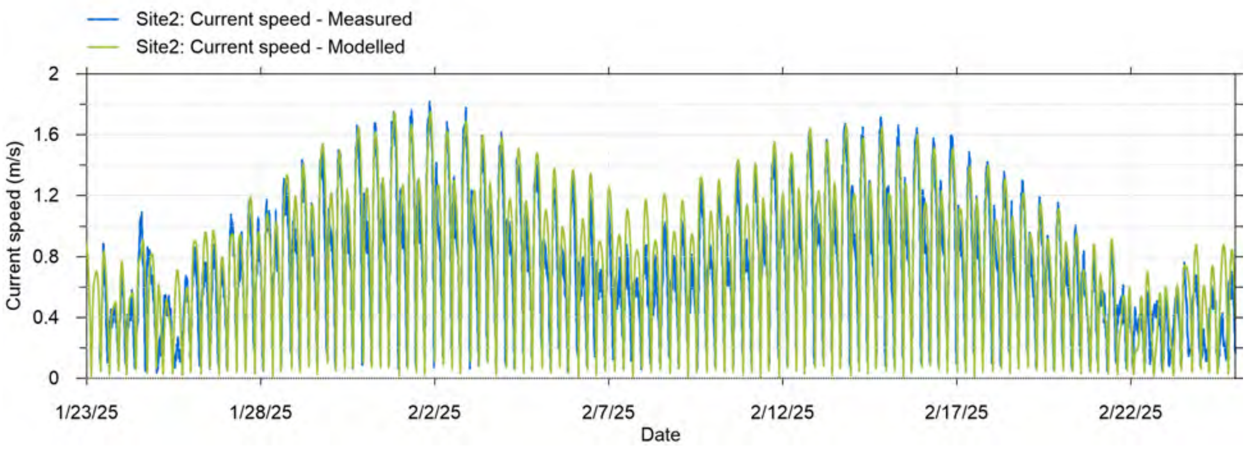

Figure 5-19 Time series comparison between simulated vs observed current speeds at Site 2 (Local model)

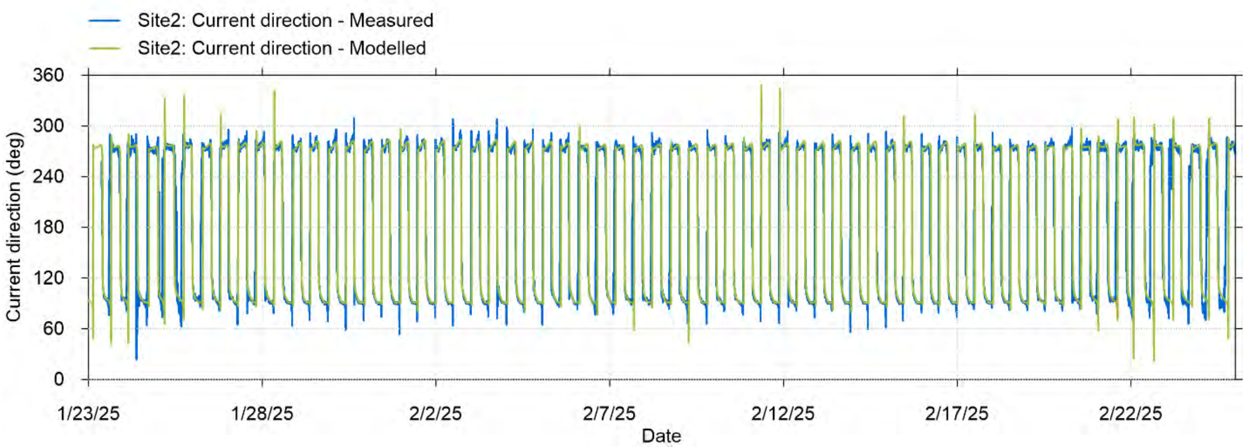

Figure 5-20 Time series comparison between simulated vs observed current directions at Site 2 (Local model)

Table 5.4 Model errors in current speed (Local model)

Site ID	ME (m/s)	MAE (m/s)	Std (m/s)	R
Site 1	-0.05	0.14	0.17	0.74
Site 2	-0.12	0.12	0.16	0.75

Note: *ME: Mean Error; MAE: Mean Absolute Error; Std: Std. dev of Residuals; R: Coefficient of Determination*

5.4 Model Parameters

The settings applied to the Local model are summarised in **Table 5.5**.

Table 5.5 Local model settings

Description	Setting
Minimum time step	0.01s
Maximum time step	60s
Critical CFL number	0.8
Flood and dry	Included
Density type	Barotropic

Description	Setting
Bed resistance	Manning number: 45[$m^{1/3}$/s]
Eddy viscosity	0.28 (Smagorinsky formulation)
Coriolis	Varying in domain
Wind forcing	Included

5.5 Hydrodynamic Model Runs

The calibrated 2D hydrodynamic model has been run for a full spring-neap tidal cycle from 14th February to 16th March 2025 covering the Tay Estuary (**Figure 5-21**). This time period was chosen as it has the highest tidal range in 2025, which produces the strongest tidal currents.

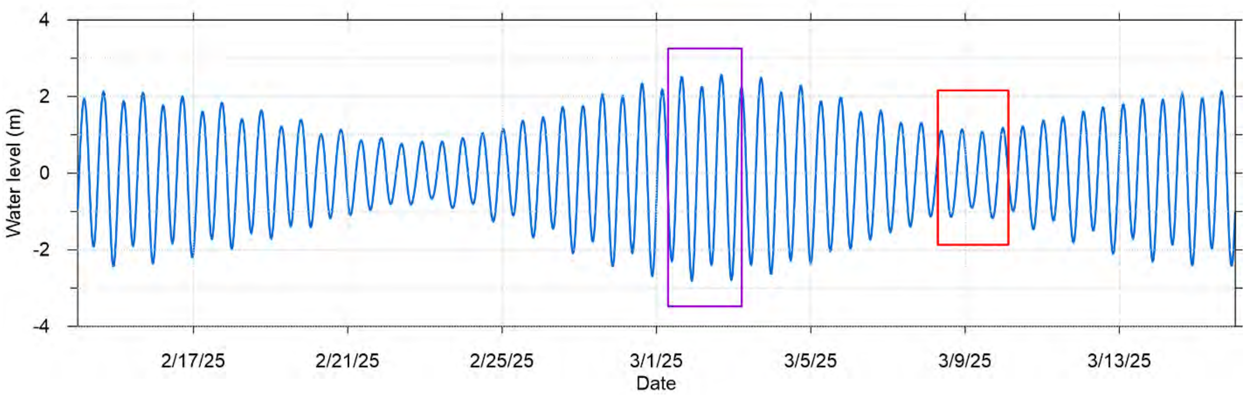

Figure 5-21 Modelled water levels at Dundee port a period of 30 days (purple frame indicates spring tides and red frame indicates neap tide)

The 2D HD model has been run for two layout scenarios:

- Without dredging (Existing), and
- With dredging (Option).

5.6 Hydrodynamic Model Results

5.6.1 Current speed

5.6.1.1 Existing layout – Port of Dundee area

Figure 5-22 to **Figure 5-25** show the current speeds modelled for the Existing layout at the Port of Dundee work area over a spring and neap tide, each for peak ebb and flood. During peak flood, overall current direction in the Port of Dundee is due West, and during peak ebb current is due East.

Current speeds in the work area generally decrease landward, with lowest current speeds occurring at the quay wall.

Within the Port of Dundee area, overall current speeds are greater during spring tides than neap tides, reaching 1.2 m/s and 0.8 m/s for spring and neap tide, respectively. The quay wall is exposed to slightly greater current speeds during peak ebb than peak flood.

Maximum current speeds for Existing conditions in the Port of Dundee area were 0.4 m/s to 1.2 m/s over a 30-day period (**Figure 5-26**), where higher maximum current speeds occurred at the outer edge of the work area (closest to the middle of the Firth of Tay), and lower maximum current speeds at the quay edge of the work area.

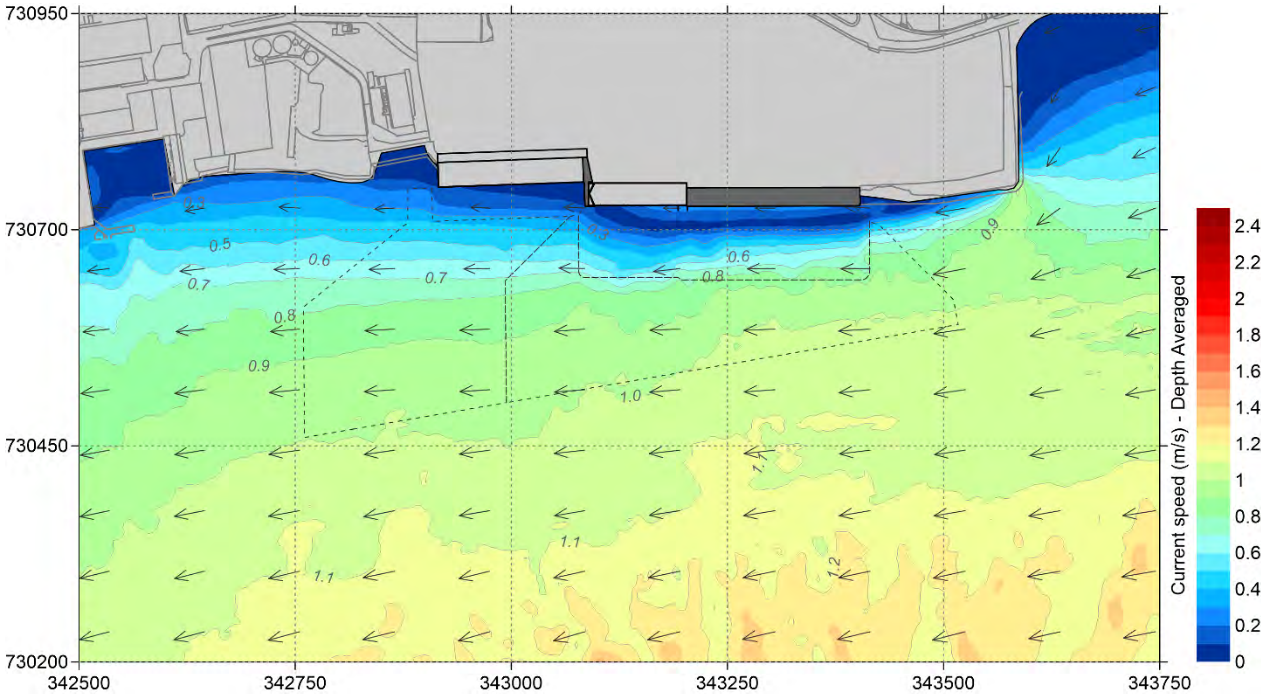

Figure 5-22 Existing layout - Current speed during spring tide - peak flood (Local model) – Port of Dundee area

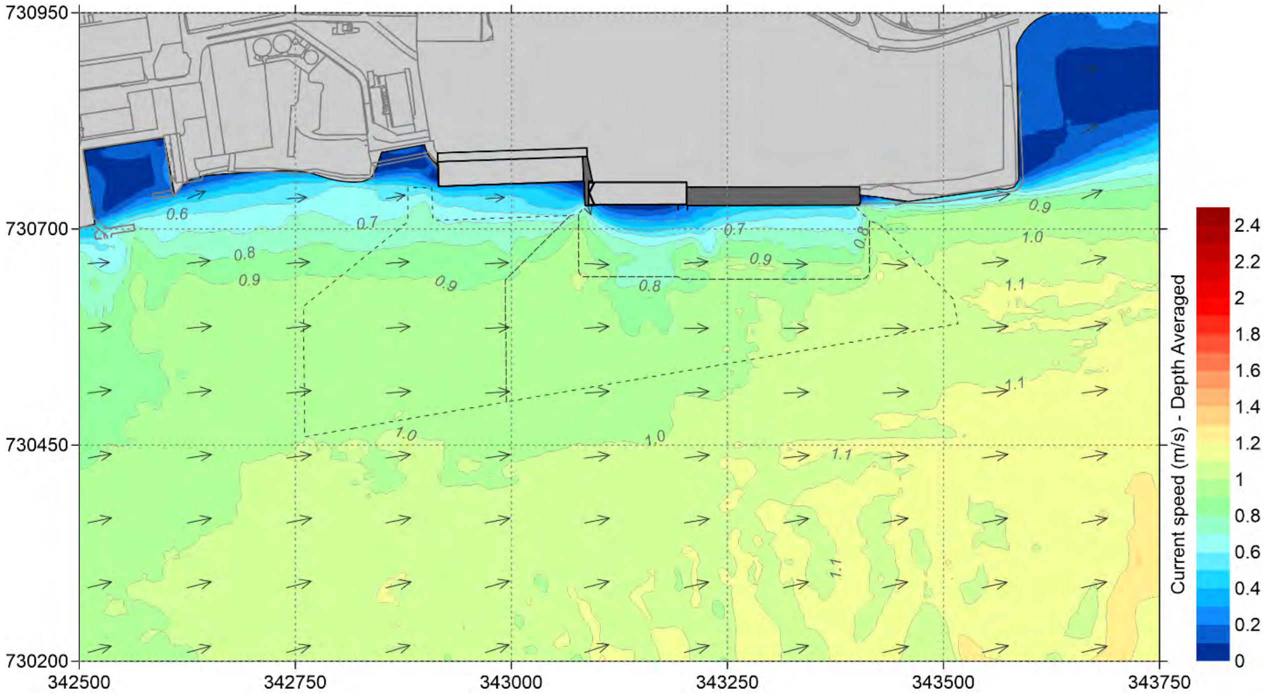

Figure 5-23 Existing layout - Current speed during spring tide - peak ebb (Local model) – Port of Dundee area

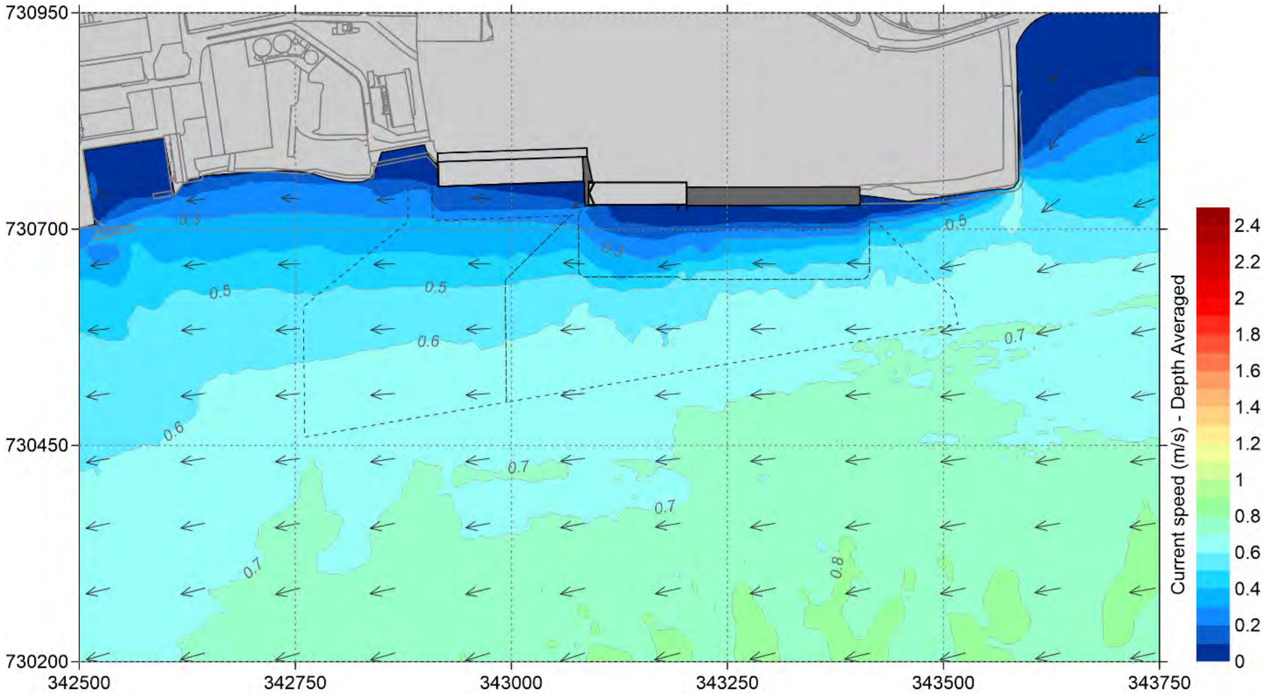

Figure 5-24 Existing layout - Current speed during neap tide - peak flood (Local model) – Port of Dundee area

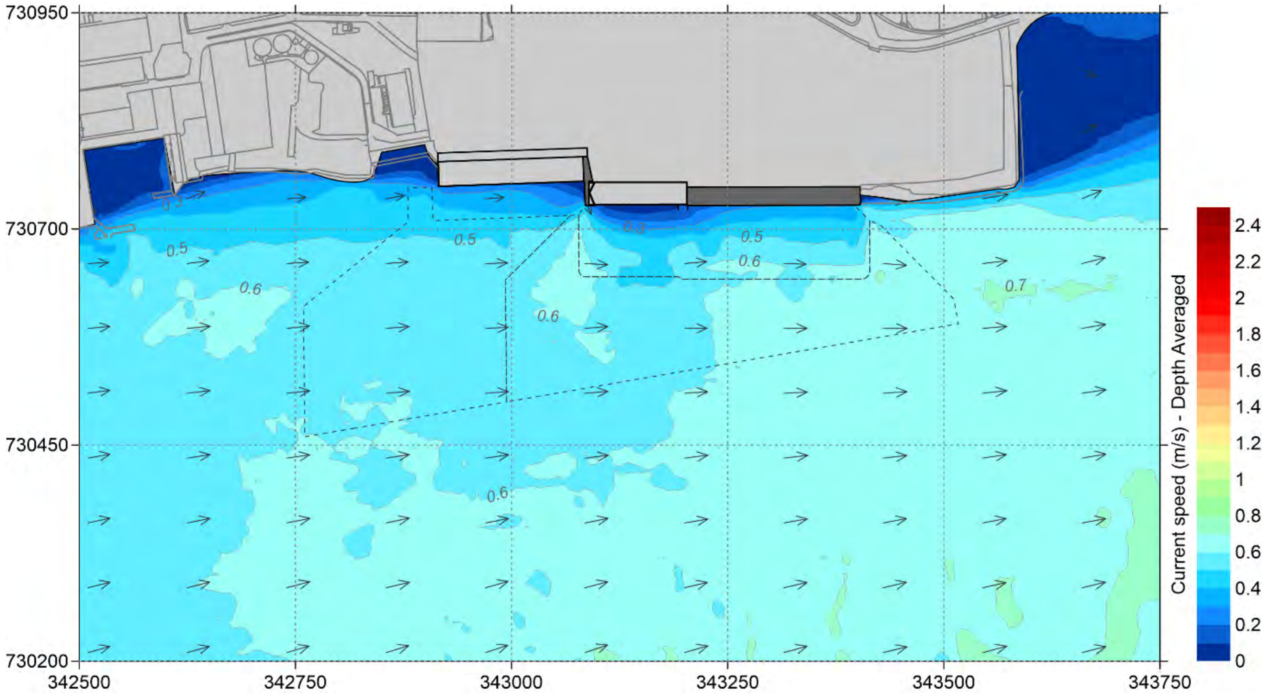

Figure 5-25 Existing layout - Current speed during neap tide - peak ebb (Local model) – Port of Dundee area

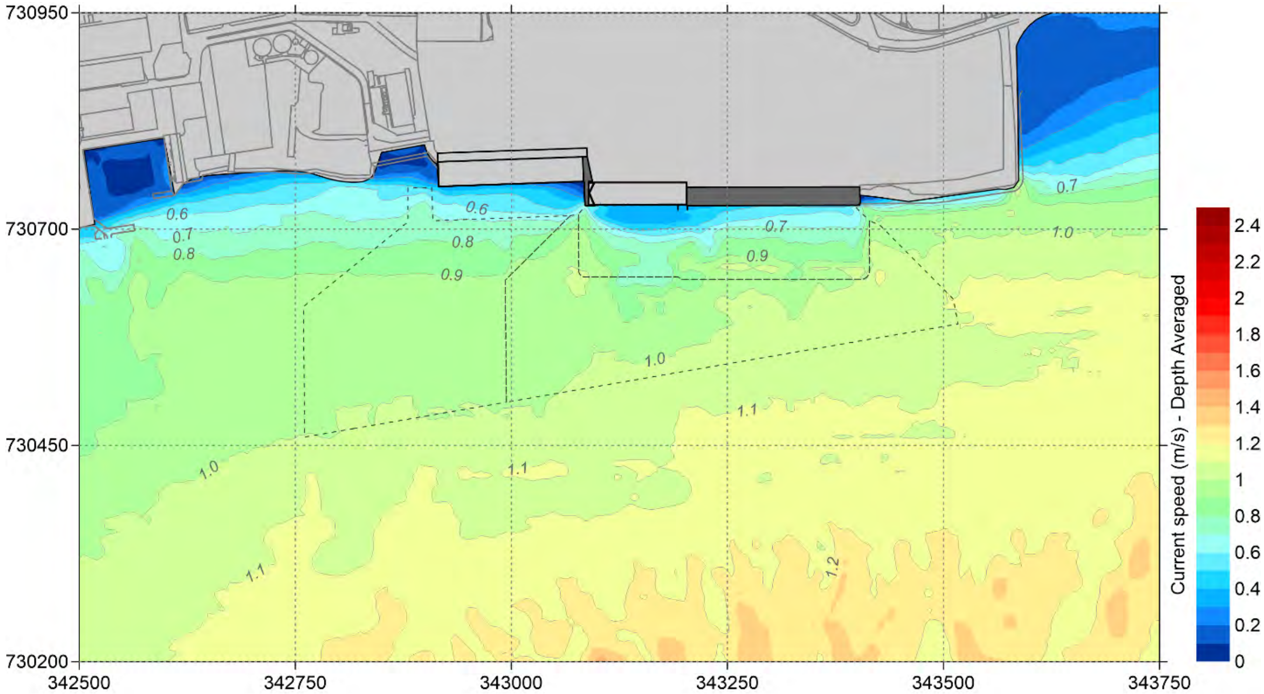

Figure 5-26 Existing layout – Maximum Current speed over 30 days (Local model) – Port of Dundee area

5.6.1.2 Existing layout – Lady Shoal approach channel

Figure 5-27 to **Figure 5-30** show the current speeds modelled for the Existing layout at the Lady Shoal approach channel over a spring and neap tide, each for peak ebb and flood. During peak flood, water comes into the Firth of Tay from the North Sea and overall current direction within the Lady Shoal approach channel work area is due West. During peak ebb, the water is coming down the Firth of Tay from inland, and main current direction in the Lady Shoal work area is due East.

Higher current speeds are indicated at the western side of the Lady Shoal approach channel, close to where the work area is in proximity to the Tay spit, than at the eastern end for both spring and neap tide. Larger current speeds also occur during spring tides, where values range from 0.9 m/s to 2.3 m/s, than neap tides, when values range from 0.7 m/s to 1.3 m/s.

The highest current speeds are indicated during spring tide at peak ebb, when current speeds range from 1.4 m/s up to 2.3 m/s.

Maximum current speeds in the Lady Shoal approach channel area ranged from 1.4 m/s to 2.3 m/s over a 30-day period covering a spring and neap cycle for Existing conditions (**Figure 5-31**), with greatest maximum current speeds occurring as patches in the central work area, and lowest maximum current speeds at the western and eastern ends of the work area.

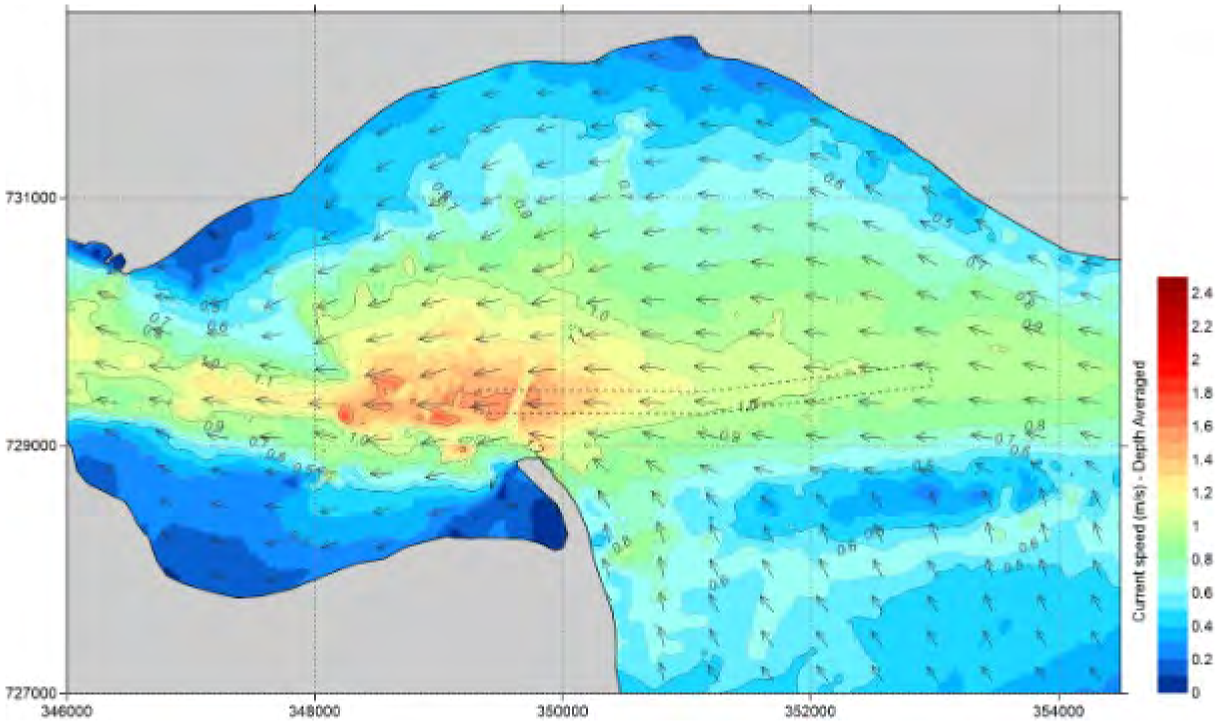

Figure 5-27 Existing layout - Current speed during spring tide - peak flood (Local model) – Lady Shoal approach channel

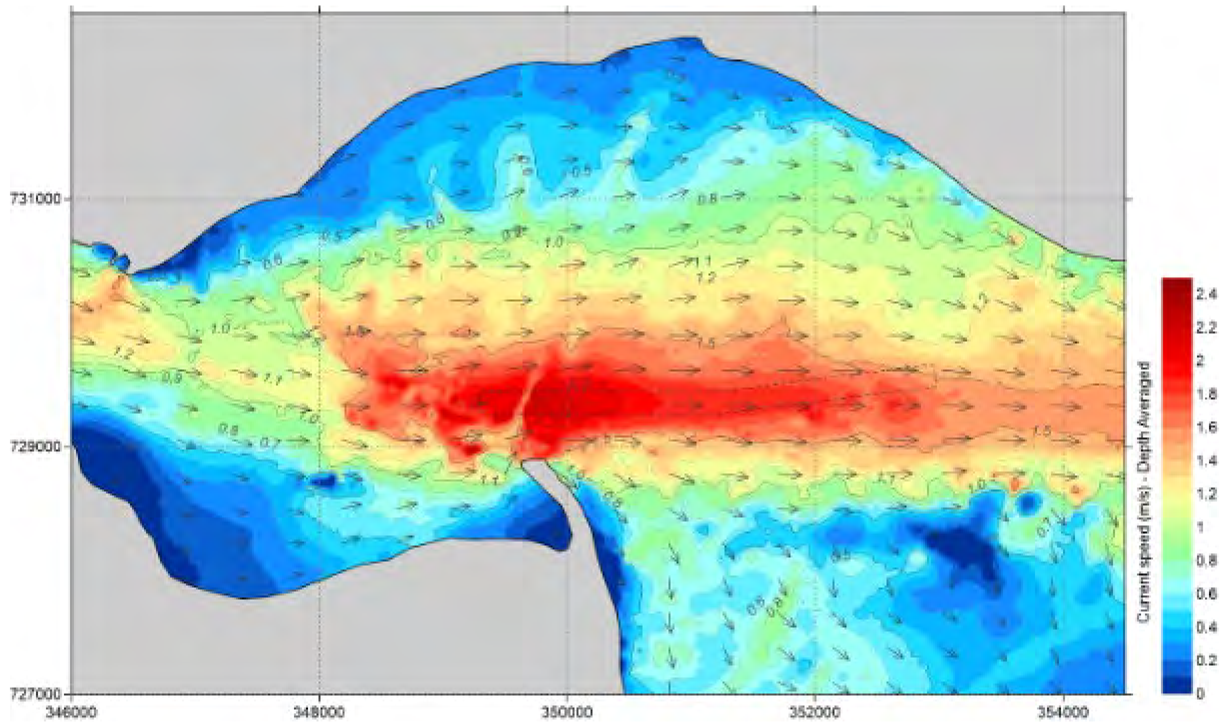

Figure 5-28 Existing layout - Current speed during spring tide - peak ebb (Local model) – Lady Shoal approach channel

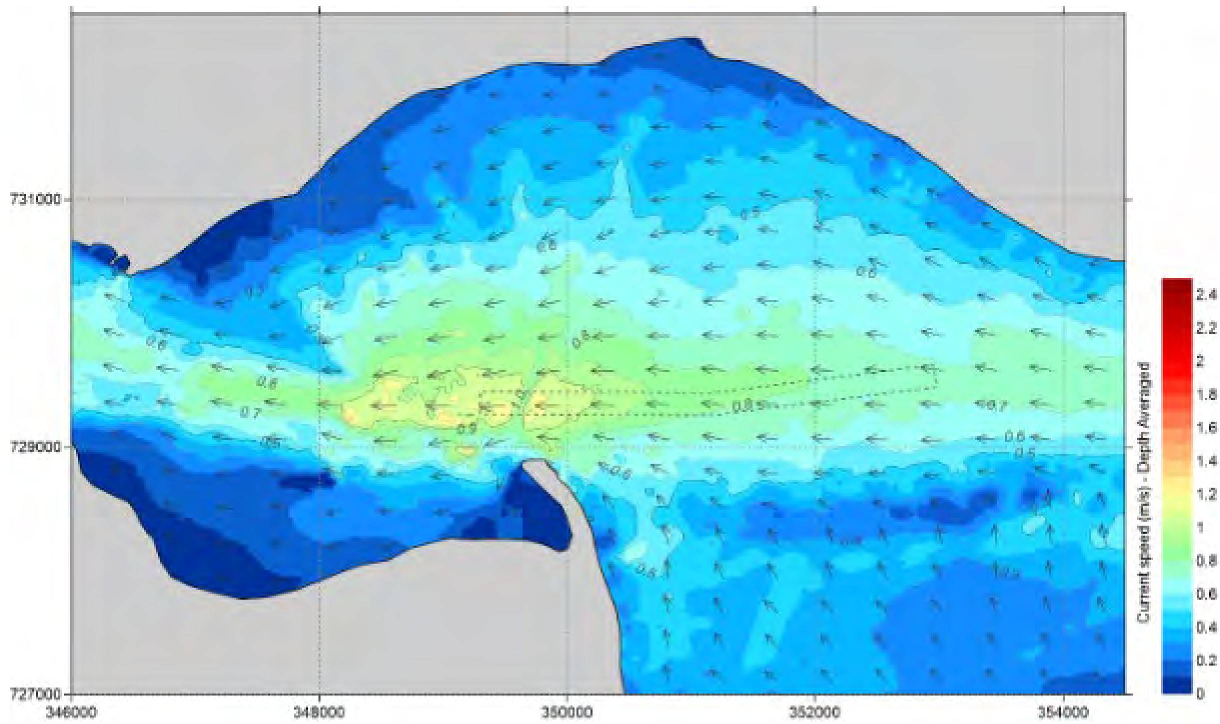

Figure 5-29 Existing layout - Current speed during neap tide - peak flood (Local model) – Lady Shoal approach channel

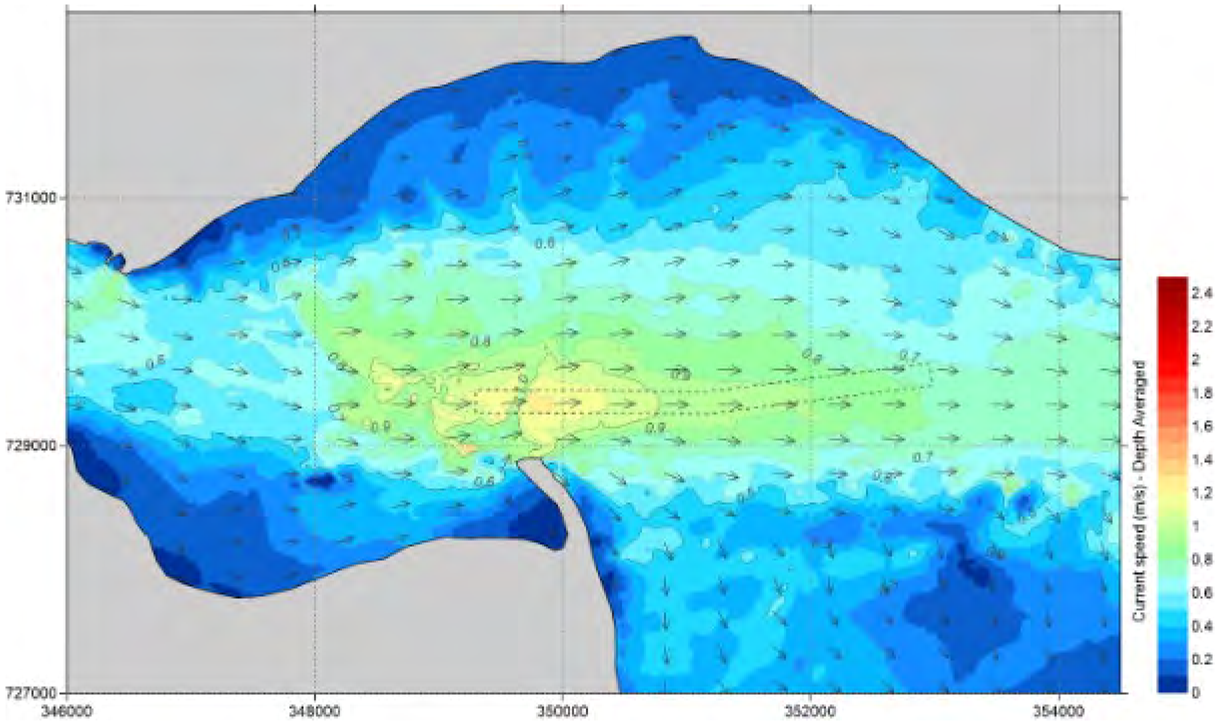

Figure 5-30 Existing layout - Current speed during neap tide - peak ebb (Local model) – Lady Shoal approach channel

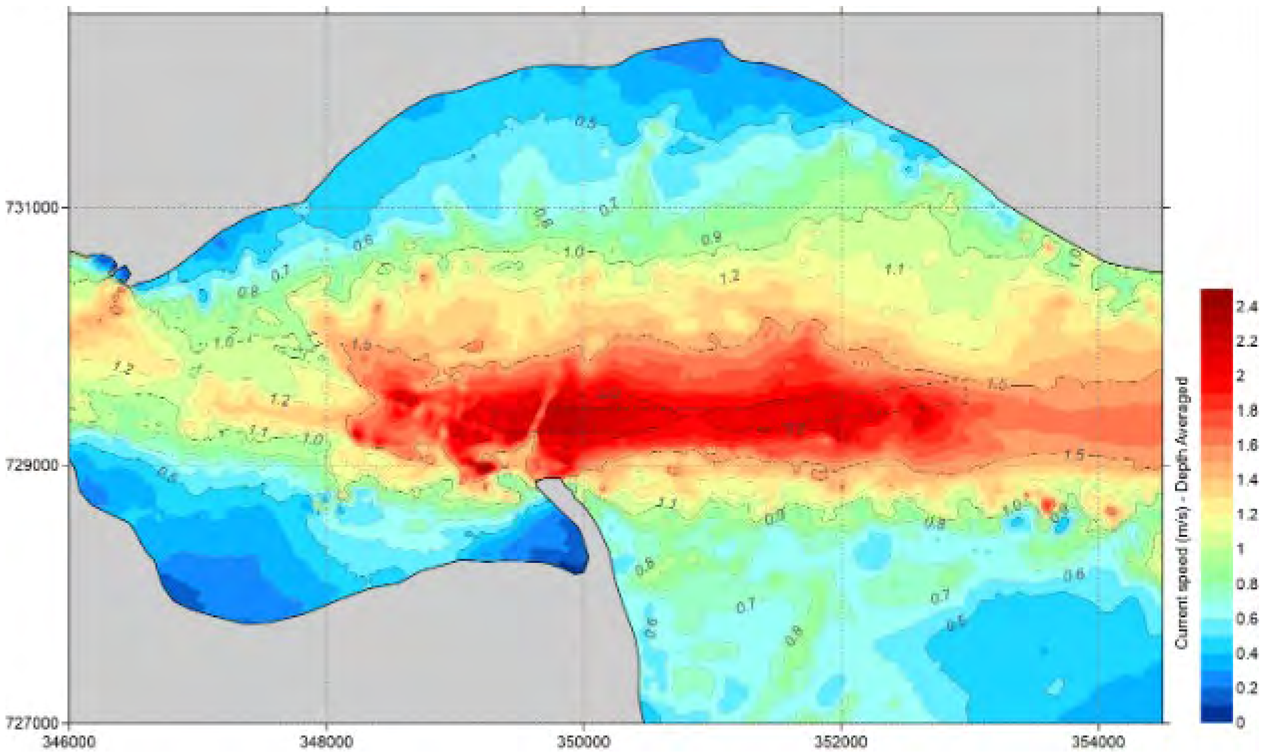

Figure 5-31 Existing layout – Maximum Current speed over 30 days (Local model) – Lady Shoal approach channel

5.6.1.3 Option layout – Port of Dundee area

Figure 5-32 to **Figure 5-35** show the current speeds modelled for the Option layout at the Port of Dundee work area over a spring and neap tide, each for peak and ebb flood. **Figure 5-36** shows the maximum current speeds over a 30-day period covering a spring and neap cycle for Option conditions.

Differences in current speed of the Option layout to the Existing layout for the Port of Dundee are outlined in **Section 5.6.1.5**.

