

Liverpool Bay CCS Ltd

HYNET CARBON DIOXIDE TRANSPORTATION AND STORAGE PROJECT - OFFSHORE

Environmental Statement

Volume 3, Appendix H: Physical Processes Technical Report



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Liverpool Bay CCS Limited
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Technical Report

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Prepared by:

RPS

Prepared for:

Liverpool Bay CCS Limited

Glossary

Term	Meaning
The Applicant	This is Liverpool Bay CCS Ltd..
Bathymetry	The measurement of water depth in oceans, seas and lakes.
Bed resistance coefficient	Represents the roughness or friction applied to the flow by the seabed.
"Do Nothing" Scenario	The environment as it would be in the future should the Proposed Development not be developed.
Ebb tide	The tidal phase during which the water level is falling.
Environmental Impact Assessment	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Statement (ES).
Erosion	Depletion of sediment in the intertidal region.
Fetch	Length in the wind direction of the marine area where water waves are generated by wind.
Flood tide	The tidal phase during which the water level is rising.
High Water Mark	The level reached by the sea at high tide.
Highest Astronomical Tide	The highest tidal height predicted to occur under average meteorological conditions and any combination of astronomical conditions.
Hydrodynamic boundary conditions	The conditions used in a model boundary which can included surface elevation and velocity which will affect the rest of the model domain. The boundary condition can vary with time and along the boundary.
Intertidal region	An area of a shoreline that is covered at high tide and uncovered at low tide.
Lee	Shelter from wind or weather given by an object.
Littoral currents	Flow derived from tide and wave climate.
Low Water Mark	The level reached by the sea at low tide.
Lowest Astronomical Tide	The lowest tidal height predicted to occur under average meteorological conditions and any combination of astronomical conditions.
Magnitude	Size, extent and duration of an impact.
Maximum Design Scenario	The maximum design parameters of the Proposed Development considered to be a worst case for any given assessment but within the range of the Project Description Envelope.
Mean High Water	The highest water level reached during and average tide.
Mean High Water Spring	The most inshore level location reached by the sea at high tide during mean high water spring tide. This is defined as the average throughout the year, of two successive high waters, during a 24-hour period in each month when the range of the tide is at its greatest.
Mean Low Water Spring	The most offshore location reached by the sea at low tide during low water spring tide. This is defined as the average throughout the year, of two successive low waters, during a 24-hour period in each month when the range of the tide is at its greatest.
Mean Sea Level	The average tidal height over a long period of time.
Metoccean	Refers to the syllabic abbreviation of meteorology and (physical) oceanography.
Mitigation Measure	Measure which would avoid, reduce, or remediate an impact
Neap tide	Tide that occurs when the sun and moon are at right angles to each other and the gravitational pull of the sun partially cancels out the pull of the moon on the ocean.
Non-statutory stakeholder	Organisations with whom the regulatory authorities may choose to engage who are not designated in law but are likely to have an interest in a proposed development.
Project	The HyNet Carbon Dioxide Transportation and Storage Project.
Project Design Envelope	Also known as the Rochdale Envelope, the PDE concept is routinely utilised in both onshore and offshore planning applications to allow for some flexibility in design options,

Term	Meaning
	particularly offshore, and more particularly for foundations and turbine type, where the full details of the Proposed Development are not known at application submission but where sufficient detail is available to enable all environmental impacts to be appropriately considered during the EIA.
Proposed Development	The offshore components of the Project which are subject of this Environmental Statement, as described in volume 1, chapter 3.
Refraction	The change in direction of a wave passing from one medium to another caused by its change in speed.
Residual Impact	Residual impacts are the final impacts that occur after the proposed mitigation measures have been put into place, as planned.
Sand wave	A lower regime sedimentary structure that forms across from tidal currents.
Scour protection	Measures to prevent loss of seabed sediment around any structure placed in or on the seabed (e.g. by use of protective aprons, mattresses, rock and gravel placement).
Sedimentation	The process of settling or being deposited as sediment.
Significant wave height	Mean wave height (trough to crest) of the highest third of the waves.
Slack tide	Tidal phase at which the current turns from flood to ebb (high-water slack tide) or from ebb to flood (low-water slack tide).
Spatiotemporal	Describing a phenomenon in a certain location and time.
Spectral waves	Describes the distribution of wave energy with frequency (1/period) and direction.
Spring tide	Tide that occurs when the sun and moon are directly in line with the Earth and their gravitational pulls on the ocean reinforce each other.
Suspended Particulate Matter	Particles that are suspended in the water column.
Turbidity	The quality of being cloudy, opaque, or thick with suspended matter.
Wave height	The distance from trough to crest of a wave.
Wave period	The time it takes for two successive crests (one wavelength) to pass a specified point.

Acronyms and Initialisations

Acronym and Initialisation	Description
ADCP	Acoustic Doppler Current Profiler
BERR	Department for Business Enterprise and Regulatory Reform
BODC	British Oceanographic Data Centre
CCO	Coastal Channel Observatory
CD	Chart Datum (generally defined as LAT)
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CIV	Cleveleys
DA	Depth Averaged
DHI	Danish Hydraulic Institute
ECMWF	European Centre for Medium Range Forecasts
EMODnet	European Marine Observation and Data Network
EIA	Environmental Impact Assessment
ES	Environmental Statement
GyM	Gwynt y Môr
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
LAT	Lowest Astronomical Tide

Acronym and Initialisation	Description
LWM	Low Water Mark
MDS	Maximum Design Scenario
MEDIN	Marine Environmental Data and Information Network
MHW	Mean High Water
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
NOAA	National Oceanic and Atmospheric Administration
NRW	Natural Resources Wales
OP	Offshore Platform
OSP	Offshore Service Platform
PoA	Point of Ayr
PSA	Particle Size Analysis°
PT	Particle Tracking
SPM	Suspended Particulate Matter
SSC	Suspended Sediment Concentration
SSS	Side Scan Sonar
TSSF	Tide and Storm Surge Forecast
UKCS	United Kingdom Continental Shelf
UKHO	United Kingdom Hydrographic Office

Units

Unit	Description
%	Percent
°	Degrees (angle from True north)
cm	Centimetre (distance)
mm	Millimetre (distance)
m	Metre (distance)
km	Kilometre (distance)
Kg/s	Kilograms per second (rate of release)
mg/l	Milligrams per litre (suspended sediment concentration)

Contents

Glossary	iii
Acronyms and Initialisations	iv
Units	v
1 PHYSICAL PROCESSES TECHNICAL REPORT	1
1.1 Introduction.....	1
1.2 Study area	1
1.2.1 Intertidal area	1
1.3 Methodology.....	3
1.4 Desktop study.....	6
1.5 Site-specific surveys	8
1.6 Baseline Environment	8
1.6.1 Bathymetry	8
1.6.2 Hydrography	12
1.6.3 Wave climate	25
1.6.4 Littoral currents	41
1.6.5 Sedimentology and seabed substrate	43
1.6.6 Sediment transport	46
1.6.7 Suspended sediments	52
1.7 Potential changes during construction	54
1.7.1 Seabed preparation	54
1.7.2 Drill cuttings	72
1.7.3 Cable installation	83
1.8 Summary	111
1.9 References	113

Tables

Table 1.1: Mike Suite Of Models	3
Table 1.2: Summary Of Modelled Environmental Variation Scenarios	4
Table 1.3: Summary Of Key Desktop Reports	6
Table 1.4: Summary Of Site-Specific Survey Data	8
Table 1.5: Tidal Levels at Standard Ports	12

Figures

Figure 1.1: Proposed Development physical processes study area	2
Figure 1.2: Model Domain (Blue Outline)	5
Figure 1.3: MEDIN Bathymetric Data Coverage	9
Figure 1.4: Model Bathymetry Within The East Irish Sea.....	10
Figure 1.5: Model Mesh Utilised For Dispersion Modelling	11
Figure 1.6: Extent And Bathymetry Of Irish Seas Tidal And Storm Surge Model	13
Figure 1.7: Availability Of Metocean Datasets Across The Eastern Irish Sea	14
Figure 1.8: Location Of Calibration Data Presented.....	15
Figure 1.9: Comparison Of Model And Admiralty Harmonic Tide Data For Llandudno	17
Figure 1.10: Comparison Of Model And Recorded Burbo Bank North Wave Buoy ADCP Data (Fugro) 53°30.113' N, 003°21.687' E - Current Speed And Direction Spring.....	17

Figure 1.11: Comparison Of Model And Recorded Burbo Bank North Wave Buoy ADCP Data (Fugro) 53°30.113' N, 003°21.687' E - Current Speed And Direction Neap	17
Figure 1.12: Comparison Of Model And Recorded Burbo Bank South Wave Buoy ADCP Data (Fugro) 53°29.101' N, 003°15.533' E - Current Speed And Direction Spring.....	18
Figure 1.13: Comparison Of Model And Recorded Burbo Bank South Wave Buoy ADCP Data (Fugro) 53°29.101' N, 003°15.533' E - Current Speed And Direction Neap	18
Figure 1.14: Comparison Of Model And Recorded Data BODC Location A – Current Speed And Direction Spring.....	18
Figure 1.15: Comparison Of Model And Recorded Data BODC Location A – Current Speed And Direction Neap.....	19
Figure 1.16: Comparison Of Model And Recorded Data BODC Location B – Current Speed And Direction Spring.....	19
Figure 1.17: Comparison Of Model And Recorded Data BODC Location B – Current Speed And Direction Neap.....	19
Figure 1.18: Comparison Of Model And Recorded Data BODC Location C – Current Speed And Direction Spring.....	20
Figure 1.19: Comparison Of Model And Recorded Data BODC Location C – Current Speed And Direction Neap.....	20
Figure 1.20: Comparison Of Model And Recorded Data BODC Location D – Current Speed And Direction Spring.....	20
Figure 1.21: Comparison Of Model And Recorded Data BODC Location D – Current Speed And Direction Neap.....	21
Figure 1.22: Comparison Of Model And Recorded Data BODC Location E – Current Speed And Direction Spring.....	21
Figure 1.23: Comparison Of Model And Recorded Data BODC Location E – Current Speed And Direction Neap.....	21
Figure 1.24: Tidal Flow Patterns – Neap Tide Flood.....	22
Figure 1.25: Tidal Flow Patterns – Neap Tide Ebb	23
Figure 1.26: Tidal Flow Patterns – Spring Tide Flood.....	24
Figure 1.27: Tidal Flow Patterns – Spring Tide Ebb.....	25
Figure 1.28: Wave Rose For The Hynet Physical Processes Study Area	26
Figure 1.29: Wind Rose For Hynet Physical Processes Study Area	27
Figure 1.30: Location Of Wave Calibration Data Presented	28
Figure 1.31: Validation Of Modelled (Pink) Mean Wave Direction With Measured (Blue) Data At GyM	29
Figure 1.32: Validation Of Modelled (Red) Significant Wave Height With Measured (Green) Data At Gym.....	29
Figure 1.33: Validation Of Modelled (Blue) Peak Wave Period With Measured (Blue) Data At GyM	30
Figure 1.34: Validation Of Modelled (Pink) Mean Wave Direction With Measured (Blue) Data At RhF	30
Figure 1.35: Validation Of Modelled (Red) Significant Wave Height With Measured (Green) Data At RhF.....	30
Figure 1.36: Validation Of Modelled (Blue) Peak Wave Period With Measured (Orange) Data At RhF	31
Figure 1.37: Wave Roses For Model Boundaries - 22 Year ECMWF Dataset And Wind Rose For 40 Year NOAA Dataset	32
Figure 1.38: Wave Climate 1:1 Year Storm From 000° MHW.....	33
Figure 1.39: Wave Climate 1:1 Year Storm From 090° MHW.....	34
Figure 1.40: Wave Climate 1:1 Year Storm From 240° MHW.....	35
Figure 1.41: Wave Climate 1:1 Year Storm From 270° MHW.....	36
Figure 1.42: Wave Climate 1:20 Year Storm From 000° MHW.....	37
Figure 1.43: Wave Climate 1:20 Year Storm From 090° MHW.....	38
Figure 1.44: Wave Climate 1:20 Year Storm From 240° MHW.....	39
Figure 1.45: Wave Climate 1:20 Year Storm From 270° MHW.....	40
Figure 1.46: Littoral Current 1:1 Year Storm From 270° - Flood Tide	41

Figure 1.47: Littoral Current 1:1 Year Storm From 270° - Ebb Tide.....	42
Figure 1.48: Seabed Classification British Geological Survey	44
Figure 1.49: Seabed Substrate Geology Comprised Of Site Specific Grab Samples And EMODnet	45
Figure 1.50: Residual Current Spring Tide	47
Figure 1.51: Potential Sediment Transport Over The Course Of 1 Day (Two Tide Cycles)	48
Figure 1.52: Sediment Transport – Flood Tide.....	49
Figure 1.53: Sediment Transport – Ebb Tide	50
Figure 1.54: Residual Current Spring Tide With 1:1 Year Storm From 270 °.....	51
Figure 1.55: Distribution Of Average Non-Algal Suspended Particulate Matter – CEFAS	53
Figure 1.56: Modelled Paths For Sand Wave Clearance South Of Douglas OP	56
Figure 1.57: Maximum Suspended Sediment Concentration Over Excavation Phase – South Of Douglas	57
Figure 1.58: Average Suspended Sediment Concentration Over Excavation Phase – South of Douglas	58
Figure 1.59: Maximum Sedimentation Over Excavation Phase – South of Douglas	59
Figure 1.60: Average Sedimentation Over Excavation Phase – South of Douglas	60
Figure 1.61: Sedimentation One Day After Cessation Of Excavation – South of Douglas	61
Figure 1.62: Modelled Dredge Path Across West Hoyle Bank.....	62
Figure 1.63: Maximum Suspended Sediment Concentration Over Dredging Phase – West Hoyle Bank	64
Figure 1.64: Average Suspended Sediment Concentration Over Dredging phase – West Hoyle Bank.....	65
Figure 1.65: Maximum Sedimentation Over Dredging Phase – West Hoyle Bank	66
Figure 1.66: Average Sedimentation Over Dredging Phase – West Hoyle Bank	67
Figure 1.67: Sedimentation One Day After Cessation Of Dredging – West Hoyle Bank	68
Figure 1.68: Suspended Sediment Concentration Day 1 Ebb – West Hoyle Bank.....	69
Figure 1.69: Suspended Sediment Concentration Day 1 Flood – West Hoyle Bank	70
Figure 1.70: Suspended Sediment Concentration Final Day Ebb – West Hoyle Bank.....	71
Figure 1.71: Suspended Sediment Concentration Final Day Flood – West Hoyle Bank	72
Figure 1.72: Modelled Drilling Locations	73
Figure 1.73: Maximum Suspended Sediment Concentration Over Drilling Phase - Hamilton Main	74
Figure 1.74: Average Suspended Sediment Concentration Over Drilling Phase - Hamilton Main	75
Figure 1.75: Maximum Sedimentation Over Drilling Phase - Hamilton Main	76
Figure 1.76: Average Sedimentation Over Drilling Phase - Hamilton Main	77
Figure 1.77: Sedimentation One Day After Cessation Of Drilling - Hamilton Main	78
Figure 1.78: Maximum Suspended Sediment Concentration Over Drilling Phase - Hamilton North	79
Figure 1.79: Average Suspended Sediment Concentration Over Drilling Phase - Hamilton North	80
Figure 1.80: Maximum Sedimentation Over Drilling Phase - Hamilton North	81
Figure 1.81: Average Sedimentation Over Drilling Phase - Hamilton North	82
Figure 1.82: Sedimentation One Day After Cessation Of Drilling - Hamilton North	83
Figure 1.83: Modelled POA To Douglas Trenching Route	84
Figure 1.84: Maximum Suspended Sediment Concentration Over Trenching Phase - POA To Douglas	86
Figure 1.85: Average Suspended Sediment Concentration Over Trenching Phase - POA To Douglas	86
Figure 1.86: Suspended Sediment Concentration Day 1 Ebb - POA To Douglas	87
Figure 1.87: Suspended Sediment Concentration Day 1 Flood - POA To Douglas	88
Figure 1.88: Suspended Sediment Concentration Day 2 Ebb - POA TO Douglas	89
Figure 1.89: Suspended Sediment Concentration Day 2 Flood - POA To Douglas	90
Figure 1.90: Suspended Sediment Concentration Day 3 Ebb - POA To Douglas	91
Figure 1.91: Suspended Sediment Concentration Day 3 flood - POA To Douglas.....	92
Figure 1.92: Suspended Sediment Concentration Day 4 Ebb - POA To Douglas	93
Figure 1.93: Suspended Sediment Concentration Day 4 Flood - POA To Douglas	94
Figure 1.94: Maximum Sedimentation Over Trenching Phase – POA To Douglas	95
Figure 1.95: Average Sedimentation Over Trenching Phase – POA To Douglas.....	96
Figure 1.96: Sedimentation One Day After Cessation Of Trenching – POA To Douglas	97
Figure 1.97: Modelled Douglas To Lennox Trenching Route.....	98

Figure 1.98: Maximum Suspended Sediment Concentration Over Trenching Phase – Douglas To Lennox.....	99
Figure 1.99: Average Suspended Sediment Concentration Over Trenching Phase – Douglas To Lennox.....	100
Figure 1.100: Suspended Sediment Concentration Day 1 Ebb – Douglas To Lennox	101
Figure 1.101: Suspended Sediment Concentration Day 1 Flood – Douglas To Lennox	102
Figure 1.102: Suspended Sediment Concentration Day 2 Ebb – Douglas To Lennox	103
Figure 1.103: Suspended Sediment Concentration Day 2 Flood – Douglas To Lennox	104
Figure 1.104: Suspended Sediment Concentration Day 3 Ebb – Douglas To Lennox	105
Figure 1.105: Suspended Sediment Concentration Day 3 Flood – Douglas To Lennox	106
Figure 1.106: Suspended Sediment Concentration Day 4 Ebb – Douglas To Lennox	107
Figure 1.107: Suspended Sediment Concentration Day 4 Flood – Douglas To Lennox	108
Figure 1.108: Maximum Sedimentation Over Trenching Phase – Douglas To Lennox	109
Figure 1.109: Average Sedimentation Over Trenching Phase – Douglas To Lennox	110
Figure 1.110: Sedimentation One Day After Cessation Of Trenching – Douglas To Lennox	111

1 PHYSICAL PROCESSES TECHNICAL REPORT

1.1 Introduction

This Physical Processes Technical Report provides information relating to the physical environment and processes for the offshore components of the Hynet Carbon Dioxide Transportation and Storage Project - Offshore (hereafter referred to as “the Proposed Development”). The purpose of the technical report is to provide details of the supporting study undertaken by means of numerical modelling. It describes the current baseline conditions and quantifies the changes as a result of cable trenching and monitoring well drilling activities. This report is divided into two main sections:

- Baseline conditions – describing current hydrography and sedimentology; and
- Construction phase changes – describing the dispersion and fate of sediment mobilised during construction phase activities.

For the purposes of this physical processes technical report, physical processes are defined as encompassing the following elements:

- Tidal elevations and currents;
- Wave;
- Bathymetry;
- Seabed sediments;
- Suspended sediments; and
- Sediment transport.

1.2 Study area

The Proposed Development physical processes study area, as shown in Figure 1.1, is defined as the area encompassing the development area, plus a buffer of one tidal excursion. The c.8 km buffer around the development area previously used in the Proposed Development EIA Scoping Report (RPS, 2022), has been updated on the basis of tidal ellipse modelling along the proposed cable route. The updated physical processes study area accounts for this tidal excursion and was extended to account for residual currents along the coastline, it therefore illustrates the areas potentially affected by changes in water quality (increases in Suspended Sediment Concentration (SSC)).

The physical processes study area forms the focus for the assessment. However, the extent of the numerical models employed in undertaking the study is not limited to this region and should they arise, would therefore identify potential impacts beyond the physical processes study area both further offshore and along the shoreline.

1.2.1 Intertidal area

The offshore topic of physical processes study area includes the intertidal area. This intertidal area overlaps with the onshore topic of Geology, Hydrology, Soils and Flood Risk (landward of Mean Low Water Springs (MLWS)).

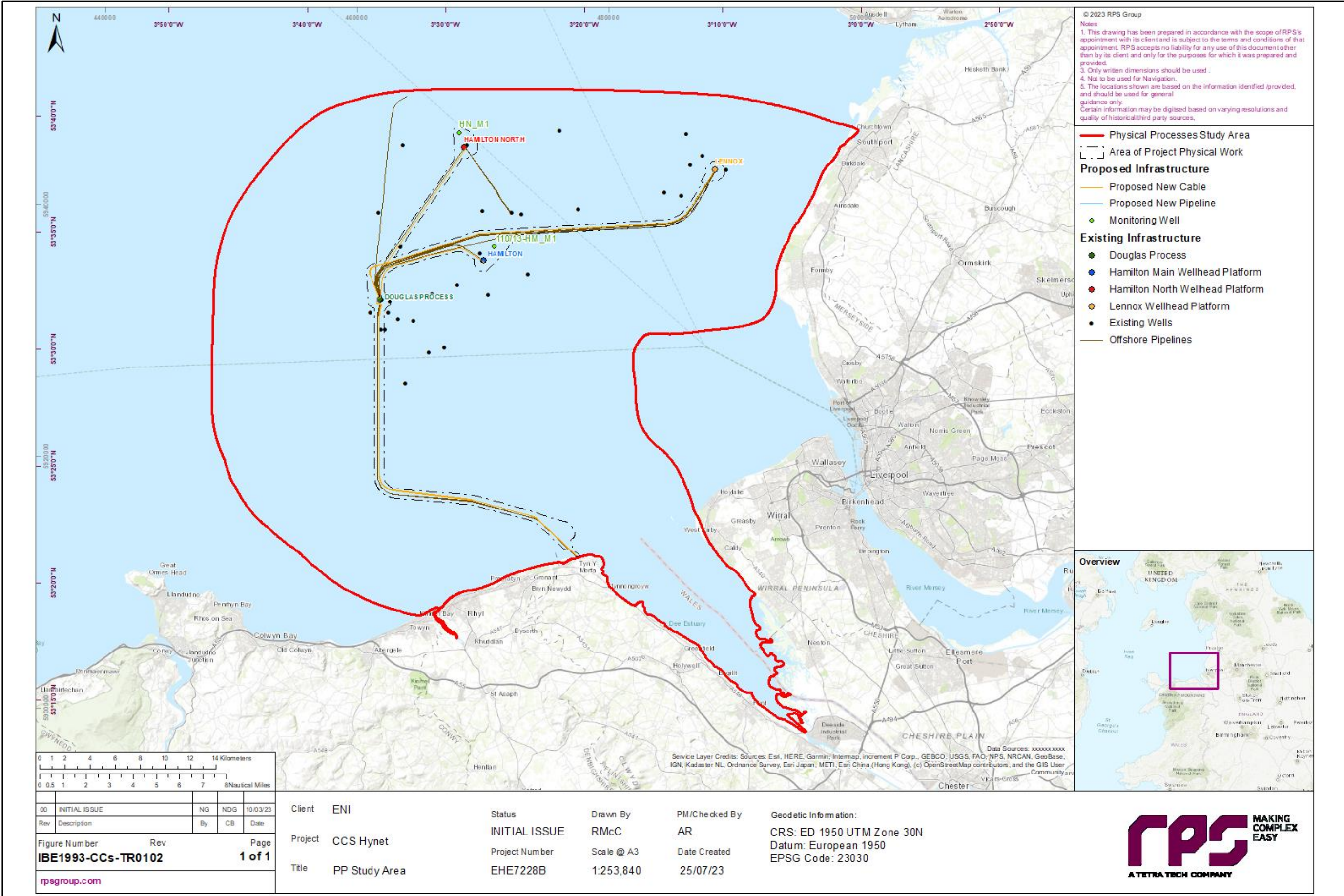


Figure 1.1: Proposed Development physical processes study area

1.3 Methodology

The physical processes study was undertaken to provide information on potential changes to physical processes and the fate of mobilised sediment during the construction phase by means of numerical modelling. Numerical models were developed and calibrated using a combination of publicly available datasets and those collected specifically for the Proposed Development.

The models were used to undertake simulations of site preparation and cable trenching activities to quantify potential increases in Suspended Sediment Concentration (SSC) and subsequent deposition. This information was then applied in the context of the physical processes environmental impact assessment and those of related disciplines.

Numerical modelling

Numerical modelling techniques were used to describe baseline tide, wave and sediment transport regimes. The MIKE suite of software was employed, as a single model mesh could be used to simulate these processes both individually and in combination. The model domain is shown in Figure 1.2. The MIKE suite of models is a widely used industry standard modelling suite developed by the Danish Hydraulic Institute (DHI). It has been approved for use by industry and government bodies including Natural Resources Wales. The MIKE suite is a modular system that contains a number of different but complementary modules encompassing different physical processes: these are summarised in Table 1.1 and described in further detail within the relevant sections. The modelled parameters are presented in

Table 1.2

Table 1.1: Mike Suite Of Models

Simulation	Model	Description
Baseline tidal flow	MIKE21 Flexible Mesh (FM) modelling system	The FM Module is a 2-dimensional, depth averaged hydrodynamic model which simulates the water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal areas. The water levels and flows are resolved on a mesh covering the area of interest when provided with bathymetry, bed resistance coefficient, wind field, hydrodynamic boundary conditions, etc.
Baseline wave climate	MIKE21 Spectral Wave (SW)	The wave modelling was undertaken using the spectral wave model, MIKE21 SW. The waves were computed on the same grid as the tidal flows. The model resolves the wave field by simulating wind generation of waves within the model domain and the propagation of externally generated swell waves through the domain. The model setup ensured that the detail of both locally generated wind waves and swell conditions from further afield were captured.
Baseline littoral currents	MIKE21 FM and SW	The MIKE suite facilitates the coupling of models. The depth averaged hydrodynamic model, used for the tidal modelling, coupled with a spectral wave model, provides a full wave climate incorporating the impact of water levels and currents on waves and wave breaking. Using this, the littoral currents (i.e. those currents driven by tidal, wave and meteorological forces) were examined.
	MIKE21 Sediment Transport (ST)	This module enables assessment of bed sediment transport rates and initial rates of bed level change for non-cohesive sediment resulting from currents or combined wave-current flows. The model combines inputs from both the hydrodynamic model and, if required, the wave propagation model. It uses sediment size and gradation to determine the bed level changes and sediment transport rates.

Simulation	Model	Description
Offshore seabed preparation	MIKE21 Particle Tracking (PT)	The Particle Tracking module was implemented for offshore construction activities as it has the advantage that it could be used to describe the transport of material released in a specific part of the water column. In this way, the dispersion would not be over-estimated, or the corresponding sedimentation underestimated.
Drill cuttings		
Offshore cable installation		
Nearshore seabed preparation	MIKE21 Mud Transport (MT)	The MIKE Mud Transport (MT) module allows the modelling of erosion, transport and deposition of cohesive and cohesive/granular sediments. This model is suited to sediment releases in the water column and allows sediment sources which may vary spatially and temporally. Utilised for activities that coincide with flooding and drying areas.
Nearshore cable preparation		

Table 1.2: Summary Of Modelled Environmental Variation Scenarios

Variation/ operation	Description	Parameter modelled
Seabed features clearance Section 1.7.1	Dispersion modelling relating to sand wave clearance channels cleared for cable laying, through sand wave features.	South of Douglas OP: Clearance is undertaken along two sand waves across lengths of 100 m and 15 m, each channel being 10 m wide and 3 m in depth. Mass flow excavator used in 3-day clearance operation, with a rate of release of 27.71 kg/s.
		West Hoyle Bank: Dredged channel through c.1 km West Hoyle Bank, each channel being 21 m wide and 7 m in depth. Backhoe dredger used in 14-day clearance operation, with a rate of release of 295 kg/s.
Drill cuttings Section 1.7.2	Dispersion modelling related to suspended sediments from drilling of monitoring wells	Drilling parameters: 26" section drilled through 30.48 m of sand/silt and 84.43 m of the Mercia Mudstone Group. 17" section below section 1 drilled through a further 518.16 m of the Mercia Mudstone Group. 100% hole washout accounting for abrasive drilling sediment (drilling muds) simulated. Drilled at 40 m/h over the course of c.16 hours.
Cable installation Section 1.7.3	Dispersion modelling of suspended sediment arising from cable installation via trenching.	Trenching operation parameters: Trench 3 m wide at seabed and 3 m deep with triangular cross section; Trenching undertaken at 450 m/h;

Modelling team

The numerical modelling study undertaken by RPS was carried by an experienced team of environmental and engineering consultants. The team was headed by a principal engineer with 23 years of post-doctoral experience in the field of computational modelling of coastal processes, with a background of qualifications encompassing a PhD in Computational Fluid Dynamics, MSc Engineering Computation and a BEng in Civil Engineering. The teams experience includes, but is not limited to, a number of existing modelling studies within Liverpool Bay, for example the Morgan Offshore Wind Project Generation Assets (RPS, 2022) and Mona Offshore Wind Project (RPS, 2022).

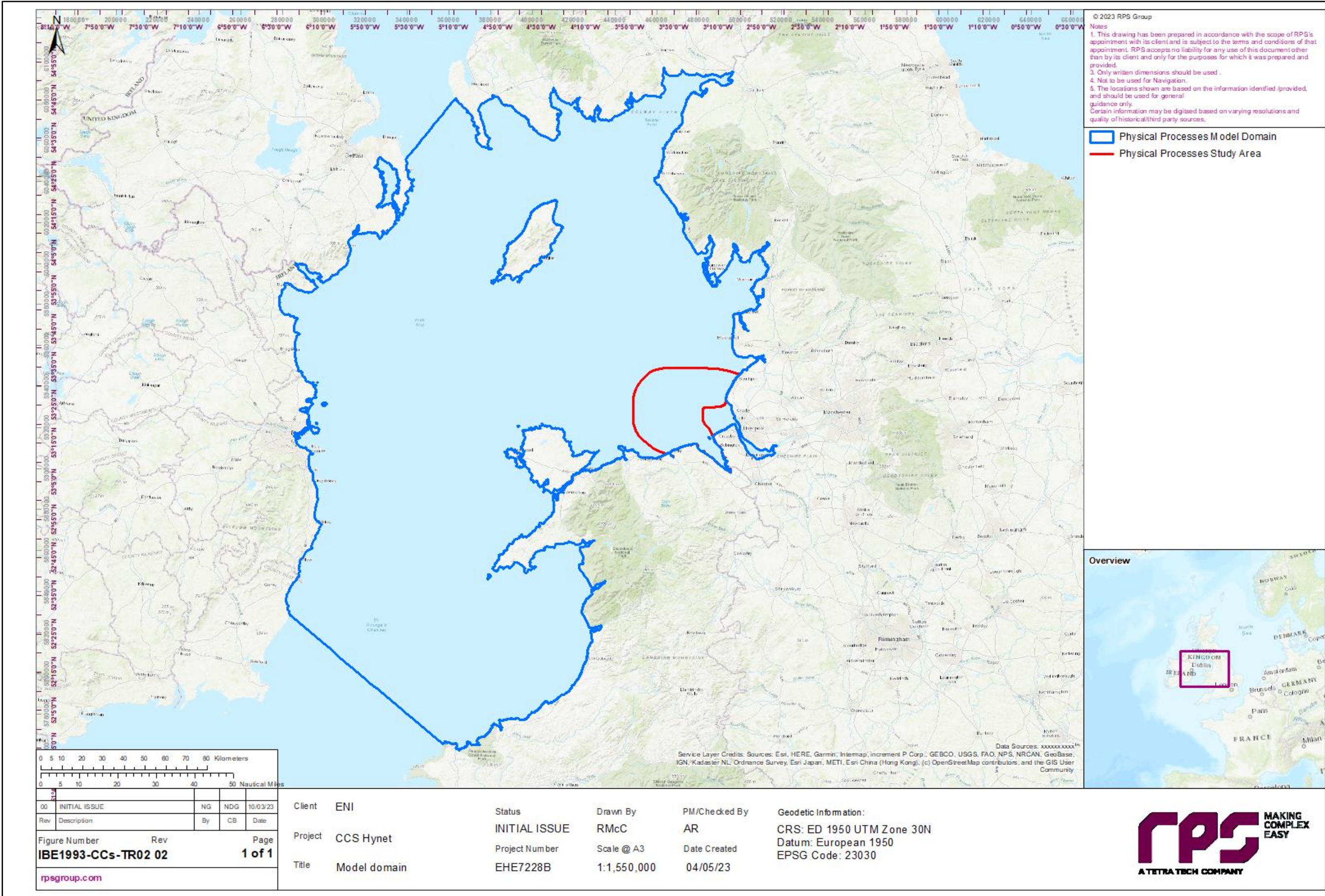


Figure 1.2: Model Domain (Blue Outline)

1.4 Desktop study

Information on physical processes within the Physical Processes Study Area was collected through a detailed desktop review of existing studies and datasets. These are summarised at Table 1.3 below.

Table 1.3: Summary Of Key Desktop Reports

Title	Source	Year	Author
Mona Offshore Wind Project Generation Assets Preliminary Environmental Information Report (PEIR) - Technical Report	https://www.morganandmona.com/en/consultationhub/	2023	RPS Group
Morgan Offshore Wind Project Generation Assets Preliminary Environmental Information Report (PEIR) - Technical Report	https://morecambeandmorgan.com/morgan/consultationhub/	2023	RPS Group
European Marine Observation and Data Network (EMODnet) – Seabed classification	https://www.emodnet-geology.eu/	2022	EMODnet
European Marine Observation and Data Network (EMODnet) – Bathymetry data	https://www.emodnet-bathymetry.eu/	2022	EMODnet
European Marine Observation and Data Network (EMODnet) – Metocean data	https://map.emodnet-physics.eu/	2022	EMODnet
Department for Environment Food and Rural Affairs – Bathymetry data	https://environment.data.gov.uk/DefraDataDownload	2022	DEFRA
The Environment Agency National LiDAR Programme	National LIDAR Programme - data.gov.uk	2022	Environment Agency
National Oceanic and Atmospheric Administration (NOAA) –Atmospheric data	DHI Metocean Data Portal	2022	NOAA
National Network of Regional Coastal Monitoring Programmes	https://coastalmonitoring.org/cco/	2022	Coastal Channel Observatory
Centre for Environment, Fisheries and Aquaculture Science (CEFAS) – wave data	https://wavenet.cefas.co.uk/map	2022	CEFAS
ABPmer Data explorer	https://www.seastates.net/explore-data/	2022	ABPmer
Hydrography of the Irish Sea, SEA6 Technical Report	UK Government	2005	Howarth M.J.
Atlas of UK Marine Renewable Energy Resources	https://www.renewables-atlas.info/	2022	ABPmer
Geology of the seabed and shallow subsurface: The Irish Sea.	British Geological Survey	2015	Mellettt <i>et al.</i>
British Geological Survey – sediment sample data	https://mapapps2.bgs.ac.uk/geoindex_offshore	2022	BGS
Suspended Sediment Climatologies around the UK.	Department for Business, Energy & Industrial Strategy (BEIS)	2016	Cefas
Metocean Data collection for the Ormonde offshore wind Project.	Marine Data Exchange	2011	Geotechnical Engineering and Marine Surveys (GEMS)
Irish Sea Zone Hydrodynamic measurement campaign	Marine Data Exchange	2010 to 2013	EMU Ltd (now Fugro Ltd)
Admiralty Tide Tables	United Kingdom Hydrographic Office (UKHO)	2022	UKHO
Marine Environmental Data Information Network (MEDIN) Seabed Mapping Programme	Admiralty Marine Data Portal	2022	MEDIN

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Title	Source	Year	Author
Integrated Mapping for the Sustainable Developments of Ireland's Marine Resource (INFOMAR) Seabed Mapping Programme	Geological Survey Ireland (GSI) and Marine Institute	2022	INFOMAR
Long term wind and wave datasets	European Centre for Medium-range Weather Forecast (ECMWF)	2022	ECMWF
UK tide gauge network and database of current observation	British Oceanographic Data Centre (BODC)	2021	BODC
UK Climate Projections (UKCP)	Met Office	2018	Met Office
Review of aggregate dredging off the Welsh coast	HR Wallingford	2016	HR Wallingford
A user-friendly database of coastal flooding in the UK from 1915-2014	Scientific Data (journal)	2015	Haigh <i>et al.</i>
Awel y Môr Offshore Windfarm PEIR and ES	Awel y Môr Offshore Wind Farm Ltd.	2021 & 2022	RWE Renewables
Burbo Bank Extension Offshore Windfarm Environmental Statement	https://www.marinedataexchange.co.uk/	2013	Ørsted
Walney Extension Offshore Wind Farm Environmental Statement	https://www.marinedataexchange.co.uk/	2013	Ørsted
Natural Variability of Turbidity in the Regional Environmental Assessment (REA) Areas.	https://www.marinedataexchange.co.uk/	2011	MALF
North West England and North Wales SMP22 - SMP2	http://www.hoylakevision.org.uk/wp-content/uploads/2012/11/SMP2Main.pdf	2011	Halcrow Group Ltd
Cell Eleven Tidal and Sediment Study Phase 2	https://coastalmonitoring.org/	2010	Halcrow Group Ltd
Cell Eleven Regional Monitoring Strategy (CERMS)	https://coastalmonitoring.org/	2010	Halcrow Group Ltd
Walney 1 & 2 Offshore Windfarm Environmental Statements	https://www.marinedataexchange.co.uk/	2006	Ørsted
West of Duddon Sands Offshore Windfarm Environmental Statement	https://www.marinedataexchange.co.uk/	2006	RSK Environment Ltd
DTI Strategic Environmental Assessment Area 6, Irish Sea, seabed and surficial geology and processes	British Geological Survey	2005	Holmes and Tappin
Ormonde Offshore Windfarm Environmental Statement	https://www.marinedataexchange.co.uk/	2005	Rudall Blanchard Associates
Barrow Offshore Windfarm Environmental Statement	https://www.marinedataexchange.co.uk/	2005	Royal Haskoning DHV
British Oceanographic Data Centre	National Oceanography Centre	various	National Oceanography Centre
Designated sites (SPAs and SACs)	JNCC mapping data (https://jncc.gov.uk/mpa-mapper/)	2022	JNCC
Designated sites (SSSIs)	Defra Spatial Data Download	2022	DEFRA
Designated Ramsar sites	Map (ramsar.org)	2022	Ramsar

1.5 Site-specific surveys

A summary of the surveys undertaken to inform the Physical Processes ES is outlined in Table 1.4 below.

Table 1.4: Summary Of Site-Specific Survey Data

Title	Extent of survey	Overview of survey	Survey contractor	Date	Reference to further information
Hynet Carbon Capture Storage and Decommissioning Benthic Survey Report 2022	Proposed Development area of physical work	Benthic/sedimentary survey carried out via seabed imagery and grab sampling utilised for particle size analysis (PSA)	<i>Ocean Ecology Ltd.</i>	2022	(Ocean Ecology , 2022)

1.6 Baseline Environment

1.6.1 Bathymetry

The model domain had full bathymetry data coverage and was populated using a combination of data sources. Primarily bathymetry data was sourced from the MEDIN Seabed Mapping Programme via the Admiralty Marine Data Portal as shown in Figure 1.3 Each of the datasets for the east Irish Sea area was combined into a single set giving priority to the most recent survey data. For areas within regions which did not have coverage from the MEDIN dataset further data was sourced from the DEFRA Survey Data Download site (DEFRA, 2022). This was undertaken for specific bays such as Conwy Bay and the Dee Estuary.

For the remaining model domain, the EMODnet 100 m resolution tiled data was utilised (EMODnet, 2020). This database is available under the European Inspire Directive and provides access to data in a variety of formats, datums and resolutions based on a combination of survey datasets. All data was converted, where necessary, to mean sea level datum generally with a resolution of at least three times the mesh resolution to ensure that coastal features were represented within the numerical modelling, as illustrated in Figure 1.4.

The resolution of the model bathymetry was designed to reflect variations in water depth and bed forms for the accurate simulation of tidal currents. Additional model resolution was also included to incorporate the installation of the Proposed Development infrastructure. Across the physical processes study area, the resolution varied between circa 500m at its western extent, down to 10m along the cable trenching route. With increasing distance from the physical processes study area, the cell size was increased but maintained at a level which retained model accuracy. Figure 1.5 illustrates the mesh resolution within the tides, waves and sediment transport model.

The extent of the domain, Figure 1.2, was designed to provide the basis for a model which could be utilised for tide, wave and sediment transport modelling. The focus of the study is a tidal excursion from the proposed cable route, to quantify sediment dispersion, however, a larger domain has the benefit of identifying any potential effects beyond the physical processes study area.

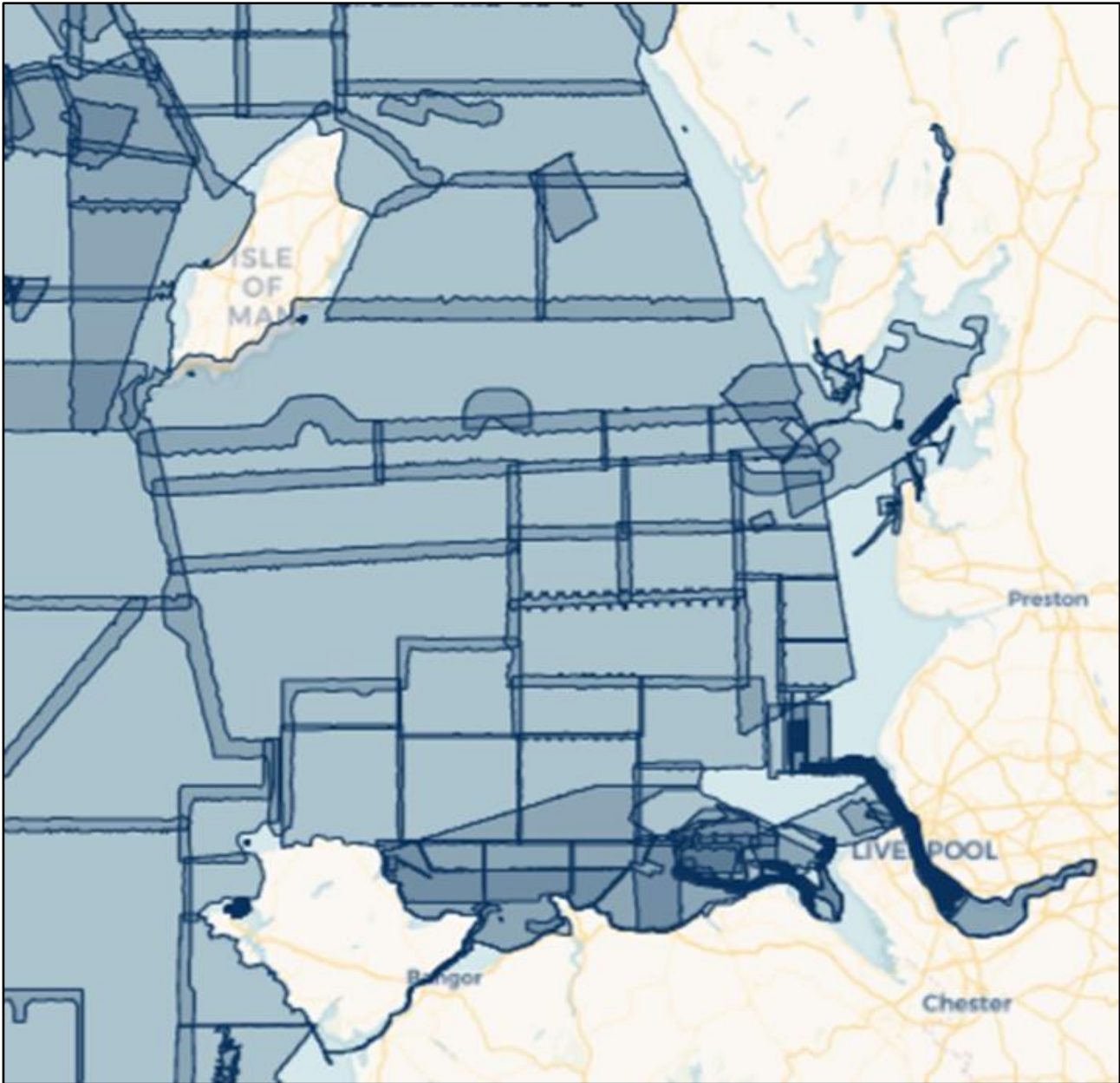


Figure 1.3: MEDIN Bathymetric Data Coverage

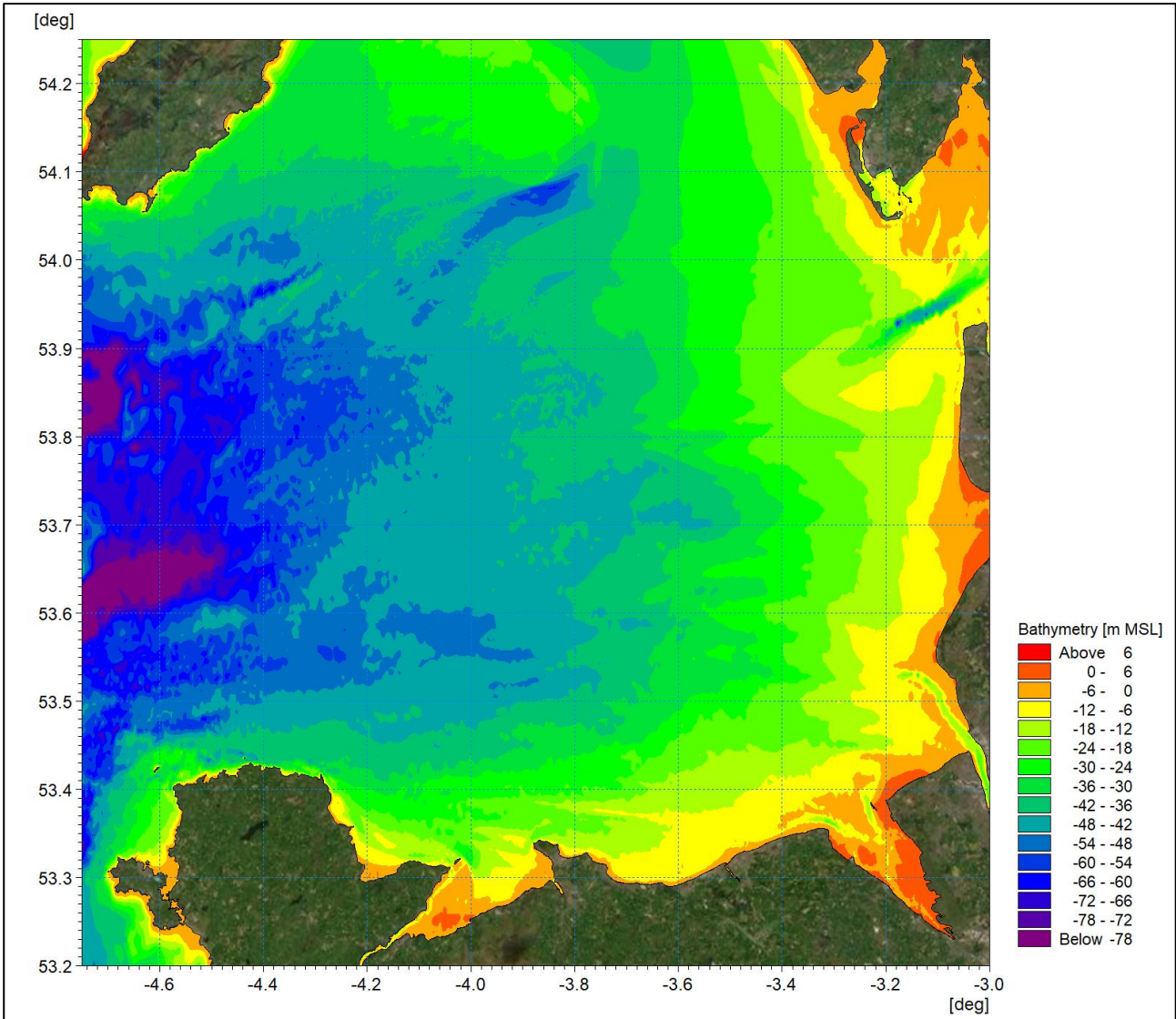


Figure 1.4: Model Bathymetry Within The East Irish Sea

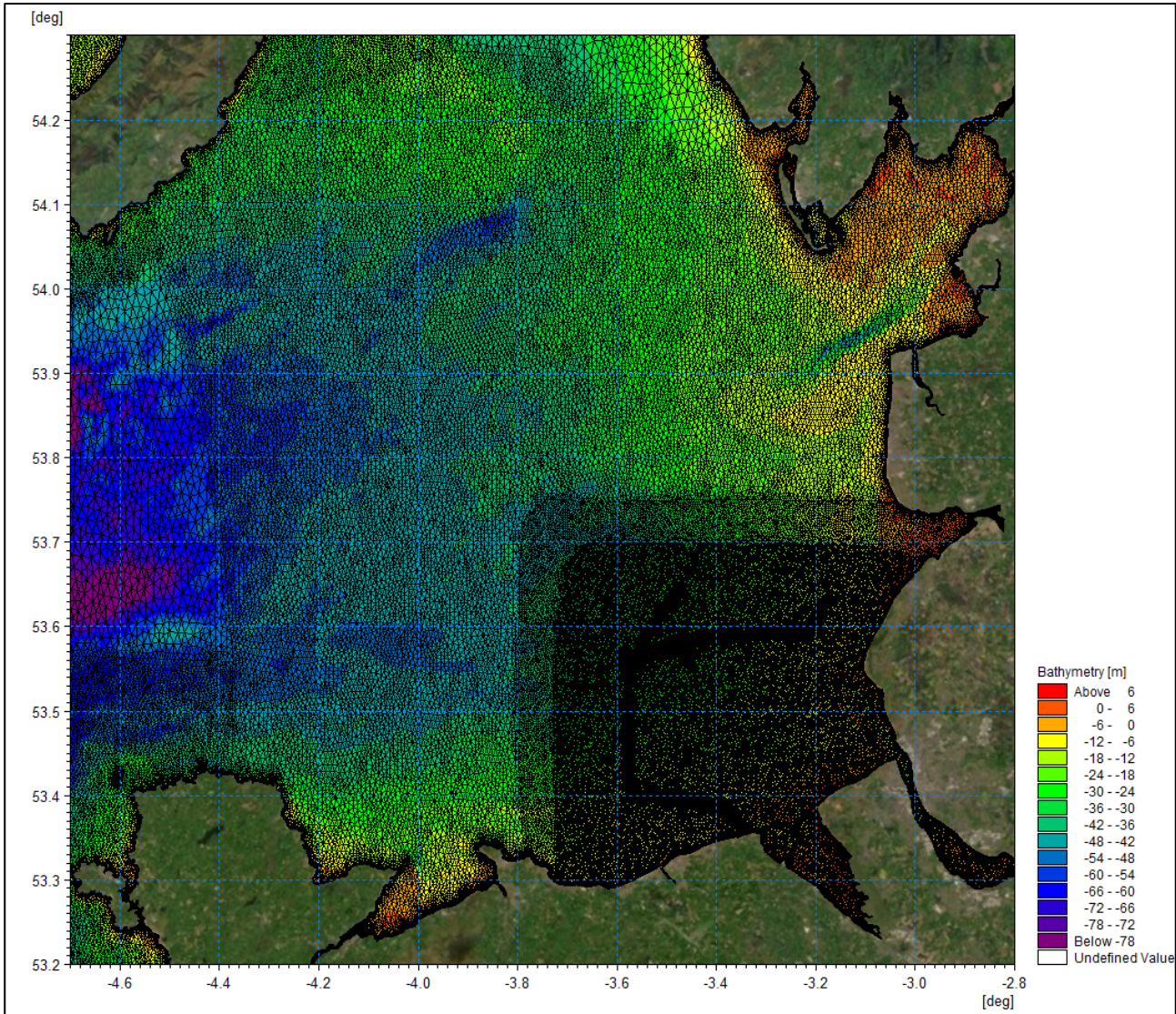


Figure 1.5: Model Mesh Utilised For Dispersion Modelling

1.6.2 Hydrography

The UKHO states that the mean tidal range at the Standard Port of Holyhead is approximately 3.65m whilst at Douglas it is 4.55m. The tidal characteristics shown in Table 1.5 in metres is referenced to Chart Datum (CD):

Table 1.5: Tidal Levels at Standard Ports

Tidal Level	Holyhead	Douglas
Lowest Astronomical Tide (LAT)	0.0	-0.3
Mean Low Water Springs (MLWS)	0.7	0.8
Mean Low Water Neaps (MLWN)	2.0	2.4
Mean Sea Level (MSL)	3.3	3.8
Mean High Water Neaps (MHWN)	4.4	5.4
Mean High Water Springs (MHWS)	5.6	6.9
Highest Astronomical Tide (HAT):	6.3	7.9

The semi-diurnal tides are the dominant physical process in the Irish Sea moving into the Irish Sea from the Atlantic Ocean through both the North Channel and St. George's Channel. The tidal range in the Irish Sea is highly variable with the range in Liverpool Bay exceeding 10m on the largest spring tides, the second largest in Britain.

The tidal flow simulations which form the basis of the study were undertaken using the MIKE21 FM flexible mesh modelling system. The FM Module is a two-dimensional, depth averaged hydrodynamic model which simulates the water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal areas. [The use of a two-dimensional model allowed for computational efficiency whilst appropriately characterising the spatiotemporal flow of water across Liverpool Bay. The use of one-dimensional or three-dimensional models are appropriate for analysing unsteady flows in riverine/urban environments or complex flow vertically throughout the water column respectively.](#) The water levels and flows are resolved on a mesh covering the area of interest when provided with bathymetry, bed resistance coefficient, hydrodynamic boundary conditions, etc.

The tidal model was driven using boundary conditions extracted from RPS' Tide and Storm Surge Forecast (TSSF) model of Irish coastal waters (RPS, 2018), the extent and bathymetry of which is illustrated in Figure 1.6. This model was also developed using flexible mesh technology with the mesh size (model resolution) varying from circa 24 km along the offshore Atlantic boundary to circa 200m around the Irish coastline. These boundaries were fully defined 'flather' boundaries for which both surface elevation and current vectors are specified. [These 'flather' boundaries are one of the most efficient open boundaries conditions particularly in downscaling coarse model simulations to local areas](#) (Oddo & Pinardi, 2009).

[The use of the flexible mesh technology included in the FM module carries the advantage of being able to include fine detail in specific areas of interest whilst allowing larger mesh elements elsewhere within the model, therefore maintaining simulation efficiency whilst using a large model domain. This is particularly useful when detail is desired around coastlines or project infrastructure in a comprehensive study of physical processes across a larger area.](#)

Principal hydrometric resources used for calibration such as Acoustic Doppler Current Profiler (ADCP) wave buoy data, Admiralty tidal harmonics, British Oceanographic Data Centre (BODC) (BODC, 2023), and Coastal Channel Observatory (CCO), are illustrated in Figure 1.7. The locations of the selection of calibration data presented in this document for tidal flow are shown in Figure 1.8.

