16th September 2024

NewDepomod Modelling Report

Meil Bay

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Summary

Cooke Aquaculture Scotland (CAS) has undertaken biomass and in-feed chemotherapeutant modelling for the proposed Meil Bay site. The pen layout uses 16, 100m circular pens, moored within 60m grids. The site was modelled using NewDepomod to determine the maximum biomass and in-feed chemical treatments. NewDepomod was ran using SEPA default values as a risk assessment tool to determine dispersion and depositional characteristics at the proposed site. The availability of enhanced benthic monitoring results at the existing Meil Bay site also meant NewDepomod could be calibrated, whereby a series of parameters controlling erosion, settling and dispersion were adjusted to obtain the best agreement between the measured and modelled benthic footprint for the existing site. The calibrated NewDepomod model allows a more site-specific review of the benthic impact. A summary of the predicted footprints of the proposed site are given in Table 1.

Spatial contour plots and 2D transects quantifying the benthic footprints are presented for both the default and calibrated NewDepomod results. The majority of deposition in both cases occurs directly beneath the pens. In the default model the predominant deposition occurs along transect 1 (T1) on a bearing of 80°, resulting in an elongated footprint towards the northeast. Conversely, the calibrated model predicts a more tightly constrained footprint, without the large area of deposition to the NE. This is potentially more representative of what is classified as a quiescent site with low resuspension event occurrence. In both the default and calibrated cases, the predicted impact of the proposed Meil Bay site is comfortably within the benthic EQS thresholds.

In-feed chemical modelling complies with environmental standards when using 850g of Emamectin Benzoate in the default model. Due to the close location of the existing site, compliance is determined by the proportion of newly impacted seabed compared to the existing chemical footprint. For the default model, 13.7% of new impact area was identified. This permits a treatable biomass of 2428.6 tonnes.

Table 1. Summary of the recommended consent limits for the proposed Meil Bay site.

<table>
<tr><td>Maximum biomass</td><td>1410</td><td>Stocking density</td><td>18.4</td></tr>
<tr><td colspan="2">Biomass modelling</td><td>Default model</td><td>Calibrated model</td></tr>
<tr><td colspan="2">100m mixing zone area (m^2)</td><td colspan="2">177,435</td></tr>
<tr><td colspan="2">Impact area (m^2)</td><td>168,750</td><td>79,375</td></tr>
<tr><td colspan="2">Percentage of 100m mixing zone (%)</td><td>95.1</td><td>44.7</td></tr>
<tr><td colspan="2">Cage edge threshold (g m^2 yr^{-1})</td><td>2036.3</td><td>3148.3</td></tr>
<tr><td colspan="2">Intensity increase from existing (%)</td><td>-</td><td>9.2</td></tr>
<tr><td colspan="2">In-Feed Treatments - EmBz</td><td colspan="2">Default model</td></tr>
<tr><td colspan="2">Chemical quantity (g)</td><td colspan="2">850</td></tr>
<tr><td colspan="2">100m mixing zone area (m^2)</td><td colspan="2">177,435</td></tr>
</table>

Predicted impact area of proposed site (m^2)	1633750
Percentage of 100m mixing zone (%)	920.8
Predicted impact area of existing site (m^2)	1795000
New area of impact (m^2)	246470.1
Percentage of new impact area (%)	13.7

1. Introduction

This report details the methodologies used for the set up and running of SEPA default and calibrated NewDepomod models for the existing and proposed Meil Bay aquaculture sites. Modelled footprint area and intensity are then used to determine the maximum biomass and in-feed chemical mass that complies with all SEPA's environmental quality standards (EQS).

1.1 Site description

Meil Bay is an existing, consented site (CAR/L/1003888) operated by Cooke Aquaculture Scotland. The site is located off the northeast coastline of the Orkney mainland, within the Bay of Meil, south of Shapinsay Sound (figure 1). The existing site consists of a single group of 10 circular, 100m circumference cages with a net depth of 6m. These are arranged in a 2 x 5 layout with a ~60 m separation, housing a maximum consented biomass of 884T at a maximum stocking density of 18.5kg/m^3. The site is aligned with a bearing of ~22.5°. The licensed site is centred on 348452.07E, 1012342.29N, with a wave exposure index of 2.94.

The proposed development adds a further six 100m circumference pens to the existing infrastructure, forming a site layout of 2x8 pens on a 60m grid, and repositions the site ~200m to the NW (348439.639E, 1012644.247N) in a deeper, less constrained location closer to the mouth of the bay (figure 1). The proposed site will house a maximum consented biomass of 1410T, providing a maximum stocking density of 18.4kg/m^3. Further information on the existing and proposed site infrastructure and pen layout is presented in table 2.

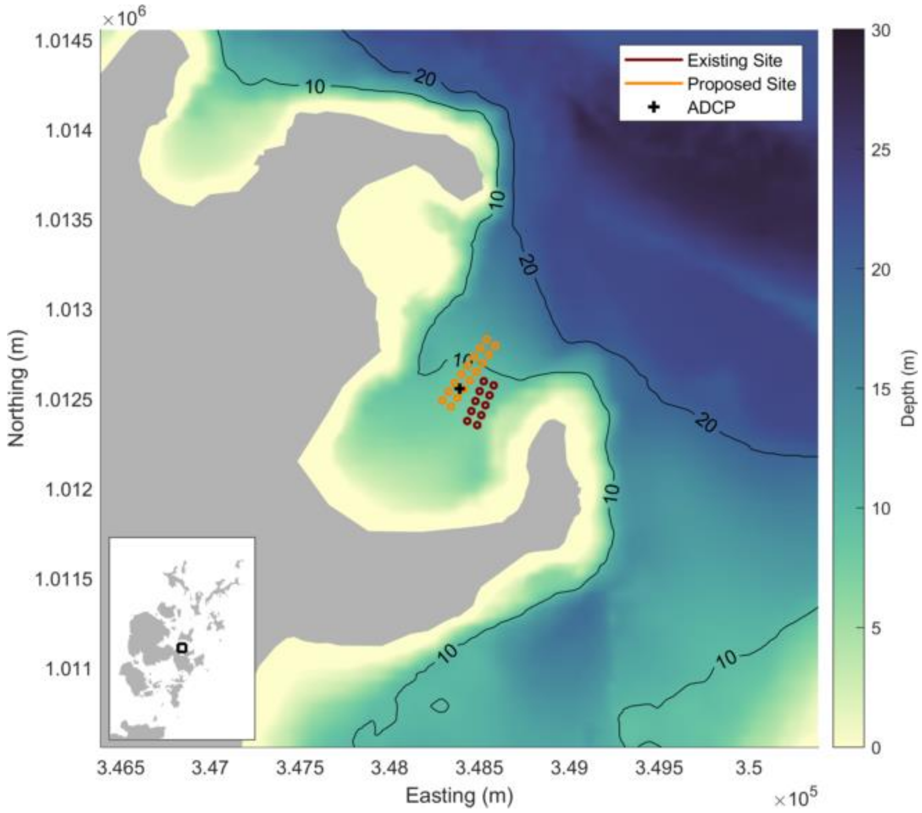

Figure 1. Existing (red) and proposed (blue) Meil Bay site infrastructure, ADCP deployment location ('+') and bathymetry.

Table 2 – Existing and proposed site infrastructure and pen layout.

	Meil Bay (Existing)	Meil Bay (Proposed)
Consent number	CAR/L/1003888	-
Company	Cooke Aquaculture Scotland	Cooke Aquaculture Scotland
Receiving water	Shapinsay Sound	Shapinsay Sound
Site centre (OSGB36)	348505E, 1012476N	348439.639E, 1012644.247N
Current meter location (OSGB36)/year of deployment	348388E, 1012558N /2021	348388E, 1012558N /2021
Distance to shore (km)	0.35	0.5
Average water depth (m)	9	12
Maximum biomass (t)	884	1410
Total number of pens	10	16
Number of pen groups	1	1
Formation	2x5	2x8
Pen group orientation (º)	22.5	36
Pen shape	Circular	Circular
Pen circumference (m)	100	100
Mooring grid (m)	60	60
Wave exposure index	2.94	3.06

2. NewDepomod modelling methods

To determine maximum biomass and compliant in-feed chemotherapeutant quantities, a particle tracking model is applied. NewDepomod (version 1.3.2-rc01) simulates the release and deposition of waste feed and faecal material from farms to the seabed, from which the benthic impact is predicted. For in-feed treatments specific chemical characteristics are accounted for to determine chemical concentration and accumulation.