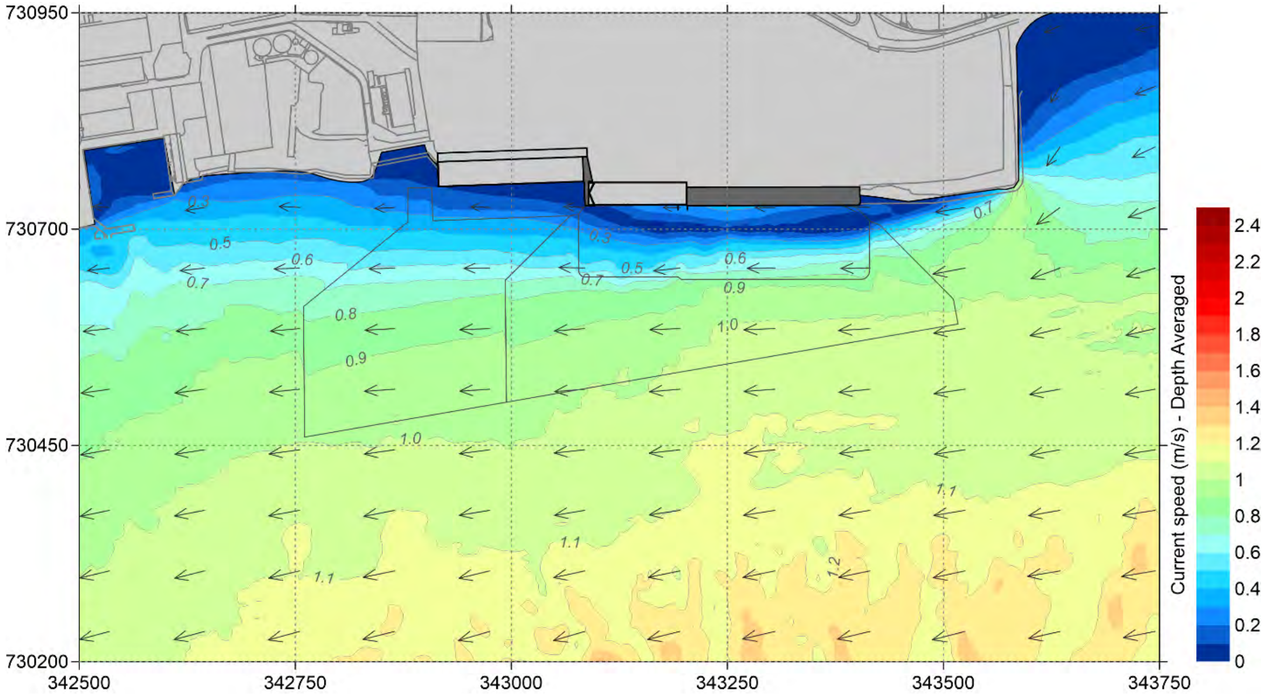

Figure 5-32 Option layout - Current speed during spring tide - peak flood (Local model) – Port of Dundee area

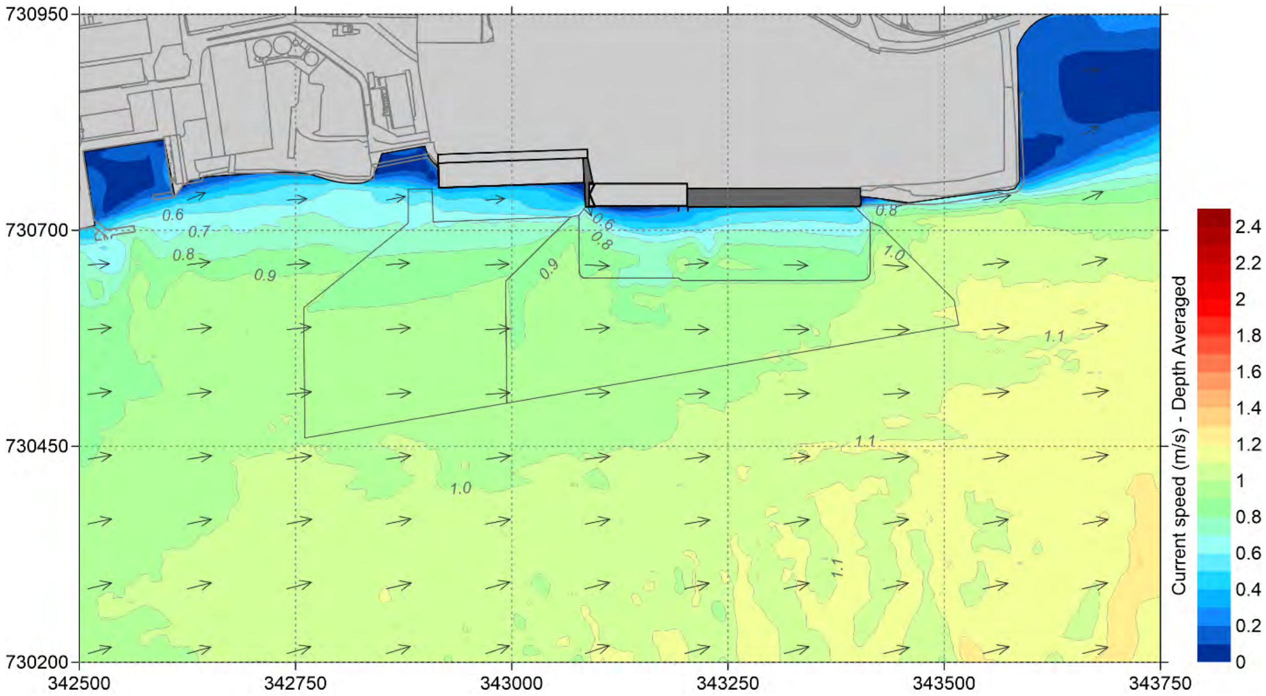

Figure 5-33 Option layout - Current speed during spring tide - peak ebb (Local model) – Port of Dundee area

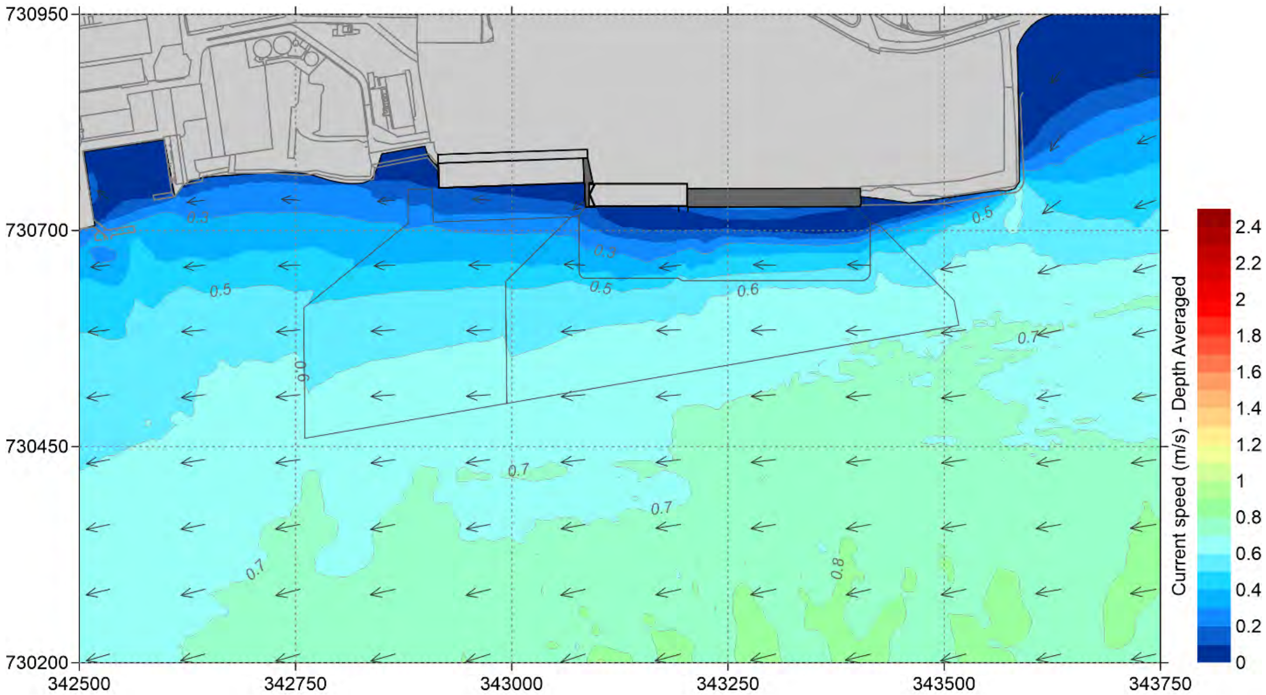

Figure 5-34 Option layout - Current speed during neap tide - peak flood (Local model) – Port of Dundee area

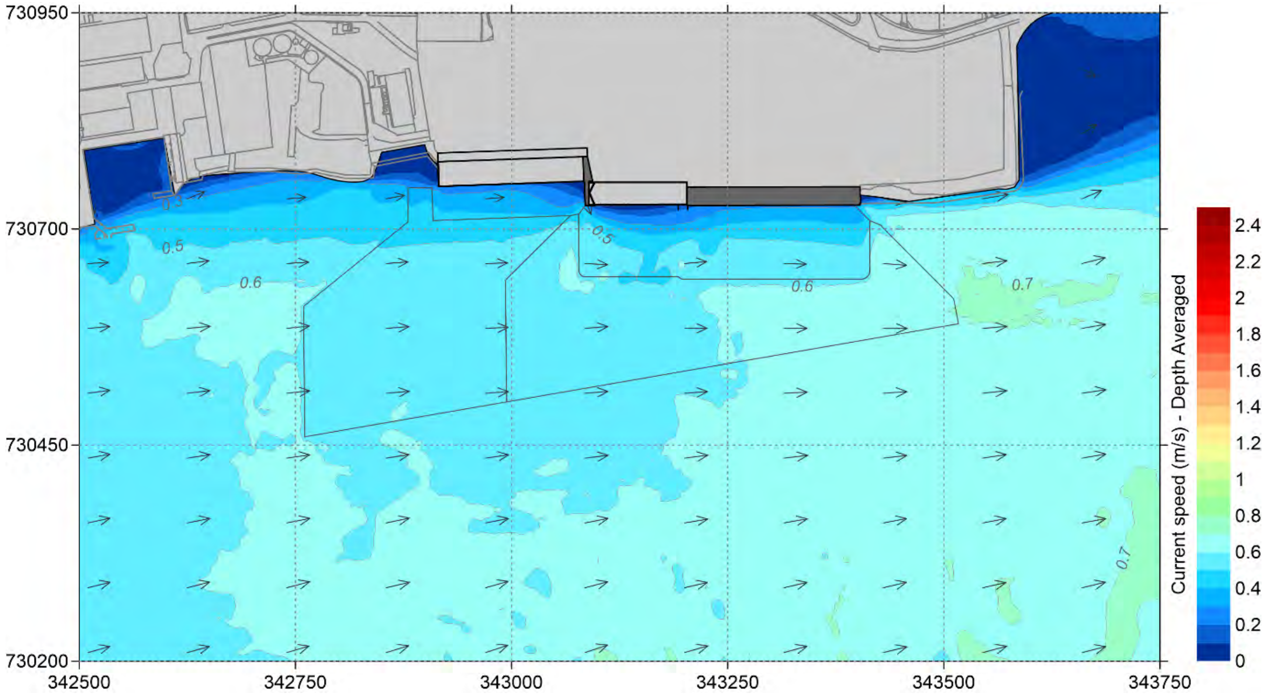

Figure 5-35 Option layout - Current speed during neap tide - peak ebb (Local model) – Port of Dundee area

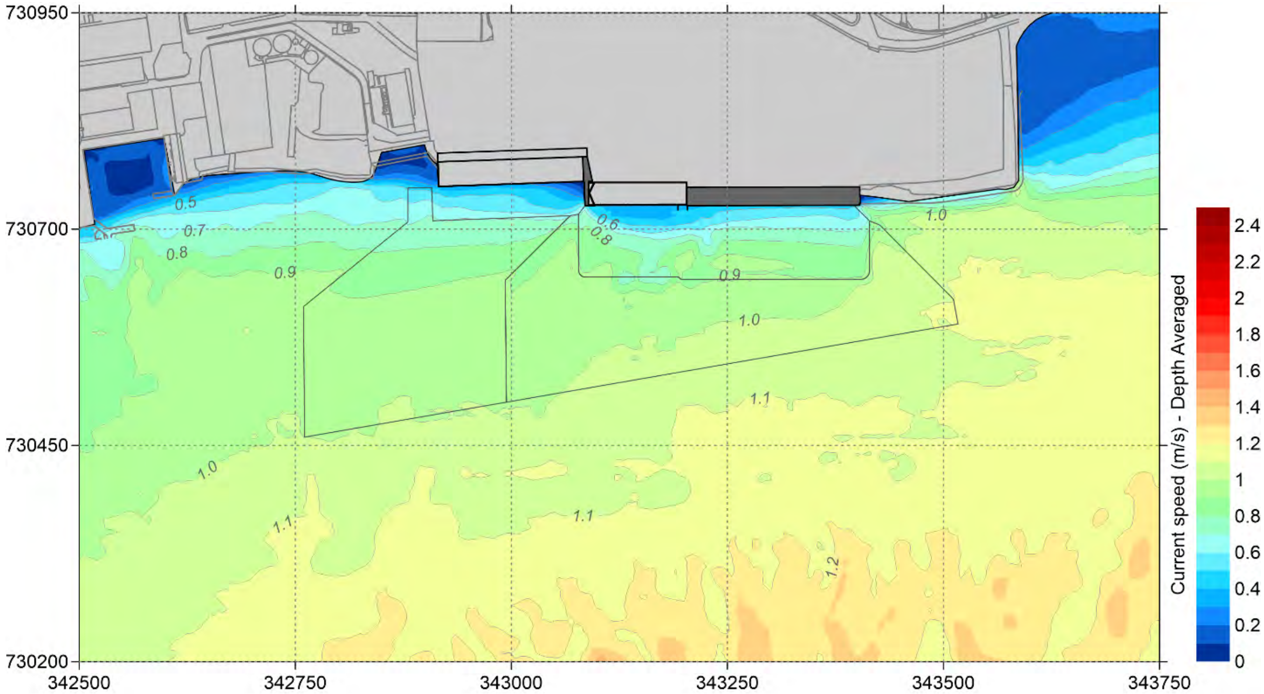

Figure 5-36 Option layout – Maximum Current speed over 30 days (Local model) – Port of Dundee area

5.6.1.4 Option layout – Lady Shoal approach channel

Figure 5-37 to **Figure 5-40** to show the current speeds modelled for the Option layout at the Lady Shoal approach channel work area over a spring and neap tide, each for peak and ebb flood. **Figure 5-41** shows the maximum current speeds over a 30-day period covering a spring and neap cycle for the Option layout.

Differences in current speed of the Option layout to the Existing layout for the Lady Shoal approach channel are outlined in **Section 5.6.1.5**.

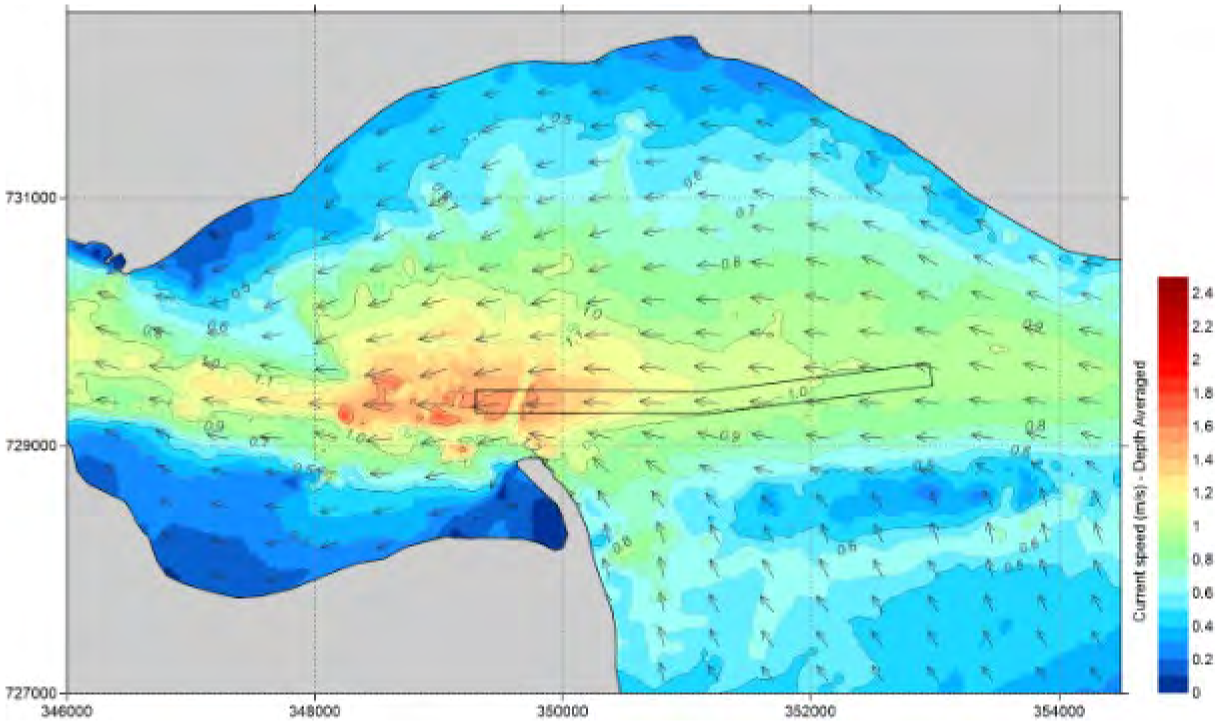

Figure 5-37 Option layout - Current speed during spring tide - peak flood (Local model) – Lady Shoal approach channel

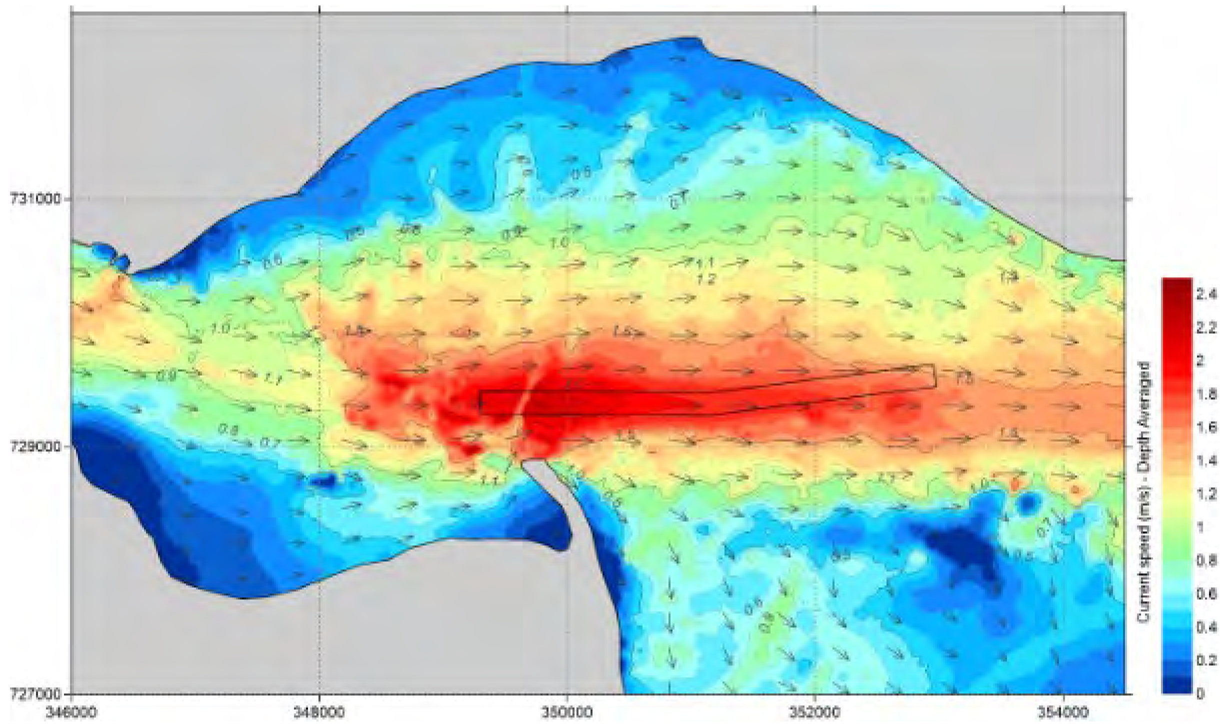

Figure 5-38 Option layout - Current speed during spring tide - peak ebb (Local model) – Lady Shoal approach channel

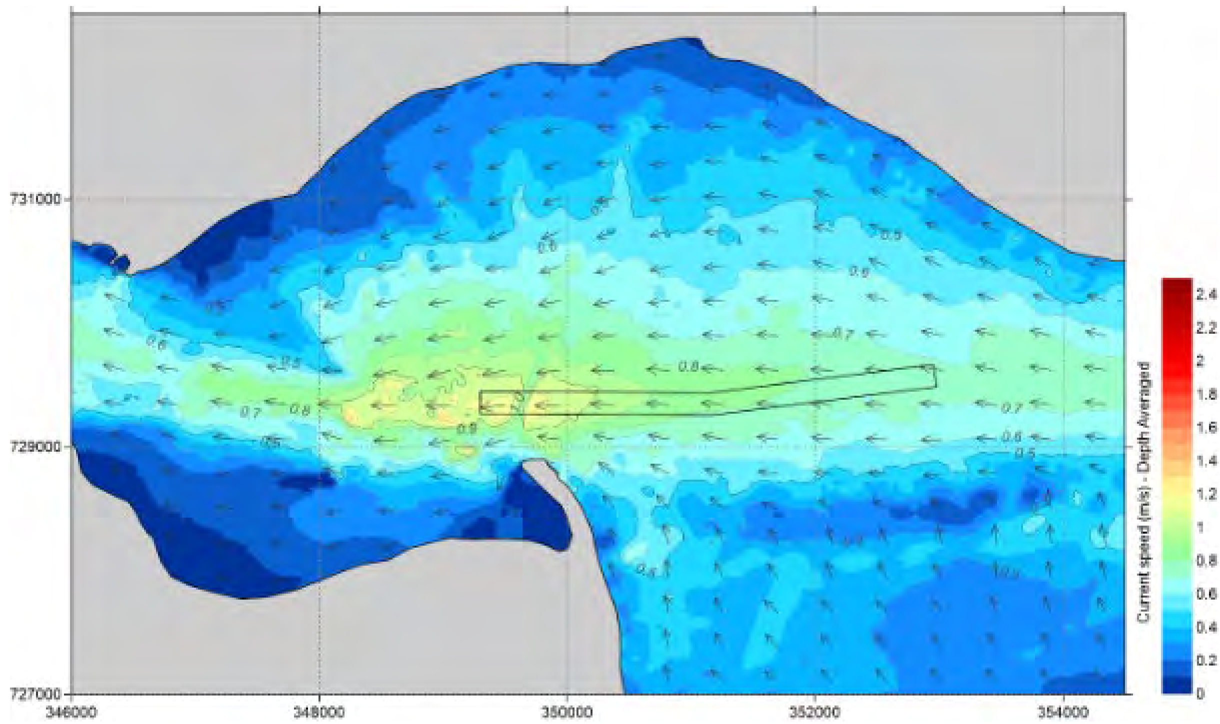

Figure 5-39 Option layout - Current speed during neap tide - peak flood (Local model) – Lady Shoal approach channel

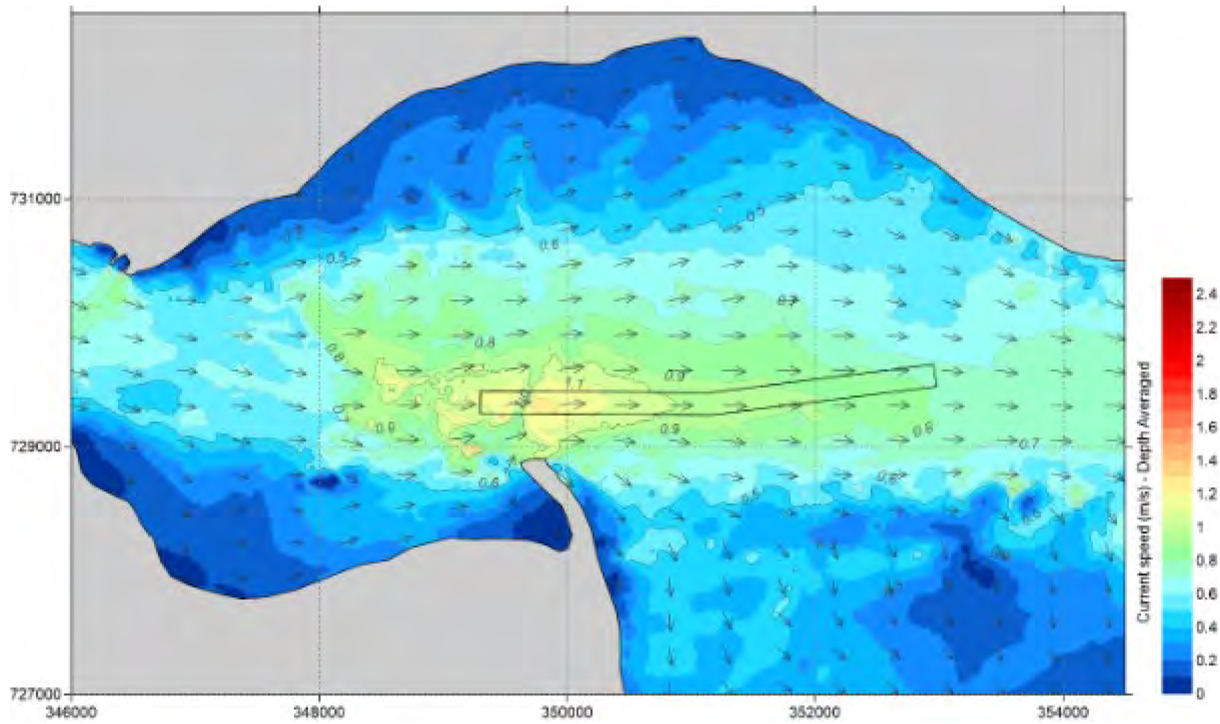

Figure 5-40 Option layout - Current speed during neap tide - peak ebb (Local model) – Lady Shoal approach channel

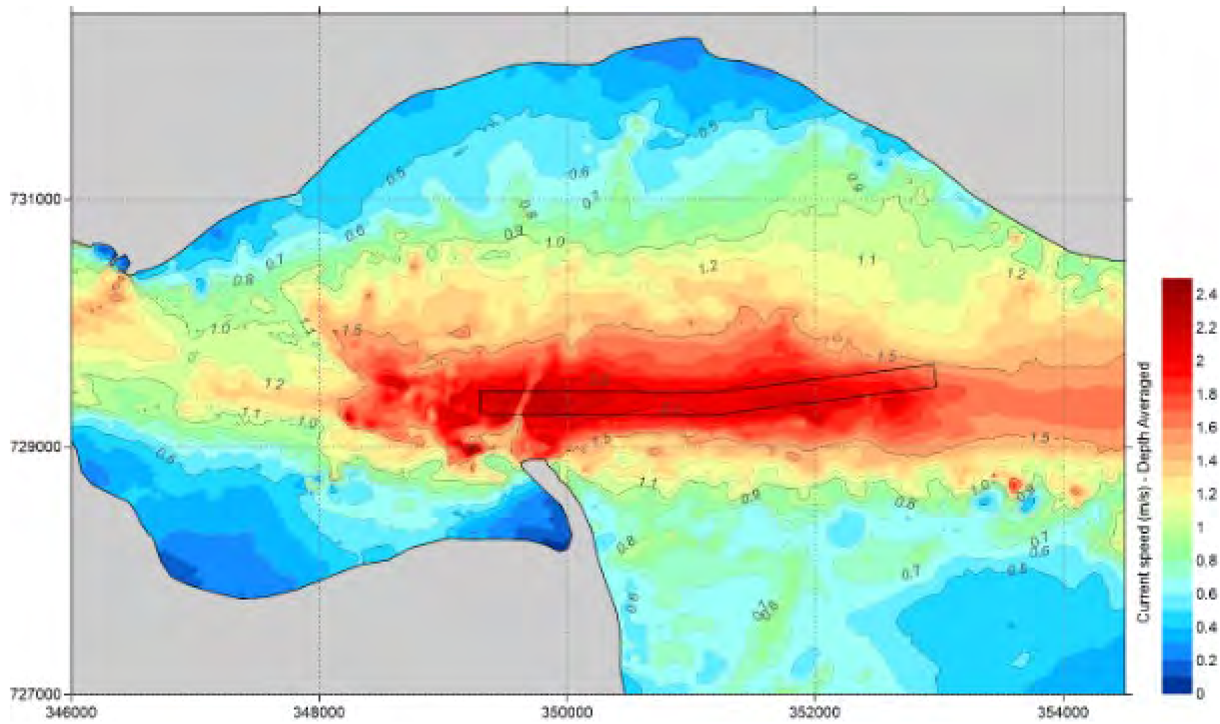

Figure 5-41 Option layout – Maximum Current speed over 30 days (Local model) – Lady Shoal approach channel

5.6.1.5 Impacts on current speed

Figure 5-42 to **Figure 5-49** show the differences in current speed between the Existing and Option layouts at the Port of Dundee and Lady Shoal approach channel work areas for a spring and neap tide, each during peak flood and peak ebb. Only relative changes in current speed greater than 0.5 m/s or less than -0.5 m/s, or percentage changes greater than 5% or less than -5%, are indicated in the figures.

At the Port of Dundee work area, the Option layout generally results in lower current speeds away from the quay wall, and greater current speeds closer to the quay wall. The largest changes in current speed occur during spring tide at peak flood, where current speeds decrease by up to 0.2 m/s in the Berth Area, and increase at the quay wall up to 0.15 m/s.

At the Lady Shoal work area, current speed is minimally impacted with changes remaining predominantly between -0.5 m/s and 0.5 m/s for both a spring and neap tide.

Figure 5-50 and **Figure 5-51** show the difference in maximum current speed and percentage change in maximum current speed, respectively, over a 30-day period at the Port of Dundee. Within the work area, maximum current speeds are reduced around the edge of Berth Areas 1 and 2 by up to 5 – 10%, and increased in one area closer to the quay wall by up to 20%.

Figure 5-52 and **Figure 5-53** show the difference in maximum current speed and percentage change in maximum current speed, respectively, over a 30-day period at the Lady Shoal approach channel. Changes to current speed remain less than 5%, with few areas showing changes between -0.1 m/s and 0.1 m/s at the eastern end of the Lady Shoal work area.

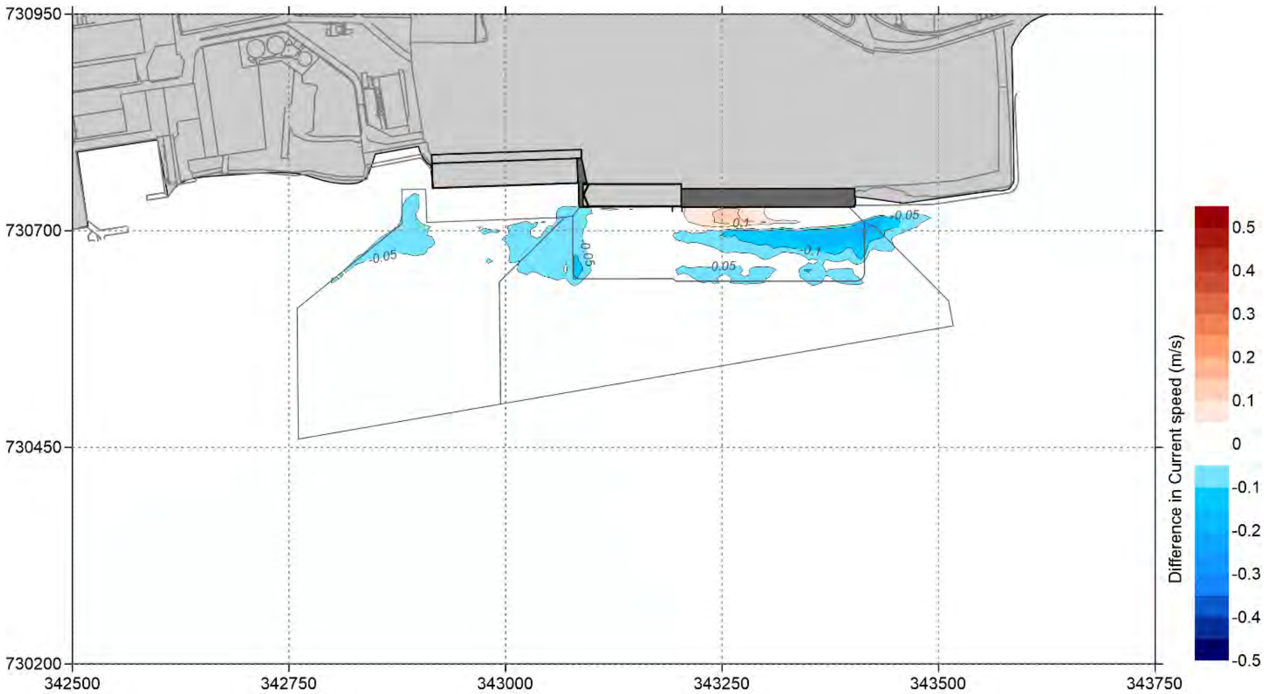

Figure 5-42 Difference in current speed (in metres per second) between 'Existing' and 'Option' during spring tide at the Port of Dundee area (positive means increase of current speed by option and vice versa) – peak flood

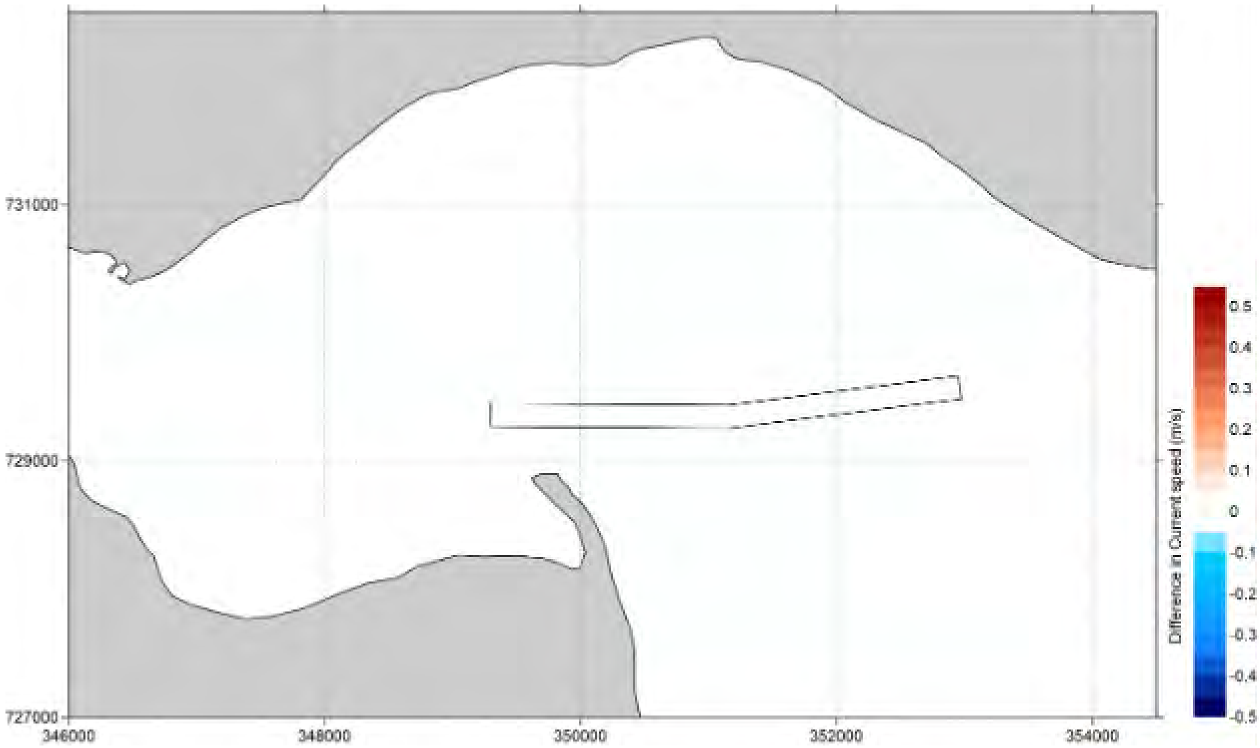

Figure 5-43 Difference in current speed (in metres per second) between 'Existing' and 'Option' during spring tide at the Lady Shoal approach channel (positive means increase of current speed by option and vice versa) – peak flood

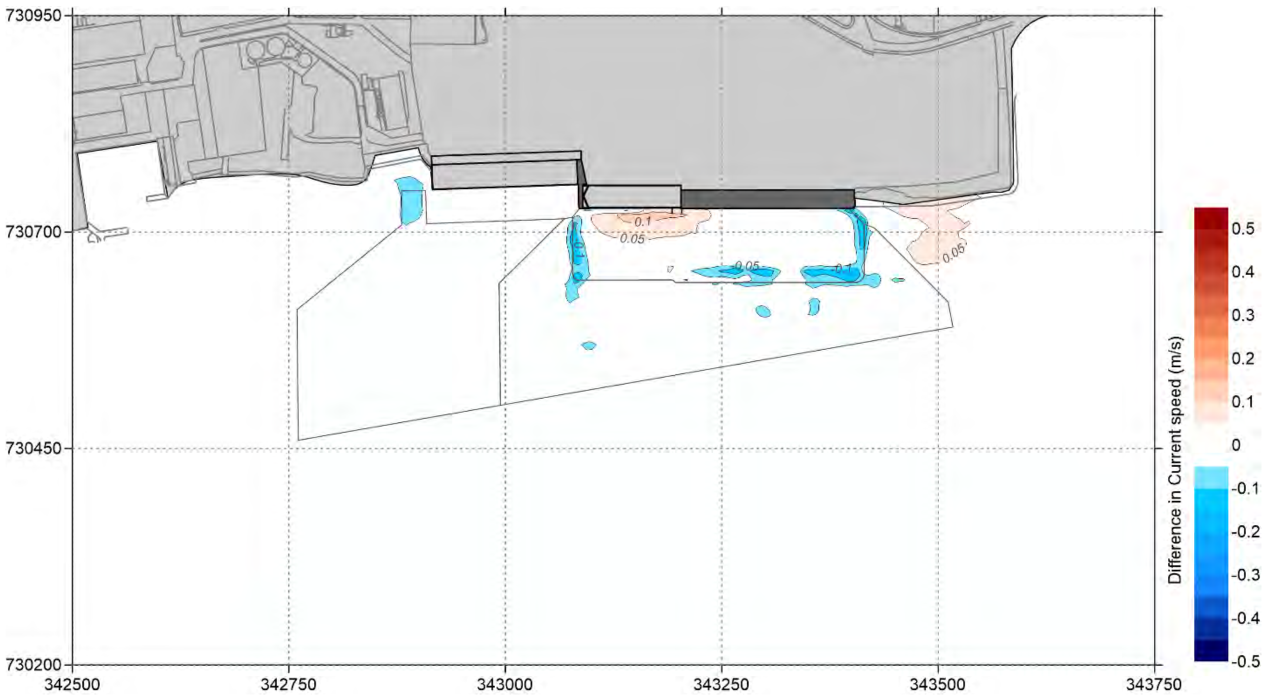

Figure 5-44 Difference in current speed (in metres per second) between 'Existing' and 'Option' during spring tide at the Port of Dundee (positive means increase of current speed by option and vice versa) – peak ebb

