



ESTABLISHED 1968

The Finest Salmon from
SCOTLAND



NewDEPOMOD and BathAuto Modelling Report

Morrison's Rock, Isle of Benbecula

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List of Abbreviations

BFS	Bakkafrost Scotland Ltd.
CAR	Controlled Activities Regulations
CTD	Conductivity, Temperature, Depth
EmBZ	Emamectin Benzoate (SLICE active ingredient)
EQS	Environmental Quality Standard
g/m²/yr⁻¹	Grams per square metre per year (deposition)
mCD	Meters below Chart Datum (local)
NB	<i>Nota Bene</i> : Note Well
NDM	NewDEPOMOD (simulation software)
OS	Ordnance Survey
SDM	Standard Default Method
SEPA	Scottish Environment Protection Agency
T	Tonnes (biomass)
TAQ	Total Allowable Quantity
WEI	Wave Exposure Index
μ	Statistical mean
λ	Half-life

1. Summary

This report was written by Bakka Frost Scotland Ltd. (BFS) to meet the requirements of the Scottish Environment Protection Agency (SEPA) for a proposed new fish farm, under the Controlled Activities Regulations ((CAR) 2011), updated by contemporary (July 2019¹) and draft (April 2023²) guidance. This report describes the methodology used to model the peak biomass and specific medicine quantities accepted by SEPA as permissible under CAR. A summary of the results of the proposed licenced quantities, assessed using SEPA default NewDEPOMOD and BathAuto setups, are presented in **Table 1.1**.

Table 1.1: Summary of modelling results

Site details		
Site name	Morrison's Rock	
Site location	Isle of Benbecula	
Site configuration details		
Number of pens	8	
Pen circumference	160 m	
Net depth	18 m	
Group layout	One group of 2x4	
Hydrographic summary		
Sub-surface currents	Average speed and direction	0.135 m/s – 155 °
	Average residual current	0.028 m/s
Cage-bottom currents	Average speed and direction	0.136 m/s – 160 °
	Average residual current	0.023 m/s
Near-bed currents	Average speed and direction	0.127 m/s – 150 °
	Average residual current	0.025 m/s
Benthic modelling		
Peak biomass	5,050T	
Stocking density	17.21 kg/m ³	
Bath treatments		

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

² SEPA (2023) *AQUACULTURE MODELLING: NewDepomod Draft Guidance*: April 2023

Deltamethrin: permissible in 3 hours/ No. Pens	36.1 g / 4.4
Azamethiphos: permissible in 3 hours/ No. Pens	532.2 g / 1.3
Azamethiphos: permissible in 24 hours/ No. Pens	356.1 g / 1.0
In-feed treatments	
EmBz: TAQ	80 g

2. Introduction

This modelling report was written by BFS to describe the application of observed hydrographic data (totalling a minimum of 90 days, collected in October 2021 and December 2023) and scoping NewDEPOMOD simulations using SEPA's prescribed Standard Default Method (SDM) to risk assess the benthic impact of the proposed finfish farm, Morrison's Rock. The report will outline modelling exercises that are intended to support the consented biomass and future benthic sampling, should the farm be permitted:

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

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

The modelling undertaken outlines permissible quantities of biomass and medicines (both in-feed and bath) by using modern data and contemporary standardised assessment methodologies. This enables proposed operations to be undertaken sustainably and in accordance with appropriate environmental regulations. It should be noted that although NewDEPOMOD has been applied successfully at farms around the Scottish coastline, the skill of the model in predicting benthic impact at Morrison's Rock is unknown.

2.1 Site Context

The proposed finfish farm, Morrison's Rock, is located on the east coast of the Isle of Benbecula (see Figure 2.1) and is influenced by a semi-diurnal, macrotidal tidal regime with a mean spring range of 3.9 m (Loch Carnan³). The location is considered exposed to significant sea swell to the northeast, where a substantial fetch exists (>100 km) through The Little Minch to northwest mainland Scotland. The proposed farm is 600 m east of the Maragay Mor Island shoreline in water depths between - 42 and - 45 mCD. In the absence of significant freshwater influence (with no significant discharges in the vicinity or the proposed site) the site is considered well mixed and flushed by tidal and frictional wave related currents.