2.1 SEPA default model

The SEPA default model allows a cautionary estimate of the proposed site's depositional footprint. Parameters controlling particle settling, dispersion and erosion are set to SEPA's predetermined values.

2.1.1 Benthic

The benthic SEPA default model is used to determine maximum biomass based on Environmental Quality Standards (EQS). These methods and NewDepomod particle dispersion parameters are outlined in more detail in SEPA (2019a) and SEPA (2019b).

For the standard default model, the domain consists of a 2 km^2 area with grid cells at 25 m spacing. The coordinate system uses the cartesian Ordnance Survey of Great Britain 1936 system (OSGB 1936), with the site centred in the domain. Uniform bathymetry is applied, with the depth value set at the minimum ADCP measured depth (10.5m). Coastline data from Ordnance Survey (2022), is used to define the land boundary, which is set to 10 m above sea level.

The simulation uses 90-days of hydrographic data recorded within 150m of the proposed and existing site centre. The processed hydrographic data uses three depth cells. These represent flow conditions at near bed, pen bottom and near surface depth intervals. Residual currents contribute 13.9% to the near-bed mean speed, therefore residual currents are included in the SEPA default model forcing. The hydrographic data is presented in more detail in the Modelling Data Collection Report (CAS, 2022) and is summarised below in section 3.1.

Peak biomass is simulated for the entire model duration, this is equal to 365.25 days for the benthic model. Maximum biomass is then used to calculate the feed waste and faecal matter using the values in table 3 and the equations below.

Table 3. Input feed parameters

Parameter	Symbol	Value
Feed requirement	f_r	7kg per 1000kg biomass per day
Feed water (%)	f_h	9%
Feed waste (%)	f_w	3%
Feed absorbed (%)	f_a	85%
Feed carbon (%)	f_c	49%
Faeces carbon (%)	f_f	30%

The amount of waste solids (w_s) per day is calculated as

$$w_s = (1 - f_h). f_w. f_r$$

Waste carbon (w_c) is calculated as

$$w_c = (1 - f_h).f_c.f_w.f_r$$

Excreted solids (e_s) are calculated as

$$e_s = (1 - f_h).(1 - f_w).(1 - f_a).f_r$$

Excreted carbon (e_c) is calculated as

$$e_c = (1 - f_h).(1 - f_w).(1 - f_a).f_f.f_r$$

To ensure consistent particle dispersion characteristics within the default model, specific parameters are defined. These are outlined in table 4. This provides a small subset of controllable model parameters, and while there are other adjustable values, these are considered as the main calibration terms. These parameters are set to the predetermined figures defined by SEPA, with the exception of the resuspension dispersion coefficient Z which uses the mean bed velocity ($\bar{u}$) to calculate the vertical resuspension coefficient.

Table 4. SEPA default model parameters.

Parameter	**Value**
tauEcritmin	0.02
Expansion T50	1
Particle release height	0
Bed roughness	0.001273
Resuspension dispersion coefficient Z	$0.0003\bar{u}^{-0.762}$
Resuspension dispersion coefficient XY	0.1
Suspension dispersion coefficient X	0.001
Suspension dispersion coefficient XY	0.1
dLayer mass	3375
Particles per area	0.0016
Density of mud	1400
Mass erosion coefficient	0.031

The default model uses the 3 hourly outputs averaged over the last 90 days of the simulation as a risk assessment tool for the benthic environment. The EQS values and descriptions that are used to define a maximum acceptable impact are provided in table 5. To determine potential risk to the seabed, the Infaunal Quality Index (IQI) provides a numerical value that corresponds to the health of the seabed. As NewDepomod does not model IQI directly, a relationship between sediment flux and IQI is used as a proxy for environmental impact. For the SEPA default model, this states that a solid flux of 250g/m^2 is equivalent to an IQI of 0.64. Therefore, any deposition above the 250g/m^2 is defined as having a significant impact on the seabed. The 100m composite mixing zone is defined as the pen area plus an additional 100m buffer zone. An additional intensity standard is applied that restricts the mean concentration of the impacted area, where the permitted average is based on the sites wave exposure. The existing and proposed Meil Bay sites have wave exposure values greater than 2.8.

Table 5. Default benthic EQS parameters

Pen-edge	Intensity	Mean deposited mass within the 250 g/m^2 impact area should not exceed 2000 g/m^2 where wave exposure is less than 2.8, and 4000 g/m^2 where wave exposure is more than 2.8.
Mixing zone	Area	Total area (m^2) with a mean deposited mass in excess of 250 g/m^2 should not exceed the 100 m composite mixing zone area (m^2). If wave exposure is 2.8 or above, the mixing area may occupy 120% of the 100m mixing zone.

2.1.2 Existing site default

NewDepomod was ran with the default SEPA parameters for the existing Meil Bay site. The results are shown in figure 2 and summarised in table 6. The modelled impact area for the default existing Meil Bay site is 101,875m^2, this is equivalent to 81.3% of the 100m mixing area. This is an overestimation of 190% in the impacted area when compared to the observed IQI results. The mean deposited concentration within the deposited footprint is 1825.4g/m^2.

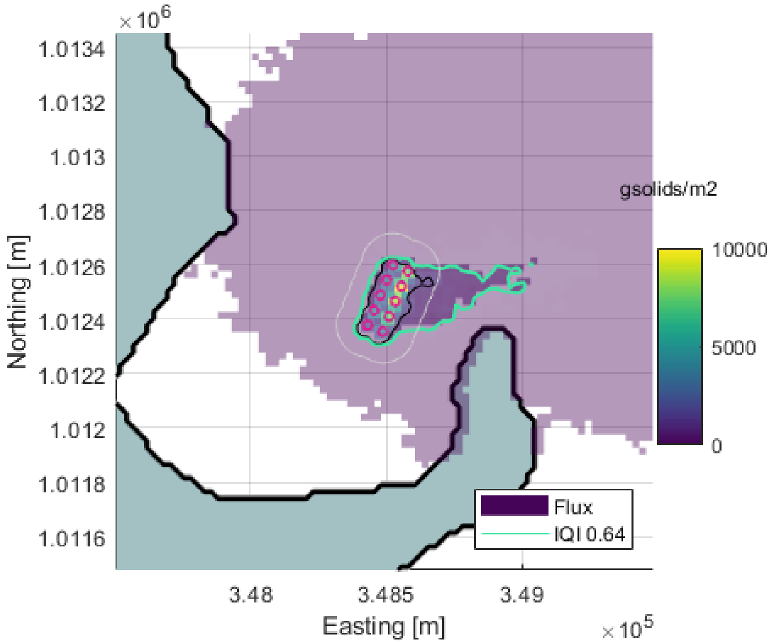

Figure 2. Existing default model benthic footprint (aquamarine contour).

Table 6. EQS results from benthic NewDepomod model runs – existing site.

Model type	SEPA default	Calibrated
Residual currents	Included	Included
Feed input	Maximum biomass	Variable feed
Sediment flux equivalent to IQI=0.64 (g/m^2)	250	250.7
Licensed biomass (tonnes)	884	884
Stocking density (kg/m^3)	18.4	18.4
100m mixing zone (m^2)	125,376.5	125,376.5
Predicted impact area (m^2)	101,875	54,375
Area of 100m mixing (%)	81.3	43.4
Mean deposited mass ($g\ m^{-2}\ yr^{-1}$)	1825.4	2882.6

2.1.3 In-feed treatment

In-feed chemical compliance determines the maximum quantity of Emamectin Benzoate (EmBz) to be used on site. These methods and NewDepomod parameters used for the SEPA default chemical model are outlined in more detail in SEPA (2019a) and SEPA (2019b). Chemical model settings are identical to the benthic model, with the exception of a handful of variables that control particle consolidation and decay (table 7). Input feed parameters are defined by table 3 and the equations in section 2.1.1. Settling, erosion and dispersion parameters are defined in table 4.

