The Scottish Salmon Company

Modelling Report

North Arran, Firth of Clyde

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Author	
Approved By	

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List of Abbreviations

2D	Two-dimensional simulations along horizontal plane
3D	Three-dimensional simulations along horizontal and vertical plane
CAR	Controlled Activities Regulations
CTD	Conductivity, Temperature, Depth
EmBZ	Emamectin Benzoate (SLICE active ingredient)
EQS	Environmental Quality Standard
$g/m^2/yr$	Grams per square metre per year (deposition)
IQI	Infaunal Quality Index
mCD	Meters below Chart Datum (local)
NB	*Nota Bene:* Note Well
NDM	NewDepomod (simulation software)
OS	Ordnance Survey
SDM	Standard Default Method
SEPA	Scottish Environmental Protection Agency
SSC	Scottish Salmon Company
T	Tonnes (biomass)
TAQ	Total Allowable Quantity
WEI	Wave Exposure Index
μ	Statistical mean
λ	Half-life

1 Summary

This report was written by The Scottish Salmon Company (SSC) to meet the requirements of the Scottish Environment Protection Agency (SEPA) for a proposed new site, under the Controlled Activities Regulations ((CAR) 2011), updated by contemporary guidance (July 2019[1])). This report describes the methodology used to model the peak biomass and specific medicine quantities accepted by SEPA as permissible under CAR consent. A summary of the results of the proposed licenced quantities, reassessed using a default NewDepomod setup, is presented in Table 1.1.

NB: Modelling undertaken assessing the proposed farm layout outlined a peak licenced biomass of 2,572 T (stocking density of 18.7 kg/m^3) would generate an acceptable impact, determined by SEPA's Standard Default Approach. However, SSC is applying for a CAR licence for 2,300 T within the proposed pen arrangement and a stocking density of 16.72 kg/m^3.

Table 1.1: Summary of modelling results

Site details		
Site name		North Arran
Site location		Isle of Arran, Greater Firth of Clyde
Site configuration details		
Number of pens		12
Pen circumference		120 m
Net depth		10 m
Group layout		Two groups of 2 x 3 pens
Hydrographic summary		
Sub-surface currents	Average speed and direction	0.114 m/s – 145 °
	Average residual current	0.011 m/s
Pen-bottom currents	Average speed and direction	0.101 m/s – 145 °

[1] SEPA (2019) *AQUACULTURE MODELLING: Regulatory Modelling Guidance for the Aquaculture Sector*: July 2019 – Version 1.1

	Average residual current	0.0262 m/s
Near-bed currents	Average speed and direction	0.0768 m/s – 145 °
	Average residual current	0.0431 m/s
Benthic modelling		
Peak biomass		2,300 T

Stocking density	16.72 kg/m^3
Bath treatments	
Deltamethrin: permissible in 3 hours/ No. Pens	31.0 g / 3.7
Azamethiphos: permissible in 3 hours/ No. Pens	457.3 g / 1
Azamethiphos: permissible in 24 hours/ No. Pens	229.2 g / 1
In-feed treatments	
EmBz: TAQ	4.28 g

2 Introduction

This modelling report was written by SSC to describe the application of modern, 90 days of observed hydrographic data (collected from June to September 2020) and updated NewDepomod simulations using the Standard Default Method to simulate benthic impacts at the proposed finfish site, North Arran, located off the north coast of the Isle of Arran, within the Firth of Clyde (Figure 2.1). The report will outline modelling exercises that are intended to support benthic sampling:

- Solid (feed and faeces) dispersal
- In-feed treatment dispersal

An additional modelling exercise was undertaken to review the permissible quantities of bath treatment informed by the 90-day, modern hydrographic dataset, the results of which are presented in this report.

The aim of this modelling report is to indicate permissible quantities of biomass and medicines (both in-feed and bath) using modern data and contemporary standardised assessment methodologies, allowing proposed operations to be undertaken sustainably and in accordance with regulations generated by SEPA. It should be noted that although NewDepomod has been applied successfully at sites around the Scottish coastline, the skill of the model in predicting benthic impact at North Arran is unknown. It is intended that the model output be used to guide the regulatory sampling exercise and be supplemented by model calibration undertaken following the completion of a four transect sampling regime.

2.1 Site context

The proposed finfish site, North Arran, is located to the north-east of the Isle of Arran within the Greater Firth of Clyde, Figure 2.1, and is influenced by a semi-diurnal, macrotidal tidal regime with a mean spring range of 3.0 m (Lochranza). The site is considered exposed to significant sea swell to the south-east, where a significant fetch exists (44 km) towards Ayr. The day-to-day wave climate at the site is dominated by locally generated frictional waves punctuated by significant non-local swell events. In the absence of significant freshwater influence and no salinity profile information the site is considered well mixed and flushed by tidal and frictional wave related currents. The farm is 250 to 400 m east of the Arran shoreline in depths of between - 25 and - 47 mCD.

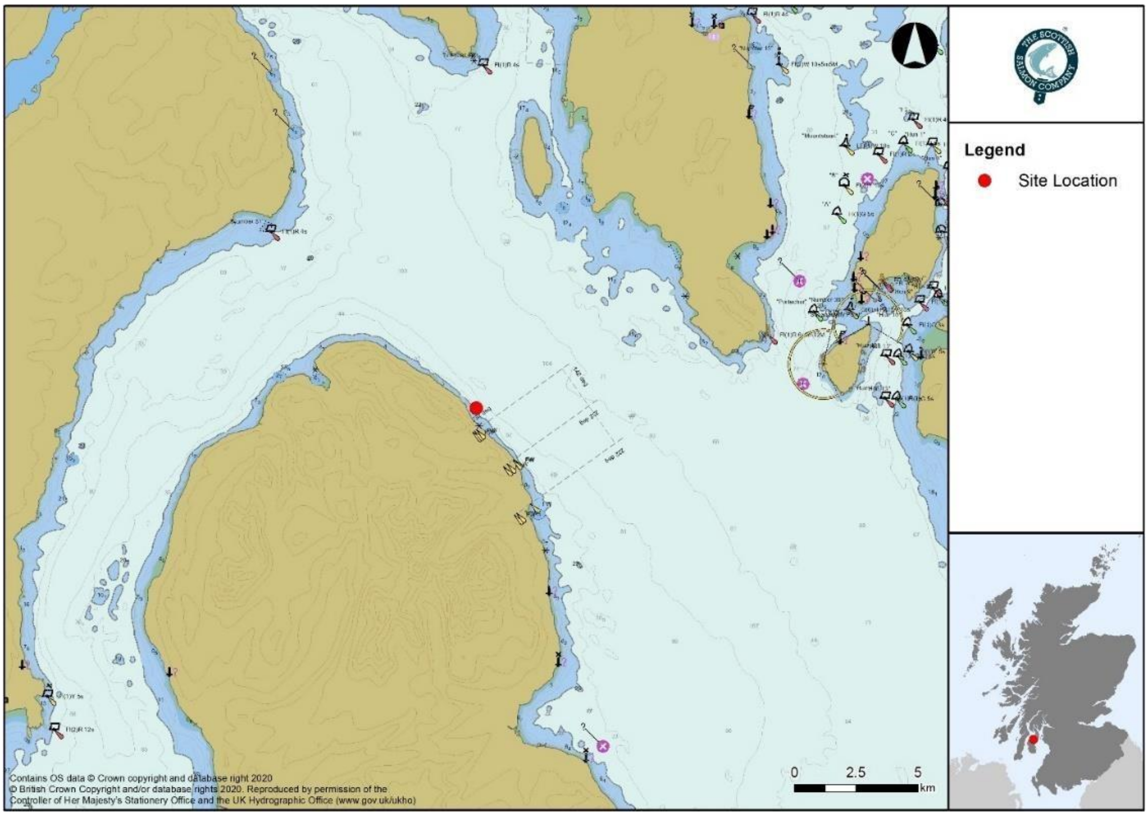


Figure 2.1: Location of the North Arran site

2.2 Site details

The site is proposed to have 12 x 120 m circular pens, held in a 75 m grid, in two groups of six (each arranged in a two by three layout) and with a net depth of 10 m. The proposed biomass on site is 2,300 T. Details of the site are provided in Table 2.1 with a graphical representation of the site visible in Figure 2.2.

Table 2.1: Summary of North Arran site information

Site Details	
Group Location	199423 E, 649398 N 199801 E, 649429 N
Number of Pens	12
Pen Circumference (m)	120
Grid Matrix (m)	75 x 75
Net Depth (m)	10
Configuration	2 x 2 x 3
Orientation (°)	330 315

Site Details	
Distance from shore (m)	250 - 400
Depth at Site (m)	25 - 45

Figure 2.2: Proposed site layout

2.3 Site exposure

The site at North Arran has a Wave Exposure Index (WEI) of approximately 3.29-3.31 as derived from the Marine Scotland wave exposure index[2]. As this is in excess of SEPA's recommended WEI threshold of 2.8, the site is considered a moderately exposed site. As a result, the average mixing zone intensity threshold here is 4,000 g/m^2/yr under SEPA's Standard Default Method.

