# Macleans Nose, Sound of Mull

NEWDEPOMOD MODELLING REPORT
05.18V2

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## EXECUTIVE SUMMARY

This report has been prepared by Marine Harvest (Scotland) Ltd. to meet the requirements of the Scottish Environment Protection Agency (SEPA) for an application to install equipment, increase production and for consent to use sufficient sealice treatments on a marine salmon farm, via NewDepomod and dispersion modelling. The report also contributes to fulfilment of the requirement of the Environmental Impact Assessment (Scotland) Regulations 2017 to inform the EIA process; results of the EIA are reported in an Environmental Report to accompany an application for Planning Consent to the Highland Council. This report describes biomass, in-feed and bath treatment modelling results for the Macleans Nose site, a summary of which is provided in Table 1 below.

Table 1. Summary of Results

| | | | |
|---|---|---|---|
| **SITE DETAILS** | | | |
| Site Name: | | Macleans Nose | |
| Site location: | | Macleans Nose, Sound of Mull | |
| Peak biomass (T): | | 3,500 | |
| **CAGE DETAILS** | | | |
| Number of cages: | | 16 | |
| Cage dimensions: | | 120m Circumference | |
| Working Depth (m): | | 16 | |
| Cage group configuration: | | 2x3 & 2x5, 75m matrix | |
| **HYDROGRAPHIC SUMMARY** | | | |
| | | **North** | **South** |
| Surface Currents | Average Speed (m/s) | 0.058 | 0.066 |
| | Residual Direction (°G) | 308 | 320 |
| | Wind-Influence | Moderate | Moderate |
| Middle Currents | Average Speed (m/s) | 0.043 | 0.052 |
| | Residual Direction (°G) | 293 | 323 |
| Seabed Currents | Average Speed (m/s) | 0.046 | 0.050 |
| | Residual Direction (°G) | 261 | 200 |
| **BENTHIC MODELLING** | | | |
| Max fish biomass proposed (T) | | 3,500t | |
| Max Average Stocking Density (kg/m³) | | 11.93 | |
| Direction of transects (˚G) | | 325, 145, 235, 55 | |
| **IN-FEED TREATMENTS** | | | |
| Recommended consent mass EmBZ (g) | | 771 | |
| Equivalent Fish Biomass (T) | | 2450 | |
| Maximum Treatment Amount EmBZ (g) | | 771 | |
| **BATH TREATMENTS** | | | |
| Recommended consent mass in 3hrs Azamethiphos (g) | | 258.4 | |
| Recommended consent mass in 24 hrs Azamethiphos (g) | | 641.8 | |
| Recommended consent mass in 3 hrs Cypermethrin (g) | | 46.8 | |
| Recommended consent mass in 3 hrs Deltamethrin (g) | | 17.5 | |

# 1 INTRODUCTION

This report has been prepared by Marine Harvest (Scotland) Ltd. to meet the requirements of the Scottish Environment Protection Agency (SEPA) for an application to install equipment, increase production and for consent to use sufficient sealice treatments on a marine salmon farm, via NewDepomod and dispersion modelling. The report also contributes to fulfilment of the requirement of the Environmental Impact Assessment (Scotland) Regulations 2017 to inform the EIA process; results of the EIA are reported in an Environmental Report to accompany an application for Planning Consent to the Highland Council. This report describes biomass, in-feed and bath treatment modelling results for the Macleans Nose site in the Sound of Mull (Figure 1) to determine EQS-compliant biomass and sea-lice treatment levels for the proposed equipment. The modelling procedure follows the Method Statement provided to SEPA in April 2018 (MHS, 2018).