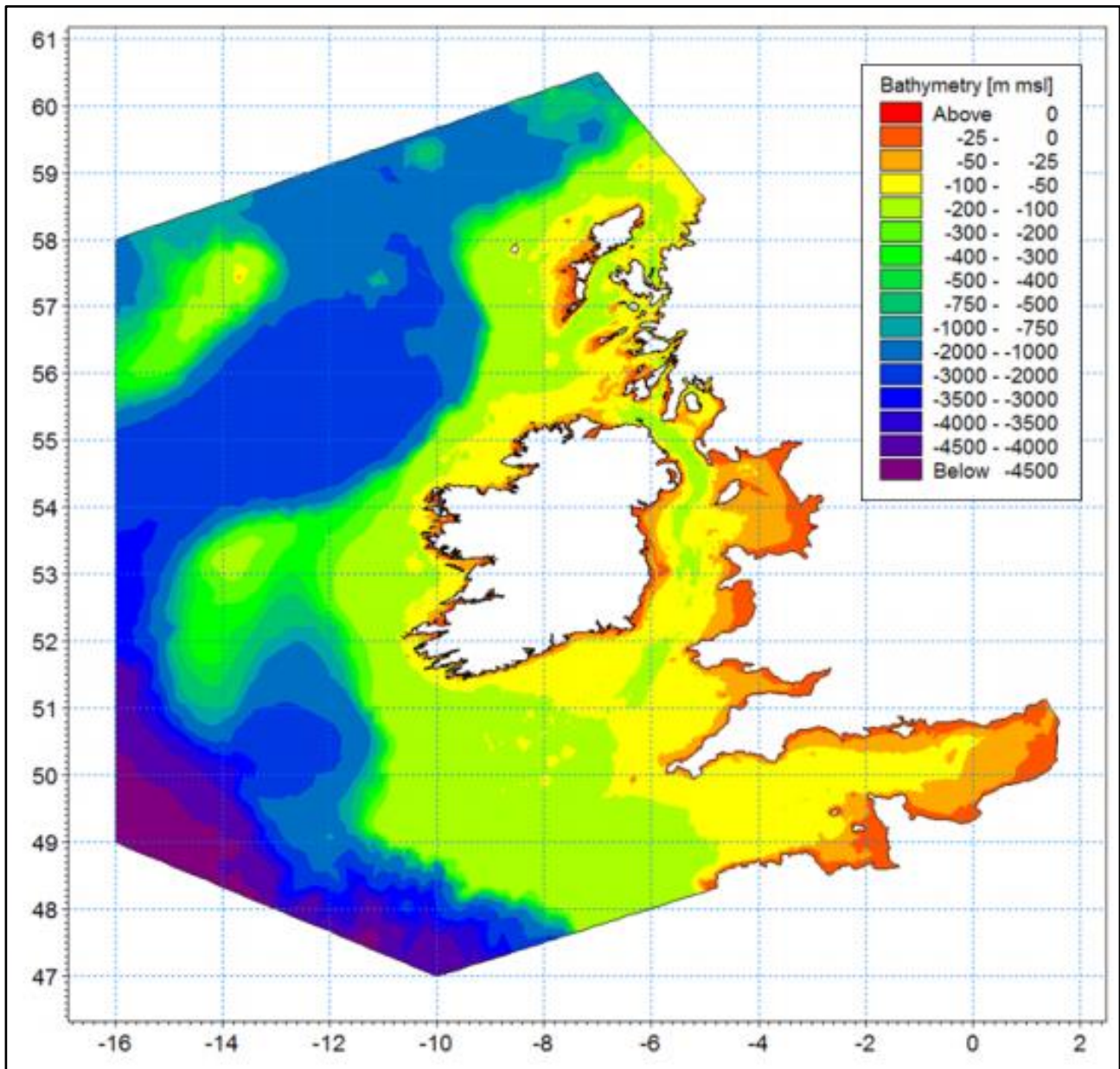


Figure 1.6: Extent And Bathymetry Of Irish Seas Tidal And Storm Surge Model

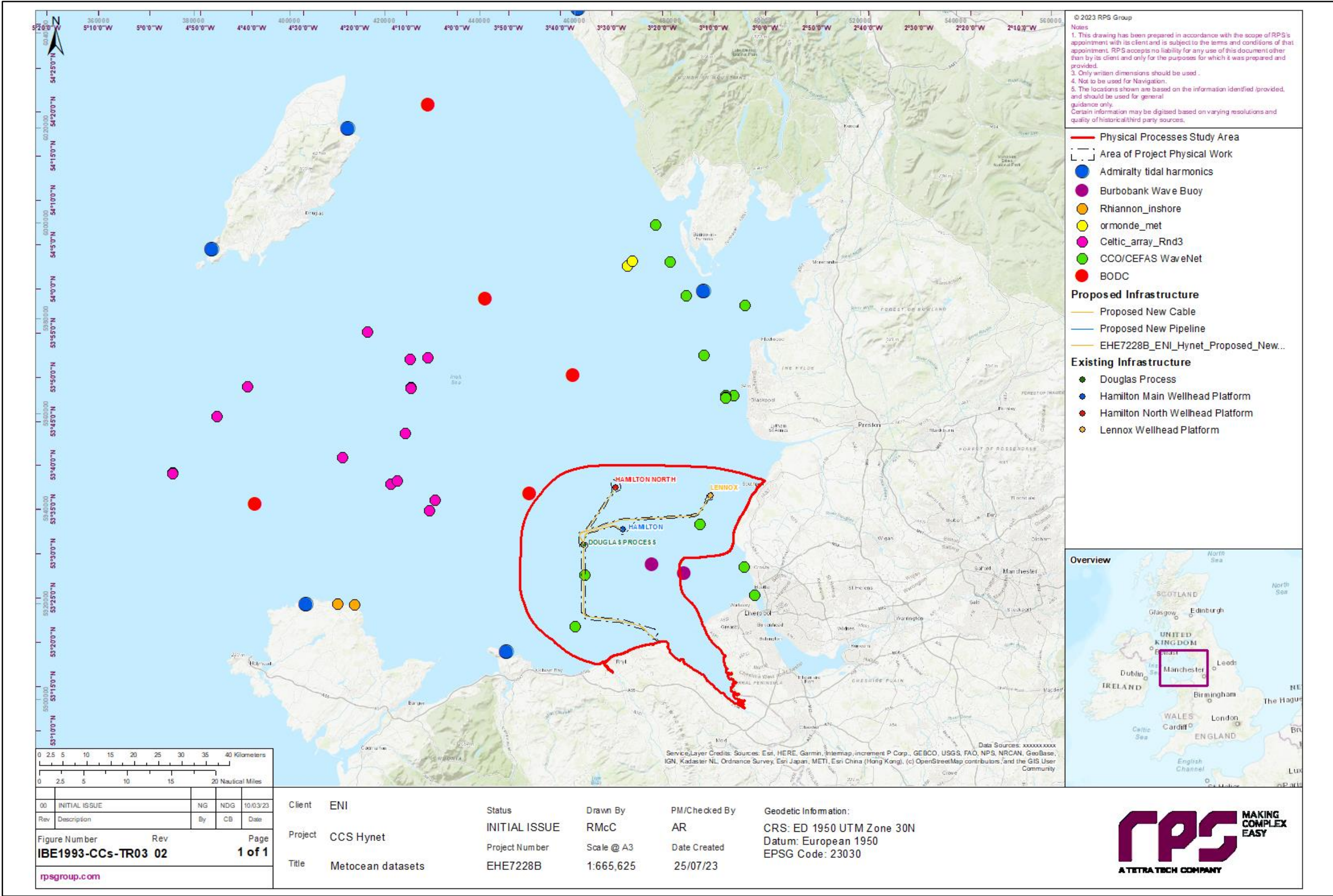


Figure 1.7: Availability Of Metocean Datasets Across The Eastern Irish Sea

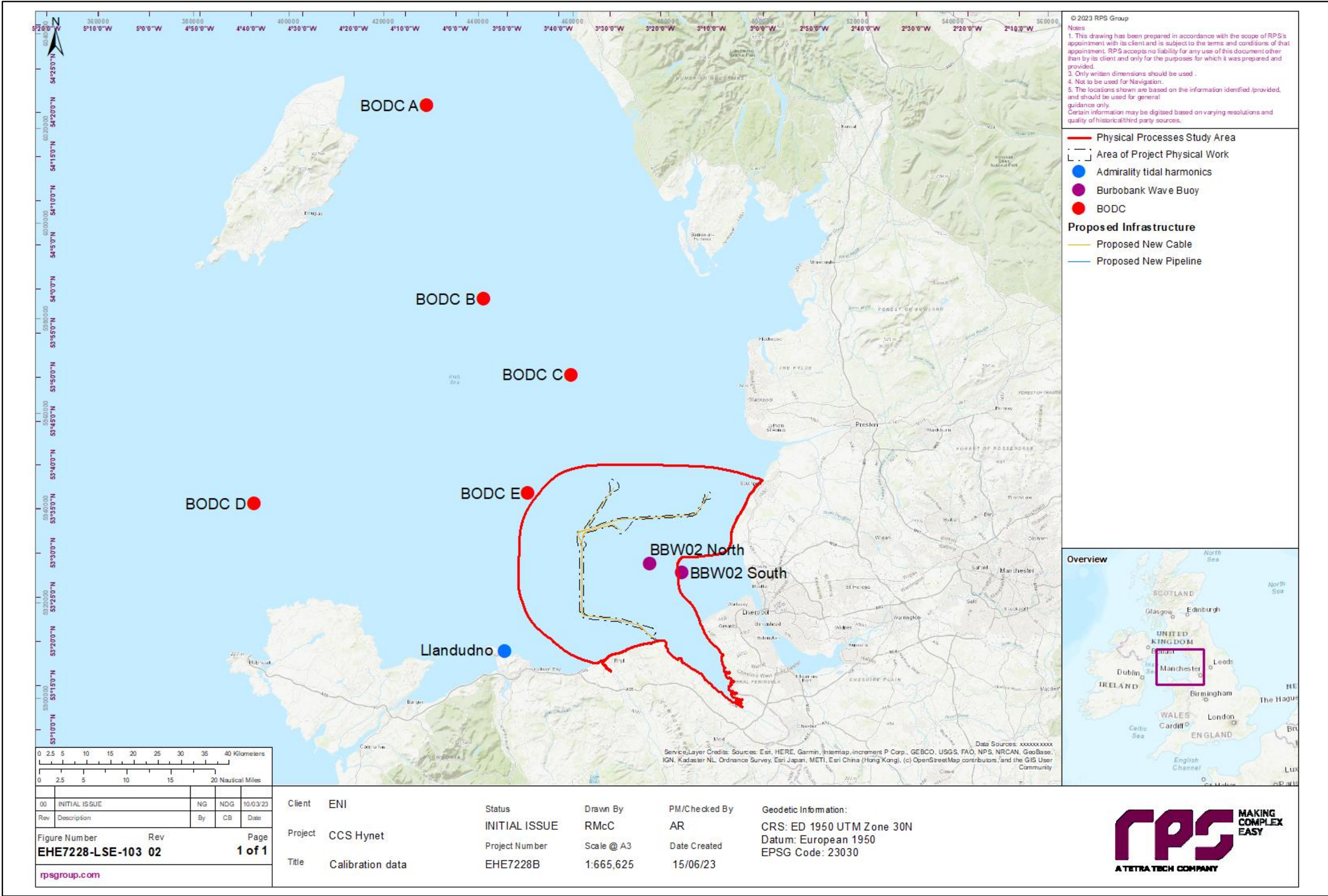


Figure 1.8: Location Of Calibration Data Presented

Figure 1.9 shows the comparison of the modelled (red) and Admiralty tidal levels predicted from harmonic analysis (blue) at Llandudno. The model correlated well through both spring and neap tidal phases.

ADCP plots are presented illustrating spring and neap tides both within and in proximity to the physical processes study area. These compare modelled results with the SEAWATCH Midi185 wave buoy data collected at two locations east of the Eni Development Area by Fugro (Fugro, 2016) for the Burbo Bank 02 offshore wind farm site (referred to as BBW02). Despite its name the wave buoy also takes measurements of current speed and direction through the water column via its subsea sensor. This ADCP data was sourced via the Marine Data Exchange portal (Marine Data Exchange, 2023). Each plot displays the current speed data on the left axis and the current direction on the right axis. The modelled depth average current speed is shown by a red trace and current direction by a black trace. The measured data was collected at various water depths, (surface, seafloor, and depth averaged) noted within the legend.

The wave buoy and modelled tidal current data are presented in Figure 1.10 to Figure 1.13 and show similar trends in that that current speeds during neap tides are half of the speed during spring tides. As well as the flood tide approaching from an easterly direction with the ebb tide being slightly weaker. The modelled data fits within the range of the Fugro measured data following similar tidal flow patterns.

For each location of BODC data, a pair of plots are presented firstly relating to spring tides and secondly neap tides. In each plot the current speed data is presented on the left axis whilst the current direction is presented to the right. The modelled depth average current speed is shown by a red trace and current direction by an orange trace. The measured data was collected at various water depths noted within the legend.

Sites A and B are presented in Figure 1.14 to Figure 1.17 and indicate that the flood tide which approaches the physical processes study area from an easterly direction is more dominant than the ebb tide. Peak neap tidal current speeds are typically half of those experienced during spring tide. The modelled data largely lie within the range of the measured data and replicates the asymmetric tidal flows patterns.

This is also the case for site C shown in Figure 1.18 and Figure 1.19 for spring and neap respectively. Current directions and the dominance of flood tides are replicated with the model domain. Tidal currents at site D are more strongly bi-directional as flow is accelerated around Anglesey as illustrated in Figure 1.20 and Figure 1.21. It is noted that there is a wide variation in the measured tidal currents with respect to depth and 70 m at this location would represent near bed conditions. The model does however correlate in terms of current directionality and the dominance of flood tide currents.

Finally, in close proximity to the Eni Development Area, site E, the tidal current speeds and directions are well represented by the model. This is the case for both spring, Figure 1.22, and neap, Figure 1.23, tidal flows. The calibration data demonstrates that the numerical model simulates the tidal currents in the region. This includes the representation of the dominant flood tide.

To provide a representation of tidal flows across the domain Figure 1.24 and Figure 1.25 illustrates tidal patterns during peak ebb and flood on a neap tide whilst Figure 1.26 and Figure 1.27 illustrates the spring tide. Residual tidal flows and how they drive sediment transport regimes are examined in section 1.6.6.

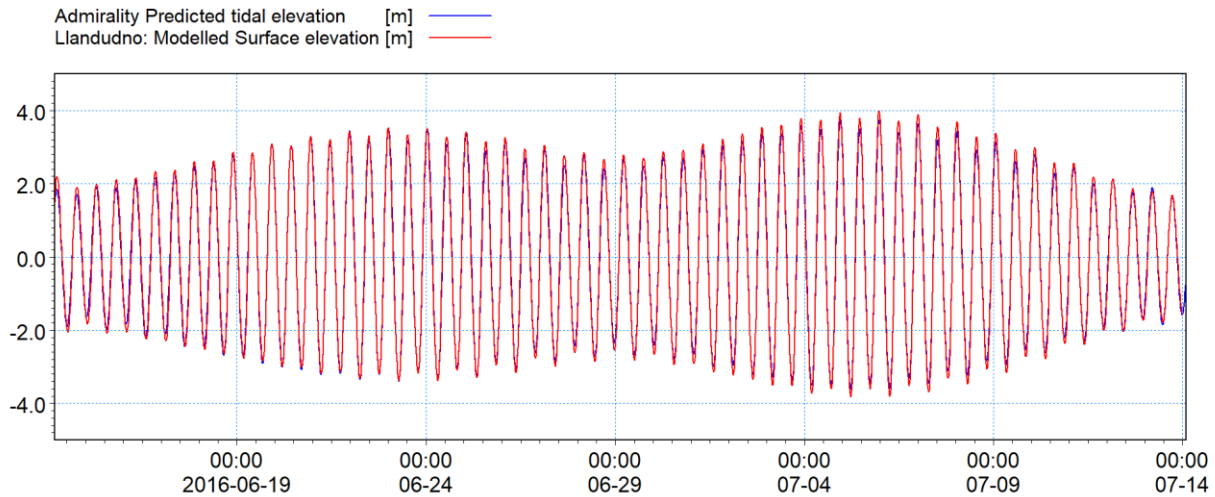


Figure 1.9: Comparison Of Model And Admiralty Harmonic Tide Data For Llandudno

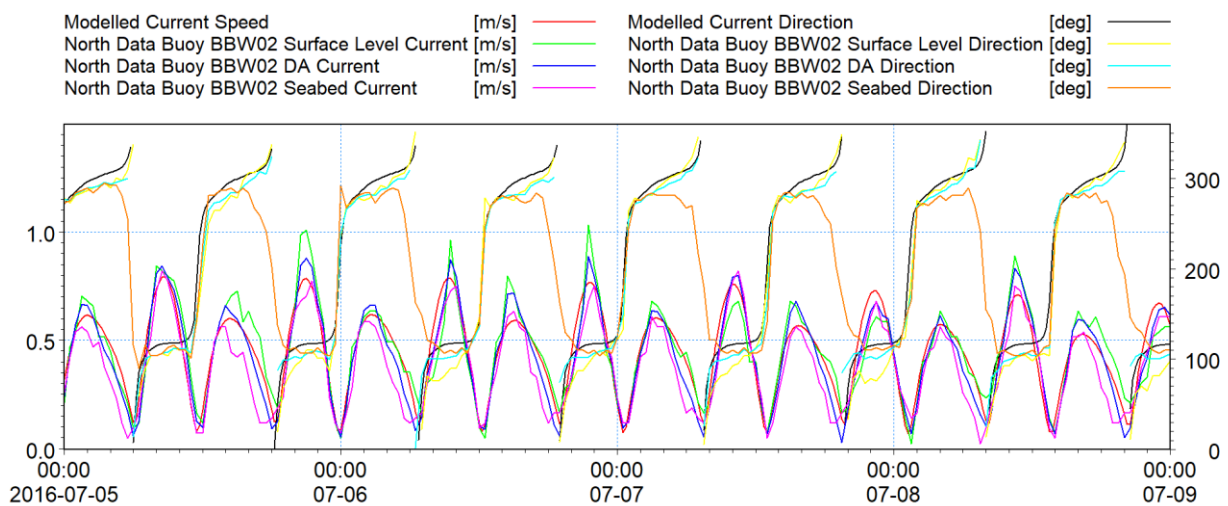


Figure 1.10: Comparison Of Model And Recorded **Burbo Bank** North Wave Buoy ADCP Data (Fugro) 53°30.113' N, 003°21.687' E - Current Speed And Direction Spring

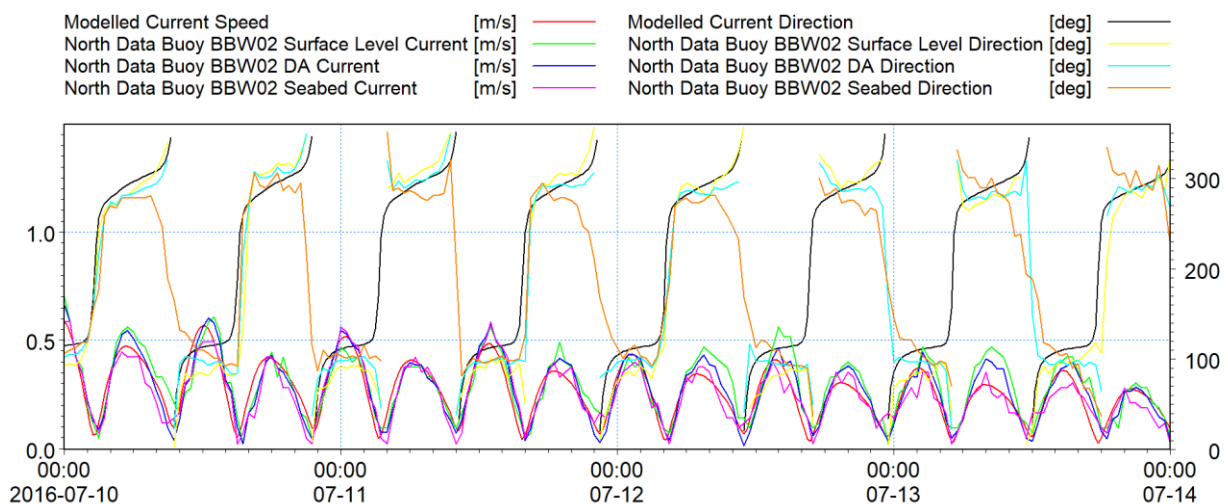


Figure 1.11: Comparison Of Model And Recorded **Burbo Bank** North Wave Buoy ADCP Data (Fugro) 53°30.113' N, 003°21.687' E - Current Speed And Direction Neap

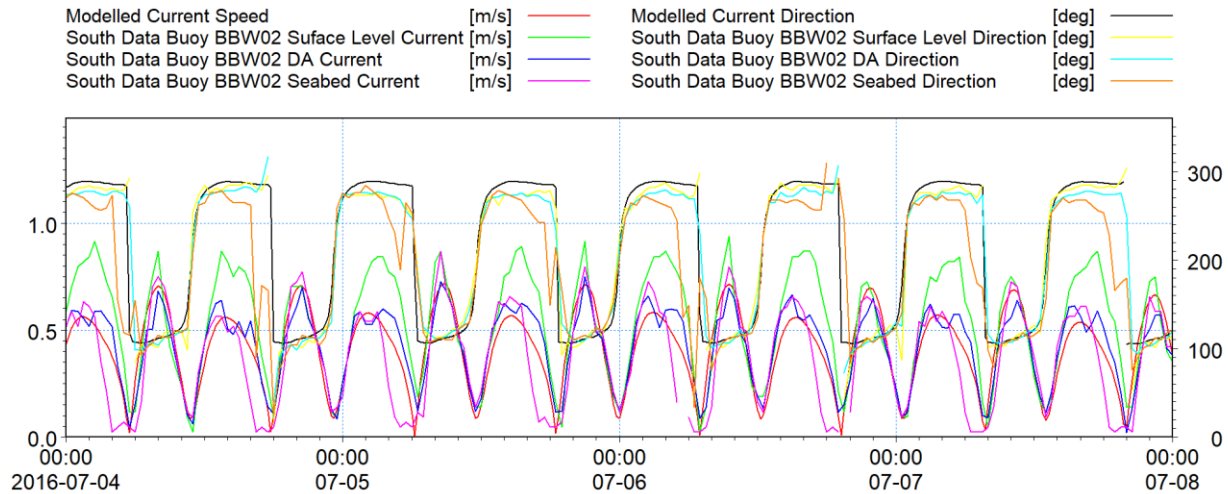


Figure 1.12: Comparison Of Model And Recorded Burbo Bank South Wave Buoy ADCP Data (Fugro) 53°29.101' N, 003°15.533' E - Current Speed And Direction Spring

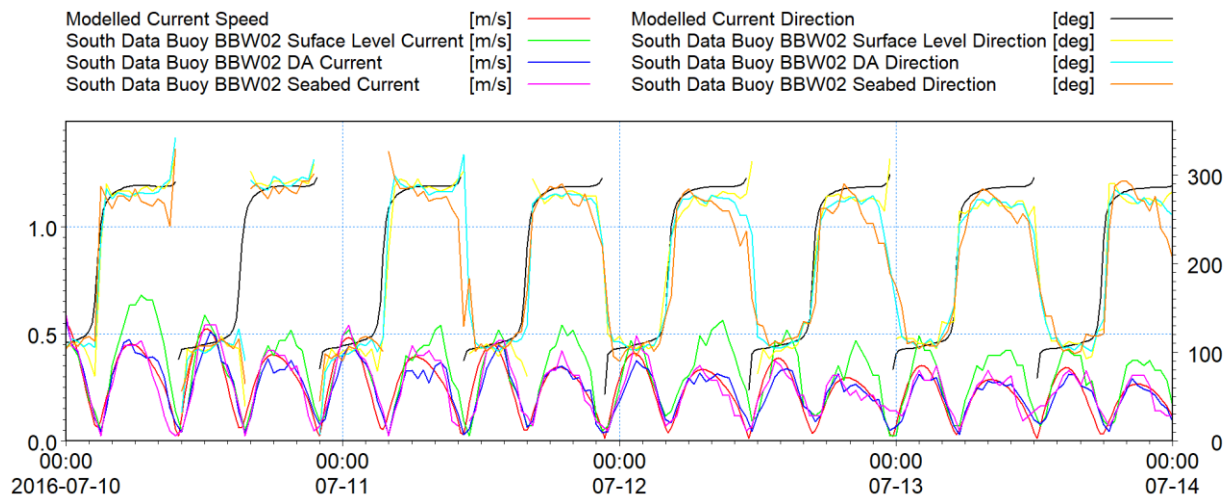


Figure 1.13: Comparison Of Model And Recorded Burbo Bank South Wave Buoy ADCP Data (Fugro) 53°29.101' N, 003°15.533' E - Current Speed And Direction Neap

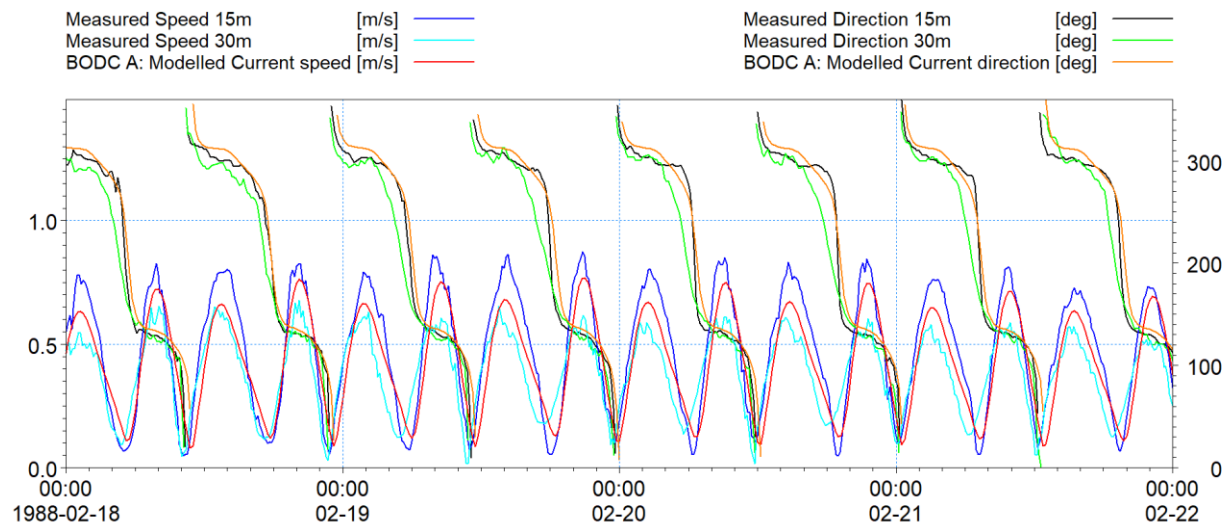


Figure 1.14: Comparison Of Model And Recorded Data BODC Location A – Current Speed And Direction Spring

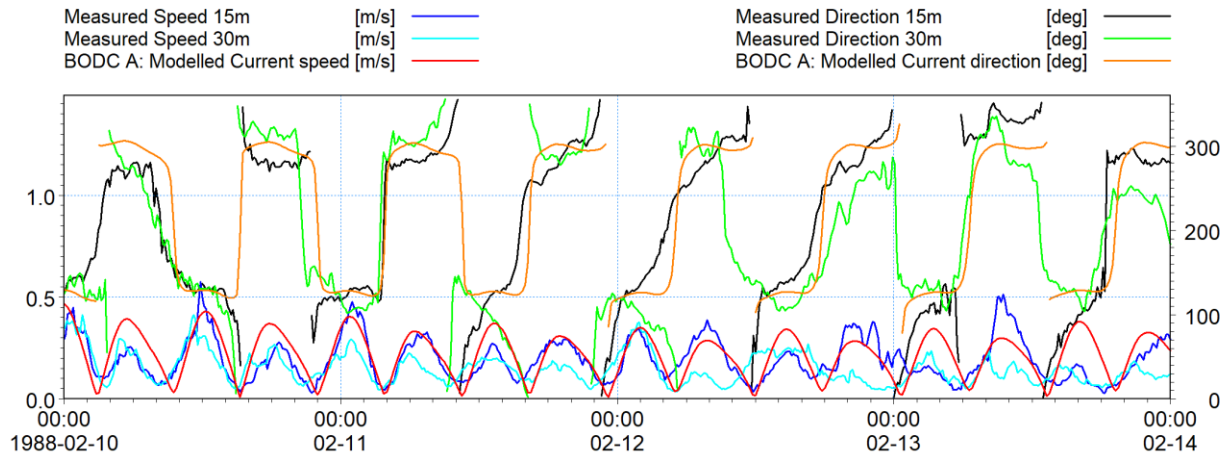


Figure 1.15: Comparison Of Model And Recorded Data BODC Location A – Current Speed And Direction Neap

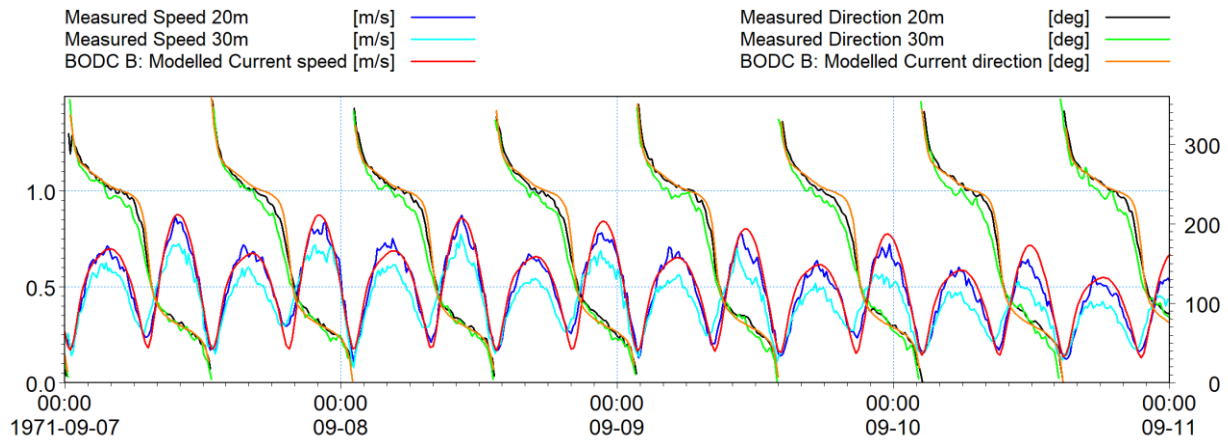


Figure 1.16: Comparison Of Model And Recorded Data BODC Location B – Current Speed And Direction Spring

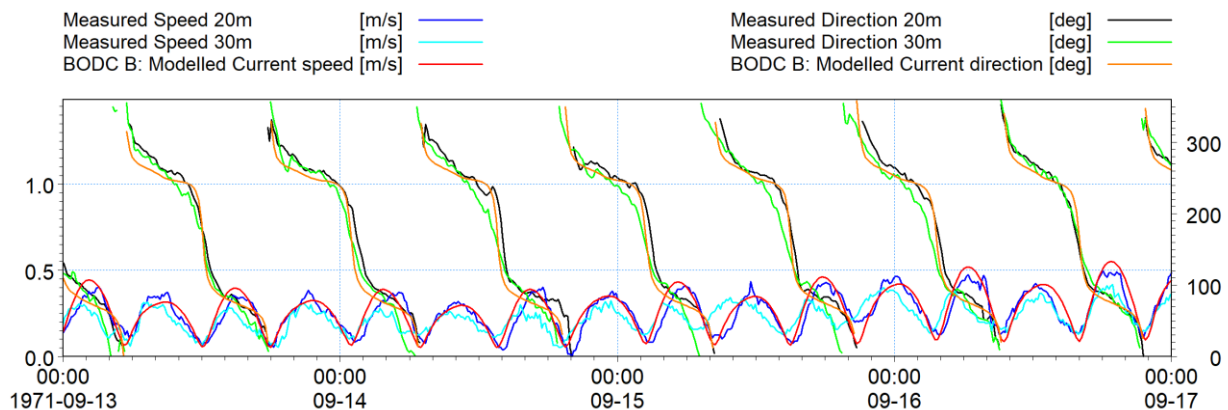


Figure 1.17: Comparison Of Model And Recorded Data BODC Location B – Current Speed And Direction Neap

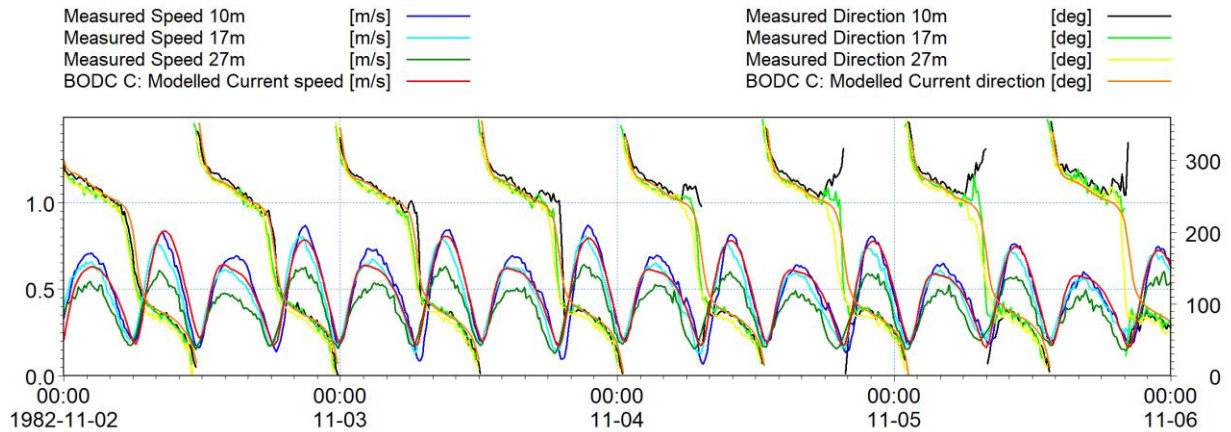


Figure 1.18: Comparison Of Model And Recorded Data BODC Location C – Current Speed And Direction Spring

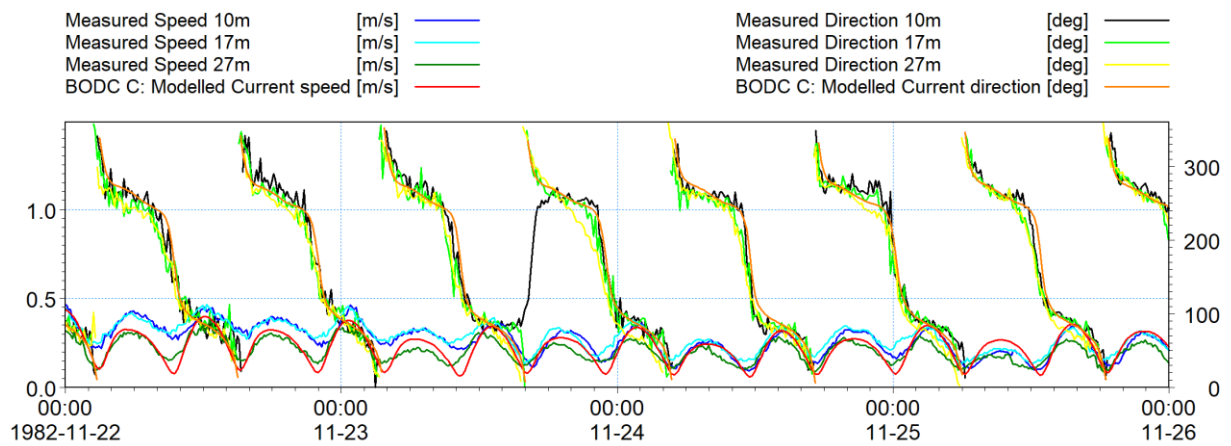


Figure 1.19: Comparison Of Model And Recorded Data BODC Location C – Current Speed And Direction Neap

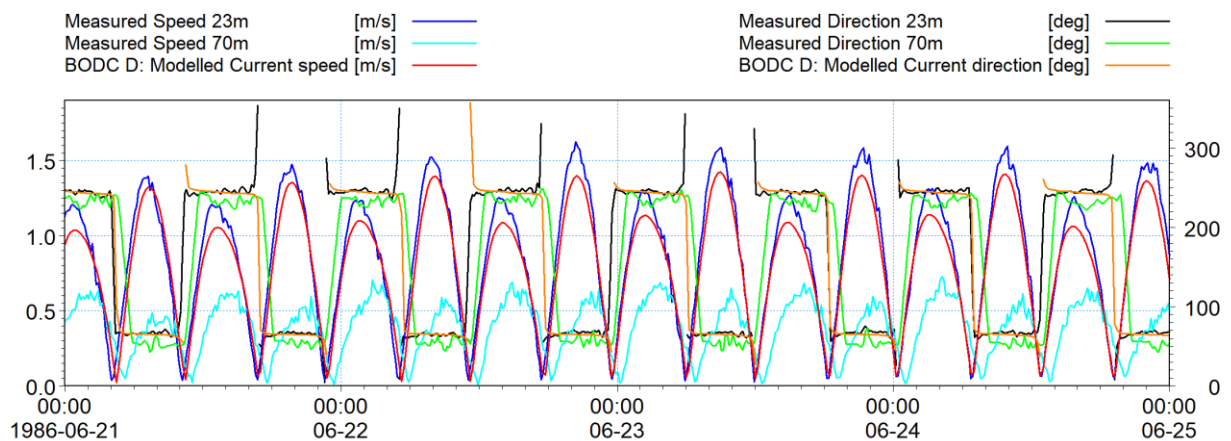


Figure 1.20: Comparison Of Model And Recorded Data BODC Location D – Current Speed And Direction Spring

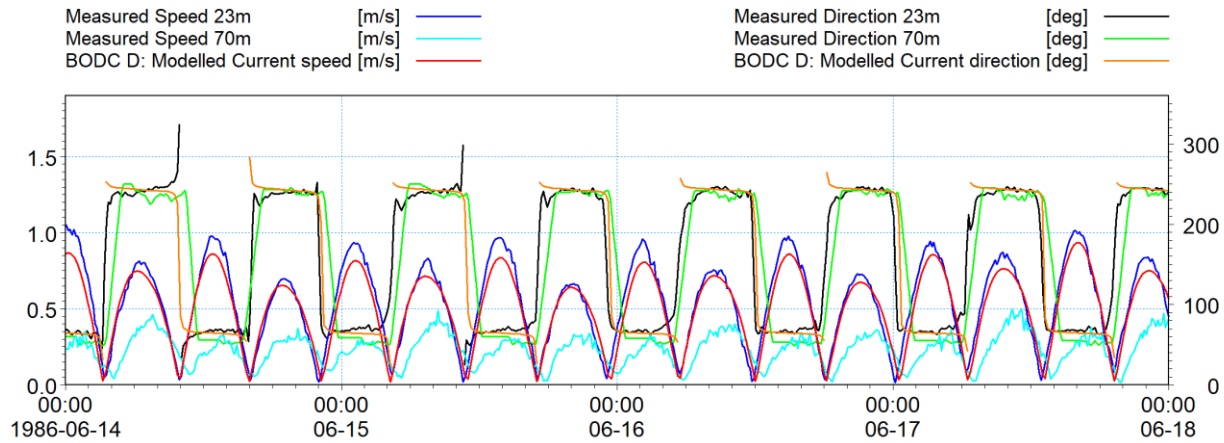


Figure 1.21: Comparison Of Model And Recorded Data BODC Location D – Current Speed And Direction Neap

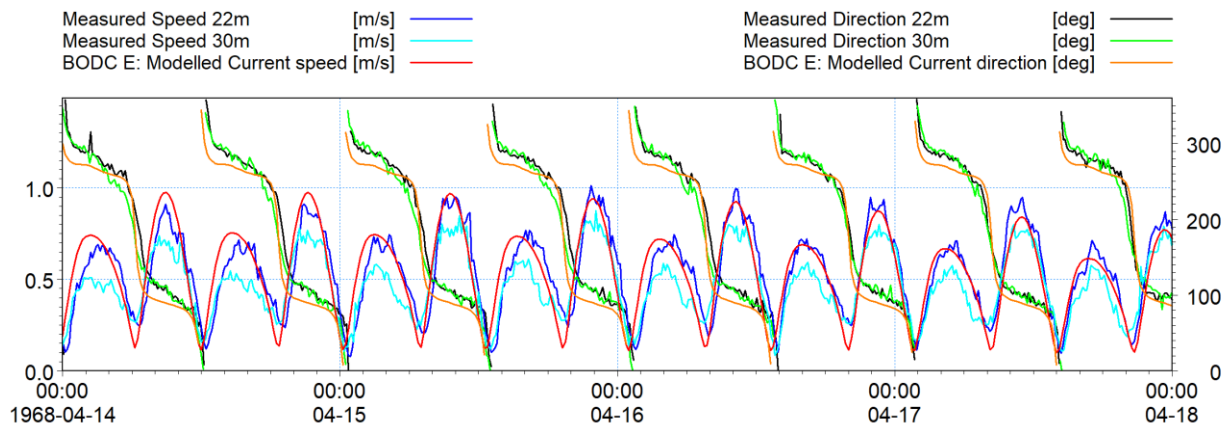


Figure 1.22: Comparison Of Model And Recorded Data BODC Location E – Current Speed And Direction Spring

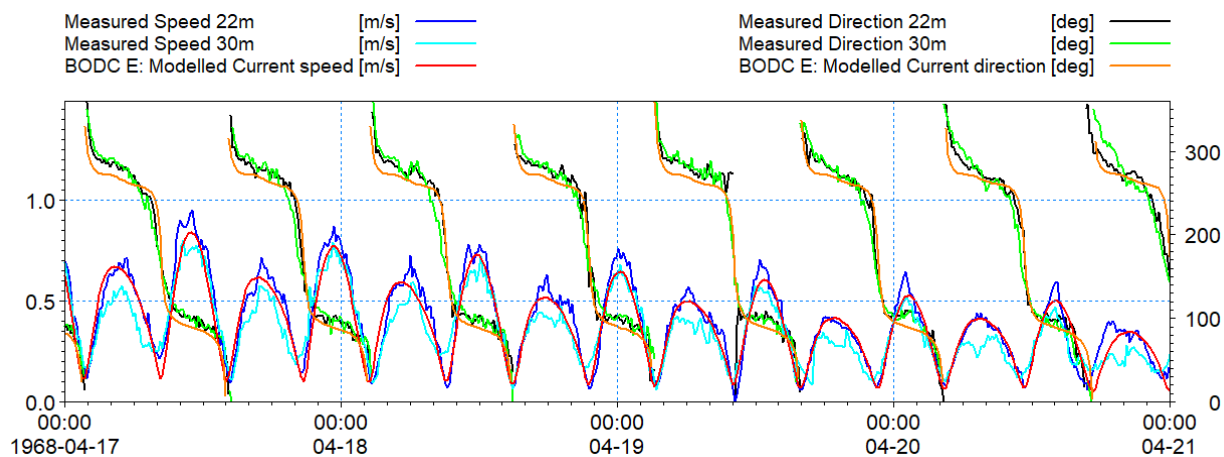


Figure 1.23: Comparison Of Model And Recorded Data BODC Location E – Current Speed And Direction Neap

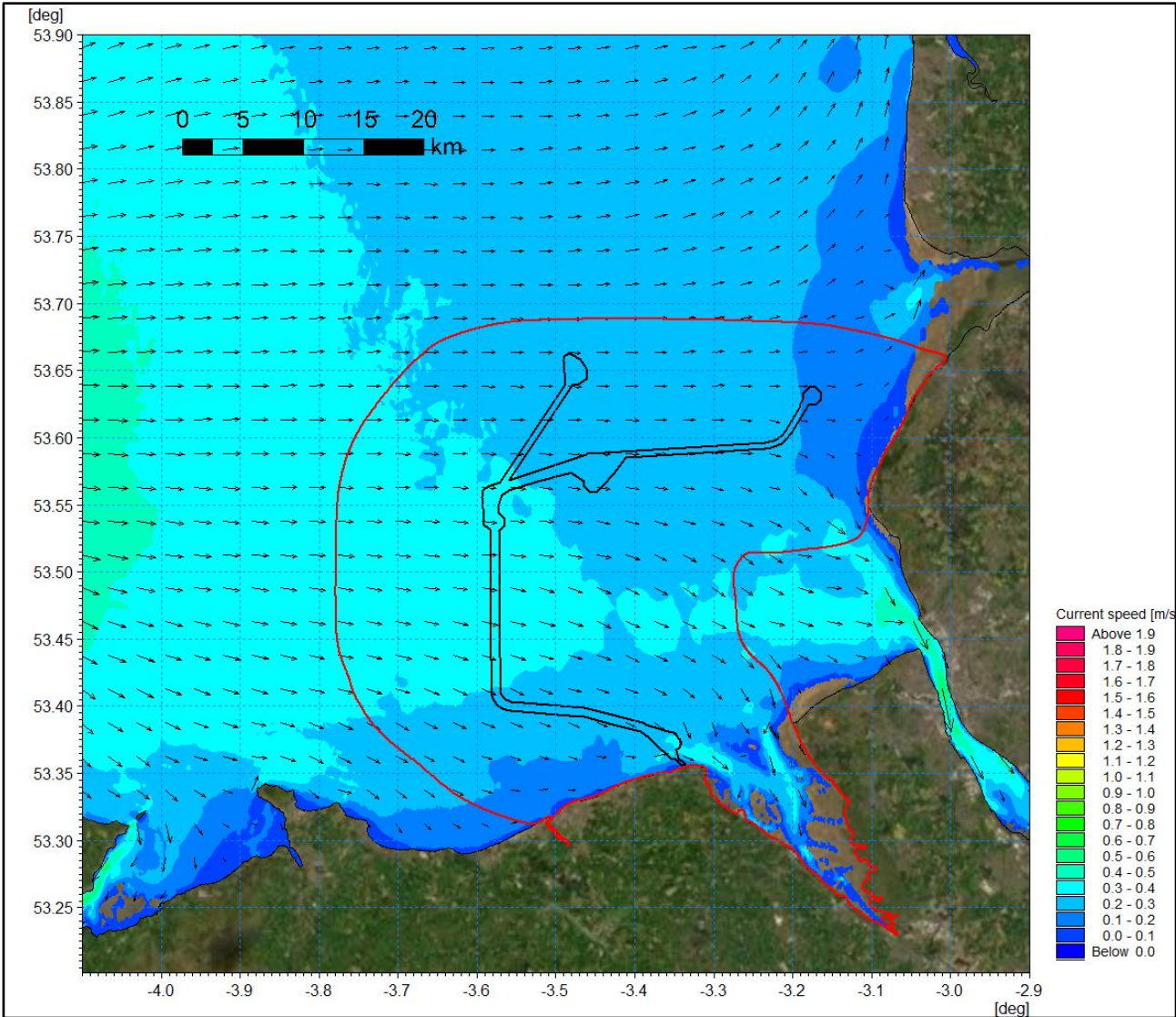


Figure 1.24: Tidal Flow Patterns – Neap Tide Flood

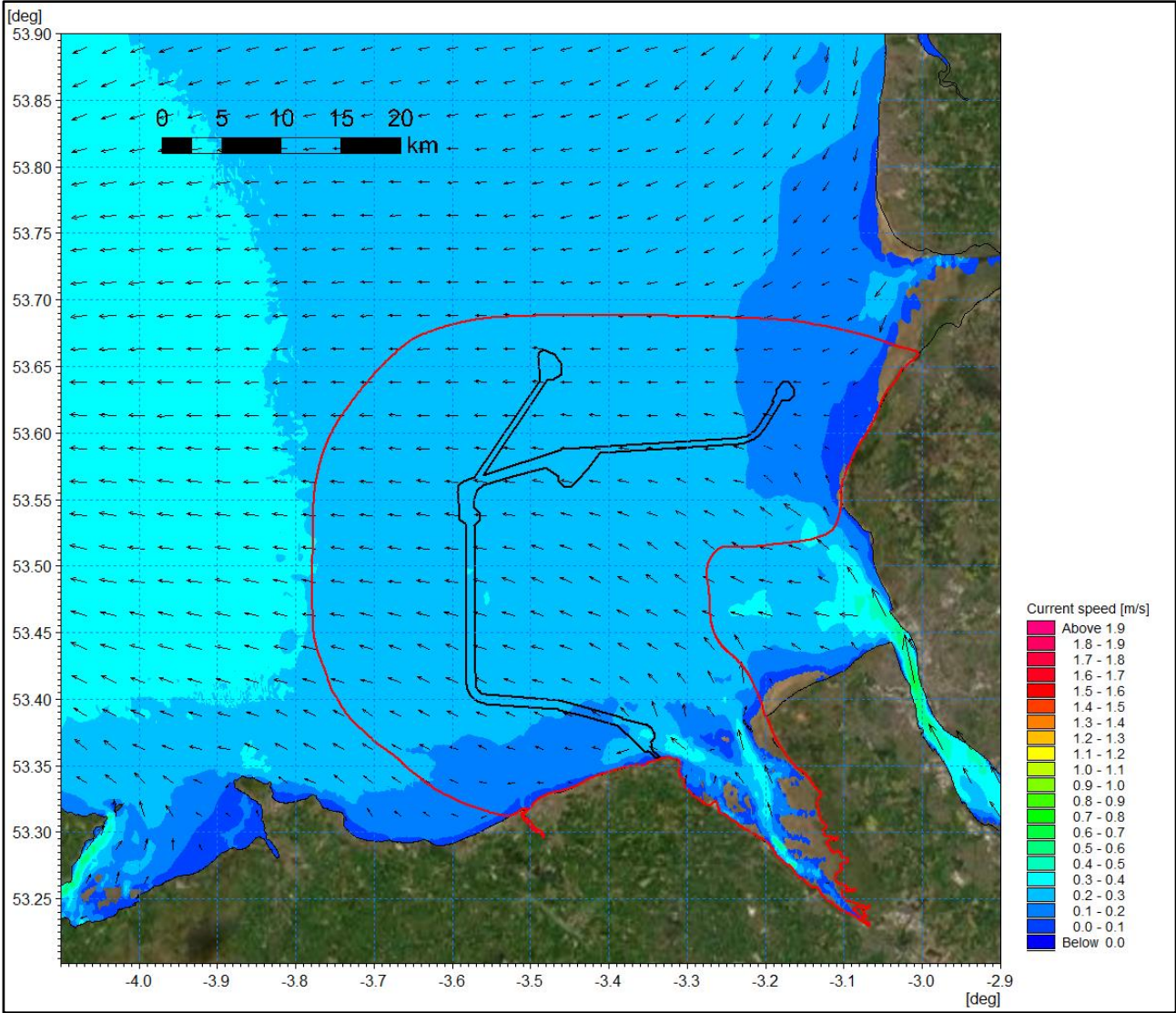


Figure 1.25: Tidal Flow Patterns – Neap Tide Ebb

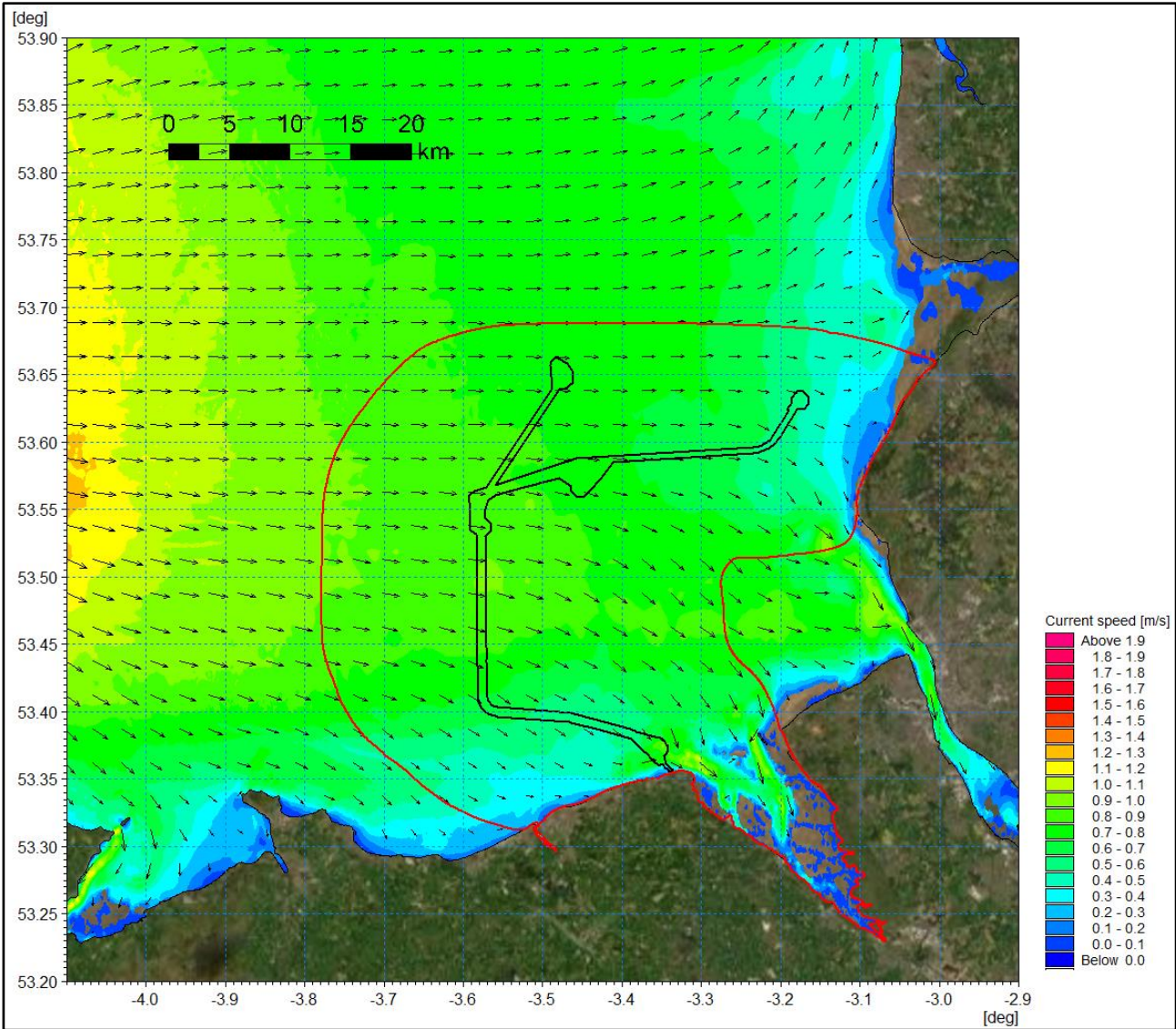


Figure 1.26: Tidal Flow Patterns – Spring Tide Flood

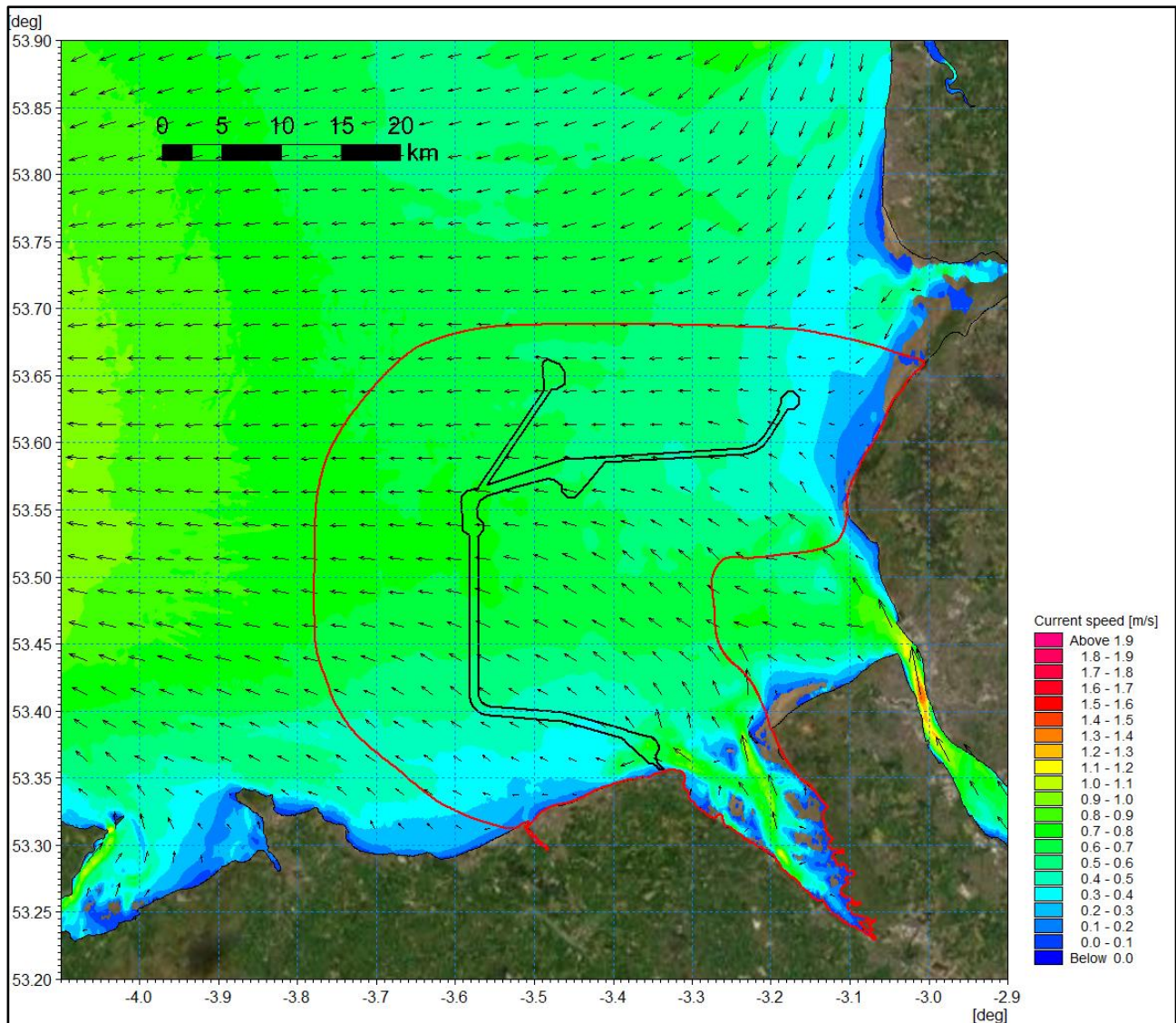


Figure 1.27: Tidal Flow Patterns – Spring Tide Ebb

1.6.3 Wave climate

Waves in the east Irish Sea are highest to the southwest of the Isle of Man with the highest mean annual significant wave height of 1.39 m recorded between the Isle of Man and Anglesey. Significant wave height is reduced closer to the coast with the lowest significant wave height of 0.73 m recorded to the west of the Dee Estuary (ABPmer, 2008). In the physical processes study area mean annual wave height ranges from 0.8 m to 1.1 m. Over 40% of the waves arise from the west with a majority of significant wave heights (>2 m) also arriving from the west (ABPmer, 2018). This is illustrated in Figure 1.28 which shows the wave rose for a point located within this area. Similarly, the corresponding wind rose presented in Figure 1.29 which illustrates the predominant winds are from the west and southwest with the site being located in the lee of the Isle of Man.