For the treatment of EmBz, simulation duration is reduced to 223 days, where the EQS is recorded at 118 days. This is based on the average chemical concentration from the 48 hours leading up to the 118th day, sampled at 3-hour intervals. The model domain is also increased for the chemical NewDepomod model runs, from 2km^2 to 4km^2, to prevent areas of impacted seabed falling outside of the model domain.

Table 7. Infeed parameter specific to chemical modelling.

Parameter	Benthic (solids input)	In-feed (EmBZ input)
Consolidation time of faeces	0	345600
Consolidation time of feed	0	345600
Degrade T50 chemical (s)	Infinity	21600000

In-feed chemical EQS values are defined using the most recent guidelines from SEPA (2022a) and the UK Technical Advisory Group (2022). These values and descriptions are given in table 8. This uses the 100m mixing zone principle, with a chemical contour value of 272 ng/kg of dry sediment. This is equivalent to 0.136 µg/kg of wet sediment.

Table 8. In-feed chemical EQS parameters

Mixing zone	Area	Total area which exceeds the pertinent EQS (0.136 µg/kg) should not exceed the 100 m mixing zone area.

For existing farms, the previous consented chemical quantity can be used providing very limited impact to new seabed areas. This is quantified using a comparison between the existing and proposed site, where any new area of EmBZ impact area must be below 15% of the existing impact area using the current EQS value (0.136 µg/kg). If the new area of impact exceeds 15%, then the proposed changes will fail, and the chemical quantity should be reduced until this area is below the maximum new area percentage.

2.2 Calibrated model

2.2.1 Existing site performance

Enhanced benthic monitoring was completed at the existing Meil Bay site on the 30/08/2021 and the 01/09/2021. This data is used to draw a fitted ellipse to assess site compliance with environmental standards. Benthic grabs were taken from 4 orthogonal transects, made up of a total of 26 sampleable monitoring stations (table 9). IQI values were then calculated at each of these sample stations. On the easterly transect, hard substrate was detected after the 25m sample station, only allowing IQI measurements to be collected at the pen edge and 25m stations, both of which had IQI values of less than 0.64. Diver observations describe the bed type from 50m to 258m along the eastern transect as rocky (PHARMAQ, 2021). This rocky substrate is determined to be unimpacted. Additional discussions with SEPA ecologists suggested using the westerly transect as a proxy. Due to differences in the bathymetry a cautionary decision was taken that used an IQI=0.64 location of 50m from the pen edge for the eastern transect, therefore allowing sufficient points for an ellipse to be calculated. The ellipse is calculated using SEPA's ellipse fitting toolbox (SEPA, 2022b). The existing pens, sample stations and fitted ellipse are shown in figure 3.

Table 9. Transect information.

Transect	**Stations Sampled**	**Direction**	**Bearing (°)**	**Distance to IQI 0.64 (m)**	**Method**
E	2	SE	112	50	Override
N	7	NE	18	5.8	MM.3 model
S	7	SW	199	100.9	Nearest Station
W	7	NW	301	27.1	MM.3 model

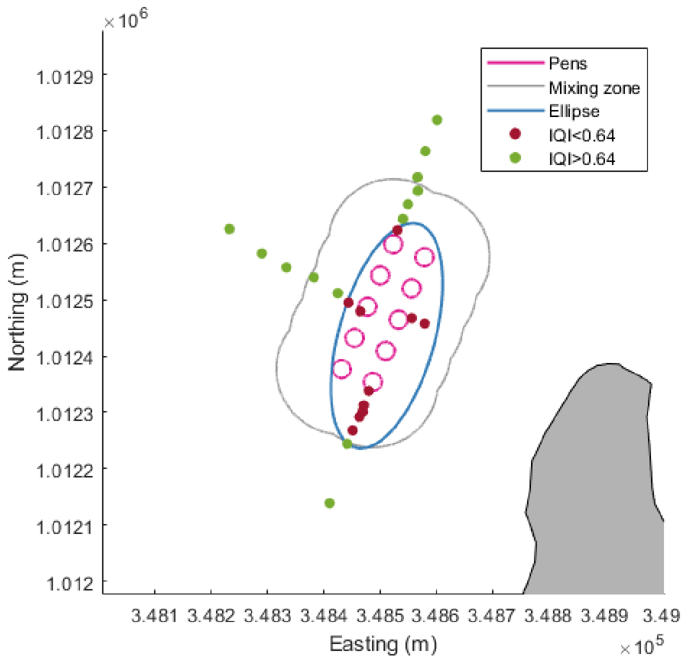

Figure 3. Pens are shown in pink, 100m mixing zone is shown in grey, marker points indicated good (IQI > 0.64) and bad (IQI < 0.64), and the calculated ellipse in blue.

Following SEPA's latest guidance, CAS has calculated the mixing area and impacted ellipse area. The results are shown in table 10. The existing site currently operates comfortably within benthic compliance limits.

Table 10. Determining compliance

100m Mixing Zone	Ellipse Area	Proportion of 100m mixing area
125,376.5 m^2	53,346.7 m^2	42.6%

2.2.2 Existing site calibration

Data from the enhanced benthic survey is used to calibrate a NewDepomod model of the existing Meil Bay site. Uniform depth and flowmetry, obtained from the 2021/2022 HG data set (table 13) with residuals included were applied across the 2km^2 NewDepomod domain. Realistic biomass and feed input values were applied by extracting a 365-day timeseries ending on the enhanced survey date from the FishTalk database (figure 4).

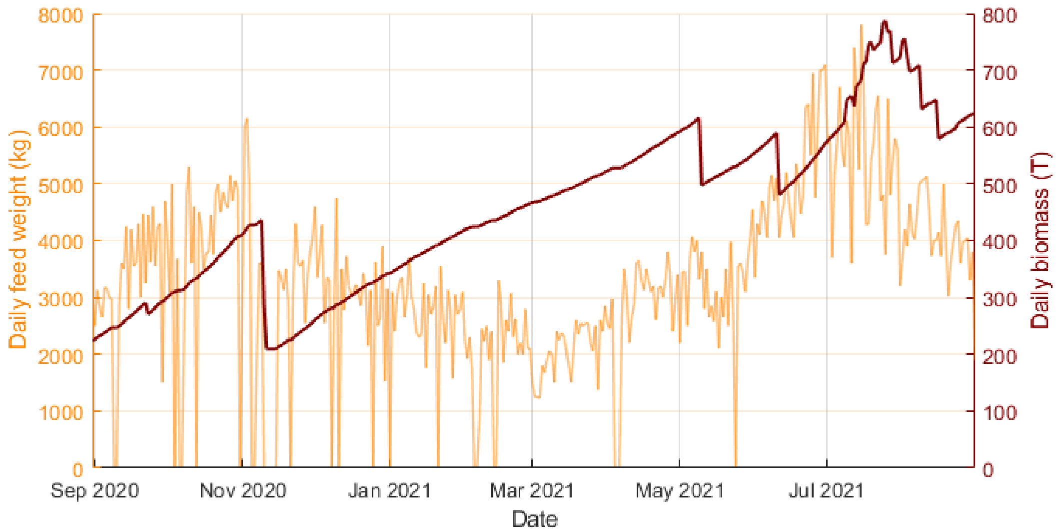

Figure 4. Daily feed input and biomass data for the existing Meil Bay site for the year prior to the enhanced survey date (31/08/2021).

Model parameters controlling settling, dispersion and bed erosion were initially set at SEPA default values and sequentially adjusted. This ultimately alters the distribution and intensity of the modelled benthic footprint.

