Stulaigh South, South Uist

Waste Solids & In-feed Medicine Deposition Modelling Report

Mowi Scotland Ltd.

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Mowi Scotland

OFFICE
Mowi, Farms Office, Glen Nevis Business Park
PH33 6RX Fort William

POSTAL
Mowi, Farms Office, Glen Nevis Business Park
PH33 6RX Fort William

PHONE
+44

FAX
-

MAIL
[redacted]

WEB
http://mowiscotland.co.uk

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EXECUTIVE SUMMARY

Model simulations have been performed to assess the likely deposition of waste solids and in-feed medicine at a proposed salmon farm site at Stulaigh South, to the south of Stulaigh Island off the east coast of South Uist. This report explains the application of the NewDepomod model to describe the deposition of waste solids and in-feed medicine beneath the pens and in the surrounding environment. The modelling procedure followed as far as possible guidance presented by the Scottish Environment Protection Agency (SEPA) in July 2019 (SEPA, July 2019) and January 2022 (SEPA, 2022a, b). Modelling of the dispersion of the in-feed medicine emamectin benzoate is also described.

Results indicated that deposition at Stulaigh South will be low, with a maximum deposition of 647.8 g m^{-2} (Table 1). The footprint area, where the deposition exceeded the critical deposition rate of 250 g m^{-2}, was 0.105625 km^2. The intensity of deposition, 327.9 g m^{-2}, was less than the critical value of 4,000 g m^{-2} for this exposed site. The in-feed medicine modelling achieved a pass with a treatment quantity of Emamectin Benzoate (EMBZ) of 151.0 g.

Cumulative solids modelling, performed using coupled hydrodynamic and particle tracking models, indicates that deposition from the site, combined with deposition from the neighbouring site at Stulaigh, will not interact with local marine sensitive features.

These results indicate that the proposed farm at Stulaigh South will comfortably meet pertinent Environmental Quality Standards for salmon farm waste solids and that the proposed quantity of emamectin benzoate will also meet the current EQS.

Table 1. Site details & summary of results

Site Details	
Site Name:	Stulaigh South
Site Location:	South Uist
Peak Biomass (T):	3,000
Feed Load (T/year):	7,665
Pen Details	
Number of Pens:	6
Pen Dimensions:	200m Circumference
Working Depth (m):	16
Configuration:	2x3, 120m matrix
NewDepomod Results	
Allowable Mixing Zone (m^2):	175,065
Maximum Deposition (g m^{-2}):	647.8
Modelled Footprint Area (m^2):	105,625
Mean Footprint Deposition (g m^{-2}):	327.9
In-feed Medicine	
Emamectin Benzoate TAQ (g)	151.0

1. INTRODUCTION

This report has been prepared by Mowi Scotland Ltd. to describe the deposition of waste solids from a proposed marine salmon farm at Stulaigh South off the east coast of South Uist (Figure 1 and Figure 2). The proposed site incorporates 6 x 200 m pens with 16 m deep nets. The report describes the application of the NewDepomod model to describe the deposition of waste solids and in-feed medicine beneath the pens and in the surrounding environment. The modelling procedure followed as far as possible guidance presented by the Scottish Environment Protection Agency (SEPA) in January 2022 (SEPA, 2022a, b).

Figure 1. Location of the proposed Stulaigh South site pens (●). The pens at the neighbouring Stulaigh site are also indicated (●).