³2022. Admiralty Total Tide. Euronav Navigation Systems

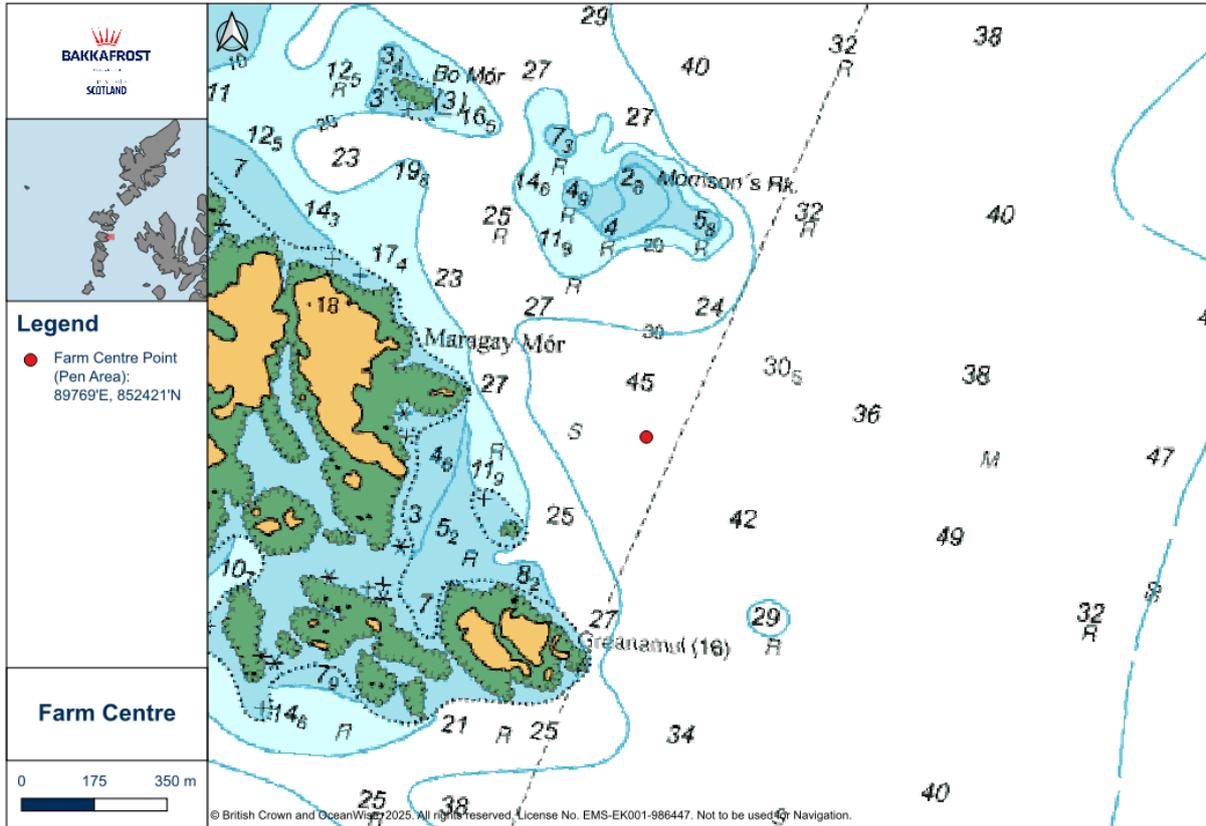


Figure 2.1: Location of the Morrison's Rock site

2.2 Site details

The site is proposed to have 8 x 160 m circular pens, held in a 100 m grid, arranged in a 2 x 4 layout and with a net depth of 18 m. The proposed biomass is 5,050 T. Details of the site are provided in **Table 2.1** with a graphical representation of the site provided in Figure 2.2.

Table 2.1: Summary of Morrison's Rock site information

Site Details	
Group Location	89768.97 E, 852420.85 N
Number of Pens	8
Pen Circumference (m)	160
Grid Matrix (m)	100 x 100
Net Depth (m)	18
Configuration	2 x 4
Orientation (°)	33.99 W
Distance from shore (m)	600
Depth at Site (mCD)	42 - 45

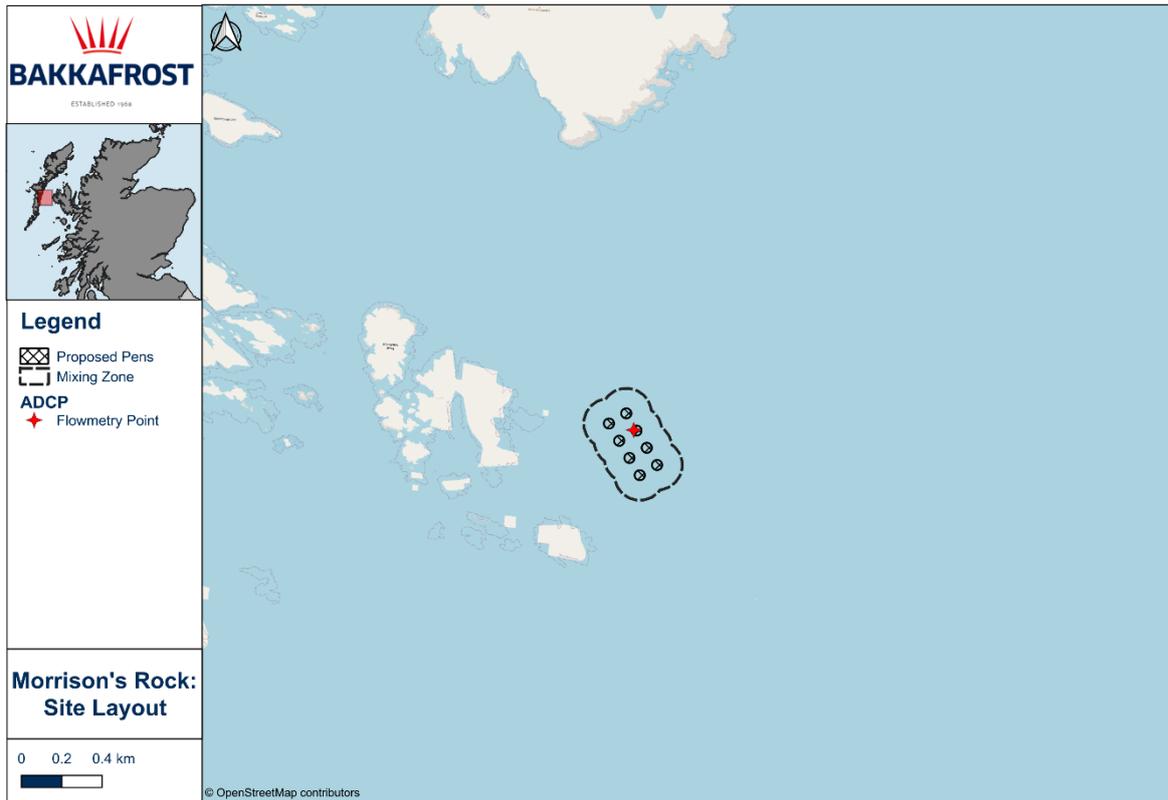


Figure 2.2: Proposed site layout

2.3 Site exposure

The site at Morrison's Rock has a Wave Exposure Index (WEI) of approximately 3.9 as derived from the Marine Scotland wave exposure index⁴. As this is in excess of SEPA's recommended threshold of 2.8, the site is considered a moderately exposed site. As a result, the average Mixing Zone intensity threshold here is uplifted to 4,000 g/m²/yr and the permitted Mixing Zone is elevated to 120%² under SEPA's Standard Default approach.