As offshore waves transfer from the deep offshore water to shallower coastal areas, a number of important modifications may result due to interactions of offshore deep-water waves with the seabed, with the resultant modifications producing shallow water waves. These physical 'wave transformation' interactions include:

- Shoaling and refraction (due to both depth and current interactions with the wave);

- Energy loss due to breaking;
- Energy loss due to bottom friction; and
- Momentum and mass transport effect.

The wave model developed for the assessment was calibrated using data collected during storm Christoph which occurred during January 2021. The model simulated water levels using boundary data extracted from the RPS storm surge model and applied meteorological conditions from the European Centre for Medium-range Weather Forecasting (ECMWF) operational dataset (ECMWF, 2022). Wave conditions at the model boundary were also provided from the ECMWF operational dataset.

The model output data was then compared with measured data obtained from the National Network of Regional Coastal Monitoring Programmes held by the CCO at the locations shown in Figure 1.30. For each of the two locations three parameters are presented relating to mean wave direction, significant wave height and peak wave period.

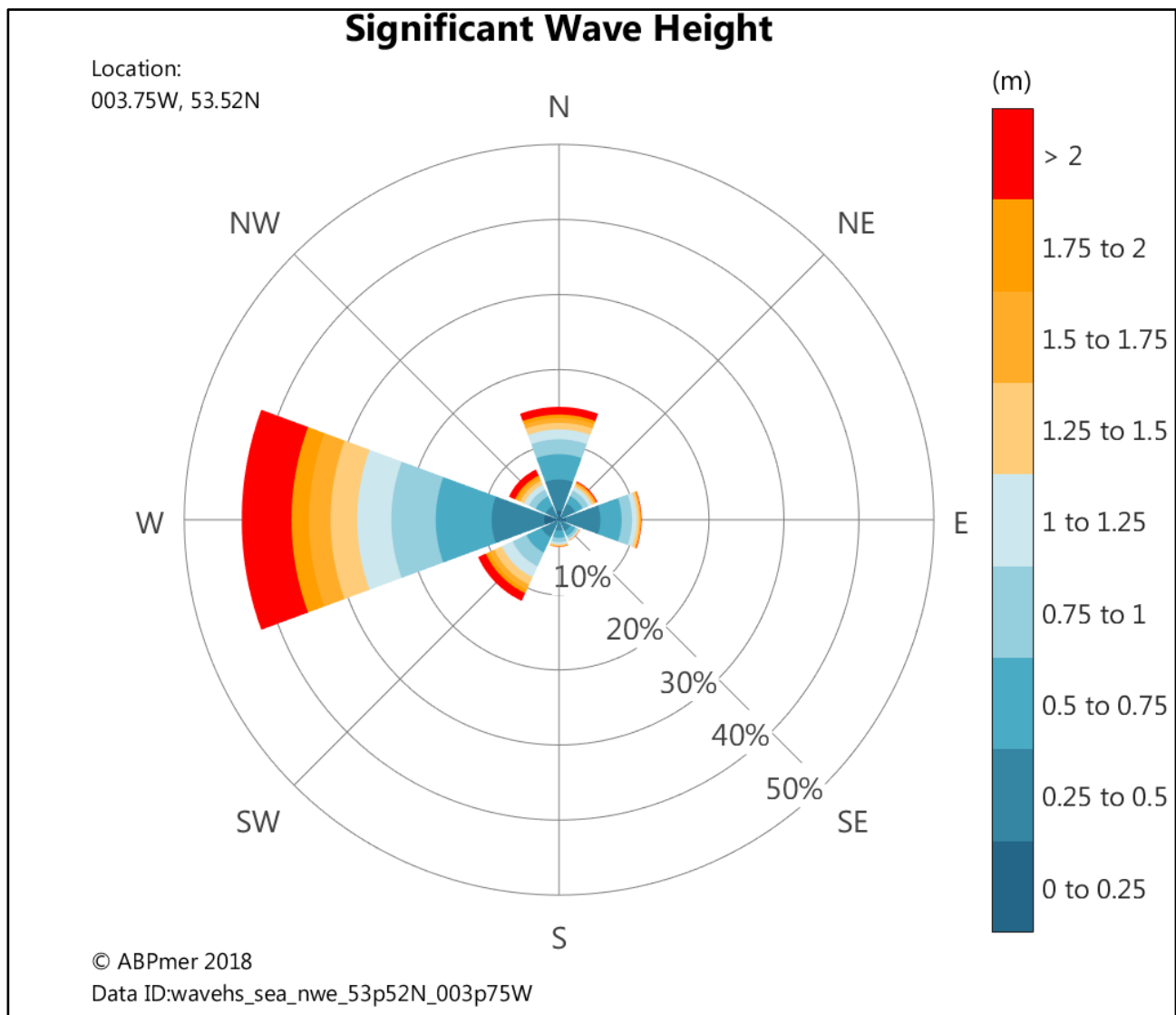


Figure 1.28: Wave Rose For The Hynet Physical Processes Study Area

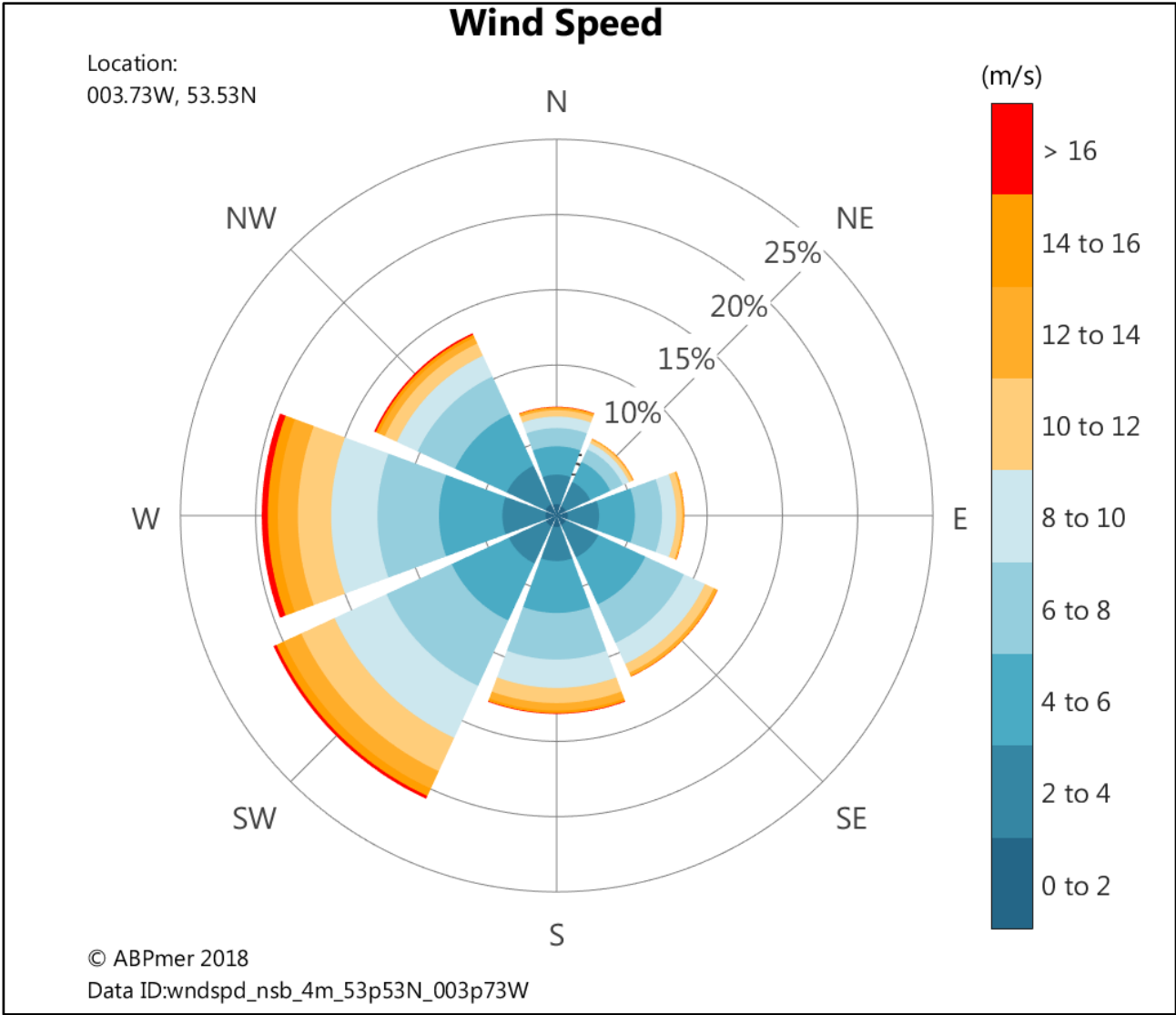


Figure 1.29: Wind Rose For Hynet Physical Processes Study Area

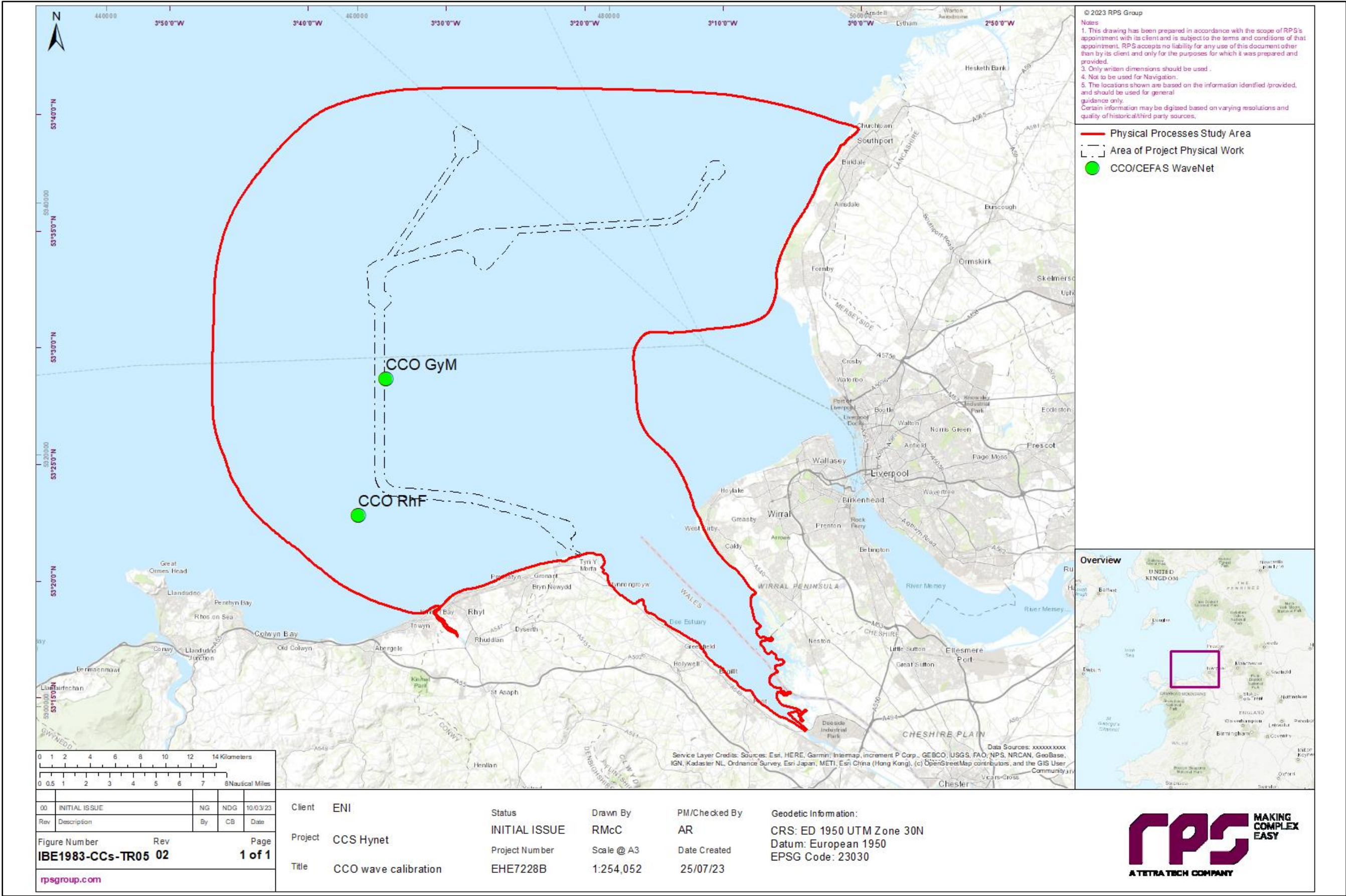


Figure 1.30: Location Of Wave Calibration Data Presented

Both the Gwynt y Môr (GyM) (Figure 1.31 to Figure 1.33) and Rhyl Flats (RfH) (Figure 1.34 to Figure 1.36) located along the Proposed Development Area of Physical Work show a good correlation between modelled and monitored data. Thus, there is confidence that baseline conditions are presented accurately.

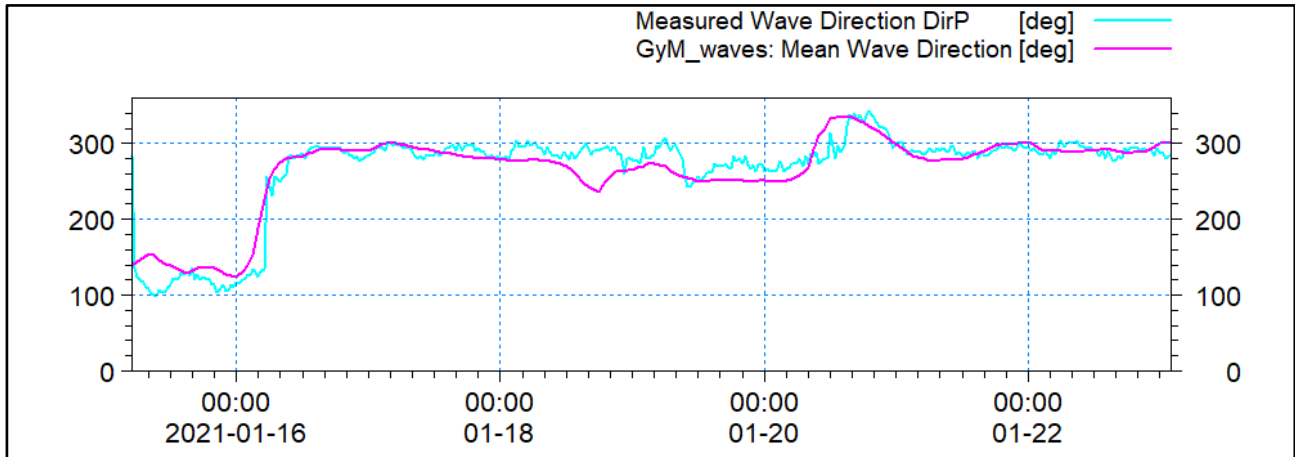


Figure 1.31: Validation Of Modelled (Pink) Mean Wave Direction With Measured (Blue) Data At GyM

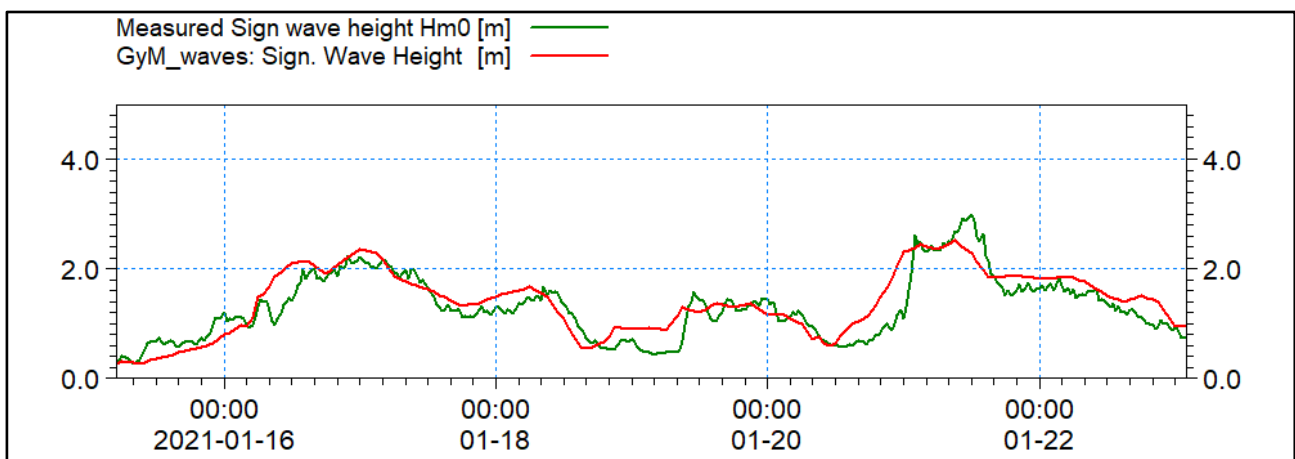


Figure 1.32: Validation Of Modelled (Red) Significant Wave Height With Measured (Green) Data At Gym

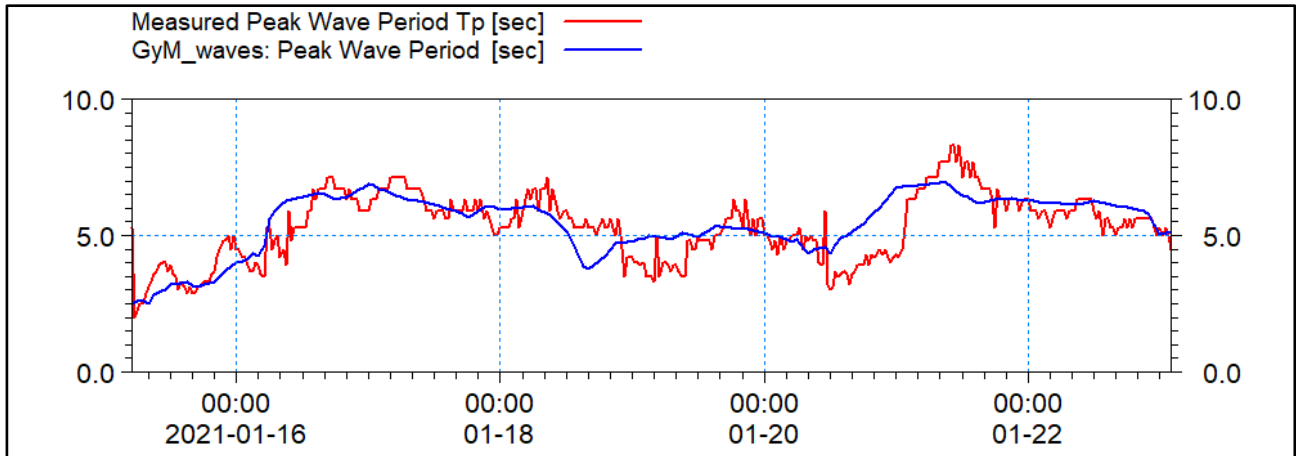


Figure 1.33: Validation Of Modelled (Blue) Peak Wave Period With Measured Red Data At GyM

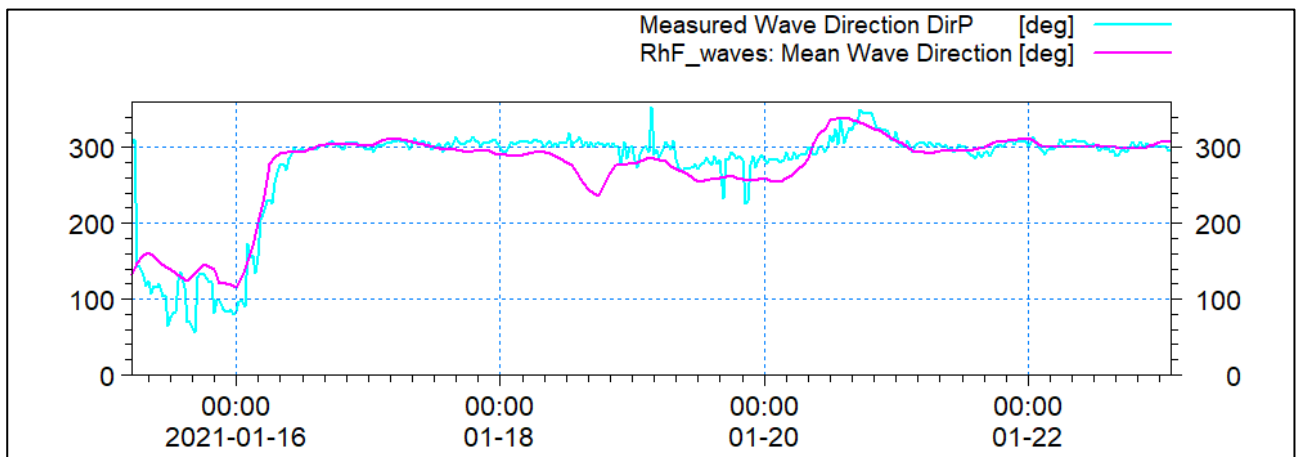


Figure 1.34: Validation Of Modelled (Pink) Mean Wave Direction With Measured (Blue) Data At RhF

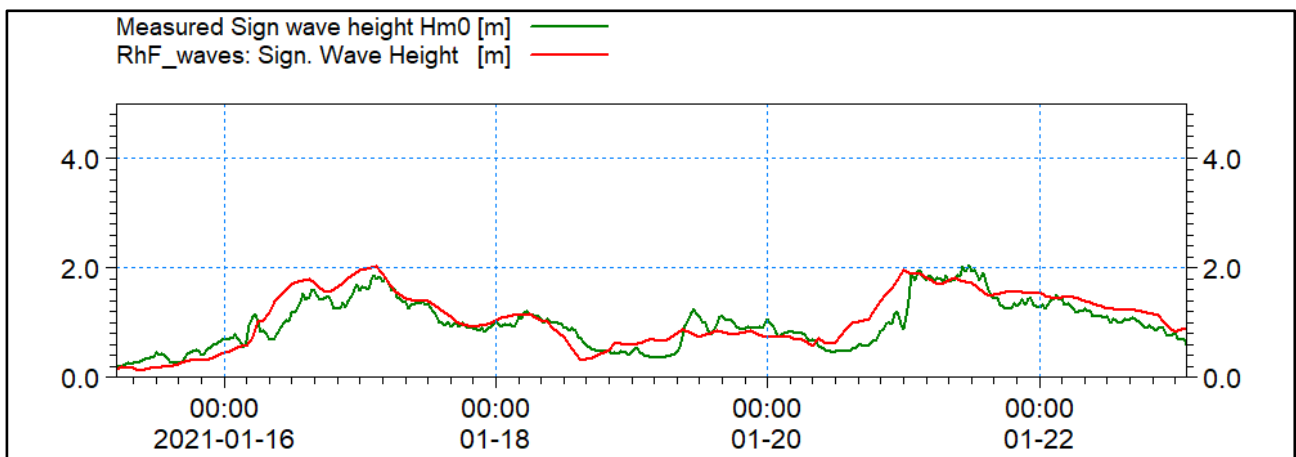


Figure 1.35: Validation Of Modelled (Red) Significant Wave Height With Measured (Green) Data At RhF

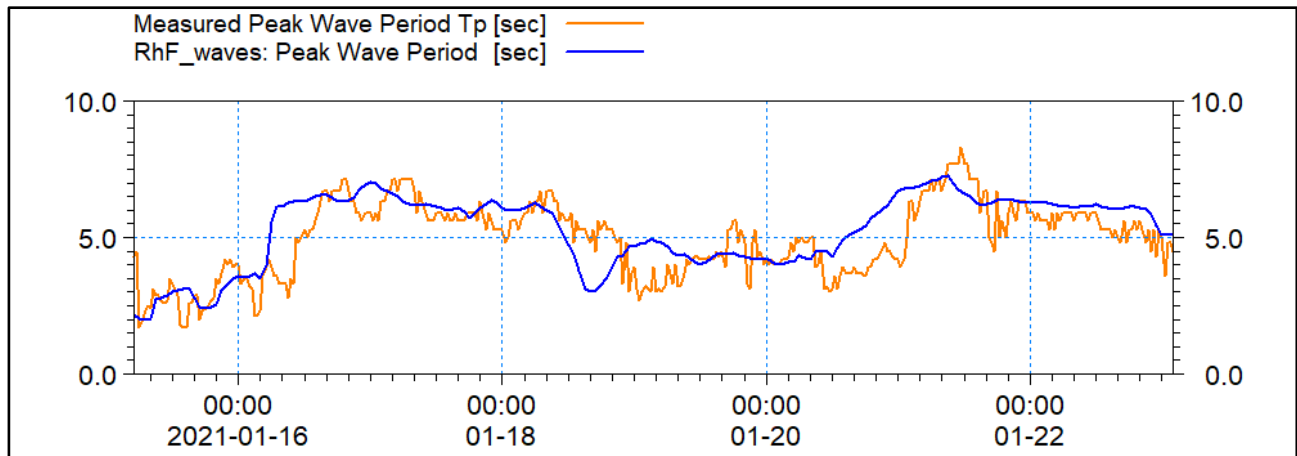


Figure 1.36: Validation Of Modelled (Blue) Peak Wave Period With Measured (Orange) Data At RhF

In order to establish baseline wave climate, a full metocean study was not essential however representative sea-states were required. An analysis was undertaken to determine the offshore conditions for which waves reach the site from all directions. Twenty-two years of data were obtained from the ECMWF operational dataset for locations on the north and south boundaries of the model domain. Extreme value analysis using peak over threshold was undertaken for each 30° sector to determine the 1in1 and 1in20 year offshore wave climate. These were then used as boundary conditions within the wave modelling to determine the resultant wave climate at the site and across the physical processes study area.

In addition to boundary wave data, it was necessary to analyse the wind field to include the contribution of local wind seas. For this, for a representative point for each of the key directions, was identified and utilised from the National Oceanic and Atmospheric Administration (NOAA) 40-year dataset. This was analysed on the same sectoral basis as the wave data to give an indication of the return period wind speed. Figure 1.37 shows the model domain with wind and wave roses relating to the forcing data.

The wave modelling was undertaken using the spectral wave model, MIKE21 SW, to provide a full wave climate and wave breaking across the physical processes study area. The model used a quasi-stationary formulation which meant that for each event the wave field fully established over a number of numerical iterations until convergence was reached. The model resolves the wave field by simulating wind generation of waves within the model domain and the propagation of externally generated swell waves through the domain. The model setup ensured that the detail of both locally generated wind waves and swell conditions from further afield were captured.

The following set of figures (Figure 1.38 to Figure 1.41) show the wave climate for four 1in1 year return period events from the principal directions; north (000°), northeast (030°), southwest (240°) and west (270°) direction respectively. These sectors were selected to be representative of the characteristics of the wave climate. The wave modelling was undertaken at mean high water (MHW) being the high water level on an average tide. Figure 1.41 shows the waves approaching from the west and demonstrates, as anticipated, the largest waves approach from this sector.

A second set of figures are presented relating to the 1in20 year return period; Figure 1.42 to Figure 1.45. These show data for the same sectors and tidal height as the 1in1 year return period.

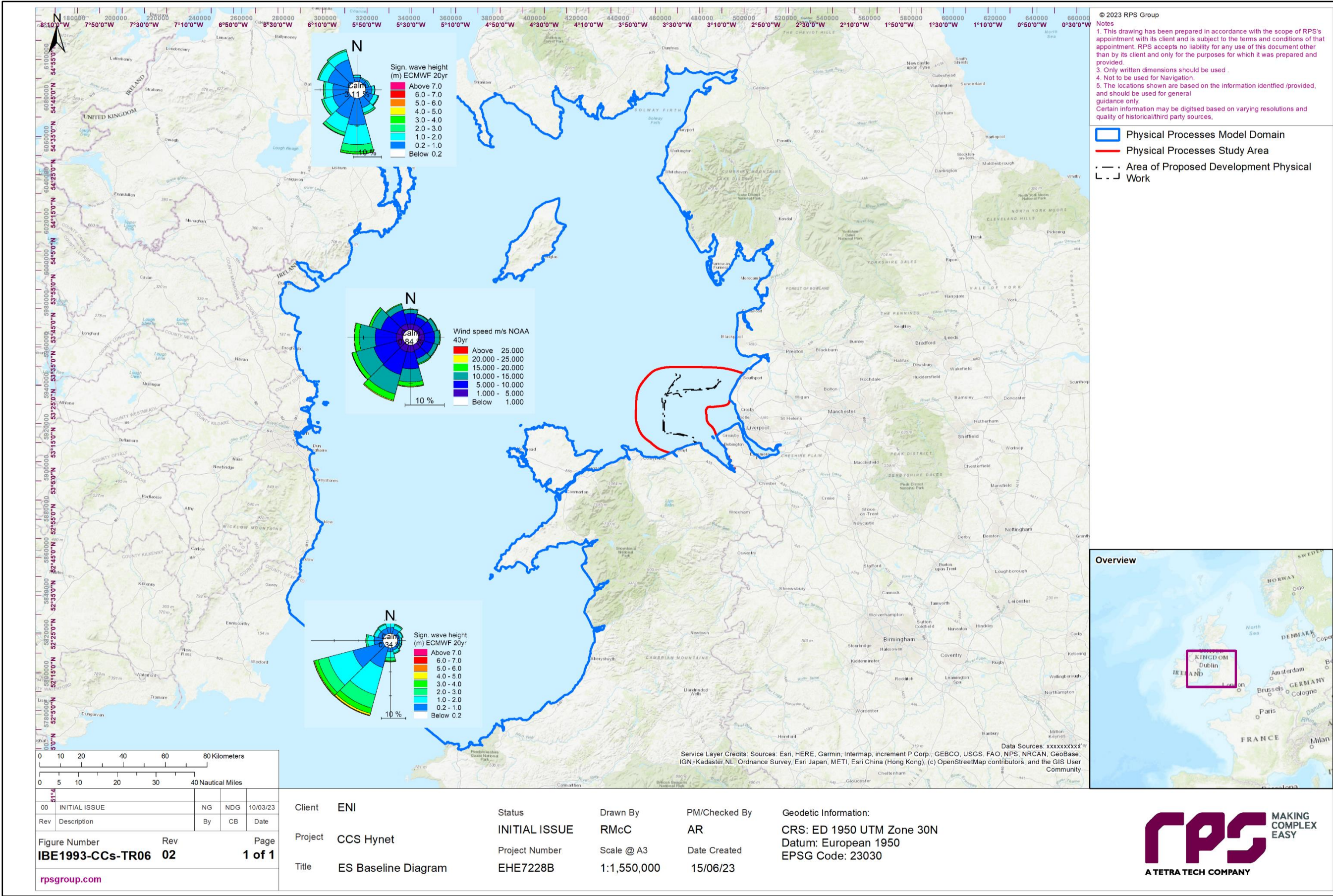


Figure 1.37: Wave Roses For Model Boundaries - 22 Year ECMWF Dataset And Wind Rose For 40 Year NOAA Dataset

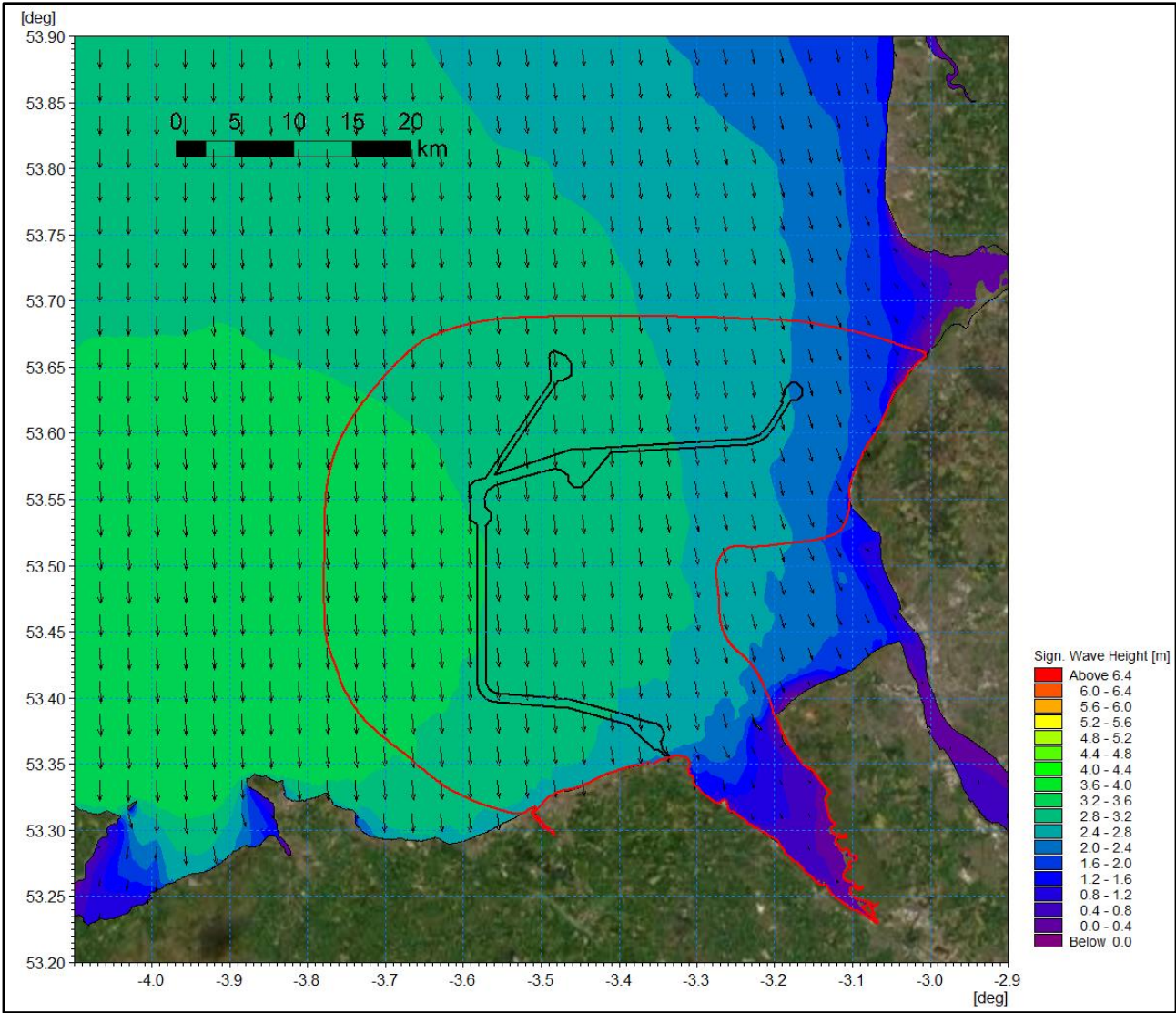


Figure 1.38: Wave Climate 1:1 Year Storm From 000° MHW

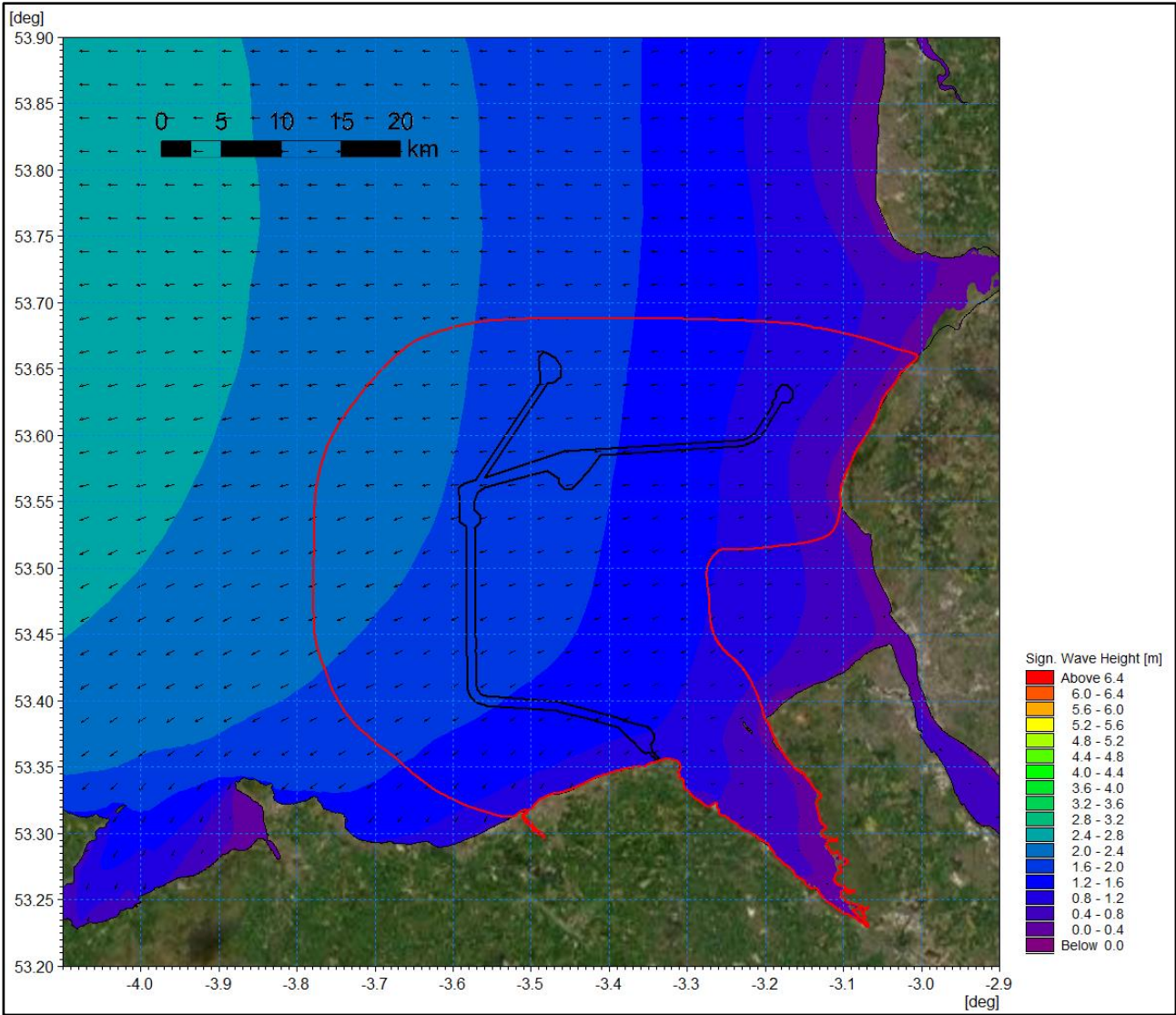


Figure 1.39: Wave Climate 1:1 Year Storm From 090° MHW

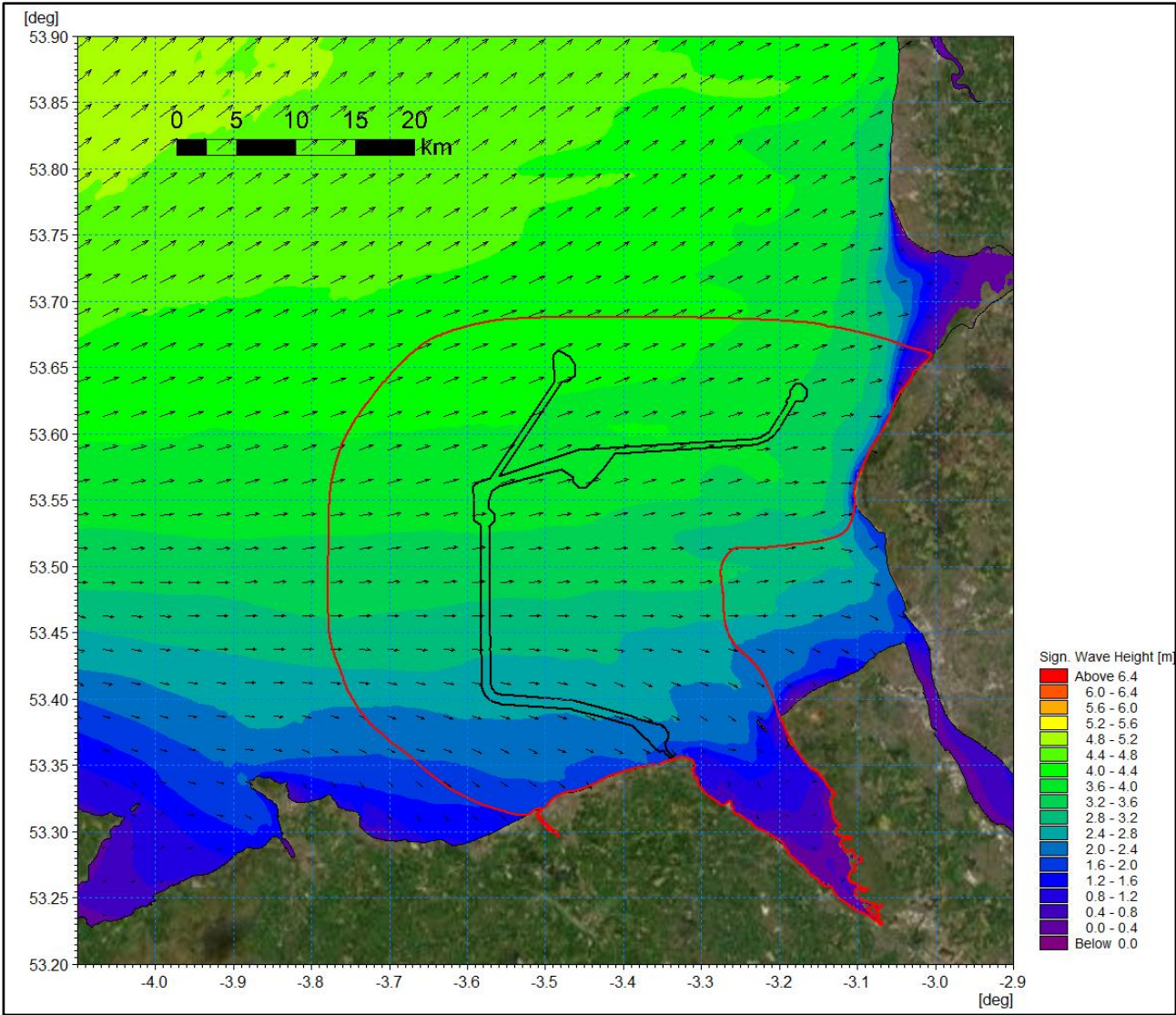


Figure 1.40: Wave Climate 1:1 Year Storm From 240° MHW

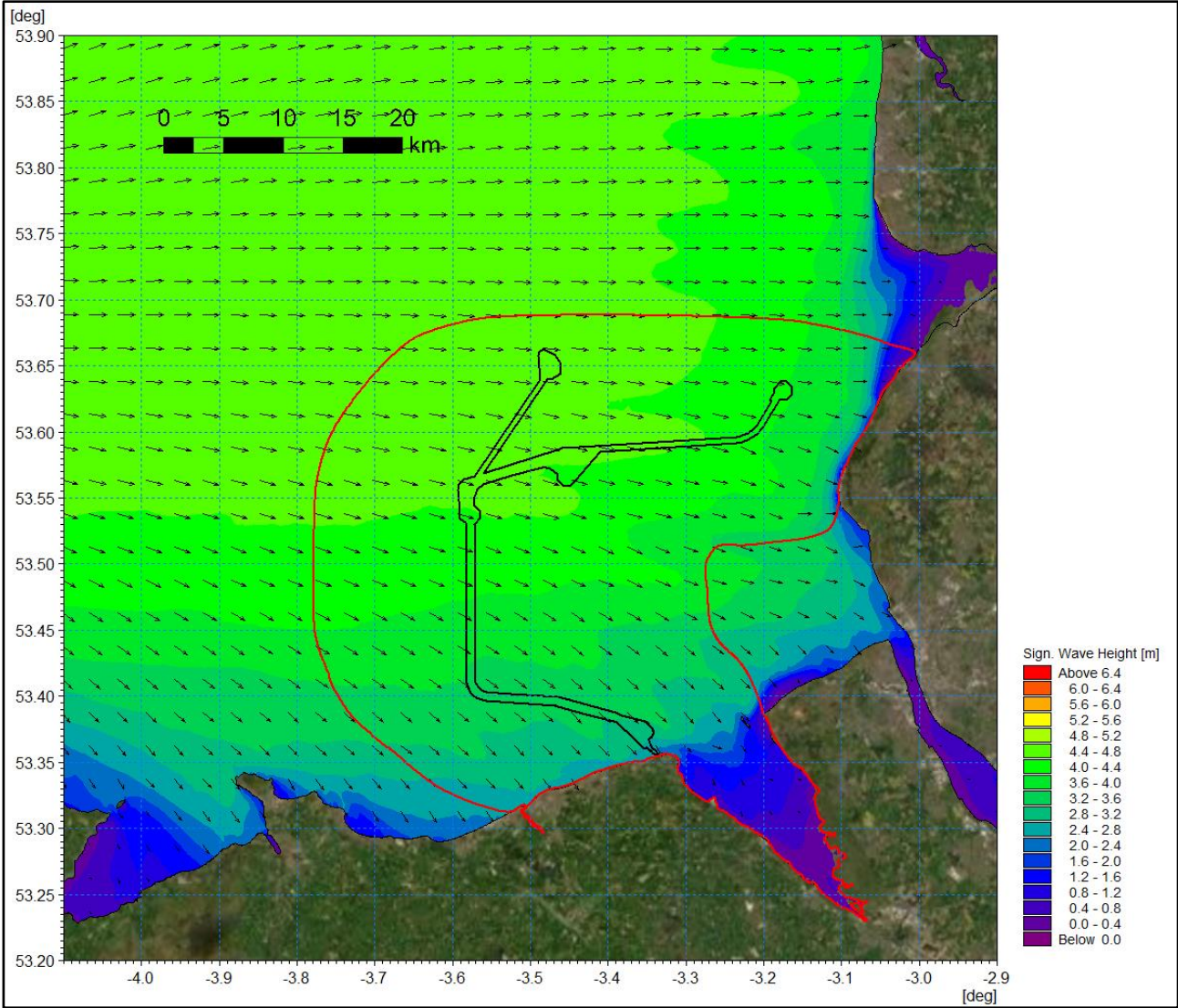


Figure 1.41: Wave Climate 1:1 Year Storm From 270° MHW

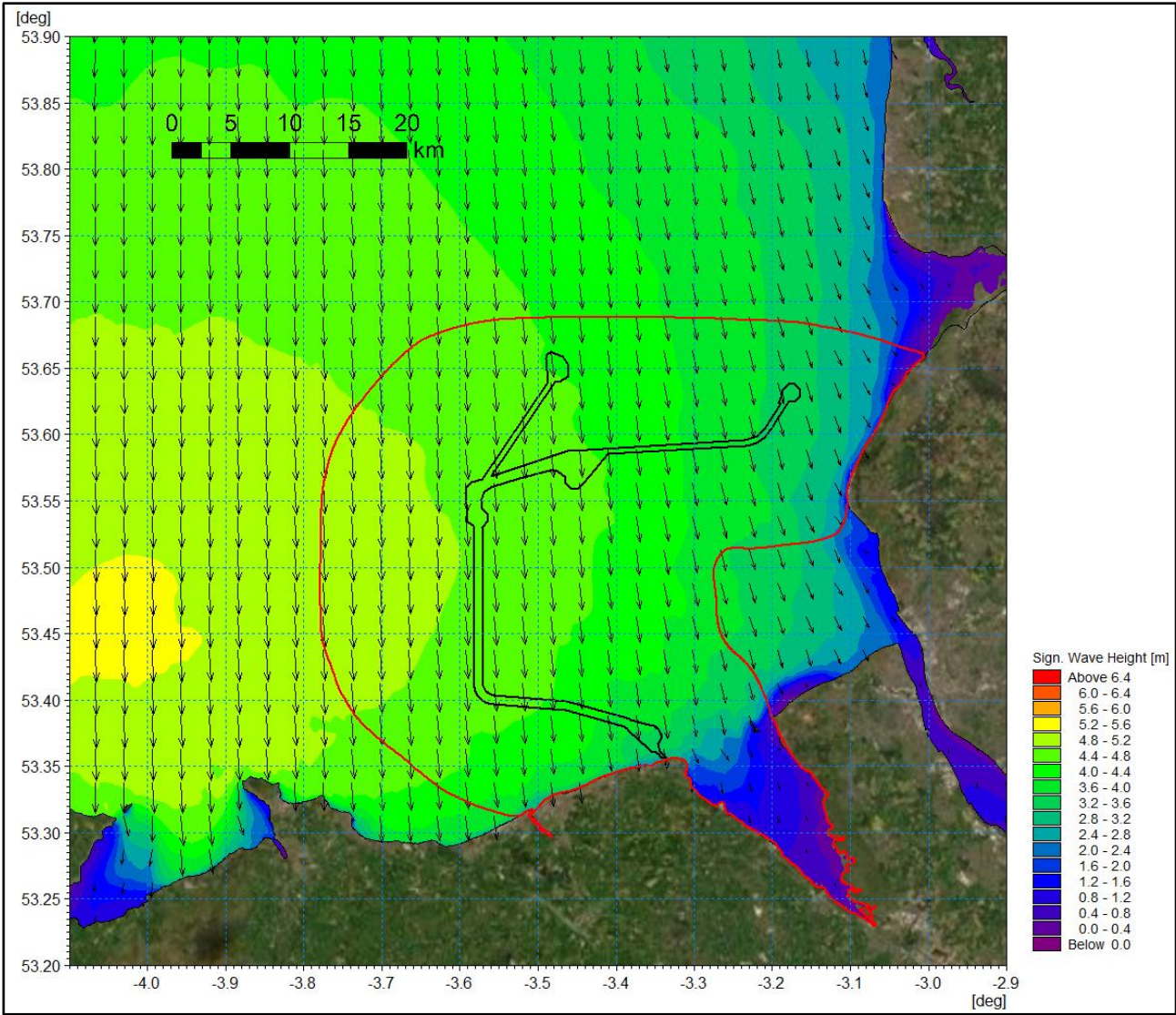


Figure 1.42: Wave Climate 1:20 Year Storm From 000° MHW

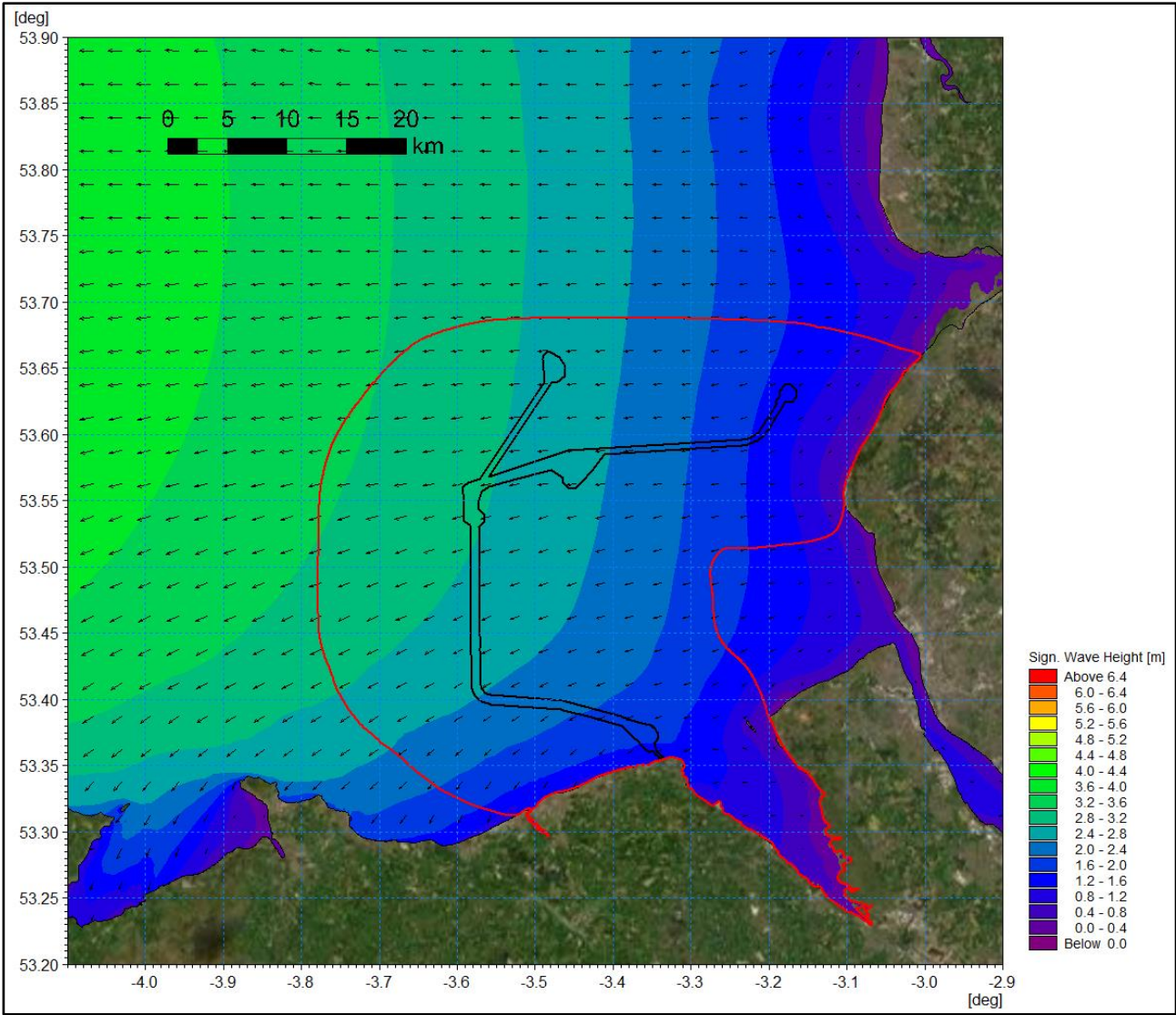


Figure 1.43: Wave Climate 1:20 Year Storm From 090° MHW

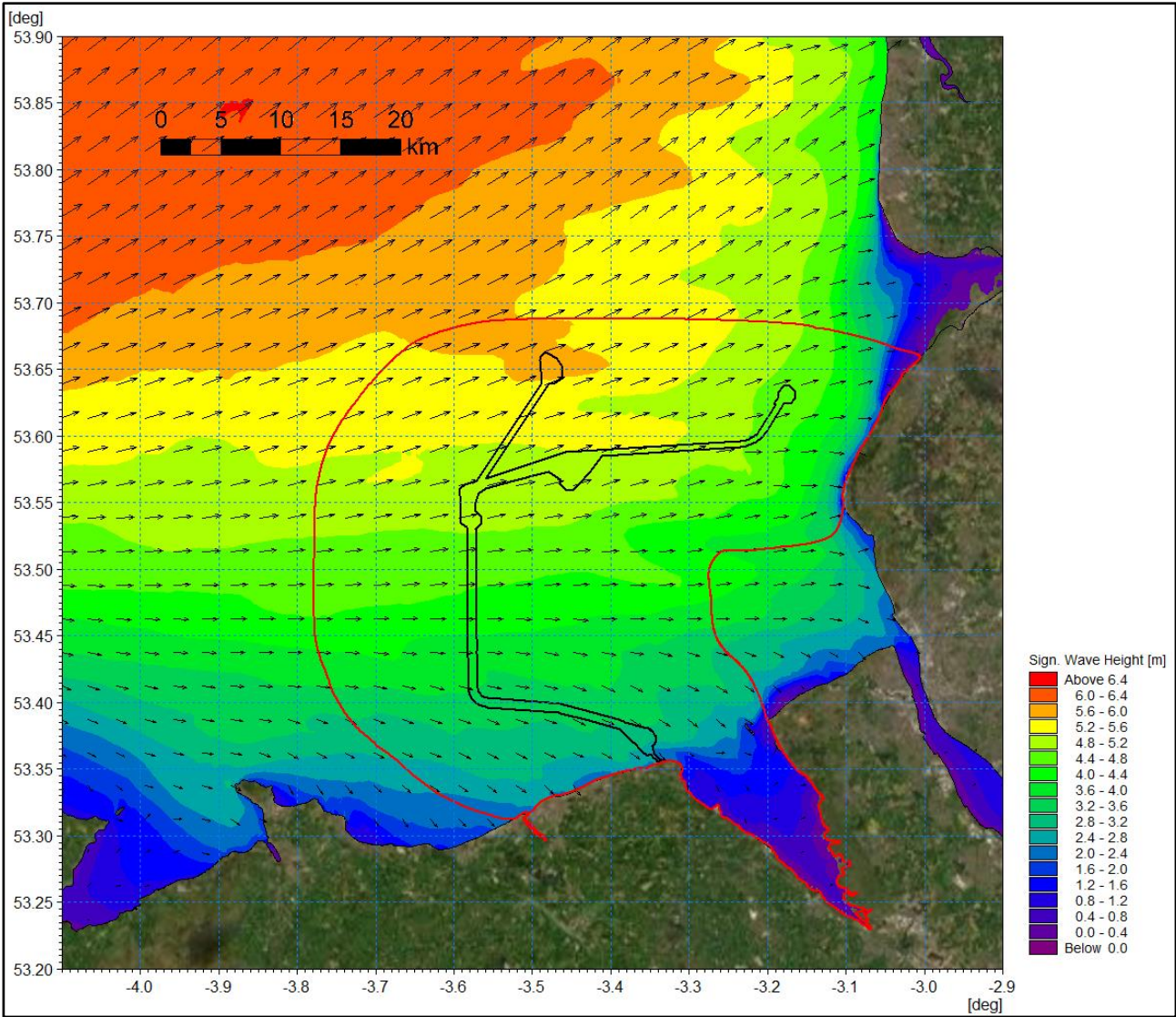


Figure 1.44: Wave Climate 1:20 Year Storm From 240° MHW

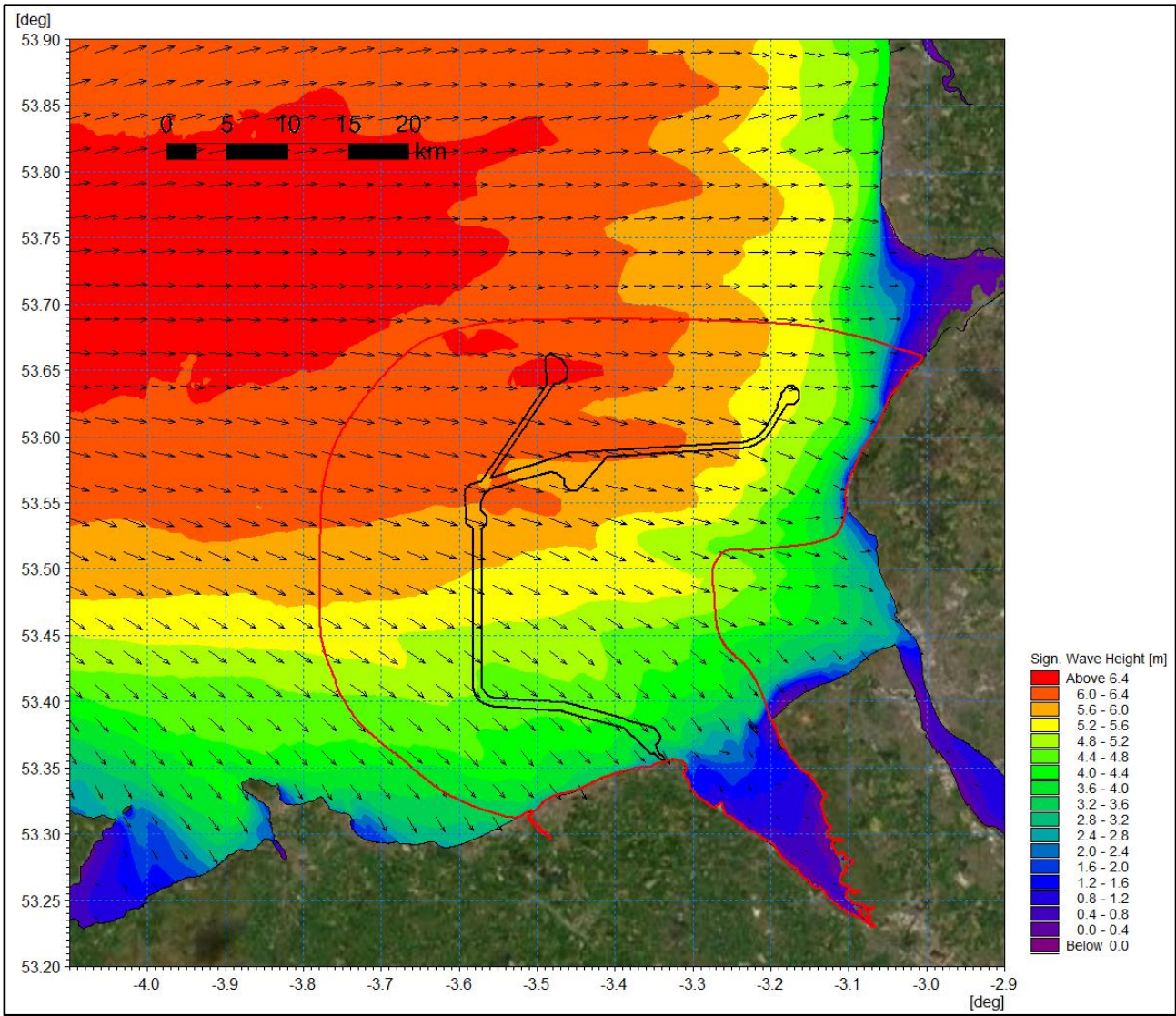


Figure 1.45: Wave Climate 1:20 Year Storm From 270° MHW

1.6.4 Littoral currents

The MIKE suite facilitates the coupling of models. The depth averaged hydrodynamic model, used for the tidal modelling, coupled with the spectral wave model, provides a full wave climate incorporating the impact of water levels and currents on waves and wave breaking. Using this, the littoral currents (i.e. those currents driven by tidal, wave and meteorological forces) were examined.