Figure 5-45 Difference in current speed (in metres per second) between 'Existing' and 'Option' during spring tide at the Lady Shoal approach channel (positive means increase of current speed by option and vice versa) – peak ebb

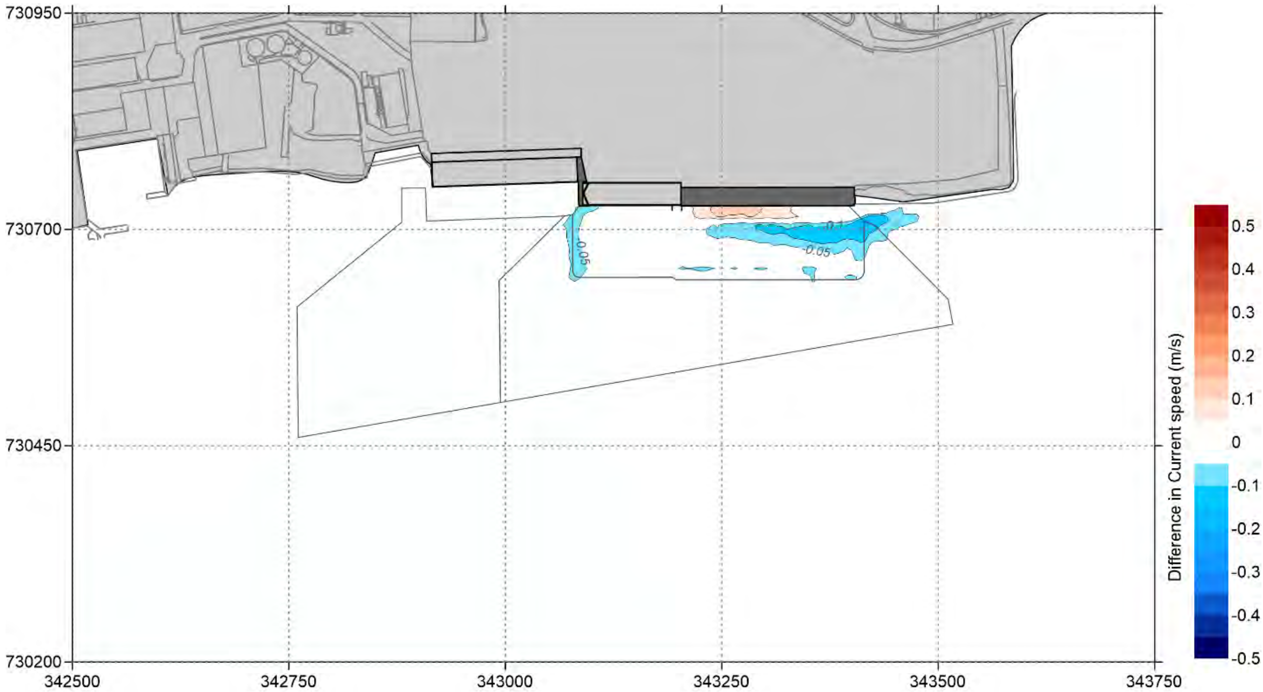

Figure 5-46 Difference in current speed (in metres per second) between 'Existing' and 'Option' during neap tide at the Port of Dundee (positive means increase of current speed by option and vice versa) – peak flood

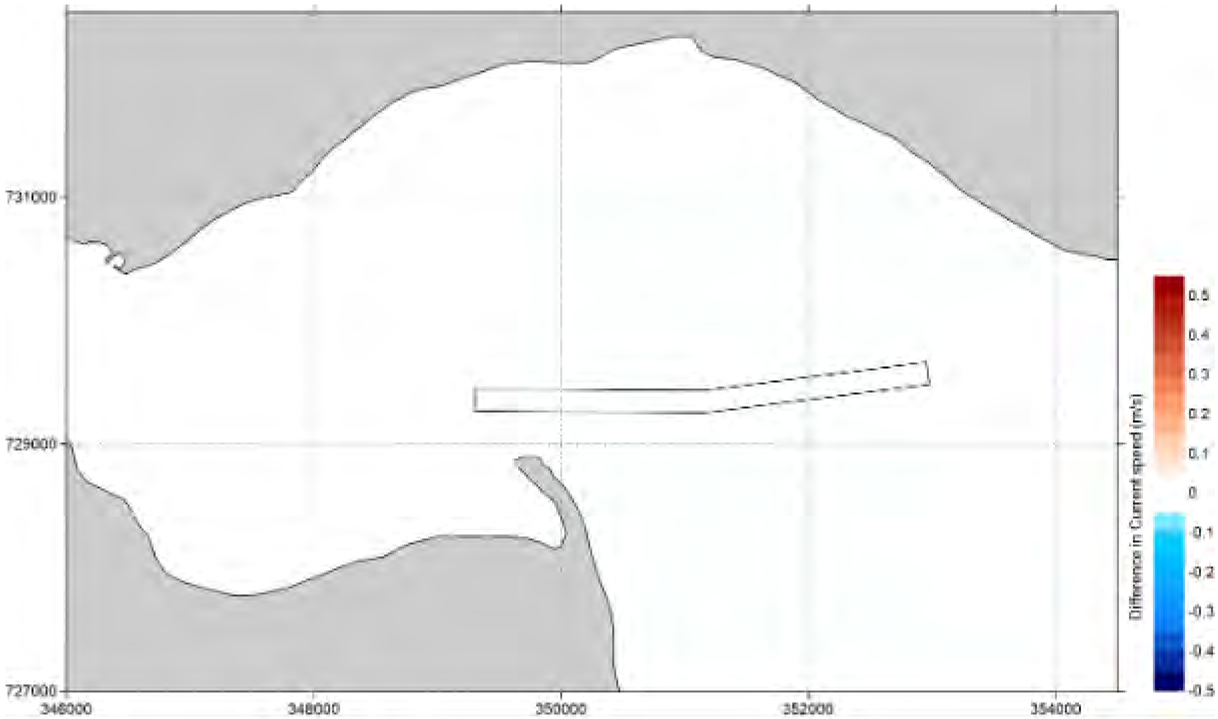

Figure 5-47 Difference in current speed (in metres per second) between 'Existing' and 'Option' during neap tide at the Lady Shoal approach channel (positive means increase of current speed by option and vice versa) – peak flood

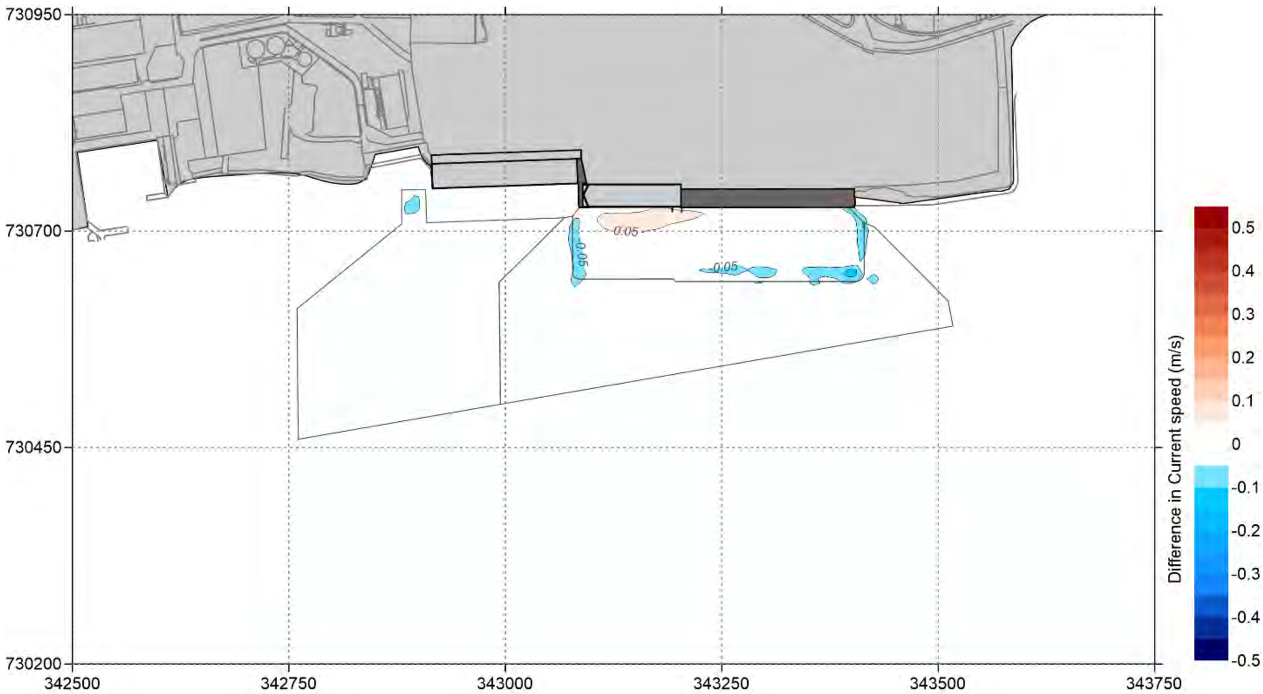

Figure 5-48 Difference in current speed (in metres per second) between 'Existing' and 'Option' during neap tide at the Port of Dundee (positive means increase of current speed by option and vice versa) – peak ebb

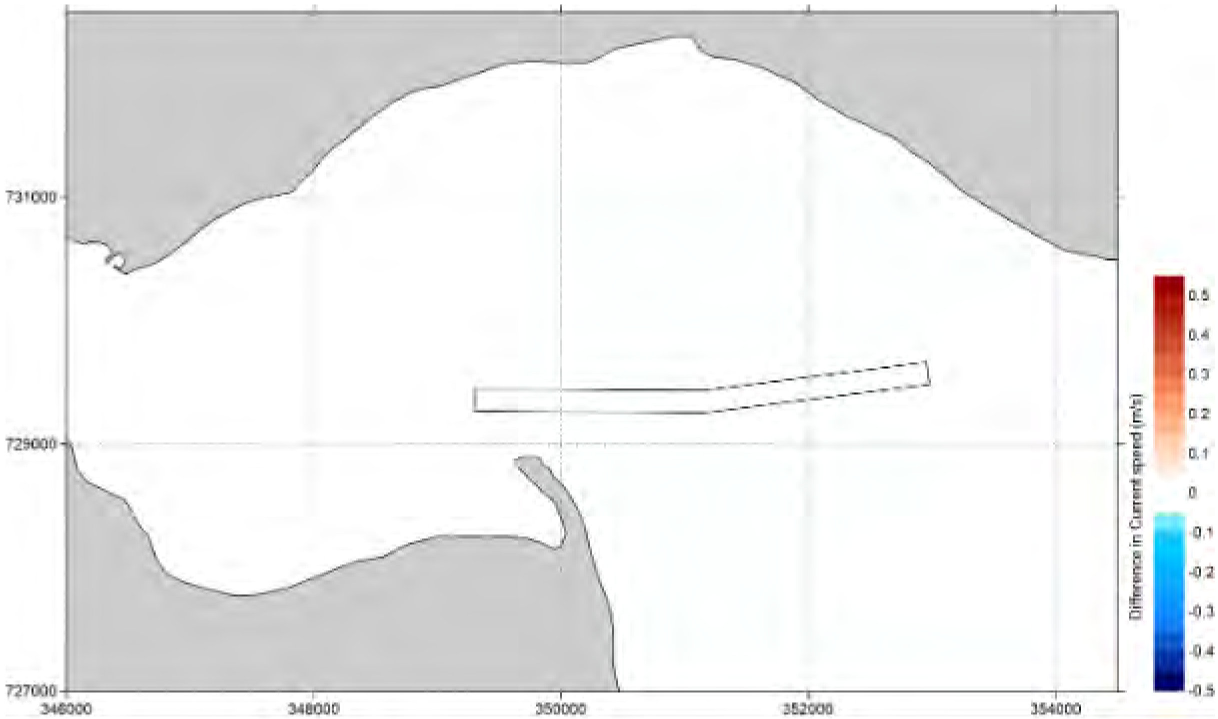

Figure 5-49 Difference in current speed (in metres per second) between 'Existing' and 'Option' during neap tide at the Lady Shoal approach channel 2 (positive means increase of current speed by option and vice versa) – peak ebb

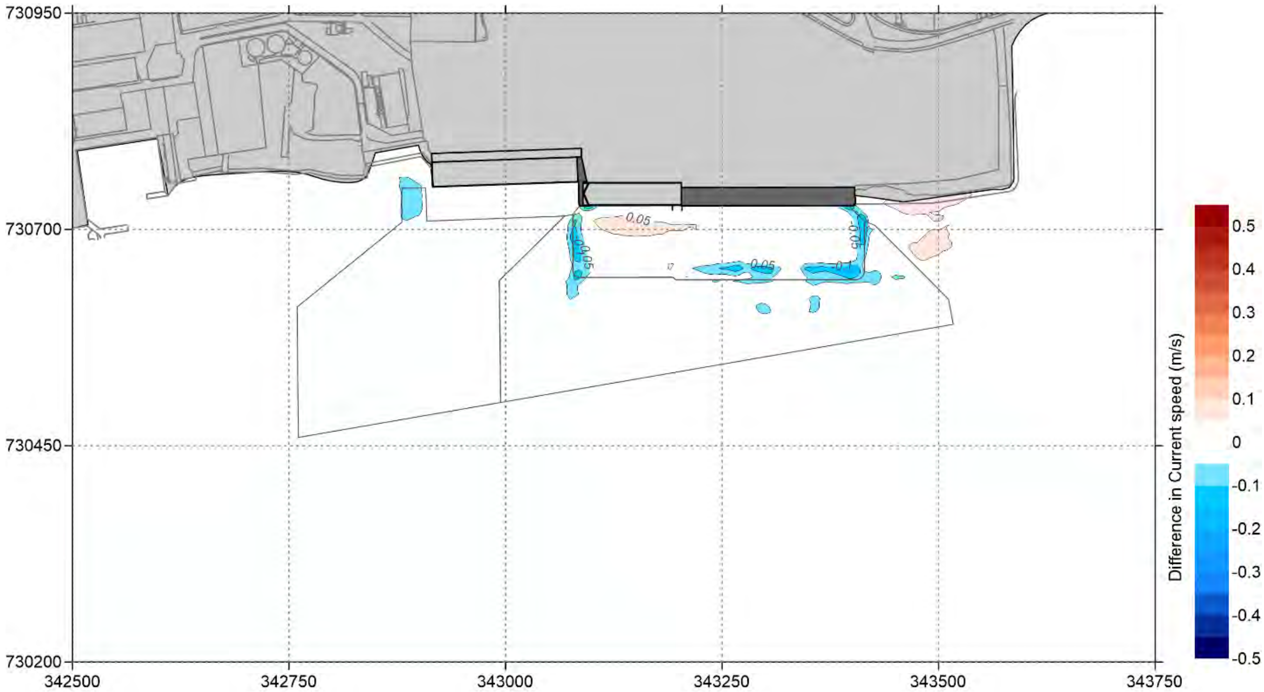

Figure 5-50 Difference in Maximum current speed (in metres per second) between 'Existing' and 'Option' over 30 days at the Port of Dundee (positive means increase of current speed by option and vice versa)

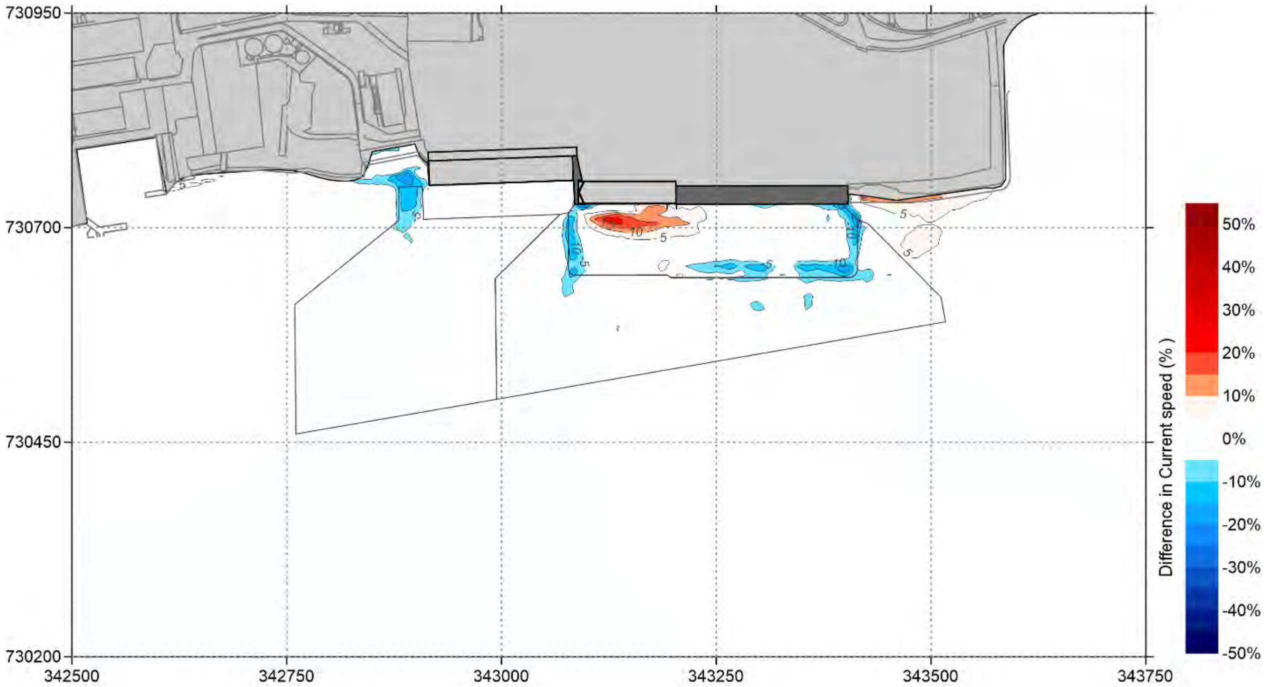

Figure 5-51 Percentage change of Maximum current speed between 'Existing' and 'Option' over 30 days at the Port of Dundee (positive means increase of current speed by option and vice versa)

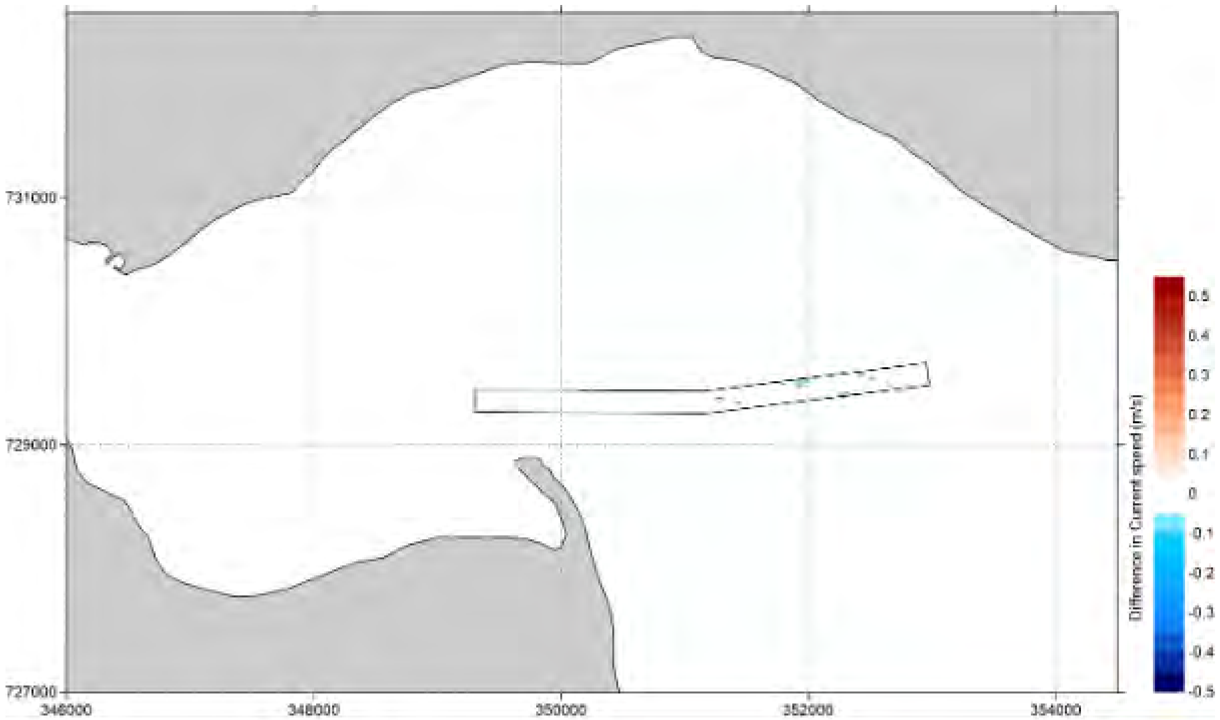

Figure 5-52 Difference in Maximum current speed (in metres per second) between 'Existing' and 'Option' over 30 days at the Lady Shoal approach channel (positive means increase of current speed by option and vice versa)

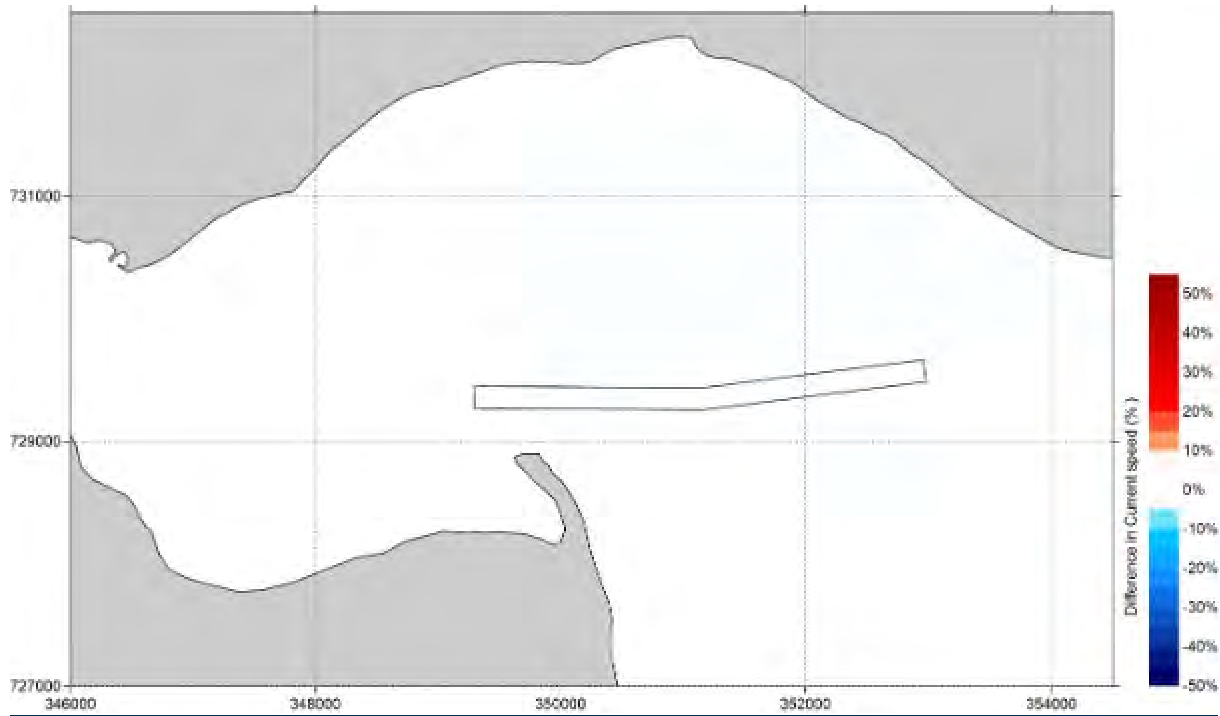

Figure 5-53 Percentage change of Maximum current speed between 'Existing' and 'Option' over 30 days at the Lady Shoal approach channel (positive means increase of current speed by option and vice versa)

5.6.2 Bed shear stress

5.6.2.1 Existing layout – Port of Dundee area

Figure 5-54 to **Figure 5-57** show the bed shear stress for the Existing layout at the Port of Dundee work area over a spring and neap tide, each for peak flood and ebb.

Bed shear stress in the Port of Dundee area generally decreases landward, with lowest bed shear stress against the quay wall. Overall bed shear stress in the work area is greater during spring than neap tide, remaining below 3.5 N/m^2 at spring tide and below 1.5 N/m^2 during neap tide.

Outside the work area, significantly higher bed shear stress values reach up to 20 N/m^2 at the southeastern corner and south edge of the eastern side of Dundee Port.

The Port of Dundee work area indicated maximum bed shear stress 3.5 N/m^2 over a 30-day period covering a spring and neap cycle for Existing conditions (**Figure 5-58**). Higher maximum bed shear stress was indicated outside of the work area, along the south wall of the eastern side of Dundee Port, where values reached 10 N/m^2 to 20 N/m^2.

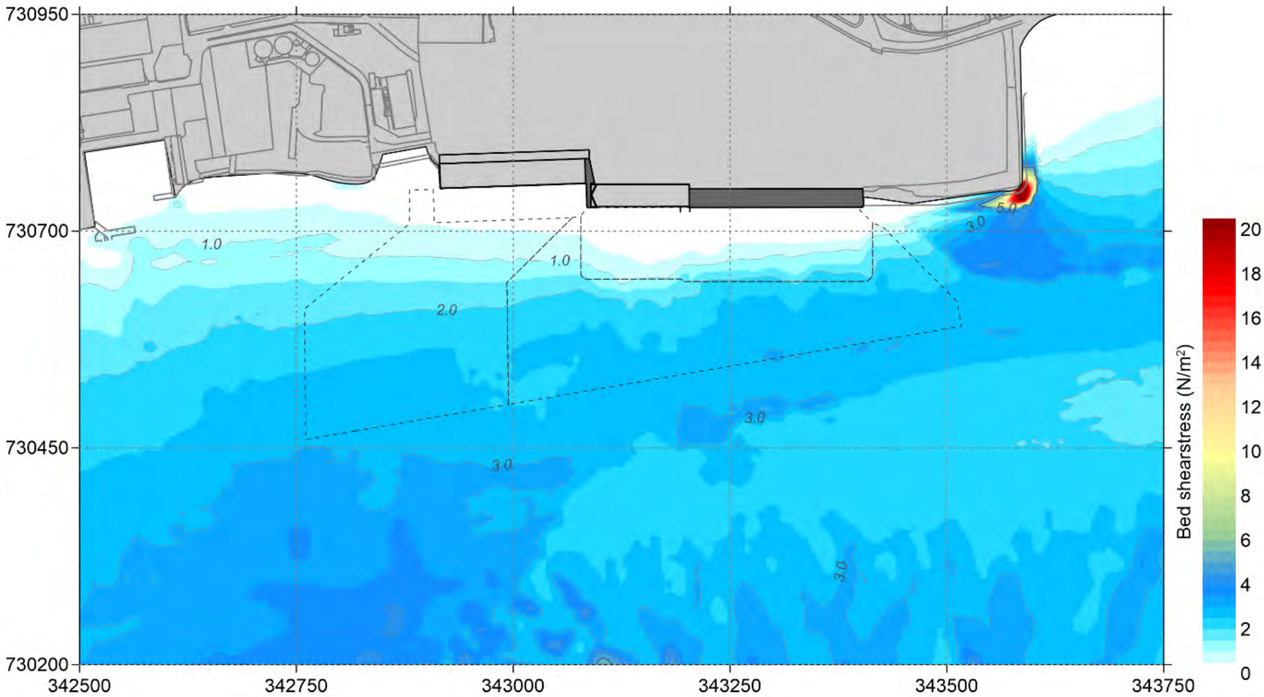

Figure 5-54 Existing layout - Bed shear stress during spring tide - peak flood (Local model) –Port of Dundee area

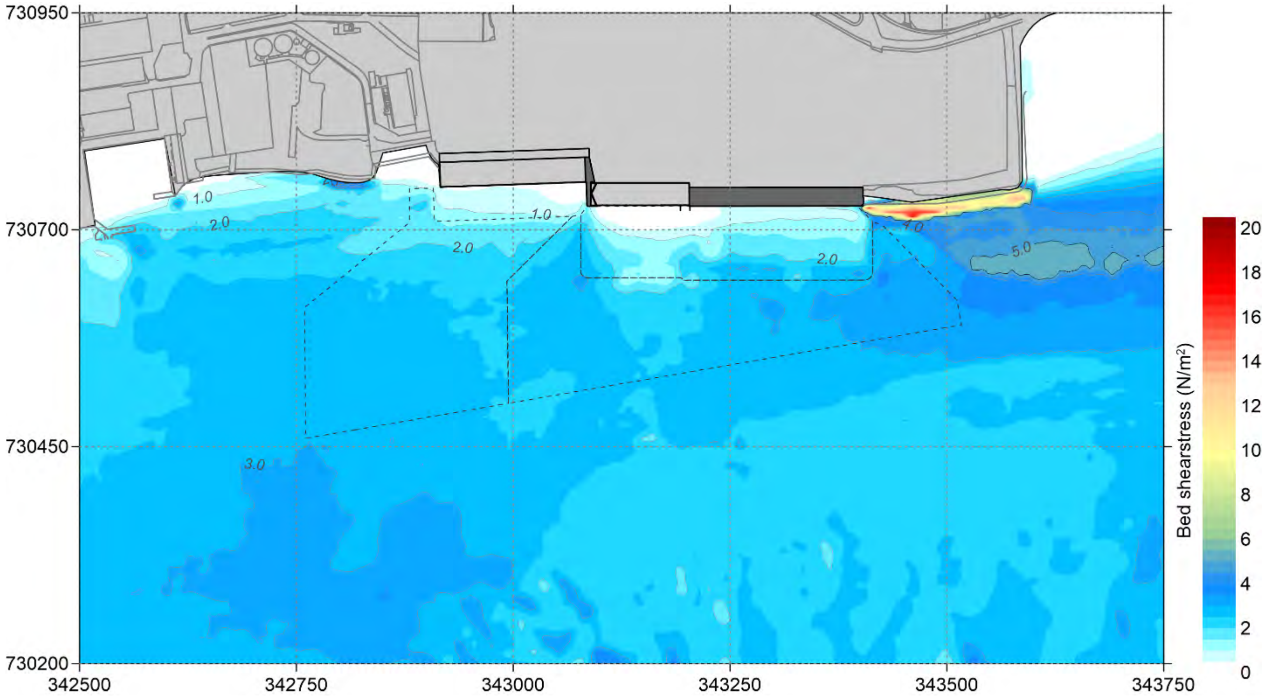

Figure 5-55 Existing layout - Bed shear stress during spring tide - peak ebb (Local model) – Port of Dundee area

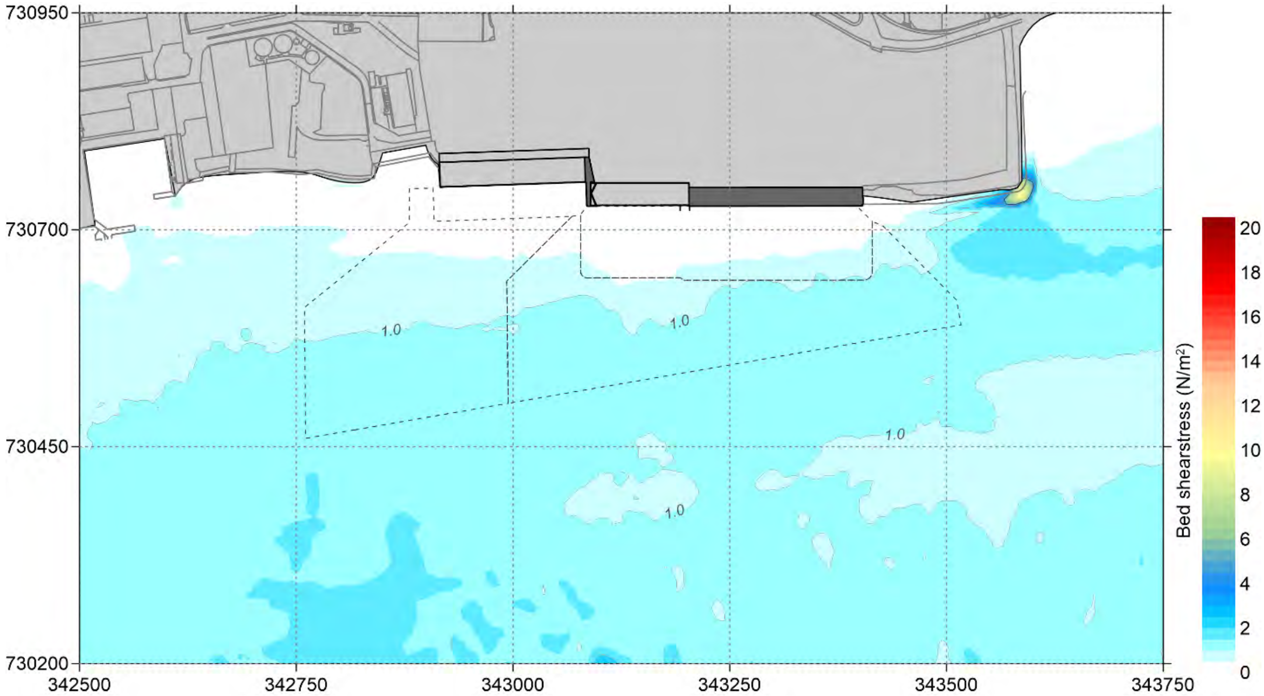

Figure 5-56 Existing layout - Bed shear stress during neap tide - peak flood (Local model) – Port of Dundee area

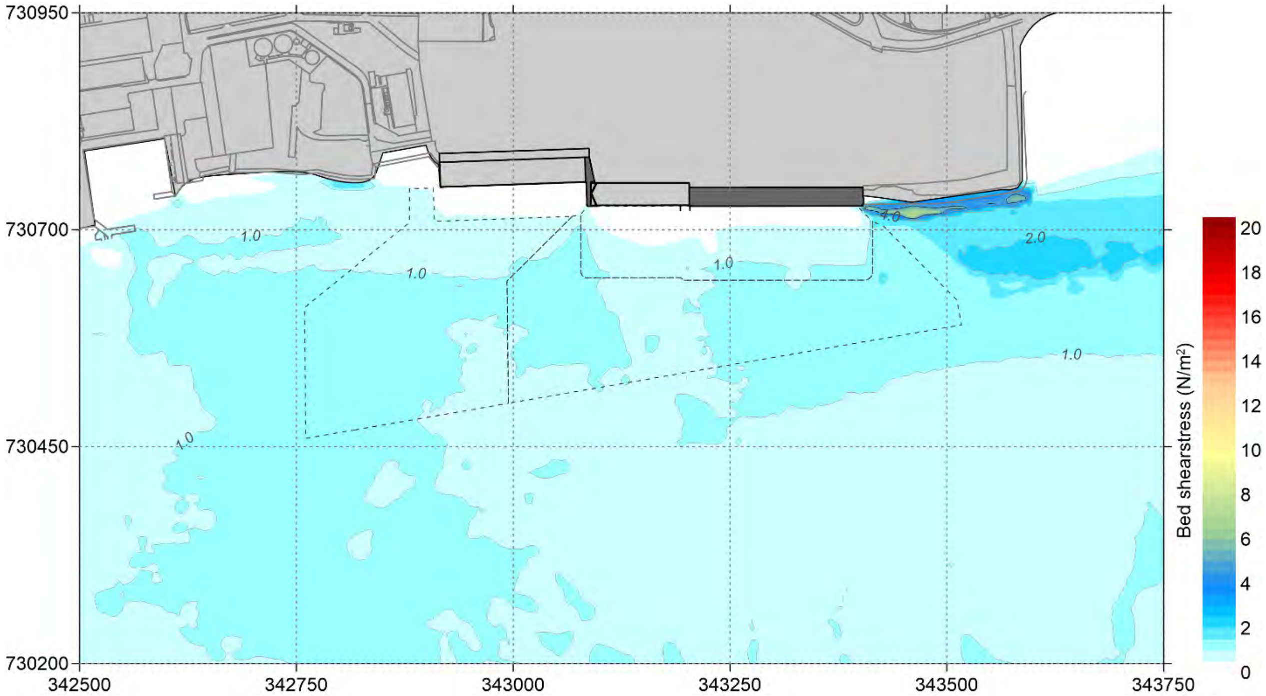

Figure 5-57 Existing layout - Bed shear stress during neap tide - peak ebb (Local model) – Port of Dundee area

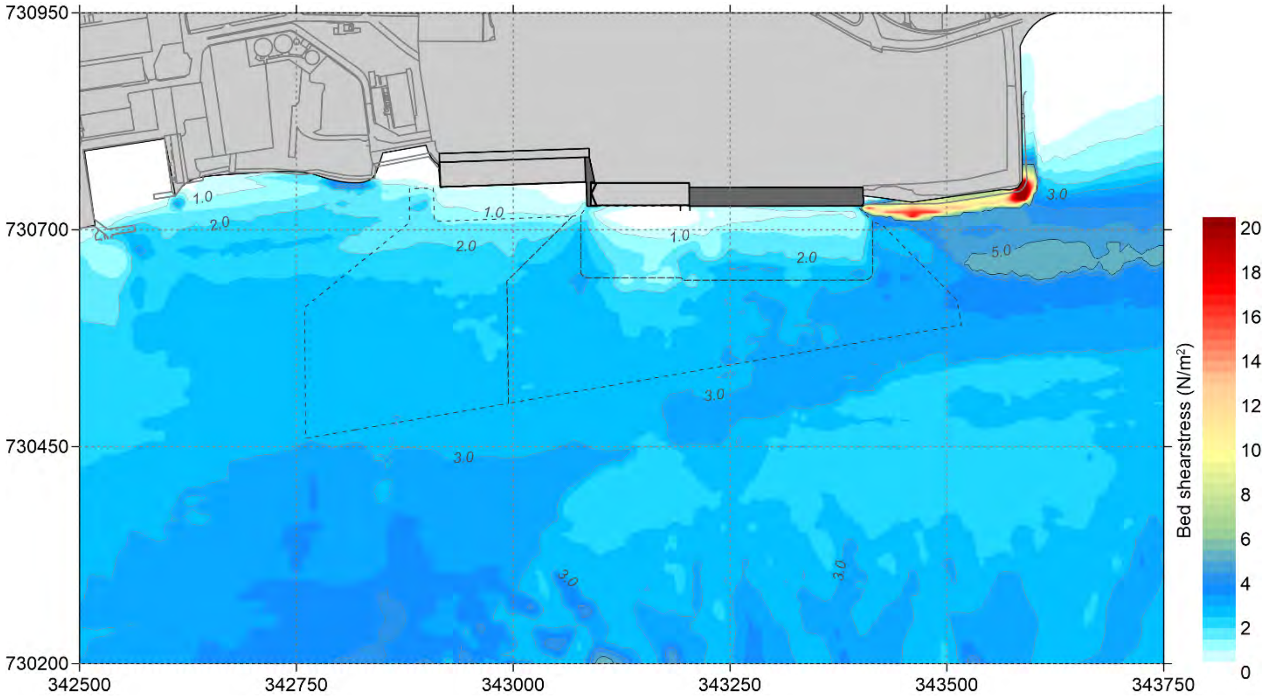

Figure 5-58 Existing layout – Maximum Bed shear stress over 30 days (Local model) – Port of Dundee area

5.6.2.2 Existing layout – Lady Shoal approach channel

Figure 5-59 to **Figure 5-62** show bed shear stress for the Existing layout at the Lady Shoal approach channel work area over a spring and neap tide, each for peak flood and ebb.