2.4 Modelling context

There is currently no farm located at Morrison's Rock. The model simulations in this report are the initial iteration of simulations undertaken representing this prospective site within NewDepomod, and so default parameters derived from SEPA's Guidance released in 2019¹ and 2023² are applied. This report presents a risk assessment undertaken using a minimum of 90 days of hydrographic data to identify the maximum biomass permissible at the site and the appropriate quantities of in feed medicines suitable for licencing.

⁴MarineScotland (2020) MAPS NMPI, part of Scotland's environment. [Accessed online 28/02/2020: <https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?layers=780>]

3. NewDepomod setup

3.1 Model hydrodynamics

Modelling was undertaken using data collected by BFS spanning two separate data collection exercises, consisting of one 56-day deployment in October 2021 and one 43-day deployment in December 2023. These datasets were stitched together, by filling the gaps with repeated data replicating the spring-neap and flood-ebb cycles, to create a seamless 103-day time-period in 20-minute timesteps. The data collected is discussed in greater detail in following sections and the accompanying hydrographic report⁵. A summary of observed data from the three bins used in NewDepomod simulations is provided in **Table 3.1** and the water column velocities are visible in Figure 3.2.

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	0.135	155	0.028	5.77
Cage-bottom	0.136	160	0.027	13.33
Near-bed	0.127	150	0.027	37.32

NB: The current meter position and depth was derived from the current meter deployments weighted averages, as per SEPA’s regulations (HG data for Aquaculture)⁶.

Residual currents at the bed were estimated to be 0.027 m/s i.e. 21% of mean velocity. As this is below SEPA’s guidance threshold of 35% for the application of a de-trended hydrography, a Full-tide dataset was used to drive simulations under the Standard Default Method. Astronomic tide simulations (using harmonic analysis data) were undertaken here and are presented for reference.

Full-tide

The Full-tide velocity profiles from the third deployment (14/12/2023 – 27/01/2024) can be seen in Figure 3.1, with the time series for the complete stitched dataset shown in Figure 3.2.

The water column demonstrates minimal vertical shear throughout the water column, which can be seen across the 25th, 50th and 75th percentile velocities with depth. In the absence of CTD (Conductivity, Temperature, Depth) casts and with no identifiable significant source of freshwater the water column was assumed to be extremely well mixed with hydrography typical of exposed, well mixed systems of the Scottish west coast.