To fully calibrate the model, the flux/IQI relationship is recalculated by applying an exponential fit to the modelled deposition at the sample locations and measured IQI data (figure 5). Several statistical models were tested, including linear 1st, 2nd and 3rd order polynomials and a nonlinear logistic model. However, the exponential model gave the best fit with r^2 and RMSE values of 0.76 and 0.12, respectively. The mathematical expression linking modelled deposition and observed IQI values allows the calculation of a new, model specific, flux value equivalent to an IQI value of 0.64. From this, the modelled impact area can be derived. Model performance is quantified by comparing the modelled footprint area with the area of the fitted ellipse. The best performing calibration parameters and statistics are shown in table 11.

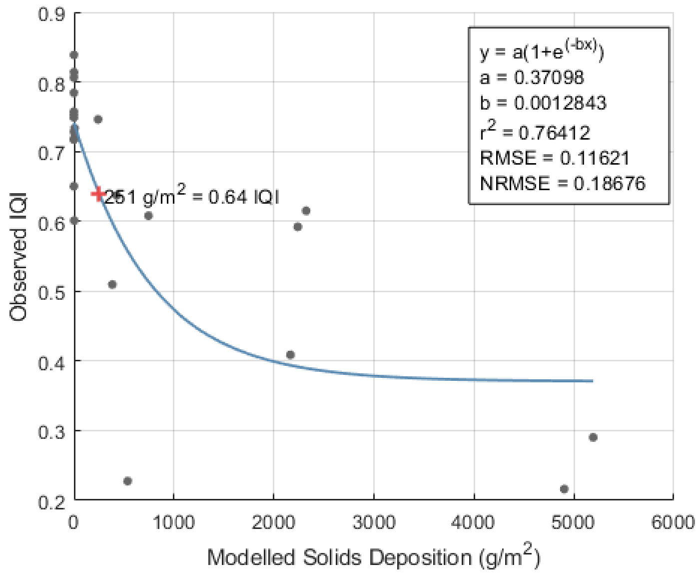

Figure 5 – Modelled solids deposition vs. observed IQI values (grey 'o') and the fitted exponential regression curve (blue line).

Table 11. Best performing model parameters

Model Parameter	Default	Best Performing Value
tauECritMin	0.02	0.1
ResusDispersionCoefficientXY	0.1	0.06
ResusDispersionCoefficientZ	0.0035	0.003
SusDispersionCoefficientXY	0.1	0.1
SusDispersionCoefficientZ	0.001	0.006
releaseHeight	0	0.05
BedRoughness	0.001273	0.0013
massErosionCoefficient	0.031	0.2
Fitting		
Flux IQI 0.64 value	250	250.7
Regression curve	-	$y = 0.37(1 + e^{-0.0013x})$
Stats		

Correlation coefficient	-	0.76
RMSE	-	0.12
NRMSE	-	0.19
Area difference (Ellipse area – modelled impact area) (m^2)	-	-1028
Area overlap (%)	-	71.8

Figure 5 shows the calibrated modelled benthic footprint alongside the benthic samples and fitted ellipse for the existing Meil Bay site. The modelled impact area where deposited concentrations exceed 250.7g/m^2 is indicated via the aquamarine contour. The scale of the modelled impact area shows a good agreement with the observed impacted seabed, with a 1028m^2 difference between the area of the fitted ellipse and modelled footprint. The model also shows satisfactory positional agreement to the fitted ellipse with a 71.8% overlap between modelled and observed impacted area.

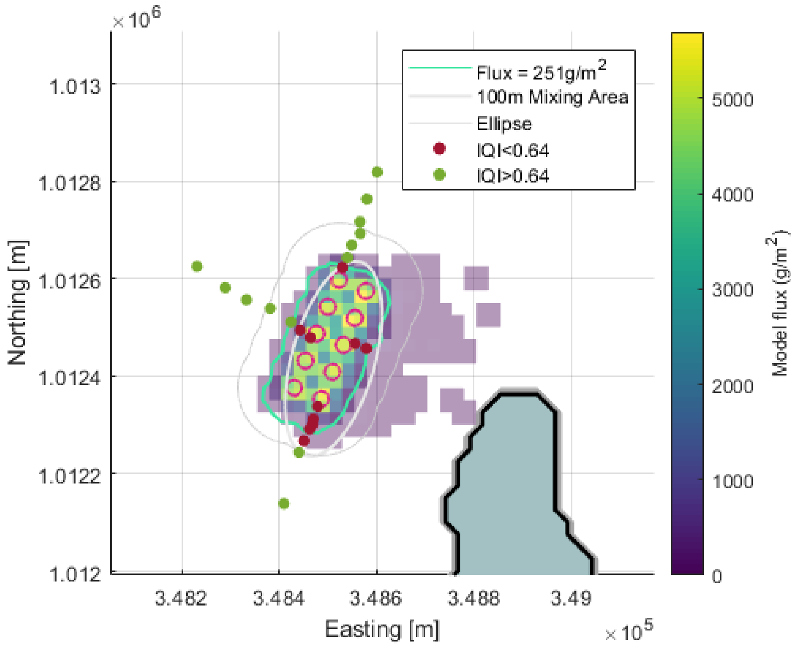

Figure 6. Existing calibrated model benthic footprint (aquamarine contour) with benthic sample data (‘o’) and fitted ellipse (grey line).

The modelled impact area for the calibrated existing Meil Bay site is 54,375m^2, this is equivalent to 43.4% of the 100m mixing area. This is an overestimation of 1.9% in the impacted area when compared to the IQI results. The mean deposited concentration within the deposited footprint is 2882.6g/m^2.

2.2.2 Benthic

The proposed changes to the site are then simulated using the best performing model parameters (table 11) and assessed using the new flux/IQI relationship (figure 6). This provides a more site-specific, predictive tool to determine potential benthic impact of the proposed site.

For the calibrated model, the domain remains a 2 km^2 area with grid cells at 25 m spacing. The coordinate system uses the cartesian Ordnance Survey of Great Britain 1936 system (OSGB 1936), with the site centred in the domain. Uniform bathymetry is applied, with a depth value set at the minimum ADCP measured depth (10.5m). Coastline data from Ordnance Survey (2020), is used to define the land boundary, which is set to 10 m above sea level.

The calibrated simulation uses the same 90-days of hydrographic data recorded within 150m of the proposed and existing site centre. The processed hydrographic data uses three depth cells. These represent flow conditions at near bed, pen bottom and near surface depth intervals. Residual currents are unaltered within the calibrated model, this allows a more realistic approach to determining particle fate.

The calibrated model run time (365 days) and averaging period (90 days) remains identical to the default model described in section 2.1.1. In the calibrated model variable feed input is used. The ratio between the existing licensed maximum biomass (884T) and the proposed site maximum biomass (1410T) is 1:1.595, therefore the September 2020- September 2021 FishTalk feed data (figure 4) is scaled up by a factor of 1.595 to provide feed quantities representative of the proposed site size.

The EQS values and descriptions that are used to define the maximum acceptable impact for the calibrated model are provided in table 12. For the calibrated model, this states that a solid flux of 250.7g/m^2 is equivalent to an IQI of 0.64. Therefore, any deposition above the 250.7g/m^2 is defined as having a significant impact on the seabed. The intensity EQS is quantified using a comparison between the calibrated existing and proposed site, where the mean deposited concentration within the footprint of the proposed site must be below 15% of the mean footprint concentration for the existing site.

Table 12. Calibrated benthic EQS parameters

Pen-edge	Intensity	An increase in intensity of a maximum of 15% from existing to proposed modelled under cage intensity is allowed.
Mixing zone	Area	Total area (m^2) with a mean deposited mass in excess of 250.7g/m^2 should not exceed the 100 m composite mixing zone area (m^2).