2.4 Modelling context

There is currently no farm located at North Arran. An application for the site has previously been submitted to SEPA in 2018 (as a farm with 5,000 T maximum standing biomass, using 20 x 120 m circumference pens). This application was supported by modelling undertaken in AutoDepomod and from other marine modelling undertaken in MIKE 21 (by DHI consulting). Following discussions with SEPA SSC have undertaken additional hydrographic data collection and reviewed NewDeopomod simulations, increasing confidence in the risk assessment modelling framework applied. This report presents the assessment undertaken using 90 days of hydrographic data to identify the maximum biomass permissible at the site and the appropriate quantities of chemicals suitable for licencing.

[2] MarineScotland (2020) MAPS NMPI, part of Scotland's environment. [Accessed online 28/02/2020: https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=780]

3 Model setup

3.1 Model hydrodynamics

Modelling was undertaken using data collected by SSC during three consecutive data collection exercises, undertaken between 23/06/2020 and 25/09/2020. Two short periods of missing data were identified, (resulting from equipment checks and battery renewal) and stitched using appropriate sections of observed currents from a similar tidal stage. The data collected is discussed in greater detail in following sections and a summary of observed data from the three bins used is provided in Table 3.1. This data has been reviewed by SEPA who have confirmed the validity of the datasets collected (Aquaculture.modelling (2020), Pers. Comm., 13th October).

Table 3.1: 90-day observed dataset summary data

Location	Average velocity (m/s)	Major axis direction (°)	Residual current magnitude (m/s)	Average depth (m)
Sub-surface	0.1144	145	0.0110	4.59
Cage bottom	0.1013	145	0.0262	11.79
Near bed	0.0768	145	0.0431	26.84

NB: The current meter position and depth was taken as the mean X and Y coordinate and depth, derived from all three current meter deployments.

Residual currents at the bed were estimated to be 0.043 m/s at 142°, 54.8% of mean velocity. As this is above SEPA's guidance threshold of 35% for application of De-trended hydrography, a De-trended dataset was used to drive simulations under the Standard Default Method. Full-tide Simulations (using the observed data) were undertaken here and are presented for reference. It should be noted that there were four significant wind events during the deployment. These events were predominantly aligned with short fetch distances[3]. The harmonic analysis undertaken at the cage bottom and subsurface demonstrate a significantly lower residual current magnitude (25.9% and 9.6%, respectively) indicating that residual currents at the bed can be considered to differ from the surface current, and may be due to shoreline related currents noted in the accompanying hydrographic report[4].

Full-tide

The Full-tide velocity profiles from the first deployment (23/06/2020 – 23/07/2020) can be seen in Figure 3.1, with the average time series shown in Figure 3.2. The water column demonstrates little vertical shear throughout the water column with only slight decreases in the calculated in 25th, 50th and 75th percentile velocities with depth. From -17.5 m to the bed there is evidence of a subsurface current causing a bowing of the average and 75th percentile profiles. Close to the bed the statistical profiles approximate the Logarithmic or Power law induced by friction at the seabed. Here, however the power law is governed by a relatively high coefficient. The differential currents observed here hint at potential stratification within the water column, however in the absence of CTD (Conductivity, Temperature , Depth) casts and with no identifiable significant source of freshwater the water column was assumed to be well mixed with hydrography typical of exposed, well mixed systems of the Scottish west coast.

[3] Weather Underground (2020), *IISLEOFA6 – Forecast for Sannox, GB*. [Accessed online 30/09/2020: wunderground.com/dashboard/pws/IISLEOFA6/graph/2020-07-11/2020-07-11/monthly]
[4] SSC. (2020). *Hydrographic Report: North Arran, Isle of Arran A2*

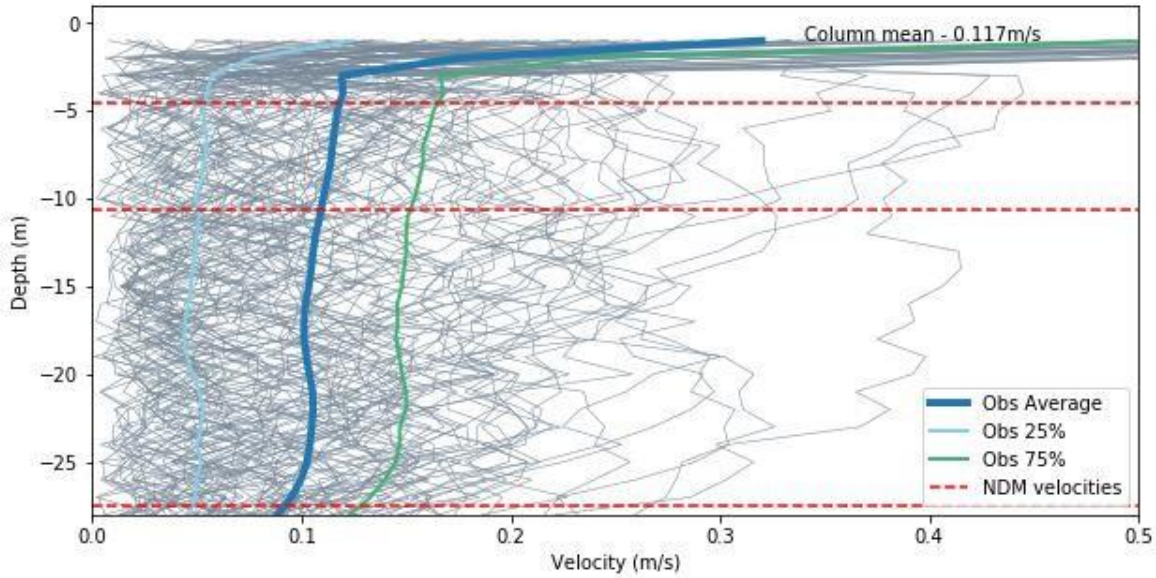


Figure 3.1: Sampled velocity profiles for the hydrographic deployment used in this assessment

The velocities in the three directional bins selected for the modelling. several occurrences of higher velocity were observed and are demonstrated in Figure 3.2 and the observations are considered largely representative of conditions observed at the site given the prevalent weather at the time. The dataset is thus considered appropriate for application within the NewDepomod simulations according to the Standard Default Approach. However, this cannot be considered fully representative of the 365 days simulated (due to the omission of relevant extreme events) but an approximation of conditions.