⁵BFS. (2025). *Hydrographic Report: Morrison’s Rock, North Uist, B1*

⁶SEPA (2022), *HG Data for Aquaculture Applications– Jan 2022*

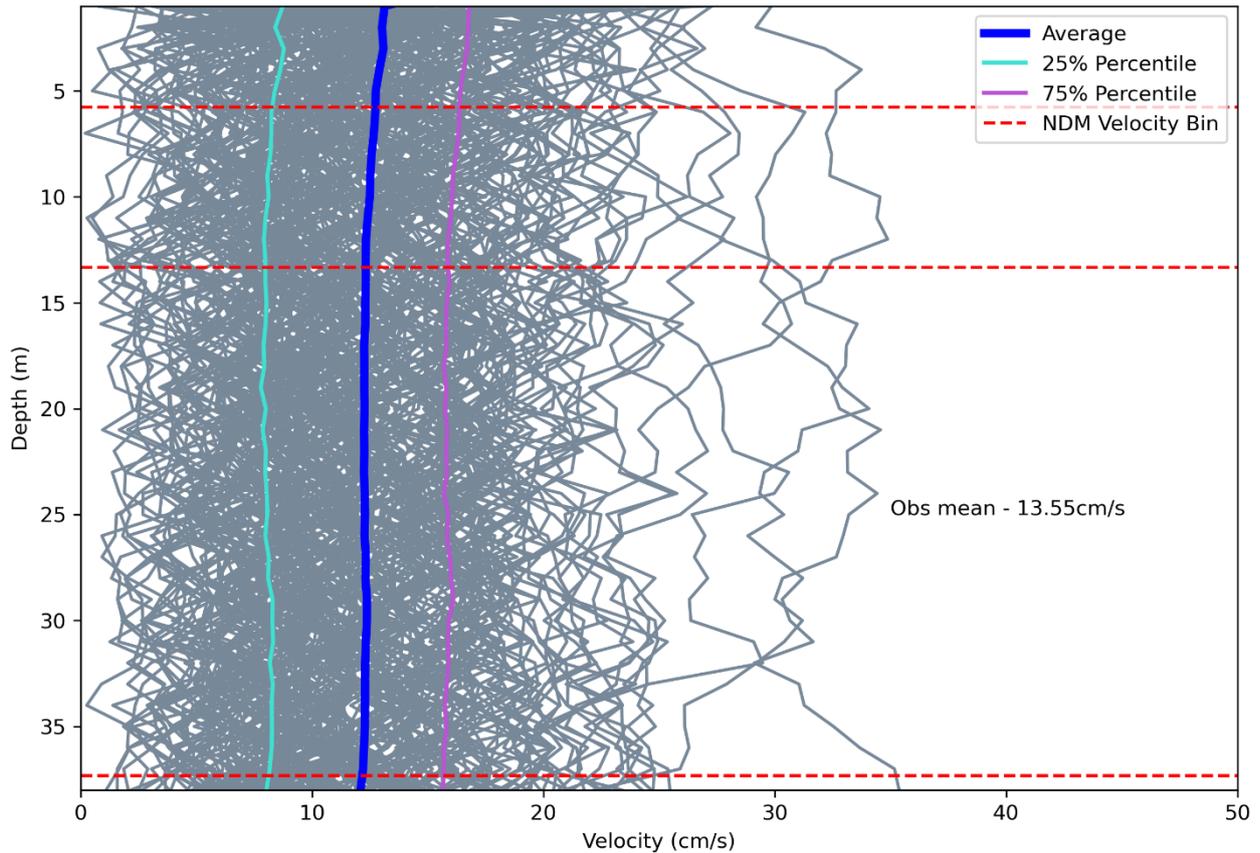


Figure 3.1: Sampled velocity profiles for the hydrographic deployment used in this assessment

The velocities in the three directional bins selected for the modelling are demonstrated in Figure 3.2 and the observations are considered largely representative of conditions observed at the site and no significant difference in velocity magnitude between the two datasets used in dataset generation was noted. There is limited difference in the mean velocity magnitude in the upper two bins selected and the average current speed is 0.01 m/s slower at the bed than the surface. This slight decrease in velocity with depth and the water column velocities visible in Figure 3.2 demonstrates very limited, vertical shear throughout the water column. The observed data does show an evident spring/neap cycle in the velocities with periods of low velocities observed bi-weekly. The dataset is thus considered appropriate for application within the NewDepomod simulations according to the Standard Default Method. However, this cannot be considered fully representative of the 365 days simulated (due to the omission of extreme events) but an approximation of conditions.

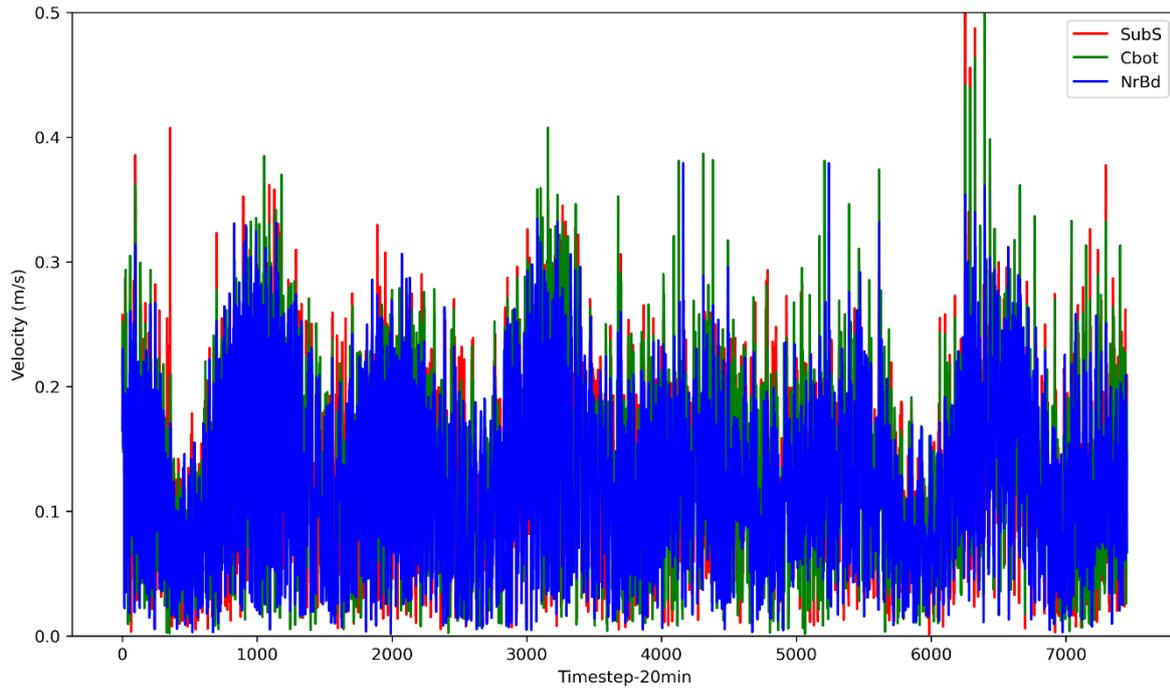
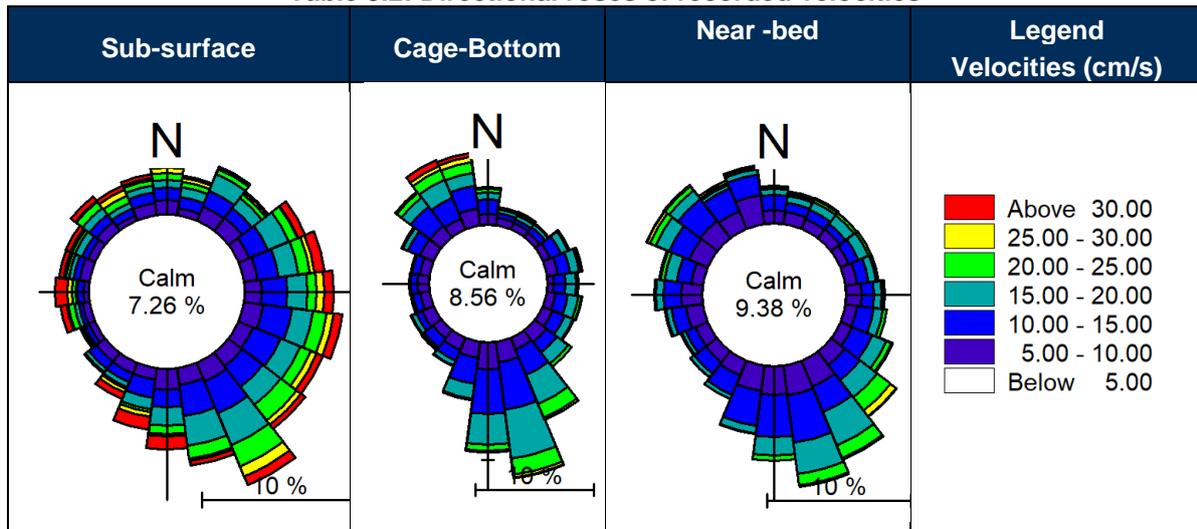