The 1in1 year storm from 270° sector was simulated with the inclusion of spring tides to encompass a wide range of tidal conditions and the resulting flood and ebb currents are presented in Figure 1.46 and Figure 1.47 respectively. These correspond with the (calm) tidal plots presented in Figure 1.26 and Figure 1.27. As expected, the presence of the southeast going waves increase the currents on the flood tide whilst reducing them on the ebb.

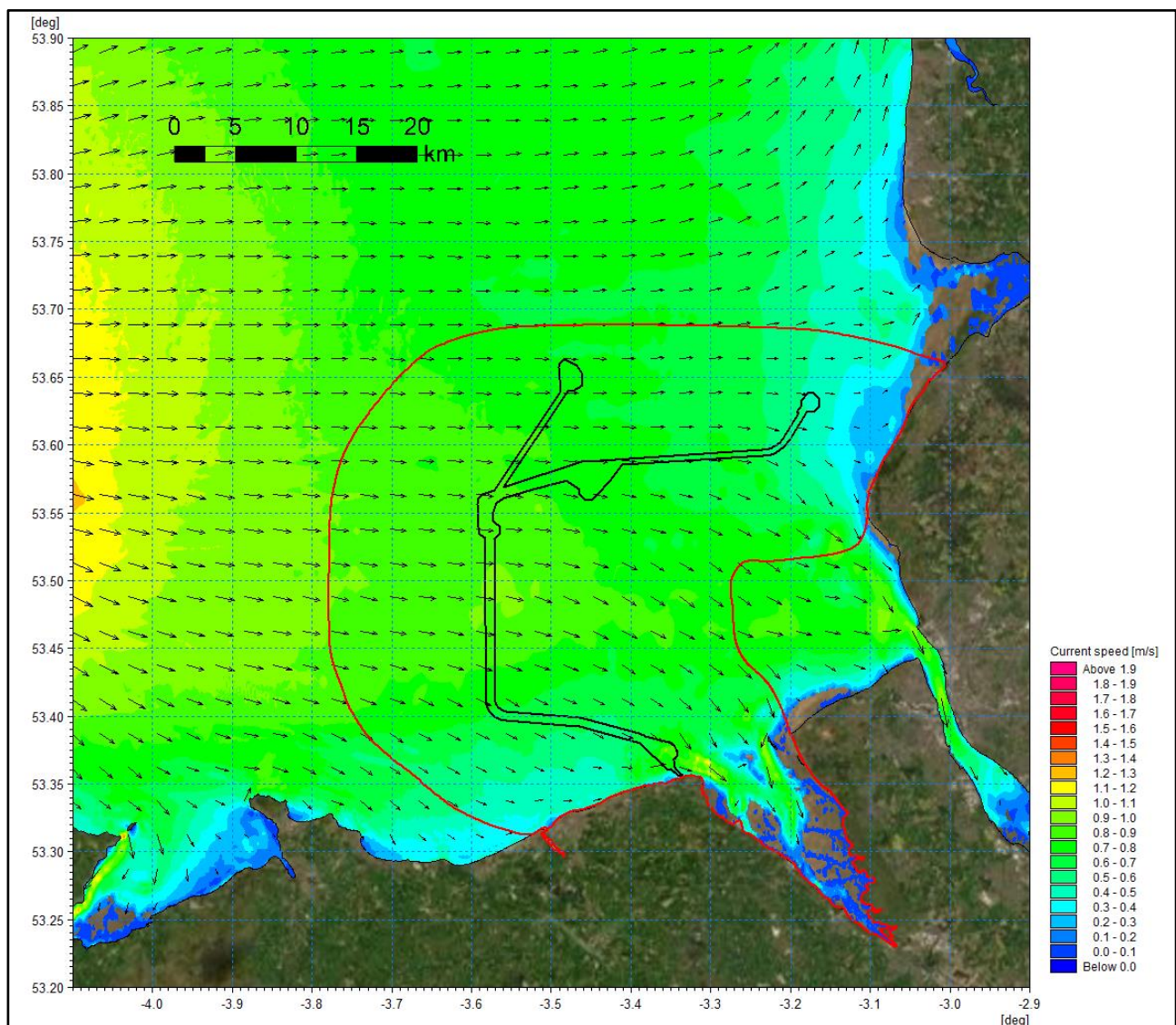


Figure 1.46: Littoral Current 1:1 Year Storm From 270° - Flood Tide

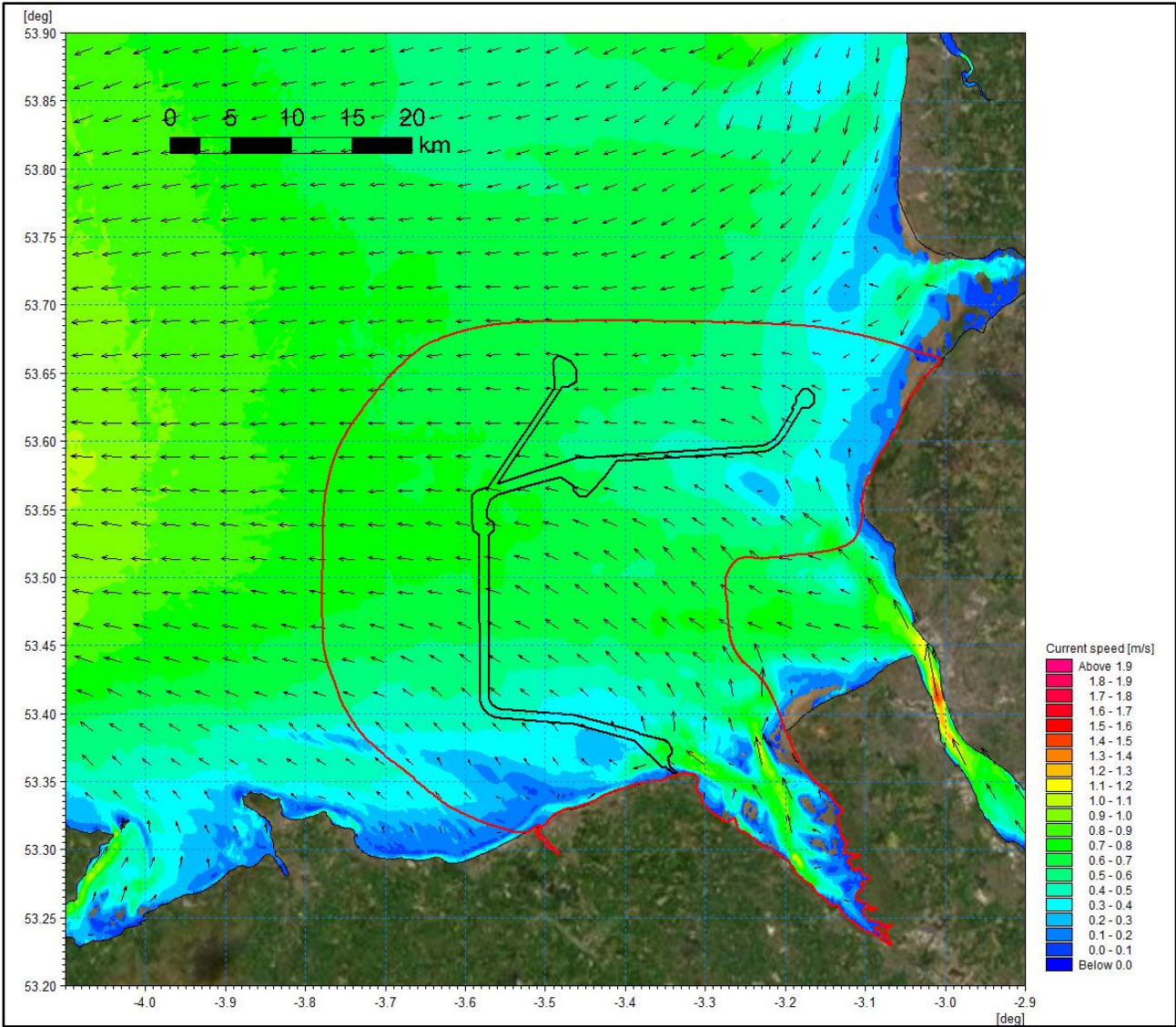


Figure 1.47: Littoral Current 1:1 Year Storm From 270° - Ebb Tide

1.6.5 Sedimentology and seabed substrate

An understanding of seabed substrate types is required to assess the potential impacts that may arise due to the installation of offshore export cables and monitoring well drilling.

The sediment grading properties applied within the modelling for both sediment transport baseline and characterisation of mobilised material during seabed preparation and installation was derived from a number of sources including the British Geological Survey (BGS) datasets (BGS, 2023) as illustrated in Figure 1.48. These datasets included both generalised Folk classification from borehole logs and detailed particle analysis data.

Site specific information was also used to inform modelled sediment grading, collected via grab sample by Ocean Ecology Limited in 2022 (Ocean Ecology , 2022) as part of a subtidal benthic survey to inform the Environmental Statement (ES). Sediment samples were obtained for 23 stations within the physical processes study area and analysed through particle size analysis (PSA). To inform the modelling study seabed sediment information was required beyond the extent of survey datasets, and the EMODnet Geology database (EMODnet , 2022) was utilised. The seabed classification shown in Figure 1.49 shows both the grab sample data collected by Ocean Ecology Limited and EMODnet classification data.

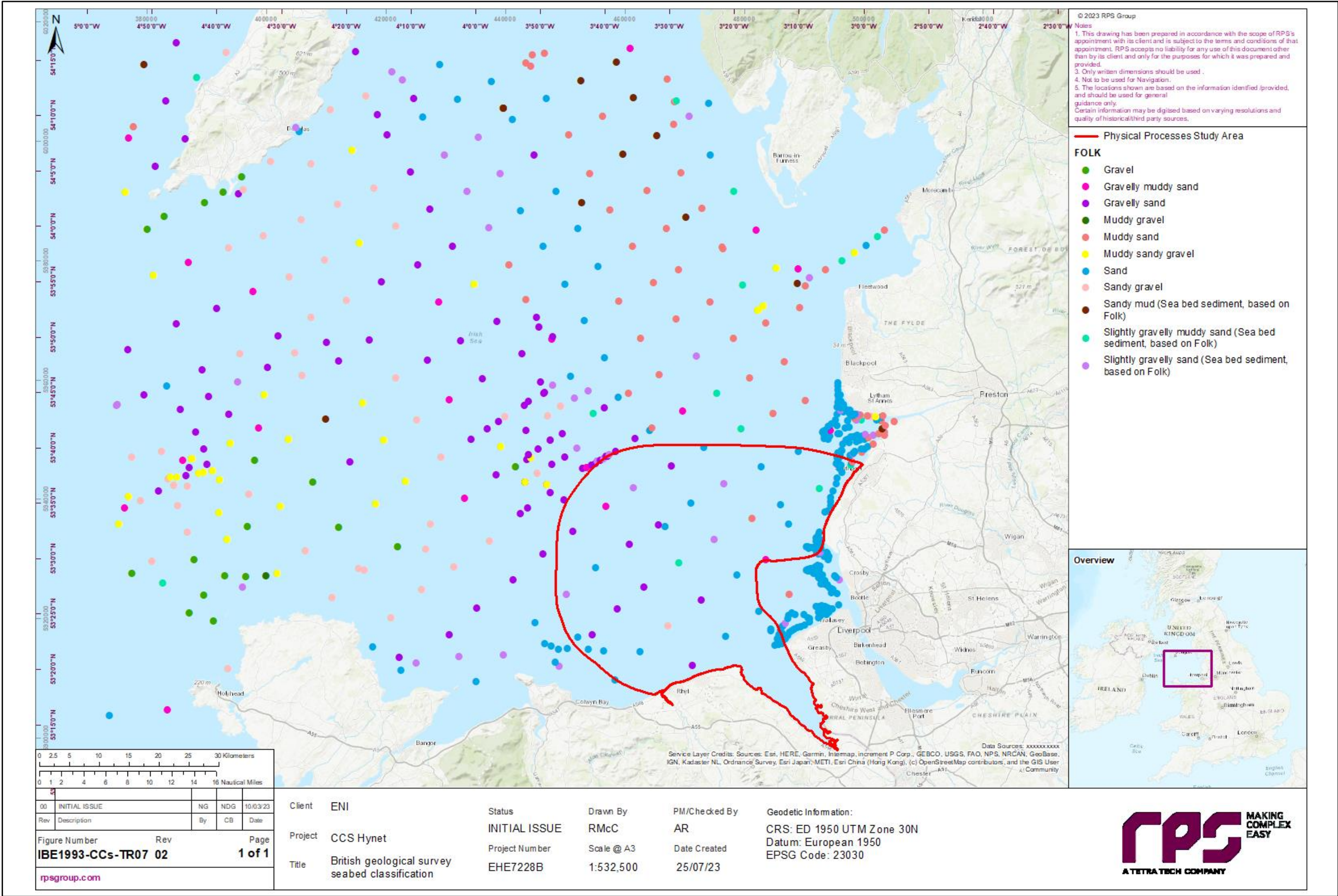


Figure 1.48: Seabed Classification British Geological Survey

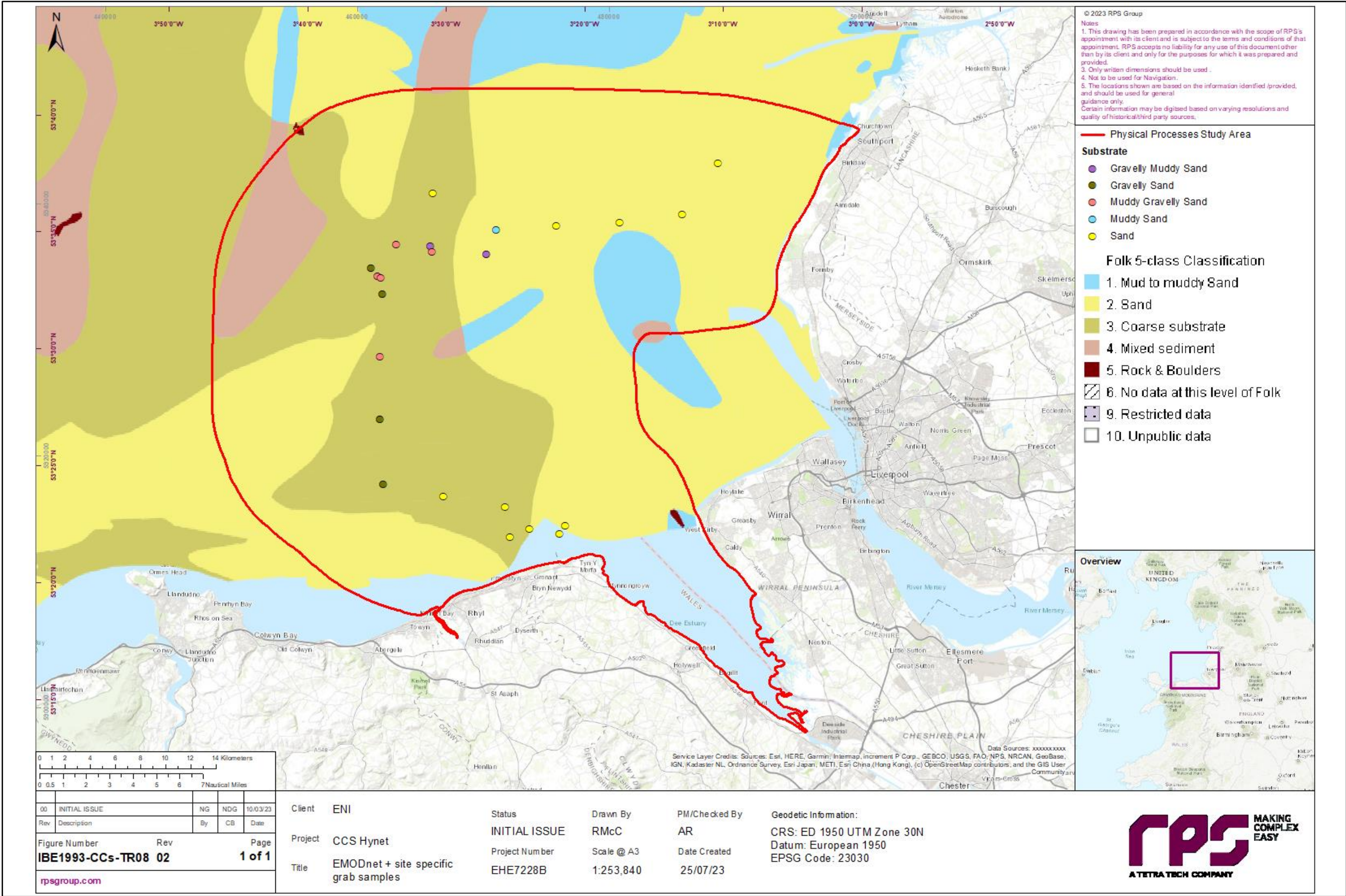


Figure 1.49: Seabed Substrate Geology Comprised Of Site Specific Grab Samples And EMODnet

1.6.6 Sediment transport

The MIKE21 Sediment Transport module enables assessment of bed sediment transport rates for non-cohesive sediment resulting from currents or combined wave-current flows. It was used to determine the sediment transport pattern within the model domain. The model combines inputs from both the hydrodynamic model and, if required, the wave propagation model. It used sediment characterisation provided by site specific survey and EMODnet data as presented in the previous section to determine the sediment transport characteristics.

It is noted that for a detailed sediment transport study greater detail of sediment characteristics across the model domain and along the coastline would be required. In the context of providing a baseline description of sediment transport patterns, the sediment characteristics identified within the survey and sampling were interpolated to those areas in the EMODnet data with similar sediment classifications.

The model domain was set up with a layer of mobile bed sediment. In areas where sediment is present an initial layer depth was set to 3 m and tapered to zero in the areas of rocky outcrops to ensure that sediment was not exhausted during the simulated events. Sediment transport was examined relating to spring tidal conditions over the course of two tidal cycles (one day) to provide a ‘snap-shot’. The simulation included a period for the hydrodynamics to stabilise and develop across the domain prior to sediment transport being enabled (i.e. a “warm-up” period).

Three aspects were examined:

- Residual current, which is the net flow over the course of the tidal cycle. This is effectively the driving force of the sediment transport;
- Potential sediment transport over this period; and
- Potential sediment transport during flood and ebb tides. This provides information for a ‘snap-shot’ in time to enable the process to be illustrated.

The residual current is presented in Figure 1.50 and it should be noted that a log scale has been used to cover the range of residual current speeds encountered. The current vectors indicate residual flow into the east Irish Sea from the north and west which correlates with this region being a sediment sink. There are strong circulatory currents where tidal flows interact with headlands and embayments.

An indication of transport rate is shown in Figure 1.51, again using a log scale palette as the values within the offshore regions are several orders of magnitude smaller than those along the coastline. The greatest transport rates are seen in areas where finer sand fractions are present and in estuaries and at headland where tidal currents are strongest. The mechanism is more clearly illustrated in Figure 1.52 and Figure 1.53 for flood and ebb tides respectively. It is evident that transport rates are highest during the dominant flood tide and the region is a sediment sink.

By way of completeness, residual currents relating to the 1in1 year return period storm approaching from 270 ° are also presented, Figure 1.54. As anticipated, the littoral currents and dominant flood tide significantly increase easterly residual currents particularly along the Welsh coastline. This in turn would result in increased sediment transport rates during storm conditions.

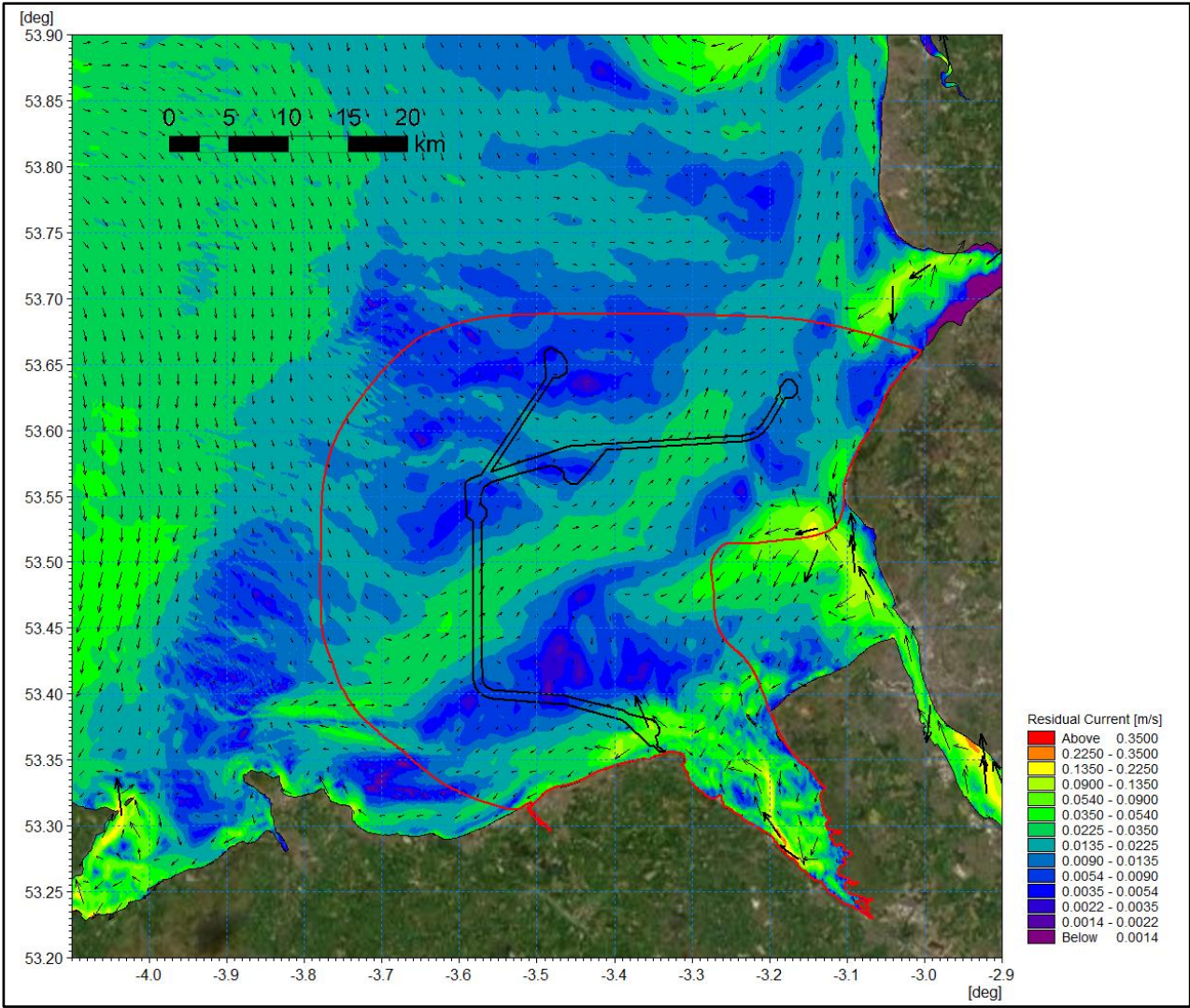


Figure 1.50: Residual Current Spring Tide

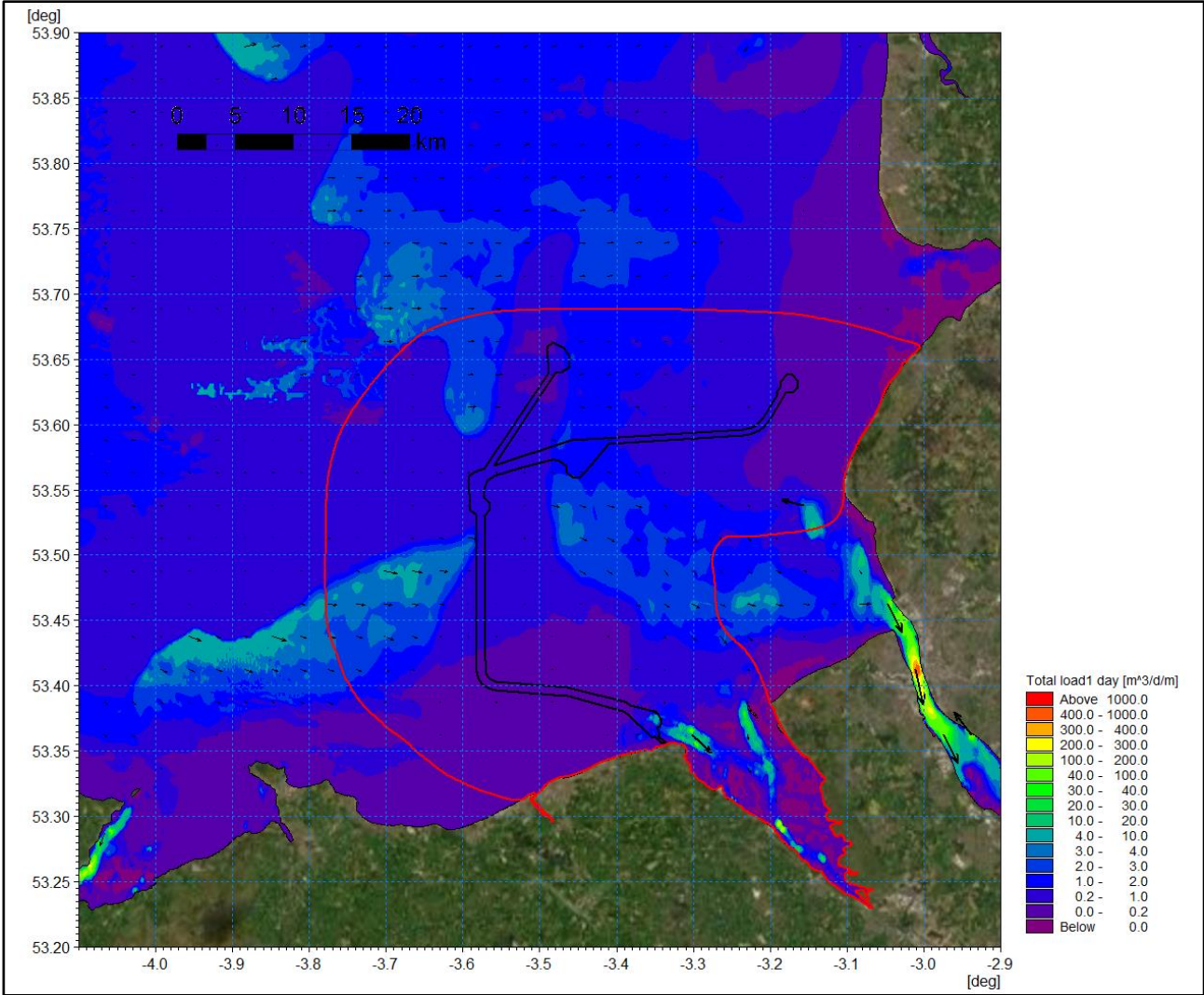


Figure 1.51: Potential Sediment Transport Over The Course Of 1 Day (Two Tide Cycles)

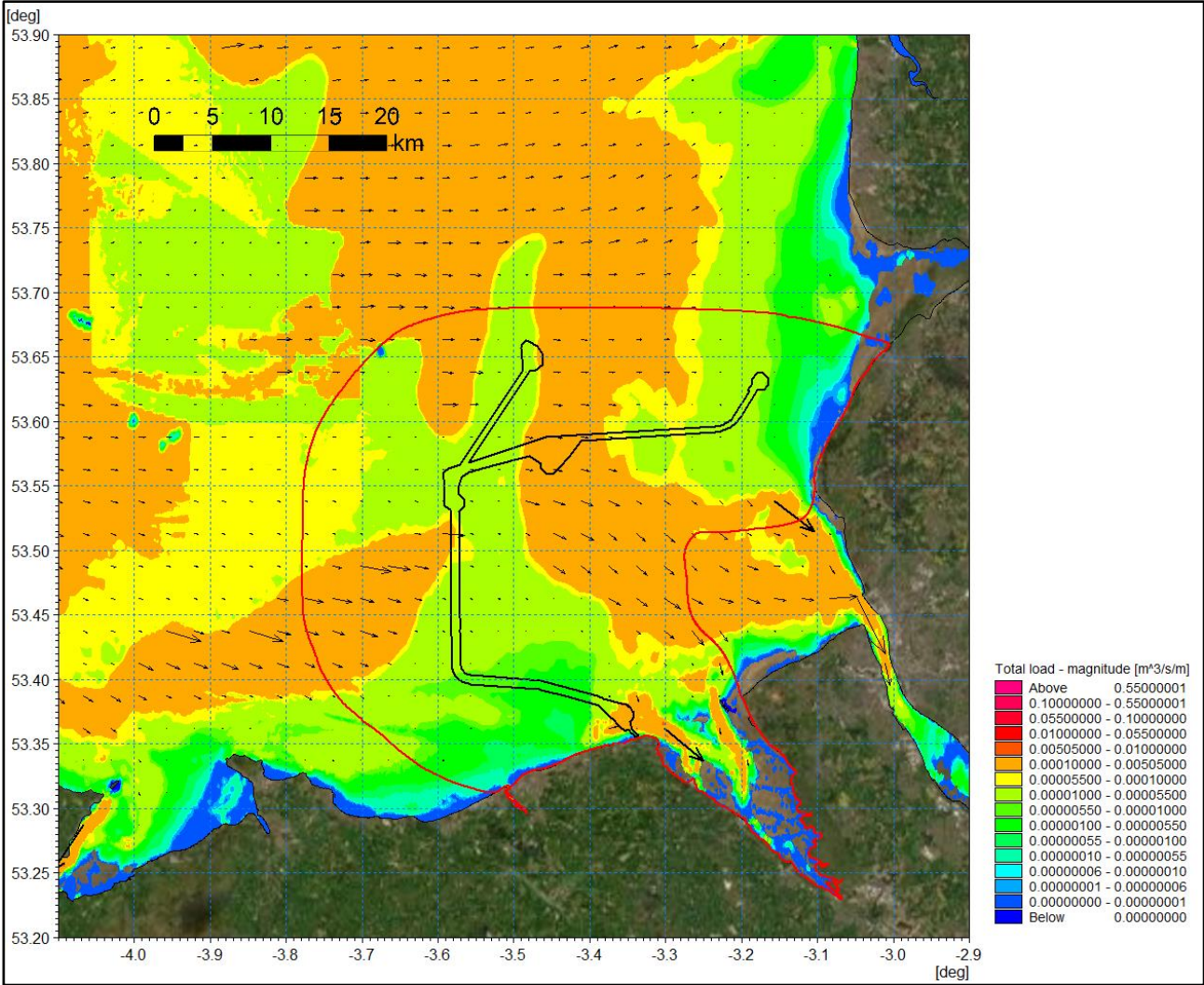


Figure 1.52: Sediment Transport – Flood Tide

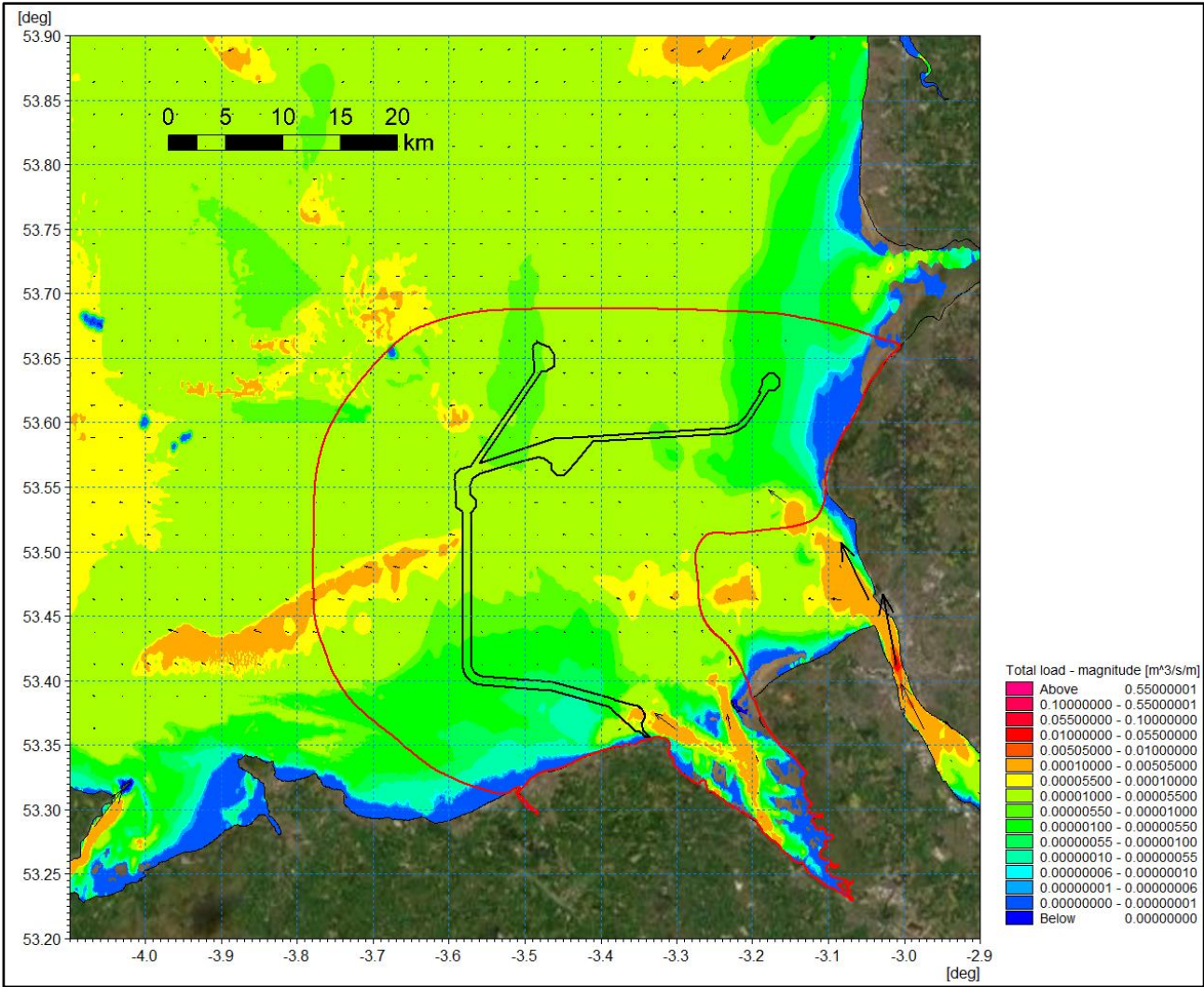


Figure 1.53: Sediment Transport – Ebb Tide

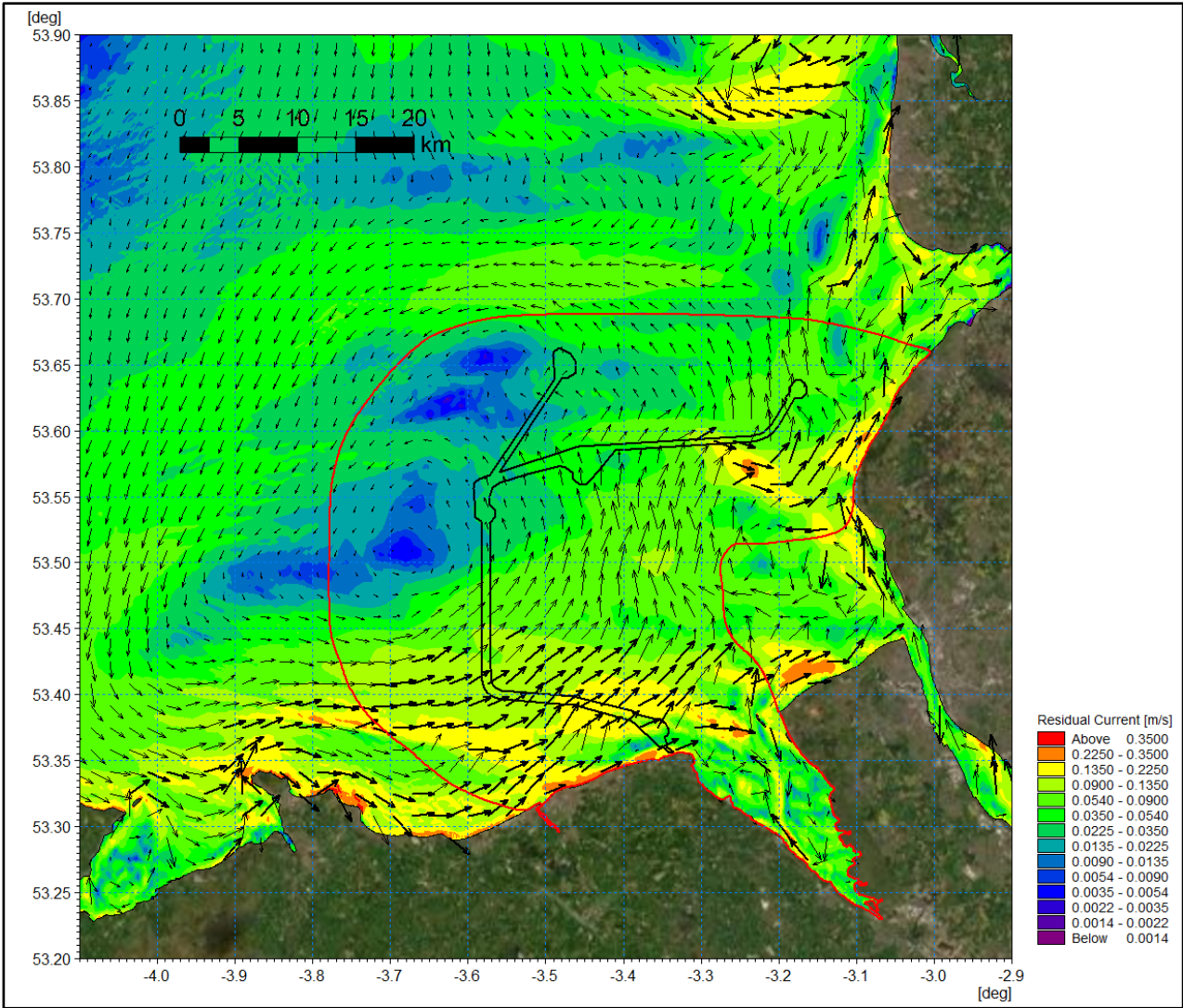


Figure 1.54: Residual Current Spring Tide With 1:1 Year Storm From 270 °

1.6.7 Suspended sediments

The principal mechanisms governing Suspended Sediment Concentration (SSC) in the water column are tidal currents, with fluctuations observed across the spring-neap cycle and across the different tidal stages (high water, peak ebb, low water, peak flood). It is key to note that SSCs can also be temporarily elevated by wave-driven currents during storm events. During high-energy storm events, levels of SSC can rise significantly, both near bed and extending into the water column. Following storm events, SSC levels will gradually decrease to baseline conditions, regulated by the ambient regional tidal regimes. The seasonal nature and frequency of storm events supports a broadly seasonal pattern for SSC levels.

CEFAS Climatology Report 2016 (CEFAS, 2016) and associated dataset provides the spatial distribution of average non-algal Suspended Particulate Matter (SPM) for the majority of the UK Continental Shelf (UKCS). Between 1998 and 2015, the greatest plumes are associated with large rivers such as those that discharge into the Thames Estuary, The Wash and Liverpool Bay, which show mean values of SPM above 30 mg/l. Similar concentrations can be found in the nearshore development area adjacent to the POA Terminal, c.20 mg/l, with smaller concentrations further offshore estimated to be between c.2-10 mg/l. Higher levels of SPM are experienced more commonly in the winter months; however, due to the tidal influence, even during summer months the levels may become elevated. CEFAS SPM data within the physical processes study area is presented in Figure 1.55.

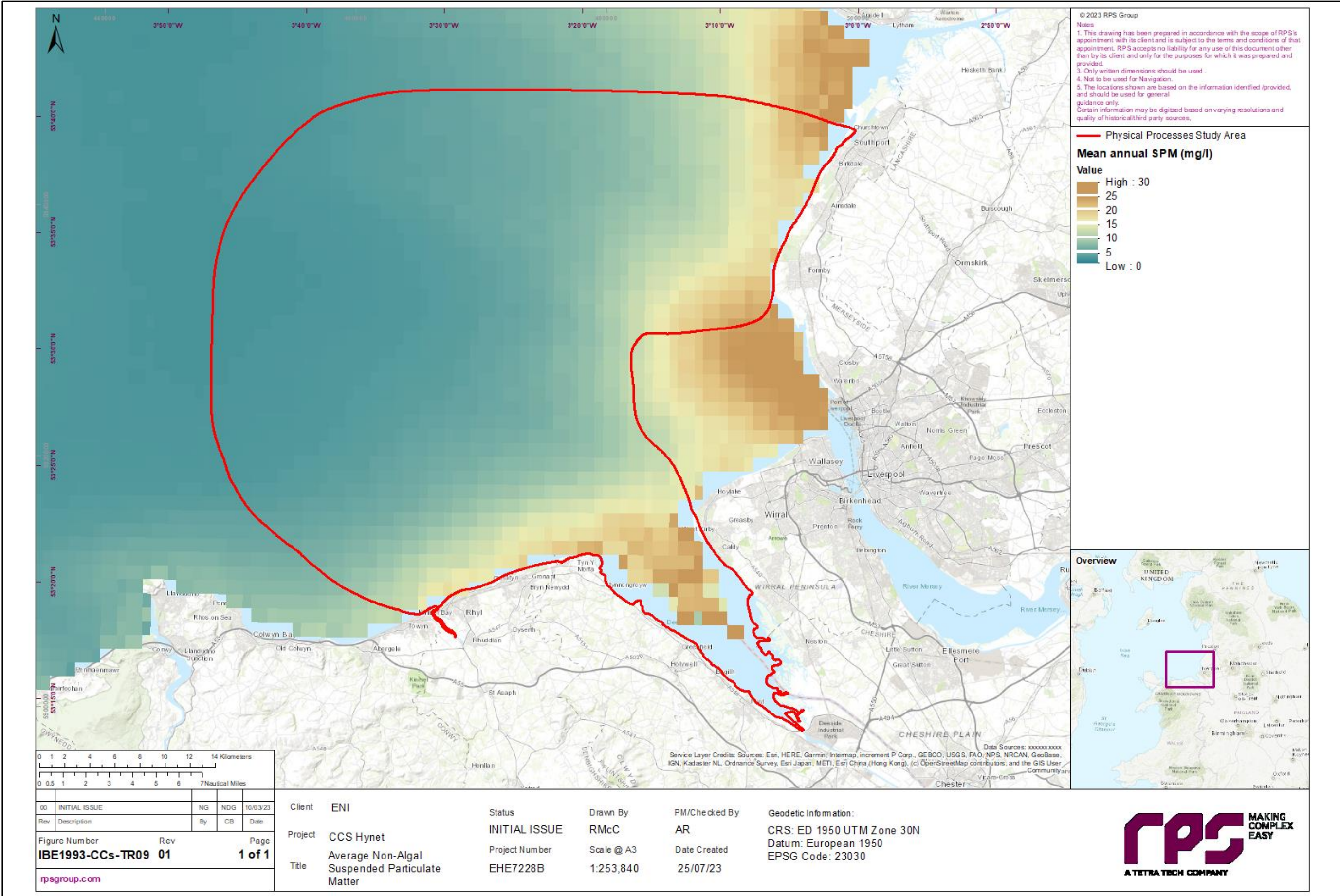


Figure 1.55: Distribution Of Average Non-Algal Suspended Particulate Matter – CEFAS

1.7 Potential changes during construction

The principal construction elements relate to the transport and fate of sediment brought into suspension due to seabed preparation, the drilling of monitoring wells, and the laying of cables. Modelling was undertaken for a representative sample of works to be undertaken, (i.e. cable laying from the Lennox OP to Douglas OP and from Douglas OP to the shore) to provide information to be utilised in the EIA.

In each scenario the modelling examined excess suspended sediment concentration (SSC) arising from the proposed activities (i.e. ambient SSC were not included). Baseline studies outlined in Section 0 indicate that turbidity levels vary greatly across the domain and throughout the year, being relatively low in deep water areas compared with active sediment transport mechanisms within the estuaries. Therefore, the excess SCC data presented would be applicable independent of the season in which the operations are undertaken.

The baseline residual currents and sediment transport modelling has corroborated the knowledge that the east Irish Sea is a sediment sink with active sediment transport processes. Sedimented material arising from the construction phase activities would therefore be amalgamated into the sediment transport regime. The numerical modelling provides depth averaged suspended sediment concentration values and do not therefore differentiate between bed load and water column suspended sediment.

During each phase of the assessment the transport of suspended sediment was modelled by undertaking simulations that released sediment at a rate and location appropriate to each type of construction. The sediment released was defined according to the characteristics derived from site specific survey data at each specific location. Where a number of locations were encountered, such as a dredging path, then a representative grading was used.

1.7.1 Seabed preparation

Due to the nature of the seabed in the development area, the cable installation will require seabed preparation in the form of seabed features clearance. The Project Design Envelope (PDE) presented by the Proposed Development description outlined in Volume 1, Chapter 3 indicates that sand waves are to be cleared along the cable route in two locations, south of the existing Douglas platforms, and at West Hoyle Bank.

Clearance activities south of the Douglas OP are set to be undertaken across two sections where sand waves are present with average heights of c.3 m and lengths of c.100 m and c.15 m respectively. To enable the laying of cables, a c.10 m wide corridor will be excavated using a mass flow excavator/jet sled, which will suspend sediment at the seafloor.

At West Hoyle Bank in order to allow the laying of the cable directly across the feature, a dredged channel will be necessary. During clearance activities material will be side cast along the c.1,000 m length of channel and backfilled after cable installation. The trench width is expected to be c.21 m in width and c.7 m in depth.

Two representative clearance operations were assessed within the modelling, one relating to the sand waves south of Douglas OP and a second for West Hoyle Bank. The grab sample survey data was used to identify the sediment grading of the two clearance areas. The modelling undertaken to quantify the potential increases in suspended sediment concentration and sedimentation simulated the two different approaches to seabed preparation.

The Particle Tracking (PT) module was utilised for the offshore sand clearance south of Douglas as it had the advantage that it could be used to describe the transport of material released in a specific part of the water column. In this way, the dispersion would not be over-estimated or the corresponding sedimentation under-estimated by the application of a current profile through the water column. Alternatively, the Mud Transport (MT) module was used to describe the sand wave clearance across West Hoyle Bank. This sandbank dries at low water and as such PT is not appropriate for use in flooding and drying area. The MT module despite its name can be used to model both cohesive (mud) and non-cohesive/granular sediments (sand) and therefore is applicable to the sandy sediments of West Hoyle.

1.7.1.1 South of Douglas

The sand waves south of Douglas OP were cleared at rate of 27.71 kg/s along the 10 m wide route across a period of 3 days. The displaced material was released along the channels 100 m and 15 m long in length at the seafloor, accounting for the mechanism of release caused through the use of a mass flow excavator. The redistributed material was classified using the sediment properties identified from the grab sampling undertaken along the route simulated as follows:

- Gravel: 23.2%;
- Coarse sand: 10.3%;
- Medium sand: 44.4%;
- Fine sand: 5.5%; and
- Very fine sand/mud: 16.6%.

Due to the relatively small size of this sand wave clearance operation, maximum suspended sediment concentrations during excavation are restrained to within 200 m of the seabed release with a peak value of c.1400 mg/l at the point of mobilisation. The finer sediments that remain suspended and carried further in the tidal ellipsis shows maximum concentrations of <100 mg/l. Average SSC values during excavation, as shown in Figure 1.58, are limited to <100 mg/l and are constrained to the location's tidal ellipse. Plumes extend c.12 km west to within c.500 m of the borders of the physical processes study area, extending a similar distance east, but with little movement north or south.