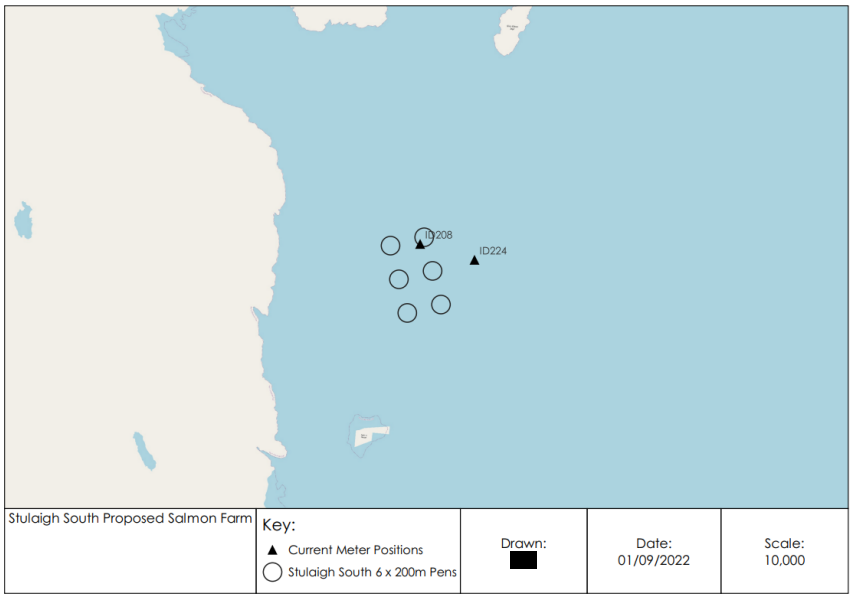

Figure 2. Proposed pen locations (○) at the Stulaigh South site. Current meter deployment locations ID208 and ID224 are marked (▲).

1.1 Site Details

The existing site is situated south of Stulaigh Island off the east coast of South Uist (Figure 1 and Figure 2). The proposed pen centre locations are given in Table 2; these locations were used in the computer modelling (Section 2). Details of the site and hydrographic summary are provided in Table 1 and Table 3. Hydrographic data were collected over two deployments in 2018 (ID208 and ID224, Figure 2). The receiving water is defined as open water.

The proposed location at Stulaigh South is sited in a high wave exposure location (wave exposure index = 3.6); as such, the deposition intensity limit within the modelled footprint will be set at 4,000 g m^2.

Table 2. Details of the proposed 6 x 200m pen centre locations and net depths used in the modelling for Stulaigh South.

Pen	Easting	Northing	Net Depth (m)
1	75626	803290	16
2	75609	803217	16
3	75699	803273	16
4	75682	803200	16
5	75772	803256	16
6	75975	803133	16

2. MODEL DETAILS

Two simulations of solid waste deposition were performed. The first focussed on localised deposition of waste solids from the proposed pen locations and utilised the **NewDepomod** model, configured with the standard default parameter values specified by SEPA and using measured flow data to force the model. The second simulation predicted the regional deposition from the proposed pen locations combined with deposition from the nearby site at Stulaigh. This second simulation used the **UnPTRACK** particle tracking model (Gillibrand, 2021) with flows from a hydrodynamic model simulation (Mowi, 2022). Simulations were also performed to determine the quantity of the in-feed medicine, emamectin benzoate, that can be discharged while meeting environmental quality standards.

Table 3. Summary of the near-bed hydrographic data at Stulaigh South.

Hydrographic Summary	ID208	ID224
Deployment Date	Mar – Apr 2018	May – Aug 2018
Easting	83371	83559
Northing	822233	822178
Mean Speed (m/s)	0.093	0.104
Residual Speed (m/s)	0.013	0.053
Residual Direction (°G)	053	341
Tidal Amplitude Parallel (m/s)	0.116	0.127
Tidal Amplitude Normal (m/s)	0.091	0.086
Major Axis (°G)	360	010

2.1 Local Deposition: NewDepomod

NewDepomod is a bespoke modelling software designed to simulate the dispersion of particulate wastes from salmon farms. The model (SAMS, 2021) has been developed by the Scottish Association for Marine Science (SAMS) and is supplied under licence. The version used for the modelling described here was:

library version:
numerics version: Final 1.20220131164706.1643647287
datatypes version: Final 1.20220131164658.1643647287
util version: v1.4.0-final-(SEPA)

A regular model grid was prepared. The grid for simulating solids deposition covered a 3 km x 3 km area, with a 25 m grid spacing in both directions. The grid size was 120 x 120 cells. A flat bathymetry was used, with a water depth of 42.1 m, the weighted average of the depths at the two current meter deployments (ID208 and ID224). The flowmetry file combined the data from ID208 and ID224; after merging the length of the combined record was truncated to exactly 90 days in total.