Figure 3.2: Water column velocities for stitched velocity profile

Table 3.2 illustrates the directional frequency and magnitude of 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. At all three bins the flow is largely asymmetrical along a north-northwest and south-southeast axis, with the latter dominating in frequency. The directional rose at the sub-surface indicates that there is more variation in flow direction with low frequencies of flow to the east and west.

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 0.095 m/s, 66% of the time. As a result, few sediments are consolidated within the bed model and sediments are readily re-suspended and dispersed throughout a wide area of the seabed.

Table 3.2: Directional roses of recorded velocities



3.2 Model bathymetry

Model bathymetry was available for the site at Morrison's Rock, generated from one, single beam data surveys collected by BFS in October 2020, supplemented by Admiralty chart data and an OS shoreline shapefile displayed in Figure 3.3. At the time of writing the Standard Default Method (SDM) risk assessment approach requires a uniform bathymetry to be applied within the model domain. As per the SDM requirements, a depth was applied based on the average depth under the proposed pen layout, 40.45 mCD.

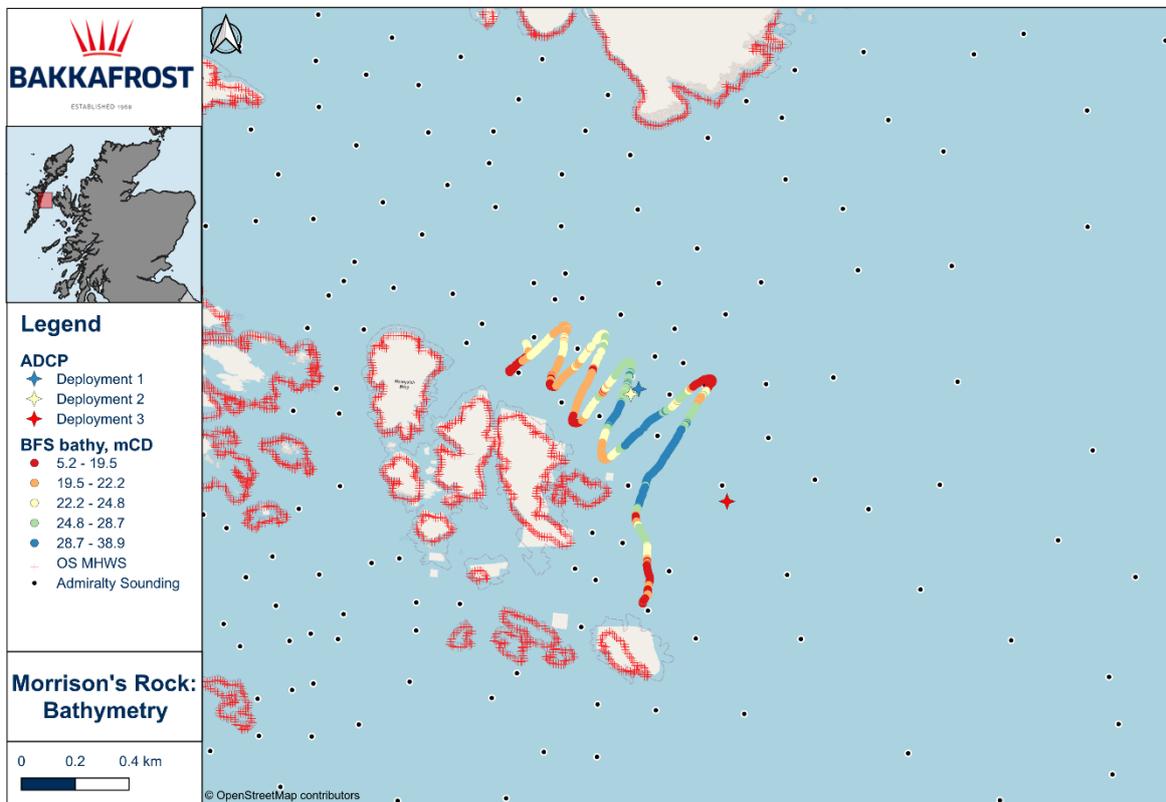


Figure 3.3: Bathymetry data available at the Morrison's Rock site.

The bathymetry was interpolated to the model grid and is displayed in Figure 3.4. The domain centre was taken as the flowmetry position. As shown in Figure 3.4, the bathymetry at the site slopes eastwards from the Maragay Mor Island shoreline to depths in excess of -45 mCD. The proposed site is to be located between the -30 and -40 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.