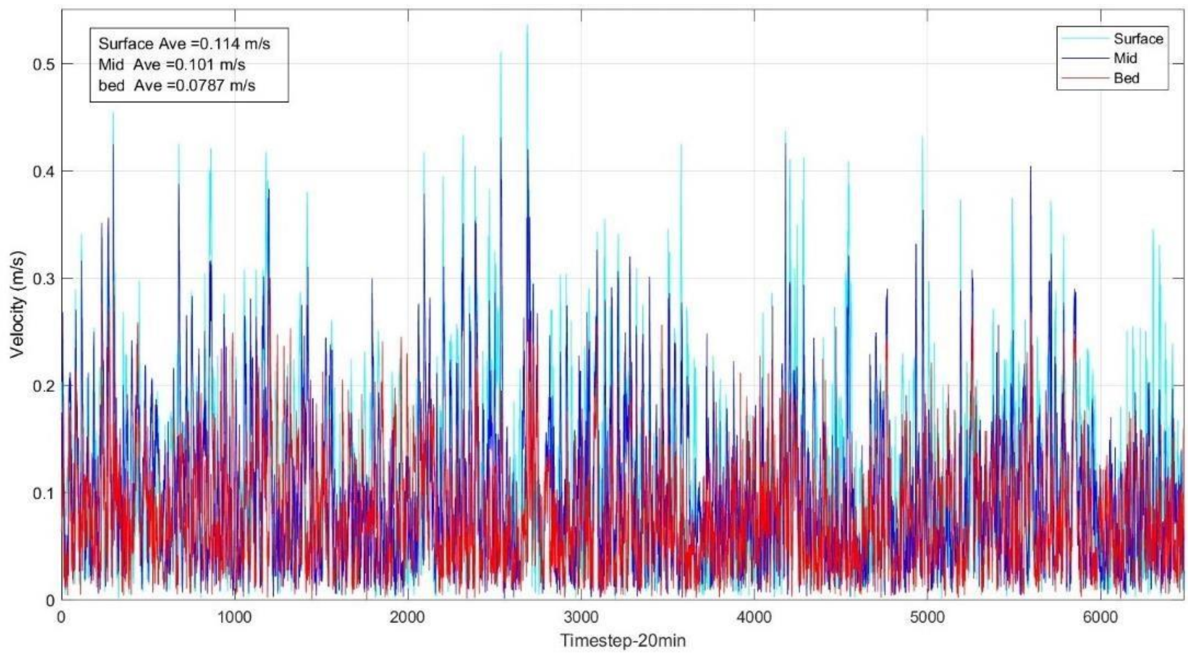


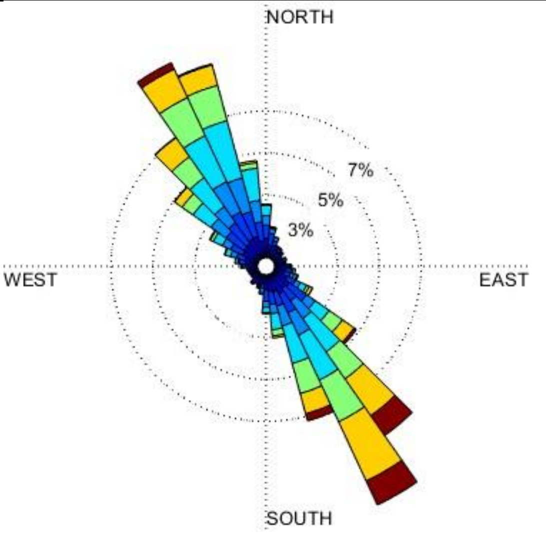
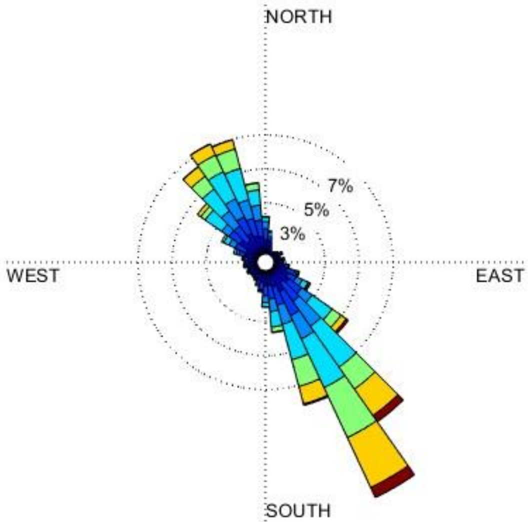
Figure 3.2: Water column velocities for an unedited velocity profile

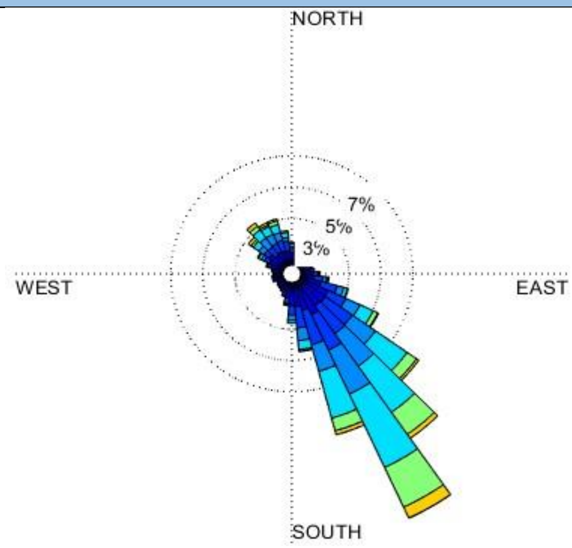
Table 3.2 illustrates the directional frequency and magnitude of the observed conditions in each of the three depth “bins” used in the modelling. These roses illustrate a strong bi-modal flow corresponding to the tidal phases and the shoreline orientation at the site in the upper observation windows. However, the bed observations are more variable illustrating a south-southwest dominant transport vector. The directional roses and the significant drop in velocities at the bed compared to the upper water column observations indicate there may be some stratification in the water column.

The peak bed-speed for the observed dataset is in excess of 0.30 m/s and the dataset exceeds an inferred critical resuspension threshold of 0.085 m/s, 38.7% of the time. As a result, under ambient conditions, sediments are rarely consolidated within the bed and resuspension is common. This can be attributed to predominant to episodic flows caused tidal and non-harmonic currents.

Table 3.2: Directional roses of recorded velocities

<table>
<tr><th>Reading location</th><th>

Directional Rose, frequency and magnitude (m/s)</th></tr>
<tr><td>Sub-surface</td><td>
</td></tr>
<tr><td>Cage bottom</td><td>
</td></tr>
</table>

Reading location	 Directional Rose, frequency and magnitude (m/s)
Near-bed	

De-trended Tide

A "De-trended" velocity profile was applied to derive the benthic impact of the proposed North Arran farm, as per the Standard Default Method. The dataset was derived as per SEPA requirements: residual values for U and V (derived from harmonic reconstruction) were subtracted from the observed U and V vectors at the bed for each timestep. The observed current vectors in the remaining bins were unedited. Figure 3.3 shows the variation between the observed set of the near-bed bin, and the corresponding modified De-trended vectors along the residual current vector.

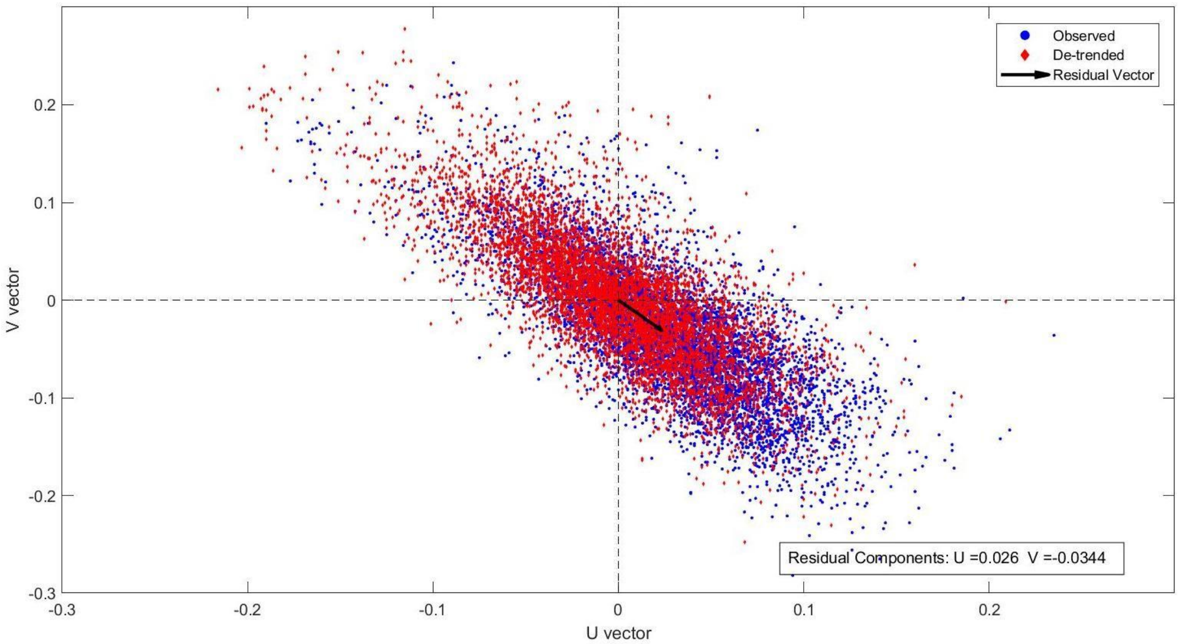


Figure 3.3: Observed and De-trended bed vectors

It should be noted that this "De-trended" dataset retains the signature of significant events in the hydrographic dataset but shifts the distribution of U and V vectors to a different median value, maintaining the Poisson distribution shape (better than smoothing obtained by a harmonic reconstruction, Table 3.3) whilst modifying the velocity magnitude in an attempt to make the dataset more representative of conditions over a longer time scale. The velocity distribution plots for the observed and detrended datasets at the bed, with the corresponding rose plot can be seen in Figure 3.4. The distribution plots illustrate the range of the Poisson distribution is approximated by the Detrended dataset; however some significant differences are noted. The modified dataset displays greater frequency of velocities below 0.07 m/s with a lower occurrence of speeds between 0.07 and 0.23 m/s, and an increase in the frequency of velocities in excess of 0.25 m/s associated with the tail of the distribution. The removal of the significant residual current (0.055 m/s) elicits an increasingly asymmetric bed rose, introducing a bias in current vector toward the northwest, shifting the dominant lobe from the southeast.