2.1.1 Local Waste Feed and Faeces

The model was configured exactly as specified by SEPA in the modelling guidance published in January 2022 (SEPA, 2022a, b). The site was modelled for a maximum biomass of 3000 tonnes with a feed load of 7 kg tonne^{-1} day^{-1}. This configuration of the model produces a conservative estimate of the benthic footprint, with a deposition rate of 250 g m^{-2} equating approximately to an Infaunal Quality Index (IQI) of 0.64 (the boundary between moderate and good status). Work by SEPA has shown that footprints predicted by this “standard default” configuration broadly match the footprint area derived from seabed samples, although there is a great deal of variability from site to site.

Following the standard default approach, NewDepomod was used to simulate one year of deposition at the maximum farm biomass. Results were analysed over the final 90 days of the simulation, with the mean deposition rate across the model domain being calculated and the footprint area being delimited by the 250 g m^{-2} contour (SEPA, 2022a, b). The results are presented in Section 3.1.

2.1.2 Local In-feed Medicine Modelling

To assess emamectin benzoate quantities, NewDepomod was run in standard default mode, configured exactly as specified by SEPA in the modelling guidance published in July 2019 (SEPA, 2019) and January 2022 (SEPA, 2022a, b). The model was run repeatedly, with the effective biomass and associated quantity of emamectin steadily reduced until the EQS was met. Each model run was performed over 223 days, with output analysed over Days 116 – 118. The mean concentrations of Emamectin Benzoate were calculated from this output period for comparison with the EQS value of 65.5 ng kg^{-1} (wet weight, equivalent to 131 ng kg^{-1} dry weight), which is the current position standard (SEPA, 2022c).

2.2 Regional Particulate Waste Deposition Modelling

The regional particulate deposition modelling, performed using the UnPTRACK model (Gillibrand 2021), simulated the settling of waste solids (waste feed and faeces) discharged from pens during a production cycle. The same pen positions were used in these simulations as the model runs used in NewDepomod (Table 2), together with pens at Stulaigh (Table 4). Particles were discharged continuously, with each numerical particle representing 2.5 kg of particulate waste. Feed and faecal particles were assigned settling velocities within the range of 0.095 m s^{-1} ±10% and 0.032 m s^{-1} ± 10% respectively, the same as the values used by NewDepomod.

The particle tracking model was used with the hydrodynamic model simulation from June – October 2020 to calibrate the particle tracking model against benthic survey data collected at the Stulaigh site in October 2020 (Mowi, 2022). The calibrated model was then used to predict regional deposition from both Stulaigh and Stulaigh South sites for their respective consented biomasses. No model parameters were changed from the model settings described in Section 6 in Mowi (2022), so a deposition rate of 1490 g m^{-2} corresponds here to an IQI of 0.64.

Table 4. Details of the 14 x 120m pen centre locations and net depths used in the modelling for the neighbouring site at Stulaigh.

Pen	Easting	Northing	Net Depth (m)
1	82599	824416	16
2	82523	824423	16
3	82592	824340	16
4	82516	824346	16
5	82586	824263	16
6	82509	824270	16
7	82579	824187	16
8	82502	824193	16
9	82572	824110	16
10	82496	824117	16
11	82566	824034	16
12	82489	824040	16
13	82559	823957	16
14	82482	823964	16