Bed shear stress is greater during spring tide than neap tide, and greater during peak ebb than during peak flood.

The greatest bed shear stress within the Lady Shoal work area is during the spring tide at peak ebb, where bed shear stress ranges from 3.5 N/m^2 to 14.5 N/m^2. During neap tide, bed shear stress in the work area ranges from 1 N/m^2 to 4 N/m^2. Higher bed stress is concentrated predominantly on the West side of the Lady Shoal approach channel

Figure 5-63 shows the maximum bed shear stress occurring over a 30-day period at the Lady Shoal approach channel. Within the work area, maximum values are predominantly range from 5 N/m^2 to 16 N/m^2.

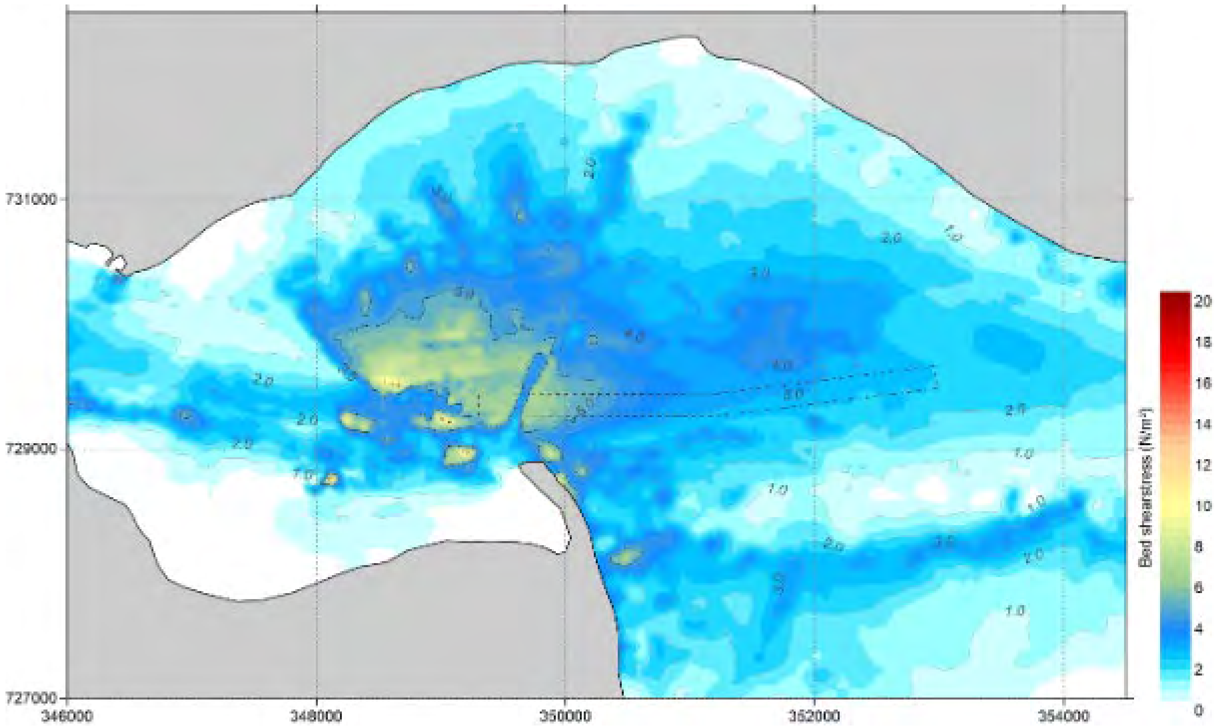

Figure 5-59 Existing layout - Bed shear stress during spring tide - peak flood (Local model) – Lady Shoal approach channel

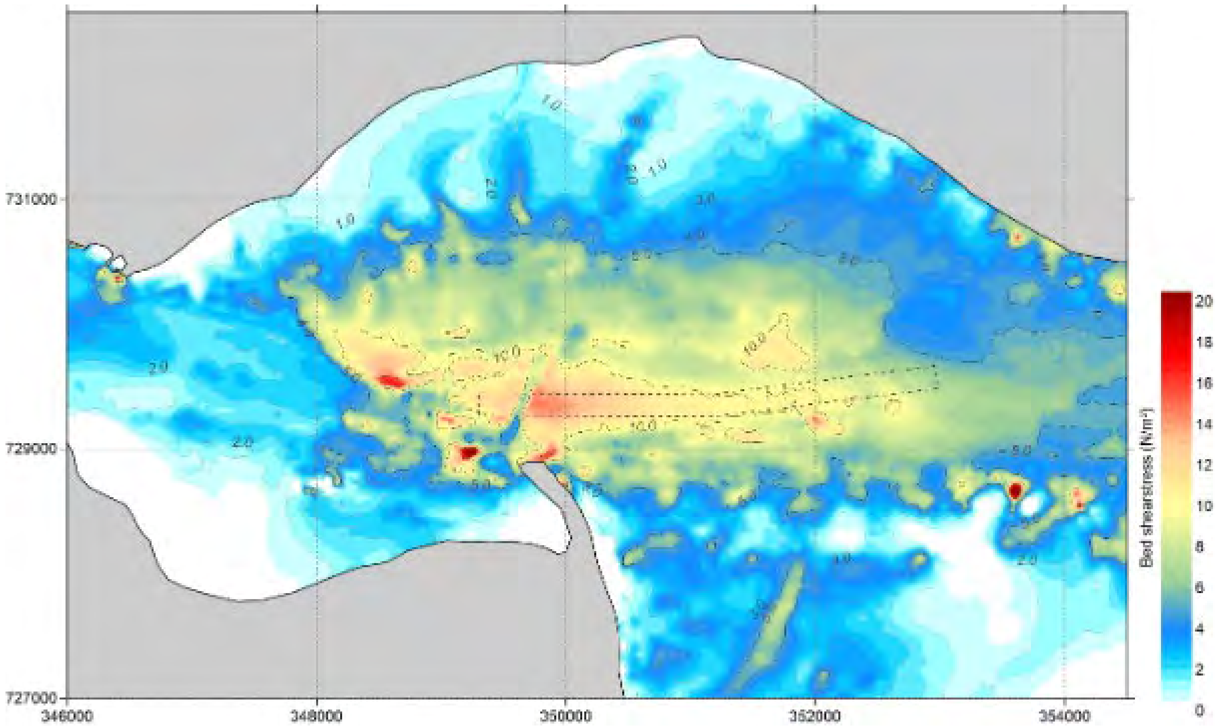

Figure 5-60 Existing layout - Bed shear stress during spring tide - peak ebb (Local model) – Lady Shoal approach channel

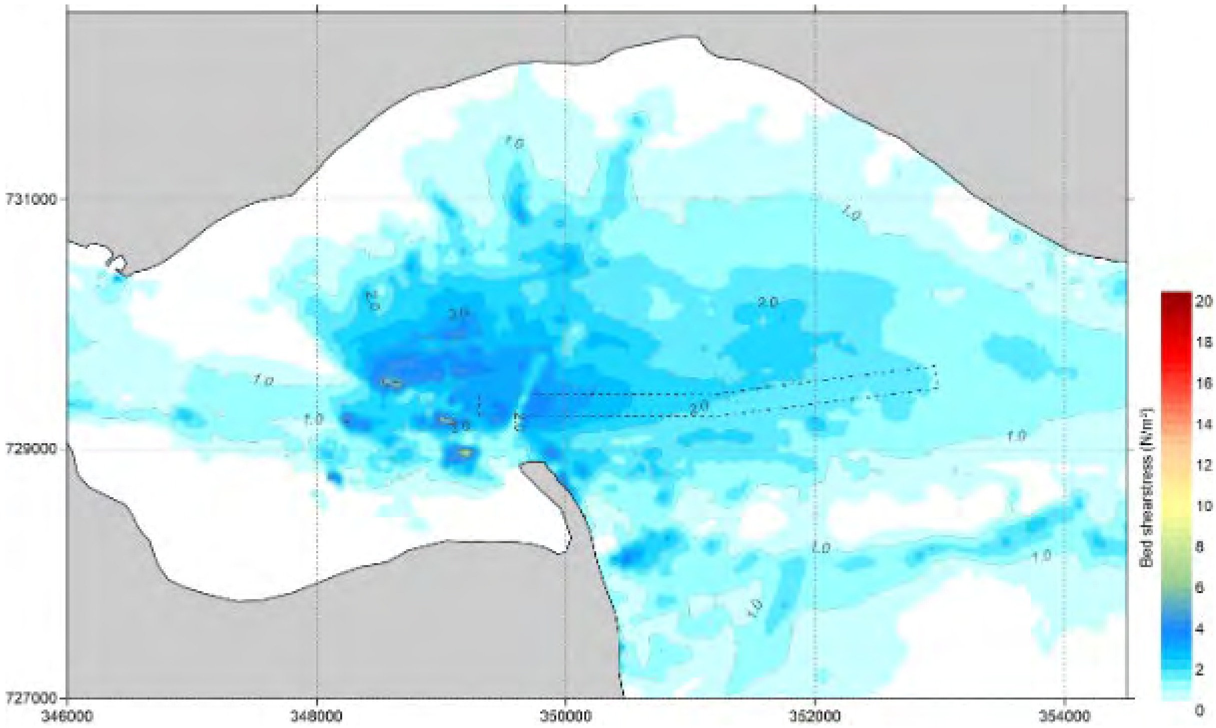

Figure 5-61 Existing layout - Bed shear stress during neap tide - peak flood (Local model) – Lady Shoal approach channel

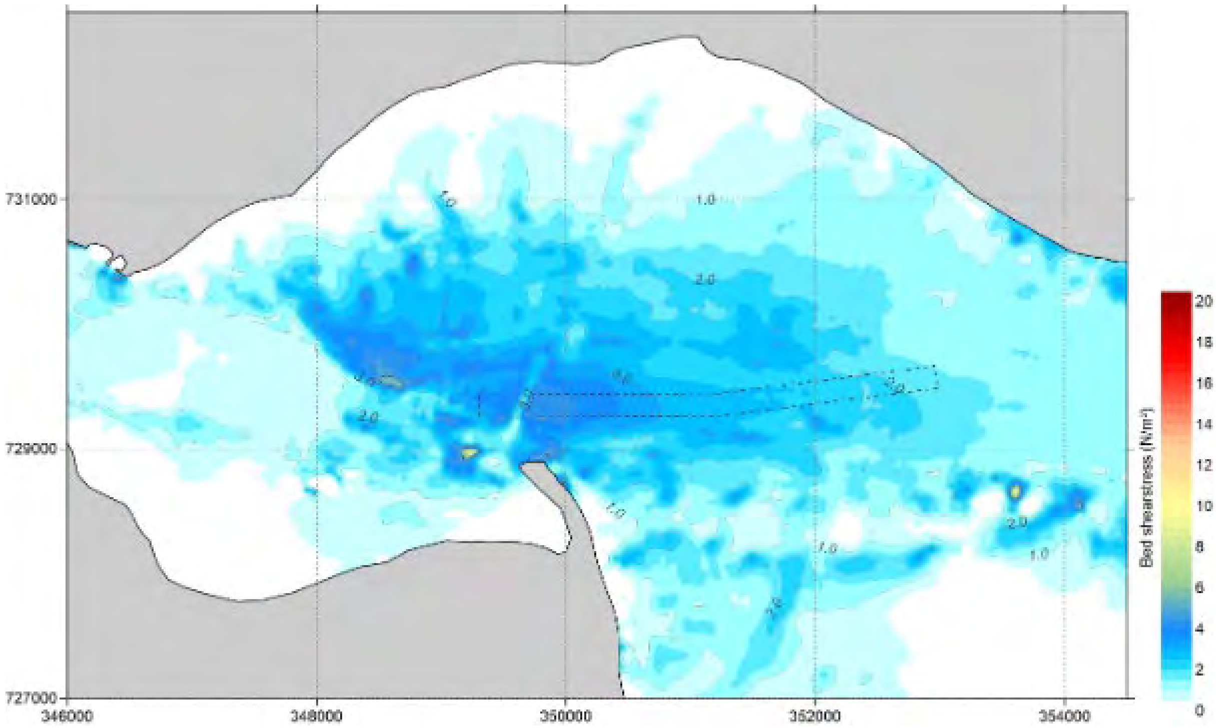

Figure 5-62 Existing layout - Bed shear stress during neap tide - peak ebb (Local model) – Lady Shoal approach channel

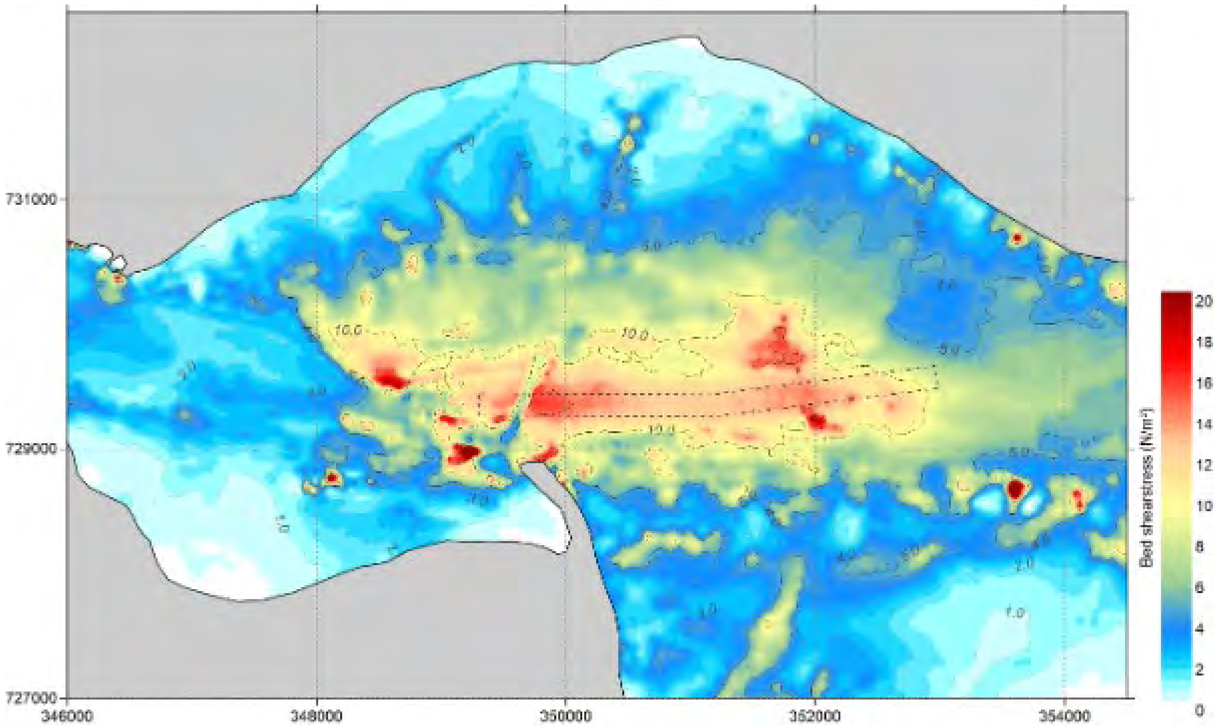

Figure 5-63 Existing layout – Maximum Bed shear stress over 30 days (Local model) – Lady Shoal approach channel

5.6.2.3 Option layout – Port of Dundee area

Figure 5-64 to **Figure 5-67** show the bed shear stress modelled for the Option layout at the Port of Dundee work area over a spring and neap tide, each for peak and ebb flood. **Figure 5-68** shows the maximum bed shear stress over a 30-day period covering a spring and neap cycle for the Option layout,

Differences in bed shear stress of the Option layout to the Existing layout for the Port of Dundee are outlined in **Section 5.6.2.5**.

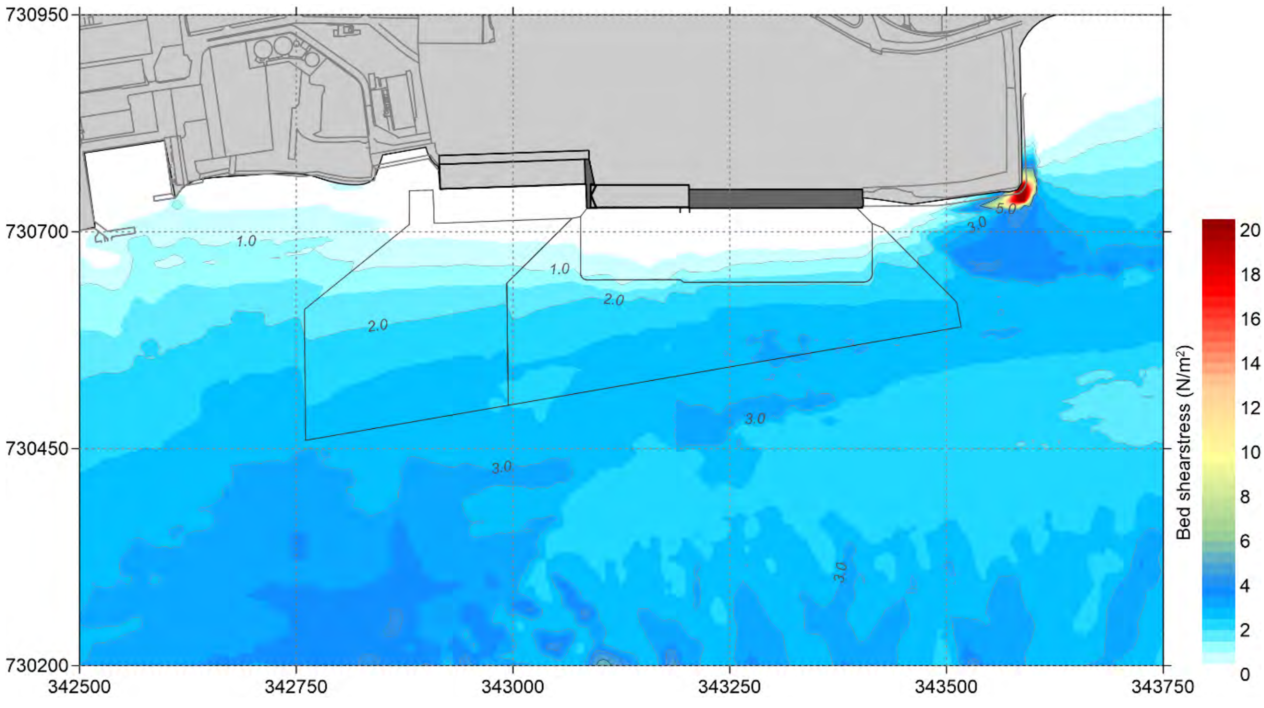

Figure 5-64 Option layout - Bed shear stress during spring tide - peak flood (Local model) – Port of Dundee area

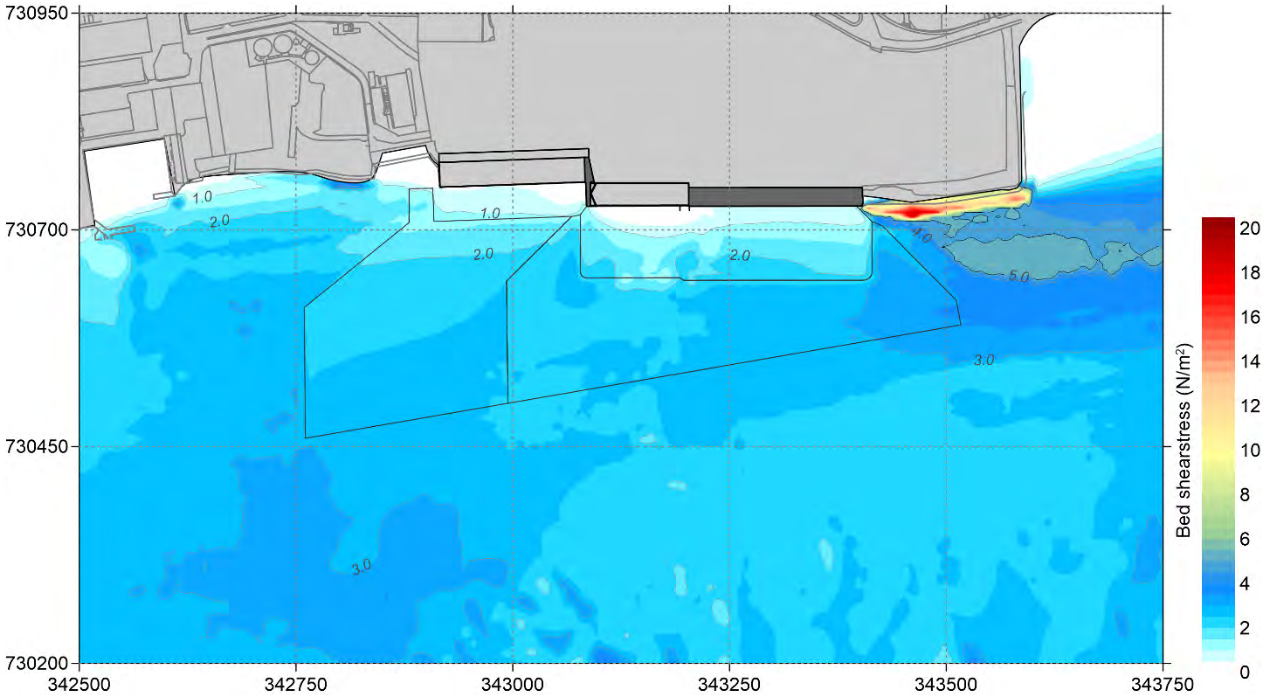

Figure 5-65 Option layout - Bed shear stress during spring tide - peak ebb (Local model) – Port of Dundee area

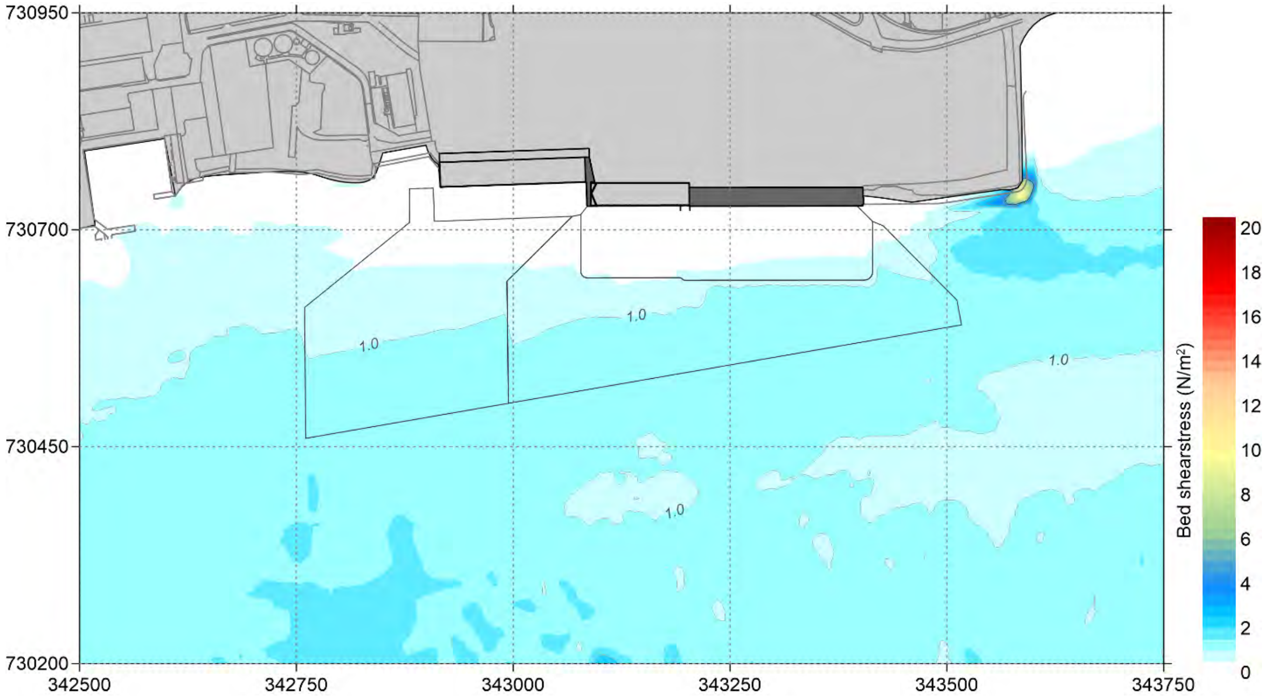

Figure 5-66 Option layout - Bed shear stress during neap tide - peak flood (Local model) – Port of Dundee area

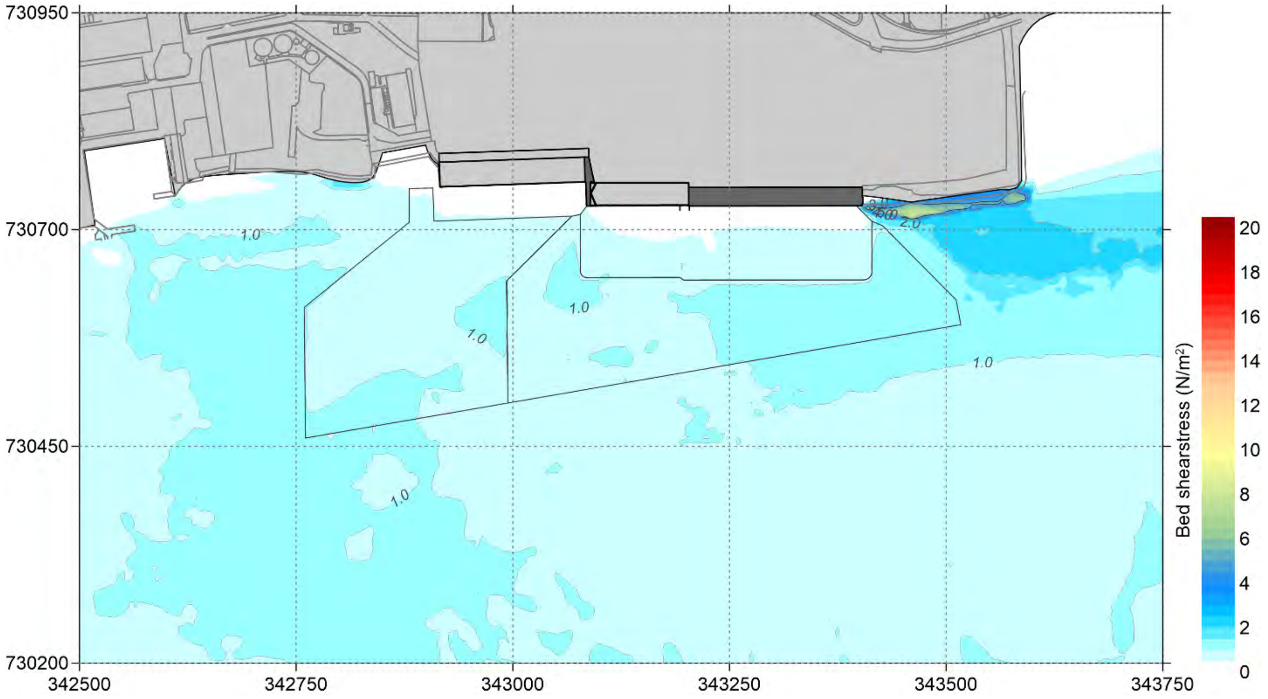

Figure 5-67 Option layout - Bed shear stress during neap tide - peak ebb (Local model) – Port of Dundee area

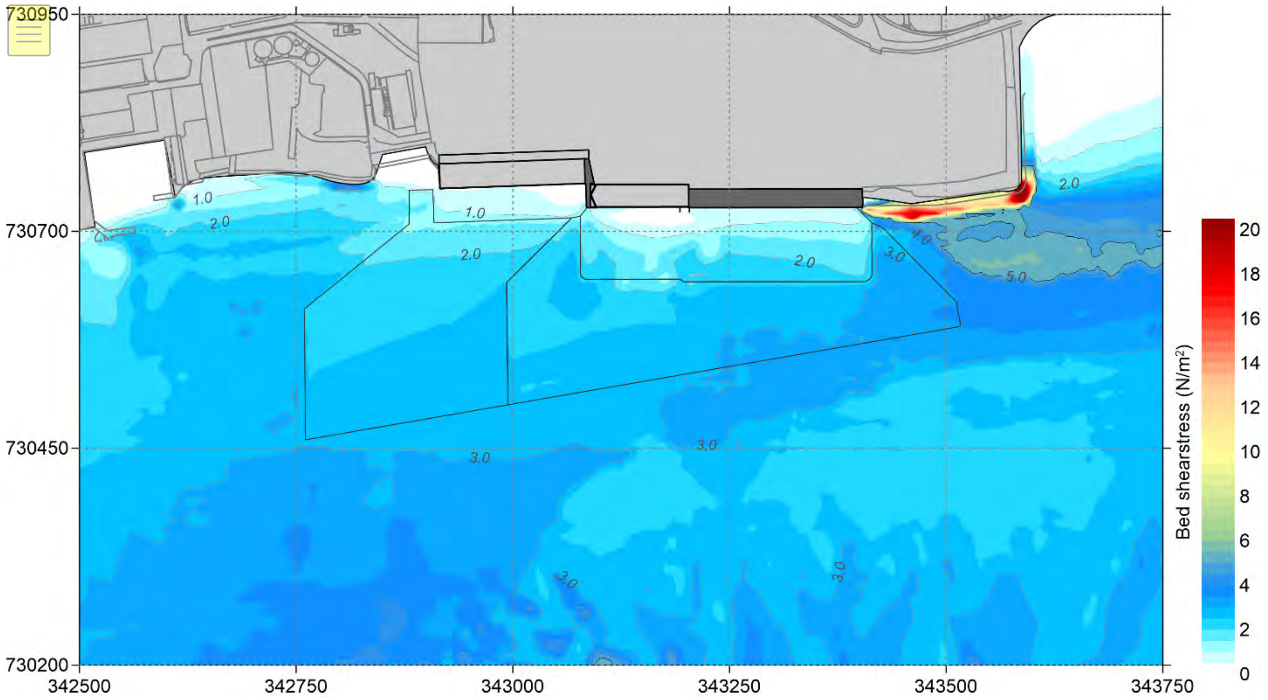

Figure 5-68 Option layout – Maximum Bed shear stress over 30 days (Local model) – Port of Dundee area

5.6.2.4 Option layout – Lady Shoal approach channel

Figure 5-69 to **Figure 5-72** show the bed shear stress modelled for the Option layout at the Lady Shoal approach channel work area over a spring and neap tide, each for peak and ebb flood. **Figure 5-73** shows the maximum bed shear stress over a 30-day period covering a spring and neap cycle for the Option layout,

Differences in bed shear stress of the Option layout to the Existing layout for the Lady Shoal approach channel are outlined in **Section 5.6.2.5**.

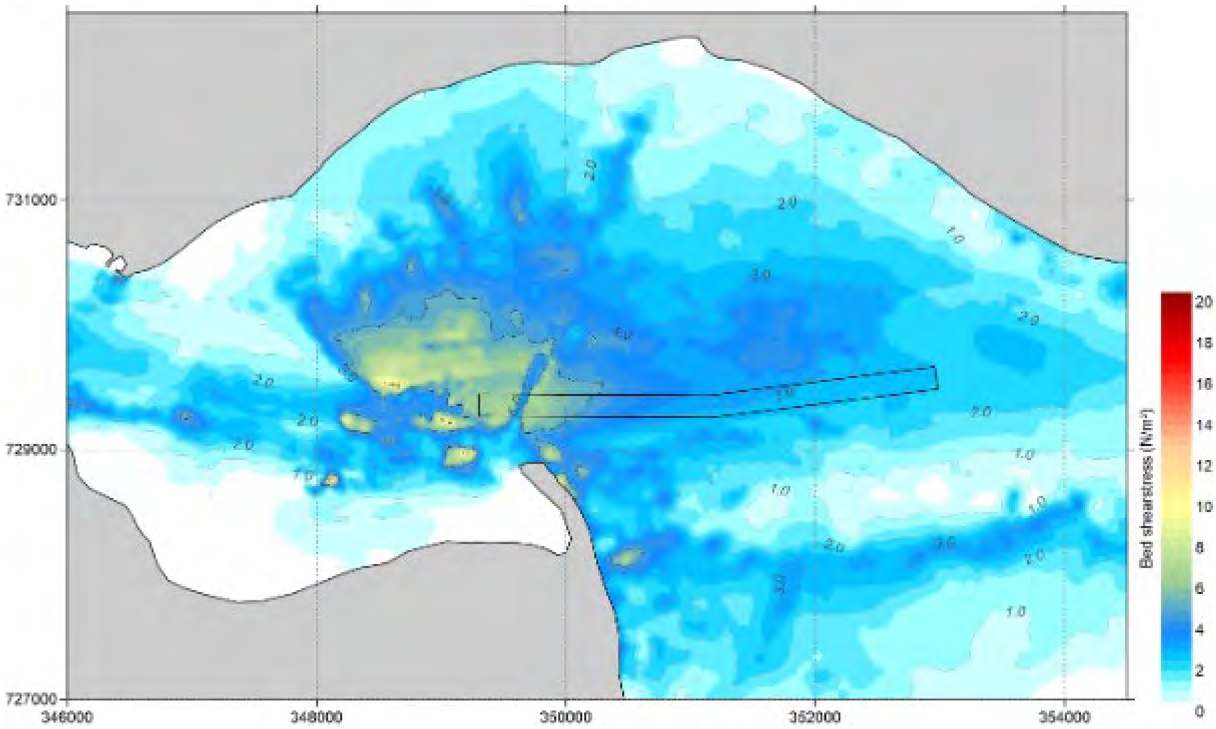

Figure 5-69 Option layout - Bed shear stress during spring tide - peak flood (Local model) – Lady Shoal approach channel

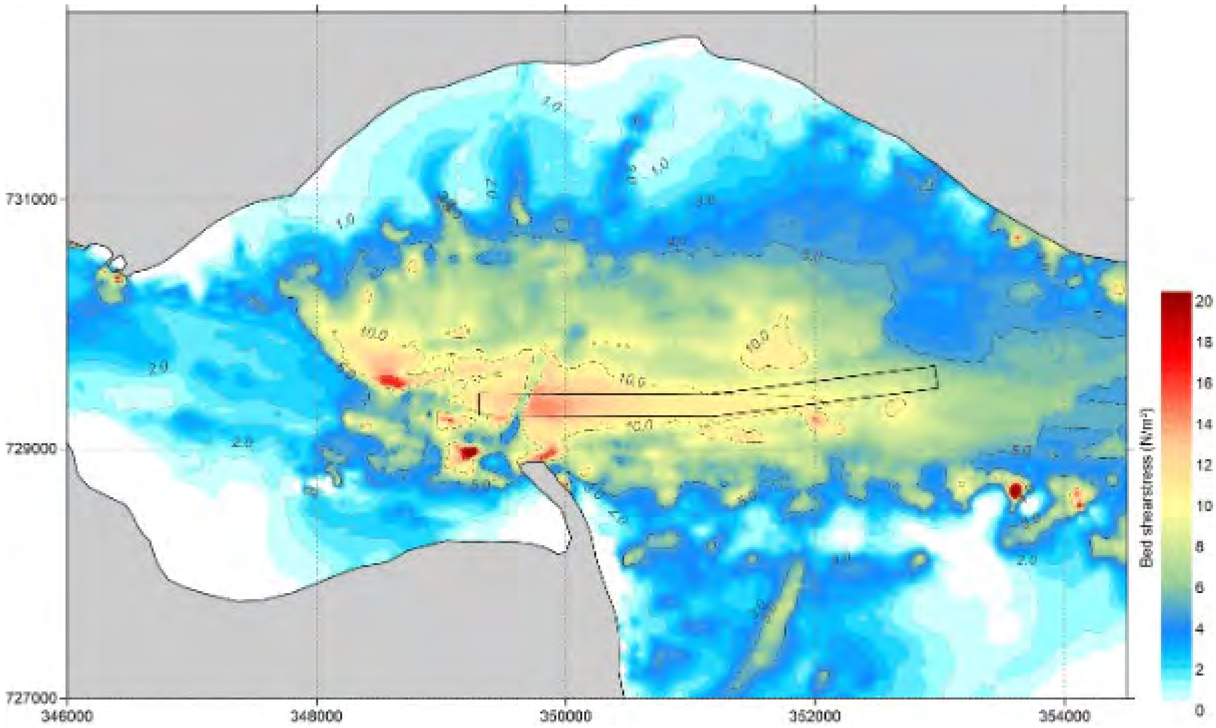

Figure 5-70 Option layout - Bed shear stress during spring tide - peak ebb (Local model) – Lady Shoal approach channel