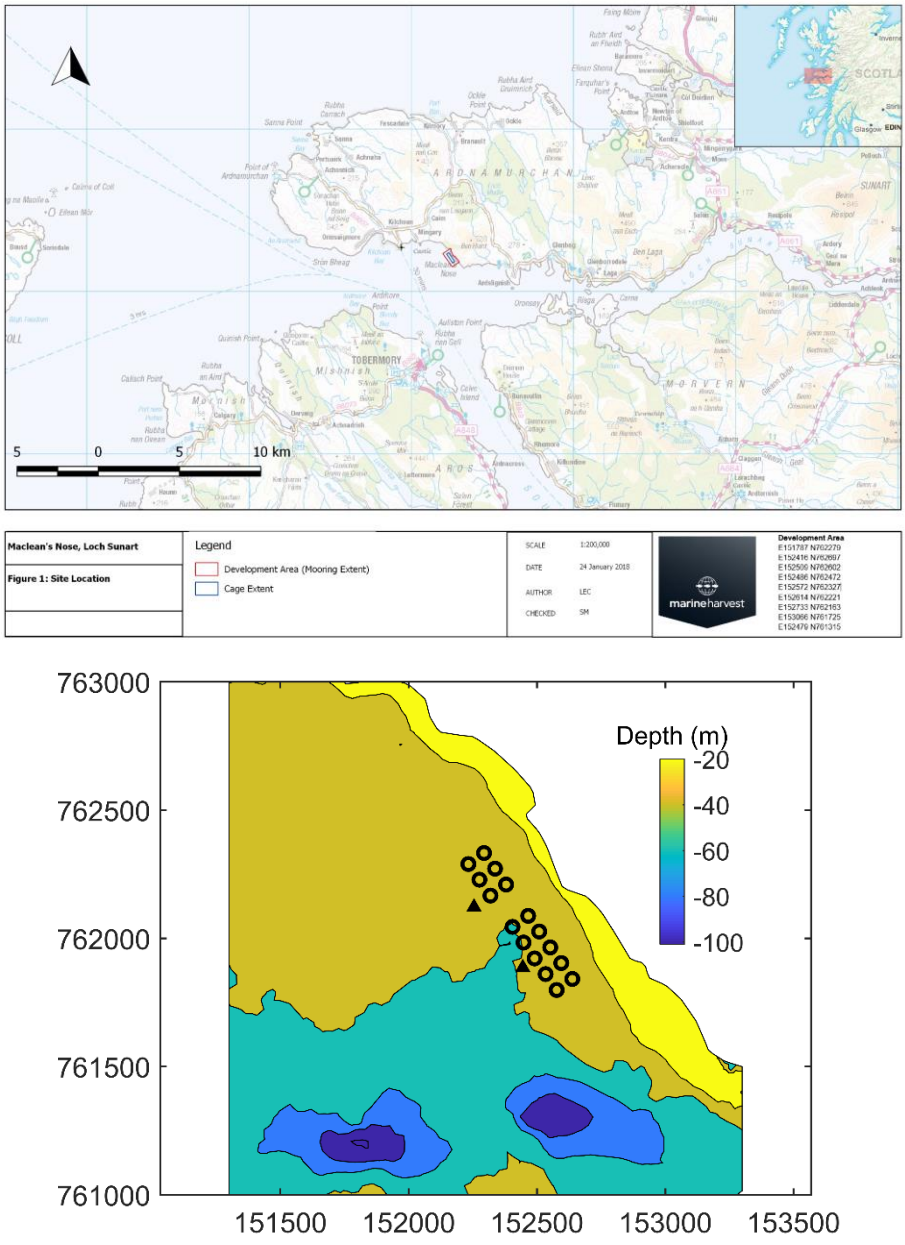


Figure 1. Location of the Macleans Nose salmon farm (top) and the location of the ADCP deployments in 2017 (▲) relative to the proposed cage positions (**o**).

# 2 MODEL INPUT DETAILS

## 2.1 HYDROGRAPHIC DATA AND HYDRODYNAMIC MODELLING

Site hydrographic data were collected at Macleans Nose Salmon Farm by Marine Harvest during 2017 for the purpose of assessing consent applications. Methods of the data collection and analysis followed current SEPA guidelines (SEPA, 2005). Two data sets are referred to in this report: (i) Macleans Nose North and (ii) Macleans Nose South, both collected from March – July 2017. Individual hydrographic data reports have been provided to SEPA for each dataset. The two datasets were each of 102 days duration; both were analysed using the SEPA HG-analysis spreadsheet.

This application used flow fields from a hydrodynamic (HD) model to drive NewDepomod. The hydrodynamic model went through a standard calibration/validation exercise to ensure that modelled currents were representative of the observed currents in the locality of the site. The cal/val exercise involved:

(i) Calibration of the HD model using observed current data from March – May 2017;
(ii) Validation of the HD model using observed data from the two locations during May – July 2017.

Table 2. A summary of the mean and residual currents recorded at the two deployment locations at Macleans Nose.

| | | |
|---|---|---|
| **SURFACE** | | |
| | **North** | **South** |
| Mean Speed (m/s) | 0.058 | 0.066 |
| Residual Speed (m/s) | 0.032 | 0.037 |
| Residual Parallel (m/s) | 0.031 | 0.036 |
| Residual Normal (m/s) | -0.010 | -0.009 |
| Tidal Amplitude Parallel (m/s) | 0.081 | 0.091 |
| Tidal Amplitude Normal (m/s) | 0.031 | 0.033 |
| Major Axis (°G) | 325 | 335 |
| **MIDDLE** | | |
| Mean Speed (m/s) | 0.043 | 0.052 |
| Residual Speed (m/s) | 0.020 | 0.025 |
| Major Axis (°G) | 315 | 325 |
| **BOTTOM** | | |
| Mean Speed m/s | 0.046 | 0.050 |
| Residual Speed m/s | 0.005 | 0.004 |
| Major Axis (°G) | 325 | 185 |

Using the HG-analysis spreadsheet, the mean speed and the residual current speed and direction were established for each of the three depths for each current meter deployment. The mean and residual currents, and the major axes of flow from May – July 2017 are summarised in Table 2. The data showed a predominant current in a northwest (to southeast) direction at surface and middle depths; at the bottom, the current direction was more variable. Tides

dominated the currents with a moderate wind-driven (non-tidal) effect. Wind data were not collected during the deployments in 2017.

The calibration and validation process was described in the Method Statement provided to SEPA in August 2018 (MHS, 2018), while details and results of the exercise for Macleans Nose are presented in a hydrodynamic modelling report submitted with this application to SEPA.

## 2.2 SITE DETAILS

The proposed site is situated in the northern Sound of Mull (Figure 1). Marine Harvest proposes to add four new pens and operate a maximum biomass of 3,500t at the new site and so the NewDepomod and the Bath Treatment models have been run to determine EQS-compliant biomass and medicinal consents for this new equipment. Details of the site are provided in Table 3. The receiving water is defined as open water.

Table 3. Project Information

| | | |
|---|---|---|
| **SITE DETAILS** | | |
| Site Name: | Macleans Nose | |
| Site location: | Sound of Mull | |
| Peak biomass (T): | 3,500 | |
| Proposed feed load (T/yr): | 8,942 | |
| Proposed treatment use: | Azamethiphos, Cypermethrin, Deltamethrin & Emamectin Benzoate | |
| **CAGE DETAILS** | | |
| Group location: | NM52536180 | |
| Number of cages: | 16 | |
| Cage dimensions: | 120m circumference | |
| Grid matrix (m) | 75 | |
| Working Depth (m): | 16 | |
| Cage group configuration: | 1 (2x3); 2 (2x5) | |
| Cage group orientation (°G): | 160.0° | |
| Cage group distance to shore (km): | 0.19 | |
| Water depth at site (m): | 30 – 40 m | |
| **HYDROGRAPHIC DATA** | | |
| | **North** | **South** |
| Current meter position: | 152255E, 762121N | 152445E, 761885N |
| Depth at deployment position (m): | 37.1 | 45.0 |
| Surface bin centre height above bed (m): | 31.7 | 38.7 |
| Middle bin centre height above bed (m): | 20.7 | 28.7 |
| Bottom bin centre height above bed (m): | 2.7 | 2.7 |
| Duration of record (days): | 43 | 43 |
| Start of record: | 22-Mar-2017 | 22-Mar-2017 |
| End of record: | 04-May-2017 | 04-May-2017 |
| Current meter averaging interval (min): | 20 | 20 |
| Magnetic correction to grid North: | 3.51W | 3.51W |

## 2.3 RUN DETAILS

The site bathymetry and proposed cage layout are shown in Figure **1**. Modelling of both the biomass and chemotherapeutants was undertaken following the methods outlined in the SEPA Forward Guidance (SEPA, 2018).