When a particle reaches the seabed due to its settling velocities, it may be resuspended into the water column and be subject again to advection and diffusion. Resuspension is modelled using a stochastic approach, whereby a probability of resuspension is specified for each settled particle every time step. In the present simulations, the probability of resuspension, P, was calculated by:

$$P = c_r(\tau_b - \tau_{bc})e^{-t_p/\lambda}$$

where $\tau_b = \rho u_*^2$ is the bed shear stress derived from the local modelled current speed, τ_{bc} is the minimum critical shear stress required to erode particles off the seabed, c_r is a

resuspension constant, t_p is the age of the particle since settlement on the seabed and λ is a timescale for consolidation. With this approach, the probability of particle erosion increases with the excess shear stress, but decreases as the time since settlement increases. This reflects a likelihood that as particles remain on the seabed they become consolidated into the sediment layer and therefore less likely to be resuspended. The parameters c_r, τ_{bc} and λ are tunable coefficients that can be used to calibrate the deposition model. Numerous model simulations were performed with varying values of c_r, τ_{bc} and λ to find the combination producing the best agreement between modelled deposition and benthic health data from a seabed monitoring survey during October 2020 (Mowi, 2022). For the simulations presented in §3.2, values of c_r = 0.2, τ_{bc} = 0.02 Pa and λ = 4 days were used. A bed roughness scale of z_0 = 0.01 m was used to calculate the bed shear stress from the local current speed. These model parameter values were used in Section 6 of Mowi (2022) to obtain a deposition threshold of 1490 g m^{-2} that corresponded to an IQI of 0.64.

3. RESULTS

3.1 Waste Solids Deposition

The modelled footprints for the proposed Stulaigh South farm using the SEPA standard default method are shown in Figure 3 for the various pen configurations. The areas of the modelled footprint, defined as the area where the deposition rate exceeds 250 g m^{-2}, are given in Table 5. For the proposed pens, the footprint area of 105,625 m^2 was well within (60% of) the allowable mixing zone. The maximum 90-day-mean deposition was 647.8 g m^{-2}, while the mean intensity of deposition within the footprint was 327.9 g m^{-2}, well below the critical value of 4,000 g m^{-2} for this highly exposed site (wave exposure index of 3.6, §1.1).

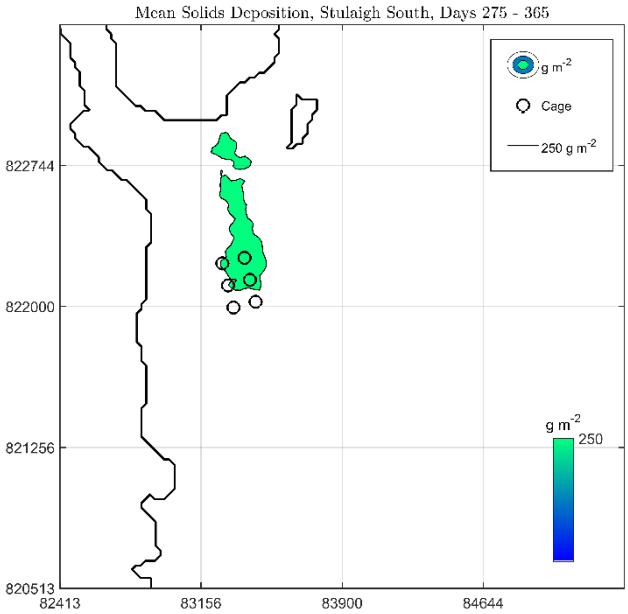

Figure 3. The modelled footprint for Stulaigh South using the SEPA standard default method for the proposed biomass of 3000 tonnes with 6 x 200m pens (O).

Table 5. The modelled footprint areas and mean footprint deposition rates for Stulaigh South for the proposed biomass of 3000 tonnes, using the SEPA standard default method.

Parameter	Value
Maximum Biomass (T)	3,000
Feed Load (T/year)	7,665
Solid Waste Release Rate (kg/day)	3,354
Allowable Mixing Zone (m^2)	175,065
Maximum Deposition (g m^{-2})	647.8
Modelled Footprint (m^2)	105,625
Mean Footprint Deposition (g m^{-2})	327.9

These results indicate that the proposed equipment change and biomass increase will comfortably meet pertinent Environmental Quality Standards for salmon farm waste solids.