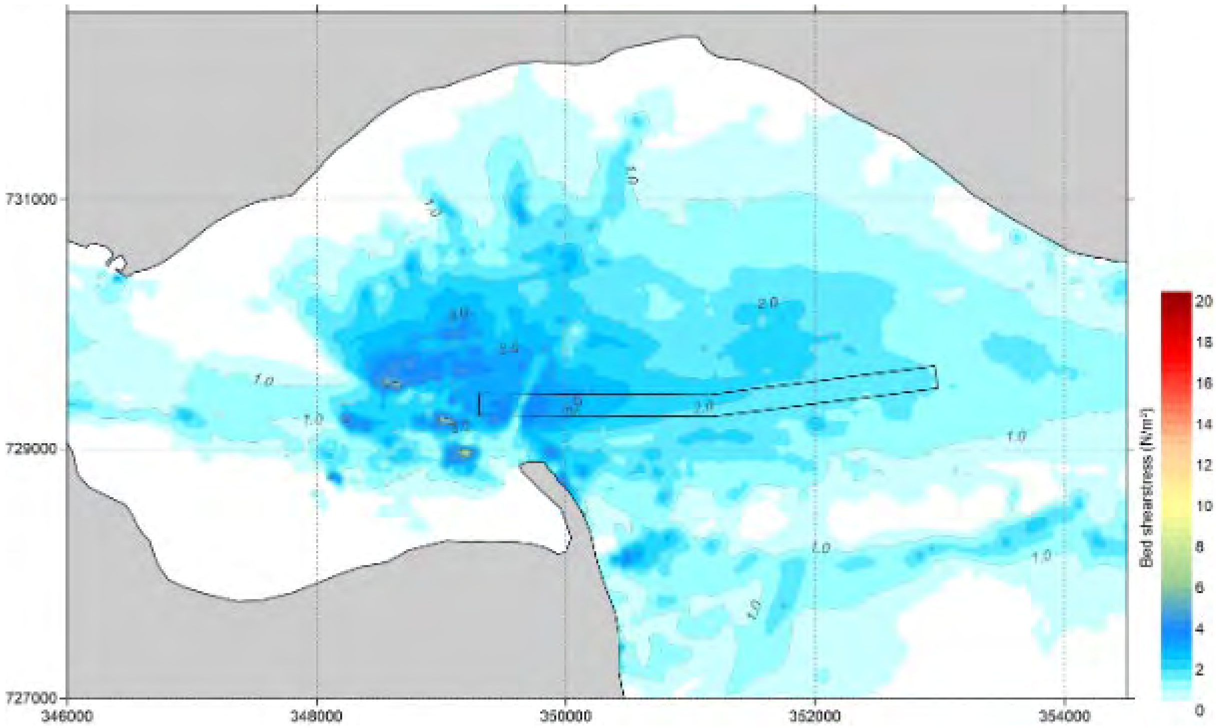

Figure 5-71 Option layout - Bed shear stress during neap tide - peak flood (Local model) – Lady Shoal approach channel

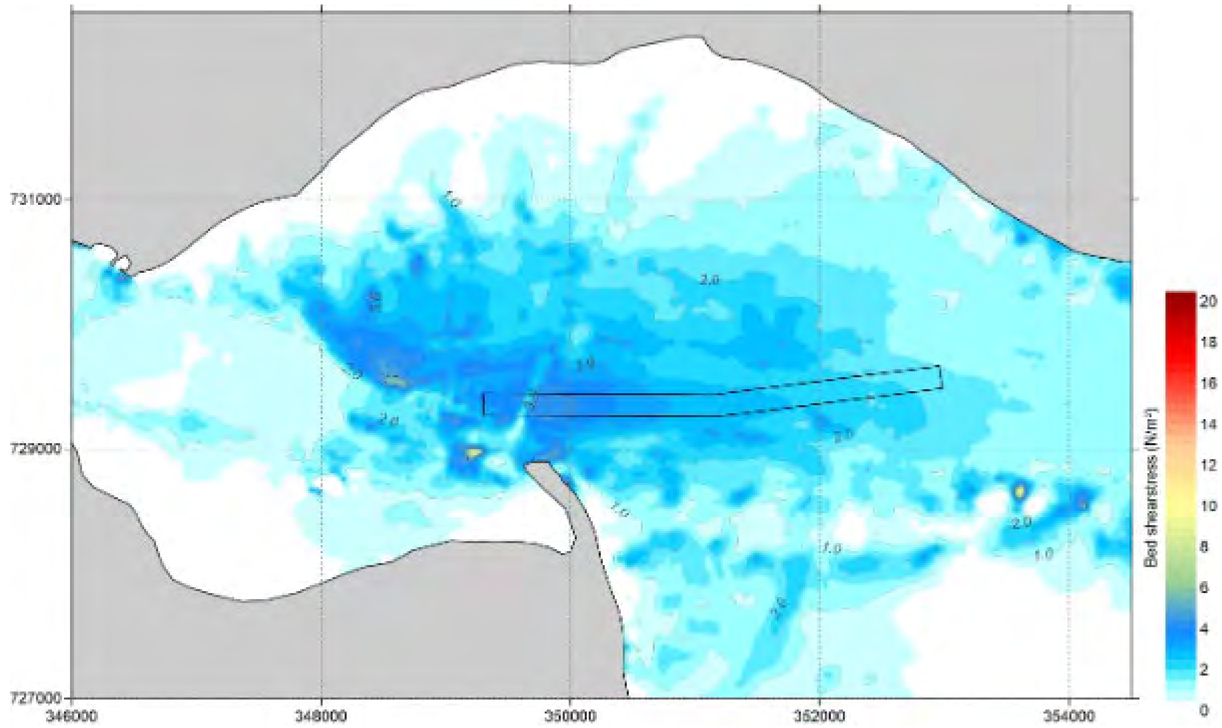

Figure 5-72 Option layout - Bed shear stress during neap tide - peak ebb (Local model) – Lady Shoal approach channel

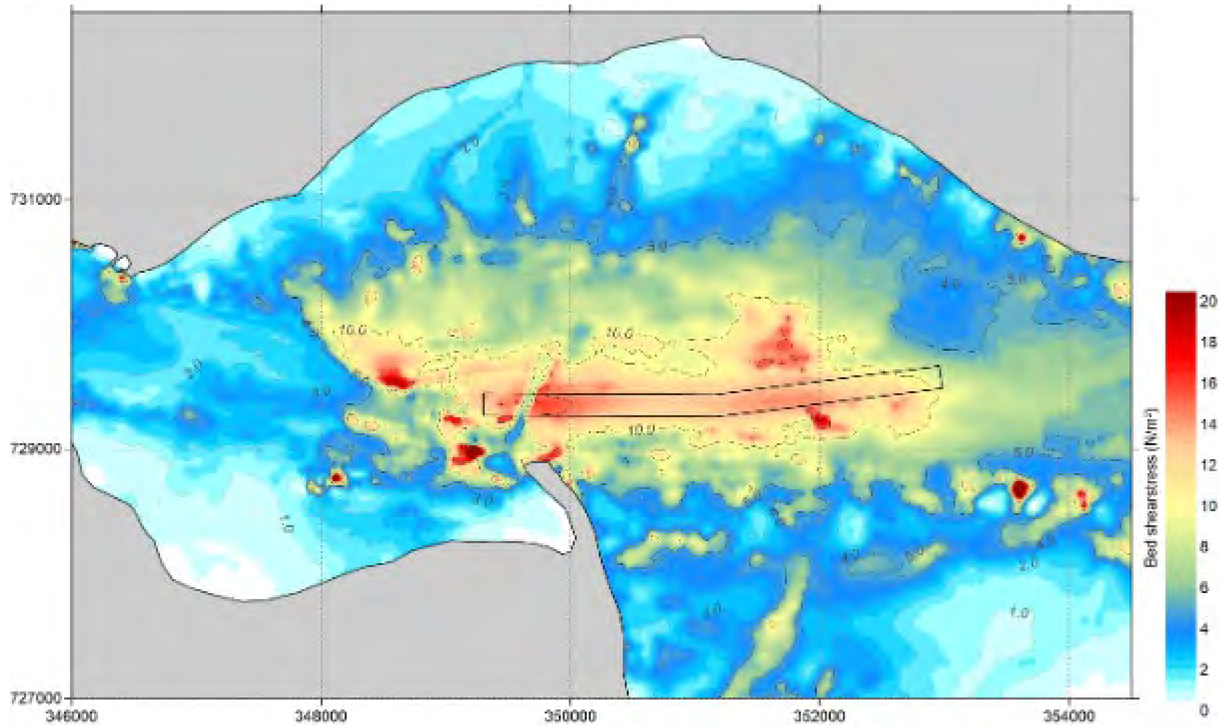

Figure 5-73 Option layout – Maximum Bed shear stress over 30 days (Local model) – Lady Shoal approach channel

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5.6.2.5 Impacts on bed shear stress

Figure 5-74 to **Figure 5-81** show the difference bed shear stress between the Existing and Option layouts at the Port of Dundee and Lady Shoal approach channel work areas for a spring and neap tide, each during peak flood and peak ebb. Only relative changes in bed shear stress greater than 0.1 N/m^2 or less than -0.1 N/m^2, or percentage changes greater than 5% or less than -5%, are indicated in the figures.

The Option layout generally results in patches of lower bed shear stress within the Port of Dundee work area during both spring and neap tide. Bed shear stress is increased in the Option layout during peak ebb along the south wall at the eastern side of the Dundee port (for both spring and neap tide), where values are higher by ~0.5 - 2 N/m^2 than in the Exiting layout.

At the Lady Shoal work area during neap tide, differences in bed shear stress between the Option and Existing layouts remain less than ±0.2 N/m^2. During spring tide, greater differences in bed shear stress between the Option and Existing layouts occur during peak ebb than at peak flood. During spring tide at peak ebb, the bed shear stress in the Option layout differ from the Existing layout by ± 0.5 N/m^2, whereas during peak flood the Option layout is 0 to 0.2 N/m^2 less than the Existing layout in small patches.

Figure 5-82 and **Figure 5-83** show the difference in maximum bed shear stress and percentage change in maximum bed shear stress, respectively, over a 30-day period at the Port of Dundee. Within the work area, maximum bed shear stress of the Option layout is lower by up to 35% in some areas, such as around the edges of Berth Areas 1 and 2. Maximum bed shear stress is also increased in patches up to 40% closer to the quay wall.

Figure 5-84 and **Figure 5-85** show the difference in maximum bed shear stress and percentage change in maximum bed shear stress, respectively, over a 30-day period at the Lady Shoal approach channel. Changes to maximum bed shear stress are predominantly less than ±5%, with few patches of ±10% change.

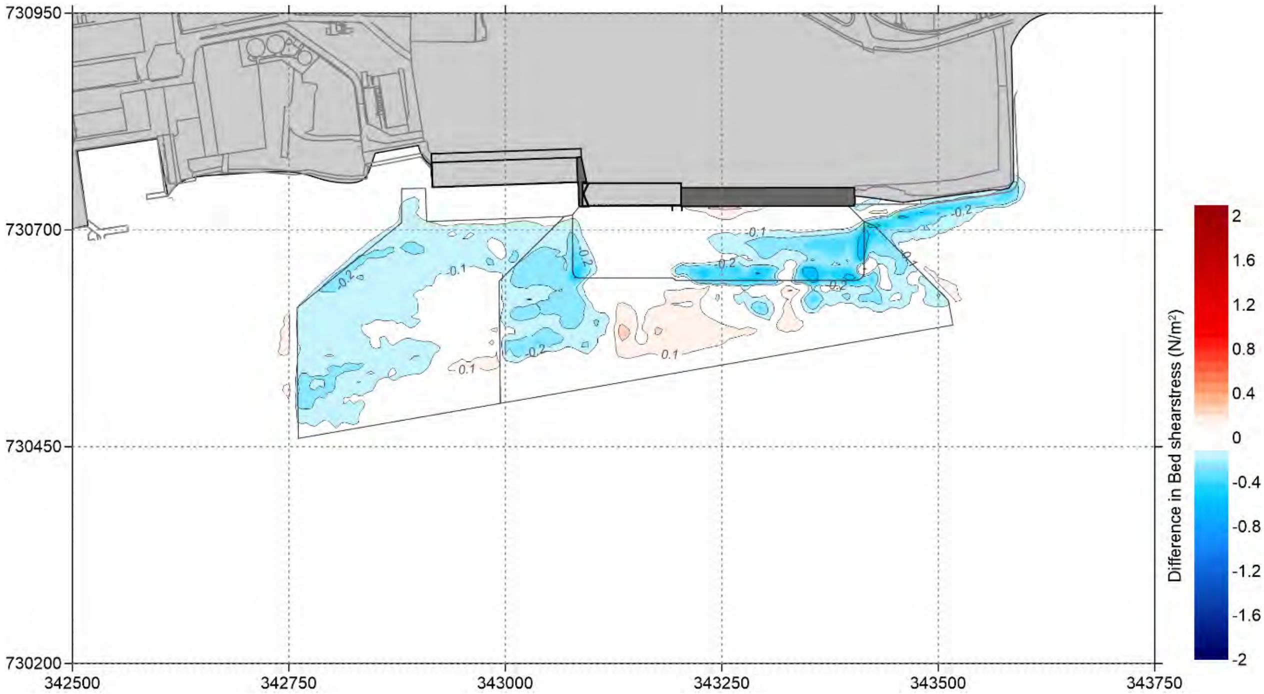

Figure 5-74 Difference in Bed shear stress (N/m^2) between 'Existing' and 'Option' during spring tide at the Port of Dundee area (positive means increase of Bed shear stress by option and vice versa) – peak flood

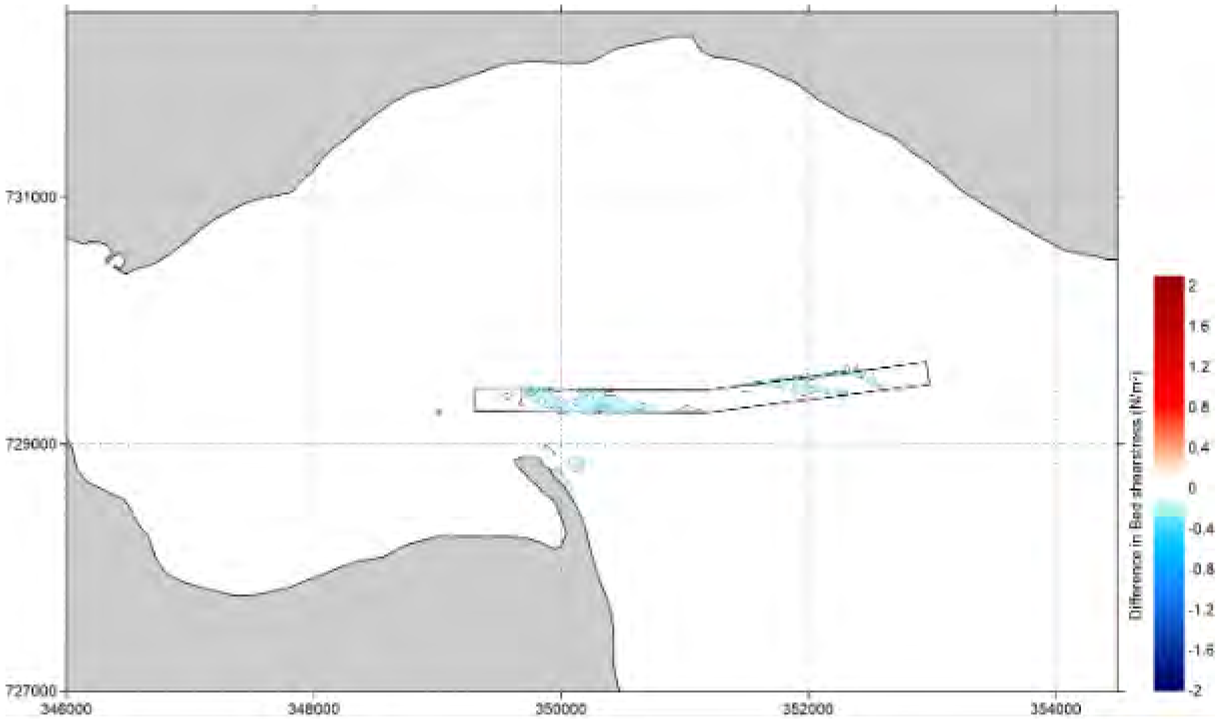

Figure 5-75 Difference in Bed shear stress (N/m^2) between 'Existing' and 'Option' during spring tide at the Lady Shoal approach channel (positive means increase of Bed shear stress by option and vice versa) – peak flood

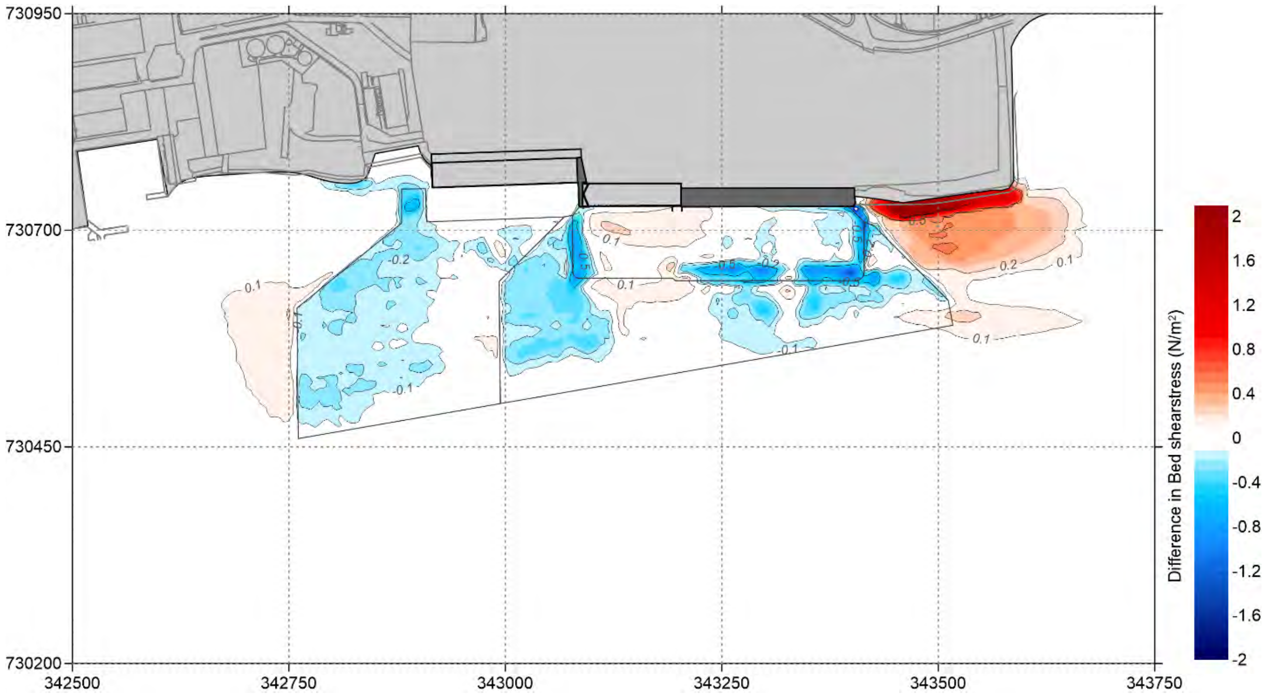

Figure 5-76 Difference in Bed shear stress (N/m^2) between 'Existing' and 'Option' during spring tide at the Port of Dundee area (positive means increase of Bed shear stress by option and vice versa) – peak ebb

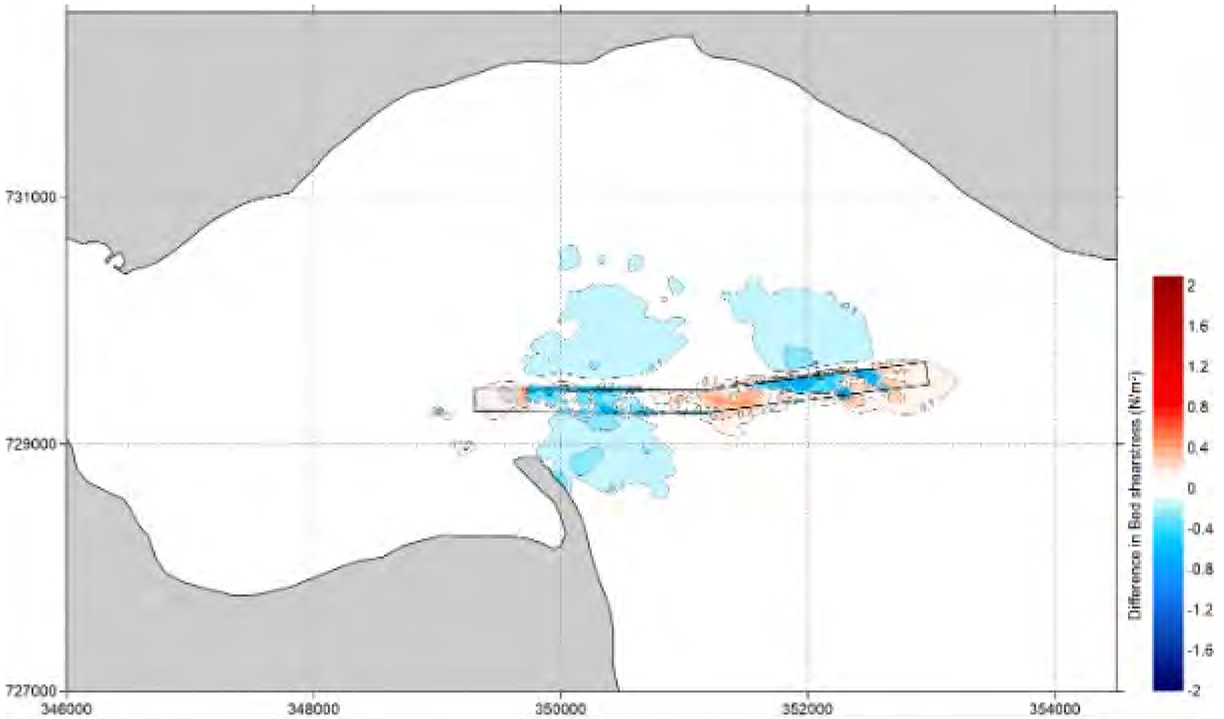

Figure 5-77 Difference in Bed shear stress (N/m^2) between 'Existing' and 'Option' during spring tide at the Lady Shoal approach channel (positive means increase of Bed shear stress by option and vice versa) – peak ebb

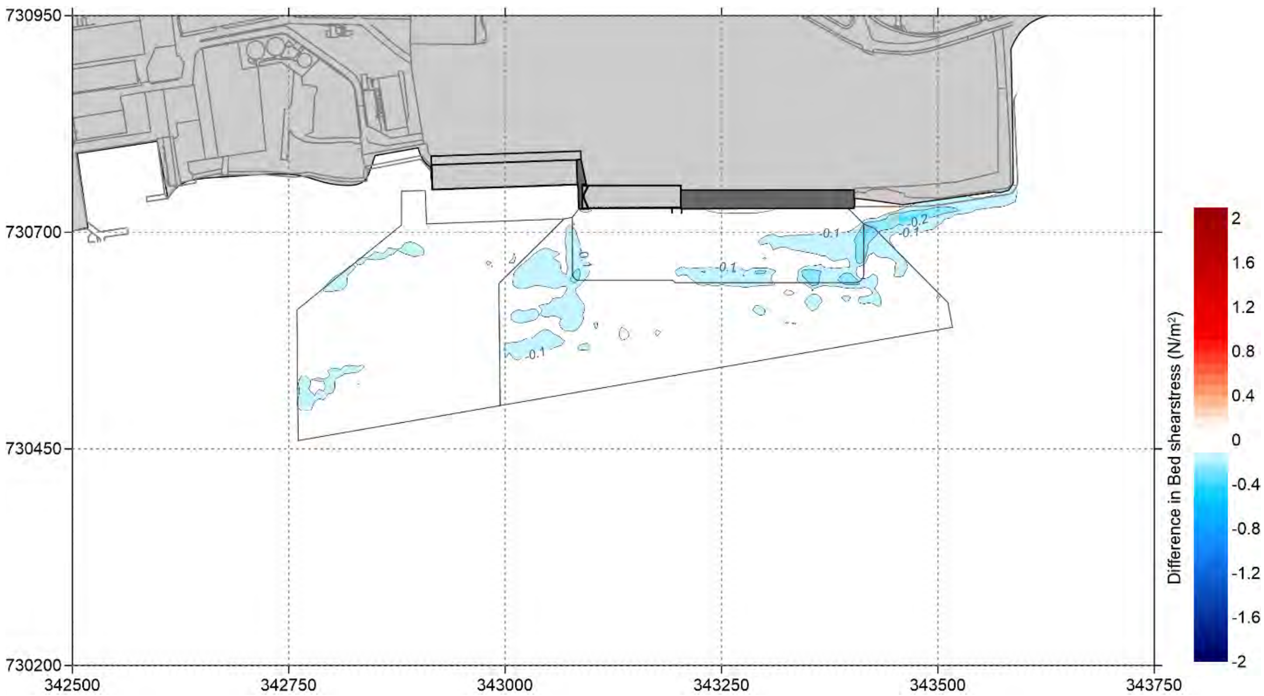

Figure 5-78 Difference in Bed shear stress (N/m^2) between 'Existing' and 'Option' during neap tide at the Port of Dundee area (positive means increase of Bed shear stress by option and vice versa) – peak flood

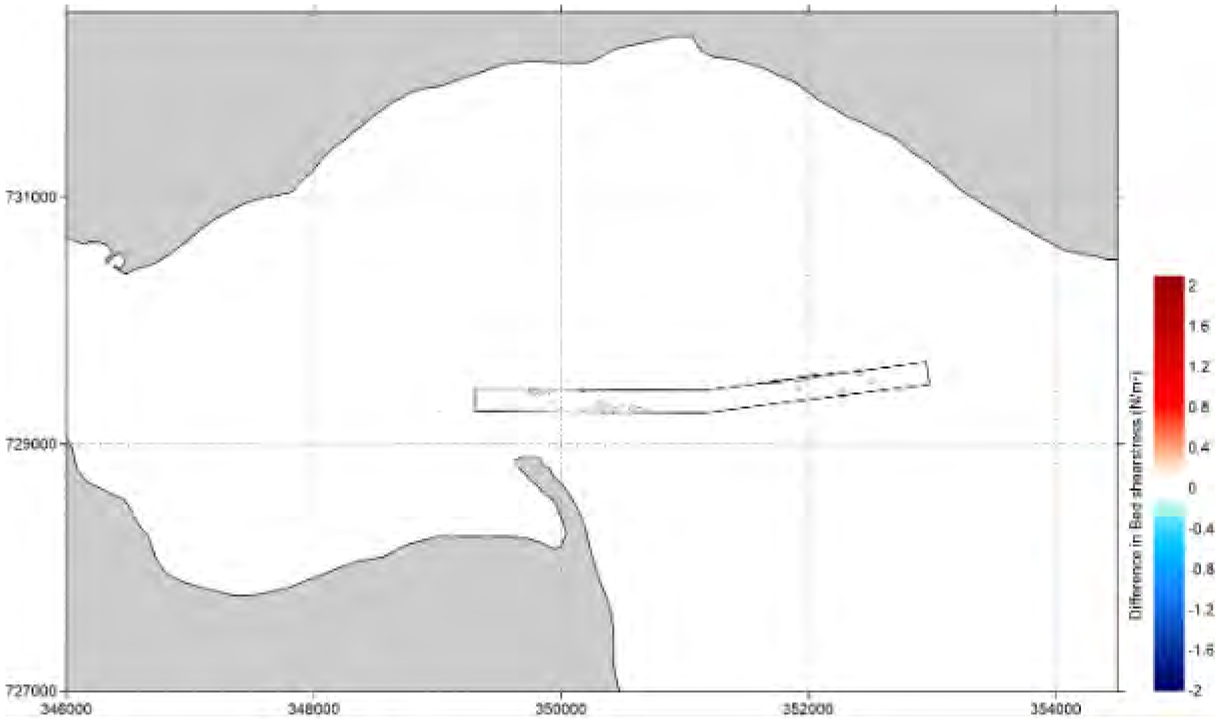

Figure 5-79 Difference in Bed shear stress (N/m^2) between 'Existing' and 'Option' during neap tide at the Lady Shoal approach channel (positive means increase of Bed shear stress by option and vice versa) – peak flood

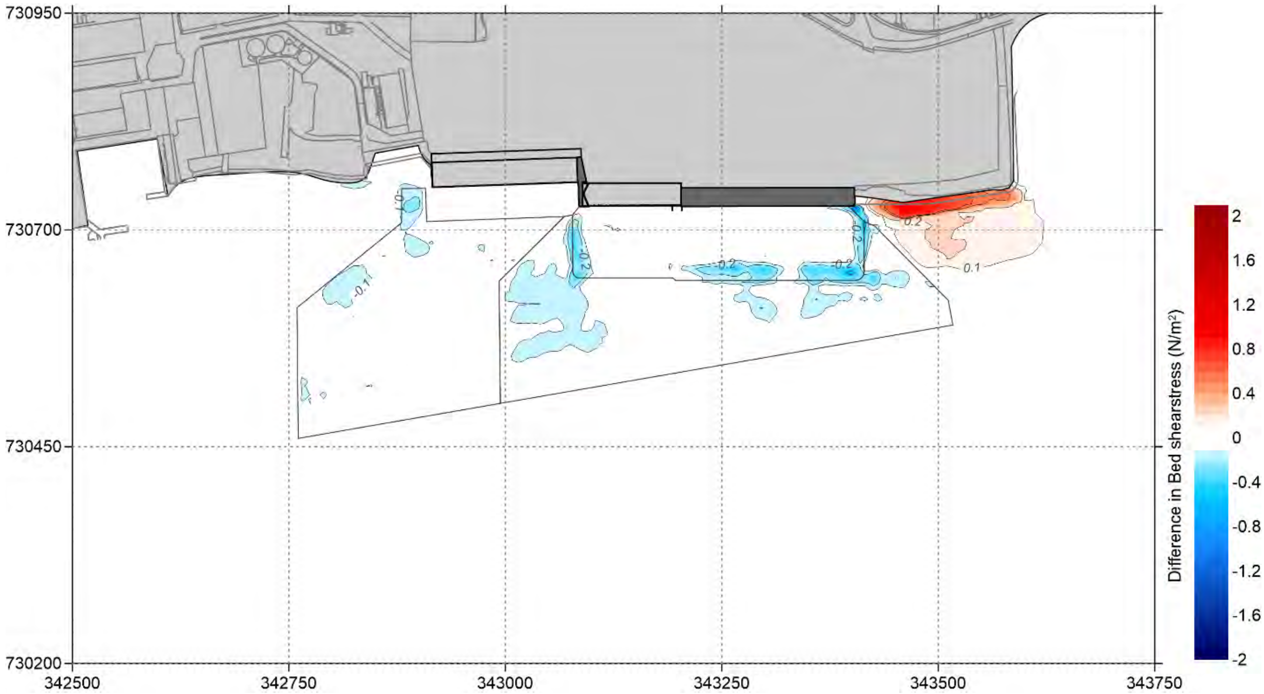

Figure 5-80 Difference in Bed shear stress (N/m^2) between 'Existing' and 'Option' during neap tide at the Port of Dundee area (positive means increase of Bed shear stress by option and vice versa) – peak ebb

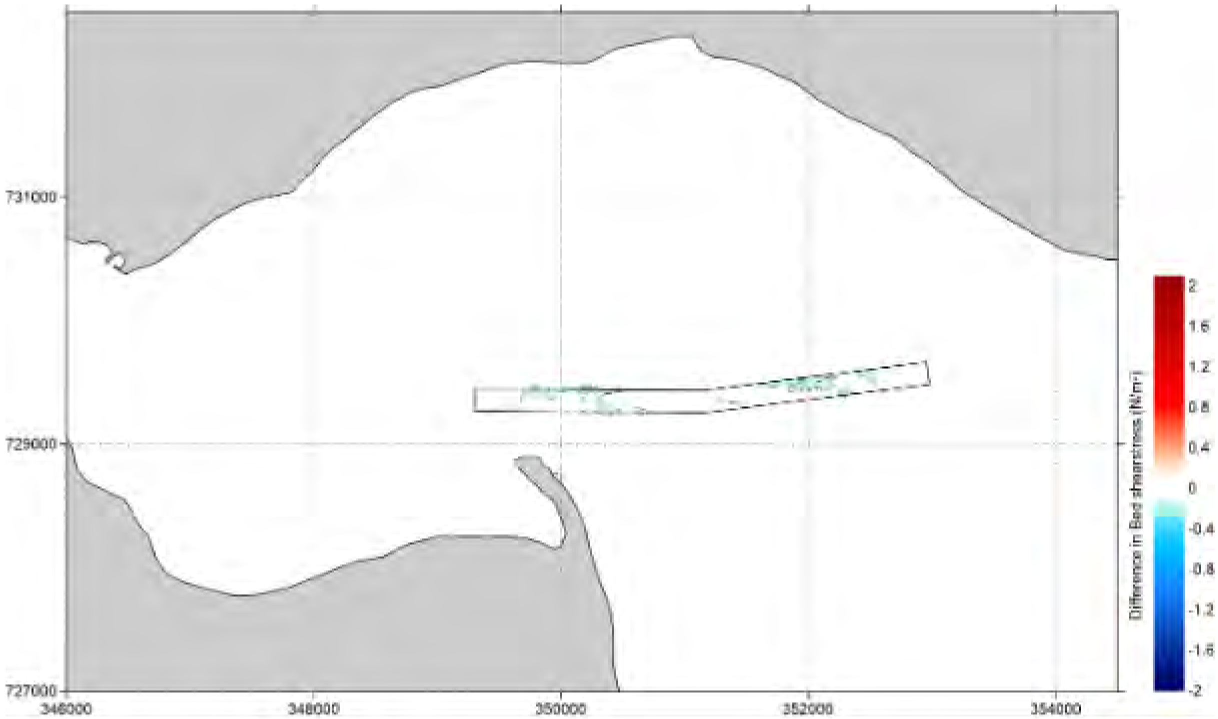

Figure 5-81 Difference in Bed shear stress (N/m²) between 'Existing' and 'Option' during neap tide at the Lady Shoal approach channel (positive means increase of Bed shear stress by option and vice versa) – peak ebb

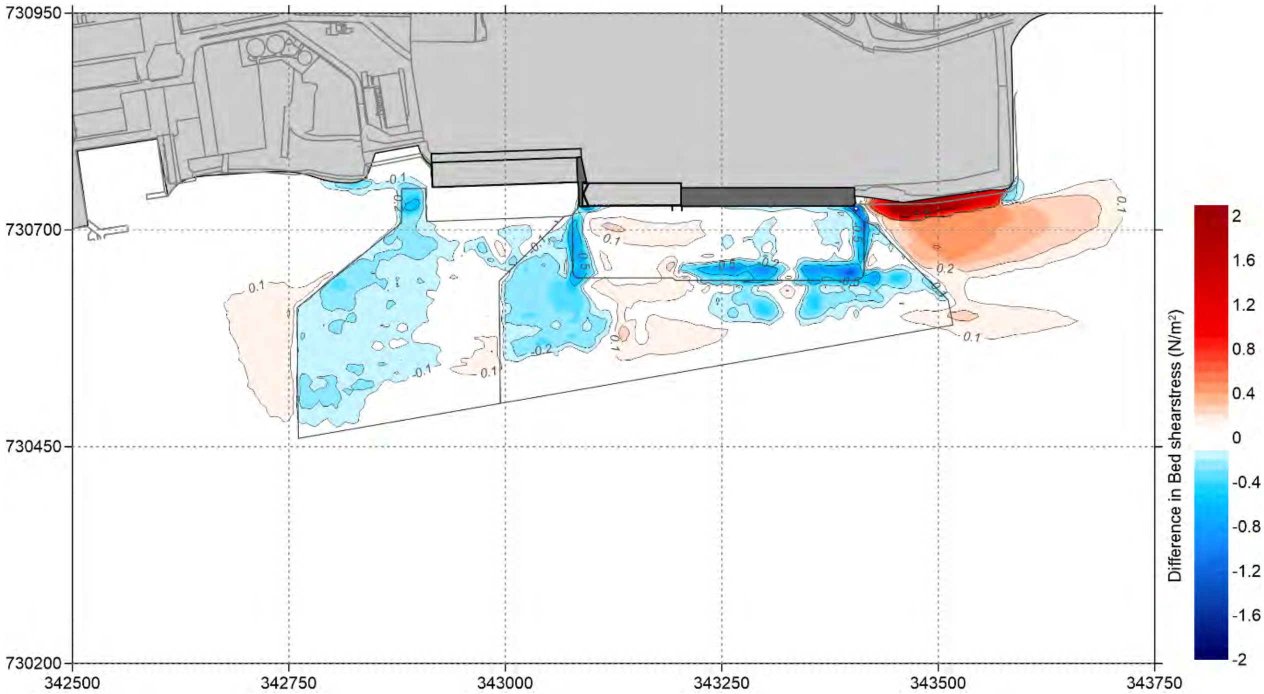

Figure 5-82 Difference in Maximum Bed shear stress (N/m²) between 'Existing' and 'Option' over 30 days at the Port of Dundee area (positive means increase of Bed shear stress by option and vice versa)