The current meter data were used to calibrate and validate a hydrodynamic model of Scottish coastal waters, with high spatial resolution in the Macleans Nose area. The hydrodynamic modelling procedure followed the methods outlined in the Method Statement provided to SEPA in April 2018, and full details are supplied with the associated CAR application for this proposal. The FVCOM hydrodynamic model was used, flow fields from which were used to provide current information to NewDepomod. The hydrodynamic model simulations used lasted 102 days, and were run both with and without wind forcing, corresponding to "Full Flow" and "Tide-Only" flow data (SEPA, 2018). The tide-only simulations are considered to be conservative and represent a minimum level of waste dispersion that can be expected, since tides are predictable and provide a baseline of current energy at the site. Details of both sets of modelling results are provided in the next section, according to SEPA requirements.

The site and cage details provided in Table 3 were prepared in the appropriate files for input to NewDepomod. Initially, NewDepomod parameter values were set to the default values recommended by SEPA in March 2018 (SEPA, 2018); these simulations are labelled **Run 1**. However, results from the calibration/validation exercise indicated that more realistic model predictions of residual emamectin benzoate (EmBZ) distributions and benthic quality (as assessed using the Infaunal Quality Index) were achieved with an alternate set of parameters (Table 4). Model simulations for biomass and in-feed chemotherapeutants were repeated with this modified parameter set (labelled **Run 2**). Both sets of results are presented below.

For modelling the biomass and benthic footprint, simulations ran for 366 days, with 3-hourly output produced over the entire simulation (Days 4 – 365). The calibration exercise indicated that an IQI value of 0.75 was achieved when the deposition was greater than 78 g $m^{-2}$ no more than 20% of the time (MHS, 2018b); the 78 g $m^{-2}$ contour is therefore presented for both sets of model runs.

Table 4. NewDepomod Parameter Values. Values in Run 2 that are different from Run 1 are highlighted in **bold**.

| | **Run 1: SEPA Defaults** | **Run 2: Calibrated** |
|---|---|---|
| Suspension X/Y dispersion coefficient | 0.1 | 0.1 |
| Bed X/Y dispersion coefficient | 0.1 | 0.1 |
| Resuspension X/Y dispersion coefficient | 0.1 | 0.1 |
| Suspension Z dispersion coefficient | 0.001 | 0.001 |
| Bed Z dispersion coefficient | 0.001 | 0.001 |
| Resuspension Z dispersion coefficient | 0.001 | 0.001 |
| Friction Velocity calculation | **Clauser charts** | **Law of the wall** |
| Bed roughness | **0.00003** | **0.01** |
| Minimum erosion stress threshold | 0.02 | 0.02 |
| Mass Erosion Coefficient | 0.031 | 0.031 |
| Bed Layer Mass (dLayerMass, kg) | **5** | **478** |
| Shear modified settling | OFF | OFF |
| Allow buoyancy | OFF | OFF |

Two types of treatment are used to control sea lice infestation in marine salmon farms and these require different modelling approaches. The in-feed treatment Slice (active ingredient

Emamectin Benzoate) requires deposition modelling using NewDepomod to predict the chemical accumulation on the seabed beneath the fish cages associated with fish faeces and uneaten treated feed. The bath treatments Salmosan (chemical name Azamethiphos), Excis (chemical name Cypermethrin) and Alphamax (Deltamethrin), where the salmon are immersed in a diluted solution of the treatment chemical require dispersion modelling to predict the concentration in the water column after release. Results from both NewDepomod and the Bath model have been provided in the next section.

## 3 MODEL CALIBRATION

The model was calibrated against Slice residue samples and a benthic survey conducted on 3rd and 4th May 2017. Full details of the calibration and validation exercise are given in the associated modelling report (MH, 2018b), and the results are only briefly summarised here. Replicate residue samples were taken at seventeen locations (Figure 2), with emamectin benzoate detected at only two locations (Stations 8 and 9). The model was run and the parameter settings adjusted to produce the best fit against the data (Table **4**). This parameter set was validated against further Slice residue surveys in October 2017 and February 2016 (MHS, 2018b).

The model parameter set obtained from the calibration against Slice residues was then utilised to model solids deposition. The modelled deposition was compared to values of the Infaunal Quality Index (IQI) measured during the benthic survey in May 2017 (Figure 3).