3. Input data

3.1 Hydrographic data

An acoustic profiling current meter was deployed ~140m from the existing site centre and ~100m from the proposed site centre for 112 days, from the 15th of September 2021 to the 5th of January

2022. From this a 90-day subset was selected, spanning 07/10/2021 10:30 to 05/01/2022 10:30. Within this 90-day subset, no pitch and roll exceedances or water column errors were identified. A summary of the flow statistics over the 90-day deployment are given in table 13.

Table 13. Hydrographic input information.

	Near Surface	Cage Bottom	Near Bed
Height from seabed (m)	7.62	6.62	1.62
Depth Cell	7	6	1
Mean Speed (m/s)	0.0345	0.0336	0.0392
Ranked Percentage at 0.03m/s (%)	46.95	49.24	35.8
Ranked Percentage at 0.045m/s (%)	75.63	76.95	65.97
Ranked Percentage at 0.095m/s (%)	99.01	99.14	98.89
Maximum Speed (m/s)	0.1906	0.1992	0.1852
Residual Speed (m/s)	0.0202	0.0183	0.0055
Residual Direction (°)	190.37	190.75	130.39

Typically, the site experiences low flow speeds, with mean velocities <0.04m/s. However, several higher energy events occur throughout the deployment where flow speeds at all depths exceed 0.1m/s, resulting in maximum recorded velocities of 0.19m/s. Little vertical structure is observed in velocity magnitudes, indicative of shallow well-mixed sites.

Residual currents are strongest near the surface and reduce in magnitude towards the bed. Within the near bed depth layer residual currents contribute ~14% to the overall mean velocity, meaning they are included in the forcing of the SEPA default NewDepomod model. The direction of the residual currents is predominantly southerly in the upper water column and south-easterly near the bed.

The vertical (z) resuspension dispersion coefficient used in the SEPA default model is calculated based on the mean bed velocity ($\bar{u}_z$). For Meil Bay the mean bed velocity is 0.039m/s.

3.2 Bathymetry and coastline

For both the SEPA default and calibrated NewDepomod models, a uniform bathymetry is applied based on the minimum recorded depth by the ADCP during the 90-day subset. This produces a uniform depth value of -10.5m. The model domain is shown in figure 7. A regular structured grid with a 25m resolution is used to represent bathymetry and coastlines. Coastline data is taken from the ordinance survey (Ordnance Survey, 2022).

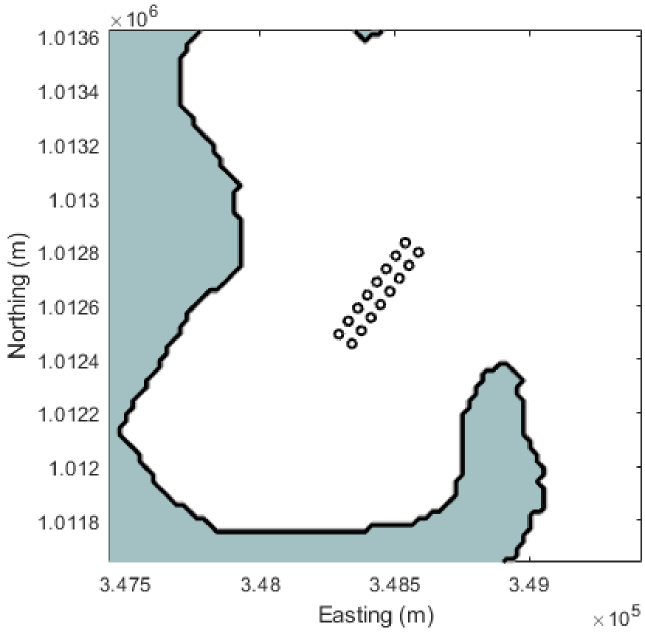

Figure 7. NewDepomod domain for the proposed Meil Bay Site.

4. Results

4.1 Benthic

4.1.1 SEPA default model

The SEPA default model was run to determine the maximum compliant biomass at the proposed site. Compliance was achieved with a biomass of 1410 tonnes, providing a stocking density of 18.4kg/m^3. A summary of the proposed site's environmental performance using the SEPA default model is given in table 14.

Table 14. EQS results from benthic NewDepomod model runs – proposed site.

Model type	SEPA default	Calibrated
Residual currents	Included	Included
Feed input	Maximum biomass	Scaled variable feed
Sediment flux equivalent to IQI=0.64 (g/m^2)	250	250.7
Biomass (tonnes)	1,410	1,410
Stocking density (kg/m^3)	18.4	18.4
100m mixing zone (m^2)	177,435	177,435

Predicted impact area (m^2)	168,750	79,375
Area of 100m mixing (%)	95.1	44.7
Mean deposited mass (g m^{-2} yr^{-1})	2036.3	3148.3
Intensity increase from existing (%)	-	9.2

The average spatial coverage of the deposited solids as predicted by the SEPA default model is shown in figure 7. Most of the deposition occurs beneath the easterly row of pens, with concentrations exceeding 10,000g/m^2 beneath some of these pens. Although the highest sediment flux is confined to the regions immediately beneath the farm, some transport beyond the 100m mixing zone is predicted. This is predominantly towards the northeast, resulting in an elongated footprint in this direction. Overall, impacted seabed, where concentrations exceed 250g/m^2, is predicted to cover an area of 168,750m^2 – this is equivalent to 95.1% of the 100m mixing zone area. Given the proposed site wave exposure index exceeds 2.8, this is within the EQS compliance limit of 120%. The pen edge EQS experiences a mean deposited flux value of 2036.3 g/m^2. This is within the compliant cage edge threshold for a site with a high wave exposure (< 4000 g/m^2). Using the SEPA default model parameters and EQS values, the proposed site passes all benthic standards.

To further illustrate the variability in sediment flux with distance from the farm, four transects are extended from the pen edges, to beyond the impact area. The locations of these are shown in figure 7. Transect 1 (T1) is aligned with the predominant direction of deposition. Transect 2, 3 and 4 are arranged orthogonally to each other and align with the major and minor axes of the 100m mixing zone. Figure 8 shows the changing deposition along these transects. As distance from the cage edge increases, flux values are shown to reduce. For transect 2 and 3 sediments flux values reach 0g/m^2within 350-400m of the pen edge, indicating a tightly constrained footprint in the SW and NW directions. Transect 1, which is aligned with the predominant direction of deposition, unsurprisingly shows higher deposited concentrations occurring further from the pen edge. However, the decline in sediment flux with distance from the pen edge is rapid along T1, with the flux decreasing by 2 orders of magnitude within the first 100m of the transect.

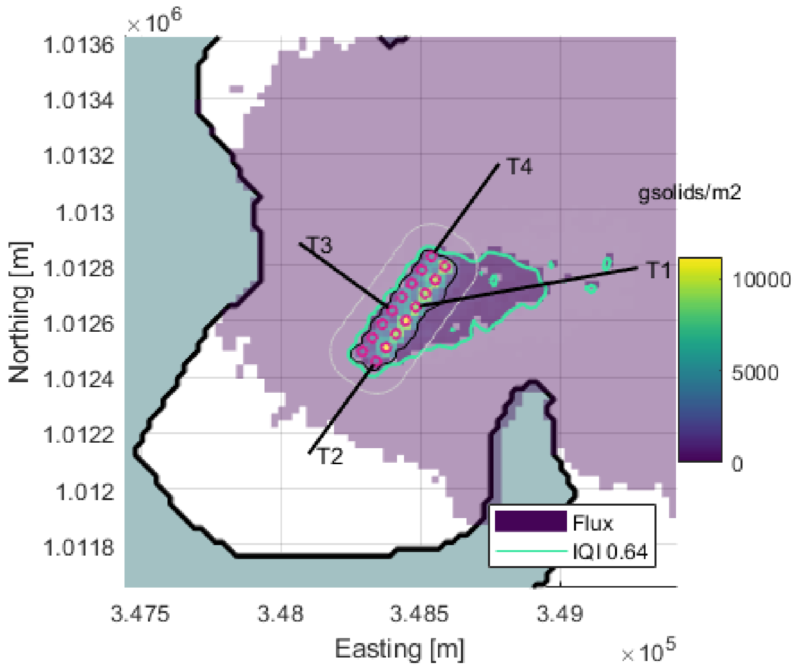

Figure 7. Modelled benthic footprint for the proposed Meil Bay site (1410T) using the default model (inc. residual currents). Transects locations 1-4 are also shown.