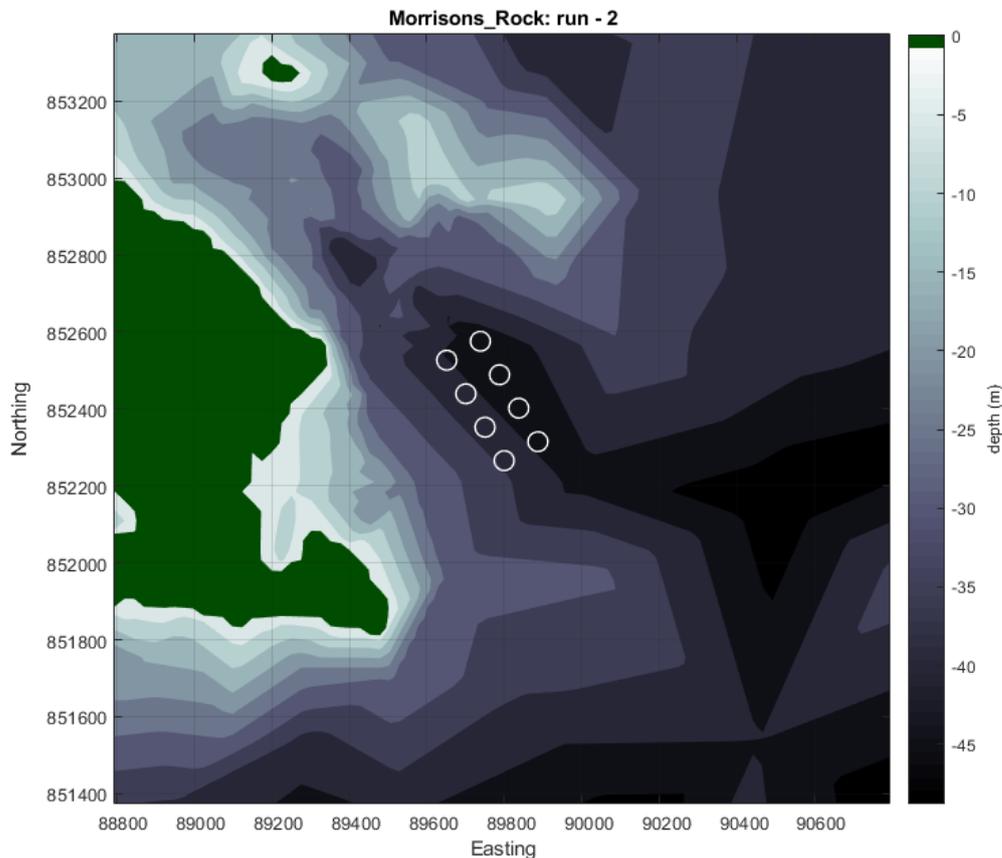


Figure 3.4: Interpolated bathymetry on the model grid with cages displayed

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. For the Standard Default Method runs presented here, peak biomass feed rates are $7 \text{ kg t}^{-1} \text{ d}^{-1}$ for 365 days.

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 rates associated with peak biomass were input for 365 days with a 3 % wastage rate.

In-feed treatments

The only in-feed treatment proposed to be administered at the Morrison's Rock 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 $136 \text{ ng/kg dry weight}$ or $272 \text{ ng/kg wet weight}$ for EmBz, 118 days following treatment (when concentrations peak)².

3.4 NewDepomod configuration

All model parameters, not specified within this document, were in accordance with the SEPA Standard Default Method for both solid dispersal and in-feed treatments. This includes the degradation of EmBz particles ($\lambda = 250$ days).

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 two bath treatment chemicals. The assessments were undertaken using the conservative, spreadsheet based BathAuto (v5) modelling package with key parameters as outlined in **Table 3.3** 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 3.3: BathAuto – Key parameters

	Variable	Parameter
Waterbody characteristics	Loch/Strait/Open water	Open Water
	Loch area (km ²)	N/A
	Loch length (km)	N/A
	Distance to head (km)	N/A
	Distance to shore (km)	1.60
	Average water depth (m)	40.46
Pen & stocking info	Number of pens	8
	Pen shape	Round
	Diameter/Width (m)	50.9
	Working depth (m)	18
	Stocking density (kg/m ³)	17.21
Treatment info	No. of pens possible to treat in 3 hours	1
	Initial Treatment Depth (m)	2
	Treatment Depth Reduction Increment (m)	0.05
Hydrographic data	Mean current speed (m/s)	0.135
	Residual Parallel Component U (m/s)	0.028
	Residual Normal Component V (m/s)	0.004
	Tidal Amplitude Parallel Component U (m/s)	0.182
	Tidal Amplitude Normal Component V (m/s)	0.101

4. Model outputs

NewDepomod model outputs for both the Full-tide 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) area of 177,035 m² and average depositional intensity within the Mixing Zone of less than 4,000 g/m²/yr.

4.1 Full- tide

The Full-tide model output was identified as the appropriate hydrographic dataset to apply to the site at Morrison's Rock. 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. Due to the rate of dispersion from the site, no upper limit for tonnage was found in deposition average or mixing zone breach.

The analysis undertaken determines that, according to the risk assessment using the Standard Default Method in NewDepomod, a peak biomass of 5,050 T is permissible, with a Mixing Zone area that is less than 120%. For all iterations, the mean depositional intensity within the Mixing Zone does not exceed 800 g/m²/yr, which is considerably below the 4,000 g/m²/yr threshold for an exposed site. This risk assessment approach is widely considered to be a conservative risk assessment method, applying two to four times the observed feed rates.