3.2 Regional Solids Deposition and Sensitive Features

Sensitive features including maerl beds and Northern sea fan and sponge communities were identified in the vicinity of the proposed site (SEPA, 2022d) and considered to be potentially at risk from sediment influence. Figure 4 shows the location of the special features identified by SEPA in relation to the solids footprints from both the proposed Stulaigh South site and the existing site at Stulaigh. For these simulations, solids deposition was simulated with realistic bathymetry using a particle tracking model, UnPTRACK, coupled with a hydrodynamic model (Mowi, 2022). This output has been compared with baseline survey data and an assessment presented separately as part of the CAR application and the planning application.

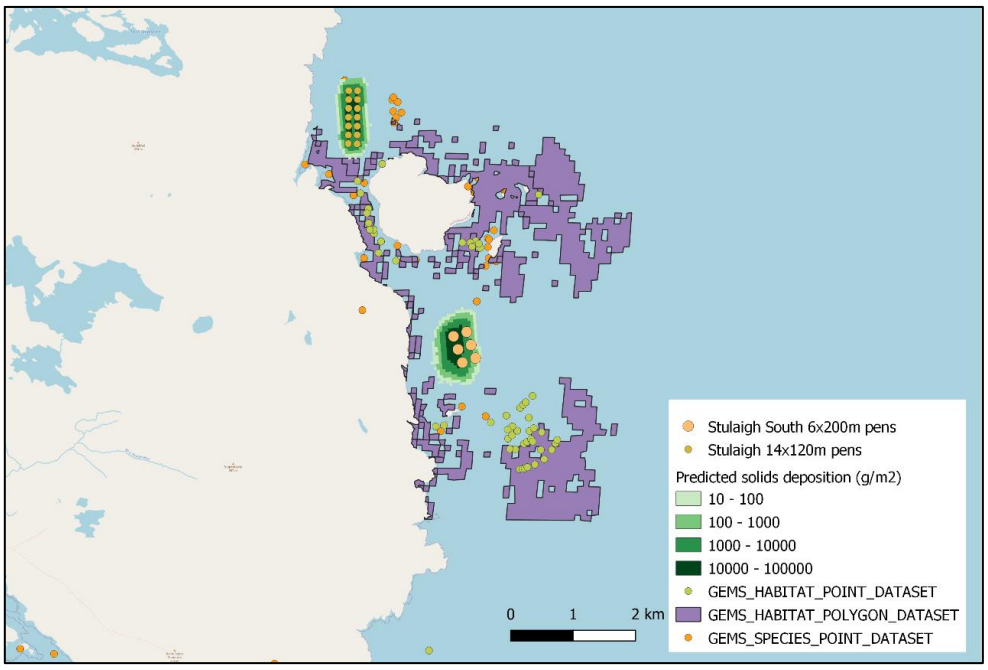

Figure 4. Predicted solids footprints at the proposed Stulaigh South salmon farm and the nearby Stulaigh site in relation to local priority marine features.

These results suggest that the modelled footprint from the proposed layout and biomass will have minimal impact on the special features. Because of the exposed location of the South Stulaigh site, a considerable proportion of the particulate waste will be exported from the area, leaving a relatively small solids footprint.

3.3 In-feed Medicine Modelling

The in-feed medicine model of NewDepomod was run using the proposed 6 x 200m pens. A compliant deposition area less than the mixing zone was achieved with a treatment quantity of emamectin benzoate of 151.0 g. The results (Figure 5) illustrate the mean predicted emamectin deposition over Days 116 – 118 following treatment using the SEPA standard default method. Note that the SEPA standard default method uses a flat bathymetry and a single-point current meter dataset; the predicted distribution of deposition, therefore, is not necessarily realistic, representing instead a risk assessment of the size of seabed area likely to be impacted by emamectin deposition. The area exceeding the EQS (65.5 ng kg^{-1} wet weight) was within the allowable mixing zone (Table 6).