As shown in Figure 1.59- Figure 1.61, all sedimentation occurs along the c.8 km wide tidal ellipse, with maximum deposition limited to <50 mm within 10 m of the point of excavation and average deposition of <30 mm (peak values of c.14 mm). This represents the larger coarser sediment that is not suspended for as long or carried as far as the finer sands/muds. Figure 1.61 showing sediment deposited one day after the cessation of excavation presents the sediment that settles at slack water, with values again limited to <30 mm.

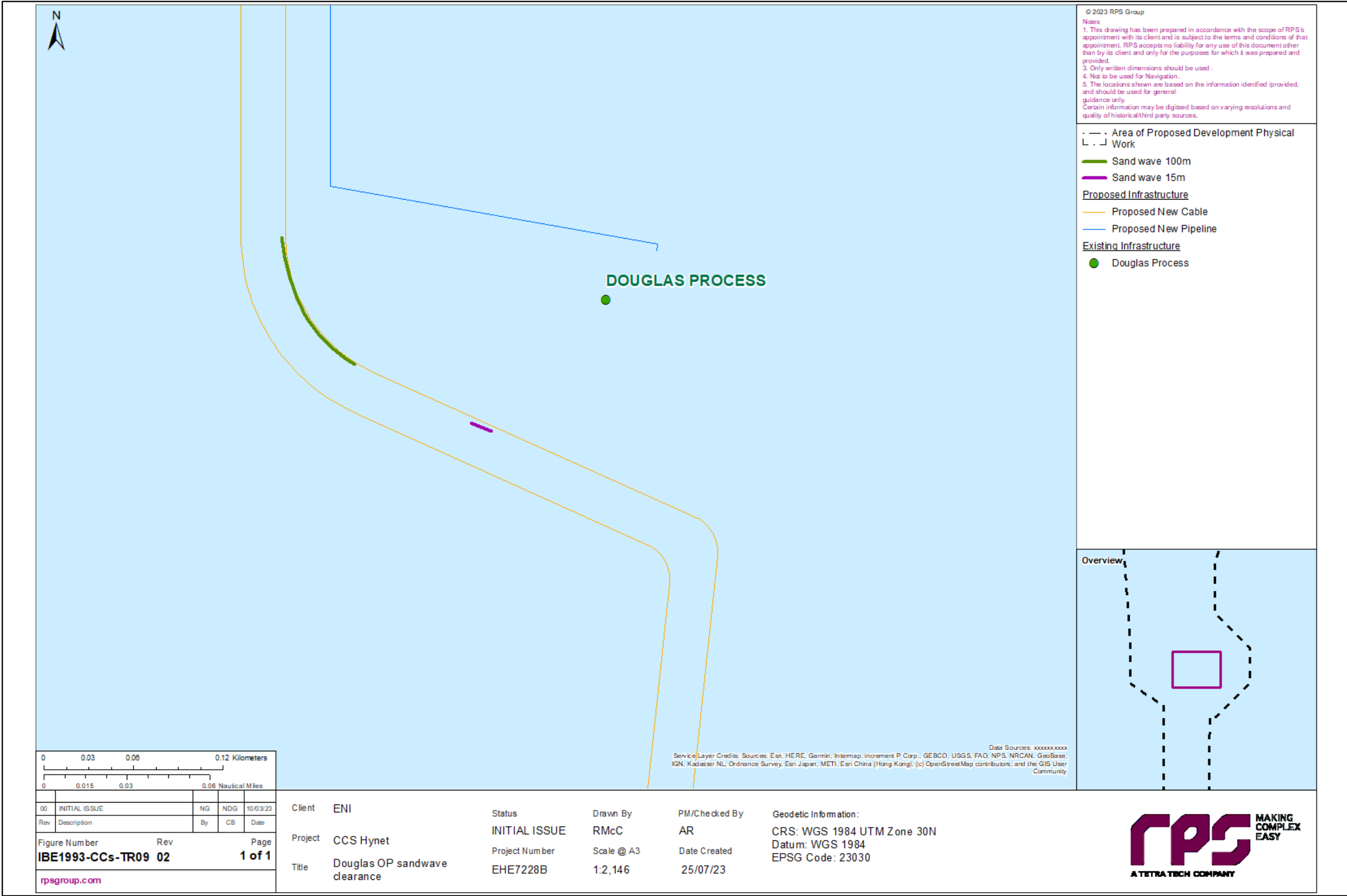


Figure 1.56: Modelled Paths For Sand Wave Clearance South Of Douglas OP

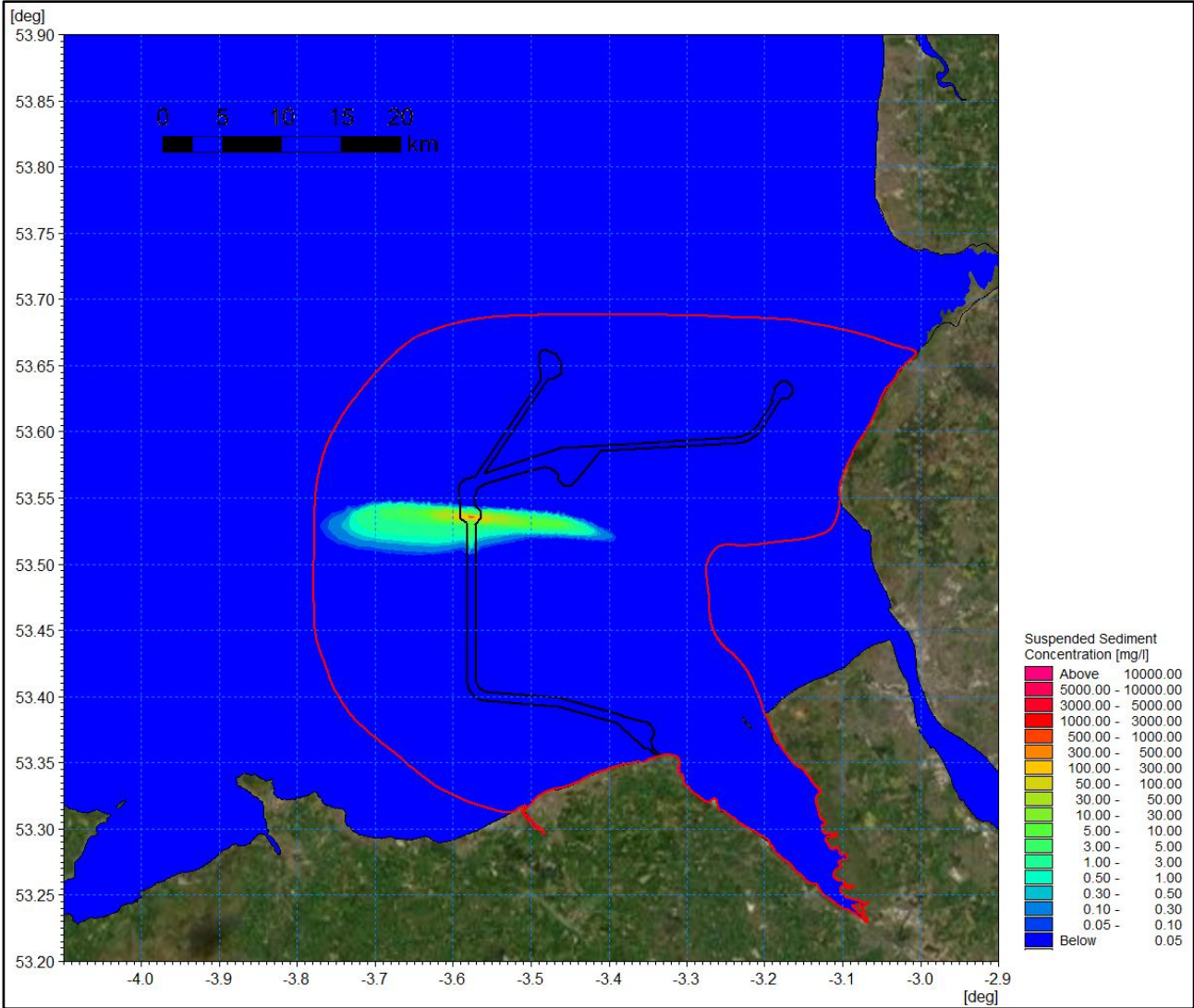


Figure 1.57: Maximum Suspended Sediment Concentration Over Excavation Phase – South Of Douglas

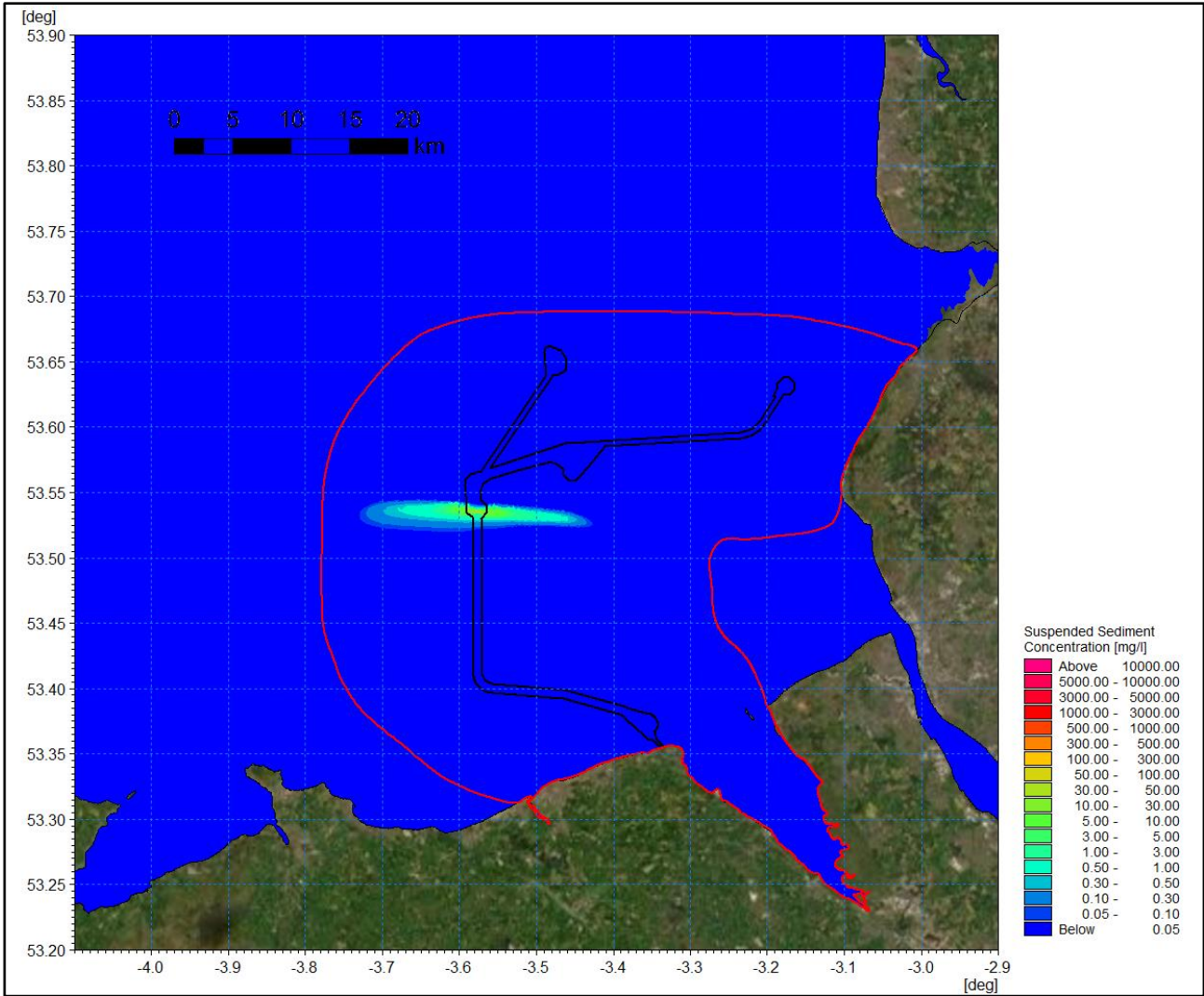


Figure 1.58: Average Suspended Sediment Concentration Over Excavation Phase – South of Douglas

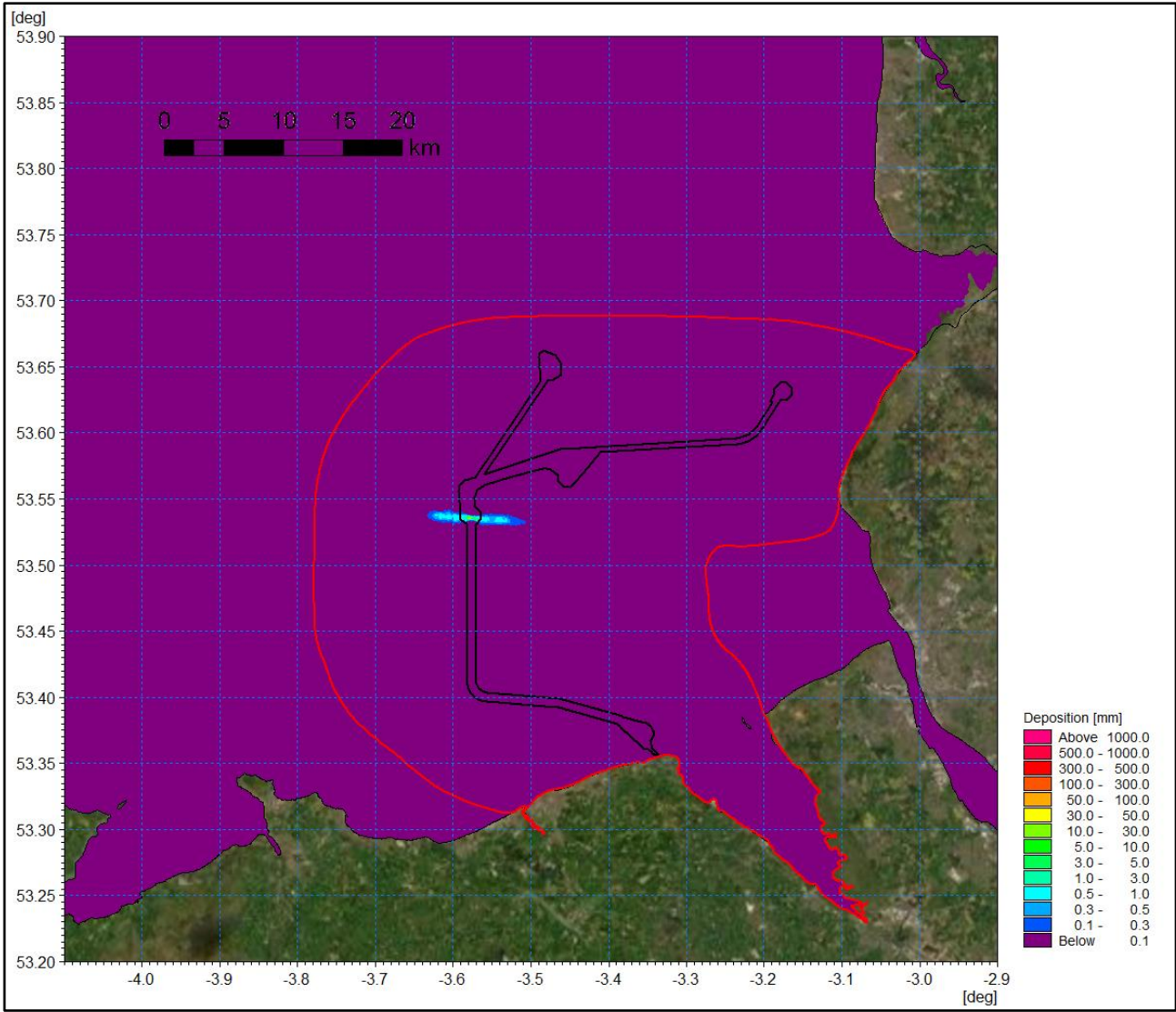


Figure 1.59: Maximum Sedimentation Over Excavation Phase – South of Douglas

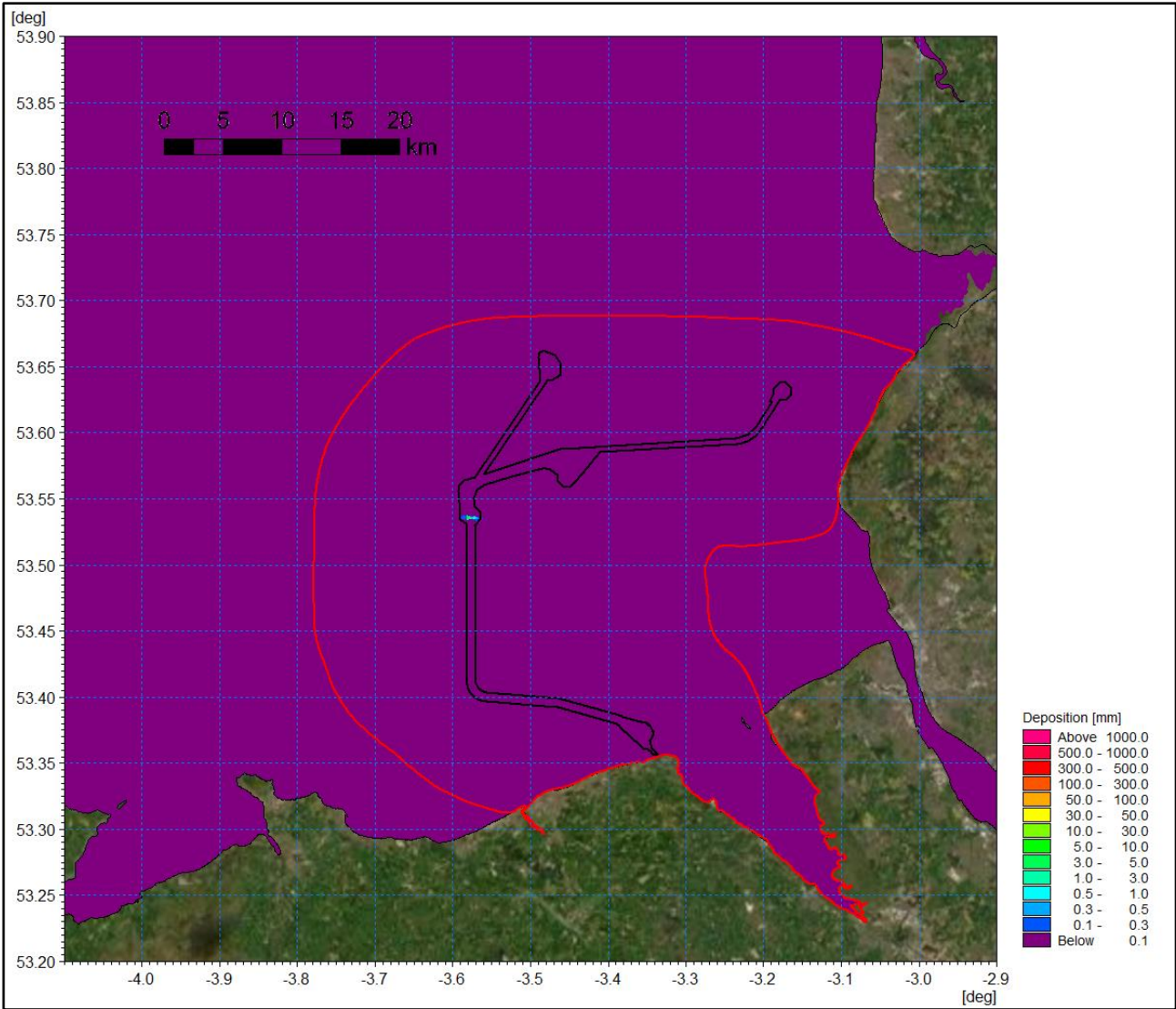


Figure 1.60: Average Sedimentation Over Excavation Phase – South of Douglas

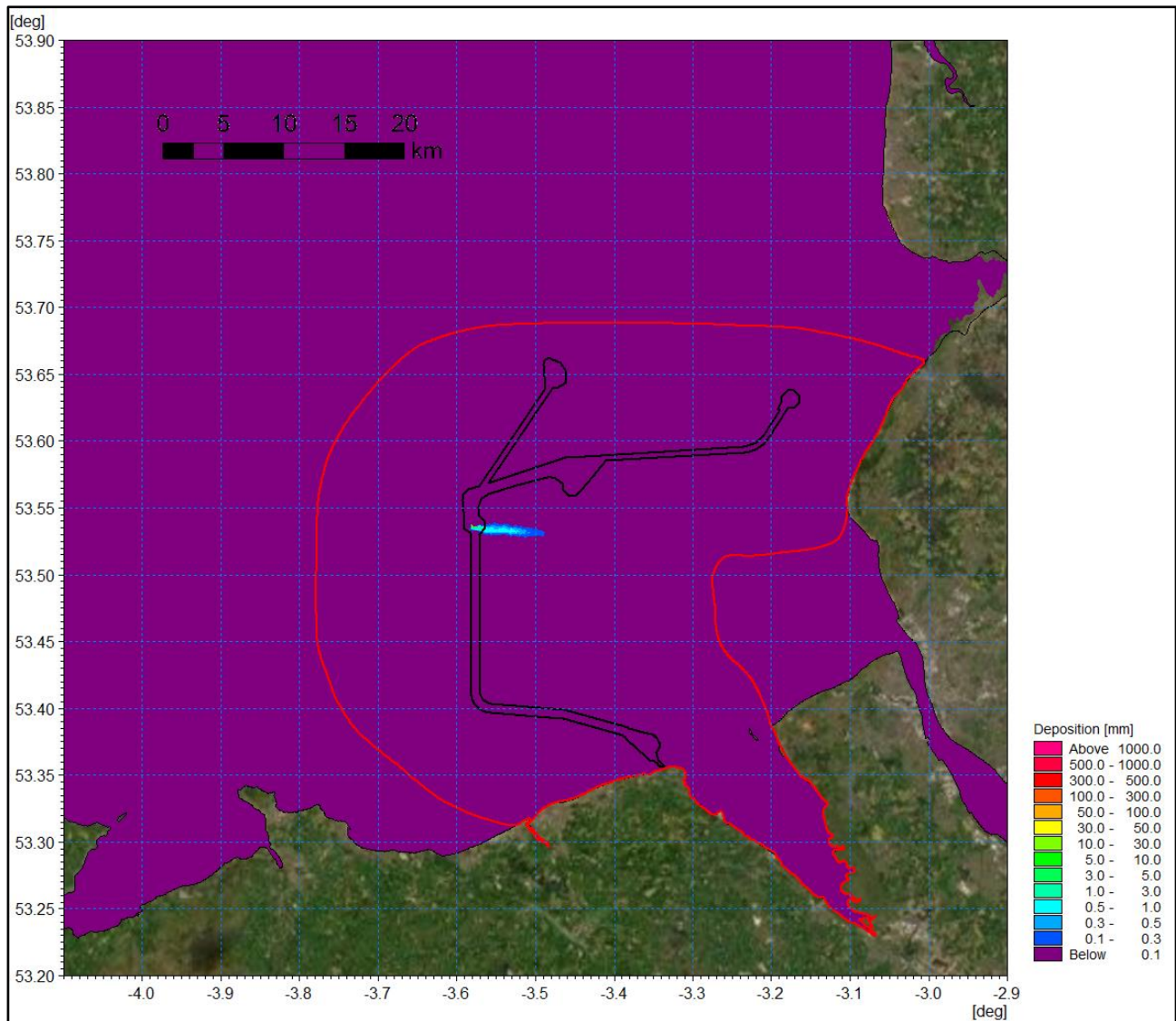


Figure 1.61: Sedimentation One Day After Cessation Of Excavation – South of Douglas

1.7.1.2 West Hoyle Bank

The dredging of a channel through West Hoyle Bank was simulated with a 1 km length with a depth of 7 m and 21 m in width and was modelled with a rate of release of c.295 kg/s uniformly released throughout the water column. The operation took approximately 14 days to complete over a range of tidal conditions. The dredging path through West Hoyle Bank is displayed in Figure 1.62

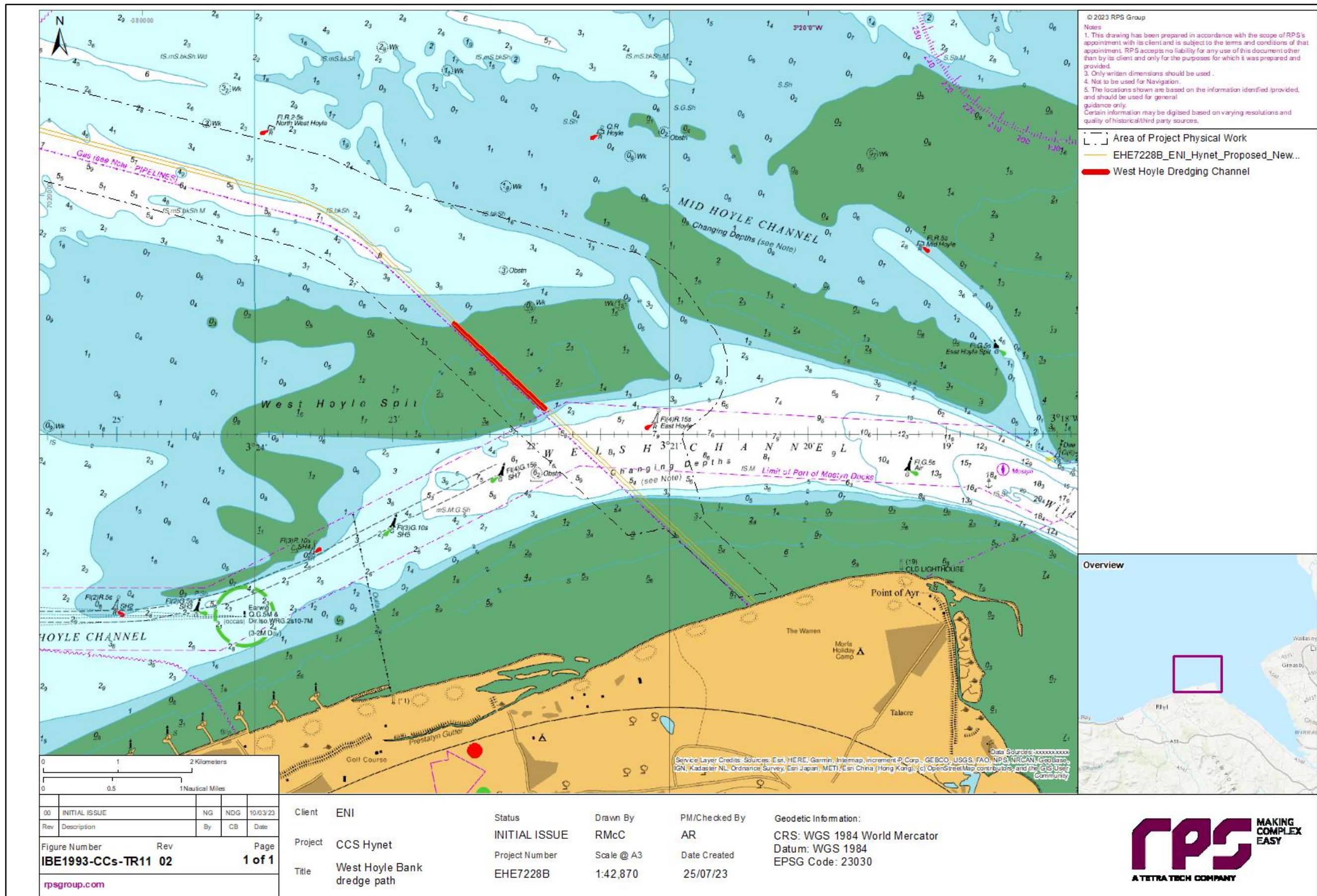


Figure 1.62: Modelled Dredge Path Across West Hoyle Bank

The redistributed material was classified using the properties identified from the grab sampling undertaken along the route simulated.

- Gravel: 0.0%;
- Coarse sand: 2.5%;
- Medium sand: 53.2%;
- Fine sand: 44.3%; and
- Very fine sand/mud: 0.0%.

As shown by Figure 1.63 and Figure 1.64, suspended sediments during dredging are concentrated around the dredge path and the coastline at the mouth of the Dee Estuary, with maximum plume extents reaching 25 km southeast to the mouth of the River Dee. Maximum SSC values in excess of 300 g/l occur along the dredging route itself, to a peak of c.320 g/l, reflecting the shallow water depths. Concentrations are seen to be generally greater inshore where water depths are shallower. Along the western coast of the Dee Estuary maximum values can fall within the range of 3,000 mg/l to 10,000 mg/l however in most areas fall below 30 mg/l. SSC values that either border or in exceptional cases, exit the physical processes study area, have concentrations limited to <1 mg/l. Where the plume exits the physical processes study area on its eastern border it does so by <500 m. Average concentrations along the dredge route are limited to <3,000 mg/l, whereas concentrations are generally <10 mg/l in the development area, and <3 mg/l in the wider physical processes study area.

The sedimentation figures shown in Figure 1.65 - Figure 1.67, demonstrate that all sedimentation occurs within the physical processes study area, with maximum values of c.5 m adjacent to the dredged channel, as to be expected with the volume of material sidecast. Average sedimentation values outside of the dredge path are generally limited to <50 mm, and <10 mm outside of the area of development area. The average deposition shown in Figure 1.66, presents sedimentation at negligible depths 8 km into the mouth of the Dee Estuary. Sedimentation one day after the cessation of dredging activity further demonstrates that deposited material is focussed in close proximity to the dredge path, beyond which deposition is generally below <100 mm.

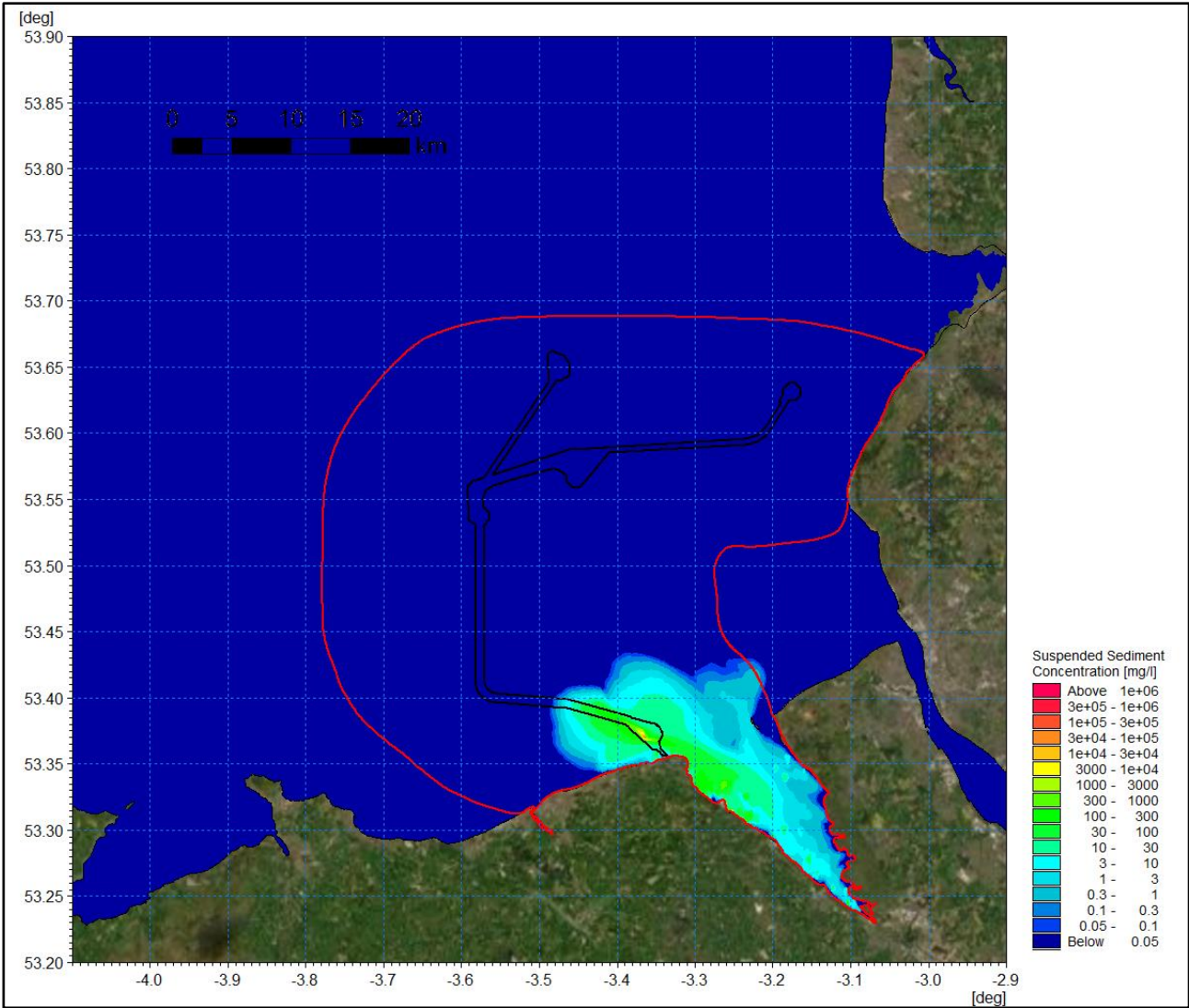


Figure 1.63: Maximum Suspended Sediment Concentration Over Dredging Phase – West Hoyle Bank

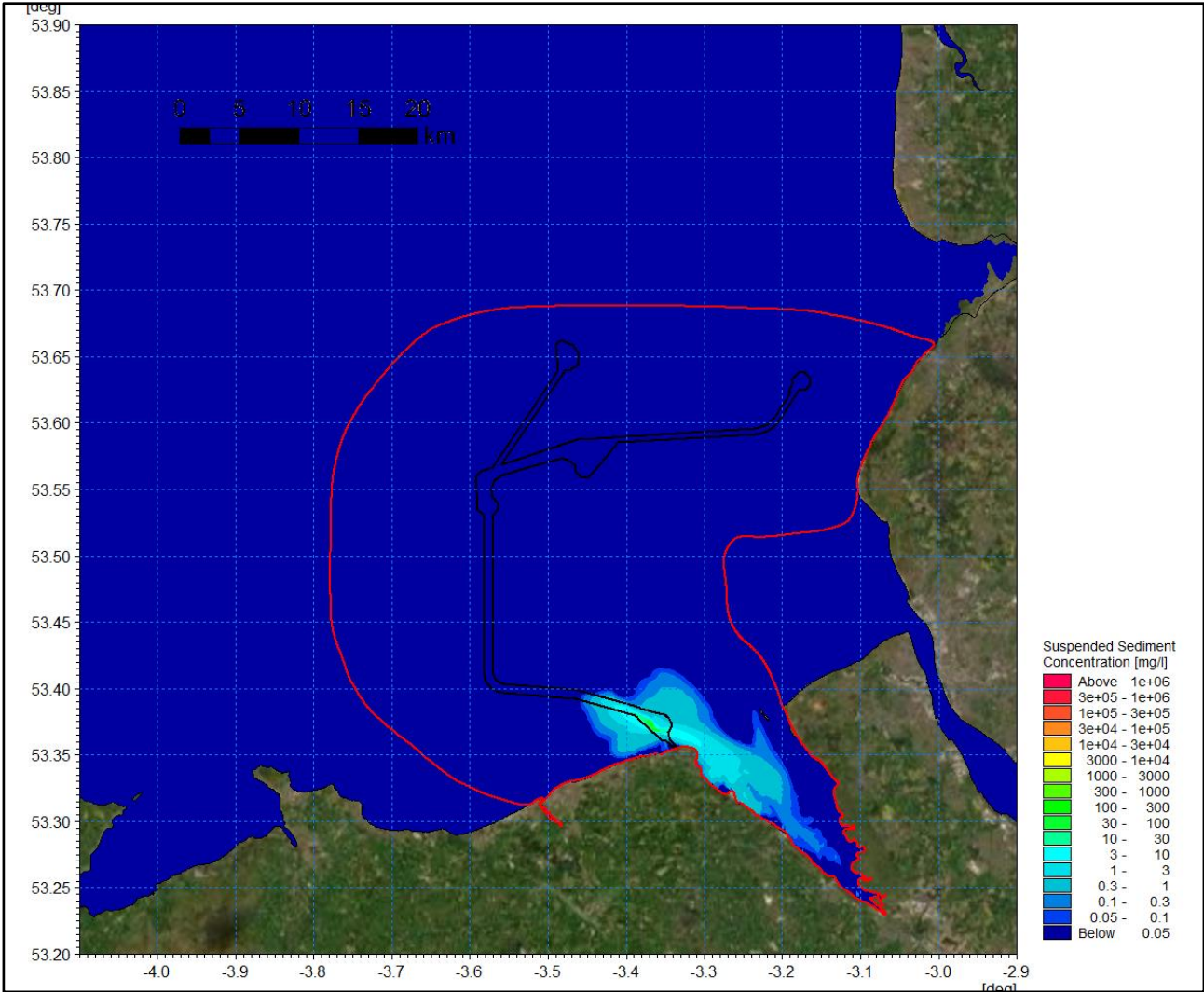


Figure 1.64: Average Suspended Sediment Concentration Over Dredging phase – West Hoyle Bank