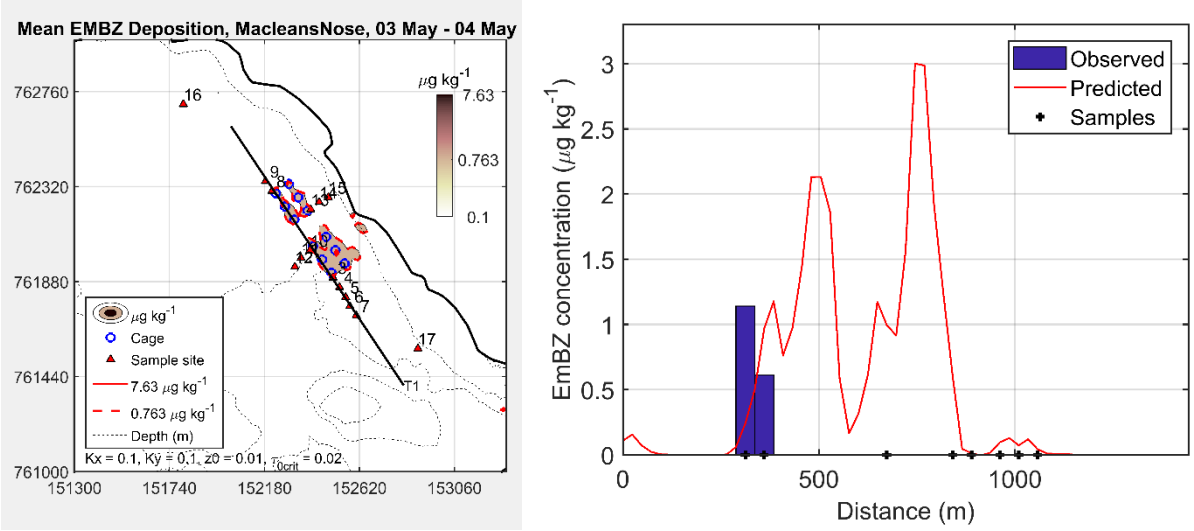


Figure 2. Results of the calibration exercise, comparing modelled deposition of Slice against residue samples taken on 3rd and 4th May 2017. The location of the transect (right) is indicated by the black lines on the map view (left). Of 17 samples taken, only two (numbers 8 and 9) contained detectable levels of emamectin benzoate.

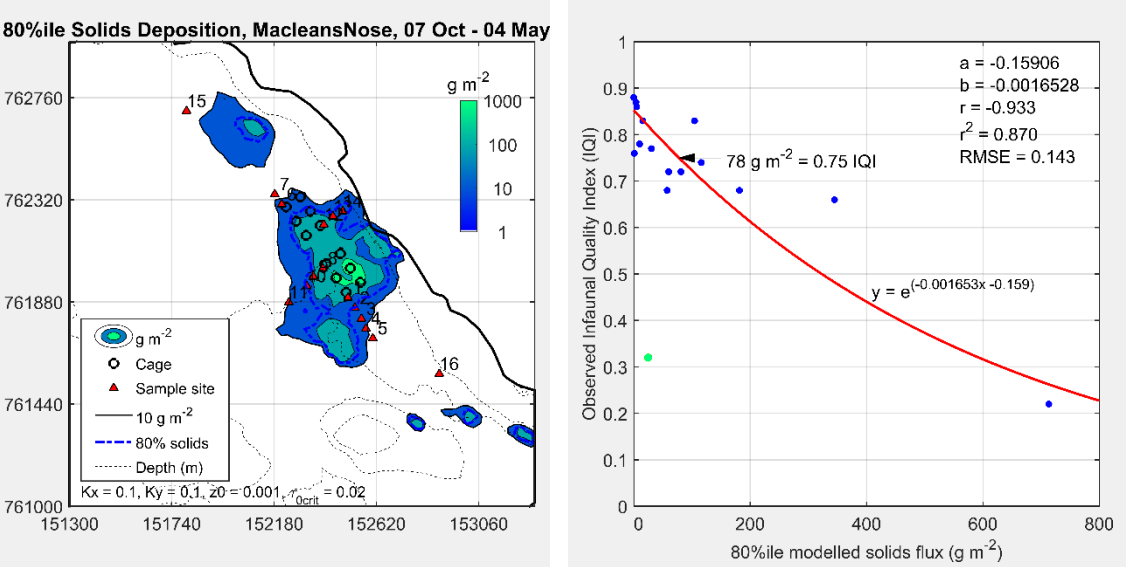


Figure 3. Results of the calibration for October 2016 – May 2017. The 80$^{th}$ percentile of deposition over the simulation period is shown with the sample locations indicated (left). On the right, the relationship between 80$^{th}$ percentile of deposition and the observed IQI is shown. The red line indicates the relationship between deposition and IQI used to forecast the future footprint. Note that deposition at Station 6 (green point) was poorly modelled, and that data point was not used when fitting the curve, but it was included when the errors ($r^2$, RMSE) were calculated.

***The calibration exercise demonstrated that, at Macleans Nose, an IQI greater than 0.75 was achieved where deposition exceeded 78 g m$^{-2}$ no more than 20% of the time (i.e. where deposition was less than 78g m$^{-2}$ for at least 80% of the time).***

Other percentile values were also obtained (Table 5). The 80$^{th}$ percentile was chosen as it provides good accuracy while allowing for periods of high but transient deposition which may not affect benthic faunal health. Using the deposition rate of 78 g m$^{-2}$ to define the area of the footprint beneath the cages where the IQI may fall below 0.75, gives a footprint area of 0.15 km$^2$ for the simulation from October 2016 – May 2017 (Figure 4).

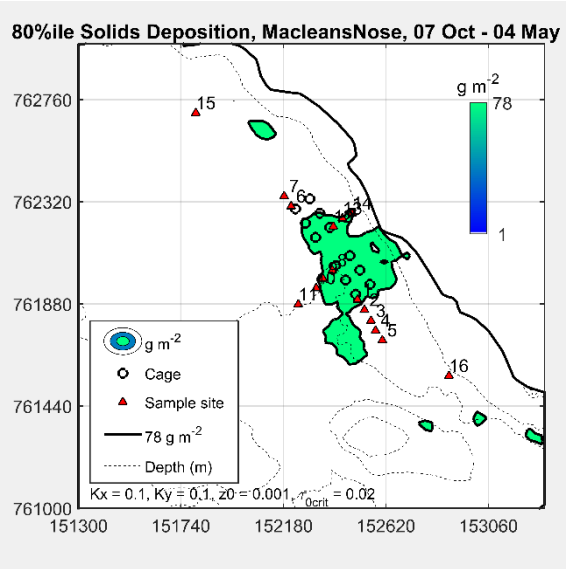


Figure 4. Modelled footprint, where IQI < 0.75, for the October 2016 – May 2017 simulation. The footprint is defined by the 80$^{th}$ percentile of deposition of 78 g m$^{-2}$.

Table 5. Modelled deposition rates associated with an IQI of 0.75 for varying percentiles.

| Percentile | 50 | 60 | 70 | 80 | 90 | 95 |
|---|---|---|---|---|---|---|
| Deposition rate (g m$^{-2}$) | 20 | 32 | 50 | 78 | 116 | 169 |

The calibration was validated by two further model runs, described in MHS (2018b), comparing modelled solids predictions against IQI values from surveys in October 2017 and February 2016.