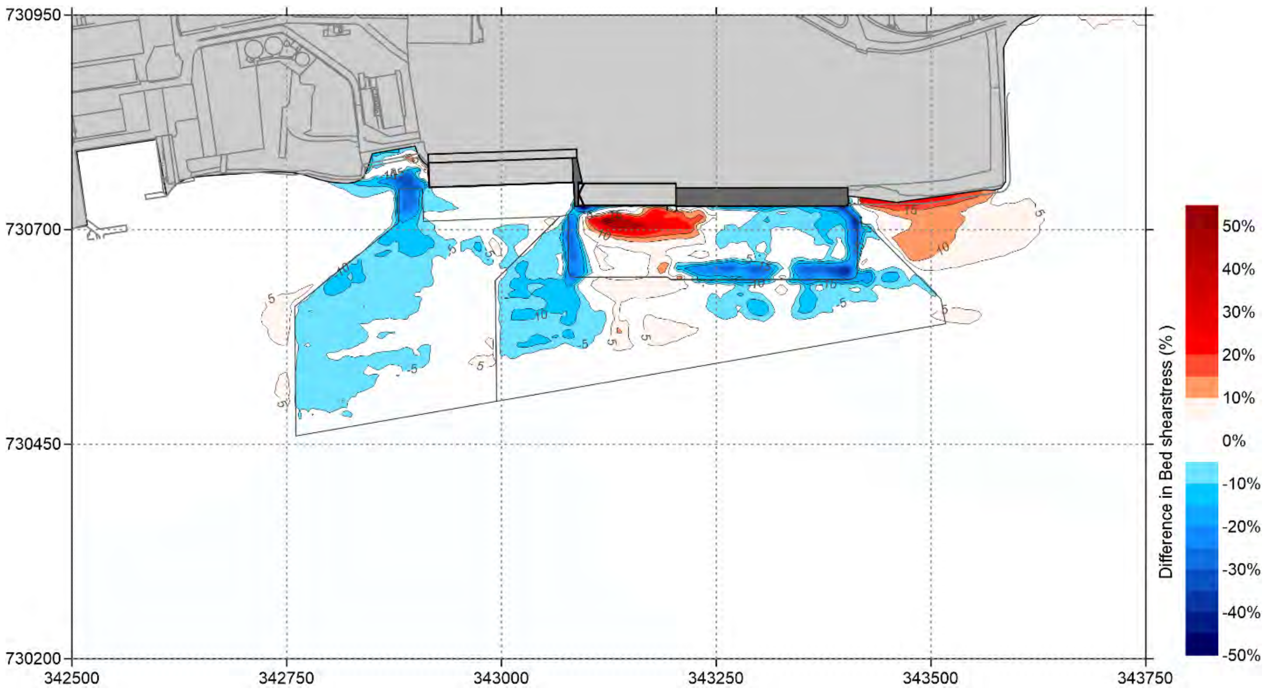

Figure 5-83 Percentage change of Maximum Bed shear stress between 'Existing' and 'Option' over 30 days at the Port of Dundee area (positive means increase of Bed shear stress by option and vice versa)

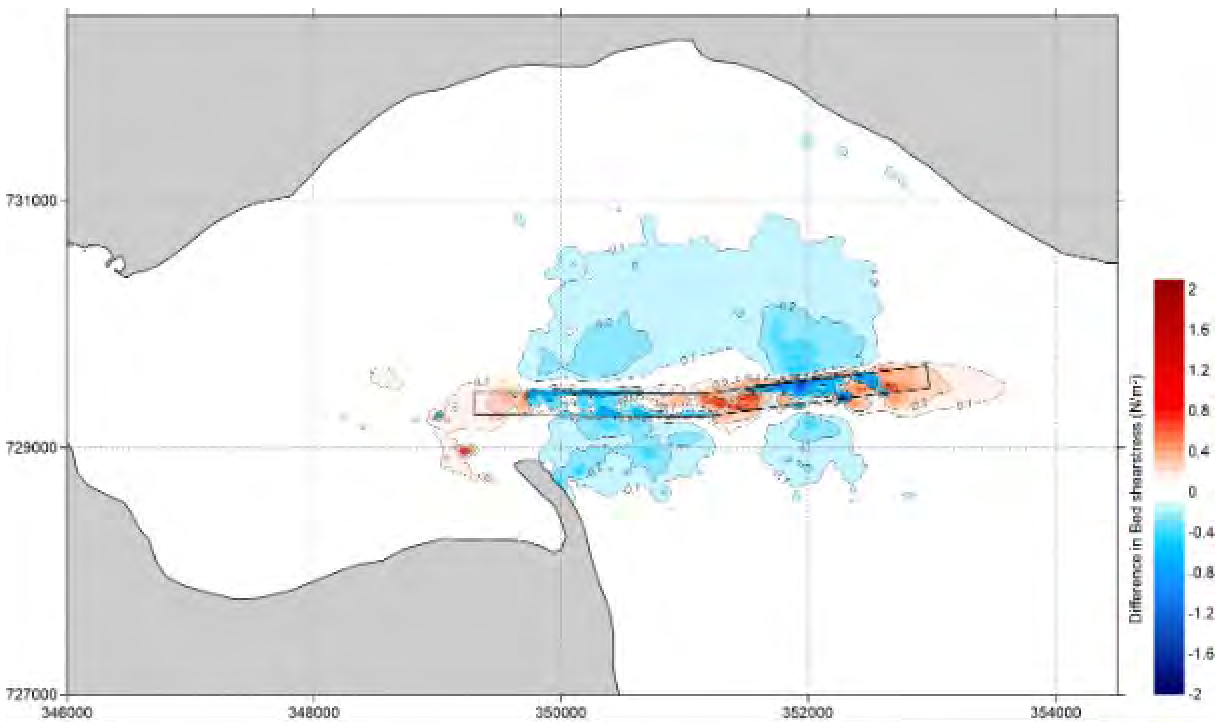

Figure 5-84 Difference in Maximum Bed shear stress (N/m^2) between 'Existing' and 'Option' over 30 days at the Lady Shoal approach channel (positive means increase of Bed shear stress by option and vice versa)

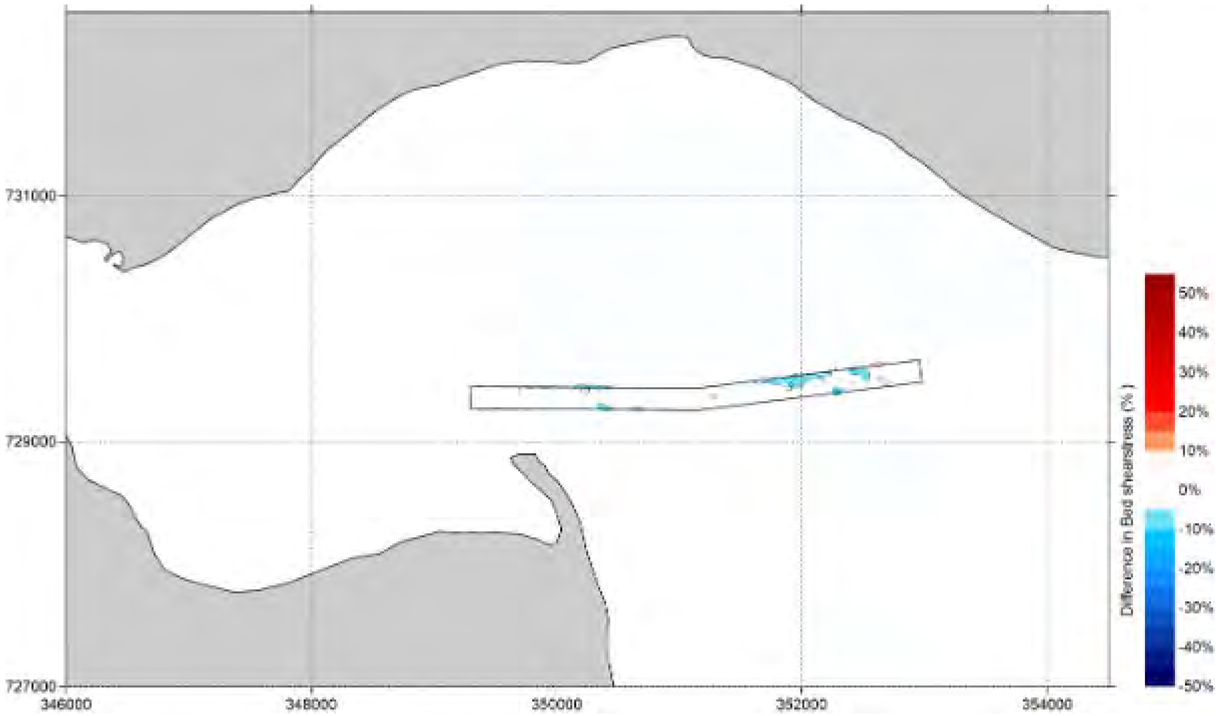

Figure 5-85 Percentage change of Maximum Bed shear stress between 'Existing' and 'Option' over 30 days at the Lady Shoal approach channel (positive means increase of Bed shear stress by option and vice versa)

6 Dispersion Model

6.1 Introduction

This section of the report details the sediment dispersion modelling exercise conducted to examine the suspended sediment dispersion and deposition resulting from the dredging and disposal activities.

The sediment dispersion model was built in MIKE3-MT software developed by DHI.

Two simulations were performed that used different production rates, 'Fast' and 'Slow', as described in **Section 6.4**. Each simulation used a backhoe dredger bucket size of 35 m^3.

6.2 Dispersion Model Setup

To simulate the suspended sediment transport throughout the water column, the 2D hydrodynamic model described in **Section 5** has been developed into a 3D hydrodynamic model by introducing vertical mesh.

The sediment dispersion model was constructed in MIKE3-MT and is coupled with the 3D hydrodynamic model built in MIKE3-HD. Both models share an identical computational mesh.

The fast and slow sediment dispersion model simulations were run for a 6-week and 8-week period respectively, to cover the full duration of the proposed dredge and disposal activities and allow the plume to fully disperse.

Due to the uncertainty of the time when the dredging will take place, the worst scenario in terms of the tidal conditions was selected. The model simulations were run for the period from 24th February to 10th / 27th April 2025 (for the fast/slow production runs), a period that includes an equinox tide with the year's largest tidal range during spring tides and the lowest tidal range during neap tides.

The sediment dispersion model was set up with 5 vertical layers to differentiate between suspended sediment concentrations throughout the water column, such as near the seabed and near the water surface.

To simulate the sediment dispersion under near-natural conditions, wave disturbance effect was included in the MIKE3-MT model. The applied wave conditions included a wave height of 1.5 m, peak wave period of 6.0 seconds and a wave direction of 90ºN. These wave conditions are considered the upper limit of the backhoe dredger.

In the model simulation, the dredger releases material along a number of lines near the Port of Dundee and a single line along the Lady Shoal approach channel, as shown in **Figure 6-1** and **Figure 6-2,** respectively. Disposal was simulated using numerous randomly created points inside the disposal site 'Middle Bank (FO028)', as shown in **Figure 6-3**. This adopted method for material release is a conservative approach. In reality, the dredger will move around the dredging area along multiple lines, resulting in more dispersed sediment release and therefore lower the maximum sediment concentrations.

During dredging, the dredger releases sediment evenly throughout the water column. During sediment disposal, the material is released near the water surface.

Figure 6-4 indicates the three point-locations used to extract time series data of the suspended sediment concentrations for all two simulations. Extraction point P1 is located in the Port of Dundee, P2 is located at the disposal site, and P3 is located in the Lady Shoal approach channel.

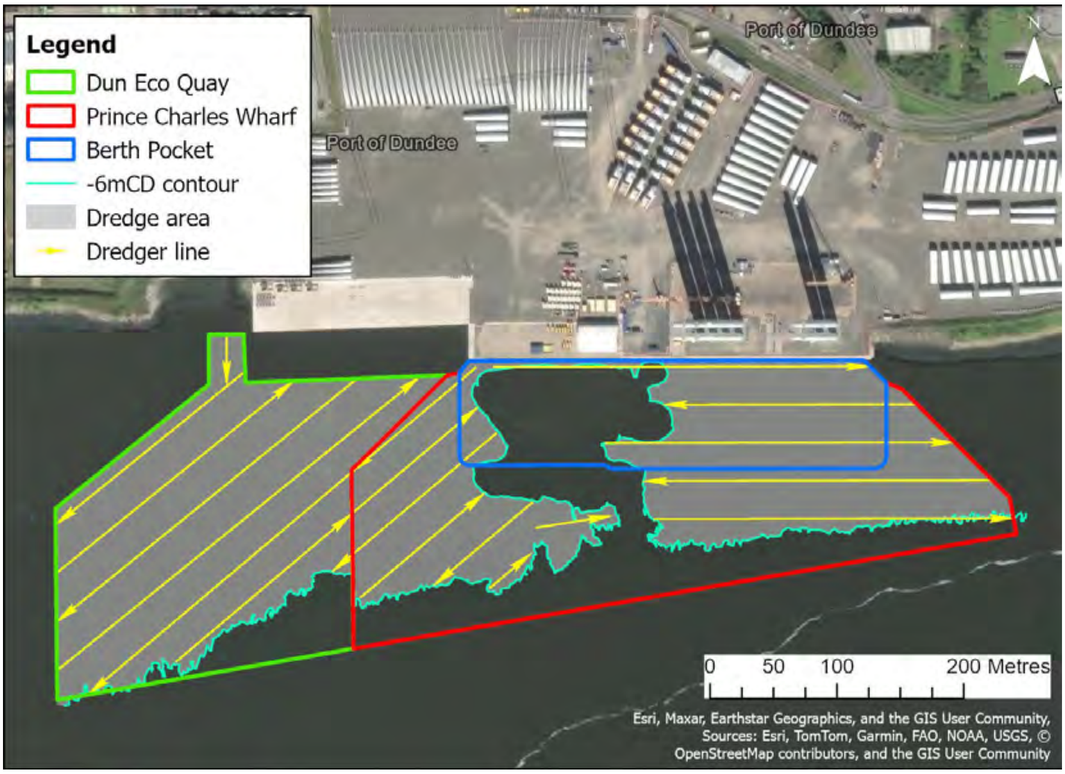

Figure 6-1 Dredger lines at Port of Dundee

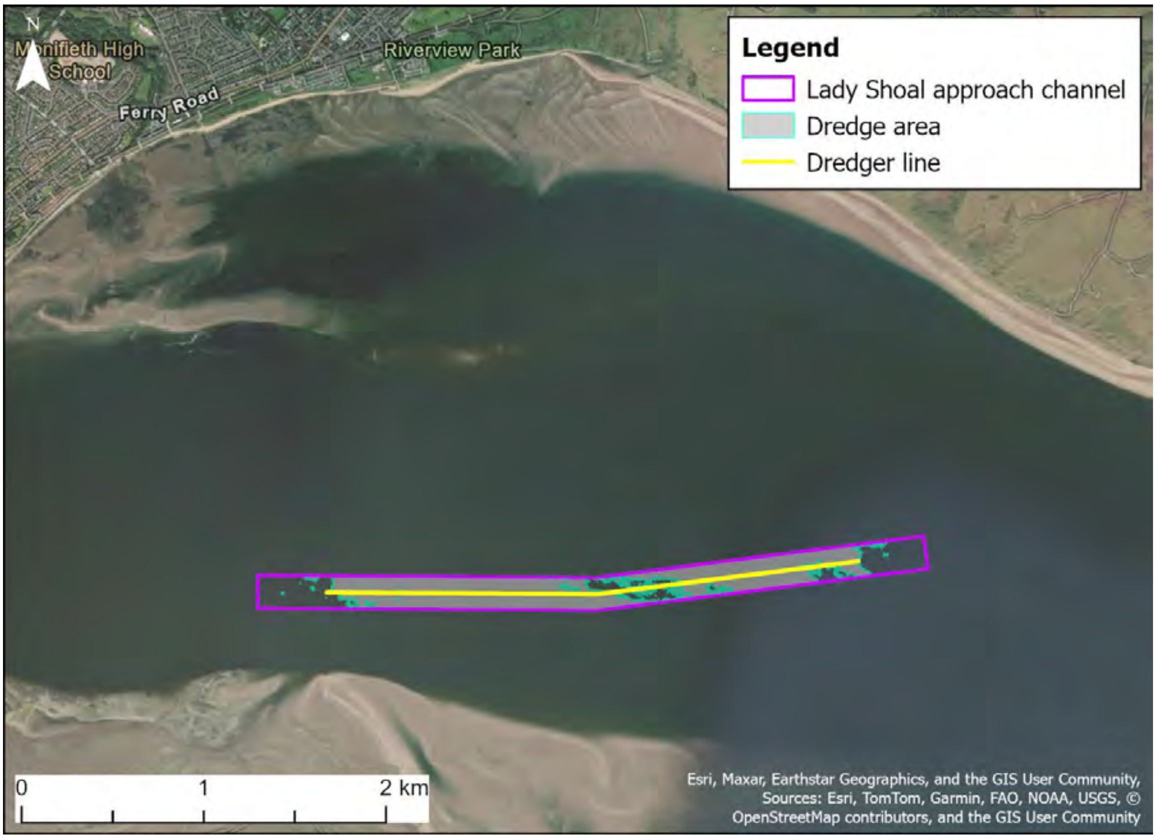

Figure 6-2 Dredger line at Lady Shoal approach channel

Figure 6-3 Disposal locations at Disposal Site

Figure 6-4 Time series model data extraction points

6.3 Sediment Properties

The seabed sediment properties can be characterised by five sediment fractions, settling velocities and critical bed shear stresses, which have been used in the suspended sediment dispersion modelling. These five fractions are detailed in **Table 6.1**. The critical bed shear stress and fall velocities were calculated using the SandCalc software developed by HR Wallingford.

Table 6.1 Characterisation of sediment type by sediment size, settling velocity and critical bed shear stress

Sediment Type	Sediment Size (mm)	Settling Velocity (m/s)	Critical Bed Shear Stress (N/m^2)
Silt/Clay	0.031	0.000554	0.0847
Fine Sand	0.13	0.00935	0.1548
Medium Sand	0.3	0.0372	0.2025
Coarse Sand	1.3	0.135	0.657
Gravel/Cobble	2	0.1734	1.166

A sediment distribution based on mean data from particle size distribution analysis was chosen as input into the model, considered to be representative and realistic with respect to the extent of the sediment plume and deposition.

The sediment distribution has different characteristics for each of the work areas, Port of Dundee', Disposal Site' and 'Lady Shoal', which are outlined in **Table 6.2**.

Table 6.2 Particle size distribution based on mean data for the three work areas: Port of Dundee, Disposal Site, and Lady Shoal.

Sediment Category	Sediment Size (mm)	Percentage (%)	
		Port of Dundee / Disposal Site	Lady Shoal
Silt/Clay	0.031	32.64	28.59
Fine Sand	0.13	21.26	20.08
Medium Sand	0.3	14.29	16.60
Coarse Sand	1.3	6.64	7.09
Gravel/Cobble	2	25.17	27.64

6.4 Summary of Sediment Release for Simulation

The dredging volumes, production rates, duration and sediment release rates used in the simulation for all activities and locations are summarised in **Table 6.3**. The volume calculations include a 0.5m over-dredge. Dredging durations are based on continuous 24-hour operation. Two production rates were modelled to allow for assessment of worst case scenarios in terms sediment plume peak (fast rate) and the duration of the dredging (slow rate).

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Table 6.3 Summary of dredging and disposal activities for the Fast production rate simulation

Area	Volume (m^3)	Production Rate (m^3/hour)	Duration (days)	Sediment Release Rate (kg/s)
Dun Eco Quay	45750	1400	1.4	21.64
Berth Pocket	23,550	1400	0.7	21.64
Prince Charles Wharf	35,700	1400	1.1	21.64
Lady Shoal	385,000	1400	11.4	21.64
Disposal Site	490,000			238.5

Table 6.4 Summary of dredging and disposal activities for the Slow production rate simulation

Area	Volume (m^3)	Production Rate (m^3/hour)	Duration (days)	Sediment Release Rate (kg/s)
Dun Eco Quay	45750	354.17	5.4	5.47
Berth Pocket	23,550	354.17	2.7	5.47
Prince Charles Wharf	35,700	354.17	4.2	5.47
Lady Shoal	385,000	354.17	45.2	5.47
Disposal Site	490,000			238.5

6.5 Simulation 1 – Fast Production Rate

Figure 6-5 to **Figure 6-13** show the maximum suspended sediment concentration (SSC) above 10 mg/l which occur during dredging and disposal near the seabed, in the middle of the water column and near the water surface for the Fast production rate simulation.

Two distinct plumes form during dredging and disposal, separated by the Firth of Tay main channel. The extents of both sediment plumes are largest near the seabed (L1, Layer 1) and gradually reduce in size as they reach the water surface (L5, Layer 5). The extents have been measured in a westward and eastward direction from the outer edge of each work area to the full plume extent.

Figure 6-5 and **Figure 6-11** show the sediment plume extents for L1 and L5, respectively. In L1, the plumes on the northern and southern edge of the Firth of Tay main channel merge in several places, whereas these remain separated in L5.

The sediment plume along the northern bank of the Firth of Tay is likely caused by the dredging activities near the Port of Dundee. It extends westward by 6.5km in L1 and 3.9km in L5, and eastward by 8.9km in L1 and 2.6km in L5, touching the shore in both directions.

There are two sediment plumes on the south side of the Firth of Tay main channel, the more westerly one likely due to the sediment disposal, and the more easterly from the dredging activities in the Lady Shoal approach channel. In L1, these two plumes merge to extend westward (from the western edge of the disposal site) by 11.2km, and eastward (from the eastern edge of Lady Shoal) by 8km. In L5, the two plumes on the south side of the Firth of Tay main channel have not merged. The plume encompassing the disposal site extends westward by 6.3km and eastward by 4.5km whereas the plume encompassing the Lady Shoal approach channel extends westward by 270m and eastward by 490m.

Between the dredge and disposal sites, overall maximum SSC levels are greatest at the Disposal site and are lowest at the Lady Shoal approach channel for both L1 and L5. Outside of the work areas, maximum SSC levels over 10 mg/l predominantly remain below 100 mg/l at L1, and 50 mg/l at L5.

At the Port of Dundee, maximum SCC levels are up to 2000 mg/l for both L1 and L5, however L1 has a greater proportion of maximum SSC levels over 200 mg/l. At the Disposal site, maximum SSC levels in L1 predominantly range from 500 mg/l up to 2000 mg/l. In contrast, maximum SSC levels in L5 are predominantly over 1000 mg/l, reaching 6,000 mg/l to 35,000 mg/l in localised spots within and up to 100m outside of the Disposal site bounds. At the Lady Shoal approach channel, maximum SSC levels are greater in L1 than in L5. In L1, maximum SSC levels range from 20 mg/l up to 1000 mg/l, where the largest levels are present as localised spots in the central and eastern end of the site. Some areas in the northeastern and northwestern corners of the Lady Shoal site drop below 10 mg/l, and maximum SSC levels remain below 500 mg/l.

Figure 6-14 to **Figure 6-16** show the time series data of maximum SSC during dredging and disposal activities near the seabed, the middle of the water column and near the water surface for three locations, P1 (Port of Dundee), P2 (Disposal Site) and P3 (Lady Shoal), as shown in **Figure 6-4**.

At P1, the highest values in maximum SSC tend to be near the seabed, and lowest at near the sea surface. The greatest peak maximum SSC levels occur at 580 mg/l, 560 mg/l and 465 mg/l for near the seabed, in the middle of the water column and near the water surface, respectively, each lasting for approximately 10 minutes. For P2, most peaks in maximum SSC remain below 1,000 mg/l, except for 3 points each lasting approximately 10 minutes, where levels of maximum SSC reached 9,700 mg/l, 7,570 mg/l and 4,500 mg/l at the sea surface. At P3, peaks in maximum SSC levels were consistently greater at the seabed than at the sea surface, whereas peaks in maximum SSC level tended to last longer durations at the sea surface. The peaks in maximum SSC gradually increased over time to reach the highest level of 330 mg/l near the seabed, 265 mg/l in the middle of the water column, and 175 mg/l near the sea surface, with timeframes ranging from 10 minutes to 5 hours.

Figure 6-17 to **Figure 6-19** show the total sediment deposition depths greater than 3.5 cm which occur during dredging and disposal. At the Port of Dundee, sediment deposition was contained within the Port of Dundee area, predominantly occurred in closer proximity to the quay wall and remained below 0.1 m. At the Disposal site, sediment was deposited in patchy areas, extending up to 150m outside of the Disposal site bounds. Inside the Disposal site area, patches of deposition remained below 0.4m. Outside the Disposal site area, the few deposition patches remained below 0.3m. Small patches of deposition occurred at the Lady Shoal approach channel area, predominantly at the eastern side, which remain below 0.1m.

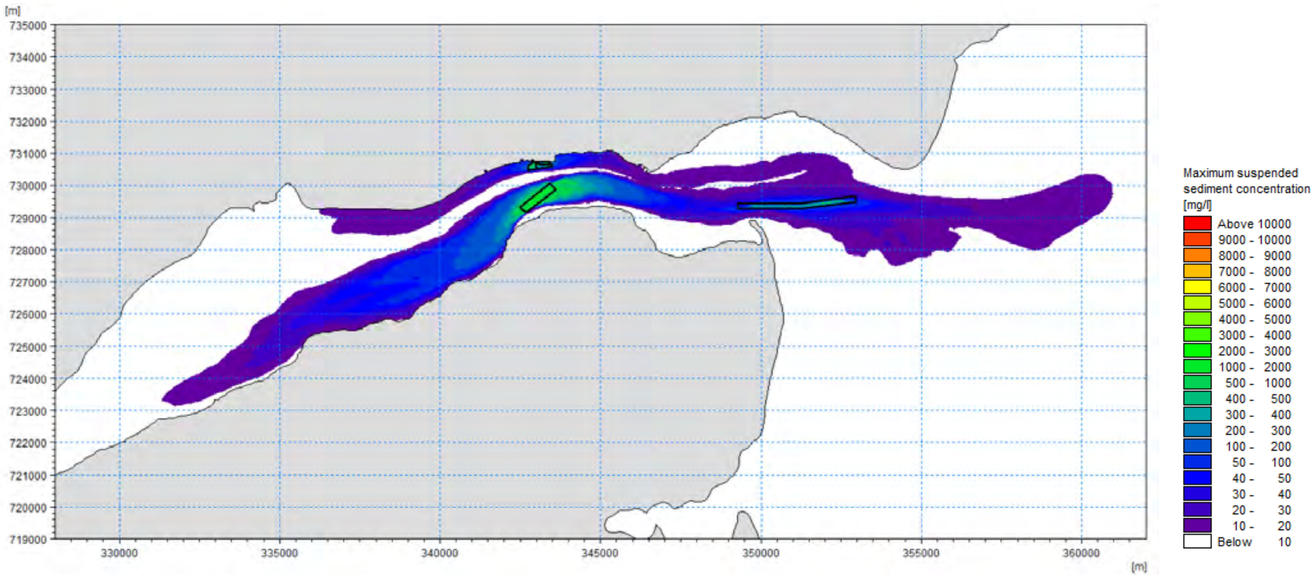

Figure 6-5 Maximum suspended sediment concentration during dredging and disposal near the seabed – Whole plume extent

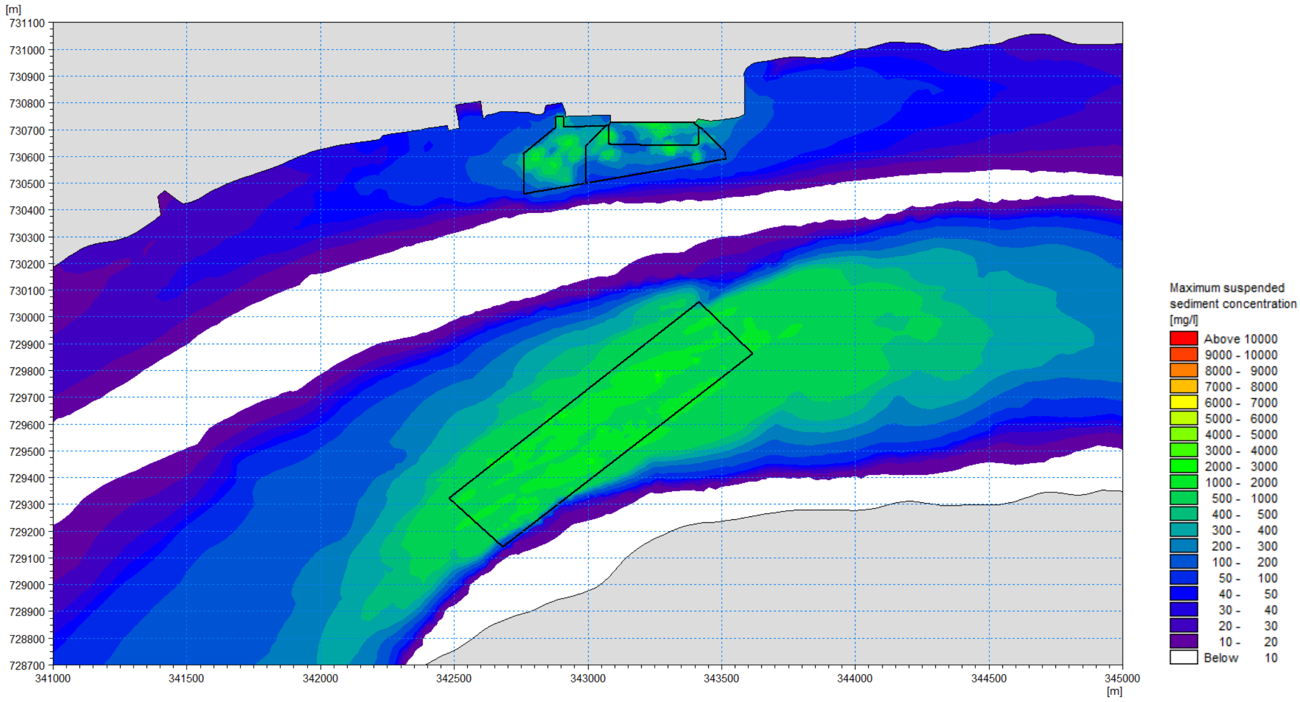

Figure 6-6 Maximum suspended sediment concentration during dredging and disposal near the seabed – 'Port of Dundee' and 'Disposal Site' areas

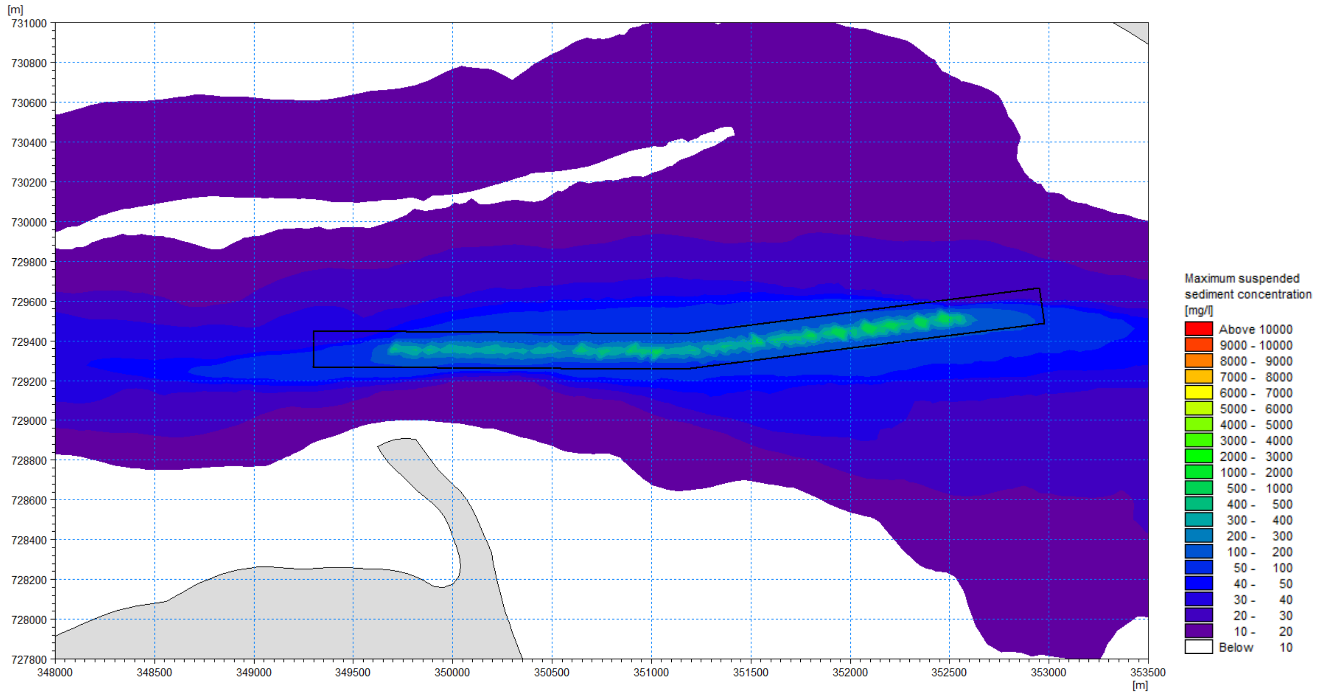

Figure 6-7 Maximum suspended sediment concentration during dredging and disposal near the seabed –'Lady Shoal' area

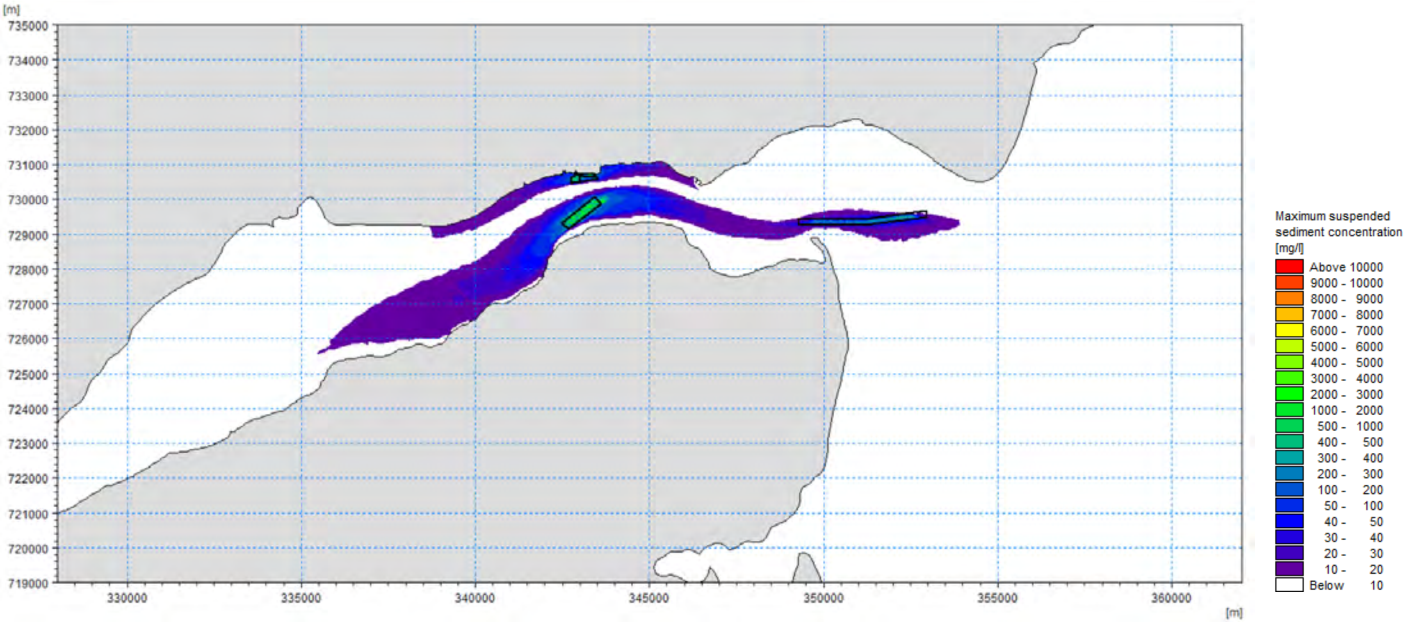

Figure 6-8 Maximum suspended sediment concentration during dredging and disposal in the middle of water column –Whole plume extent

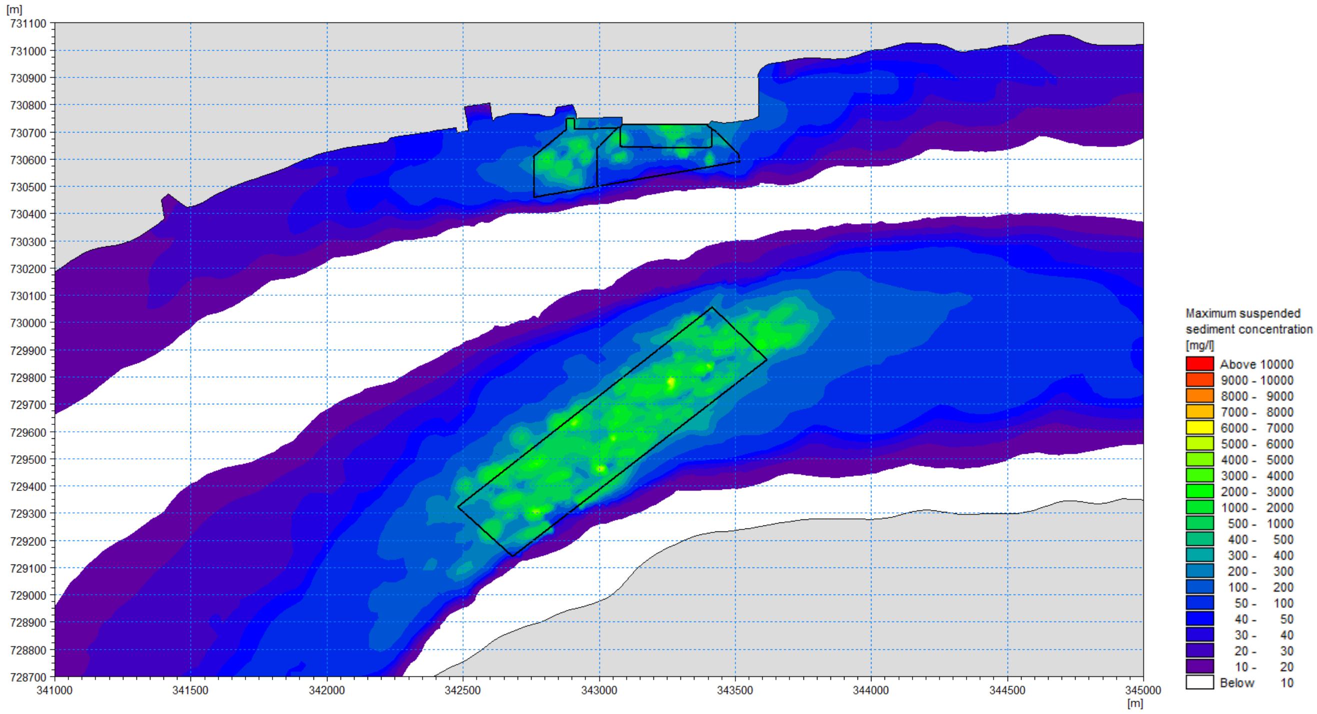

Figure 6-9 Maximum suspended sediment concentration during dredging and disposal in the middle of water column - 'Port of Dundee' and 'Disposal Site' areas