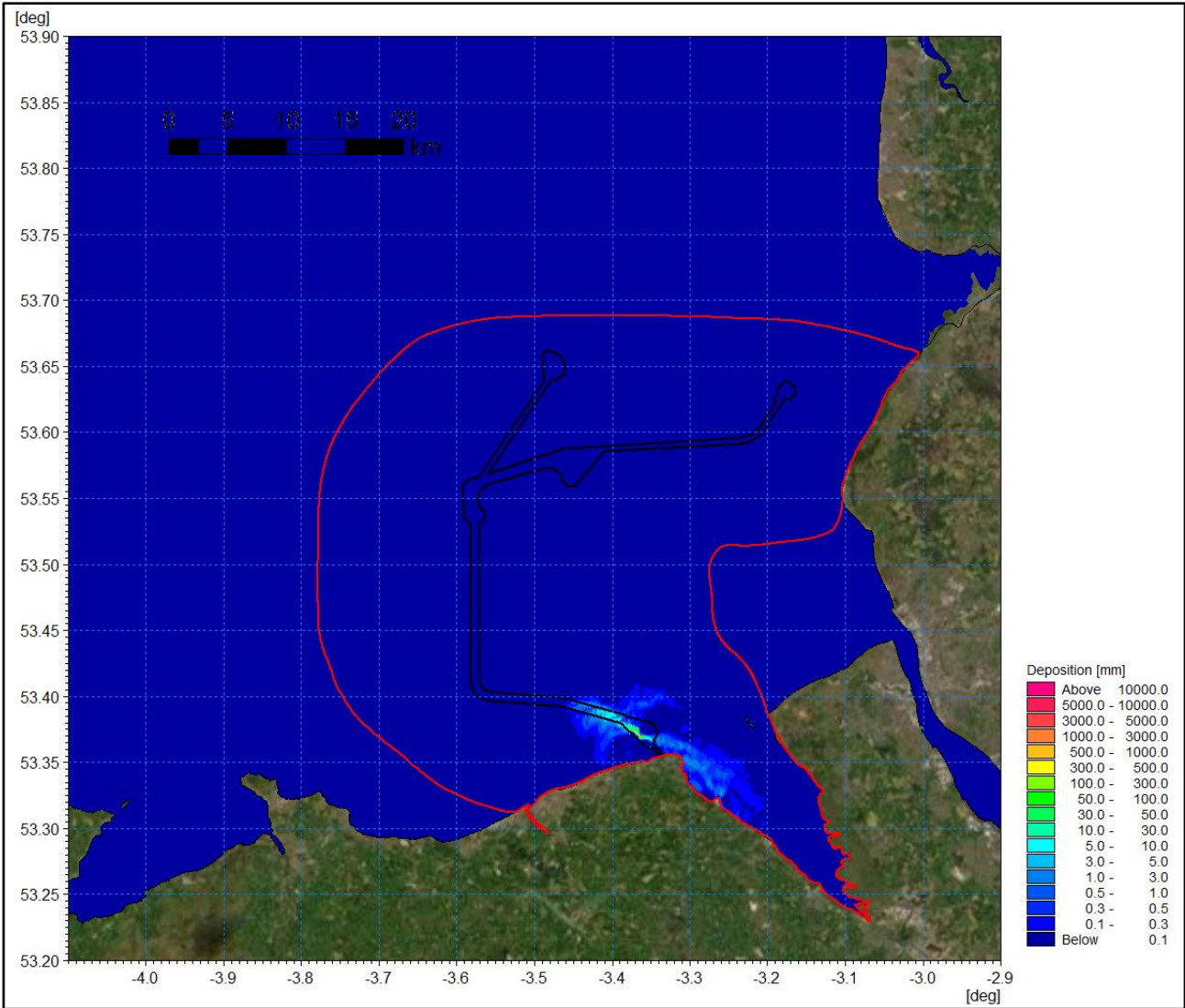


Figure 1.65: Maximum Sedimentation Over Dredging Phase – West Hoyle Bank

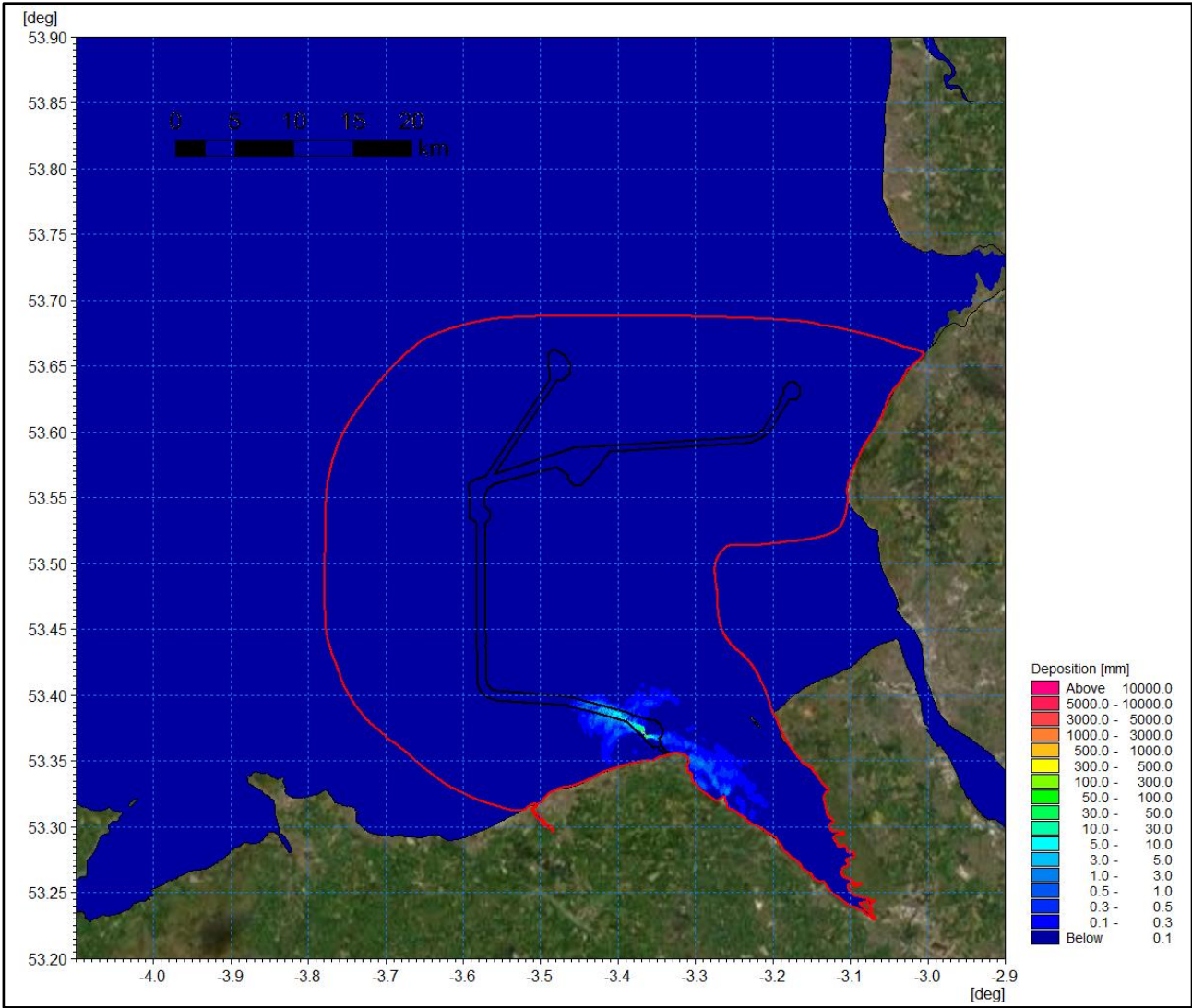


Figure 1.66: Average Sedimentation Over Dredging Phase – West Hoyle Bank

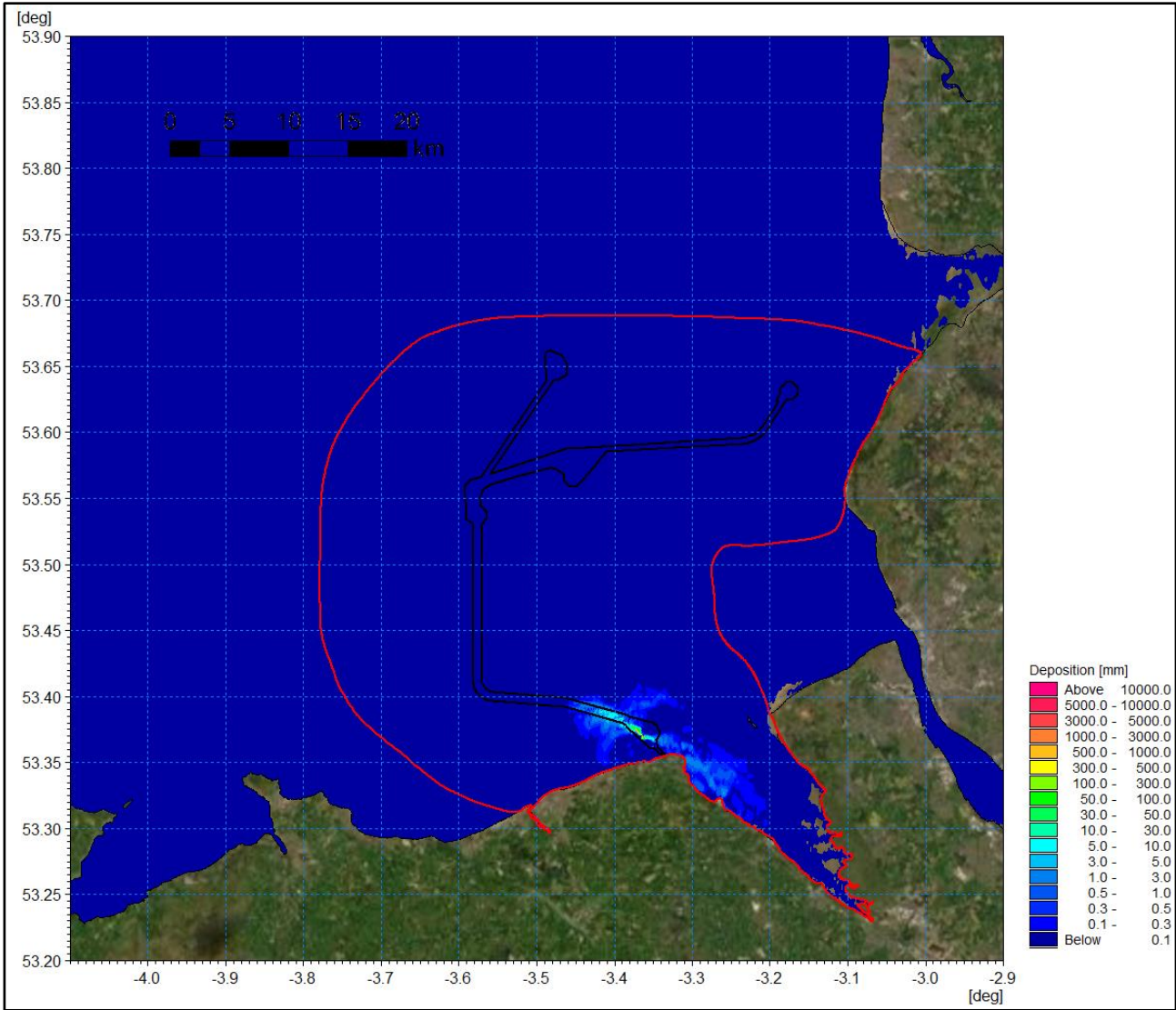


Figure 1.67: Sedimentation One Day After Cessation Of Dredging – West Hoyle Bank

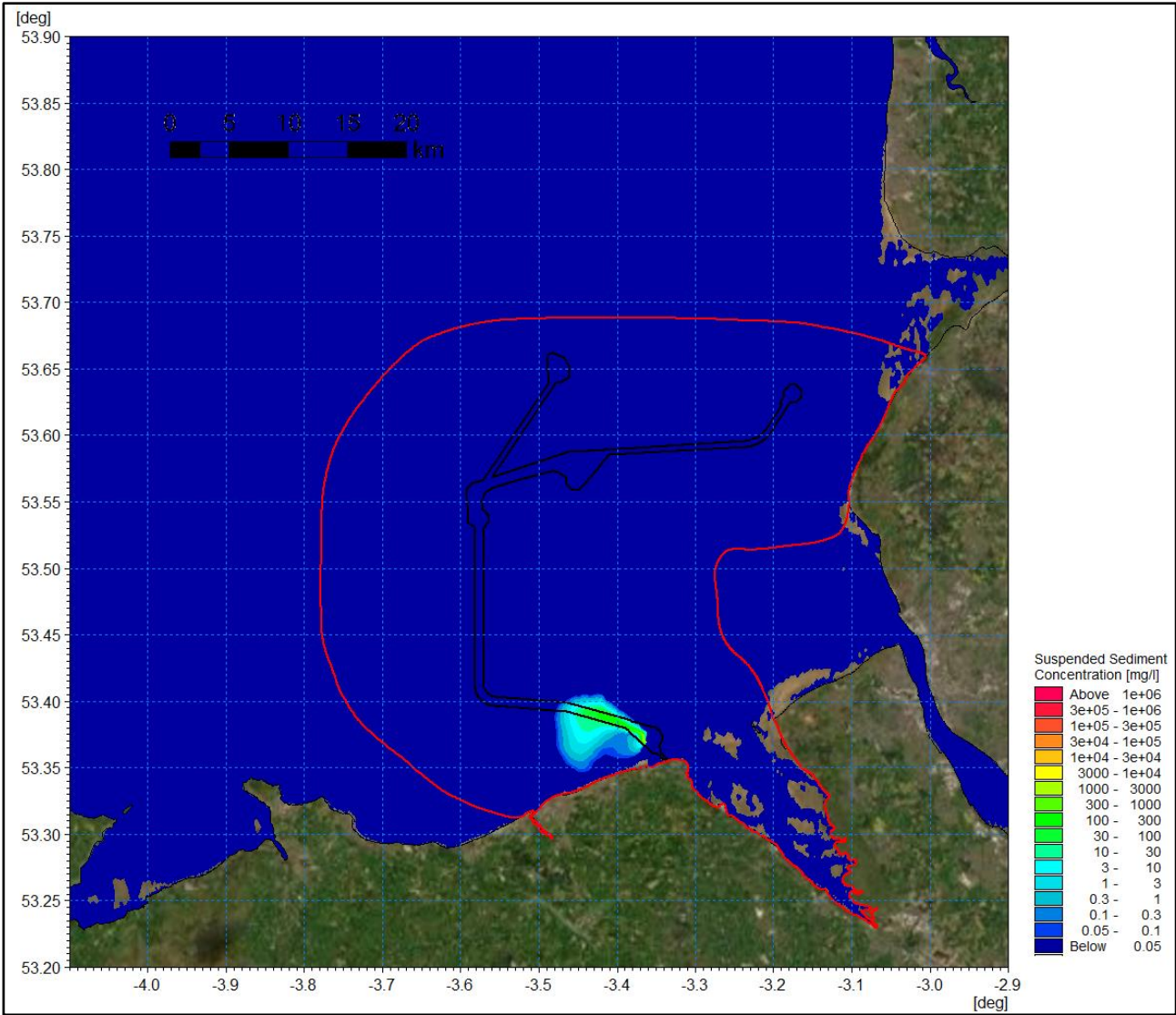


Figure 1.68: Suspended Sediment Concentration Day 1 Ebb – West Hoyle Bank

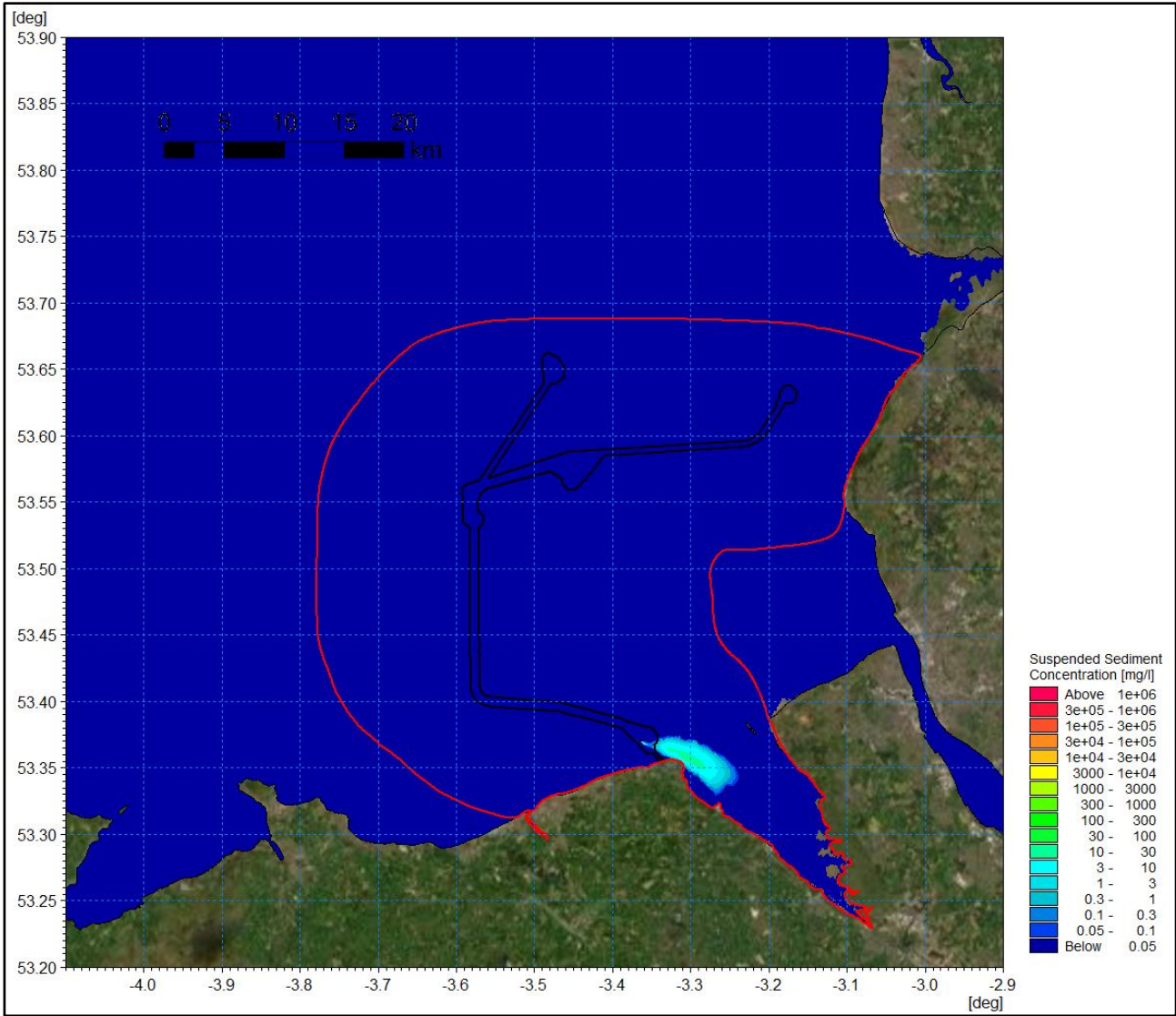


Figure 1.69: Suspended Sediment Concentration Day 1 Flood – West Hoyle Bank

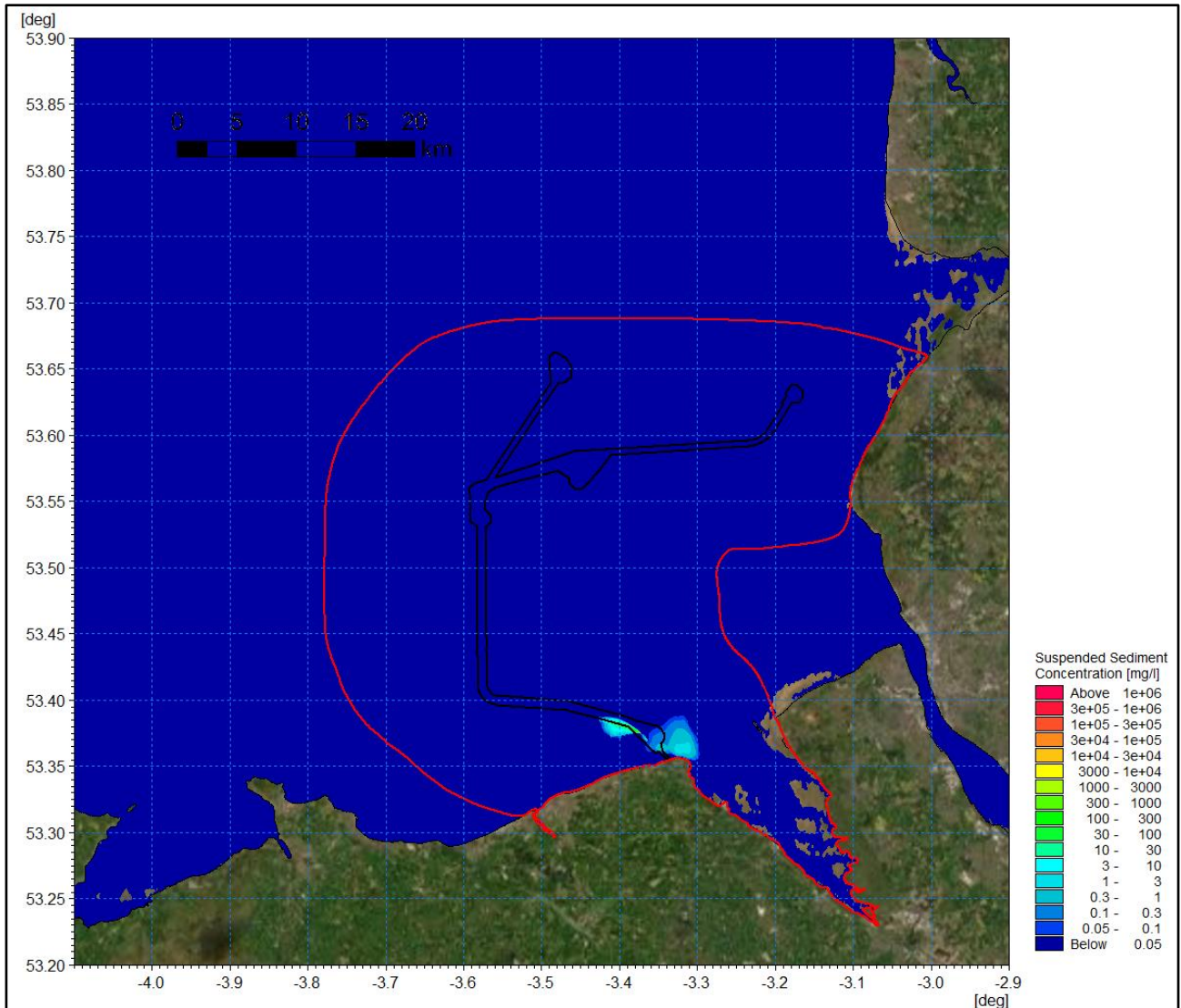


Figure 1.70: Suspended Sediment Concentration Final Day Ebb – West Hoyle Bank

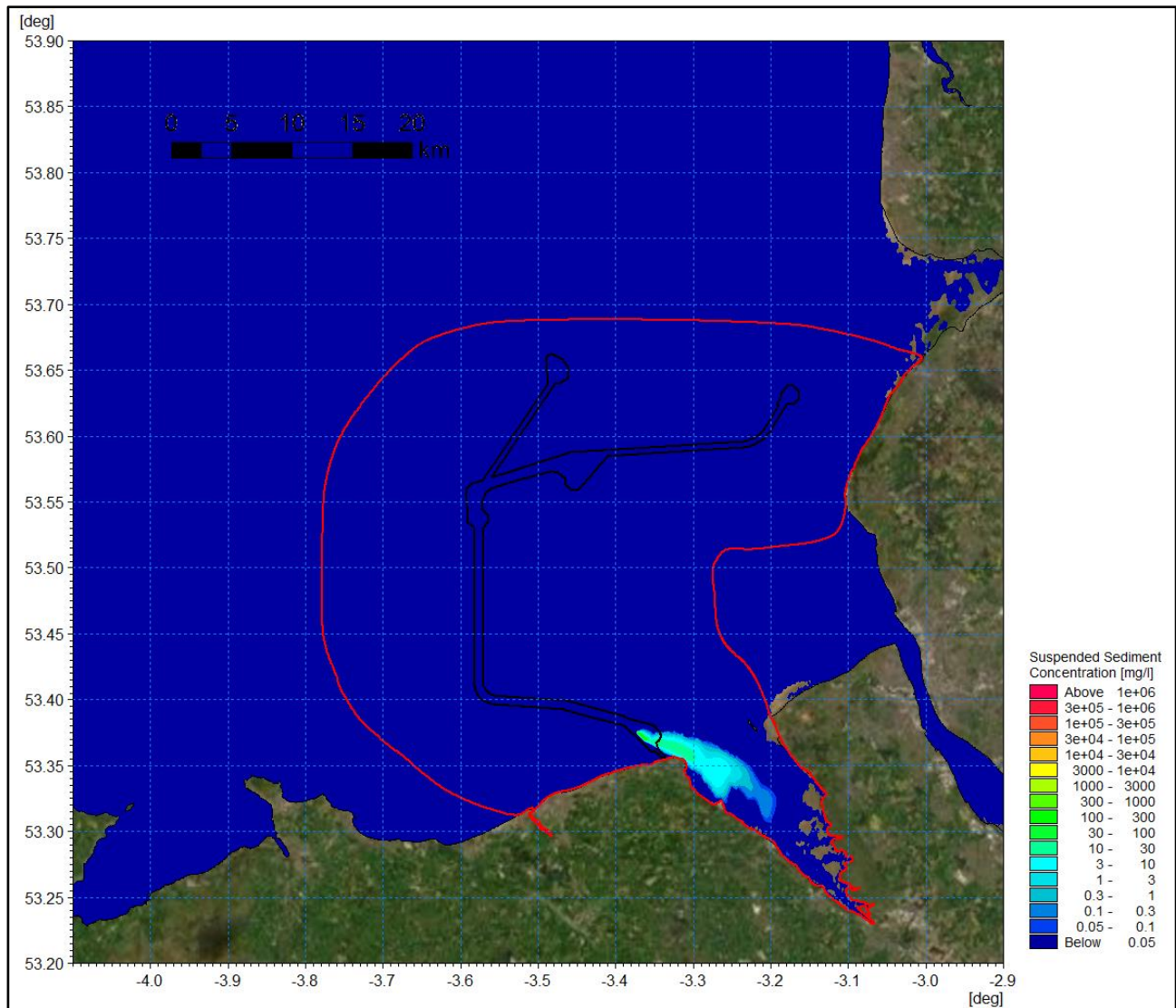


Figure 1.71: Suspended Sediment Concentration Final Day Flood – West Hoyle Bank

1.7.2 Drill cuttings

The Project design envelope presented in volume 1, chapter 3 includes for the drilling of two new monitoring wells situated at Hamilton Main and Hamilton North, locations shown in Figure 1.72. Both wells require the drilling of two sections the first of which is a 26" opening in which the 20" conductor will be encased, and a second and deeper 17" section. The first section will involve penetration of the surface sand and silt layer and then the use of seawater and sweeps drilling to penetrate the coarser Mercia Mudstone Group below. The first section will see the clearance of c.30.48 m of sand and silt and the drilling of c.84.43 m of coarser sediment. The second section will be drilled with water-based mud and will also penetrate through the Mercia Mudstone Group, which is largely composed of claystone, over a vertical length of c.518.16 m. Both lengths of the 26" and 17" holes have been modelled with an assumed 100% washout, (i.e. twice the volume of the cavity is released as cuttings). The rate of drilling for both wells was 40 m/h with the individual operations taking approximately 16 hours each. Given both wells are positioned offshore and involve releases at a number of locations in the water column the PT module was implemented.

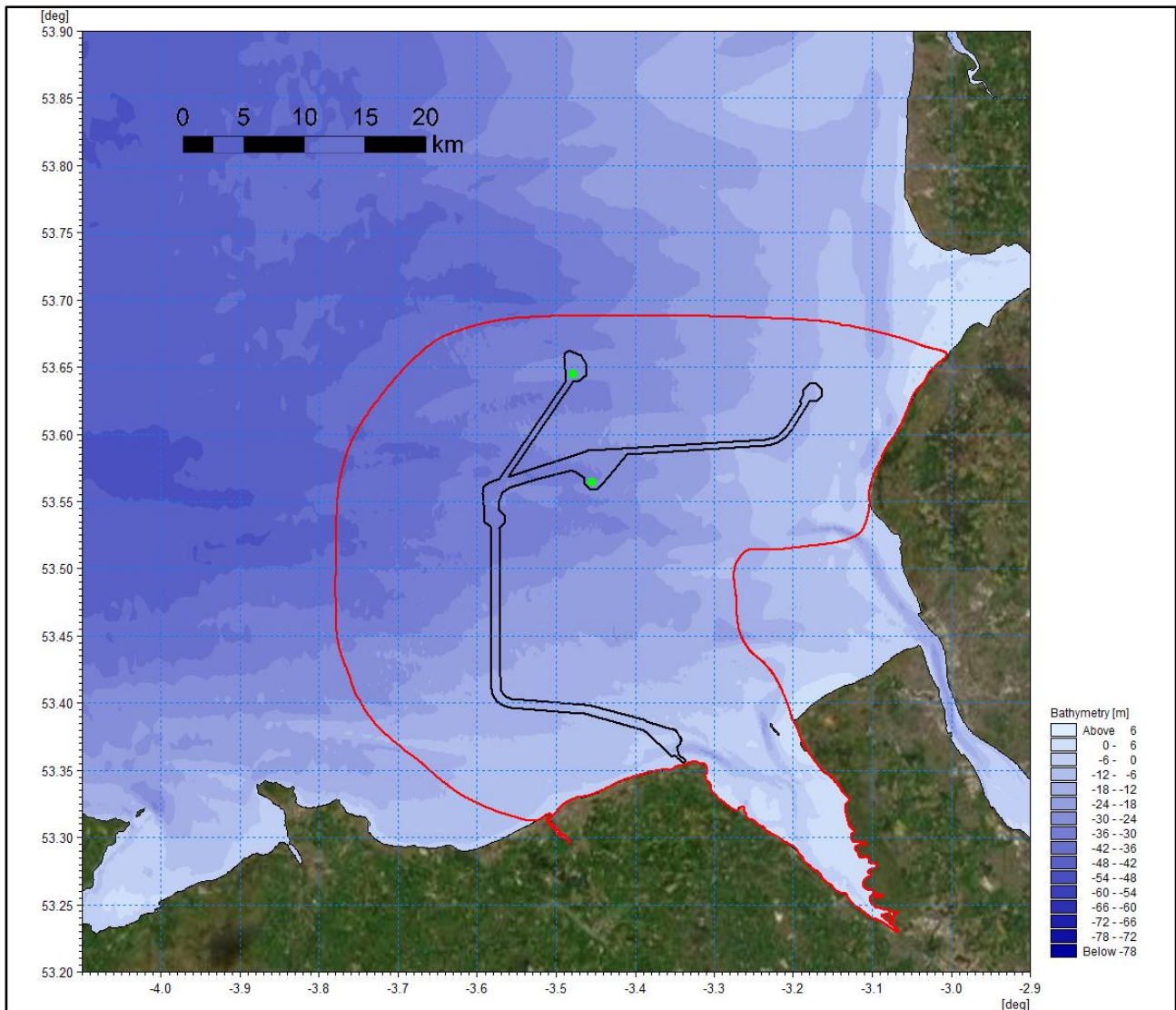


Figure 1.72: Modelled Drilling Locations

1.7.2.1 Hamilton Main

The sediment composition at the Hamilton Main location is comprised of mixed sediments with a sediment grading as follows implemented in the simulation:

- Gravel: 7.7%;
- Coarse sand: 29.3%;
- Medium sand: 31.5%;
- Fine sand: 17.5%; and
- Very fine sand/mud: 14.0%.

The maximum suspended sediment concentrations (SSC) and average SSC plots are shown in Figure 1.73 and Figure 1.74 respectively. Maximum concentrations across the plume can rise in excess of 300 mg/l to a peak of c.360 mg/l, however maximum concentrations are generally limited to <20 mg/l. The extents of the plume reach c.8 km to the east and west following the tidal ellipse, with concentrations within background level

range (as described in Section 0) along its extremities. The average concentrations are typically <30 mg/l at the drill site and reduce rapidly with distance from the discharge location.

Figure 1.75 and Figure 1.76 showing maximum and average sedimentation during the drilling phase demonstrate that sediment is retained within the sediment cell and settles along the length of the tidal ellipse. It is evident that the greatest sedimentation depths occur at the drilling site itself with localised values of up to c.70 mm occurring within c.50 m of the site. Average deposition across the area can be up to c.30 mm at the drill site but is generally less than a tenth of a millimetre across the tidal ellipse. Analysis of sedimentation 1 day after cessation of drilling activities, as displayed in Figure 1.77, shows the sediment can stay suspended for a considerable time before it finally settles; this would relate to the fine drilling mud fraction. As seen in the figure, around the drill site deposition values can be in excess of 50 mm however a vast majority of deposition due to released sediment is under 0.03 mm. This is explained by the coarser material remaining at the drill site whilst the finer mud particles are dispersed with residual currents.

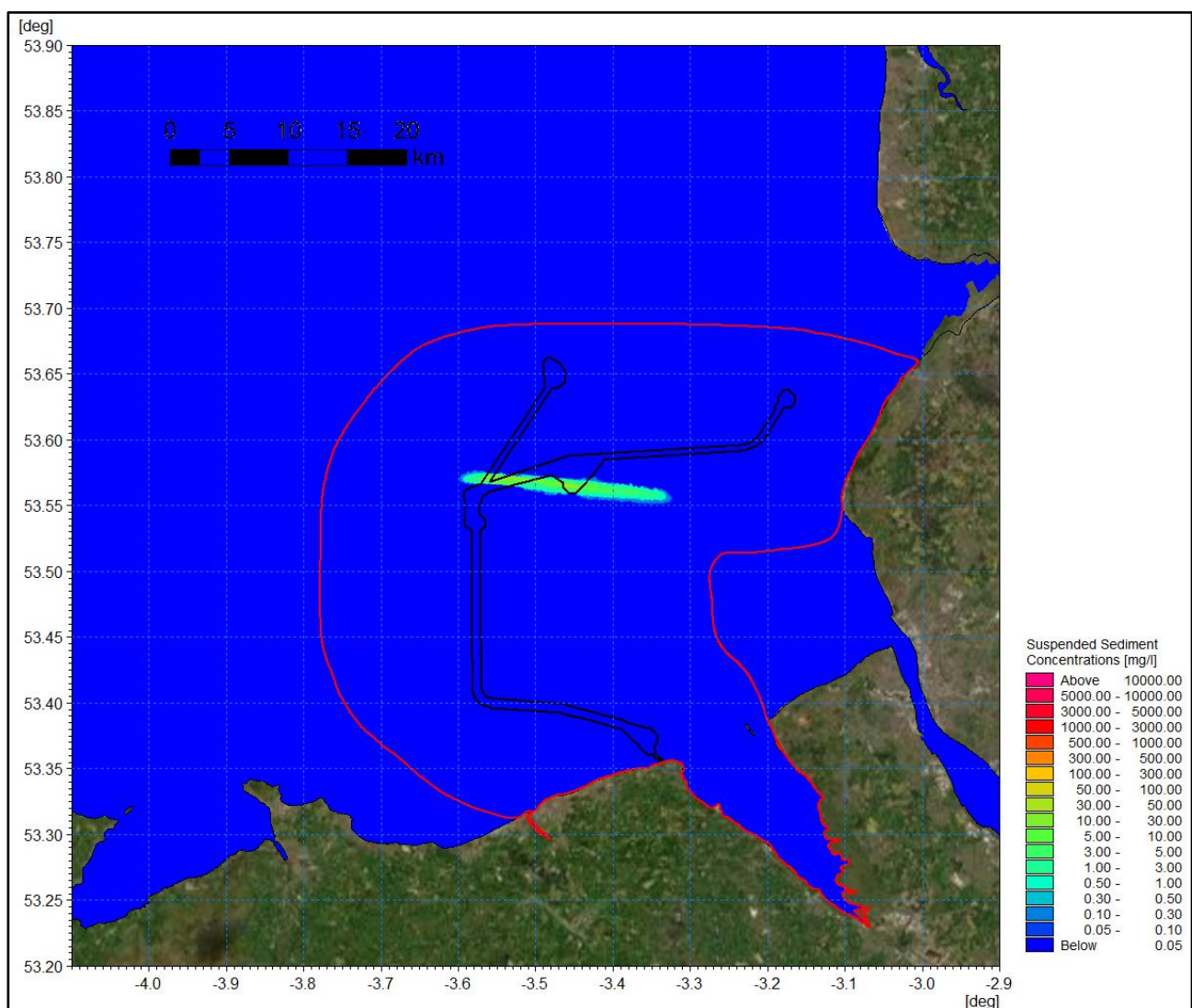


Figure 1.73: Maximum Suspended Sediment Concentration Over Drilling Phase - Hamilton Main

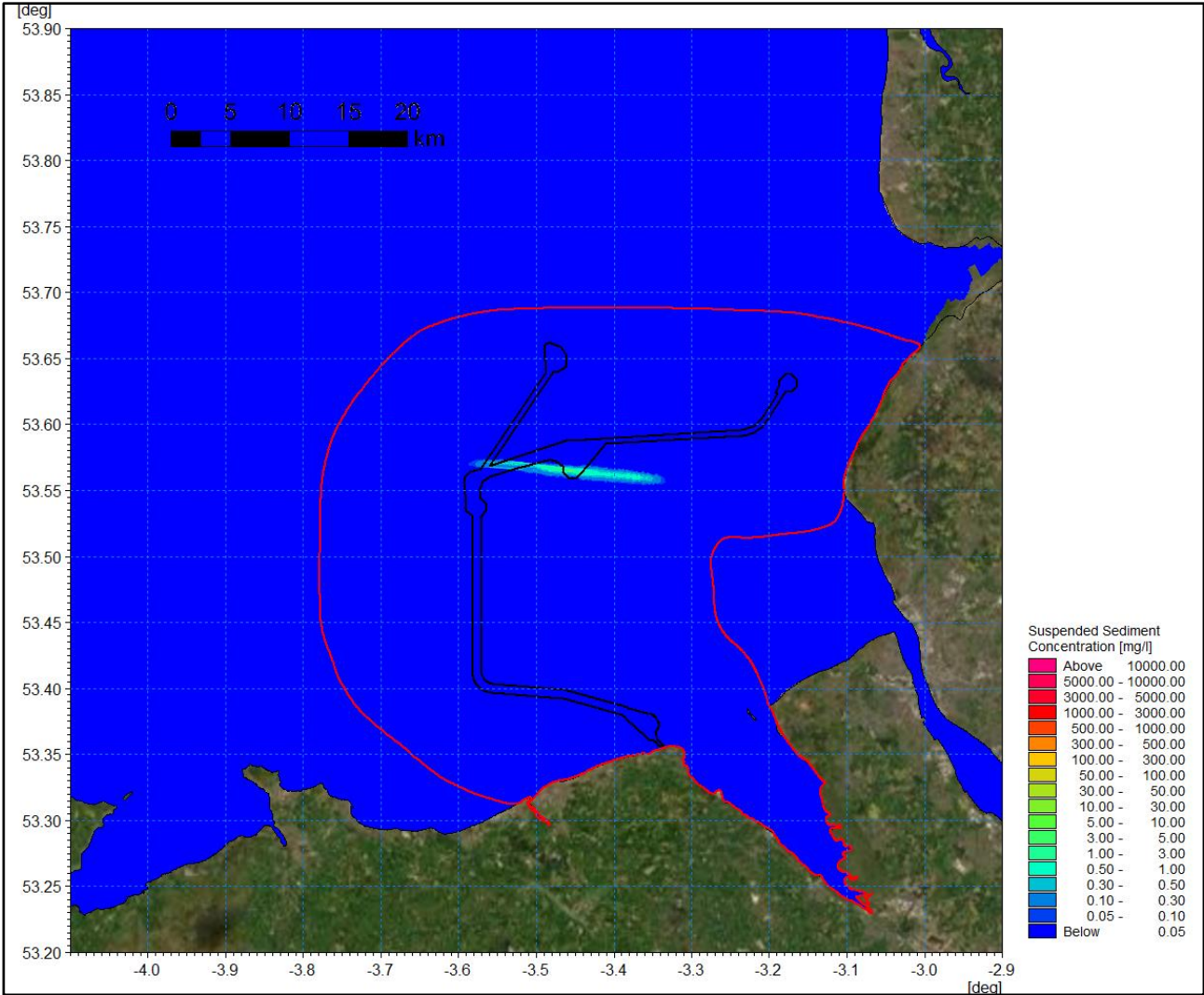


Figure 1.74: Average Suspended Sediment Concentration Over Drilling Phase - Hamilton Main

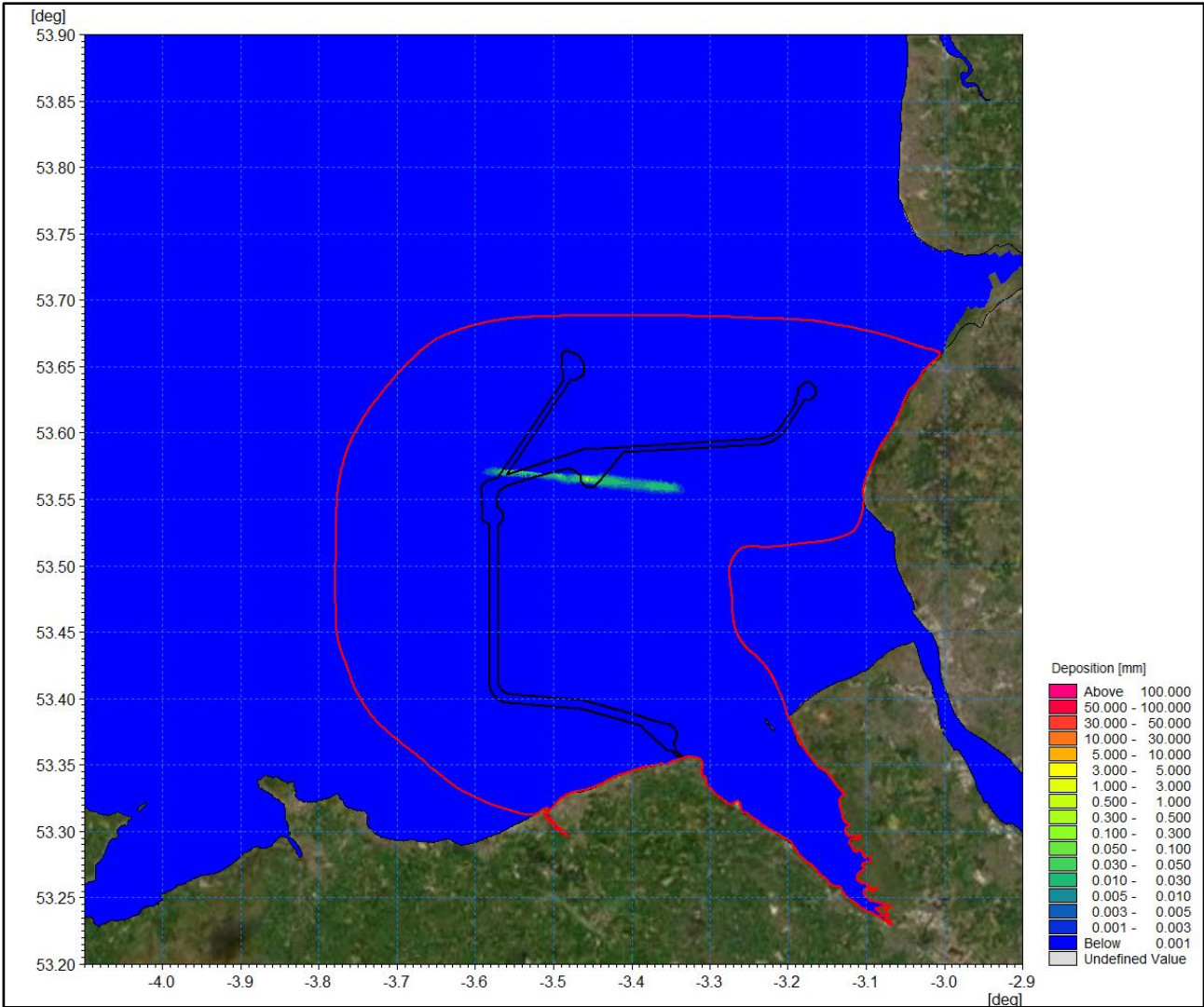


Figure 1.75: Maximum Sedimentation Over Drilling Phase - Hamilton Main

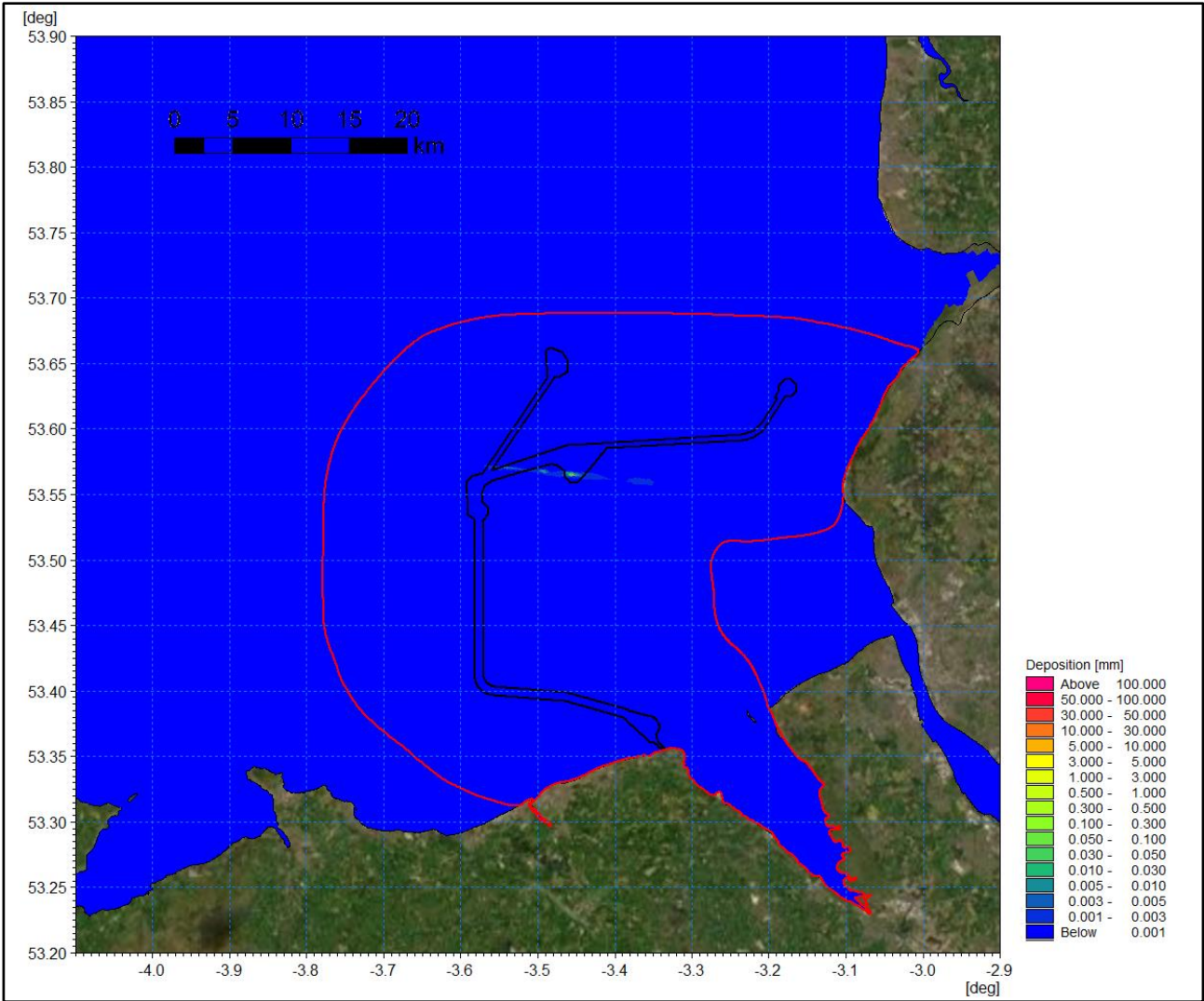


Figure 1.76: Average Sedimentation Over Drilling Phase - Hamilton Main

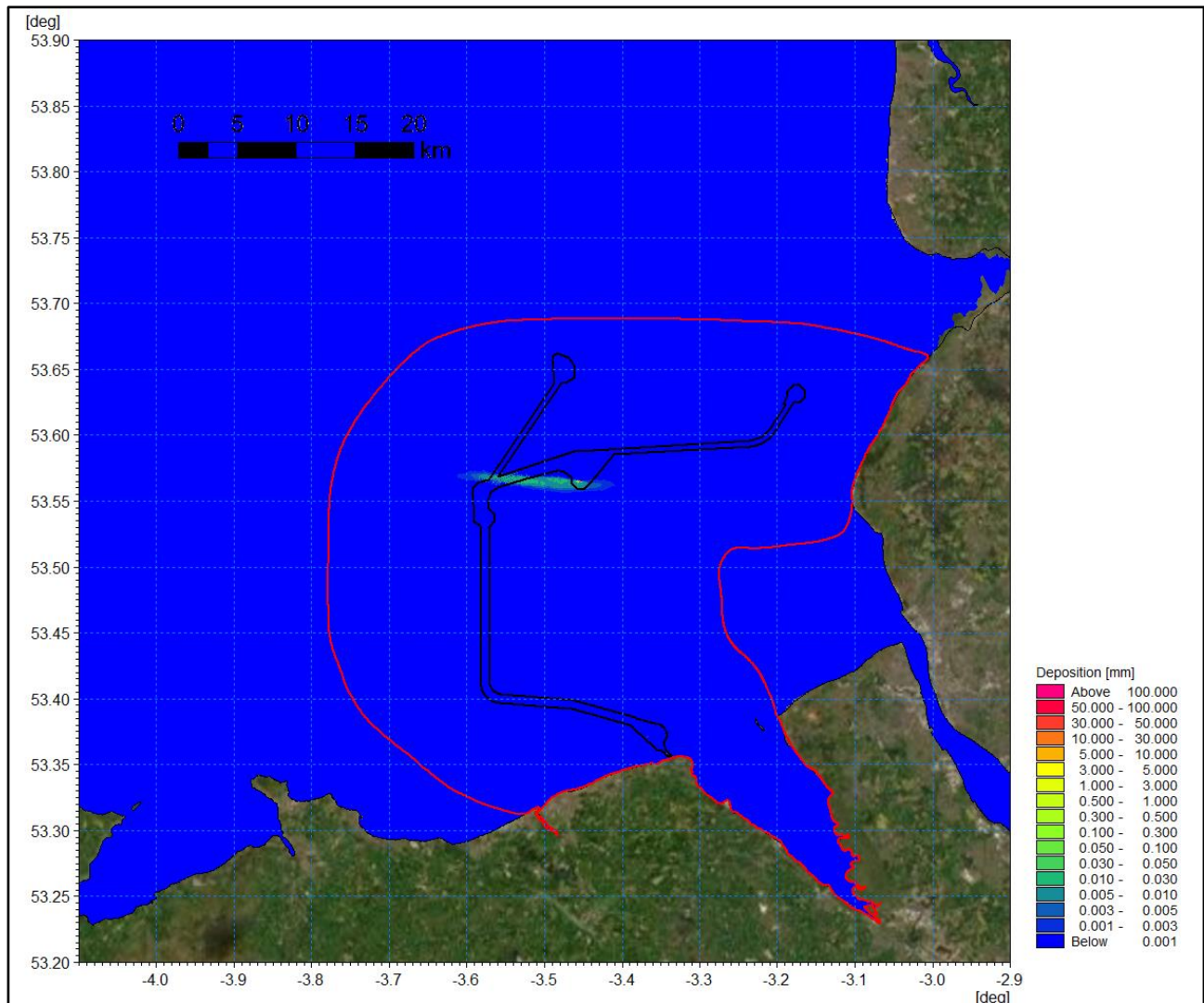


Figure 1.77: Sedimentation One Day After Cessation Of Drilling - Hamilton Main

1.7.2.2 Hamilton North

The sediment composition at the Hamilton North location is comprised of predominantly sandy sediment with a sediment grading as follows which was implemented in the simulation:

- Gravel: 0.2%;
- Coarse sand: 20.3%;
- Medium sand: 59.7%;
- Fine sand: 17.7%; and
- Very fine sand/mud: 2.1%.

Suspended sediment plumes are presented for Hamilton North in Figure 1.78 and Figure 1.79. SSC concentrations remain similar to those of Hamilton Main, with a similar sized maximum plume c.8 km east and west, with slightly more dispersion north and south (c.2 km from the drill site). Maximum suspended sediment concentrations are limited to 500 mg/l in the direct vicinity of the drill site and are generally less than 5 mg/l

across the rest of the plume envelope. Mean concentrations around the drill site are <30 mg/l and further from the source <0.3 mg/l.

Maximum and mean sedimentation during the drilling phase is presented in Figure 1.80 and Figure 1.81. As with Hamilton Main the coarse sediment released directly at the seafloor during drilling remains by the drill site, with maximum deposition values of c.100 mm within c.50 m of the site. Mean sedimentation across the drill site is for the most part contained in a c.500 m radius from the drill site and is limited to <0.1 mm. Again, upon examining sedimentation a day after cessation of drilling activities, as shown in Figure 1.82, it is clear that much of the fine drilling mud remains suspended for a more prolonged period. The figure clearly shows how sediment is deposited along the tidal ellipse, with coarser sediment falling at the drill site and drilling muds dispersed to settle further from the source.

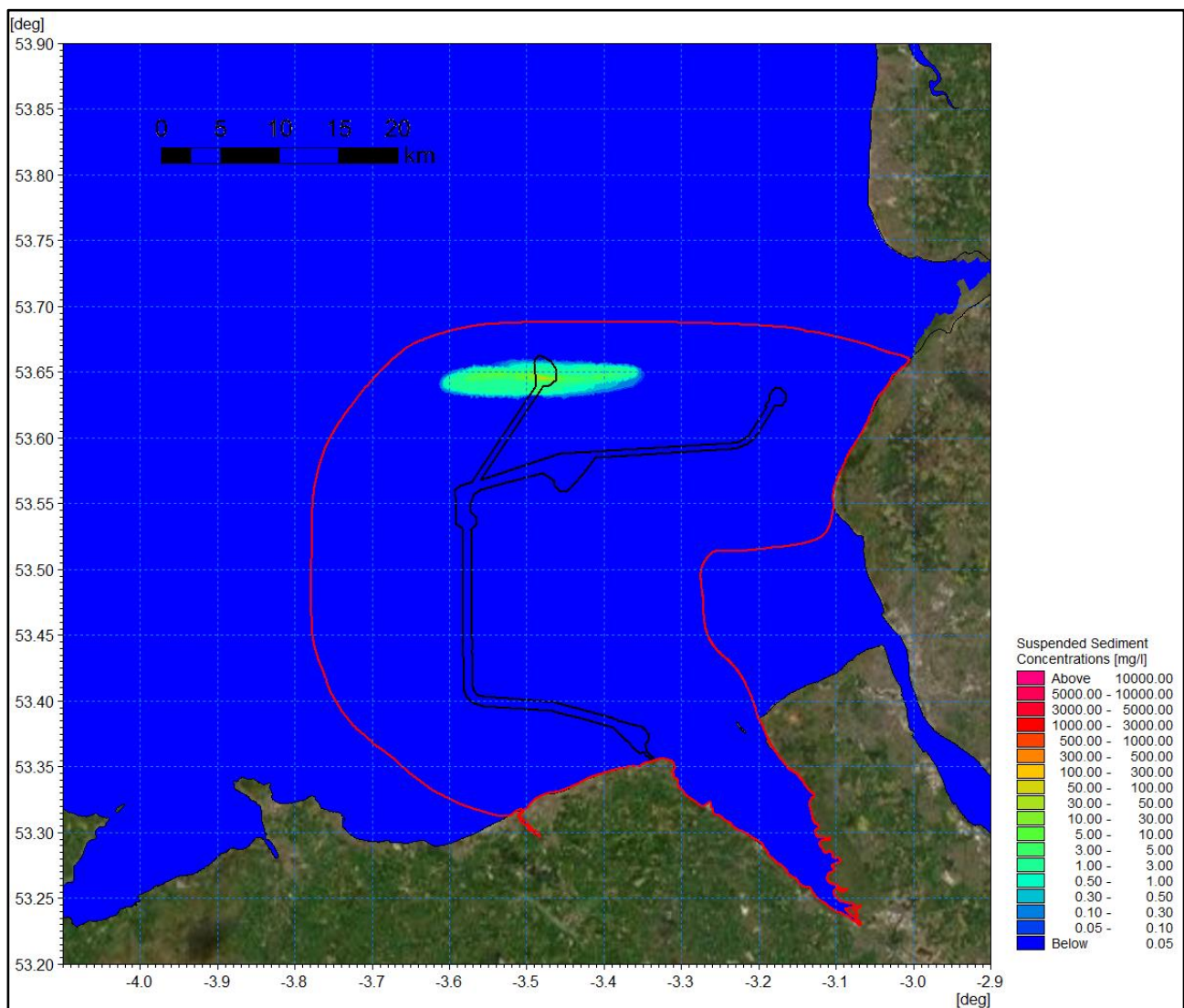


Figure 1.78: Maximum Suspended Sediment Concentration Over Drilling Phase - Hamilton North

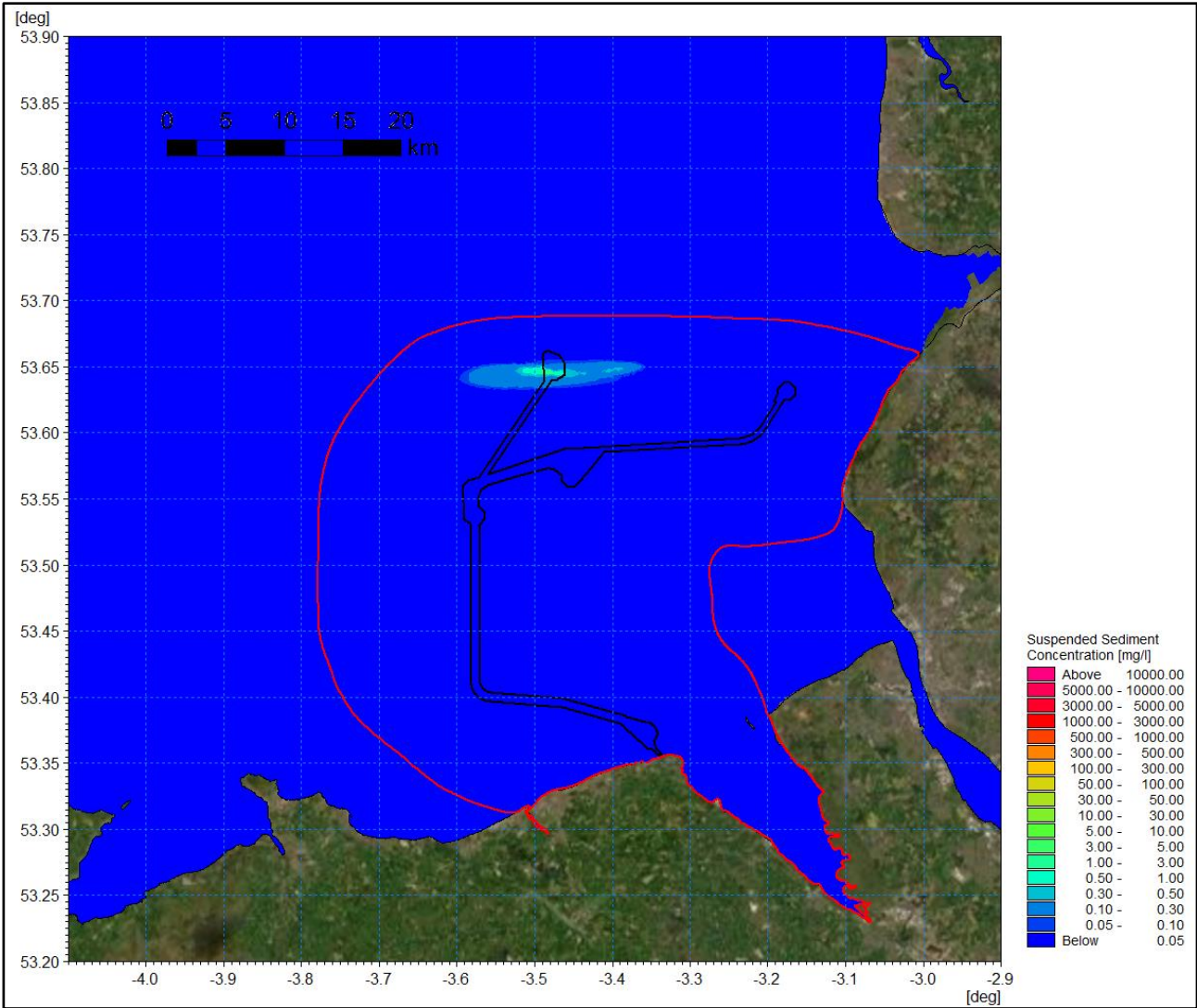


Figure 1.79: Average Suspended Sediment Concentration Over Drilling Phase - Hamilton North

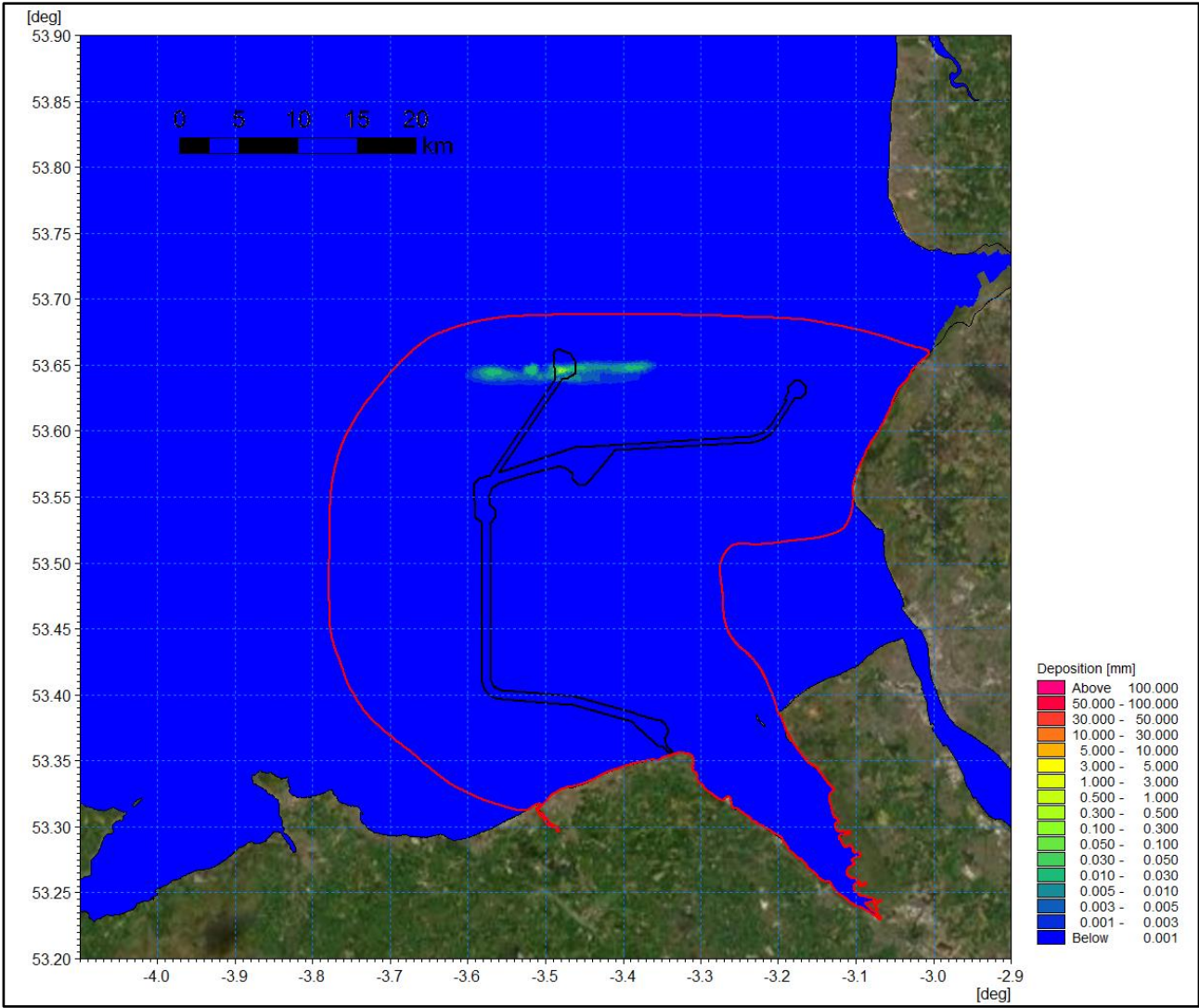


Figure 1.80: Maximum Sedimentation Over Drilling Phase - Hamilton North

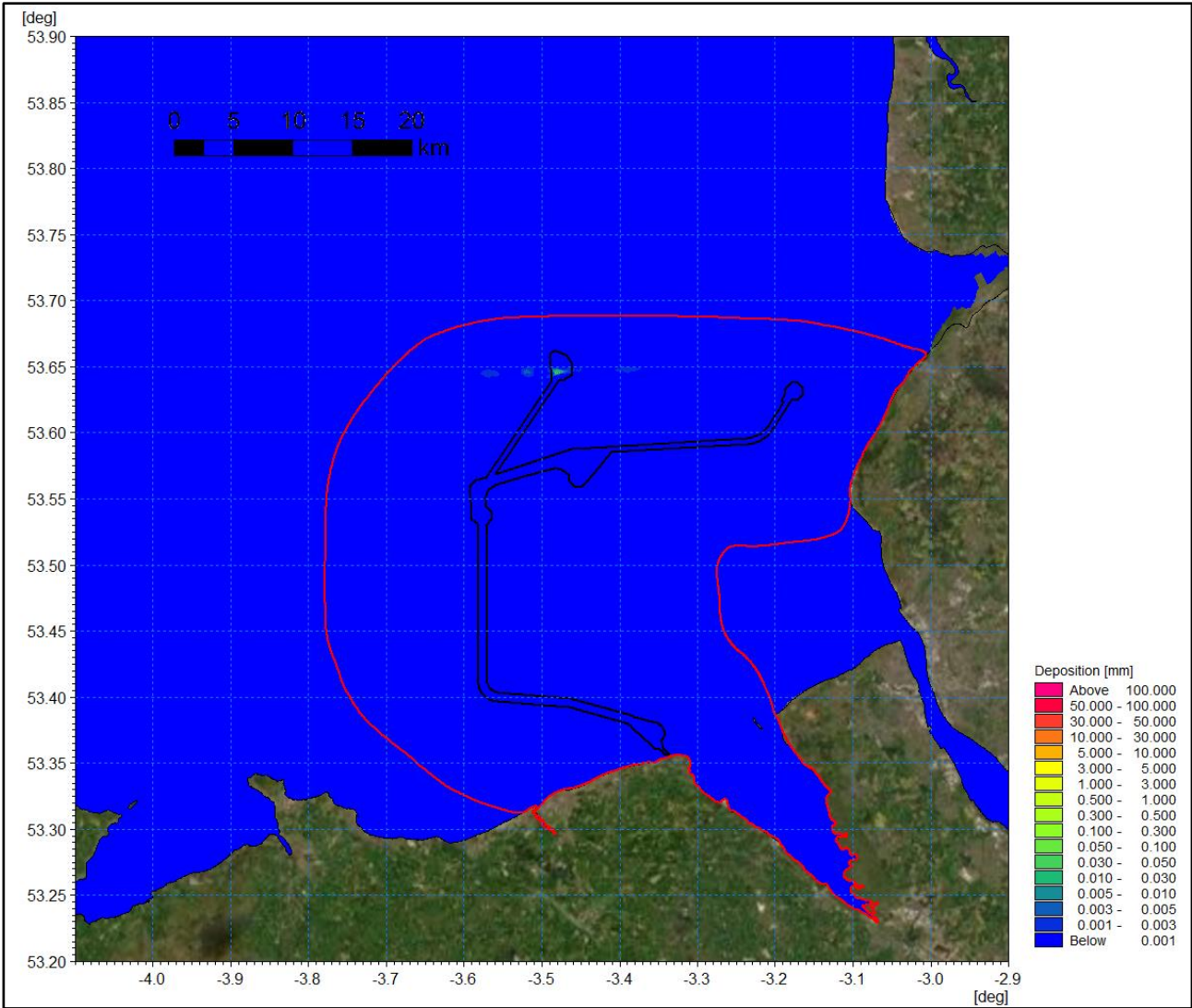


Figure 1.81: Average Sedimentation Over Drilling Phase - Hamilton North

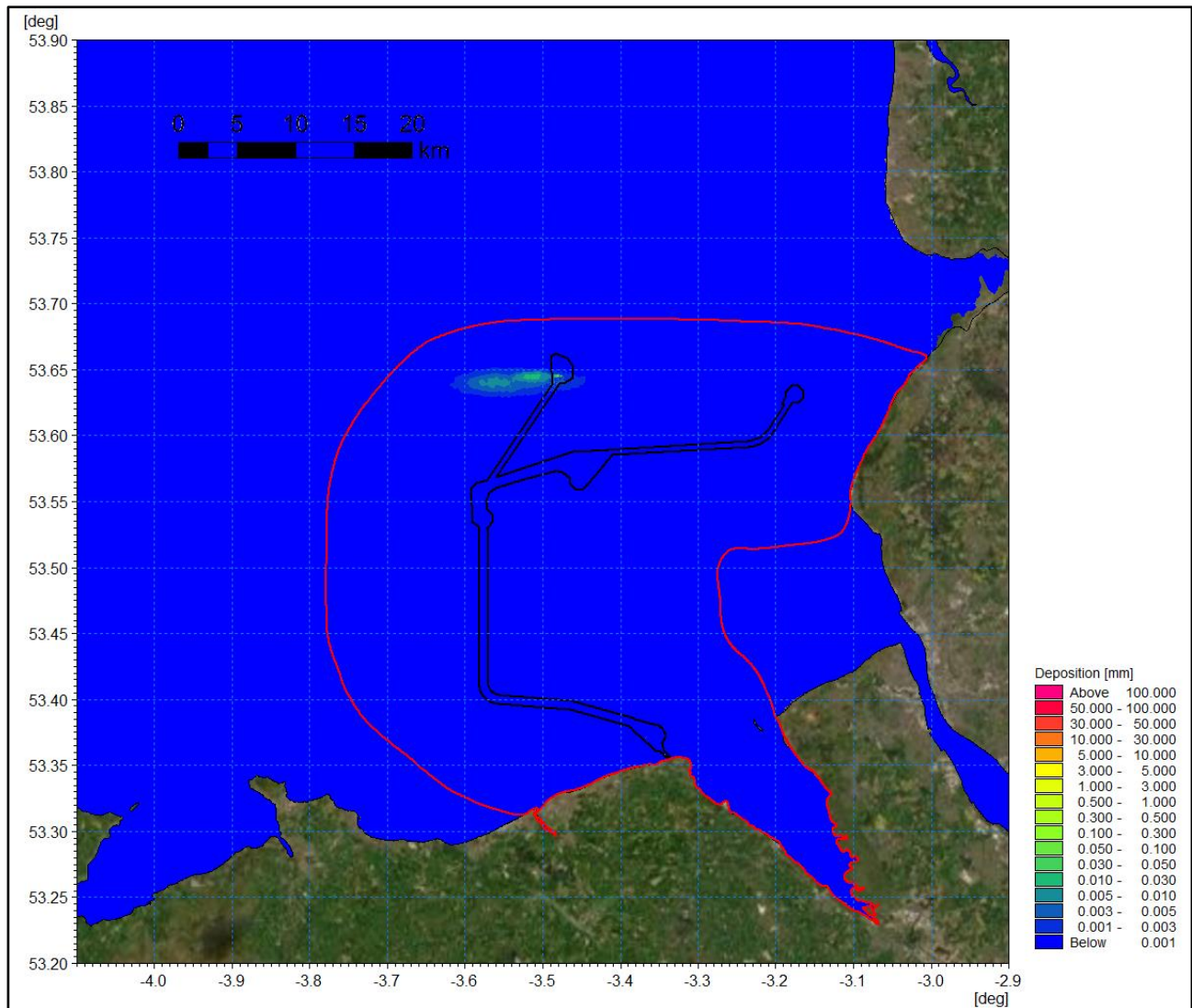


Figure 1.82: Sedimentation One Day After Cessation Of Drilling - Hamilton North

1.7.3 Cable installation

The third aspect of the construction phase is cable installation between OPs and the onshore terminal Point of Ayr (POA). For the maximum design scenario in terms of release of sediment into the water column, cables were assumed to be trenched. A number of trenching techniques may be suited to the ground conditions; however, it was assumed within the modelling that a trench of material of the maximum depth presented in the Proposed Development description outlined in Volume 1, Chapter 3. Description of the ES was mobilised into the lower water column as a result of the burial process, in line with the Business Enterprise and Regulatory Reform (BERR) guidelines (BERR, 2008). In reality the installation technique implemented may result in less sediment being mobilised and the maximum depth may not always be achieved with a corresponding reduction in the amount of material disturbed.

Similar to the sand wave clearance and drill cuttings, the model simulations used the sediment grading determined from the site specific grab sample sediment data. The same approach used for seabed preparation was again utilised for cable installation, with both the MT and PT modules used. Two representative sample routes were modelled. The MT module was used for modelling of the nearshore cabling from the POA to

Douglas OP, whereas further offshore to characterise cabling from Douglas OP to Lennox, the PT module was used.

Trenching rates can vary widely depending on the bed material and equipment used; typically, rates are between 25 m/h and 780 m/h. For the simulation, a relatively high rate of 450 m/h was used over an extensive sample route ensuring that material was released at all tidal states over a number of tides and ensuring initial concentrations were not underestimated.

1.7.3.1 POA to Douglas

The POA to Douglas cable trenching route was examined using numerical modelling. Two cables will be trenched along the same route therefore one cable installation operation was simulated over the range of conditions and is reflective of the outcome of each of the installations. The simulation assumed a trenching rate of 450 m/h, and that installation began from onshore and continued offshore. Each trench was 3 m at the surface extending to a depth of 3 m (i.e. the greatest burial depth proposed), with a triangular profile. The operation took approximately 3 days to complete, encompassing a range of tidal conditions. Figure 1.83 shows the modelled route from POA to Douglas, running from the onshore terminal to the offshore platform in open sea. The sediment grading characteristics along the route were derived from the PSA grab sample locations, with the grading interpolated along the route between data points.