Design Run

The peak biomass for the site layout was found to 5,050 T within the 8 pens outlined in Section 2.5. To appropriately risk assess this proposed farm setup, five additional model simulations were undertaken at this biomass. The run closest to the average of results of these simulations is provided in Figure 4.11 with the average depositional intensity from each model run shown in Figure 4.11. Model IDs correspond to model runs provided with this report. The average peak simulated deposition in all five model runs was 206,979.2 g/m²/yr and the average within the Mixing Zone was 723.07 g/m²/yr, satisfying SEPA's requirements of a simulated average deposition of less than 4,000 g/m²/yr.

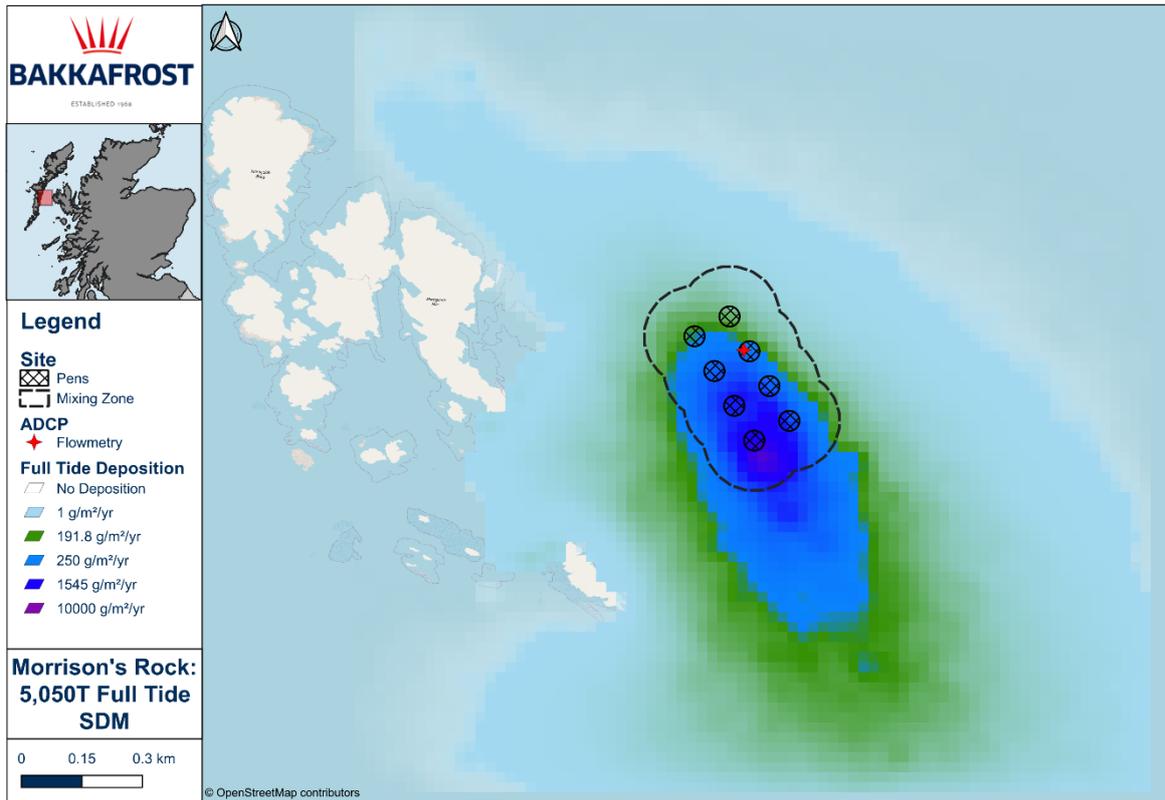


Figure 4.1: Average deposition throughout the model domain for simulated design runs

Table 4.1: Model runs assessing the impact of 5,050 T

Run ID	Average Mixing Zone deposition (g/m ² /yr)	Mixing Zone area (% of permissible)
Solids-2	695.50	117.91
Solids-3	732.69	116.50
Solids-4	762.29	119.68
Solids-5	685.23	115.79
Solids-6	762.64	113.32
Solids-7	700.11	118.26
μ	723.08	116.91

Table 4.1 displays an average Mixing Zone of 117%, with little variation between runs. This average Mixing Zone percentage is considered appropriate and conservative because it is lower than the permitted quantities recommended by SEPA (120%).

The observed dataset produces a south-eastward dispersal plume distributing sediments parallel to the easternmost Maragay Mor Island shoreline. Deposition is concentrated to the southwest of the pens, with higher rates of deposition simulated under the southwestern pen footprint. It is likely this is influenced by the resuspension events at the site causing sediments deposited on the pen footprint to be resuspended and redistributed toward the south, in the direction of the dominant ebb tide. The simulation does demonstrate a widespread dispersal of sediments, with a lower concentration, due to the high frequency of symmetry in the direction of flow and high frequency of resuspension events. The south-eastward sloping shoreline is likely to cause increased distribution downslope. However, there is currently no site at the proposed location, 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 Morrison's Rock site.

4.2 In-feed treatments

In-feed treatments were simulated using the Full-tide hydrographic dataset as per SEPA guidance. Emamectin Benzoate treatment levels were iterated to identify the appropriate quantity to satisfy requirements in terms of Mixing Zone area. The trend of the simulated model runs was used to derive the relationship between the quantity of EmBz administered and the permissible Mixing Zone (136 ng/kg dry weight or 272 ng/kg wet weight). This relationship was then used to define the total amount of EmBz permissible for the site at 80 g. To appropriately risk assess the benthic impact, additional model simulations were undertaken at this quantity. The footprint of the run closest to the average is shown in Figure 4.2. The results of these simulations are provided in **Table 4.2**.