Table 3.3: Summary statistics of hydrographic datasets at the bed cell

Parameter	Full Flow (m/s)	De-trended (m/s)	Astronomic (m/s)
Mean	0.0787	0.0678	0.0452
Median	0.0689	0.0564	0.0465
Standard Deviation	0.1100	0.0921	0.0654
Peak	0.3002	0.3063	0.1083

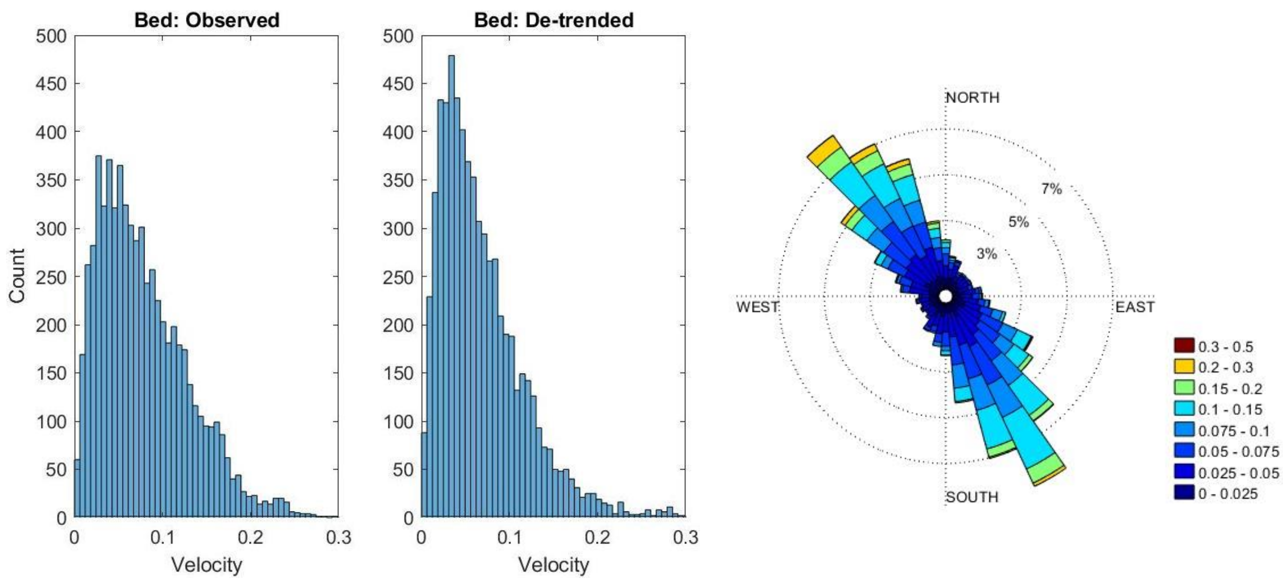


Figure 3.4: Velocity distribution plots for the bed from observed and De-trended datasets (left) and the Detrended bed rose, derived from the 90-day observed dataset (right)

It should be noted that the direct relevance of this De-trended dataset to the hydrodynamic data is undefined, but its application is required as part of the Standard Default Method.

3.2 Model bathymetry

Model bathymetry was available for the site at North Arran, generated from single beam data collected by SSC in August 2018, supplemented by Admiralty chart data and an OS shoreline as displayed in Figure 3.5. At the time of writing the Standard Default Method risk assessment approach requires a uniform bathymetry to be applied within the model domain. Following discussion with SEPA on the appropriate depth of this uniform bathymetry, a depth was applied based on the recorded depth of the current meter data. This depth was -29.34 m, relative to chart datum.

The domain centre was shifted 300 m northward from the site centre to better represent the dispersion plume of the De-trended dataset and its movement north. For the Full-tide sensitivity test the model domain was based on the farm centre as per SEPA requirements.

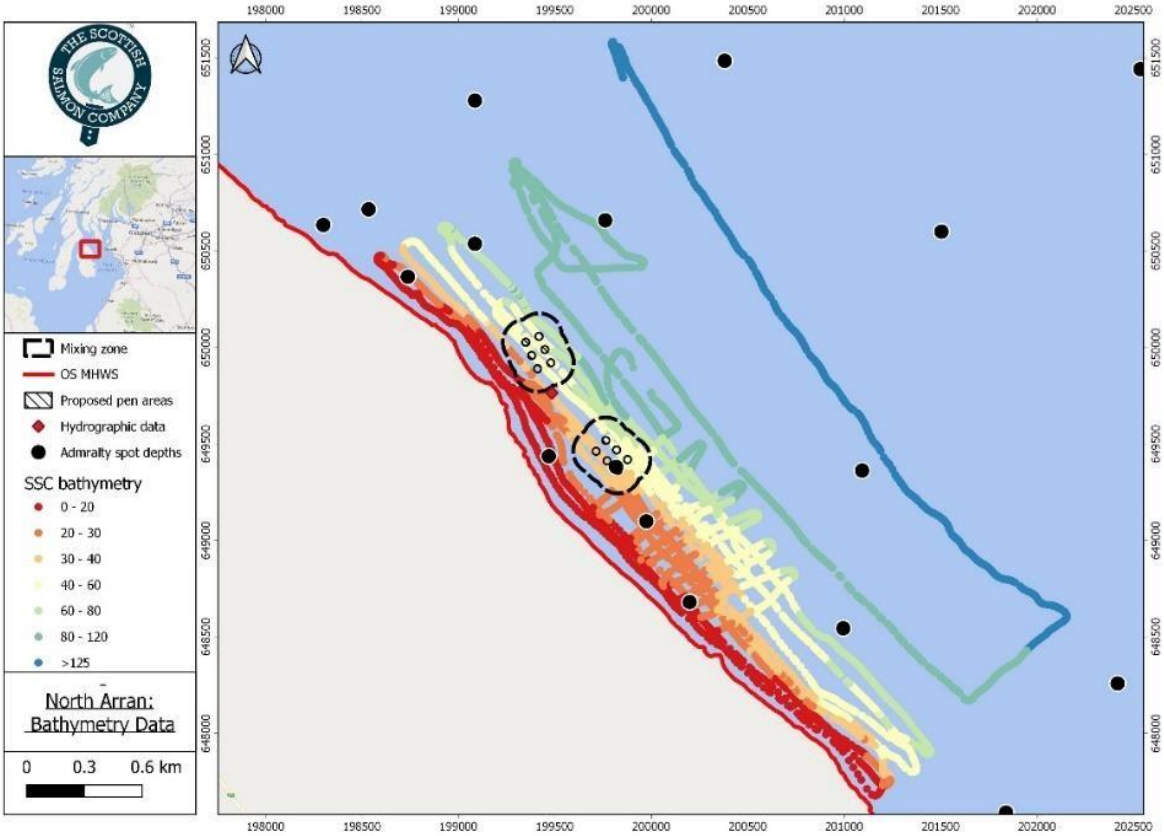


Figure 3.5: Bathymetry data available at the North Arran Site

As shown in Figure 3.6, the bathymetry at the site slopes steeply from the shoreline to depths in excess of -100 mCD. The proposed site is to be located between the -30 and -50 mCD contours. It is likely that this sloping bathymetry will have a significant impact on the dispersal of sediments, eliciting increased dispersal in deeper water. This however is not represented in the Standard Default Method.

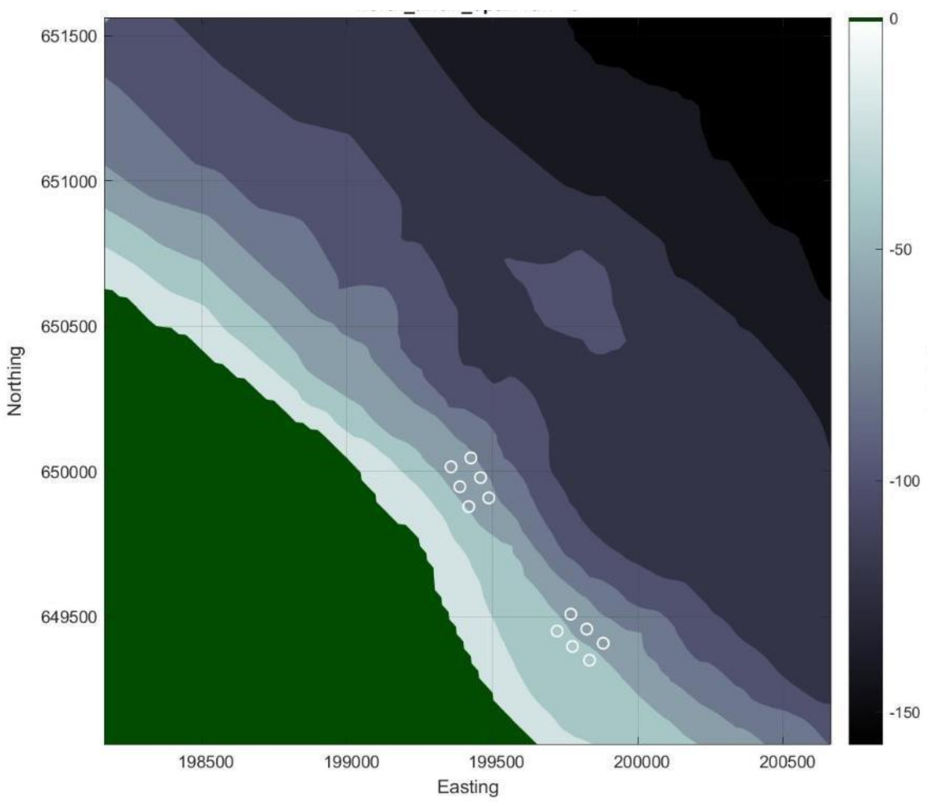


Figure 3.6: Interpolated bathymetry on the model grid with cages displayed

3.3 Pen inputs

Standard feed rates were used as per the SEPA Standard Default Method. These rates were related directly to the simulated biomass (between 2,500 and 2,800T). For the Standard Default Method runs presented here, peak biomass feed rates are 7 kg t^{-1} d^{-1} for 365 days.