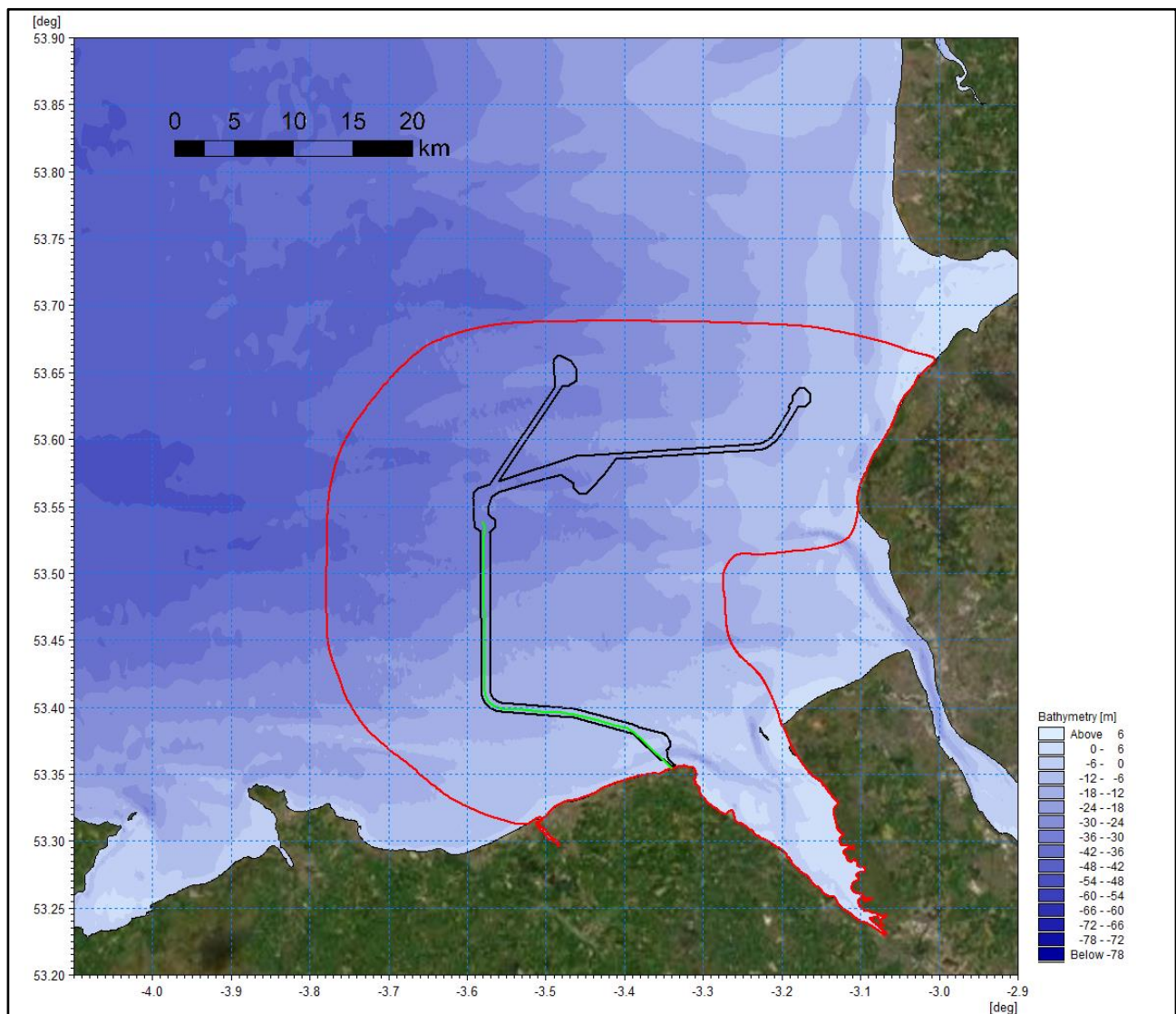


Figure 1.83: Modelled POA To Douglas Trenching Route

The model results presented follow the same format as those for the seabed preparation and drill cuttings described in the previous sections. Figure 1.94 shows the maximum suspended sediment concentration over the course of the trenching phase, plume may extent up to 15 km to the west, exiting the physical processes study area by c.1 km. However, they do so at background levels (i.e. <1 mg/l), it is clear that the sediment is dispersed on subsequent tides as the plume envelope illustrates the flood and ebb tidal excursions as trenching progresses offshore. Localised maximum suspended sediment concentrations are seen along the cable route south of the Douglas OP are generally <10,000 mg/l. However, SSC increases rapidly over the very shallow drying area of West Hoyle Bank which, with maximum values in excess of 300,000 mg/l, peaking at c.640,000 mg/l. Average suspended sediments, as shown in Figure 1.85, follow a similar pattern, with concentrations along the route having mean values of <1,000 mg/l, the largest of which occur over West Hoyle Bank where water depth is very limited.

As was evident in the previous operations, the material settles during slack water and then is re-suspended to form a secondary plume which becomes amalgamated. This is further illustrated in Figure 1.94 and Figure 1.96, showing maximum sedimentation and sedimentation one day after cessation of trenching activities at slack water. Maximum sedimentation occurs within c.30 m of the cable route and is limited to <300 mm with peak deposition of c.175 mm. Average sedimentation, as is shown in Figure 1.95, is greatest at the location of the trenching and may be up to c.160 mm in depth where the coarser material has settled within close proximity.

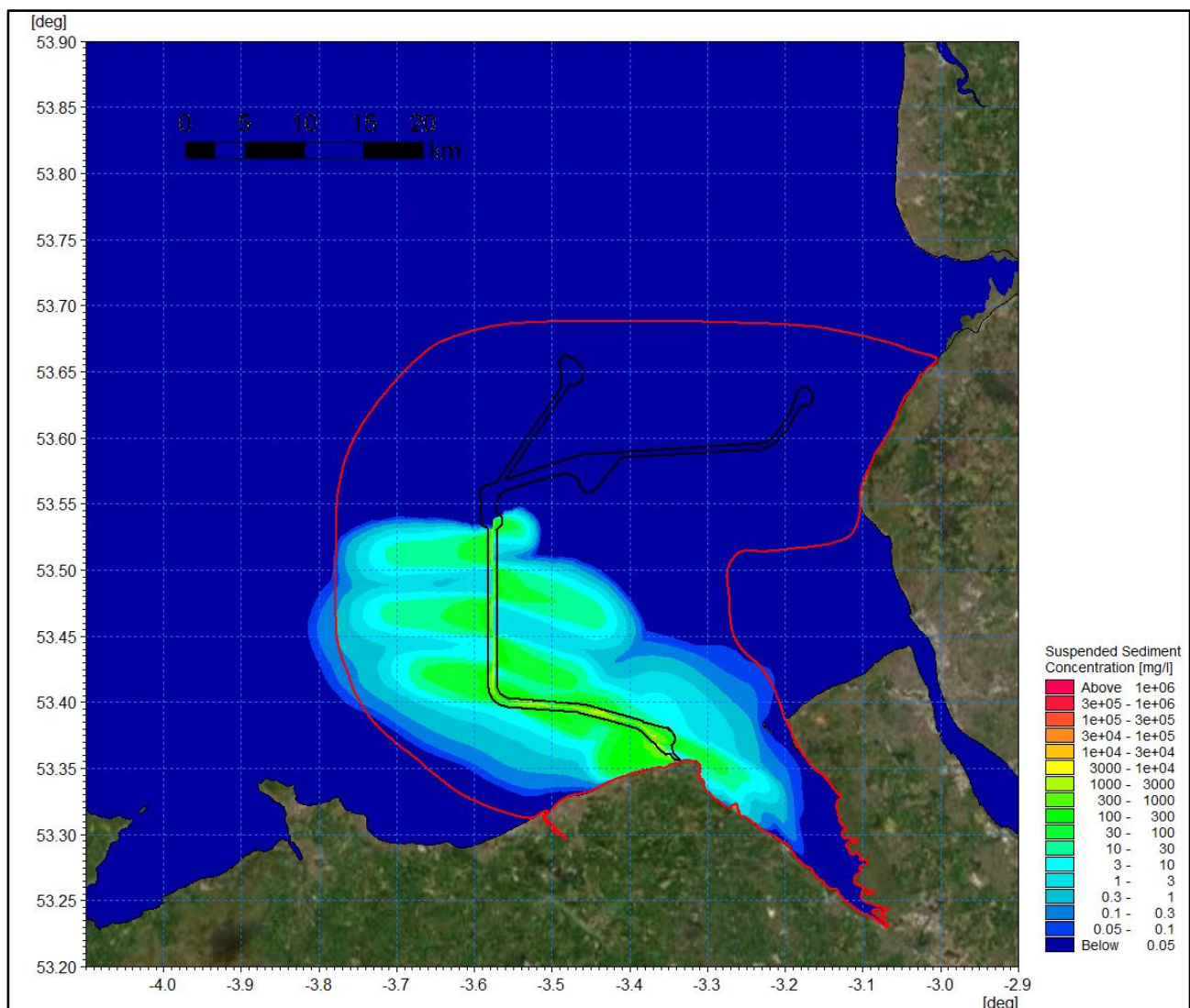


Figure 1.84: Maximum Suspended Sediment Concentration Over Trenching Phase - POA To Douglas

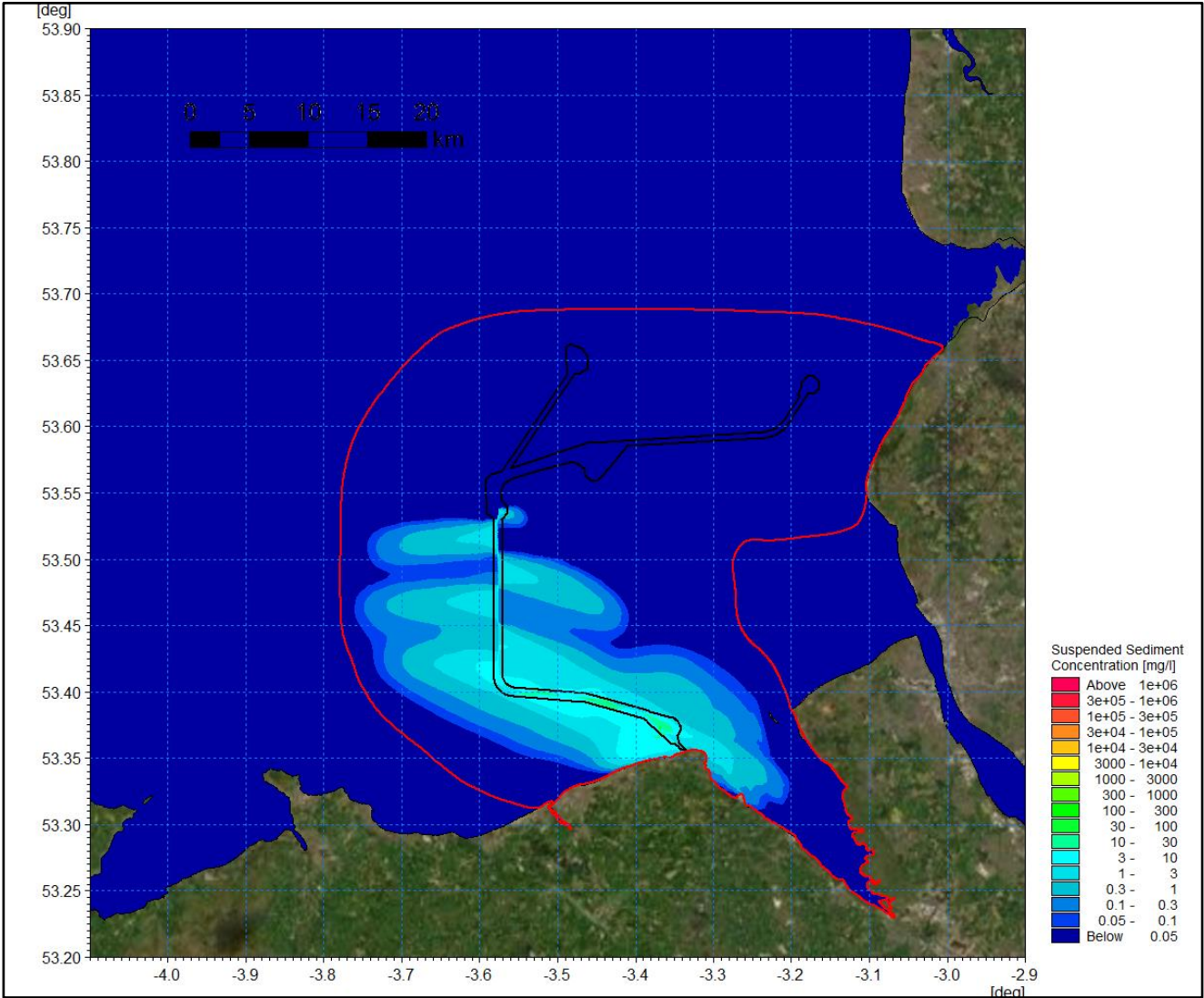


Figure 1.85: Average Suspended Sediment Concentration Over Trenching Phase - POA To Douglas

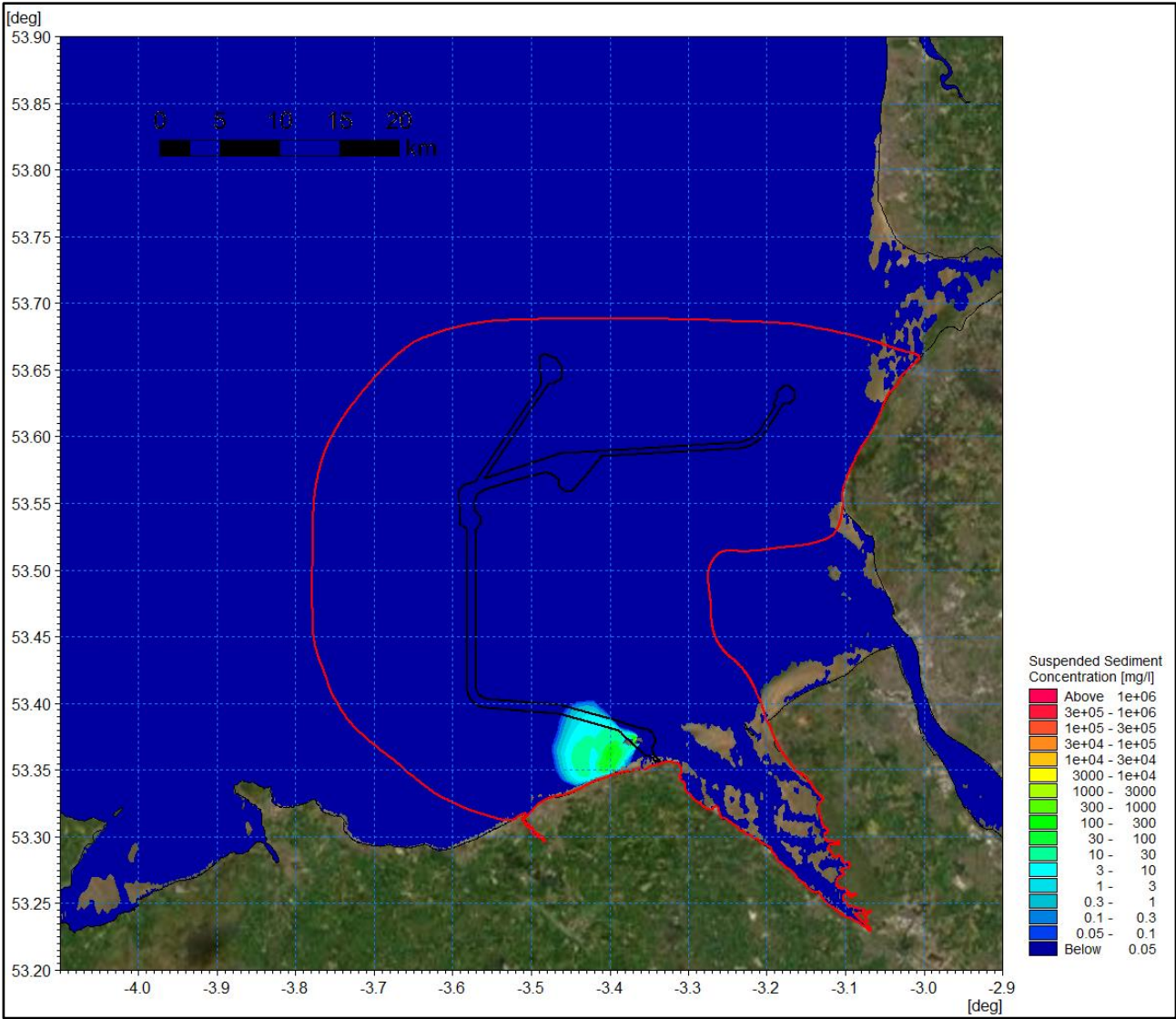


Figure 1.86: Suspended Sediment Concentration Day 1 Ebb - POA To Douglas

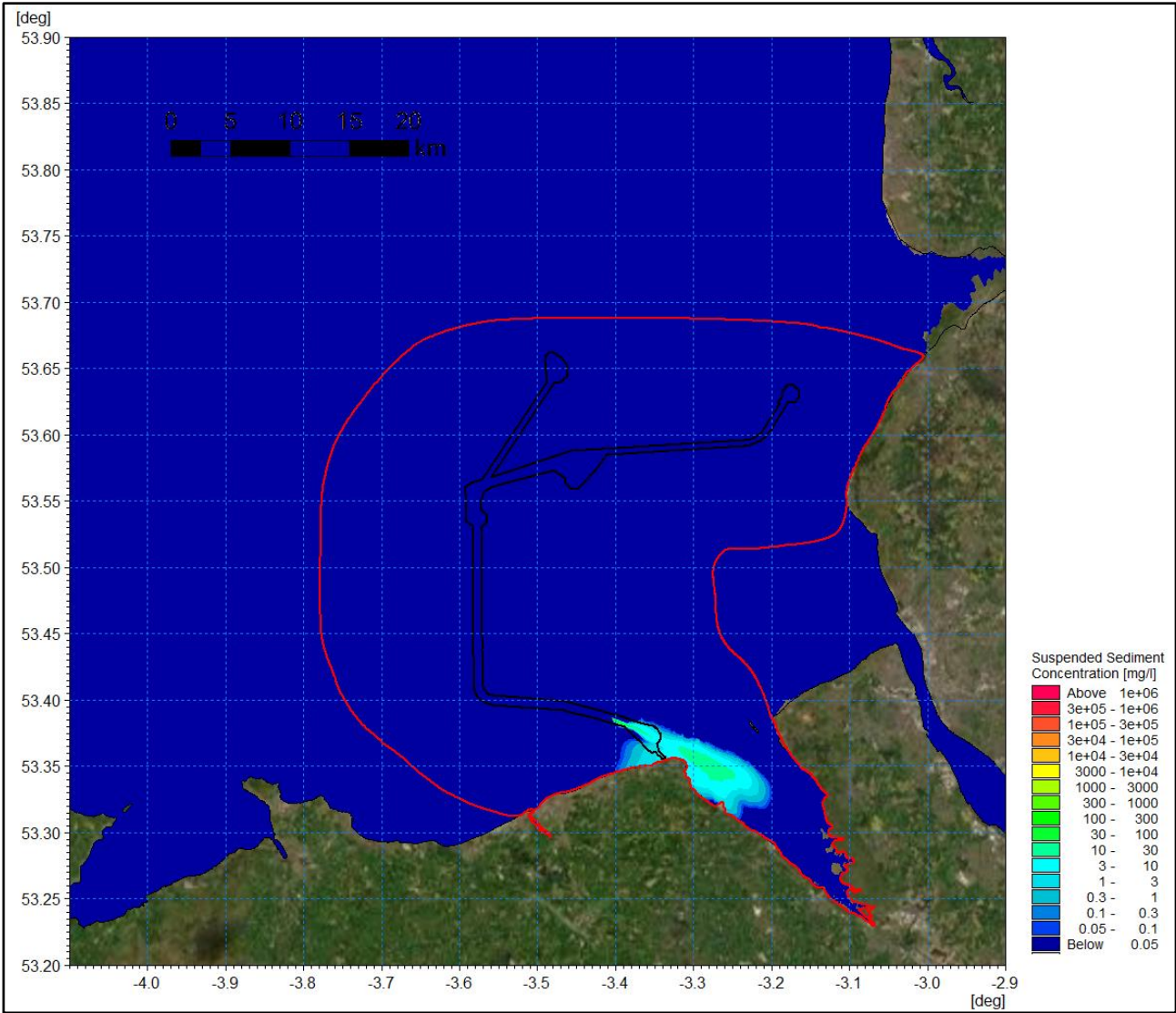


Figure 1.87: Suspended Sediment Concentration Day 1 Flood - POA To Douglas

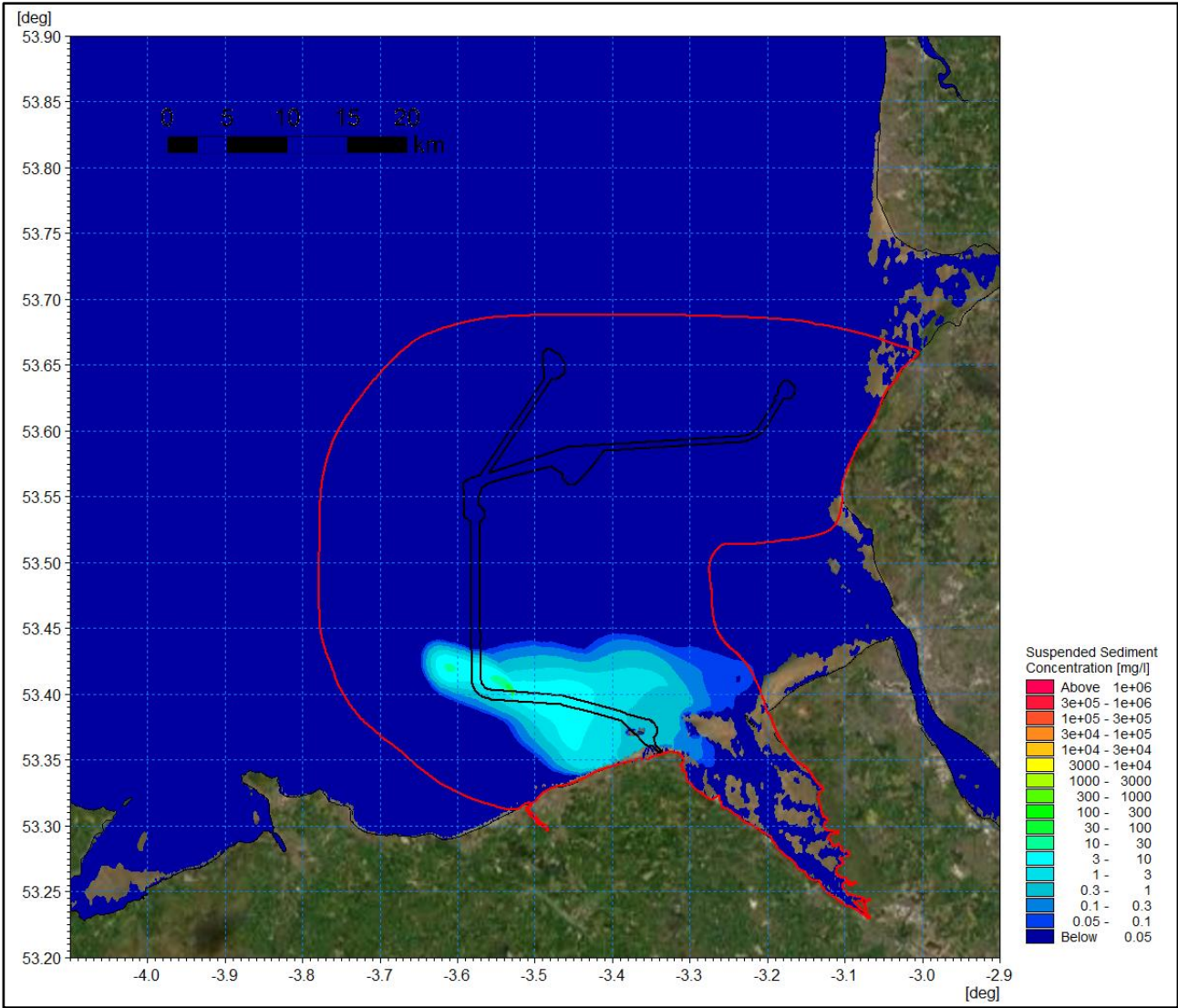


Figure 1.88: Suspended Sediment Concentration Day 2 Ebb - POA TO Douglas

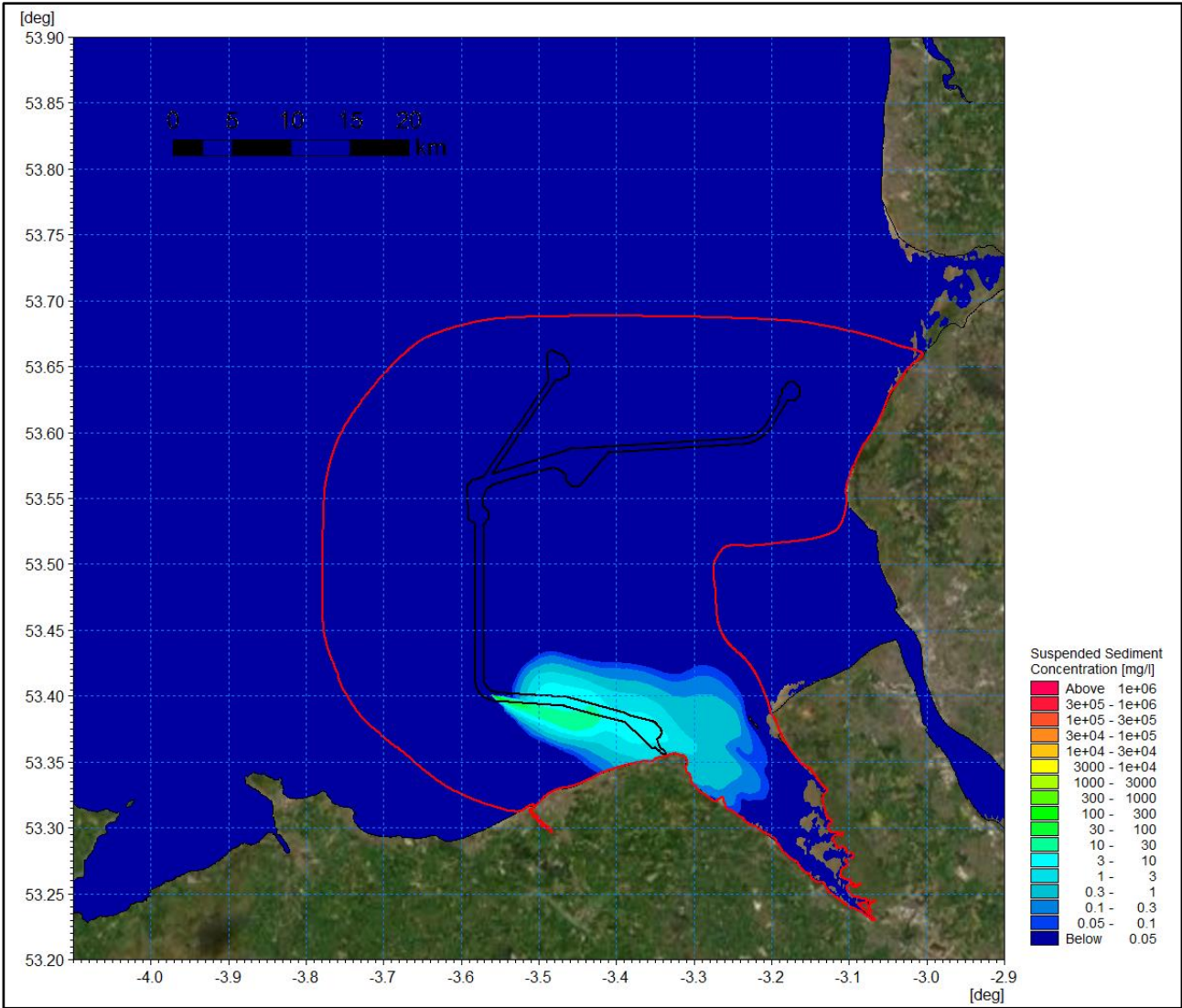


Figure 1.89: Suspended Sediment Concentration Day 2 Flood - POA To Douglas

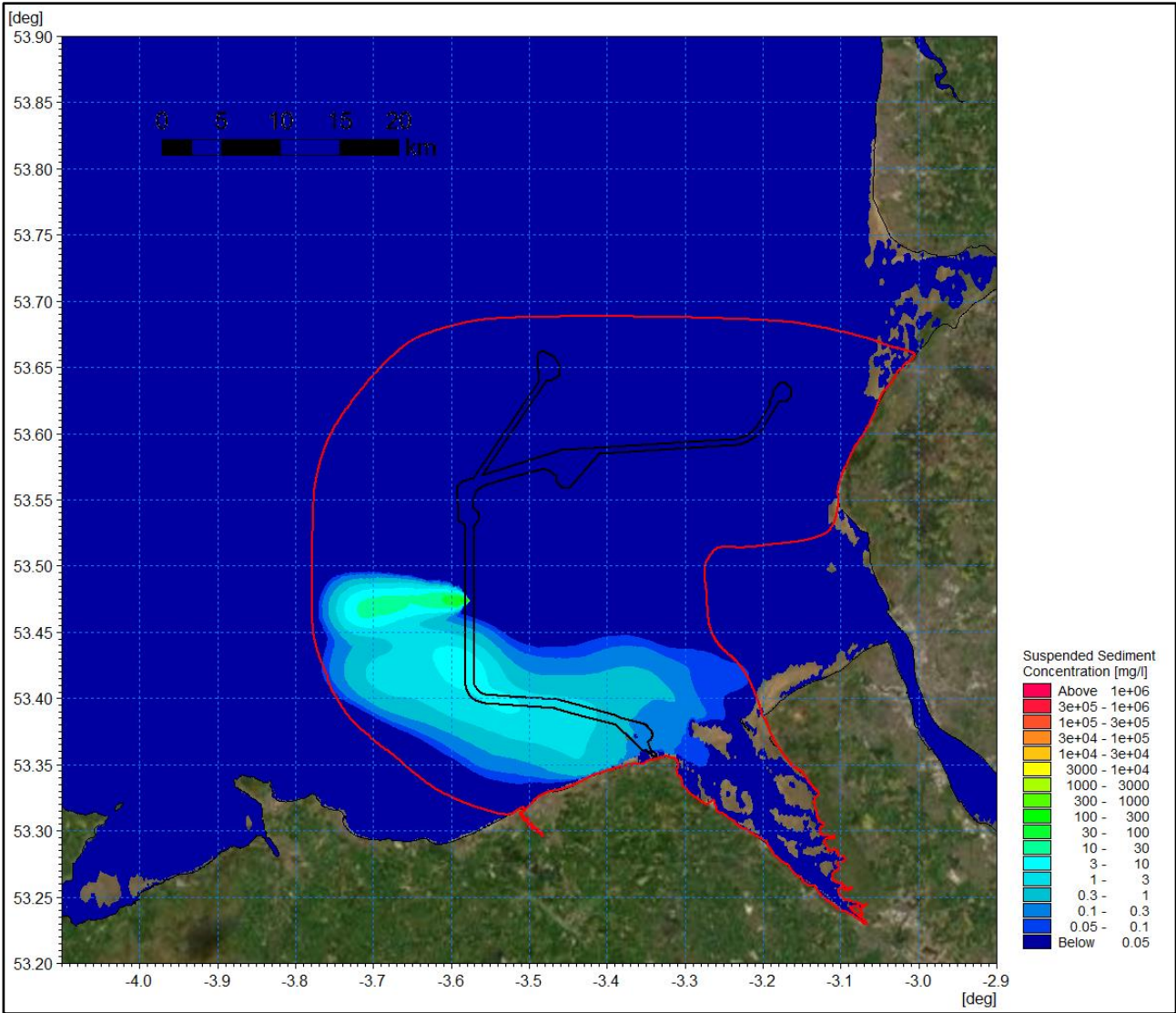


Figure 1.90: Suspended Sediment Concentration Day 3 Ebb - POA To Douglas

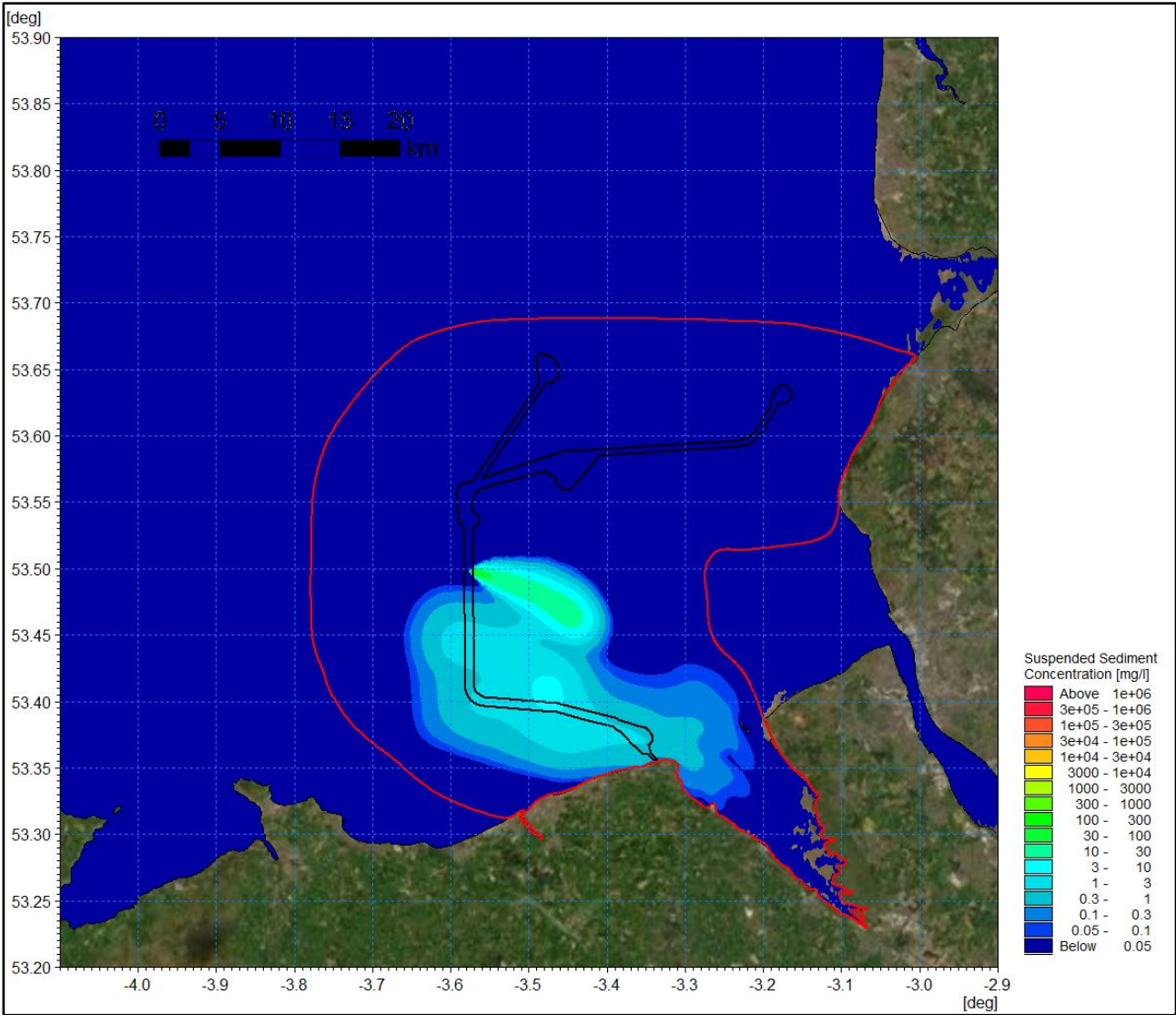


Figure 1.91: Suspended Sediment Concentration Day 3 flood - POA To Douglas

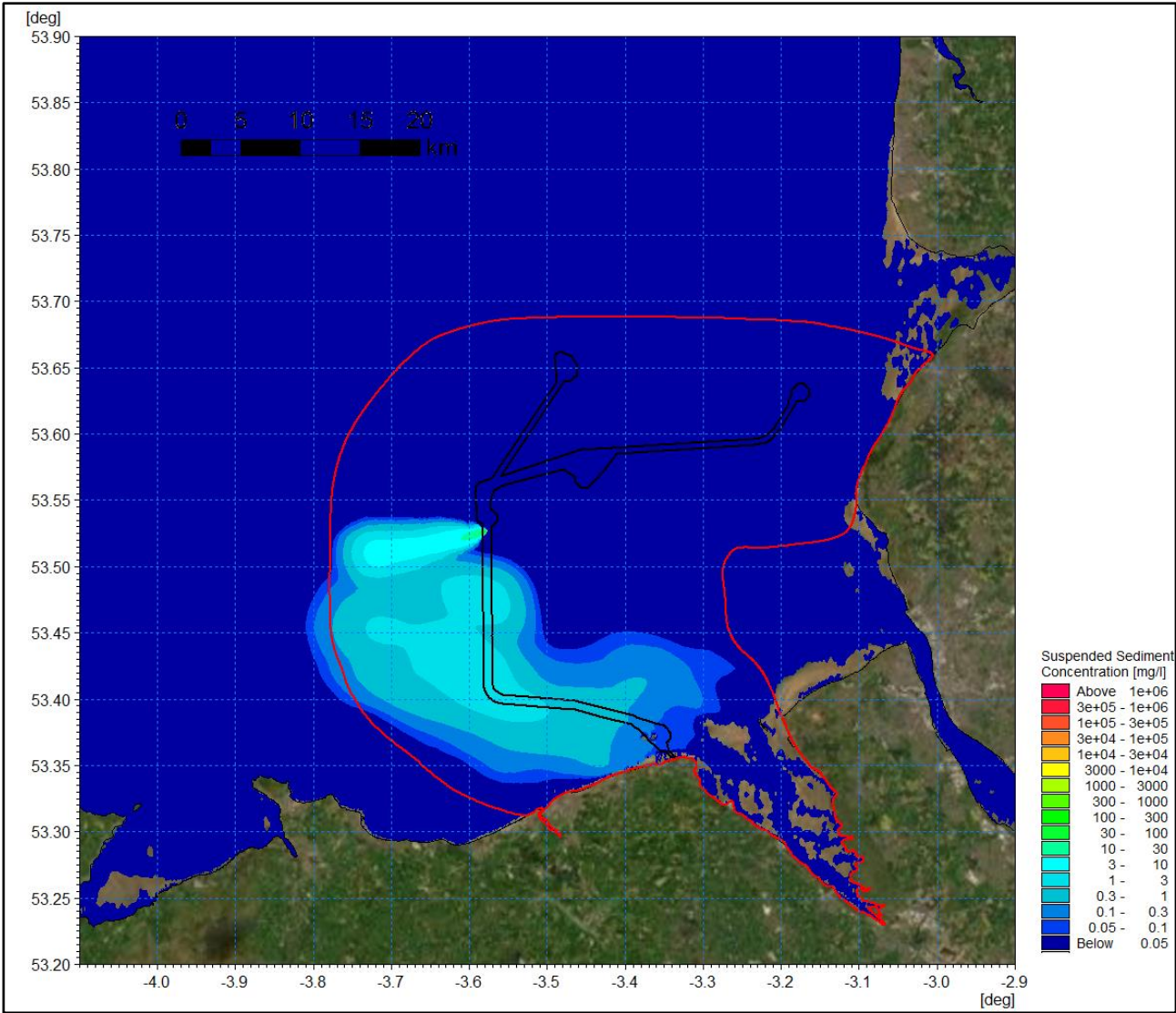


Figure 1.92: Suspended Sediment Concentration Day 4 Ebb - POA To Douglas

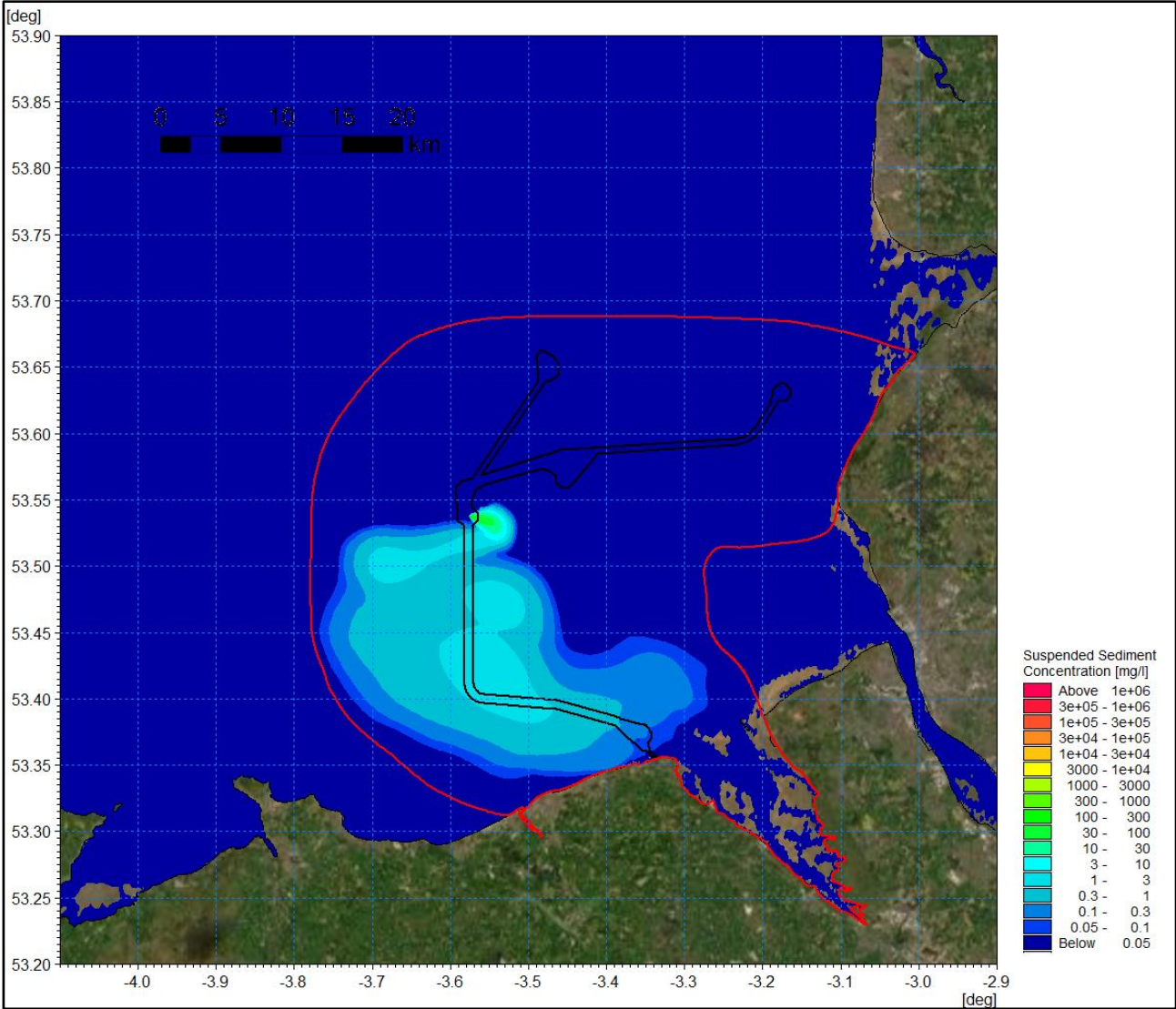


Figure 1.93: Suspended Sediment Concentration Day 4 Flood - POA To Douglas

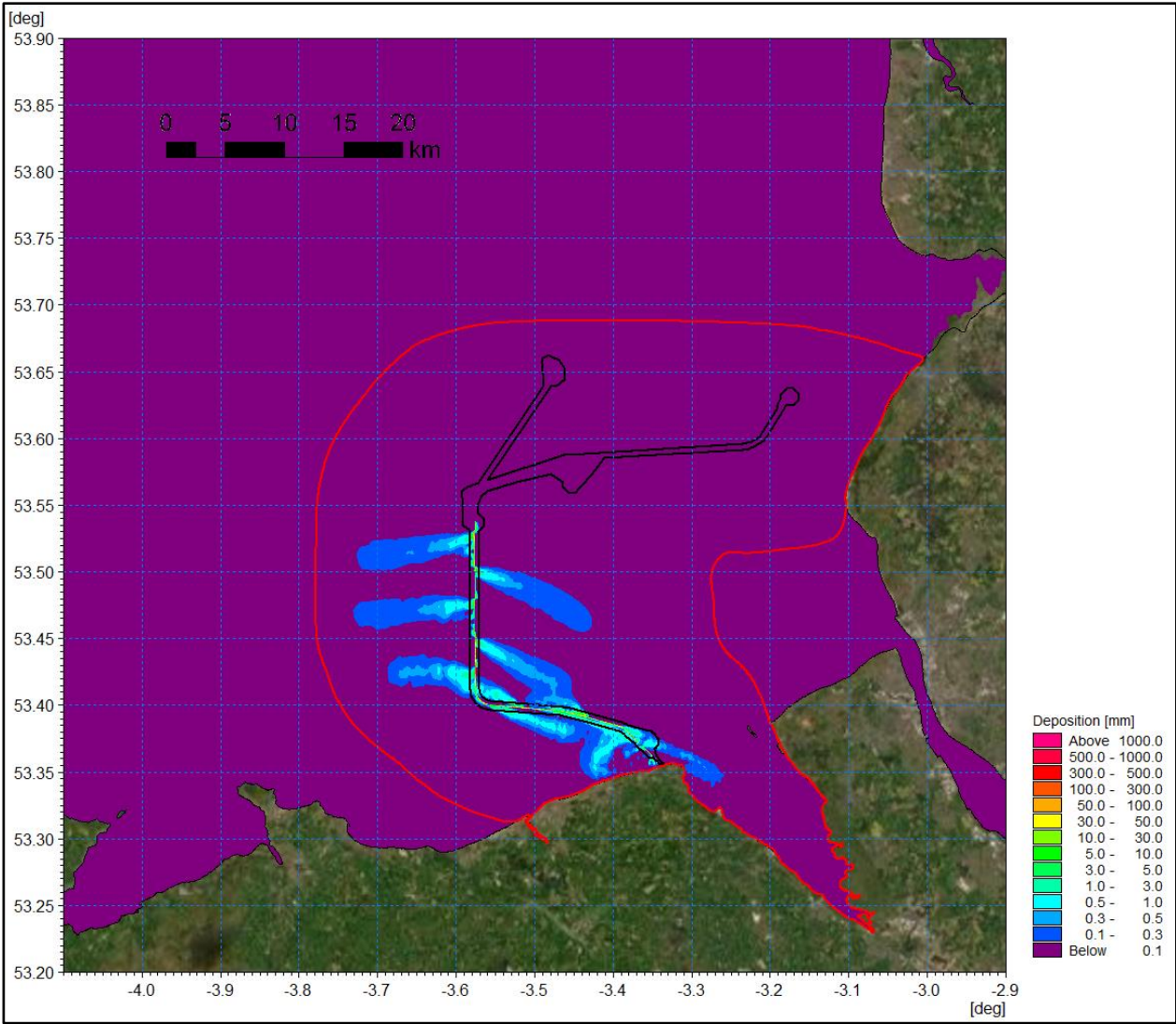


Figure 1.94: Maximum Sedimentation Over Trenching Phase – POA To Douglas

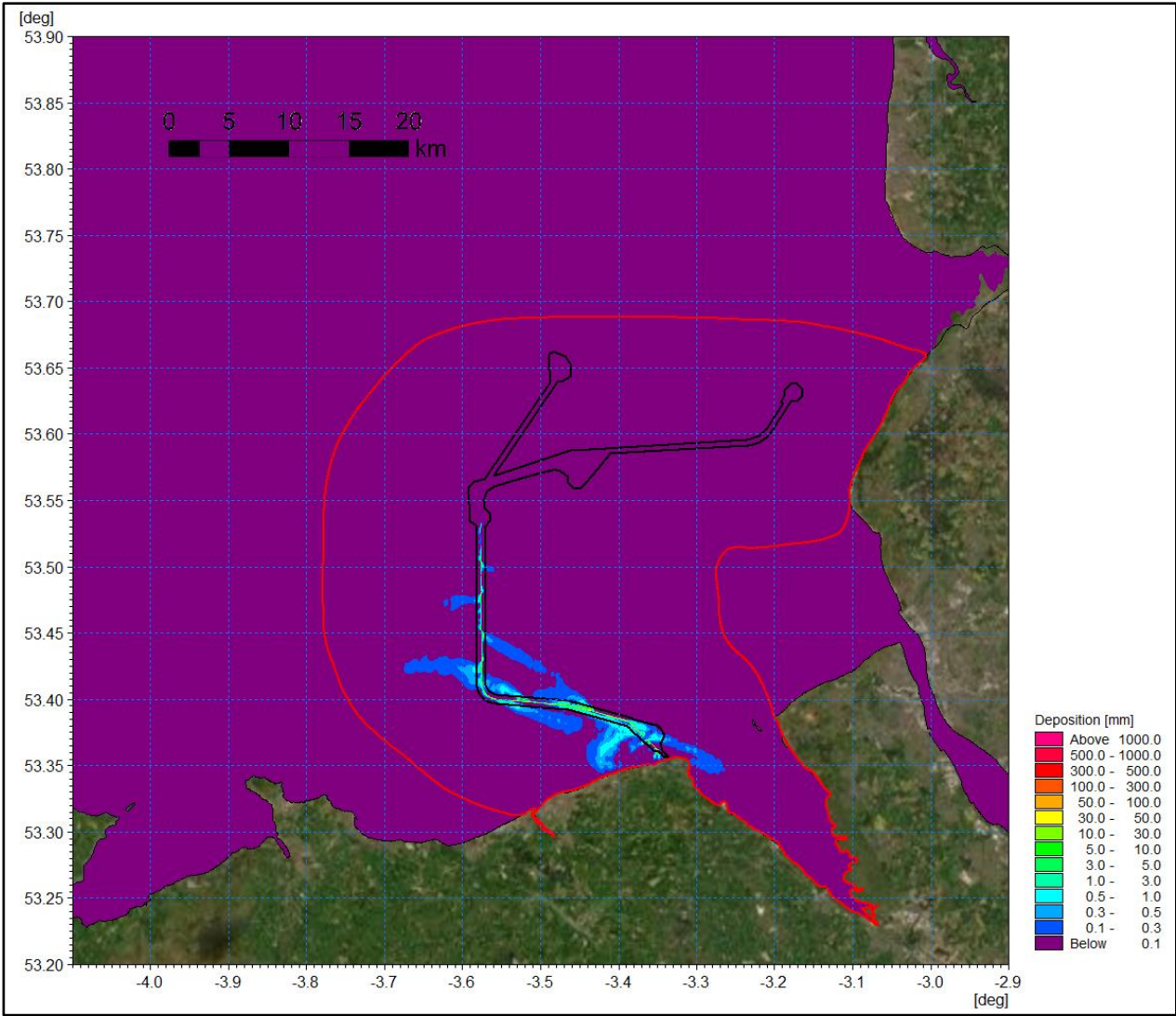


Figure 1.95: Average Sedimentation Over Trenching Phase – POA To Douglas

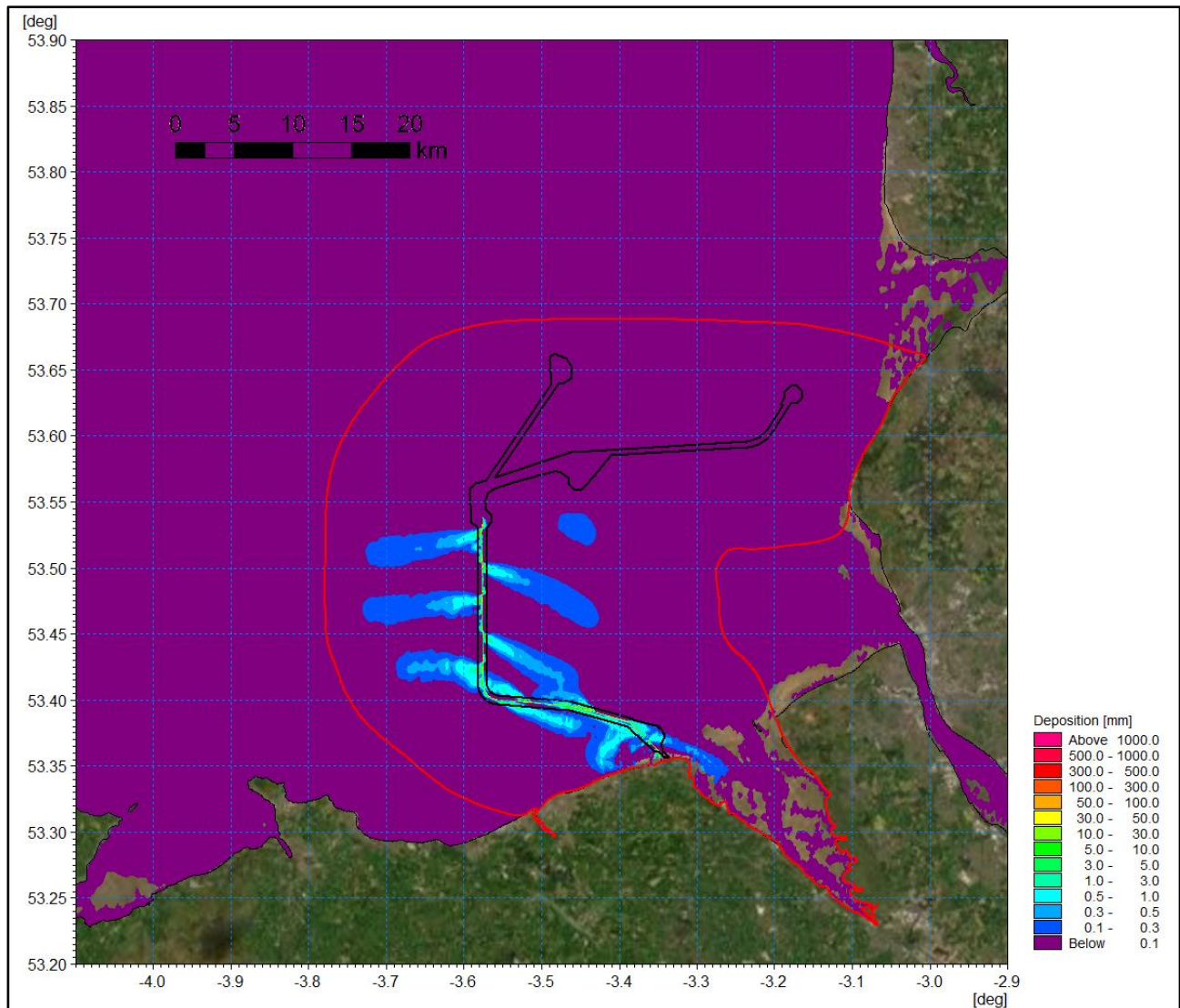


Figure 1.96: Sedimentation One Day After Cessation Of Trenching – POA To Douglas

1.7.3.2 Douglas to Lennox

As with the POA to Douglas, the Douglas to Lennox cable trenching route was examined using numerical modelling. The simulation again assumed trenching rate of 450 m/h and that each trench was 3 m at the surface extending to a depth of 3 m (i.e. the greatest burial depth proposed), with a triangular profile. The operation similarly took approximately 3 days to complete, encompassing a range of tidal conditions. Figure 1.97 shows the modelled route from the Douglas OP to Lennox OP. The sediment grading characteristics along the route were derived from the PSA grab sample locations, with the grading interpolated along the route between data points.