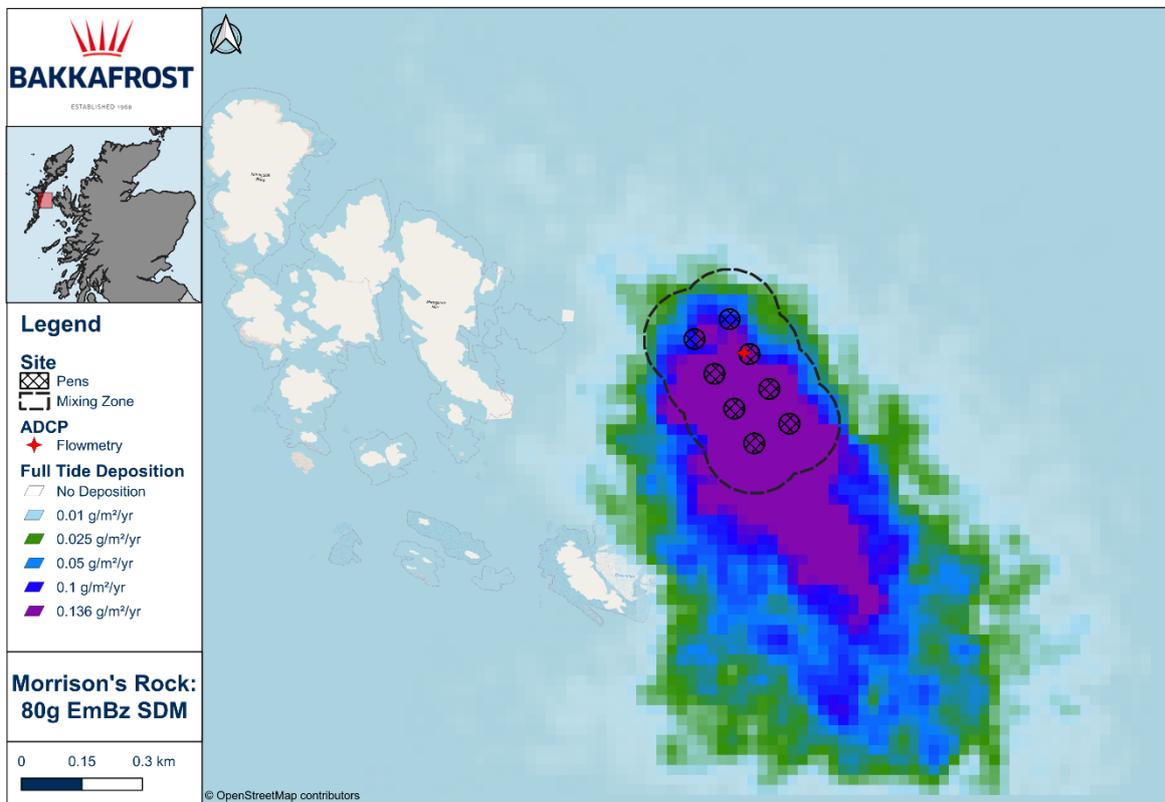


Figure 4.2: Average in-feed treatment deposition throughout the model domain

Table 4.2: Model runs assessing the impact of 80g of EmBz

Run ID	Mixing Zone area (% of permissible)
EmBz-2	96.03
EmBz-3	98.85
EmBz-4	95.32
EmBz-5	90.02
EmBz-6	84.73
EmBz-7	88.612
μ	92.26

Table 4.2 displays an average Mixing Zone of 92.26%, with an individual iteration deviating as low as 84.73%, below the permitted quantities recommended by SEPA.

4.3 Bath treatments

Bath treatment modelling was undertaken by BFS for the use of Deltamethrin and Azamethiphos. Results are displayed in **Table 4.3**, which were derived using BathAuto (v5) and the Environmental Quality Score (EQS) compliance of two medicines was determined and is presented in **Table 4.3**.

Table 4.3. Results of bath treatment modelling at Morrison's Rock

Medicine	Permissible quantity – 3 hours	No. of pens – 3 hours	Permissible quantity – 24 hours	No. of pens – 24 hours
Deltamethrin	36.1 g	4.4	-	-
Azamethiphos	532.2 g	1.3	356.1	1.0

These quantities are considered highly conservative as the BathAuto methodology does not integrate any horizontal shear and reviews the releases as a dispersal plume simulating material to disperse slower than in the physical environment and omits interaction with shoreline features and bathymetry. Detailed HD modelling of bath treatments will be undertaken in BFS's HD model for the proposed site to determine the consentable values of both medicines against the appropriate EQS standards.

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). The model simulations were undertaken with NewDepomod, using 90 days of hydrographic data, to assess a proposed pen arrangement. BathAuto simulations have also been undertaken to determine a conservative estimate of 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 6 pens at Morrison's Rock demonstrates that a peak biomass of 5,050 T satisfies SEPA's regulatory requirements (using a 90-day Full-tide hydrographic dataset), in respect of Mixing Zone area and depositional intensity for a well-exposed site. The modelling demonstrates this tonnage is considered to have minimal impact on the benthic environment with an acceptable Mixing zone (117% of the permitted 120%) and a low depositional intensity (723/4,000 g/m²/yr). Additionally, the simulations undertaken are considered a conservative estimate of the potential impact of the proposed farm, based on research undertaken by SEPA to develop the Standard Default Method risk assessment approach within NewDepomod.

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 80 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 36.1 g in three hours, and for Azamethiphos be set at 532.2 g in three hours and 356.1 g in twenty-four hours. This is considered a highly conservative assessment of bath treatment quantities and will be replaced with detailed HD modelling of bath treatments for the proposed site.