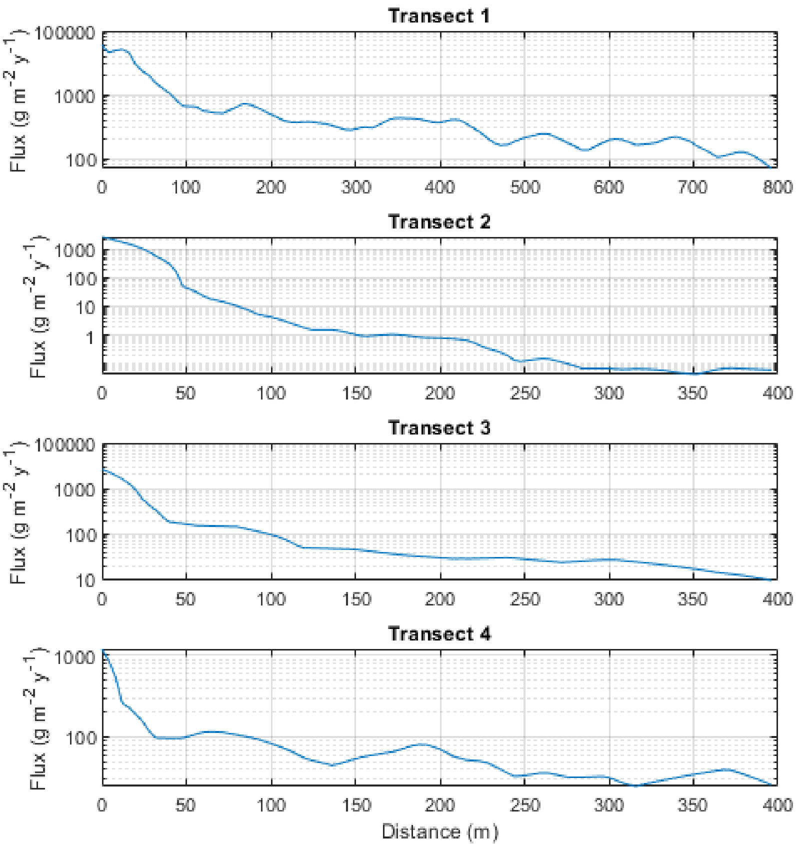

Figure 8. Transects (T1-T4) of organic solids depostion with distance from cage edge for the proposed Meil Bay site using the default model.

4.1.2 Calibrated model

The calibrated benthic model also achieved compliance at the proposed site with a biomass of 1410 tonnes. A summary of the proposed site's environmental performance using the calibrated model is given in table 14.

The average spatial coverage of the deposited solids predicted by the calibrated model is shown in figure 9. Similar to the default model, the calibrated model shows the majority of deposition occurring beneath the pens. However, unlike the default model, the calibrated model predicts a more tightly constrained footprint, without the large area of deposition to the NE. This is potentially more representative of what is classified as a quiescent site with low resuspension event occurrence. Overall, impacted seabed, where concentrations exceed 250.7g/m^2, is predicted to cover an area of 79,375 m^2 – this is equivalent to 44.7% of the 100m mixing zone area. Given the proposed site wave exposure index exceeds 2.8, this is within the EQS compliance limit of 120%. The pen edge EQS experiences a mean deposited flux value of 3148.3 g/m^2 - a 9.2% increase on the mean deposited flux calculated for the calibrated model of the existing Meil Bay site. This is compliant with the 15% threshold for a calibrated site. Using the calibrated model parameters and EQS values, the proposed site passes all benthic standards.

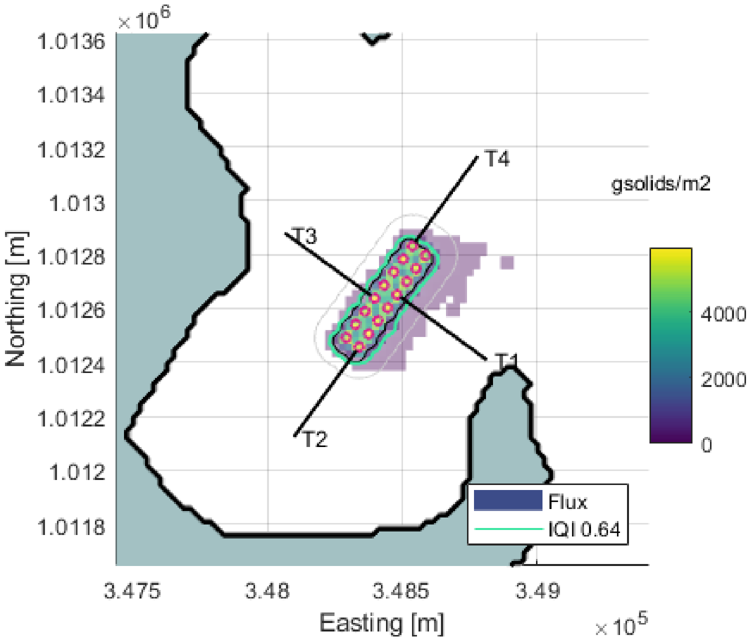

Figure 9. Modelled benthic footprint for the proposed Meil Bay site (1410T) using the calibrated model. Transects locations 1-4 are also shown.

Four transects are extended from the pen edges to beyond the impact area. The locations of these are shown in figure 9. Transects are arranged orthogonally to each other and align with the major and minor axes of the 100m mixing zone. Figure 10 shows the changing deposition along these transects. The transects show higher pen edge values but a more rapid decrease in flux with distance than their default model counterparts, indicative of the more constrained nature of the calibrated model footprint.

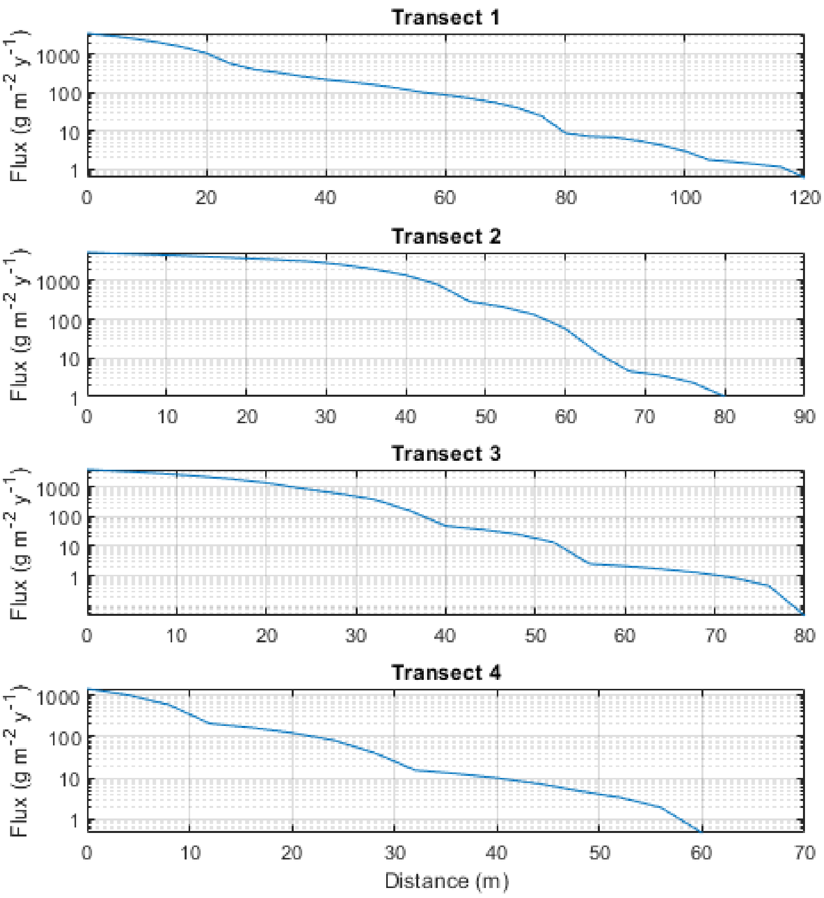

Figure 10. Transects (T1-T4) of organic solids depostion with distance from cage edge for the proposed Meil Bay site using the calibrated model.