Using the marine modelling approach described earlier (hydrodynamic model coupled with a particle tracking model), the deposition of emamectin was more localised at the site (Figure 6).

On the basis of these results, a total allowable quantity (TAQ) of emamectin benzoate of **151.0 g** will be applied for.

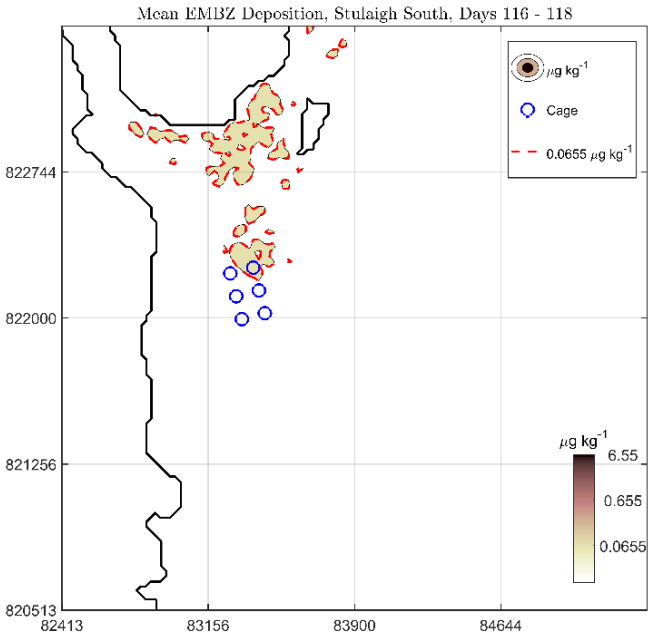

Figure 5: Predicted mean Emamectin Benzoate deposition over days 116 – 118 for the proposed 6x200m pens (○) following a treatment of 151.0 g using the SEPA standard default method.

Table 6: Predicted EmBZ footprint areas (m^2) and peak concentration (ng kg^{-1}) for the proposed 6 x 200 m pen layout at Stulaigh South for a discharged quantity of emamectin benzoate of 151.0 g from the SEPA standard default NewDepomod simulation.

Parameter	Value
Allowable Mixing Zone (m^2)	175,065
Area > EQS (65.5 ng kg^{-1}) (m^2)	156,875
Area > EQS (655 ng kg^{-1}) (m^2)	0.000
Peak concentration (ng kg^{-1})	186.0