3.3.1 Feed and faeces

Default feed and faeces rates were input corresponding to the consented biomass of the site. As per the Standard Default Method outlined by SEPA, feed rated associated with peak biomass were input for 365 days with a 3 % wastage rate.

3.3.2 In-feed treatments

The only in-feed treatment proposed to be administered at the North Arran site is Emamectin Benzoate (EmBz) and subsequently the only assessment undertaken to review the impact of in-feed treatments was to assess EmBz impact. At the time of writing, SEPA guidance assesses the input of EmBz based on an updated Mixing Zone threshold of 0.0235 g/kg dry weight or 0.01183 g/kg wet weight. To identify the maximum permissible level of EmBz that can be administered to the farm during operation, the quantity of EmBz administered, through in-feed treatments, was increased until the Mixing Zone area was breached.

3.4 NewDepomod configuration

All model parameters, not specified within this document, were specified according to SEPA Standard Default Method for both solid dispersal and in-feed treatments. This includes the degradation of EmBz particles (λ = 250 days). It is intended that, when appropriate benthic sampling is available, the modelling be updated and tuned to these simulations, increasing confidence in model outputs and quantifying predictive validity.

3.5 BathAuto configuration

An assessment was undertaken into the dispersal of bath treatments (administered in the pens and allowed to diffuse throughout the environment post-treatment) following the administration of three bath treatment chemicals. The assessments were undertaken using the conservative, spreadsheetbased BathAuto (v5) modelling package with key parameters as outlined in Table 3.4 below. For this assessment, summary hydrographic data from the full observed dataset was applied and the average bathymetry depth (derived from available bathymetry) was applied to approximate conditions over a larger area than NewDepomod simulations.

Table 3.4: BathAuto – Key parameters

	Variable	Parameter
Waterbody characteristics	Loch/Strait/Open water	Open Water
	Loch area (km^2)	9999.00
	Loch length (km)	9999.00
	Distance to head (km)	9999.00
	Distance to shore (km)	0.38
	Average water depth (m)	57.77
Pen & stocking info	Number of pens	12
	Pen shape	Round
	Diameter/Width (m)	38.2
	Working depth (m)	10
	Stocking density (kg/m^3)	16
Treatment info	No. of pens possible to treat in 3 hours	1
	Initial Treatment Depth (m)	3.95
	Treatment Depth Reduction Increment (m)	0.05
Hydrographic data	Mean current speed (m/s)	0.116
	Residual Parallel Component U (m/s)	0.010
	Residual Normal Component V (m/s)	0.002
	Tidal Amplitude Parallel Component U (m/s)	0.195
	Tidal Amplitude Normal Component V (m/s)	0.047

4 Model outputs

Model outputs for both the Full-tide, De-trended and astronomic (astro) tidal cycles are presented below. These assessments are reviewed on criteria outlined by SEPA, based on a Mixing Zone (area encompassed from 100 m radius from pen edge) of 217,455 m^2 and average depositional intensity within the Mixing Zone of less than 4,000 $g/m^2/yr$.

4.1 De-trended tide

The De-trended model output was identified as the appropriate hydrographic dataset to apply to the site at North Arran (due to the high percentage of residual currents at the bed). To identify the maximum permissible biomass at the site using the conservative Standard Default Method in NewDepomod, multiple iterations were undertaken to determine the appropriate tonnage, which was identified to fall between 2,600 and 2,800 T. 15 model simulations were undertaken to derive the relationship between simulated tonnage and modelled impact as displayed in Figure 4.1.

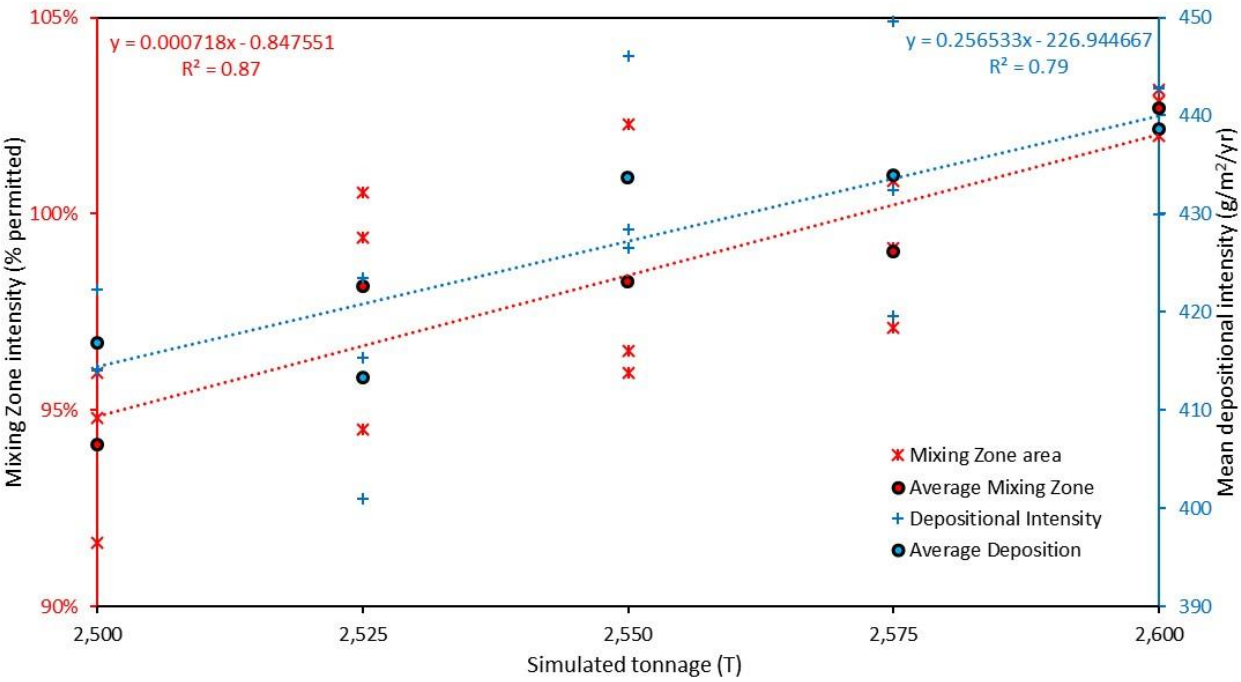


Figure 4.1: De-trended, scoping runs used to define maximum permissible tonnage. NB: each tonnage was run in triplicate and an average taken (mitigating Fickian processes within the modelling framework)

This analysis undertaken determines that, according to the risk assessment using the Standard Default Method in NewDepomod a peak biomass of 2,572 T is permissible under July 2019 regulation, with a Mixing Zone area of 100% and a depositional intensity within the Mixing Zone of 432.92 $g/m^2/yr$. This risk assessment approach is widely considered to be a conservative method, overestimating simulated deposition of waste material below the farm in the majority of farms Modelled.

Design Run

SSC are applying for a peak biomass of 2,300T within the 12 pens outlined in Section 2. Although the analysis undertaken above demonstrates a peak tonnage of 2,572 T is permissible under current regulations, six additional runs were undertaken for submission to SEPA, supporting the consenting of 2,300T. The results of these simulations are provided in **Figure** 4.2 with the average depositional intensity from each model run shown in Figure 4.2. Model IDs correspond to model runs provided with this report. These additional simulations demonstrate a tonnage of 2,300T in the proposed configuration satisfies the conservative SDM risk assessment method with an average Mixing Zone of

71.61% but deviating as low as 63.67%. The peak simulated deposition in all six model runs was 1,218.8 $g/m^2/yr$ and the average within the Mixing Zone was 380.1 $g/m^2/yr$, comfortably satisfying SEPA's requirements of a simulated average deposition of less than 4,000 $g/m^2/yr$.