Figure 1.98 presenting the maximum suspended sediment concentration over the course of the trenching phase, shows a larger plume than that seen for POA to Douglas, due in part to the finer nature of the sediment further out to sea, and the stronger littoral currents. Maximum suspended sediment concentrations occur within c.50 m the trenching route, with values in excess of 300 g/l, and peak values of c.70 g/l at the location at which trenching is undertaken. Average suspended sediments, as shown in Figure 1.99, are described with concentrations as having mean values of <1,000 mg/l in close proximity to the trenching, and mean SSC of <10 mg/l outside of the development area. It is at these near background values that the plume may on

occasion extend beyond the physical processes study area to the west by up to c.1,500 m. Maximum sedimentation during the trenching phase also occurs along the cable route within c.50 m, however even so deposition is limited to <50 cm (peak of c.32 cm), average values along the route as shown in Figure 1.109 are further limited to <10 cm. It is noted that the trenching activities are in alignment with the axis of tidal flow. Sedimentation one day following the cessation of trenching activities is shown in Figure 1.110, which at its northern extent around the Lennox OP, further demonstrates the settlement along tidal ellipsis during slack water.

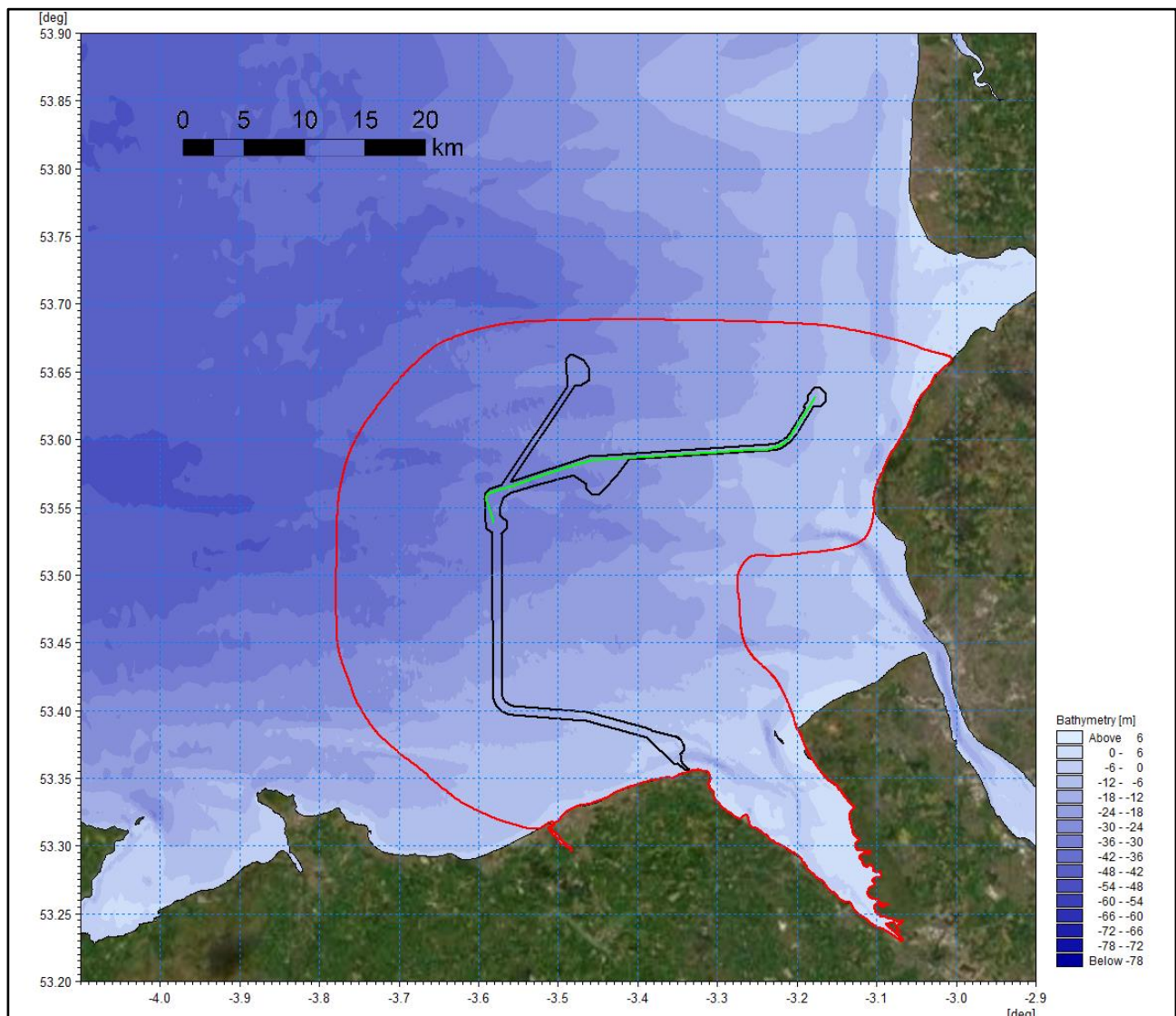


Figure 1.97: Modelled Douglas To Lennox Trenching Route

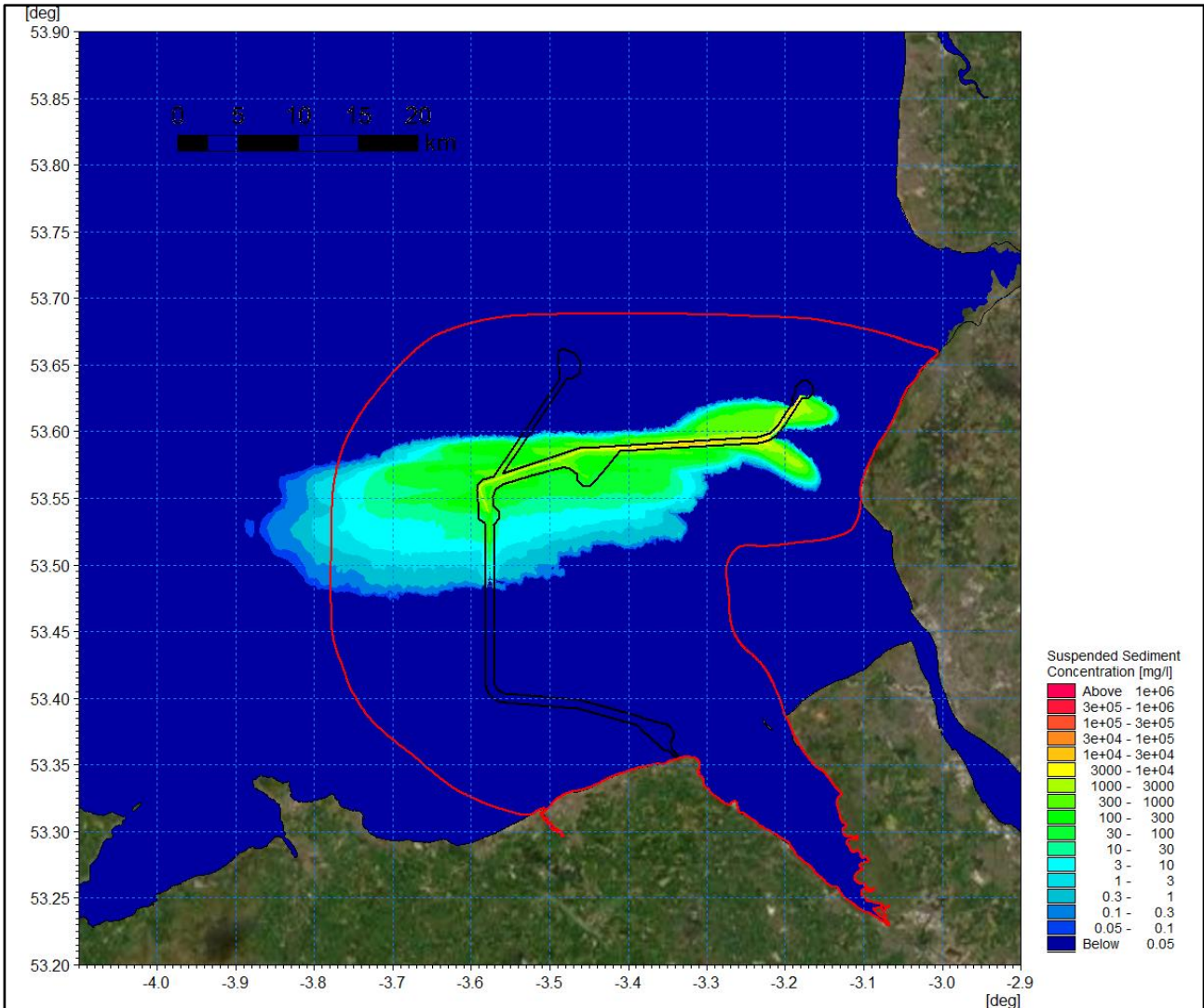


Figure 1.98: Maximum Suspended Sediment Concentration Over Trenching Phase – Douglas To Lennox

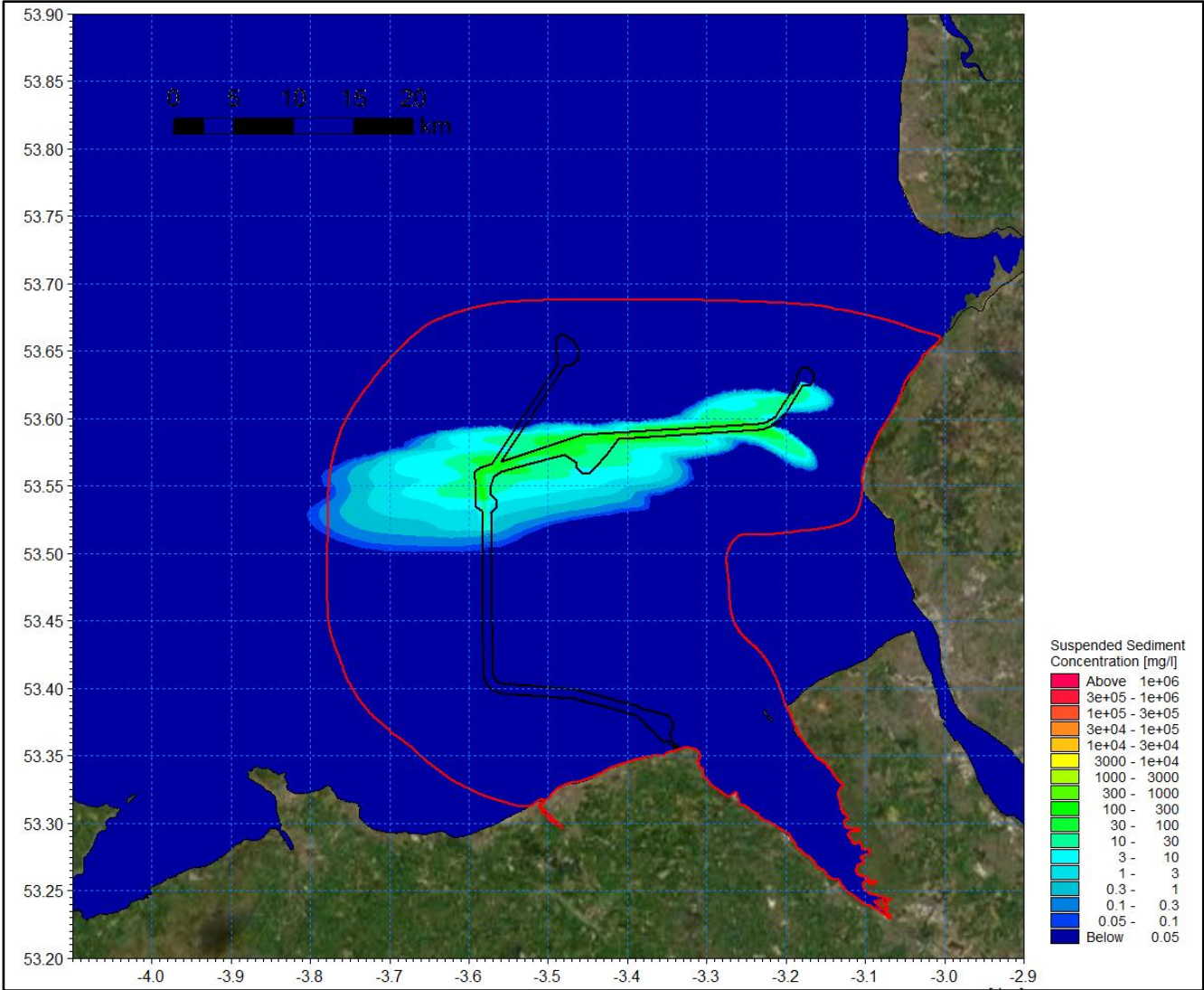


Figure 1.99: Average Suspended Sediment Concentration Over Trenching Phase – Douglas To Lennox

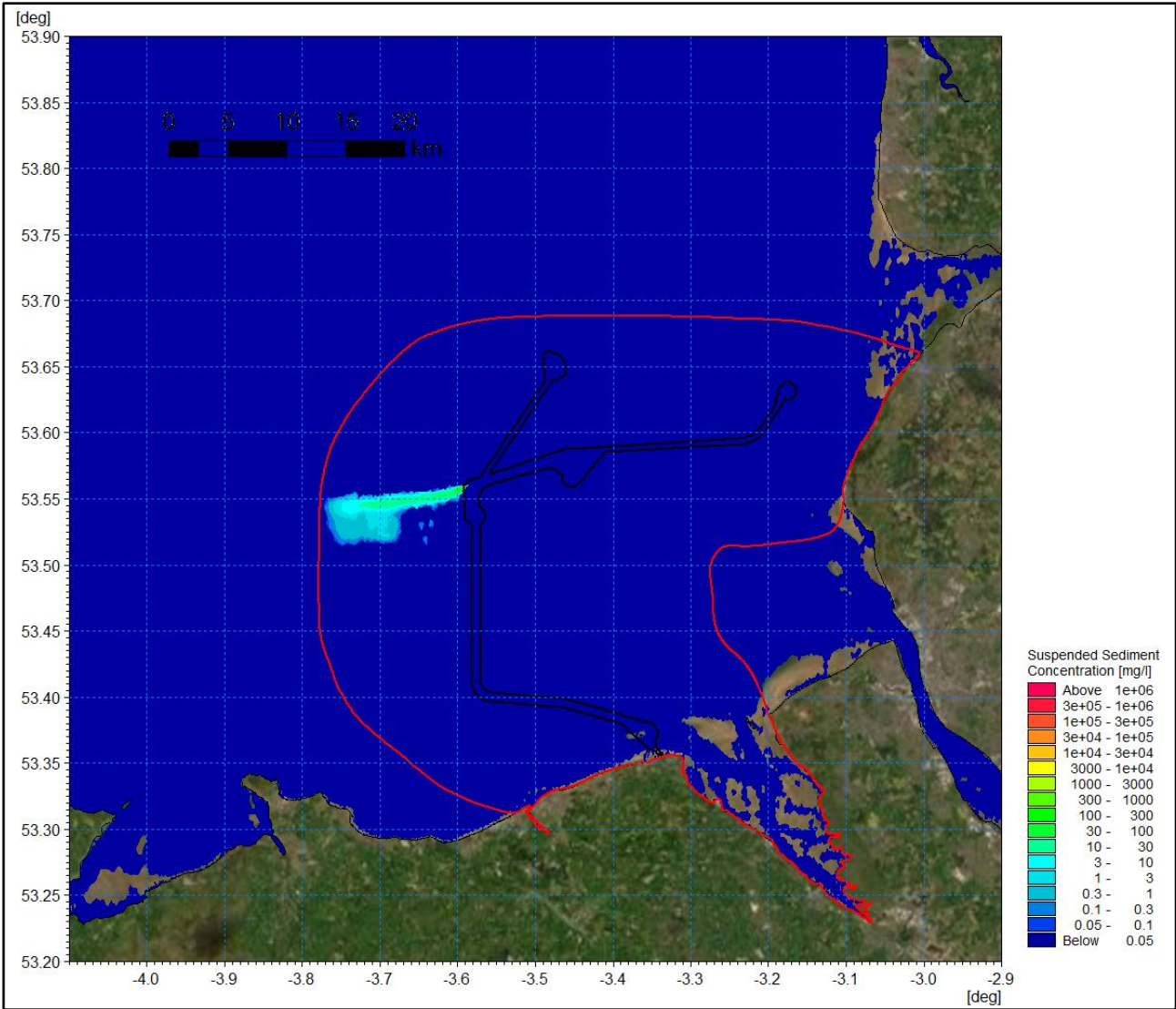


Figure 1.100: Suspended Sediment Concentration Day 1 Ebb – Douglas To Lennox

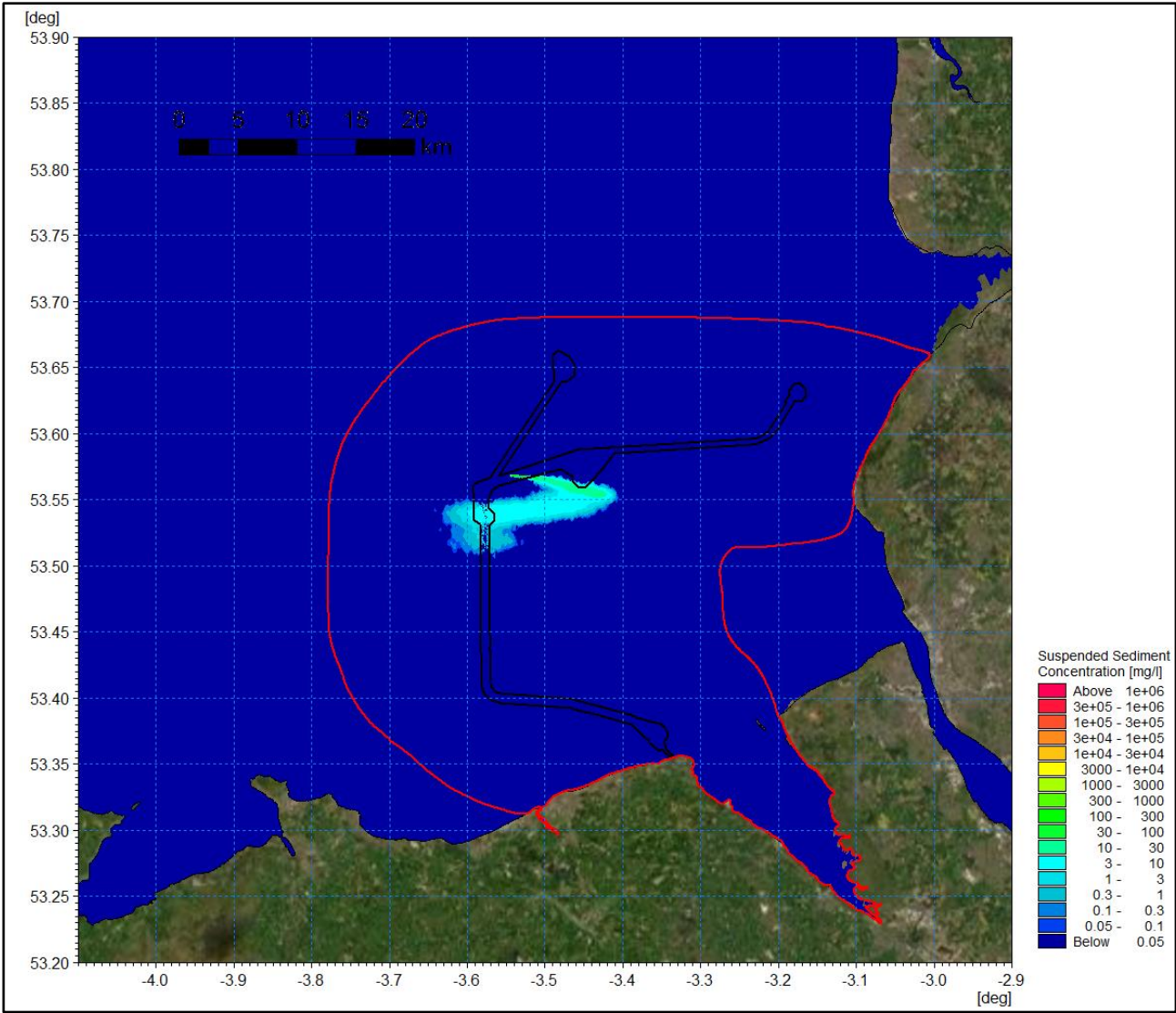


Figure 1.101: Suspended Sediment Concentration Day 1 Flood – Douglas To Lennox

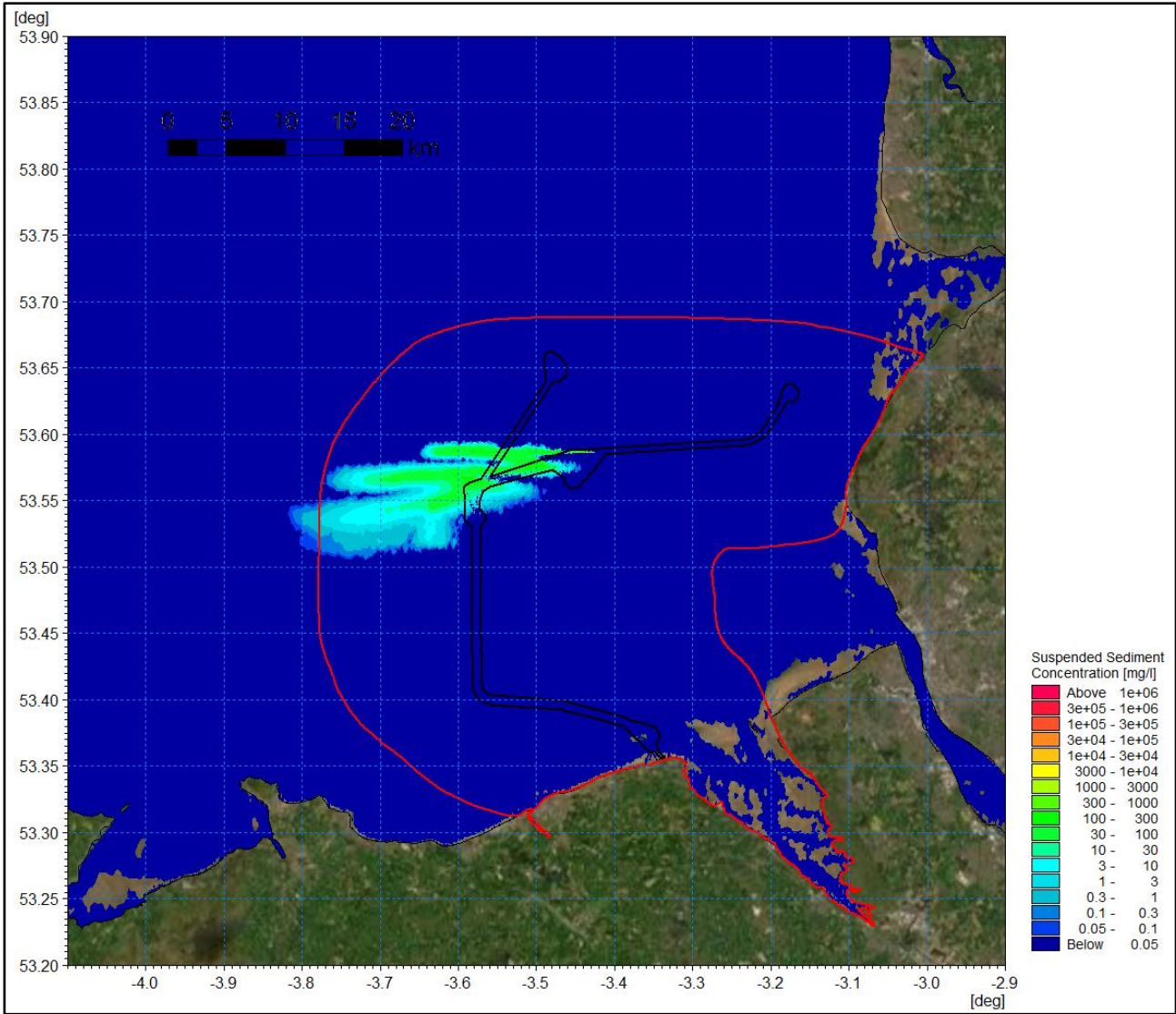


Figure 1.102: Suspended Sediment Concentration Day 2 Ebb – Douglas To Lennox

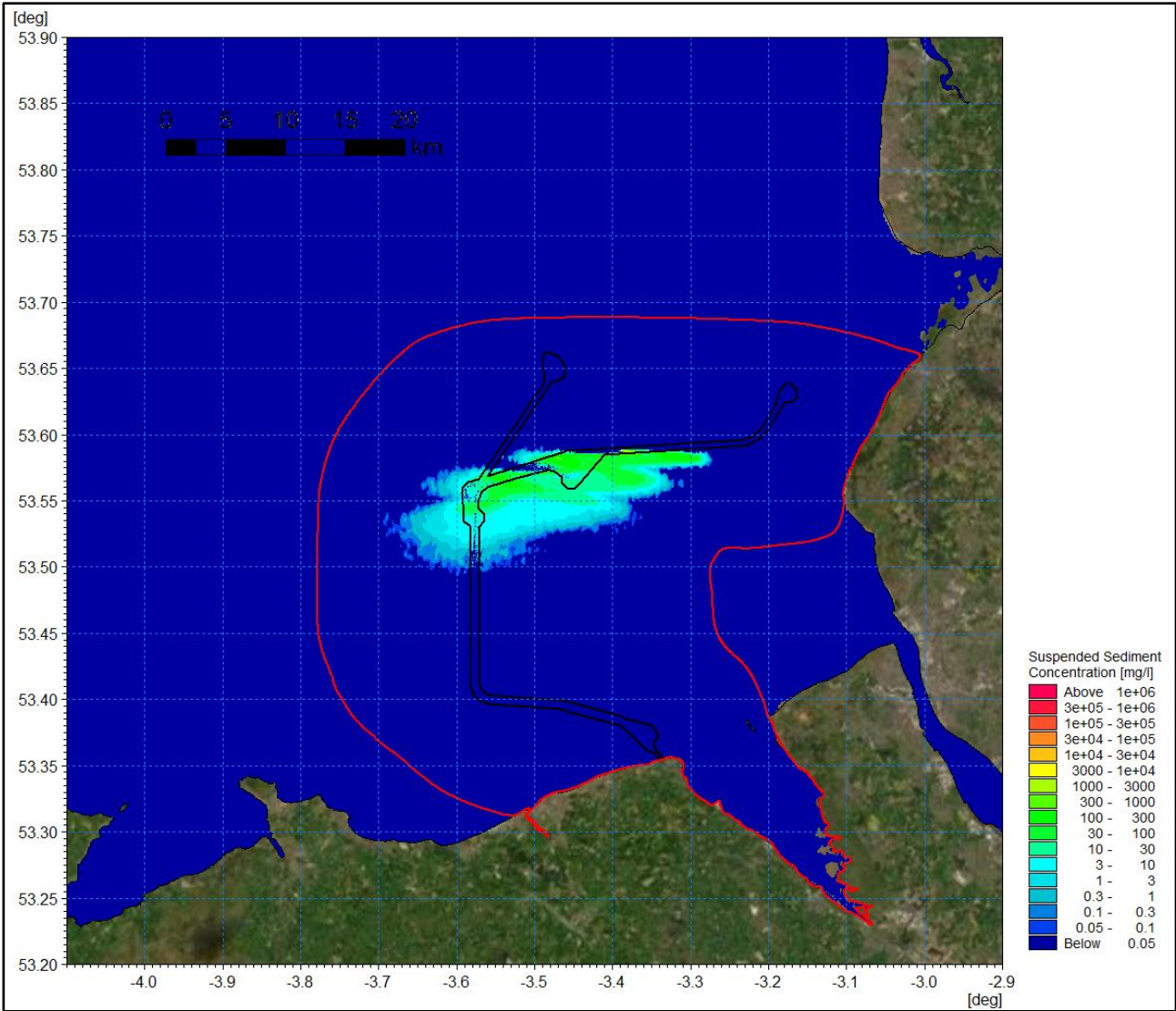


Figure 1.103: Suspended Sediment Concentration Day 2 Flood – Douglas To Lennox

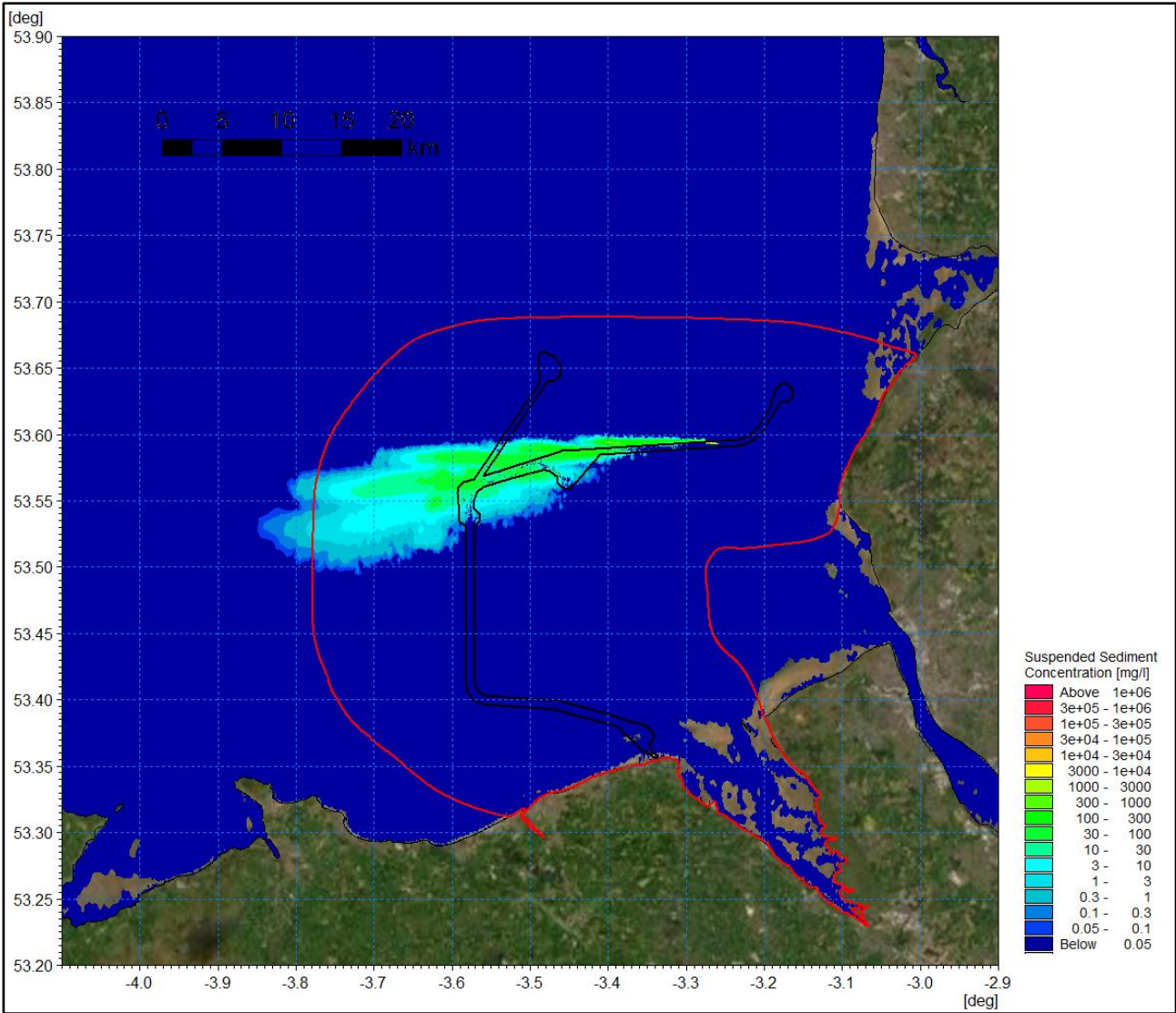


Figure 1.104: Suspended Sediment Concentration Day 3 Ebb – Douglas To Lennox

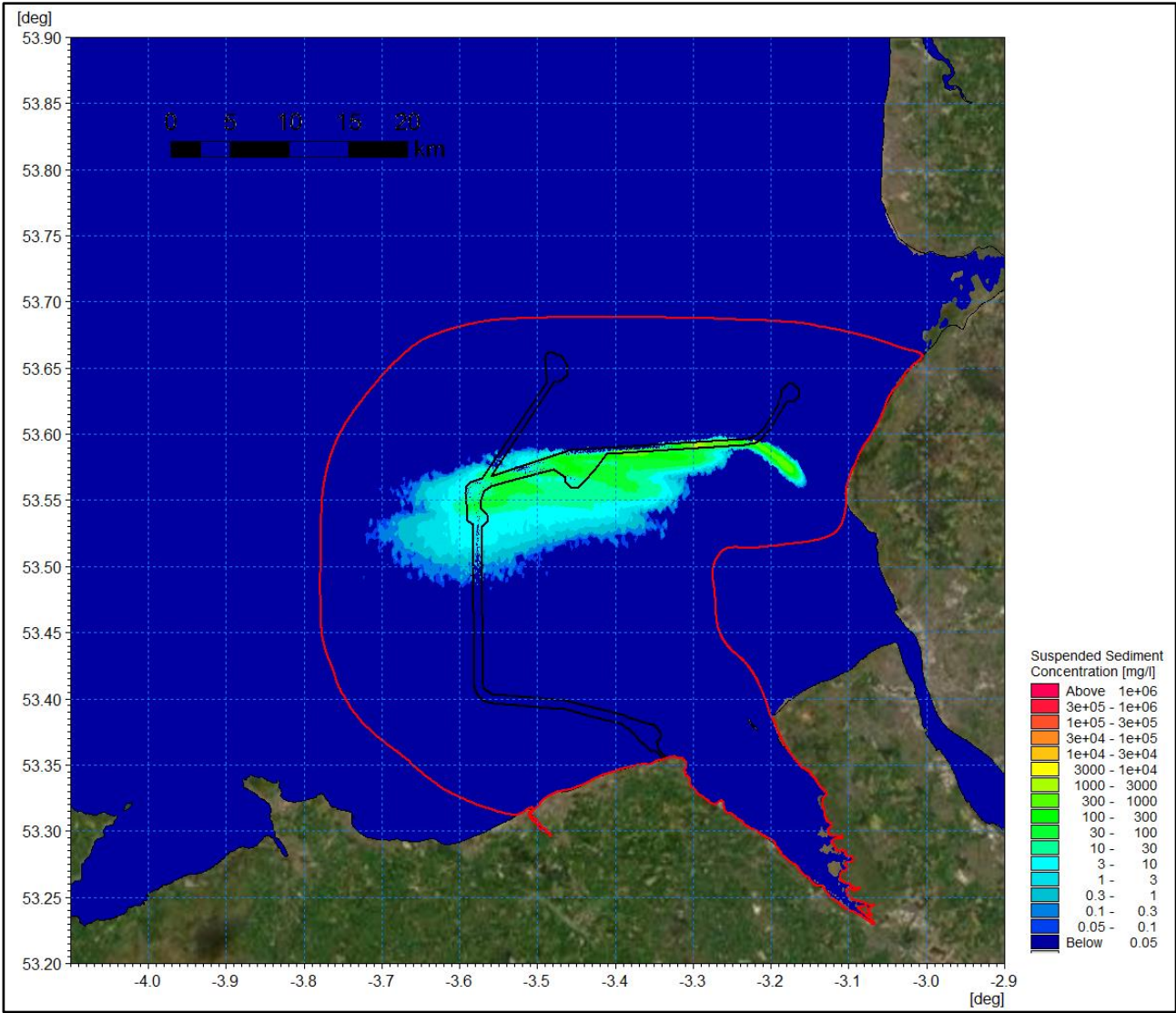


Figure 1.105: Suspended Sediment Concentration Day 3 Flood – Douglas To Lennox

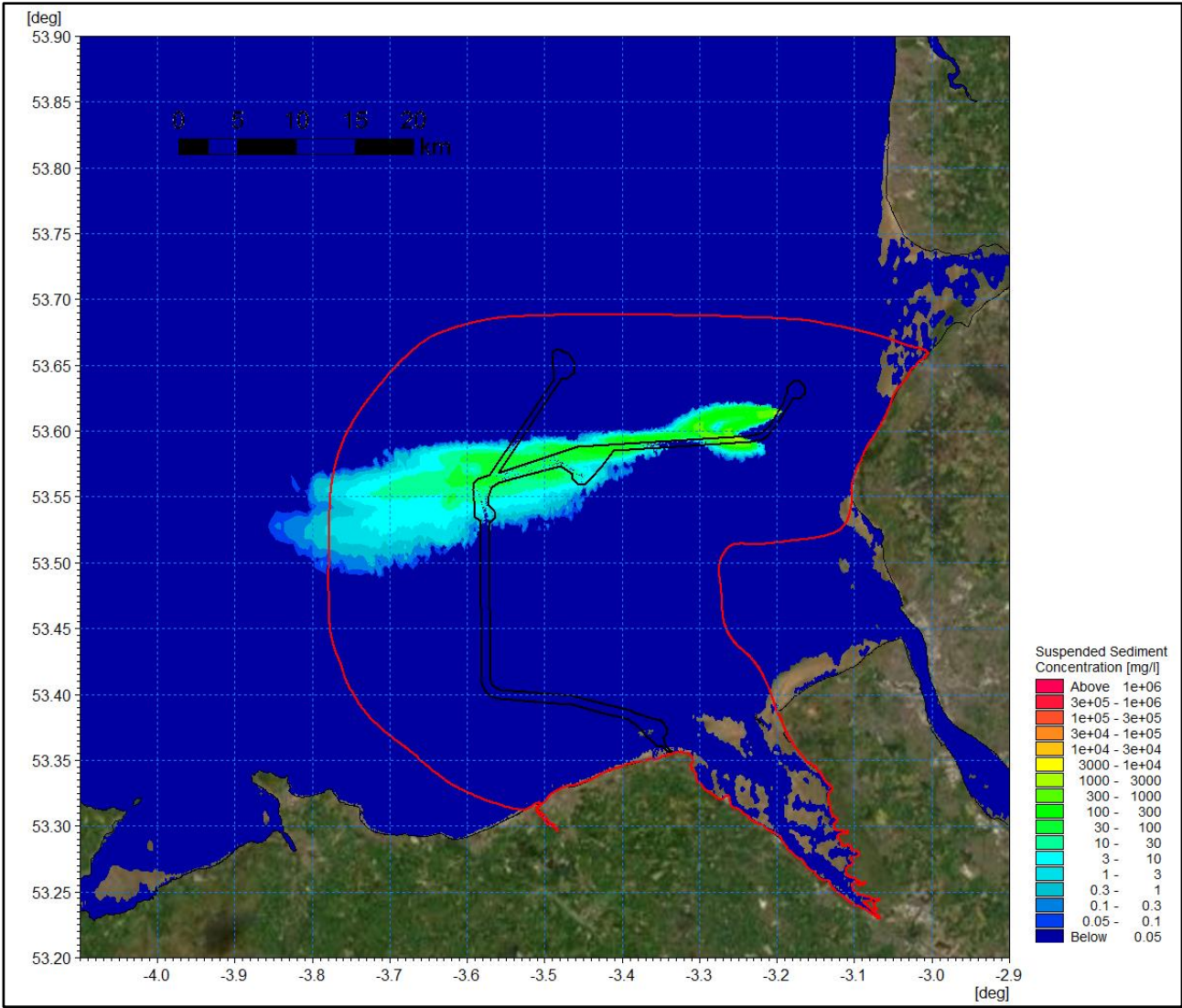


Figure 1.106: Suspended Sediment Concentration Day 4 Ebb – Douglas To Lennox

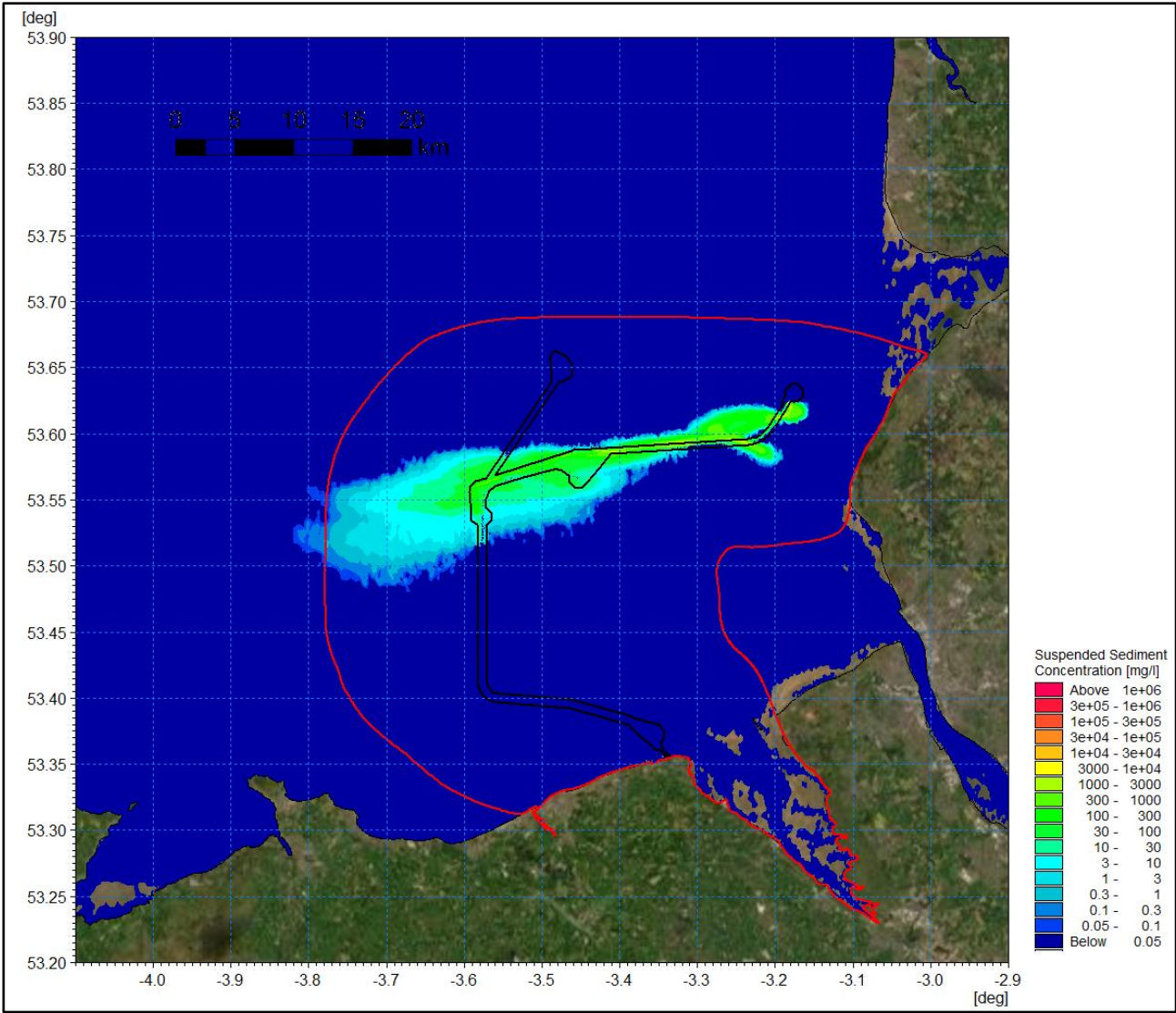


Figure 1.107: Suspended Sediment Concentration Day 4 Flood – Douglas To Lennox

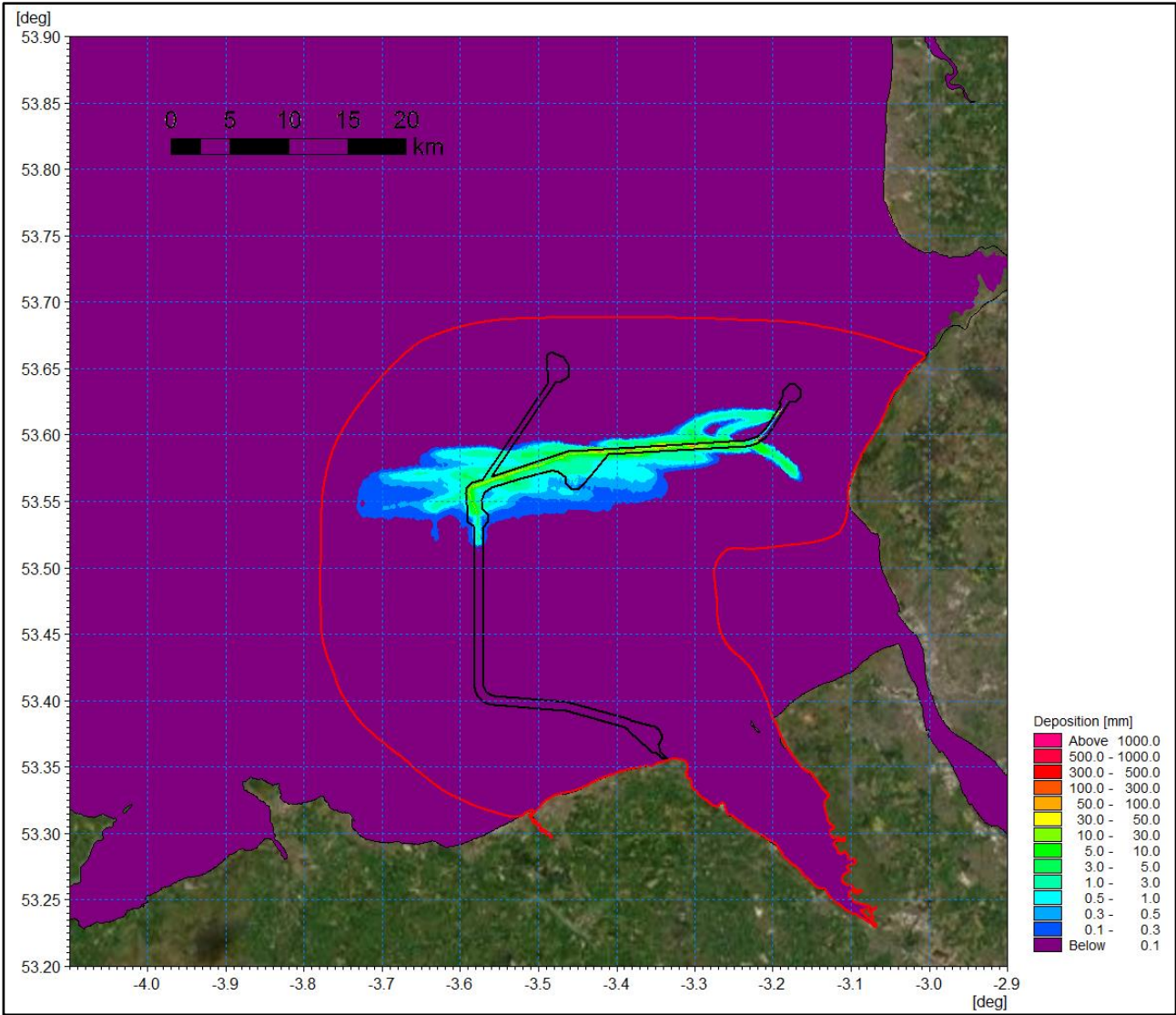


Figure 1.108: Maximum Sedimentation Over Trenching Phase – Douglas To Lennox

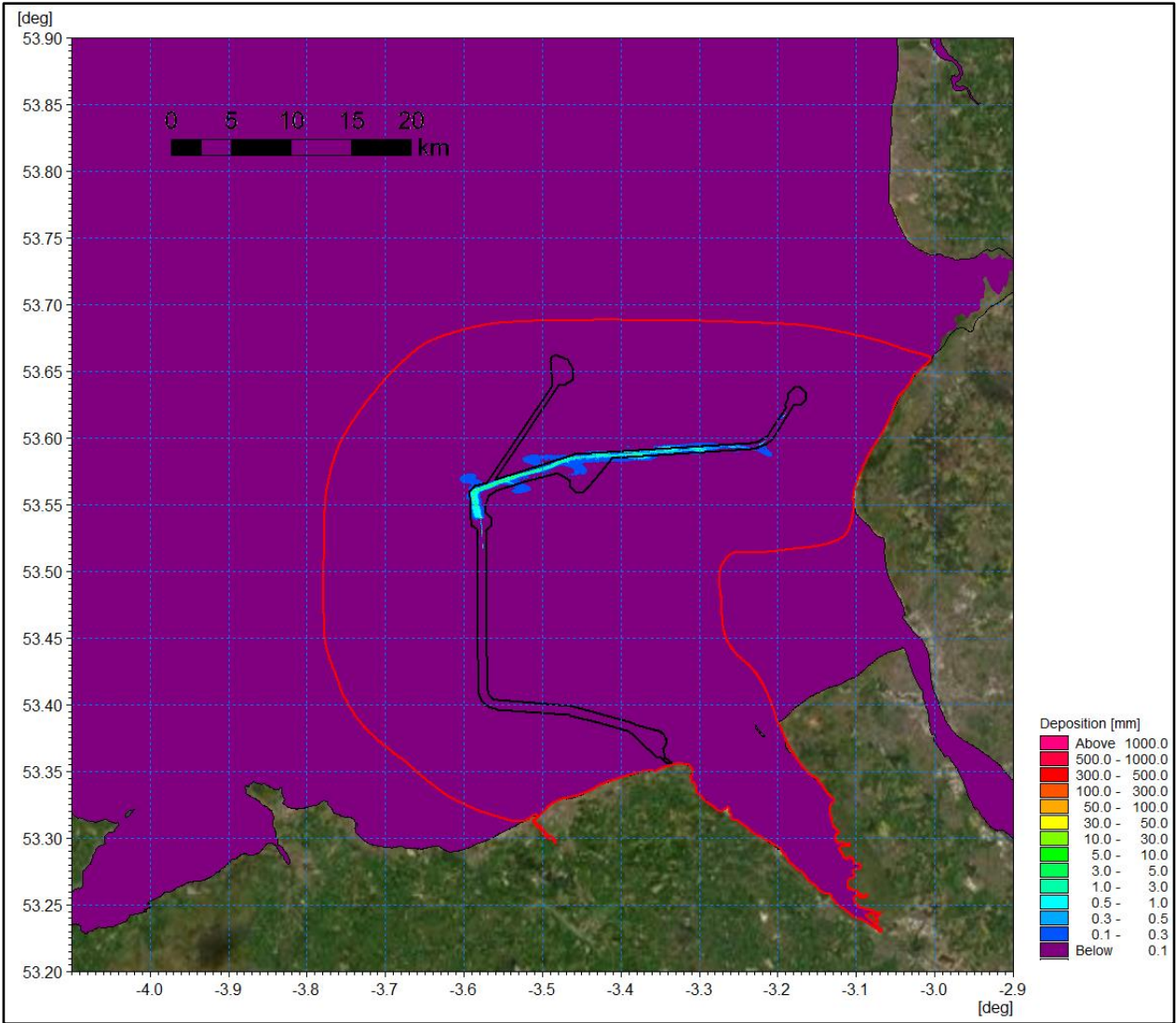


Figure 1.109: Average Sedimentation Over Trenching Phase – Douglas To Lennox

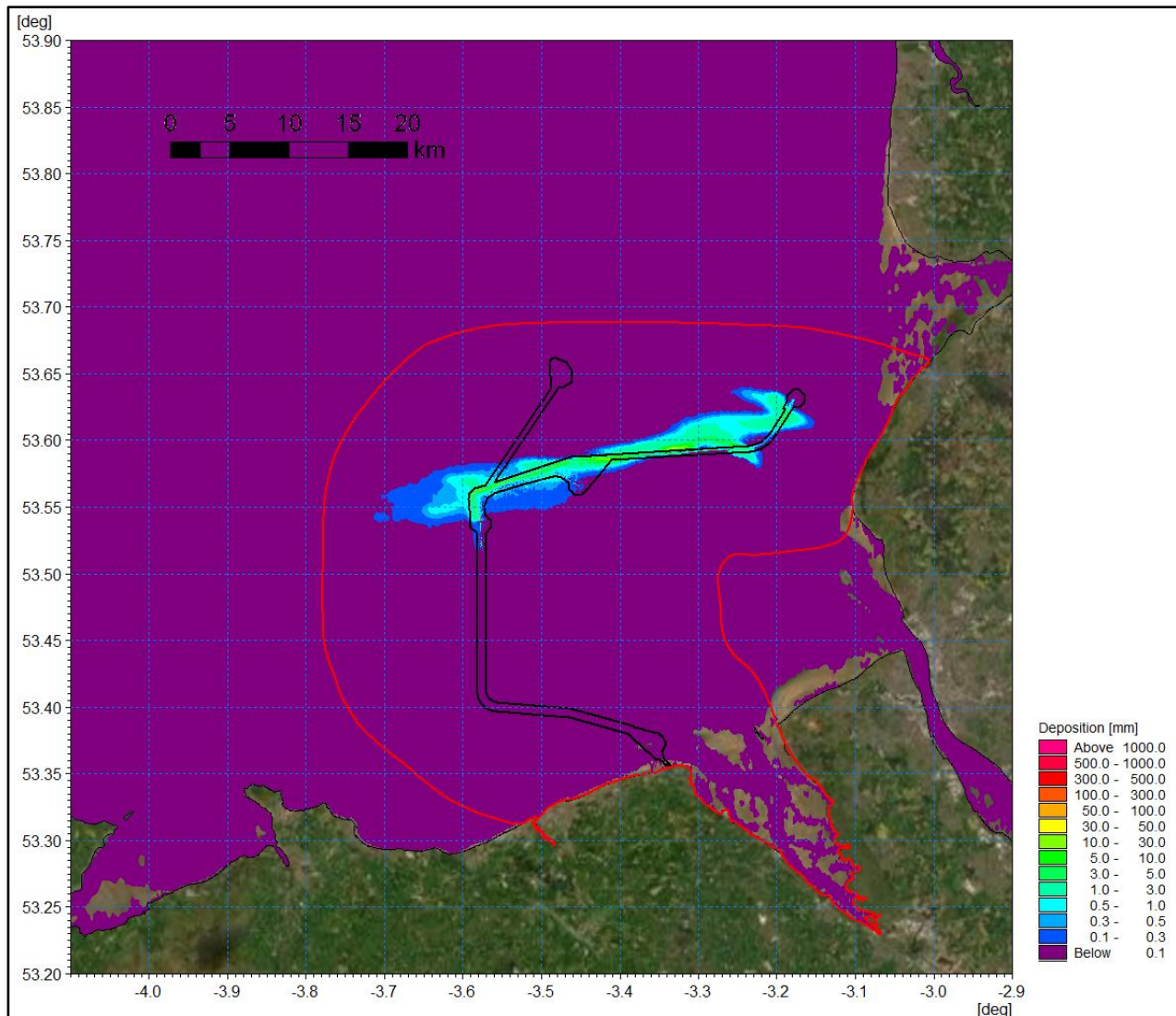


Figure 1.110: Sedimentation One Day After Cessation Of Trenching – Douglas To Lennox

1.8 Summary

A numerical modelling study was undertaken to inform and qualify the potential impacts of the Proposed Development on physical processes. This report has outlined the baseline characteristics of the region in terms of physical processes. This includes tidal current, wave climate and sediment transport under both calm and storm conditions. Numerical modelling has been used to quantify the changes in physical processes, predominantly suspended sediment concentrations, due to seabed preparation activities, the drilling of new monitoring wells, and laying of cables.

Suspended sediment plumes for seabed preparation activities were quantified. In all cases, the material released was native to the bed sediments and, although there are periods of increased turbidity, the material was retained in the sediment cell and would be subsequently assimilated into the existing sediment transport regime. Suspended sediments may reach into the estuary during cable trenching from POA to Douglas, but generally do so at background levels, (i.e. 30 mg/l).

Both SSC and deposition related to the drill cutting releases were further limited than the seabed preparation and cable installation activities both spatially and in magnitude. With sedimentation restrained to negligible levels across the drill site and along the tidal ellipse.

During cable installation sediment again showed it was retained within the Solway Firth sediment cell and is again incorporated into the sediment transport regime. Sedimentation occurs predominantly during slack water and is then again resuspended to form a secondary plume.

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