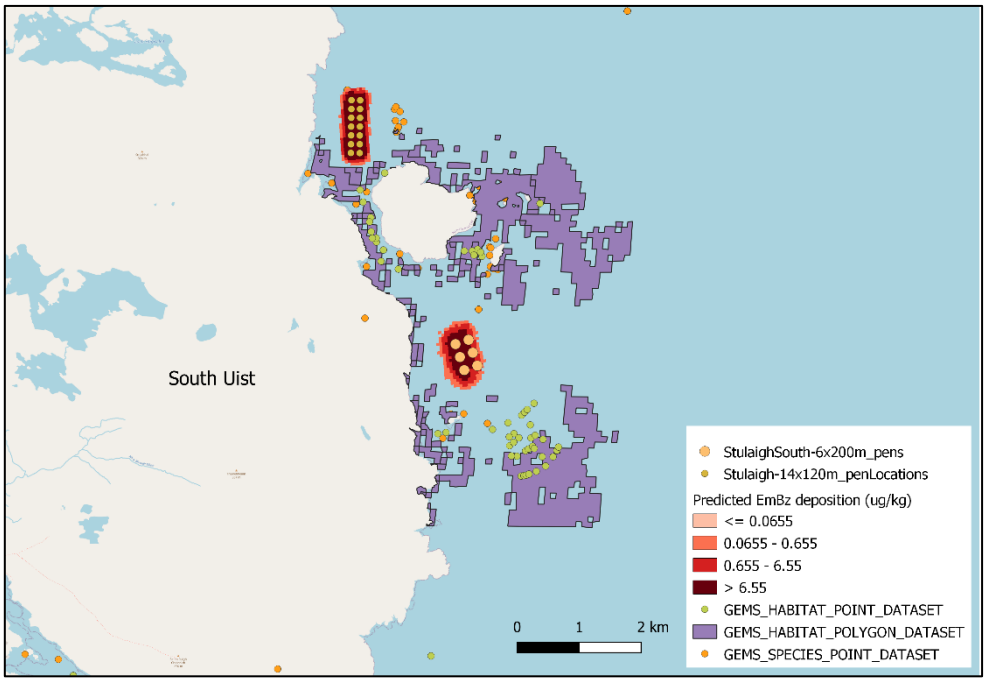

Figure 6. Predicted mean Emamectin Benzoate deposition over days 116 – 118 for the proposed 6x200m pens at Stulaigh South (●) following a treatment of 151.0 g using the marine modelling approach.

4. SUMMARY AND CONCLUSIONS

The proposed biomass of 3000 tonnes in 6 x 200m pens requested for consent at Stulaigh South, and the associated feed loading (Table 7), has been shown to comfortably meet pertinent Environmental Quality Standards. The SEPA standard default method, which is designed to provide a conservative prediction of particulate deposition, suggested no significant deposition will occur at the site, meeting both mixing zone and deposition intensity criteria.

Cumulative solids modelling indicates that deposition from the site, combined with deposition from the neighbouring site at Stulaigh, will not interact with local marine sensitive features shown on public records (baseline survey results assessed separately).

The results indicated that 151 g of emamectin benzoate could be discharged without breaching the current Environmental Quality Standard (131 ng/kg dry weight; 65.5 ng/kg wet weight).

Table 7. Summary of Results

Site Details	
Site Name:	Stulaigh South
Site Location:	South Uist
Peak Biomass (T):	3,000
Feed Load (T/year):	7,665
Pen Details	
Number of Pens:	6
Pen Dimensions:	200m Circumference
Working Depth (m):	16
Configuration:	2x3, 120m matrix
NewDepomod Results	
Allowable Mixing Zone (m^2):	175,065
Maximum Deposition (g m^{-2}):	647.8
Modelled Footprint Area (m^2):	105,625
Mean Footprint Deposition (g m^{-2}):	327.9
In-feed Medicine	
Emamectin Benzoate TAQ (g)	151.0

5. REFERENCES

Gillibrand, P.A., 2021. Unptrack User Guide. Mowi Scotland Ltd., February 2021, 31pp. https://github.com/gillibrandpa/unptrack

Mowi, 2022. Stulaigh South Marine Modelling Report. Mowi Scotland Ltd., December 2022. 22 pp.

Scottish Association of Marine Science (SAMS), 2021, NewDepomod https://www.sams.ac.uk/science/projects/depomod/

SEPA, 2019. Aquaculture Modelling. Regulatory modelling guidance for the aquaculture sector. Scottish Environment Protection Agency, Air & Marine Modelling Unit, July 2019, 68pp.

SEPA, 2022a. NewDepomod Draft Guidance – 25/01/2022. Scottish Environment Protection Agency, Air & Marine Modelling Unit, 25th January 2022.

SEPA, 2022b. Interim Marine Modelling Guidance for Aquaculture Applications. Scottish Environment Protection Agency, Air & Marine Modelling Unit, 25th January 2022.

SEPA, 2022c. Interim position statement for protecting the water environment in relation to emamectin benzoate in finfish farm regulation, Scottish Environment Protection Agency, Air & Marine Modelling Unit, July 2022.

SEPA, 2022d. Aquaculture modelling screening & risk identification report: Stulaigh South (STIS1). Scottish Environment Protection Agency, Air & Marine Modelling Unit, January 2022, 30 pp.