In the following sections, results from the “screening tool” approach (i.e. Run 1), as defined by SEPA (2018) will be presented as the mean deposition over the final 15 days of a year-long simulation, whereas the deposition from the calibrated model (i.e. Run 2) will be presented as 80$^{th}$ percentiles over the full year-long simulation, following the calibration exercise summarised above.

# 4 MODELLING RESULTS

## 4.1 BIOMASS RESULTS

NewDepomod was run initially with a stocking density of 11.93 kg/m3, giving a maximum biomass of 3500 tonnes, and the proposed cage layout, with the biomass evenly distributed between the cages. The proposed layout and tonnage results in a benthic cage area of 59,588m$^2$. Below, we first summarise the calibration of the model against observations of emamectin benzoate residues and benthic health, and then describe the results of the modelling of the proposed cage layout and biomass.

### *4.1.1 FULL MODELLED FLOW*

The predicted mean and maximum deposition, for Days 350 – 365 of a year-long simulation at maximum biomass with full flow, are shown in Figure 5, with values of the derived metrics given in Table 6. The calibrated deposition from Run 2, using the 80$^{th}$ percentile of deposition over the full year-long simulation, is shown in Figure 6 with derived metrics given in Table 7.

The mass of solids released per year was estimated to be 1,429,136kg. Under full flow conditions, particulate waste was dispersed slightly more widely; however, the great majority of the particulate waste remained within the model domain, with less than 5% exported from the model domain. Current data recorded at the site demonstrates a weak near-bed average residual current of about 0.01m/s to the south, with the tidal ellipse orientated from northwest – southeast. Consequently, the predicted deposition footprints (Figure 5 and Figure 6) indicate dispersal of waste material predominantly to the northwest and southeast with some minor residual transport of waste to the south. Using full modelled flow, with a maximum biomass of 3500 tonnes, the calibrated model predicts the area where the IQI may fall below 0.75 to be 280,625 m$^2$ (Table 7), less than the 0.5 km$^2$ limit. Other percentiles and associated deposition rates given can be used (Table 8).

Table 6. NewDepomod simulation results for full flow after 365 days at maximum biomass for Run 1 ("Screening").

| | Mean | Maximum |
|---|---|---|
| Mass of solids released (kg yr$^{-1}$) | 1,429,136 | 1,429,136 |
| Total mass of solids present (kg) | 1,383,147 | 1,412,481 |
| Area > 20 g/m$^2$ (m$^2$) | 213,125 | 217,500 |
| Mean 80% solids area (m$^2$) | 106,875 | 107,500 |
| 80% solids flux (g/m$^2$) | 2080.6 | 2119.2 |
| Benthic sampling area (ITI = 30, m$^2$) | 146,875 | 147,500 |

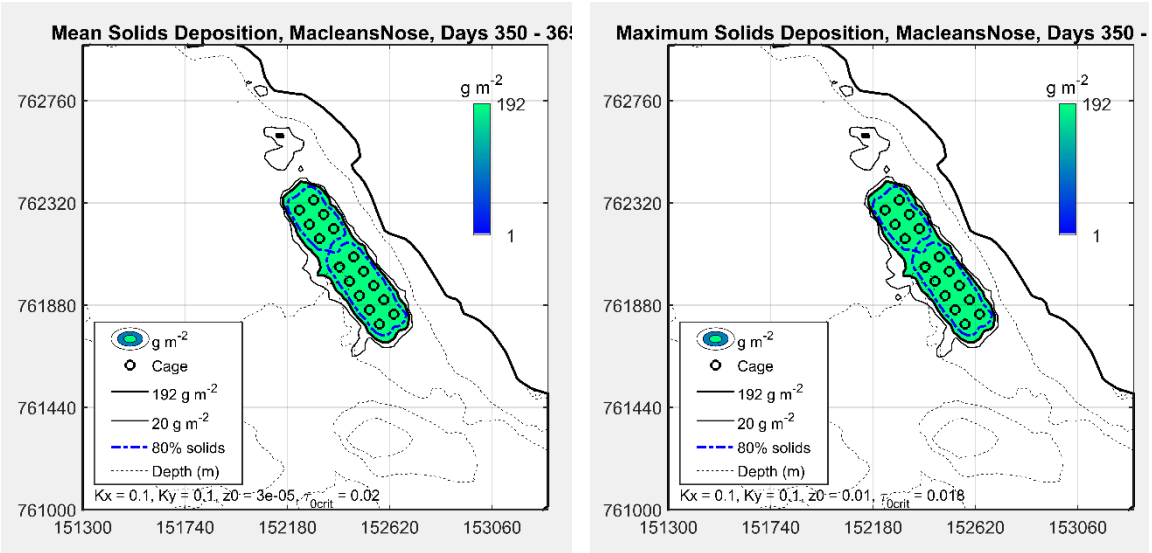


Figure 5. Predicted mean (left) and maximum (right) benthic impact for 3500 tonnes with full flow for Run 1 ("Screening").

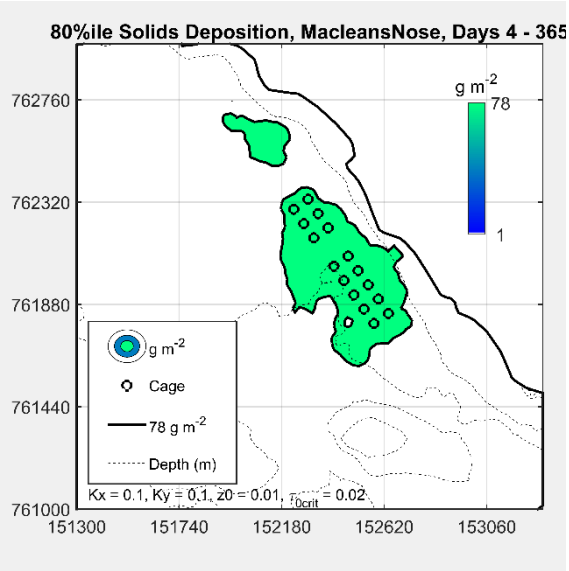


Figure 6. Predicted calibrated deposition with full flow from Run 2 ("Calibrated"), using the 80th percentile deposition value of 78 g $m^{-2}$ to delineate the benthic footprint.