4.2 In-feed treatment

In-feed treatments are used to control sea lice numbers in salmon farms. Slice™, active ingredient Emamectin Benzoate (EmBZ), is applied as a coating to the daily feed quota. To better understand the environmental effects of chemotherapeutants, the in-feed chemical default model was applied. Meil Bay is an existing site with a licensed EmBz quantity (TAQ) of 1500g. A comparison between the existing and proposed impact areas is used to determine a new compliant chemical quantity for the expanded Meil Bay site. In-feed modelling uses the SEPA default model parameters to assess the new complaint In-feed treatment mass.

4.2.1 Existing site

The predicted chemical footprint for the existing Meil Bay site as predicted by the default NewDepomod chemical model is shown in figure 11. Applying a mixing zone EQS of 0.136 µg/kg, the currently consented TAQ of 1500g results in an 1795000 m^2 impact area (1431.7% of the 100m mixing zone) for the default model (table 15).

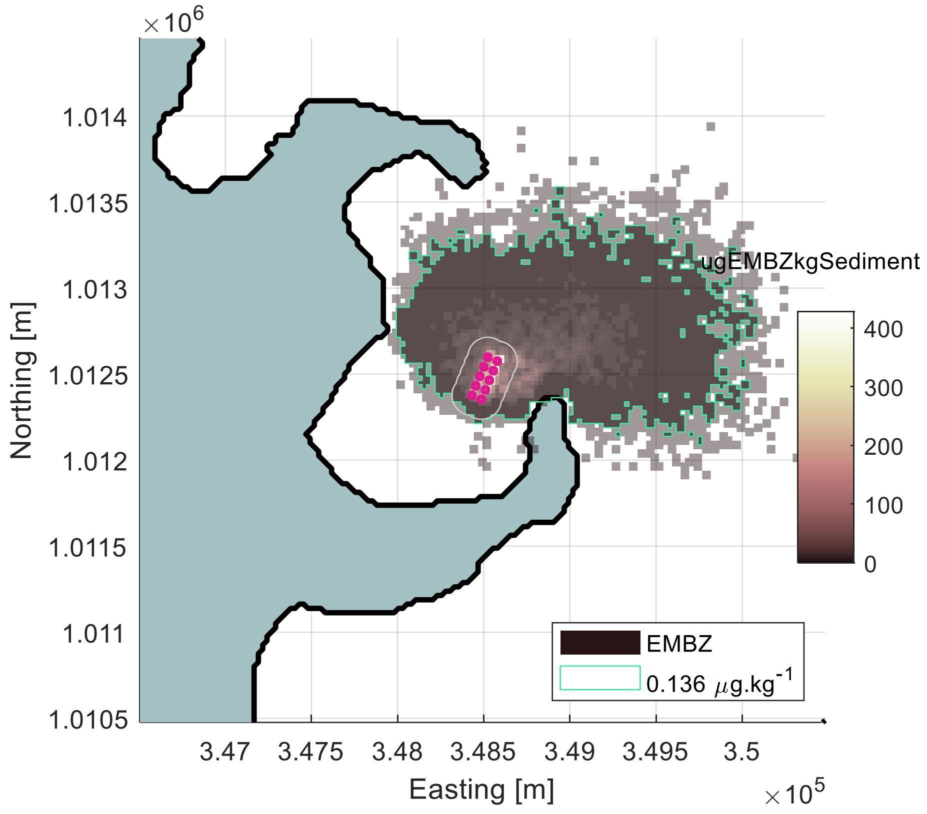

Figure 11. EmBz impact area for the existing Meil Bay site using the default NewDepomod model and an EQS of 0.136 µg/kg.

4.2.2 Proposed site

EQS compliance, using the SEPA default model was achieved with a maximum EmBz quantity of 750g. The proposed site centre is shifted ~200m NW of the existing site centre, meaning relative to the existing site, the proposed site footprint is also shifted northwest. The majority of the proposed footprint overlaps the existing site footprint, however some new seabed is impacted outside the northern boundary of the existing footprint. This new area of impact is equivalent to 14.89% of the existing site footprint. EQS performance for the existing and proposed default model runs are summarised in table 15. The existing and proposed chemical footprints predicted by the default model are shown in figure 12.

Table 15. EQS results from the EmBz SEPA default model.

	Existing	**Proposed**
Model type	Default	Default
Biomass (tonnes)	884	1410
Stocking density (kg/m^3)	18.5	18.4
Chemical quantity (g)	1500	850

Domain size (km²)	4	4
100m mixing zone (m²)	125,376.5	177,435
Predicted impact area (m²)	1795000	1633750
Area of 100m mixing zone (%)	1431.7	920.8
New impact area (m²)	246470.1	
Percentage of new impact area (%)	13.7	

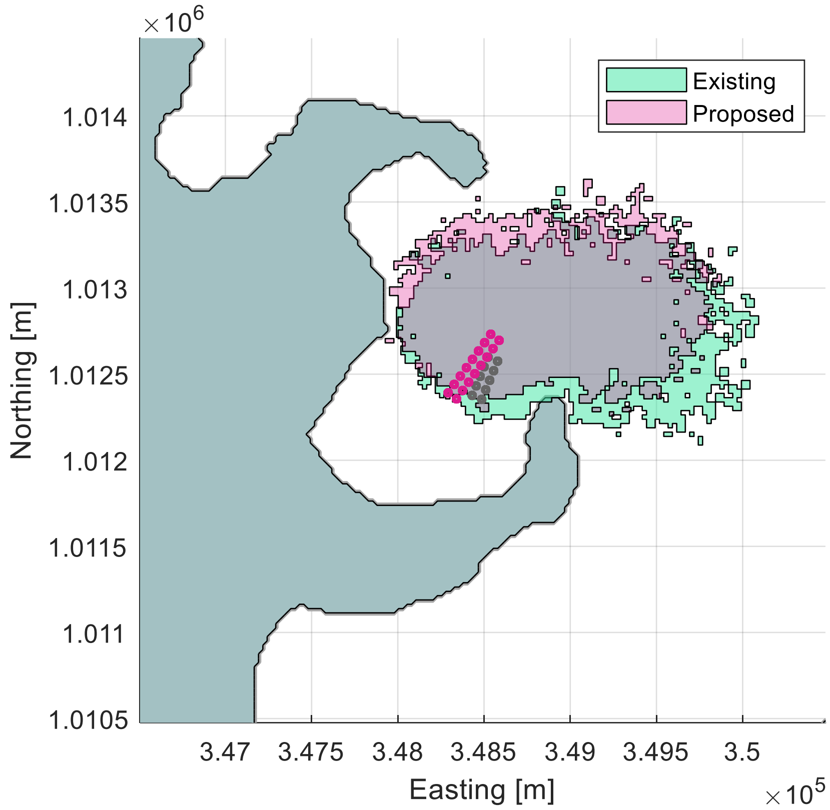

Figure 12. EmBz footprint for the existing and proposed Meil Bay sites using the default NewDepomod model and an EQS of 0.136 µg/kg.

Figures 13 and 14 show the distribution of the proposed footprint with hypothetical transects showing the presents of EmBz as distance from the site increases. This indicates net transport towards the NEE, resulting in an elongated footprint in the direction of 80°. Little EmBz is predicted to be deposited further into the bay towards the SW, with concentrations decreasing rapidly along transect 2. Peak chemical accumulation occurs directly beneath the pens. The resultant chemical impact area is 1633750m^2, 920.8% of the 100m mixing zone area.