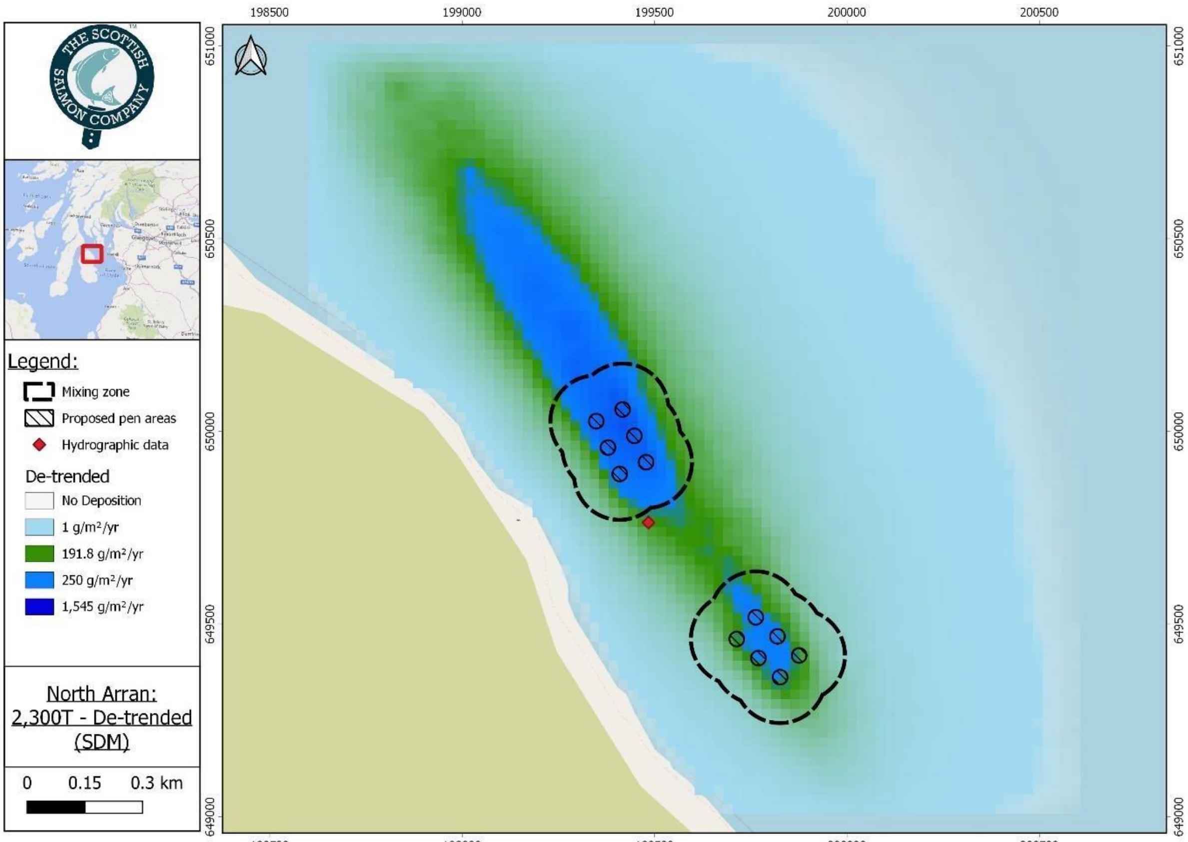


Figure 4.2: Average deposition throughout the model domain for simulated design runs

Table 4.1: Model runs assessing the impact of 2,300 T

Run ID	Average Mixing Zone deposition ($g/m^2/yr$)	Mixing Zone area (% of permissible)
Solids-3	384.0	73.18
Solids-5	392.1	63.67
Solids-6	377.2	67.13
Solids-7	367.0	78.95
Solids-8	382.0	76.06
Solids-9	378.1	72.61
μ	**380.1**	**71.93**

The De-trended dataset produces a northwest net sediment transport, facilitating the dispersion of sediment along the shoreline. The persistence of low current speeds within the dataset and the dominant tidal lobe (within the De-trended dataset) produces high deposition below the northern cage group. The application of a uniform bathymetry here is likely to have a significant impact on the destination of sediments. The southerly sloping shoreline is likely to cause increased distribution downslope. However, there is currently no site at the proposed location and so it is not possible to validate the results against observations. As a result, the Standard Default Method applied in

NewDepomod is considered the best estimation of the impact of the proposed North Arran site on benthic IQI.

4.2 Sensitivity

The sensitivity of the modelling to the hydrographic dataset used to force the model was reviewed to determine the impact on model function as a result of the modification of the observed hydrographic dataset. To review this, the model was forced using the full, observed dataset ("Full-tide") and a reconstructed astronomic timeseries, derived from the 90 days of consecutive hydrographic data ("Astro Tide"). The results of these assessments are presented in this section. For these assessments the domain has been focused on the site centre.

4.2.1 Full-tide

The model was found to be highly sensitive to the application of the observed and synthetic datasets. The single simulation produced highly asymmetrical deposition, toward the southeast, as displayed in Figure 4.3, producing a maximum deposition of 239.2 $g/m^2/yr$ and so does not produce a Mixing Zone.

The high velocities observed here are translated to a high degree of dispersal with small rates of deposition below the southern pen group. This observed tidal dataset generates significantly different particle behaviour within the model with less deposition and greater export of particles throughout the domain with an inversion of the depositional pattern and current residual. The modelling is thus considered significantly sensitive to the hydrographic conditions applied to force model simulations.

Figure 4.3: Observed, Full-tide simulation outputs

It is recommended that, following farm operation, benthic sampling be undertaken with reference to this model run given the direct relevance of this output to observed hydrographic processes in the site.

4.2.2 *Astro Tide*

Forcing using the astronomic tide was also undertaken, primarily to better understand the role of normal tidal flow and episodic currents (particularly the sub-surface flow) on the benthic deposition. The modelling produced high levels of deposition within the cage footprint with minimal dispersal, as displayed in Figure 4.4, thus illustrating the role of normal astronomic currents has some muted impact on the dispersal of sediments shore-parallel, toward the south along a similar bearing to the observed Full-tide outputs presented above. It is hypothesised that the sediment deposition and consolidation regime here is dominated by episodic currents, with periods of moderate to high velocities causing excessive resuspension, allowing sediments to be dispersed throughout a wider area (at a lower concentration). This mobilisation of sediments causes high degrees of dispersal (as seen in the wider dispersal plume, visible in Figure 4.3) while the remobilised sediments are entrained and carried southeast by the astronomic currents.