Table 7**.** NewDepomod simulation results for full flow after 365 days at maximum biomass for Run 2 ("Calibrated").

| | **Run 2** |
|---|---|
| Total mass of solids released (kg $yr^{-1}$) | 1,429,136 |
| Mass of solids within footprint (kg) | 1,045,752 |
| Area > 78 g/$m^2$ ($m^2$) | 280,625 |

Table 8. Forecast footprint areas, defined as the area where the IQI may fall below 0.75, for a biomass of 3500 tonnes and using differing percentiles of deposition under full flow and tide-only flow.

| **Percentile** | **Deposition (g $m^{-2}$)** | **Area (Full Flow, $m^2$)** | **Area (Tide Only, $m^2$)** |
|---|---|---|---|
| 50 | 20 | 336,200 | 340,000 |
| 60 | 32 | 321,900 | 321,200 |
| 70 | 50 | 294,400 | 297,500 |
| 80 | 78 | 280,625 | 260,625 |
| 90 | 116 | 285,600 | 240,600 |
| 95 | 169 | 270,600 | 215,600 |

### *4.1.2 TIDE-ONLY FLOW*

The predicted mean and maximum deposition, for Days 350 – 365 of a year-long simulation at maximum biomass with tide-only flow, are shown in Figure 7, with values of the derived metrics given in Table 9. The calibrated deposition from Run 2, using the 80th percentile of deposition over the full year-long simulation, is shown in Figure **8** with derived metrics given in Table 9.

The mass of solids released per year was estimated to be 1,429,136kg. Under tide-only flow conditions, particulate waste was dispersed less widely, with the great majority of the particulate waste remained within the model domain. Less than 5% of the released solids were exported from the model domain. Current data recorded at the site demonstrates that the tidal ellipse was orientated from northwest – southeast; consequently, the predicted deposition footprints (Figure 7 and Figure **8**) indicate dispersal of waste material predominantly beneath the cage array in that orientation. Using tide-only modelled flow, with a maximum biomass of 3500 tonnes, the model predicts the impacted area to be 260,625 $m^2$ (Table 10).

These results indicate that the area where the Infaunal Quality Index (IQI) may fall below 0.75 is substantially less than 0.5 km. It is also noted again that the validation exercise indicated that the model predictions were conservative i.e. the measured IQI values were higher than the modelled IQI.

Table 9. NewDepomod simulation results for tide-only flow after 365 days at maximum biomass from Run1 ("Screening").

| | Mean | Maximum |
|---|---|---|
| Mass of solids released (kg) | 1,429,136 | 1,429,136 |
| Total mass of solids present (kg) | 1,383,161 | 1,412,507 |
| Area > 20 g/$m^2$ ($m^2$) | 153,750 | 155,000 |
| 80% solids area ($m^2$) | 95,625 | 95,625 |
| 80% solids flux (g/$m^2$) | 2594 | 2654 |
| Benthic sampling area (ITI = 30, $m^2$) | 131,250 | 130,625 |

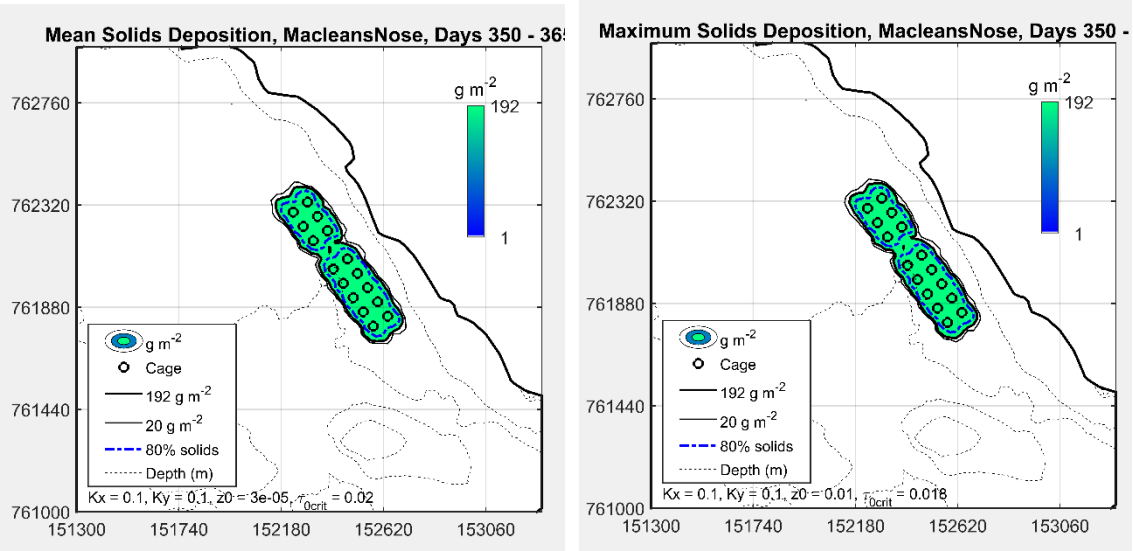


**Figure 7.** Predicted mean (left) and maximum (right) benthic impact for 3500 tonnes with tide-only flow for Run 1 ("Screening").

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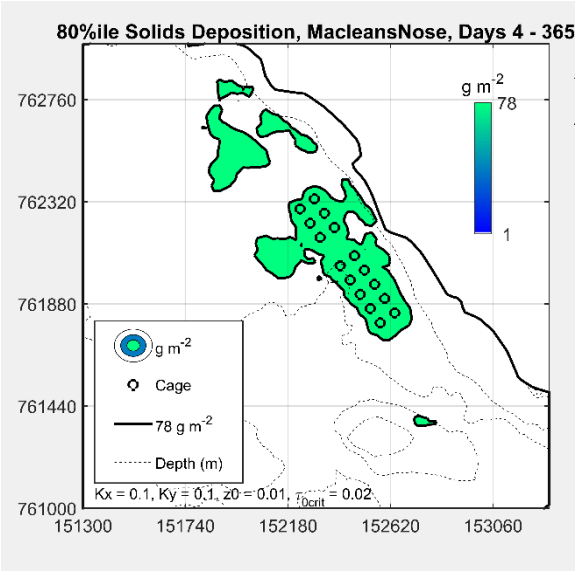


Figure 8. Predicted calibrated deposition with tide-only flow from Run 2 ("Calibrated"), using the 80th percentile deposition value of 78 g $m^{-2}$ to delineate the benthic footprint.