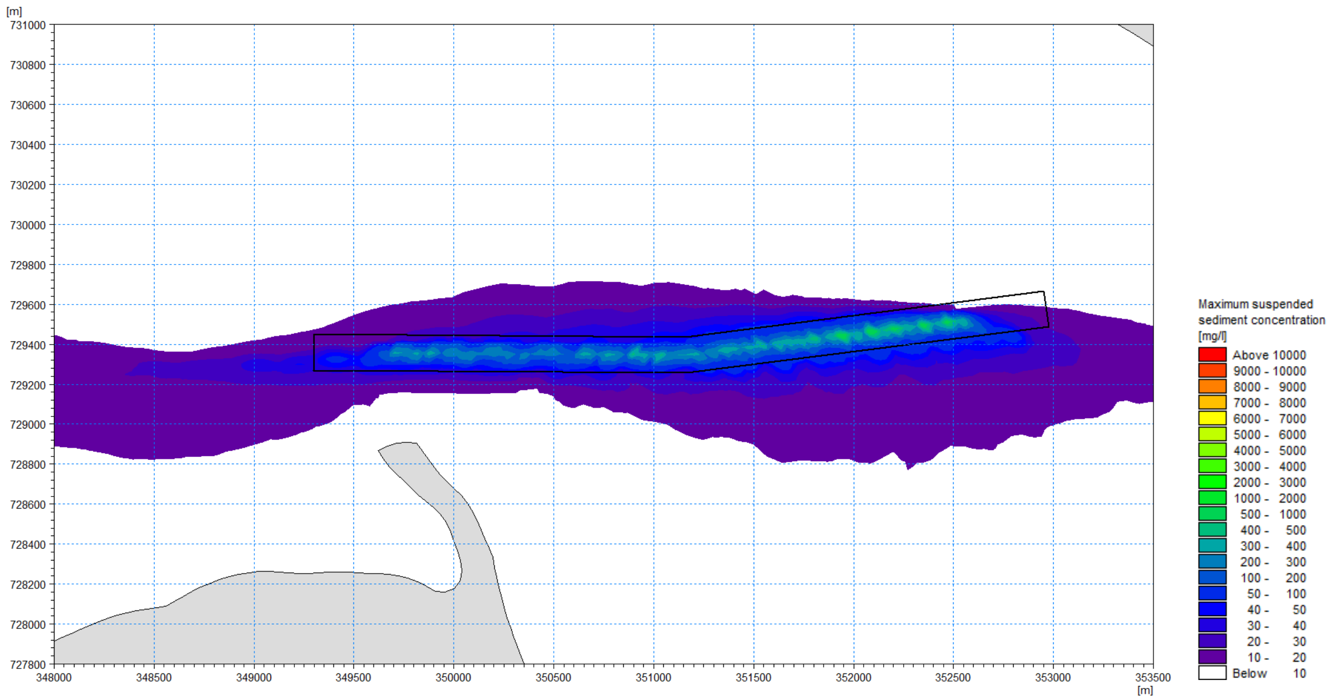

Figure 6-10 Maximum suspended sediment concentration during dredging and disposal in the middle of water column – Lady Shoal' area

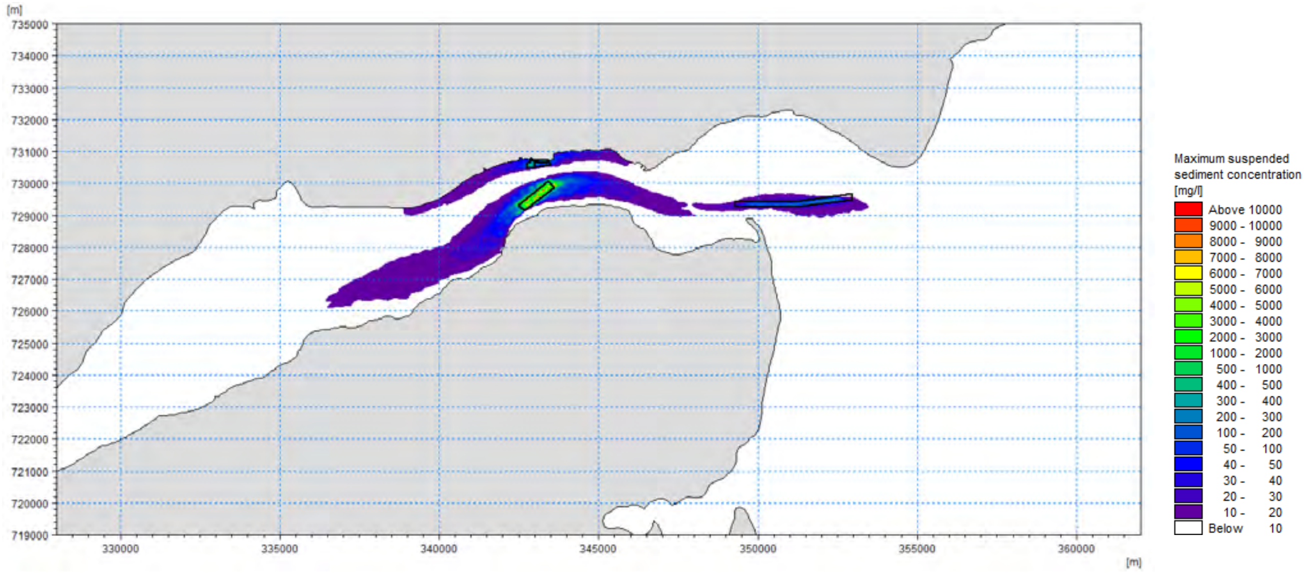

Figure 6-11 Maximum suspended sediment concentration during dredging and disposal near the water – Whole plume extent

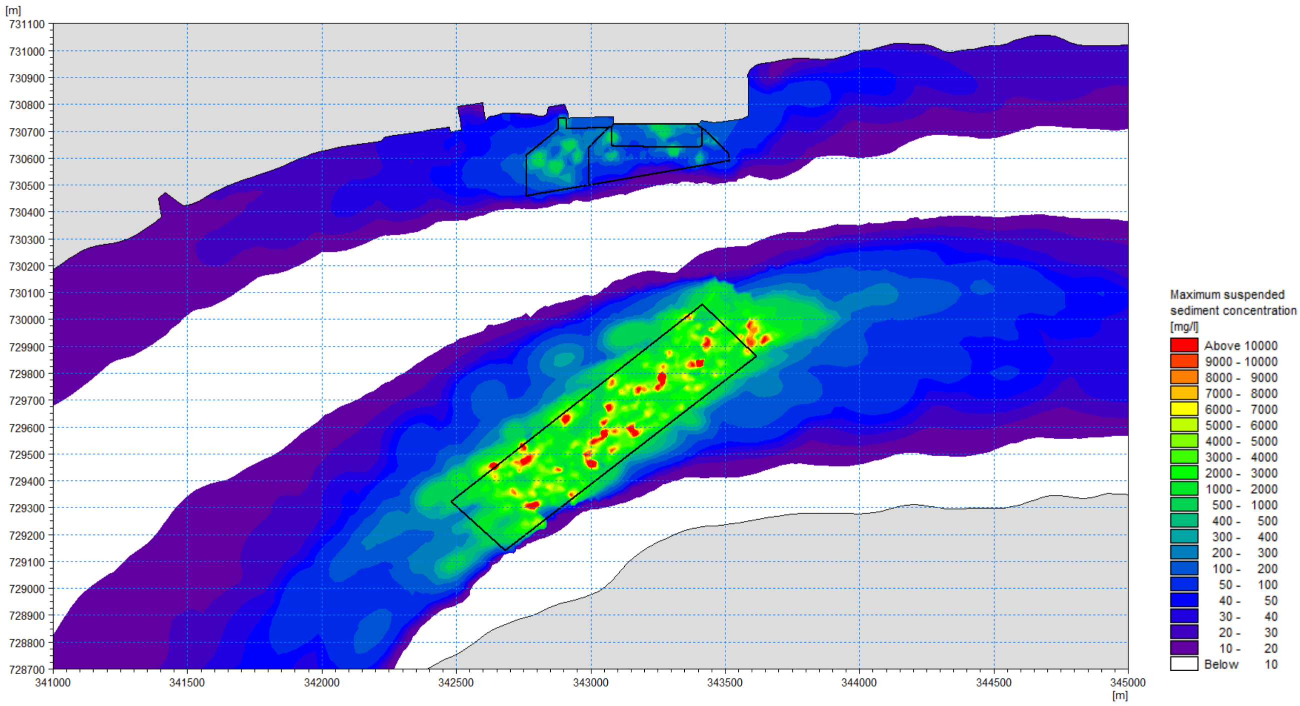

Figure 6-12 Maximum suspended sediment concentration during dredging and disposal near the water surface – 'Port of Dundee' and 'Disposal Site' areas

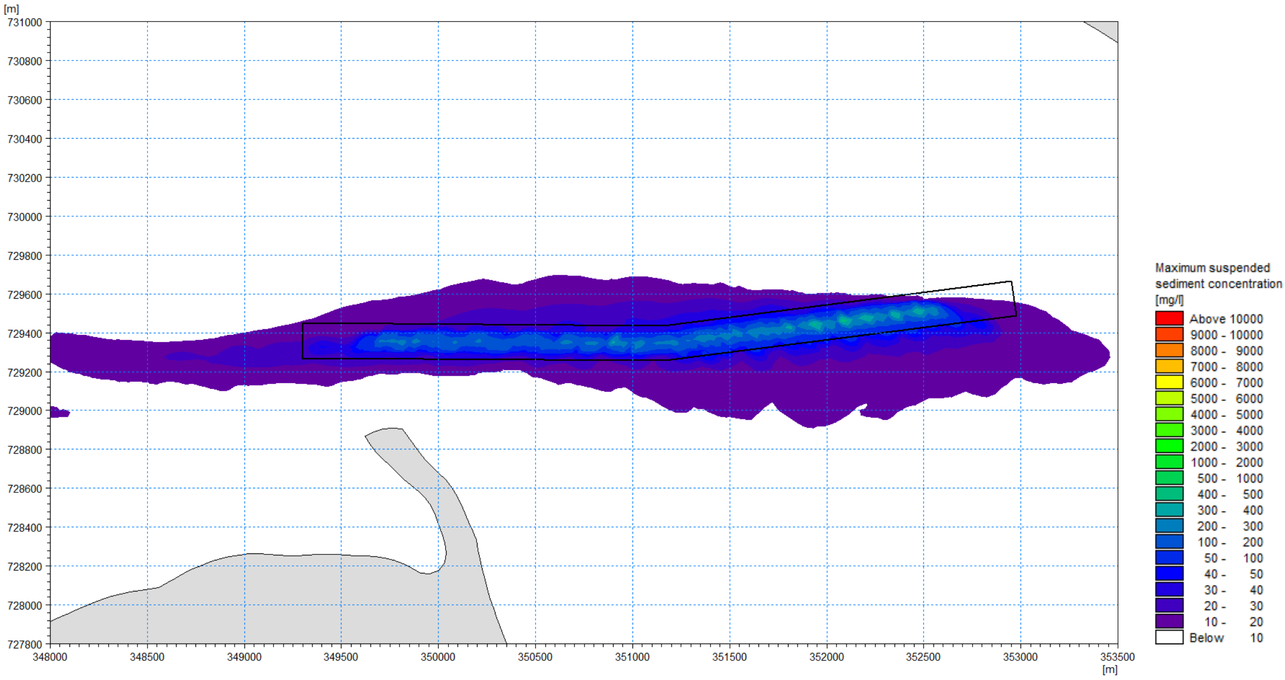

Figure 6-13 Maximum suspended sediment concentration during dredging and disposal near the water surface – 'Lady Shoal' area

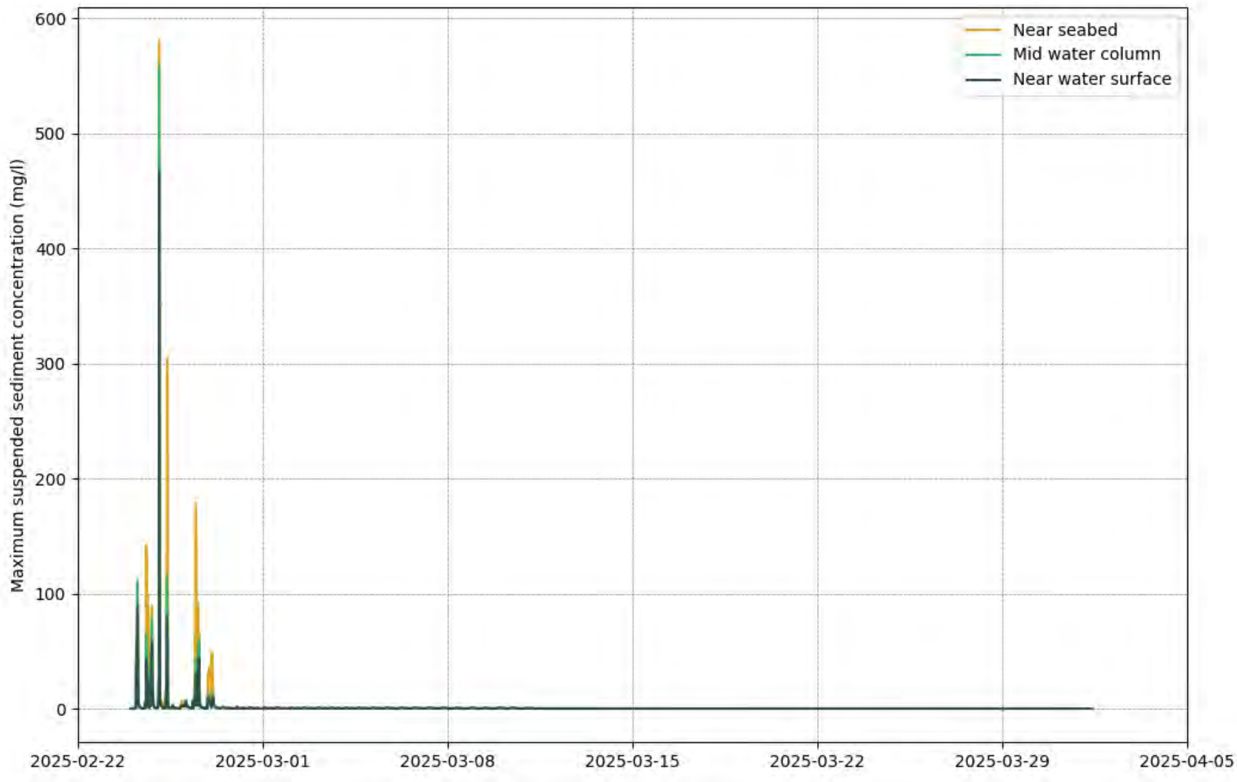

Figure 6-14 Time series of suspended sediment concentration at P1 (Port of Dundee) during dredging activities for seabed, middle of water column and near water surface

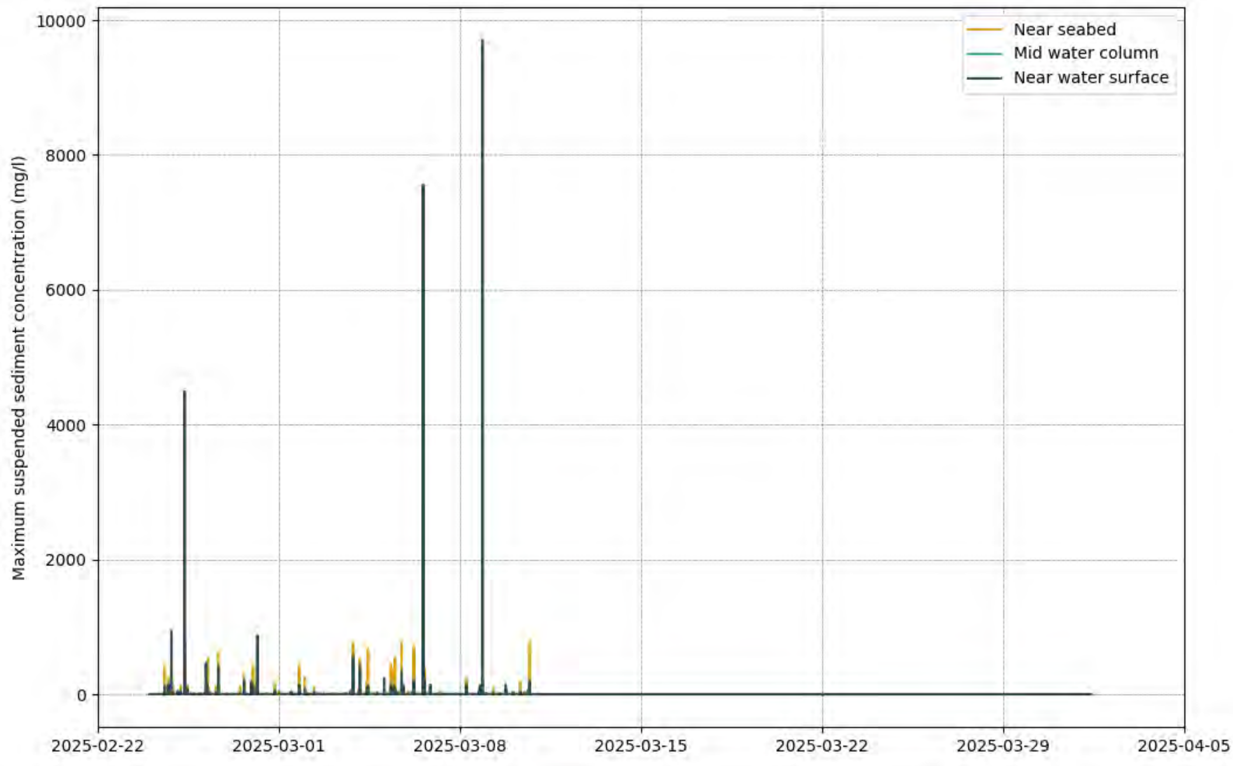

Figure 6-15 Time series of suspended sediment concentration at P2 (Disposal Site) during disposal activities for seabed, middle of water column and near water surface

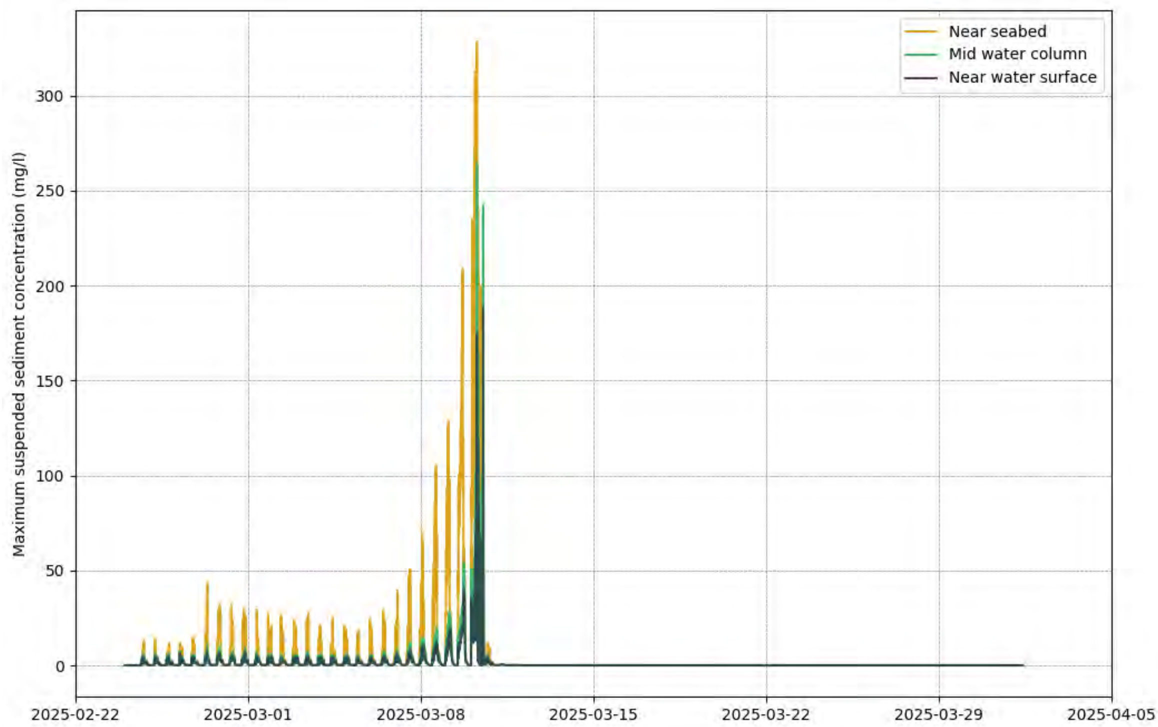

Figure 6-16 Time series of suspended sediment concentration at P3 (Lady Shoal) during dredging activities for seabed, middle of water column and near water surface

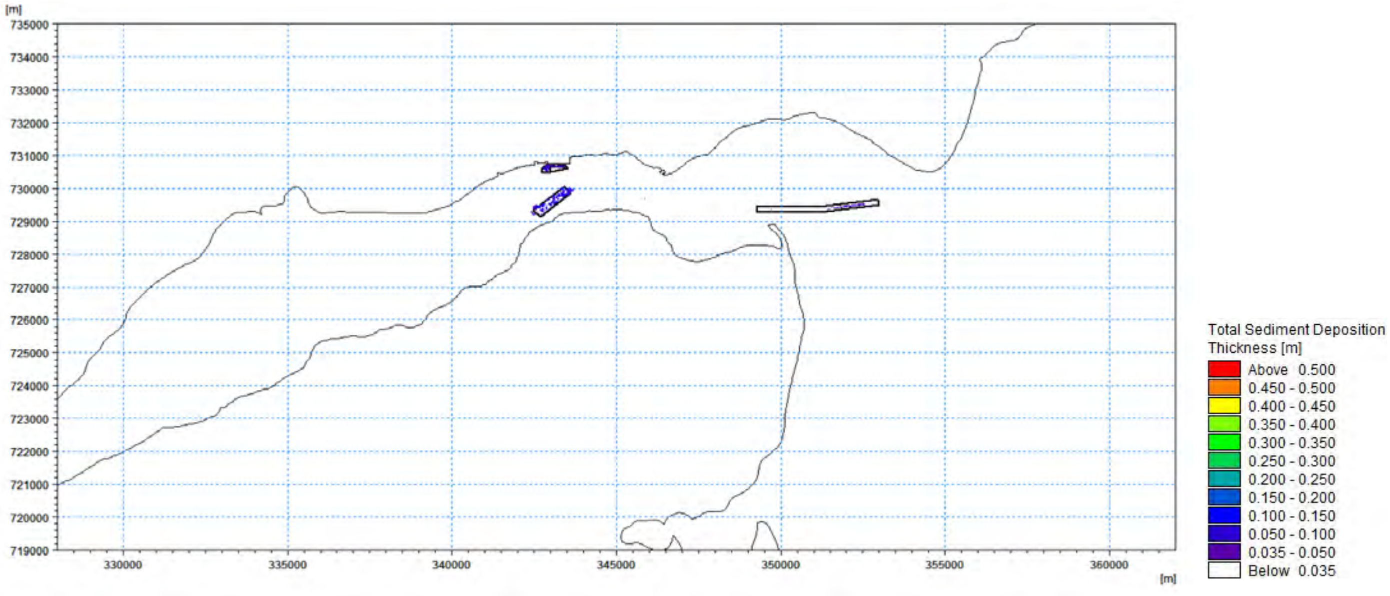

Figure 6-17 Total sediment deposition depths during dredging and disposal – Whole plume extent

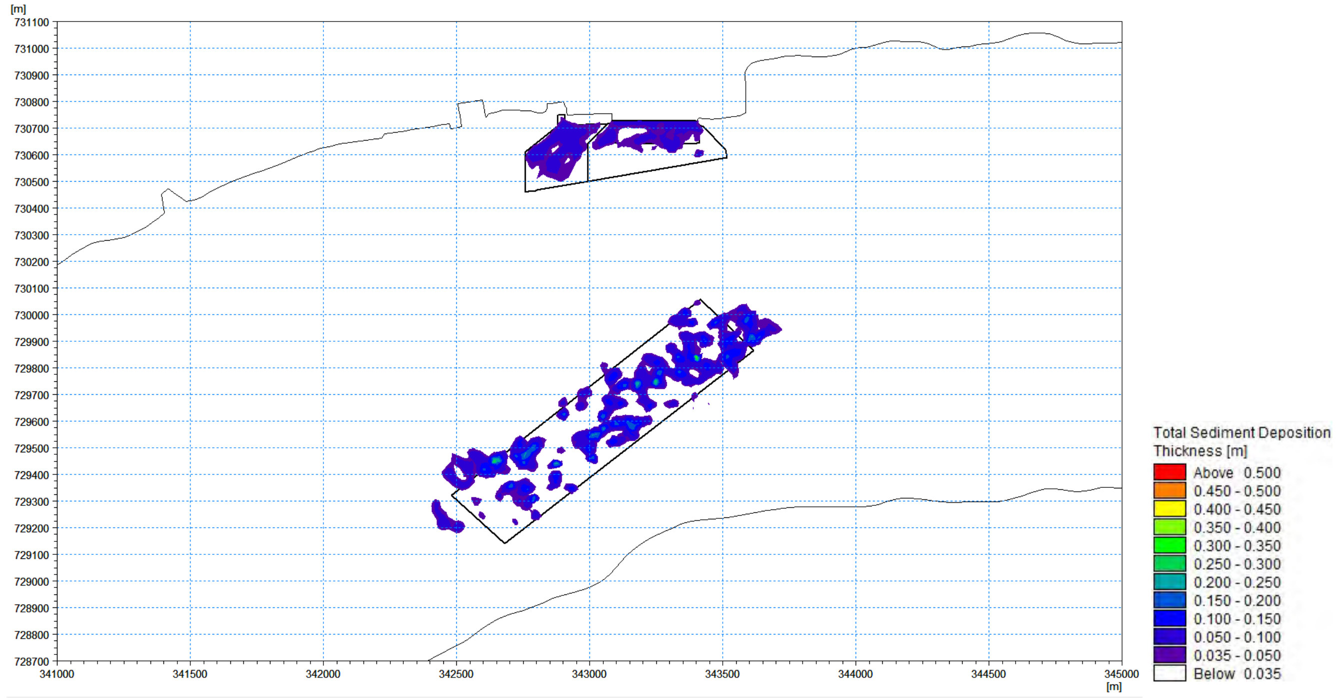

Figure 6-18 Total sediment deposition depths during dredging and disposal - 'Port of Dundee' and 'Disposal Site' areas

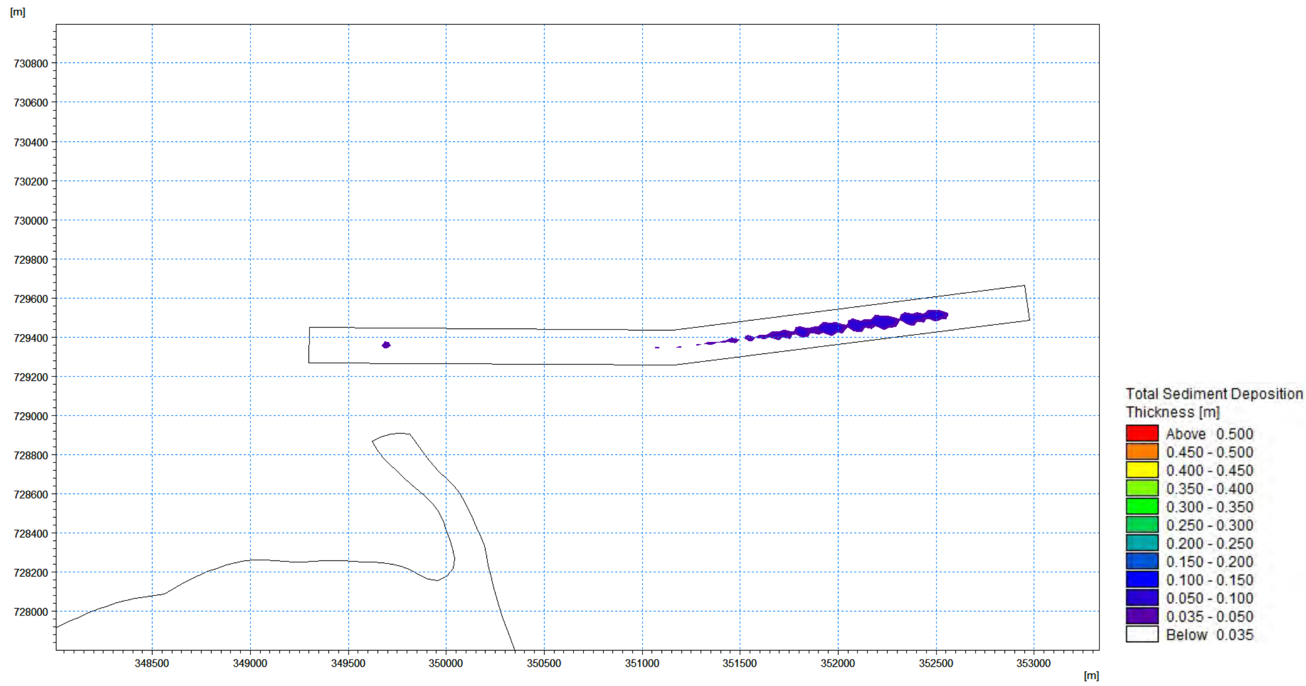

Figure 6-19 Total sediment deposition depths during dredging and disposal - 'Lady Shoal' area

6.6 Simulation 2 – Slow Production Rate

Figure 6-20 to **Figure 6-28** show the maximum suspended sediment concentration (SSC) above 10 mg/l which occur during dredging and disposal near the seabed, in the middle of the water column and near the water surface for the 'Slow' production rate simulation.

Two distinct plumes form during dredging and disposal, separated by the Firth of Tay main channel. The extents of both sediment plumes are largest near the seabed (L1, Layer 1) and gradually reduce in size as they reach the water surface (L5, Layer 5). The extents have been measured in a westward and eastward direction from the outer edge of each work area to the full plume extent.

Figure 6-20 and **Figure 6-26** show the sediment plume extents for L1 and L5, respectively.

The sediment plume along the northern bank of the Firth of Tay is likely caused by the dredging activities near the Port of Dundee. It extends westward by 1.3km in L1 and 900m in L5, and eastward by 1.1km in L1 and 450m in L5, touching the shore in both directions.

There are two sediment plumes on the south side of the Firth of Tay main channel, the more westerly one likely due to the sediment disposal, and the more easterly from the dredging activities in the Lady Shoal approach channel. In L1, these two plumes merge to extend westward (from the western edge of the disposal site) by 9.3km, and eastward (from the eastern edge of Lady Shoal) by 7.5km. In the middle of the water column (L3) and L5, the two plumes on the south side of the Firth of Tay main channel do not merge. The L5 sediment plume encompassing the disposal site extends westward by 3.3km and eastward by 3.2km, whereas maximum SSC levels at the Lady Shoal approach channel stay within the eastern and western work area bounds.

Between the work areas, overall maximum SSC levels are greatest at the Disposal site and are lowest at the Lady Shoal approach channel for both L1 and L5. Outside of the work areas, maximum SSC levels over 10 mg/l predominantly remain below 100 mg/l.

At the Port of Dundee, maximum SCC levels are predominantly between 30 mg/l and 200 mg/l in L1, and between 10 mg/l and 100 mg/l at L5. Higher levels are indicated as localised spots, that remain below 1000 mg/l in L1 and below 500 mg/l in L5 (**Figure 6-21**). At the Disposal site, maximum SSC levels in L1 predominantly range from 500 mg/l up to 2000 mg/l. In contrast, maximum SSC levels in L5 are predominantly over 1000 mg/l, with localised spots of 6,000 mg/l to 20,000 mg/l within and up to 100m outside of the Disposal site bounds.

At the Lady Shoal approach channel, maximum SSC levels are greater in L1 than in L5. In L1, maximum SSC levels are predominantly above 20 mg/l and remain below 300 mg/l. In L5, there is minimal plume that extends beyond the bounds of the Lady Shoal approach channel. Within the work area, maximum SSC levels remain below 200 mg/l, and at both western and eastern ends, maximum SSC levels remain below 10 mg/l,

Figure 6-29 to **Figure 6-31** show the time series data of maximum SSC during dredging and disposal activities near the seabed, the middle of the water column and near the water surface for three locations, P1 (Port of Dundee), P2 (Disposal Site) and P3 (Lady Shoal), as shown in **Figure 6-4**.

At P1, the highest values in maximum SSC are predominantly near the seabed, and lowest near the sea surface. Maximum SSC peaks occur predominantly within the first 14 days of the model simulation, during the time frame that dredging occurs at Port of Dundee. The largest maximum SSC peak reaches 106 mg/l near the seabed, lasting for approximately 10 minutes. At P2, peaks in maximum SSC levels are spread over the duration of the simulation time and occur predominantly at the sea surface. Most peaks in maximum SSC at P2 remain below 800 mg/l, except for 3 points each lasting approximately 10 minutes, where levels of maximum SSC reach 2,927 mg/l, 1,945 mg/l and 1,177 mg/l at the sea surface. At P3, peaks in maximum SSC levels are consistently greater near the seabed than near the sea surface and tend to increase towards the end of the simulation time. The greatest maximum SSC peak occurs at the same time for all layers, reaching 424 mg/l near the sea bed, 402 mg/l in the middle of the water column, and 296 mg/l and near the sea surface, respectively, at the same point in time.

Figure 6-32 to **Figure 6-34** show the total sediment deposition depths greater than 3.5 cm which occur during dredging and disposal for the ‘Slow’ production rate and 0.5m over-dredge, using a 35 m^3 bucket. At the Port of Dundee, sediment deposition was contained within the Port of Dundee area, predominantly occurred in close proximity to the quay wall, and remained below 0.15 m. At the Disposal site, sediment was deposited in patchy areas, extending outside of the Disposal site bounds by around 150m in some areas. The patches of sediment deposit predominantly remained below 0.15m, with the largest sediment deposition remaining below 0.4m. The Lady Shoal approach channel area indicates relatively small patches of sediment deposition larger than 0.035m, which remain below 0.1m.