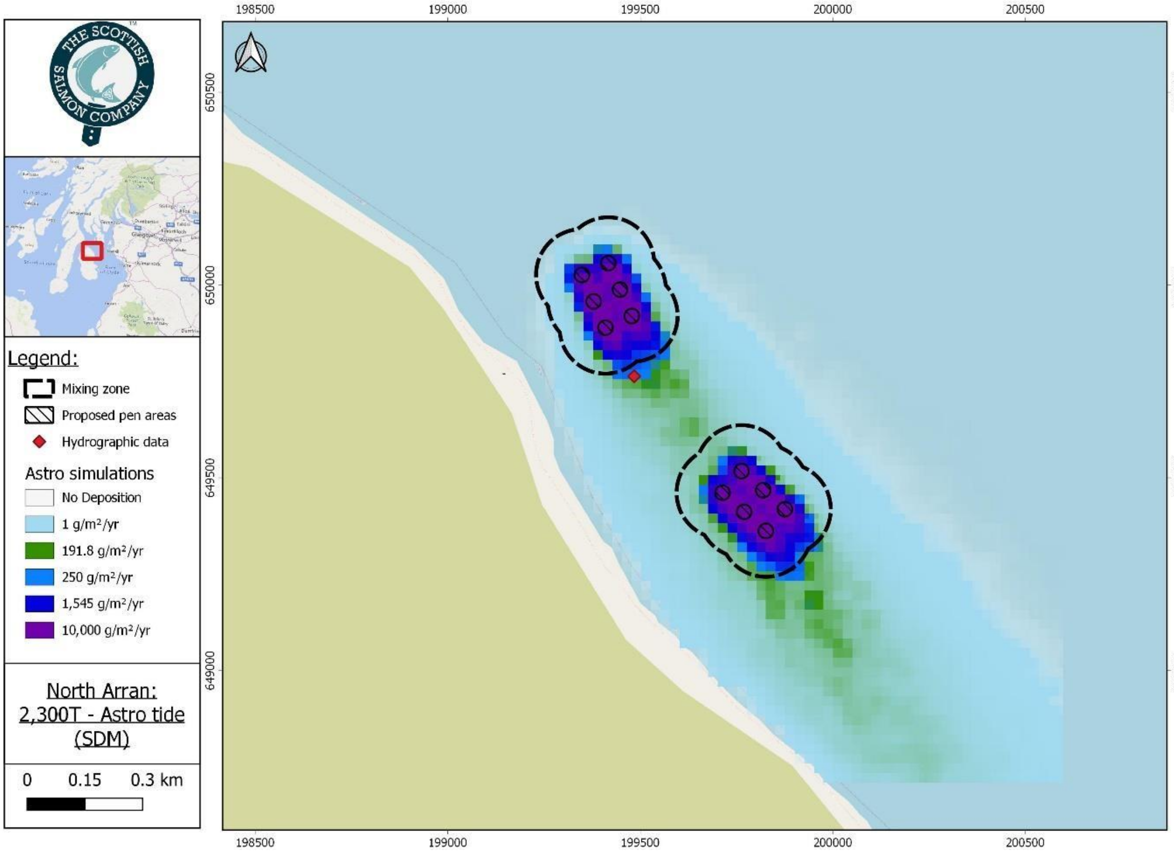


Figure 4.4: Reconstructed, Astronomic tide simulation outputs

These sensitivity tests outline that the application of a De-trended hydrographic dataset is highly conservative in terms of the simulated Mixing Zone. The application of the modified dataset is designed to reduce asymmetry in simulated transport, as discussed above, and compliments the risk assessment presented here. It remains a synthetic dataset, designed to increase deposition and "normalise" tidal vectors and in doing so, it modifies processes driving the re-distribution of sediments (such as storm driven and other non-harmonic currents), reducing or omitting these mechanisms within the modelling undertaken. These processes are shown (in Figure 4.3) to increase dispersal and reduce sedimentation below the farm, enforcing the conservative nature of the application of a De-trended dataset in this risk assessment approach. In-feed treatments

In-feed treatments were simulated using the De-trended hydrographic dataset as per SEPA Guidance and the strong residual current at the bed. The modelling output, presented in Figure 4.5, demonstrates that the iteration of EmBz administered to identify the appropriate quantity that satisfies requirements in terms of intensity and Mixing Zone. The trend of the simulated model runs was used to derive the relationship between the quantity of EmBz administered and the permissible Mixing Zone (0.0235 g/m^2, dry and 0.01183 g/m^2, wet). This relationship was then solved to define the total amount of EmBz permissible for the site, at 4.279 g. These model outputs are acceptable according to SEPA's regulations released in December 2019[5].

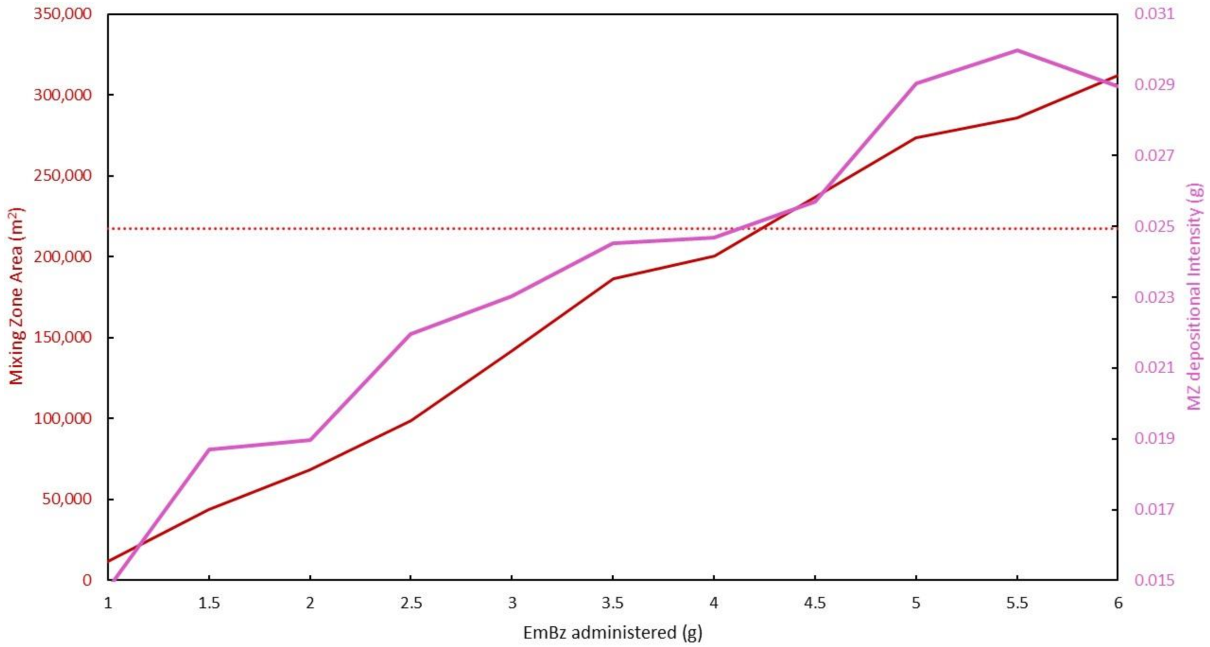


Figure 4.5: Simulated EmBz impact

4.3 Bath treatments

Bath treatment modelling was undertaken by SSC for the use of Deltamethrin and Azamethiphos. Results are displayed in Table 4.2, which were derived using BathAuto (v5) and the Environmental Quality Score (EQS) compliance of all three medicines was determined (Table 4.2).

Table 4.2. Results of bath treatment modelling at North Arran

Medicine	Permissible quantity – 3 hours	No. of pens – 3 hours	Permissible quantity – 24 hours	No. of pens – 24 hours
Deltamethrin	31.0 g	3.4	-	-
Azamethiphos	457.3 g	1	229.2 g	1

[5] SEPA (2019), *WAT-PS-17-03: Interim position statement on EmBz*. [Available online 17/08/2020: https://www.sepa.org.uk/media/492064/interim-position-statement-on-emamectin-benzoate-discharges.pdf]

5 Conclusion

The release of organic matter (waste feed and faeces), in-feed and bath treatments has been simulated using two software packages (NewDepomod and BathAuto). NewDepomod simulations are aimed at updating simulations previously undertaken in AutoDepomod for use in an updated modelling framework using 90 days of modified hydrographic data and assess a modified pen arrangement with eight pens less than the original application. BathAuto simulations have also been undertaken to determine the permissible quantities of bath treatment quantities at the site. Conclusions drawn from the simulations are outlined below.

5.1 Sediment dispersal

The model simulations undertaken using NewDepomod for the proposed 12 pens at North Arran demonstrates that a peak biomass of 2,572 T satisfies SEPA's regulatory requirements (using a 90-day de-trended hydrographic dataset), in respect of Mixing Zone area and depositional intensity. The simulations undertaken are considered a conservative estimate of the potential impact of the proposed farm, based on extensive research undertaken by SEPA to develop the Standard Default Method risk assessment approach within NewDepomod.

The proposed licenced biomass for the site at North Arran is 2,300T with application of the Standard Default Approach eliciting an average Mixing Zone of 71.93% and an average depositional intensity of 380.1 g/m^2/yr. The model simulations therefore illustrate that farm operation at a peak biomass at 2,300 T comfortably satisfies SEPA's, already conservative, Standard Default Approach.

5.2 In-feed treatments

The in-feed treatment, EmBz, was modelled in NewDepomod using the SEPA's Standard Default Method, with 90-days of de-trended hydrographic data. Model simulations identified that 2.92 g of EmBz, administered as an in-feed treatment satisfy contemporary requirements for benthic quality.

5.3 Bath treatments

An observed, 90-day hydrographic dataset was used to drive simulations of bath medicine dispersal in BathAuto v5. This modelling recommended that the bath treatment consent for Deltamethrin be set at 31.0 g in three hours and the release of 457.3 g of Azamethiphos in three hours or 229.2 g in 24 hours be licenced.

5.4 Benthic sampling

The proposed benthic sampling regime is presented in Appendix 1. Due to the large discrepancy between the simulated behaviour and fate of particles when the observed Full-tide and the De-trended dataset is applied, it is recommended that any sampling be undertaken with reference to the Full-tide dataset as this dataset holds direct relevance to observed conditions at the site and not in the risk assessment exercise using a modified hydrographic dataset.