The compliant chemical mass (850g) is used to determine the maximum treatable biomass. The total amount of Slice required is calculated using the chemical quantity multiplied by 0.5. Treatable biomass is calculated by dividing the chemical quantity by 0.35. This provides a treatable biomass of 2428.6T, requiring 425 kg of SLICE.

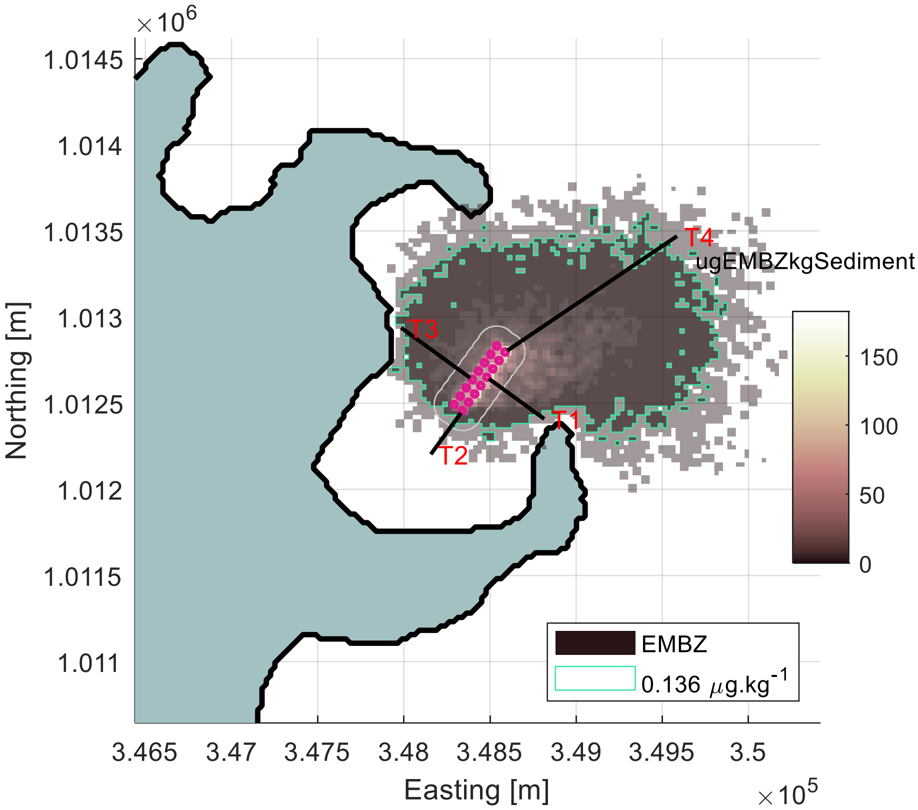

Figure 13. EmBz deposition for the proposed Meil Bay sites using the default NewDepomod model and an EQS of 0.136 µg/kg. Transect locations 1-4 are also shown.

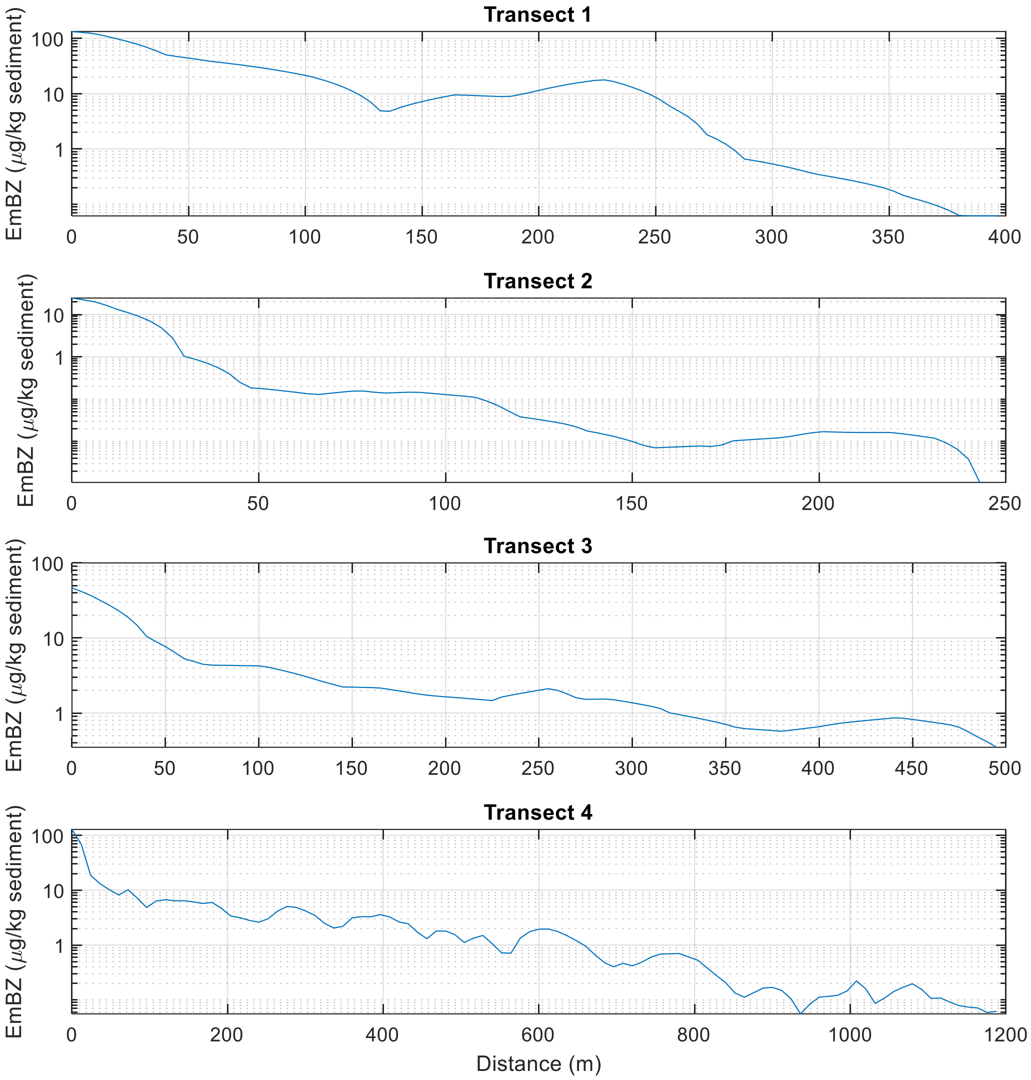

Figure 14. Transects (T1-T4) of EmBz deposition with distance from cage edge for the proposed Meil Bay site using the default model.

5. Conclusion

Results for both the SEPA default and calibrated NewDepomod models have been presented in this report. The SEPA default model shows a strong preference for north easterly transport of particulate matter, resulting in the prediction of elongated footprints along this axis. On the other hand, the calibrated model predicts a more tightly constrained footprint, with the majority of deposition occurring directly beneath the farm and concentrations decreasing approximately uniformly with distance from the pen edge in every direction.

The risk-assessment (default) and site-specific (calibrated) benthic modelling approach shows a maximum biomass of 1410 tonnes at the proposed Meil Bay site complies with all EQS thresholds. A predicted impact area equivalent to 95.1% and 44.7% of the 100m mixing area was predicted in the default and calibrated models, respectively. The mean deposited concentration for the default model run was 2036.3g/m^2. Whereas, for the calibrated model a concentration of 3148.3g/m^2 was calculated, this represents a 9.2% increase in the mean deposited concentration from the calibrated existing site value.

Due to the close location of the existing and proposed sites, in-feed chemical compliance was determined by the proportion of newly impacted seabed compared to the existing chemical footprint. Results from the default model determined a compliant EmBz quantity of 850g, which resulted in a new area of impact equivalent to 13.7% of the existing site footprint. This permits a treatable biomass of 2428.6 tonnes.

6. References

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