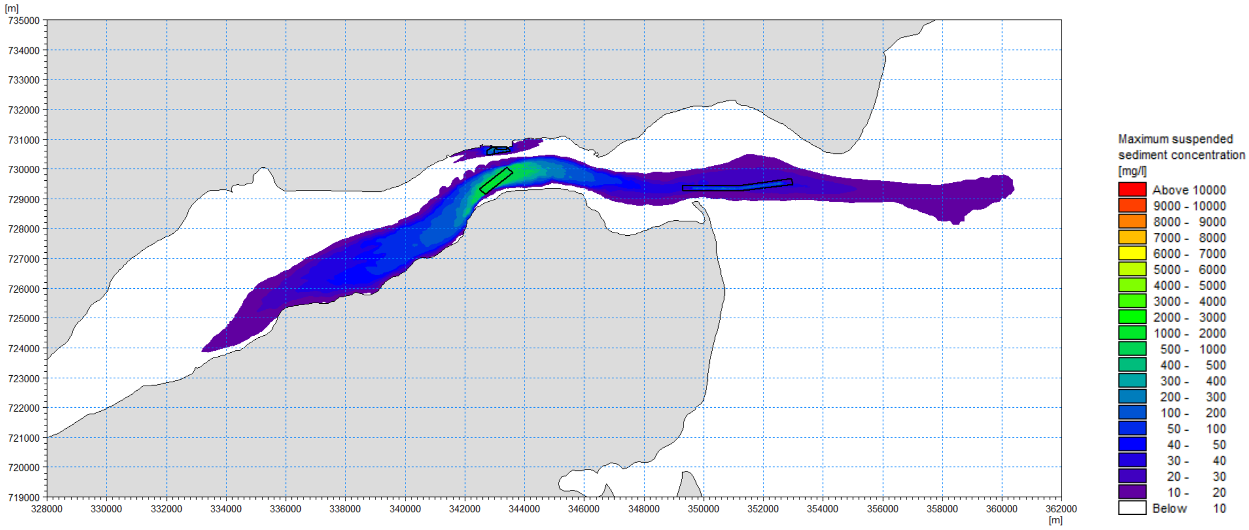

Figure 6-20 Maximum suspended sediment concentration during dredging and disposal near the seabed – Slow production rate – Map of whole plume extent

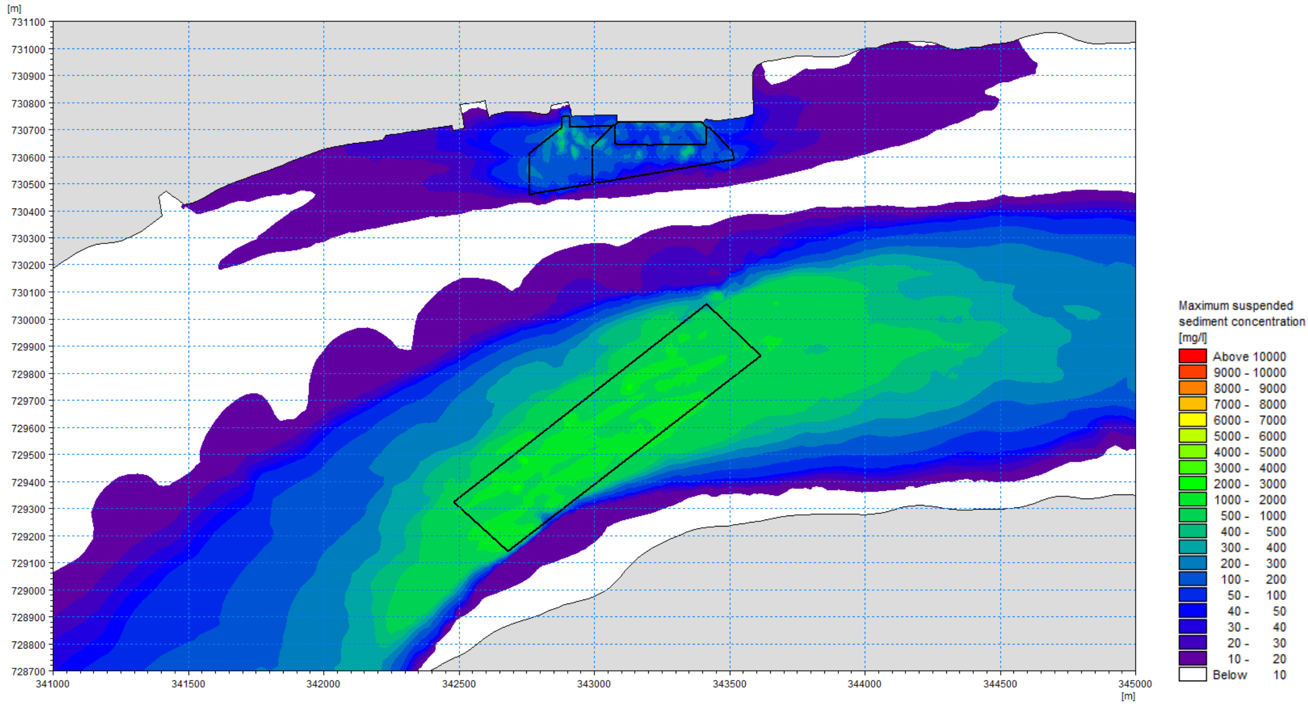

Figure 6-21 Maximum suspended sediment concentration during dredging and disposal near the seabed – Slow production rate – Map of 'Port of Dundee' and 'Disposal Site' areas

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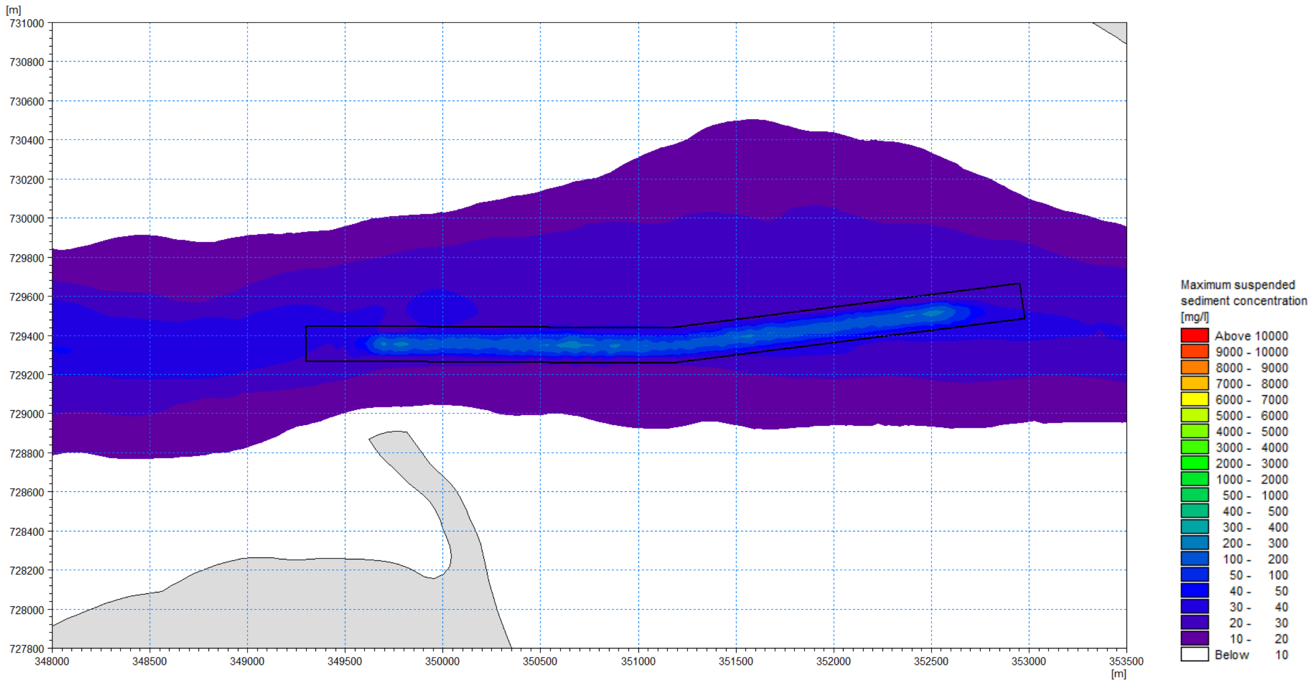

Figure 6-22 Maximum suspended sediment concentration during dredging and disposal near the seabed – Slow production rate – Map of 'Lady Shoal' area

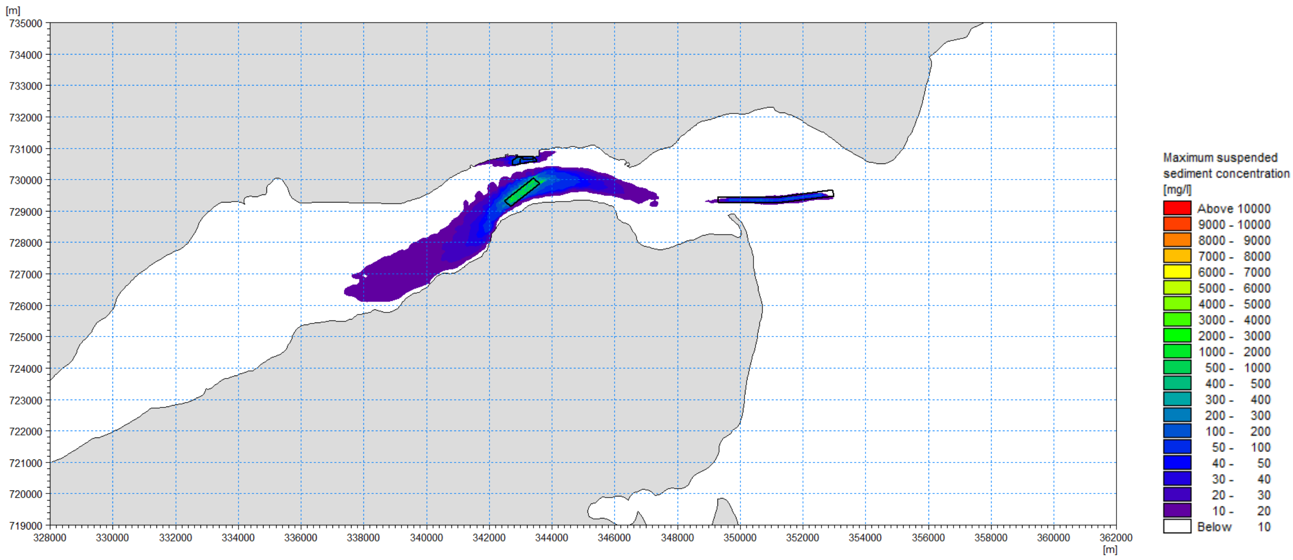

Figure 6-23 Maximum suspended sediment concentration during dredging and disposal in the middle of water column – Slow production rate – Map of whole plume extent

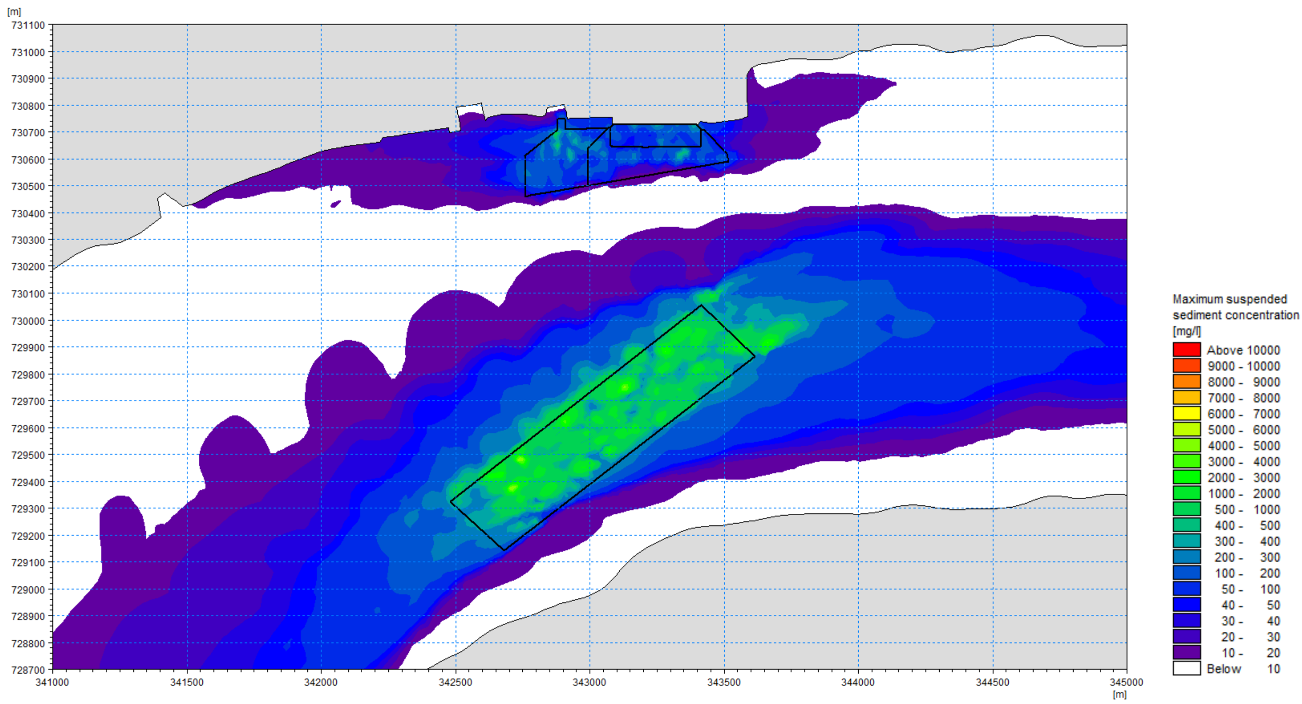

Figure 6-24 Maximum suspended sediment concentration during dredging and disposal in the middle of water column - Slow production rate – Map of 'Port of Dundee' and 'Disposal Site' areas

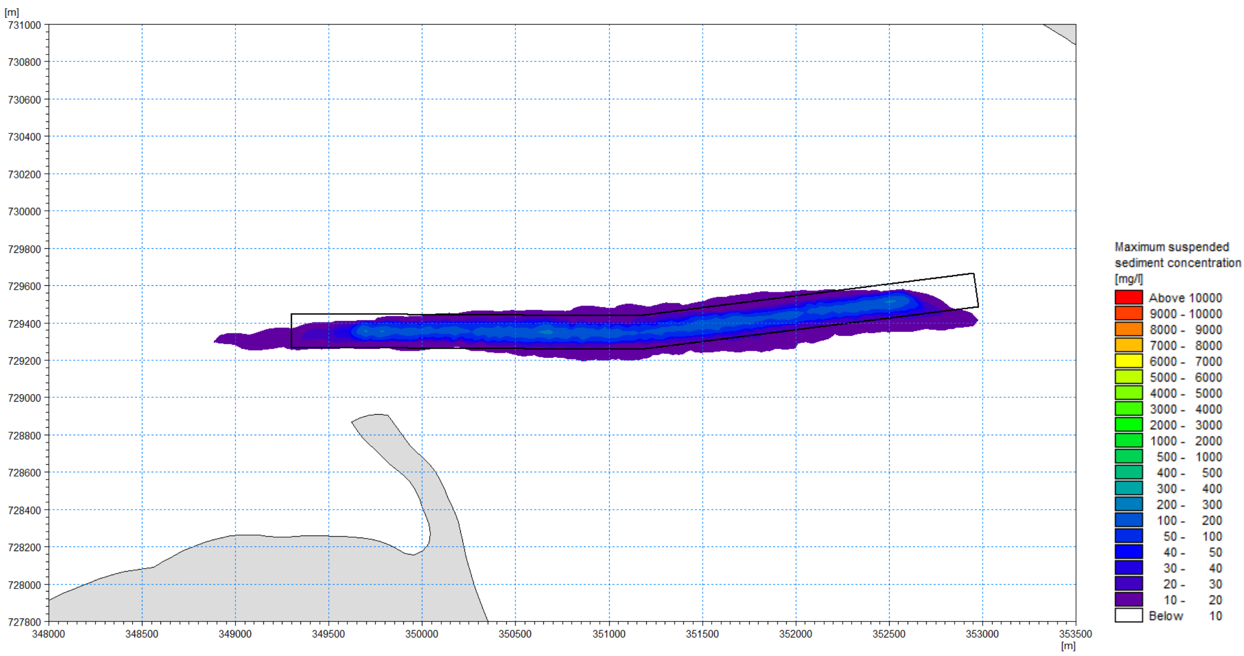

Figure 6-25 Maximum suspended sediment concentration during dredging and disposal in the middle of water column – Slow production rate – Map of ''Lady Shoal' area

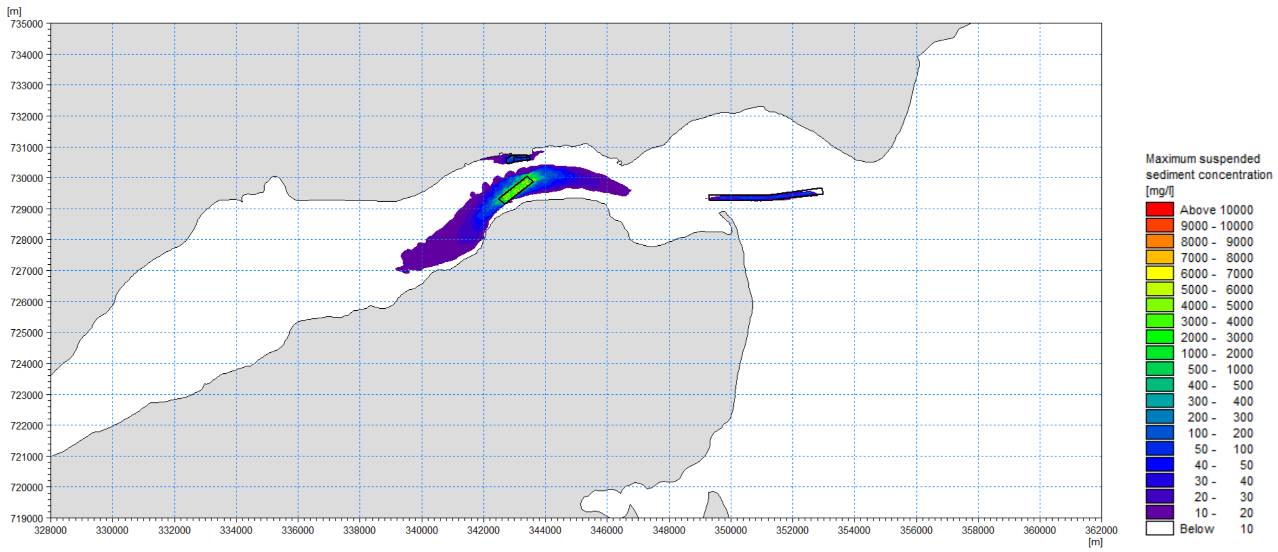

Figure 6-26 Maximum suspended sediment concentration during dredging and disposal near the water surface –Slow production rate – Map of whole plume extent

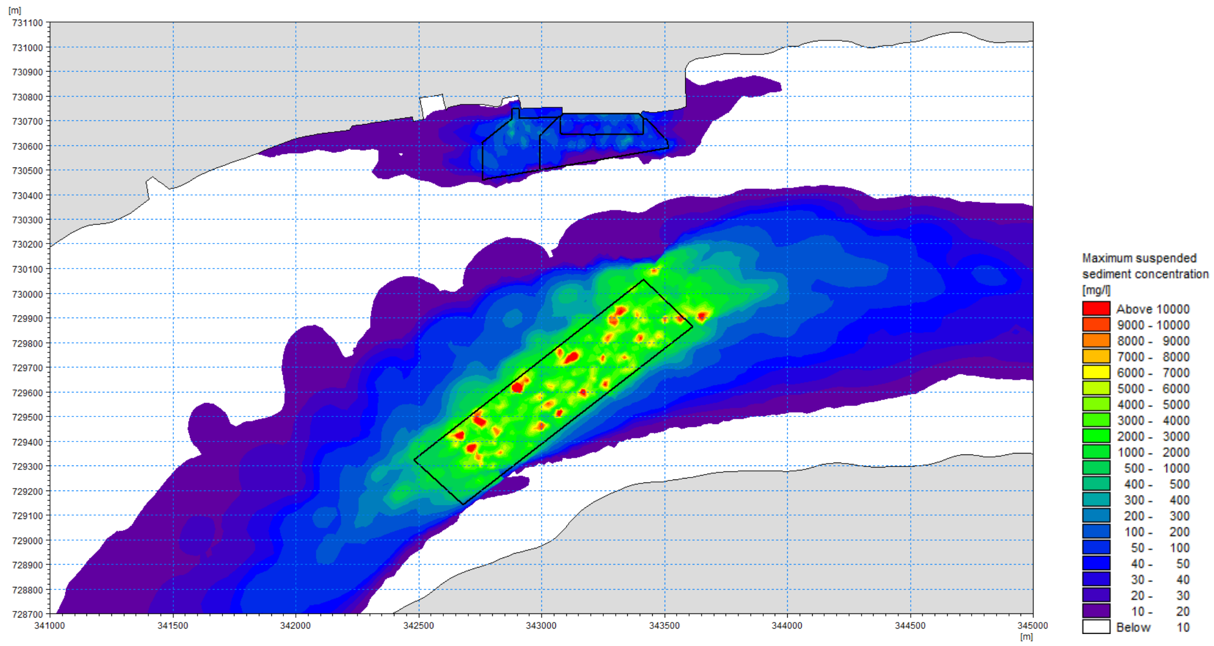

Figure 6-27 Maximum suspended sediment concentration during dredging and disposal near the water surface –Slow production rate – Map of 'Port of Dundee' and 'Disposal Site' areas

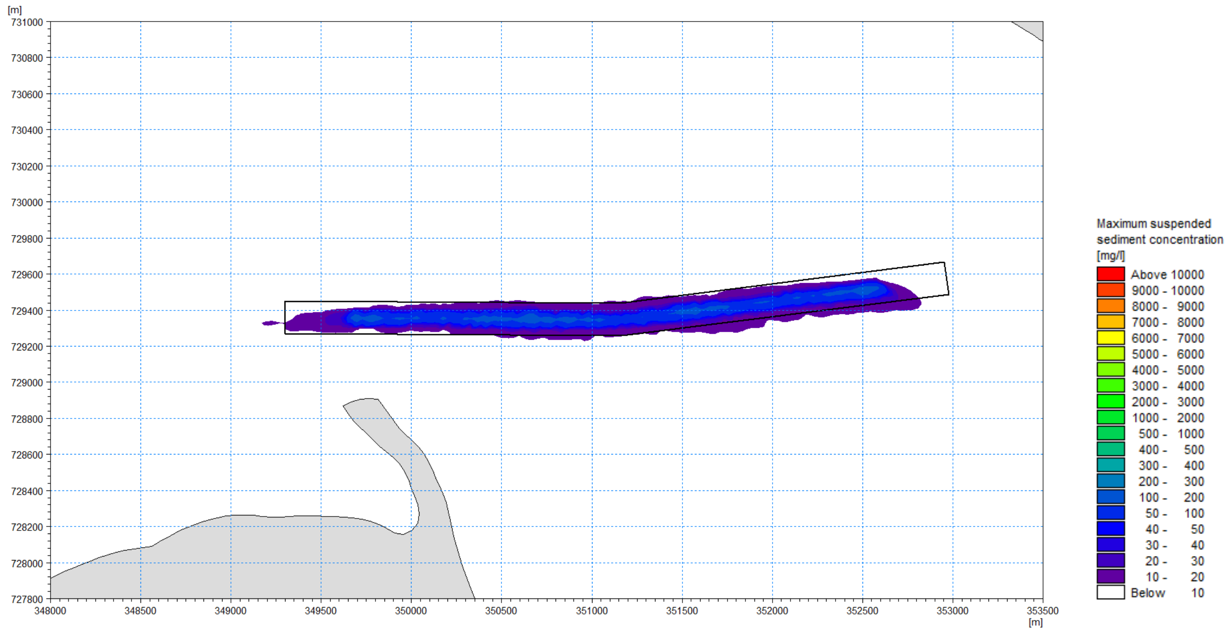

Figure 6-28 Maximum suspended sediment concentration during dredging and disposal near the water surface –Slow production rate – Map of 'Lady Shoal' area

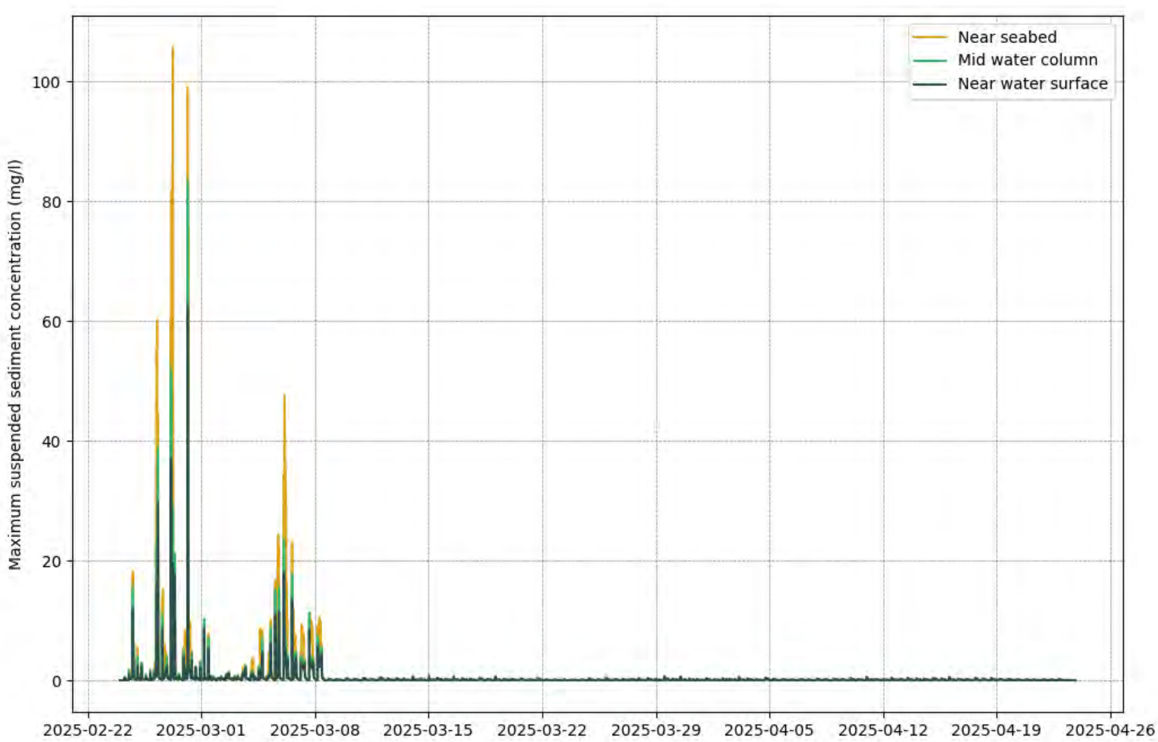

Figure 6-29 Time series of suspended sediment concentration at P1 (Port of Dundee) during dredging activities for seabed, middle of water column and near water surface – Slow production rate simulation

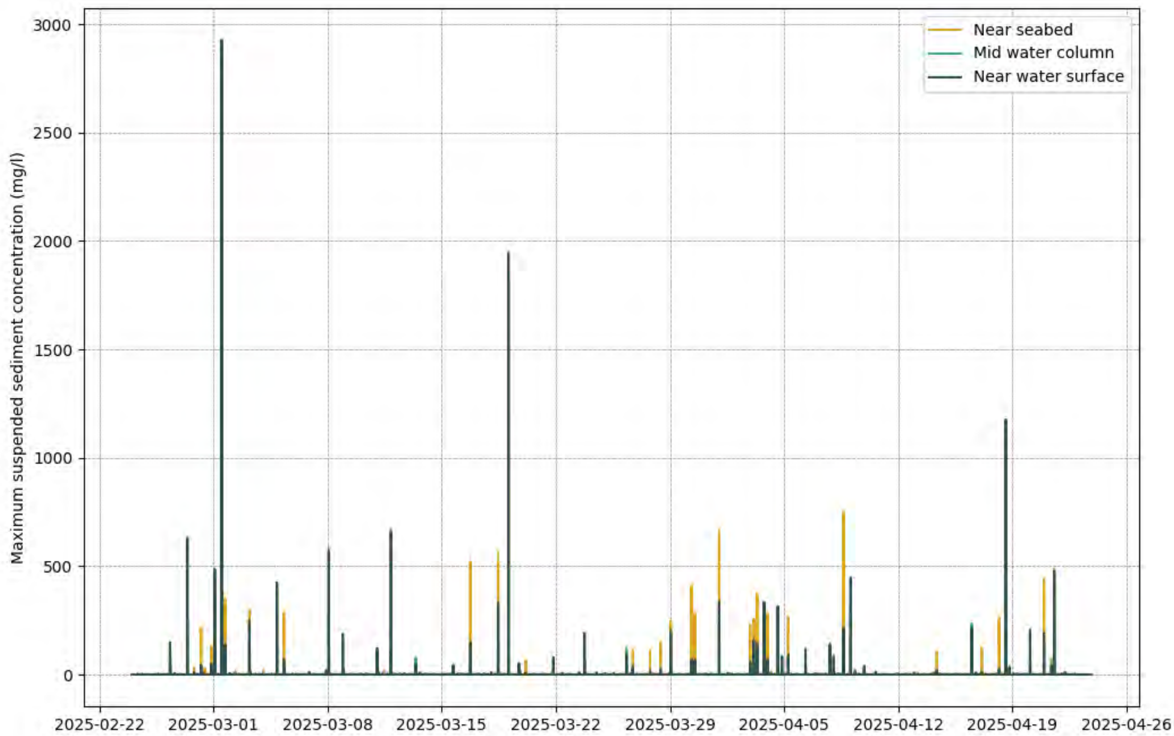

Figure 6-30 Time series of suspended sediment concentration at P2 (Disposal Site) during disposal activities for seabed, middle of water column and near water surface – Slow production rate simulation

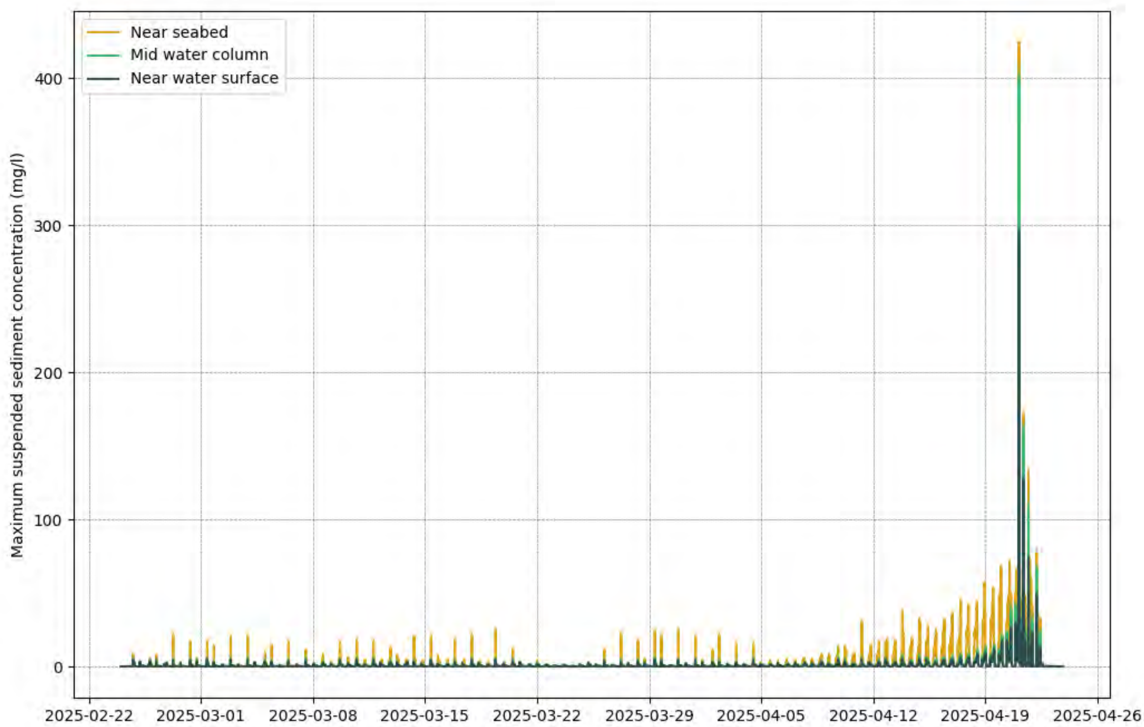

Figure 6-31 Time series of suspended sediment concentration at P3 (Lady Shoal) during dredging activities for seabed, middle of water column and near water surface – Slow production rate simulation

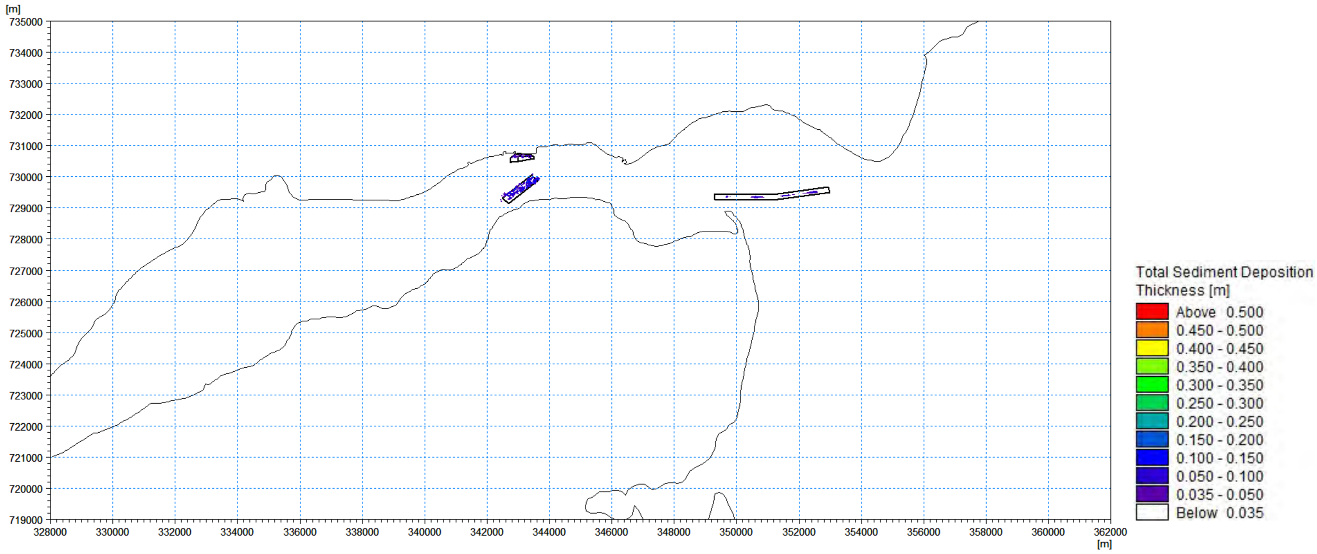

Figure 6-32 Total sediment deposition depths during dredging and disposal –Slow production rate – Map of whole plume extent

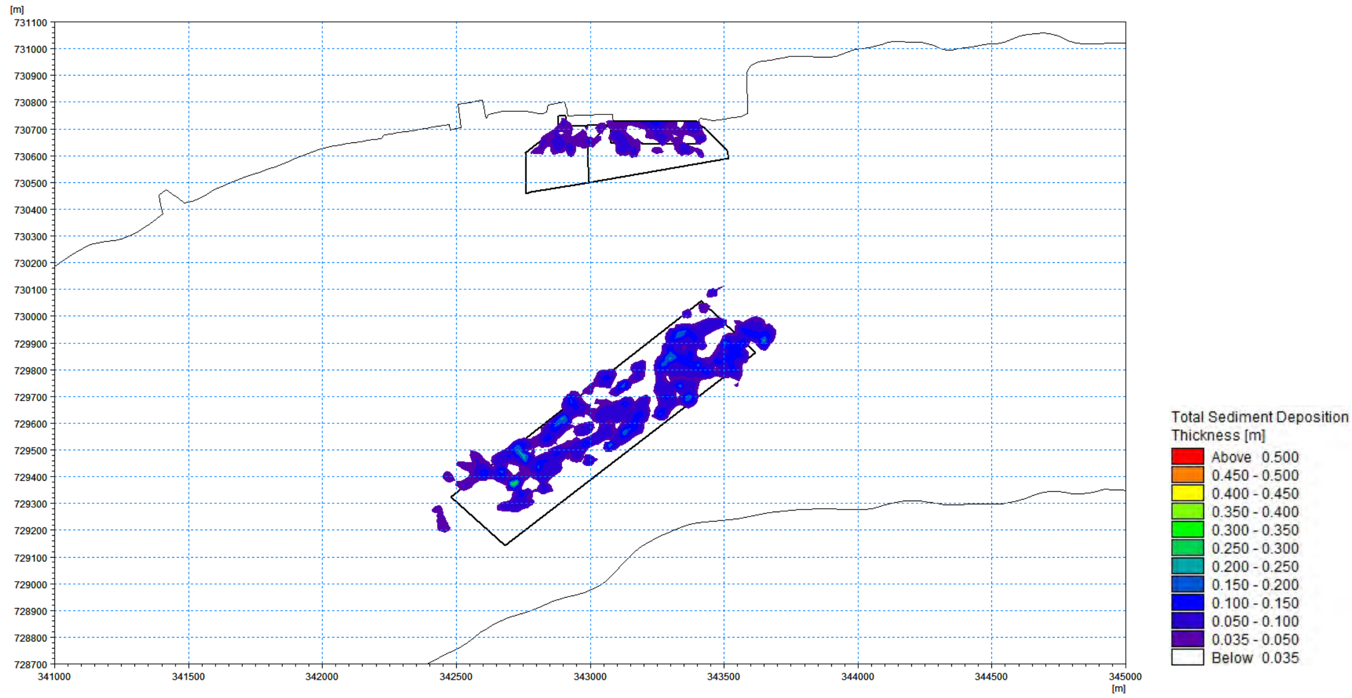

Figure 6-33 Total sediment deposition depths during dredging and disposal –Slow production rate - Map of 'Port of Dundee' and 'Disposal Site' areas

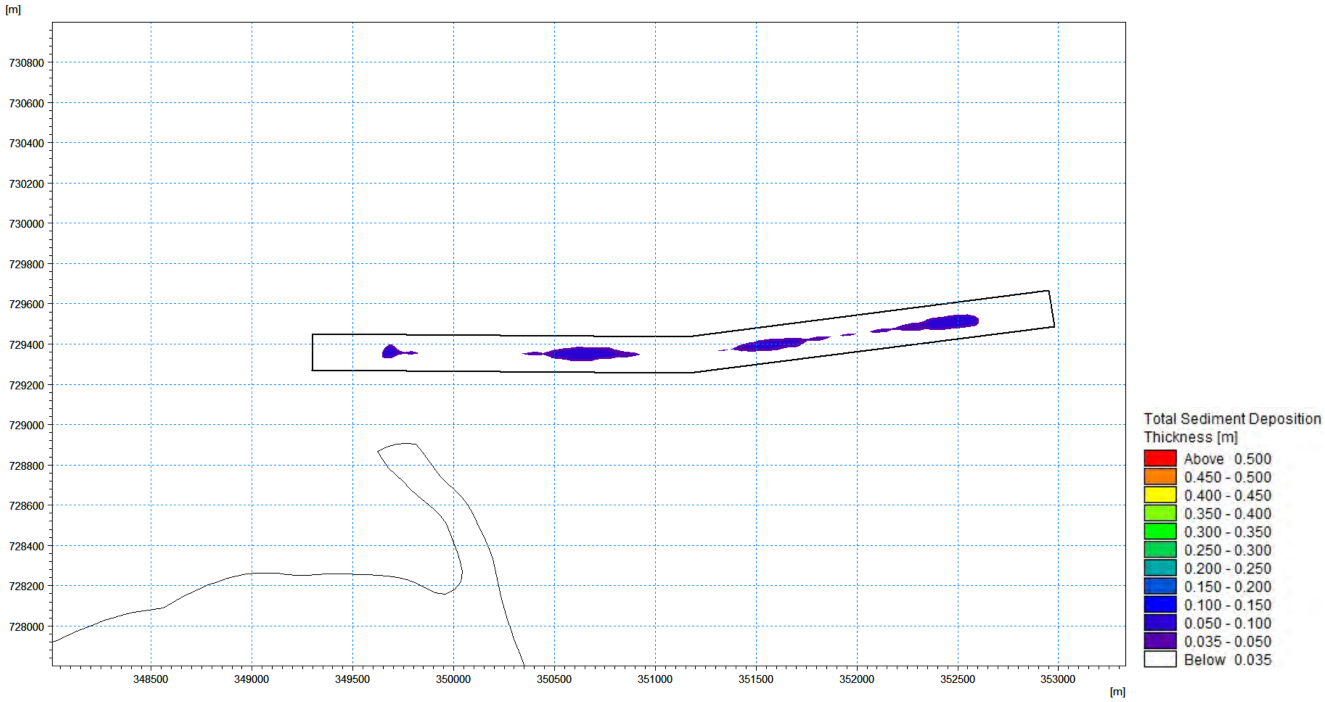

Figure 6-34 Total sediment deposition depths during dredging and disposal –Slow production rate – Map of 'Lady Shoal' area

7 Conclusion

Hydrodynamic and dispersion modelling was undertaken to inform environmental assessments associated with the proposed dredging for Dundee Port. Haskoning's calibrated regional model of the UK was used to provide boundary conditions to a local hydrodynamic model for simulating tidal hydrodynamics and sediment plume dispersion. The regional and local model calibration showed good agreement between predicted and measured water levels and currents, although slightly overpredicting high water levels and therefore was considered to accurately predict tidal and current conditions in the Firth of Tay.

The calibrated local model was then used to model local hydrodynamics and simulate the sediment dispersion from dredging and disposal activities.

The comparison between the 'Existing' and 'Option' layouts in the hydrodynamic model revealed minimal differences in current speed and bed shear stress for the Lady Shoal approach channel. At the Port of Dundee work area, the Option layout had lower current speed and bed shear stress up to 10% than the Existing layout, especially around the edges of Berth Areas 1 and 2, and in the western sides of the dredged areas. Higher values of current speed and bed shear stress were indicated in the Option layout in two areas close to the quay wall, up to 20% and 40% greater for current speed and bed shear stress, respectively.

The Dispersion models of the 'Fast' and 'Slow' production rates demonstrated that the faster production rates result in more extensive dredging sediment plumes, and higher maximum suspended sediment levels especially at the disposal site. Overall plume extents were largest near the seabed, merging on the south side of the Firth of Tay, and reduced in size towards the sea surface. Sediment deposition over 0.035 m remained predominantly within the boundaries of the work areas, and was greatest at the disposal site. Spatially, the Port of Dundee and Disposal site experienced higher peaks of maximum SSC under the 'Fast' scenario, whereas the Lady Shoal approach channel showed higher peaks of maximum SSC under the ‘Slow’ scenario.

Overall, the hydrodynamics conditions in the Firth of Tay were accurately represented, and the hydrodynamic modelling indicated relatively little change in the bed shear stress and current conditions, especially at the Lady Shoal approach channel. The sediment dispersion simulations indicated that impacts from dredging and disposal activities are reduced spatially and in magnitude when using a slower production rate but increased temporally.

Appendix 1

Port of Dundee ADCP Monitoring Campaign