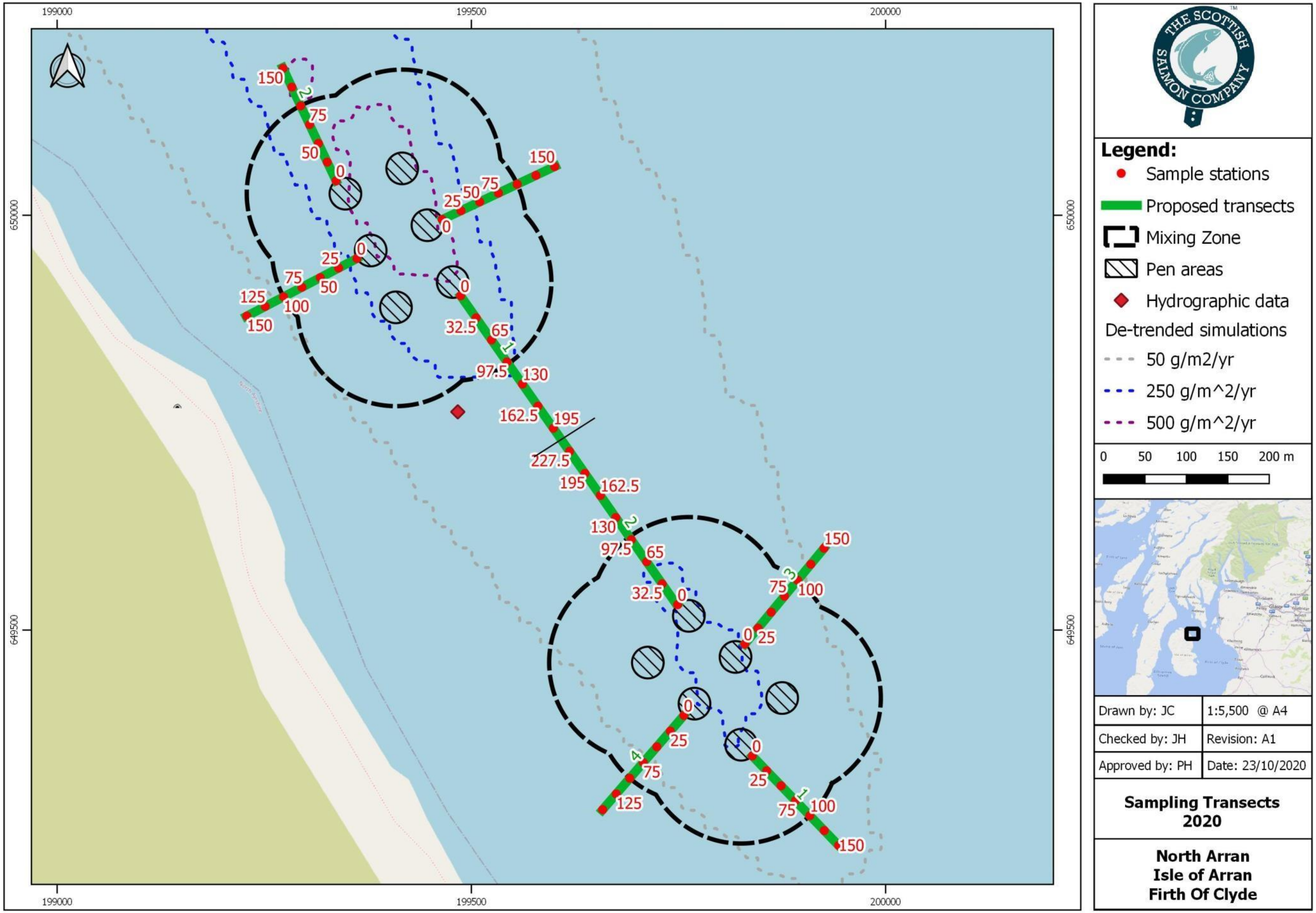
57 draft sample stations were selected along eight transects to accurately assess the benthic impact of the site. This highly comprehensive sampling regime was generated on the assumption that four transects, with a minimum of seven samples each are required for each pen group. These sample locations and the overall number of samples are subject to change, prior to sampling. The model output indicates that the majority of sediment is distributed southward, along both the north group's Transect One (N1) and the south group's Transect One (S1). Subsequently, it is recommended that the southern Transect One (136˚) include EmBz samples at pen edge (2020-1-A), 100m (2020-1-E) and 150m from the pen edge (2020-1-G).

Appendices

Appendix 1: Benthic sampling transects. NB: Coloured cells represent EmBz sample stations

Sample ID	Distance	Bearing	X	Y	lat	long
2020-S1-A	0	136	199839	649348	55.69617	-5.18649
2020-S1-B	25	136	199857	649330	55.69602	-5.1862
2020-S1-C	50	136	199874	649312	55.69586	-5.18591
2020-S1-D	75	136	199891	649294	55.69571	-5.18563
2020-S1-E	100	136	199909	649276	55.69555	-5.18534
2020-S1-F	125	136	199926	649258	55.6954	-5.18505
2020-S1-G	150	136	199943	649240	55.69524	-5.18476
2020-S2-A	0	325	199749	649531	55.69777	-5.18806
2020-S2-B	32.5	325	199730	649556	55.69799	-5.18837
2020-S2-C	65	325	199712	649582	55.69822	-5.18869
2020-S2-D	97.5	325	199693	649609	55.69845	-5.189
2020-S2-E	130	325	199674	649636	55.69868	-5.18932
2020-S2-F	162.5	325	199656	649662	55.69891	-5.18964
2020-S2-G	195	325	199637	649689	55.69914	-5.18995
2020-S2-H	227.5	325	199619	649715	55.69937	-5.19027
2020-S3-A	0	040	199830	649483	55.69738	-5.18673
2020-S3-B	25	040	199846	649502	55.69756	-5.1865
2020-S3-C	50	040	199862	649522	55.69773	-5.18626
2020-S3-D	75	040	199878	649541	55.69791	-5.18602
2020-S3-E	100	040	199894	649560	55.69809	-5.18578
2020-S3-F	125	040	199910	649579	55.69827	-5.18554
2020-S3-G	150	040	199926	649599	55.69845	-5.1853
2020-S4-A	0	221	199757	649397	55.69657	-5.18784
2020-S4-B	25	221	199740	649378	55.6964	-5.18809
2020-S4-C	50	221	199724	649359	55.69622	-5.18833
2020-S4-D	75	221	199708	649340	55.69604	-5.18858
2020-S4-E	100	221	199691	649321	55.69587	-5.18882
2020-S4-F	125	221	199675	649302	55.69569	-5.18907
2020-S4-G	150	221	199659	649283	55.69551	-5.18931
2020-N1-A	0	145	199487	649903	55.701	-5.19249
2020-N1-B	32.5	145	199506	649876	55.70077	-5.19218
2020-N1-C	65	145	199524	649850	55.70054	-5.19186
2020-N1-D	97.5	145	199543	649823	55.70031	-5.19154
2020-N1-E	130	145	199562	649796	55.70008	-5.19123
2020-N1-F	162.5	145	199580	649770	55.69985	-5.19091

2020-N1-G	195	145	199599	649743	55.69962	-5.1906
2020-N2-A	0	335	199337	650041	55.70218	-5.19498
2020-N2-B	25	335	199326	650064	55.70238	-5.19517
2020-N2-C	50	335	199315	650087	55.70258	-5.19535
2020-N2-D	75	335	199305	650109	55.70278	-5.19554
2020-N2-E	100	335	199294	650132	55.70298	-5.19573
2020-N2-F	125	335	199283	650154	55.70317	-5.19591
2020-N2-G	150	335	199273	650177	55.70337	-5.1961
2020-N3-A	0	065	199465	649995	55.70182	-5.19291
2020-N3-B	25	065	199487	650005	55.70192	-5.19256
2020-N3-C	50	065	199510	650016	55.70203	-5.19221
2020-N3-D	75	065	199533	650027	55.70213	-5.19186
2020-N3-E	100	065	199555	650037	55.70224	-5.19151
2020-N3-F	125	065	199578	650048	55.70234	-5.19115
2020-N3-G	150	065	199601	650059	55.70245	-5.1908
2020-N4-A	0	242	199362	649948	55.70135	-5.19451
2020-N4-B	25	242	199340	649936	55.70124	-5.19486
2020-N4-C	50	242	199318	649925	55.70113	-5.1952
2020-N4-D	75	242	199295	649913	55.70101	-5.19554
2020-N4-E	100	242	199273	649902	55.7009	-5.19589
2020-N4-F	125	242	199251	649890	55.70079	-5.19623
2020-N4-G	150	242	199229	649878	55.70068	-5.19657


199000
199500
200000
650000
649500
Legend:
Sample stations
Proposed transects
Mixing Zone
Pen areas
Hydrographic data
De-trended simulations
50 g/m2/yr
250 g/m^2/yr
500 g/m^2/yr
0 50 100 150 200 m
Drawn by: JC
1:5,500 @ A4
Checked by: JH
Revision: A1
Approved by: PH
Date: 23/10/2020
Sampling Transects 2020
North Arran
Isle of Arran
Firth Of Clyde