Table 10. NewDepomod simulation results for tide-only flow after 365 days at maximum biomass for Run 2 ("Calibrated").

| | **Run 2** |
|---|---|
| Total mass of solids released (kg $yr^{-1}$) | 1,429,136 |
| Mass of solids within 80th %ile footprint (kg) | 988,084 |
| Area > 78 g/$m^2$ ($m^2$) | 260,625 |

### *4.1.3 TRANSECT AND SAMPLING STATIONS*

In order to set meaningful transect locations, given the highly dispersive nature of this site, as evidenced by the variability in the benthic footprint from the full flow simulations, we use the tide-only simulation from Run 1 in §3.1.2 above. Three transect profiles are proposed (Figure 9) as part of SEPA's requirements to determine site-specific sampling locations. Details of the transect starting points, bearings and proposed sample locations are provided in Table 11 below. The location of the transects are intended to monitor the expected higher deposition areas to the northwest and northeast, and to monitor the seabed to the south of the cages for completeness (although the model and previous compliance surveys do not predict intensive deposition to the south).

The modelled deposition along the three transects is shown in Figure 10. The modelled footprint gives AZE distances of 400 m and 200 m along Transects T1 and T3 respectively (specified as the location at which the 80th percentile of deposition drops below 78 g $m^{-2}$). Predicted deposition is very low along T2 and T4 (Figure 10). These transects provide a comprehensive monitoring strategy designed to ensure that the level of benthic enrichment from this development is detected and can be quantified.

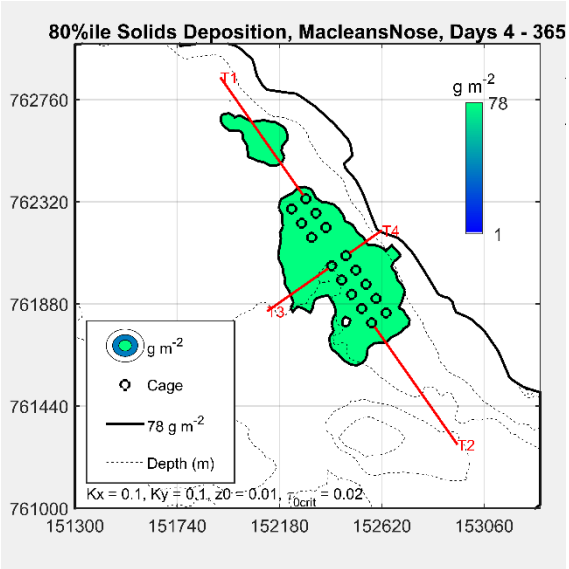


Figure 9. Locations of the proposed monitoring transects.

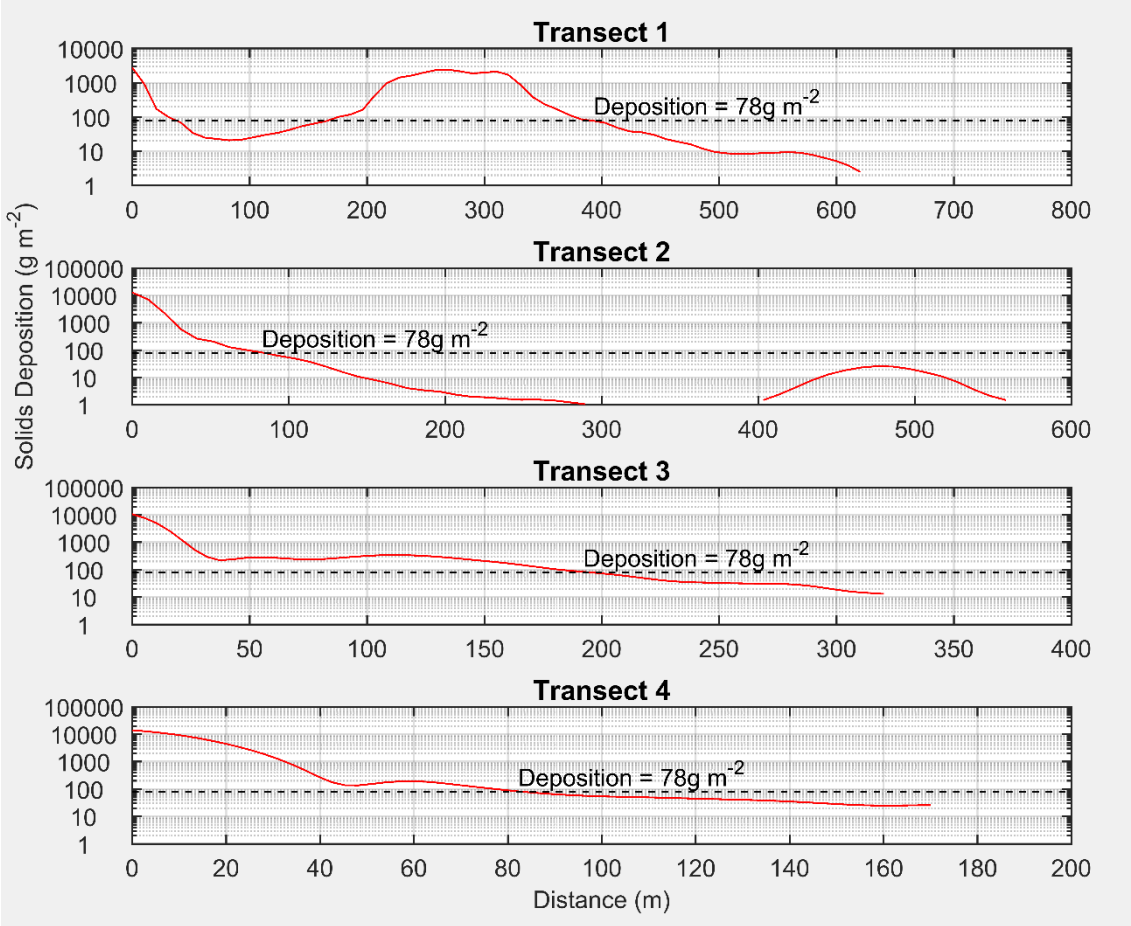


Figure 10. Predicted mean deposition along the proposed transects. The horizontal dashed line indicates deposition of 78 g $m^{-2}$ which corresponds to an IQI of 0.75.

Table 11. Transect and Reference Station Coordinates

| **Transect Start Point Coordinates (Cage Centres)** | | | | |
|---|---|---|---|---|
| | **T1** | **T2** | **T3** | **T4** |
| NGR Easting | 152282 | 152589 | 152389 | 152482 |
| NGR Northing | 762348 | 761782 | 762032 | 762099 |
| Bearing (°N) | 325 | 145 | 235 | 55 |
| **Sample Stations (Easting Northing)** | | | | |
| 0 m | 152282 762348 | 152589 761782 | 152389 762032 | 152482 762099 |
| 25 m | 152268 762369 | 152603 761761 | 152368 762018 | 152503 762113 |
| 50 m | 152254 762389 | 152617 761741 | 152348 762004 | 152523 762127 |
| 100 m | 152225 762430 | 152646 761700 | 152307 761975 | 152564 762156 |
| 200 m | 152168 762512 | 152703 761618 | 152266 761946 | 152646 762213 |
| 400 m | 152053 762676 | 152818 761454 | 152122 761846 | - |
| 600 m | 151938 762840 | 152933 761290 | - | - |

| **Reference Positions** | | |
|---|---|---|
| NGR Easting | 151805 | 152891 |
| NGR Northing | 762702 | 761570 |
| Depth (m) | 32.7 | 33.1 |

## 4.2 IN-FEED TREATMENTS (SLICE)

The SLICE aspect of NewDepomod was run initially for a Total Allowable Quantity sufficient to treat 5.0 times the proposed maximum biomass (*ca.* 5506 g & 3,500 tonnes respectively) i.e. using an Over Treatment Factor (OTF) of 5. Model simulations were then iterated, reducing the OTF until the exported mass and far-field areas did not breach the required limits. The final values of the OTF and mass of EmBZ released that satisfied the EQS requirements are described below.

For the minimum biomass simulations, an over-treatment factor of 1.2 was used, as the maximum allowable under veterinary guidelines for a single treatment.

The treatment was simulated using the flow fields from the hydrodynamic model with and without wind forcing (full flow and tide-only flow respectively). The model was run for 119 days, with concentrations output at 118 days (SEPA, 2018). Export values were taken from the NewDepomod log file after 119 days.

### *4.2.1 FULL MODELLED FLOW*

Results from the full flow simulations are shown in Figure 11 and Figure 12. In the discussion below, summarised in Table 13, we refer to the values for the maximum predicted deposition from **Run 2** (results from Run 1 are presented in Table 12).

Table 12. NewDepomod EmBZ simulation results after 118 days with full flow from Run 1 ("Screening").

| | **Minimum Biomass** | **Maximum Biomass** |
|---|---|---|
| Over-Treatment Factor | 1.2 | 5.0 |
| Biomass of fish (tonnes) | 30 | 3500 |
| Mass of EmBZ released (g) | 11.3 | 5506.2 |
| Mass of EmBZ exported* (g) | 0.0 | 0.0 |

| | | |
|---|---|---|
| Far-Field Area Limit ($m^2$) | 245,552 | 245,552 |
| Area > 0.763 µg $kg^{-1}$ ($m^2$) | 31,875 | 232,500 |
| Area > 7.63 µg $kg^{-1}$ ($m^2$) | 0.0 | 155,000 |
| Peak concentration (µg $kg^{-1}$) | 1.9 | 697.1 |

* The exported mass refers to the end of the simulation at 119 days.

Table 13. NewDepomod EmBZ simulation results after 118 days with full flow from Run 2 ("Calibrated").

| | Minimum Biomass | Maximum Biomass |
|---|---|---|
| OverTreatment Factor applied | 1.2 | 0.7 |
| Biomass of fish (tonnes) | 30 | 3500 |
| Mass of EmBZ released (g) | 11.3 | 770.8 |
| Mass of EmBZ exported* (g) | 0.0 | 0.0 |
| Far-field Area Limit ($m^2$) | 245,552 | 245,552 |
| Area > 0.763 µg $kg^{-1}$ ($m^2$) | 0.0 | 235,000 |
| Area > 7.63 µg $kg^{-1}$ ($m^2$) | 0.0 | 101,875 |
| Peak concentration (µg $kg^{-1}$) | 0.235 | 102.5 |

* The exported mass refers to the end of the simulation at 119 days.

A successful pass was achieved with an Over Treatment Factor of 0.7, with a released mass of emamectin benzoate of 770.8g. The predicted area inside the 0.763 µg/kg contour was smaller than the predicted far-field area limit of 245,552 $m^2$ by 10,552 $m^2$. The mass of emamectin benzoate exported from the model domain after 119 days was zero. After 118 days, the peak concentration of EmBZ in the near-field are did exceed the EQS trigger value of 7.63 µg $kg^{-1}$ by 94.9 µg $kg^{-1}$; thus enhanced monitoring will be required at the site if Slice is used.

A model pass was achieved for a minimum biomass of 30 tonnes, with an over-treatment factor of 1.2 and a released quantity of emamectin benzoate of 11.3 g. No emamectin benzoate concentrations above 0.763 µg $kg^{-1}$ were predicted (Figure 12).

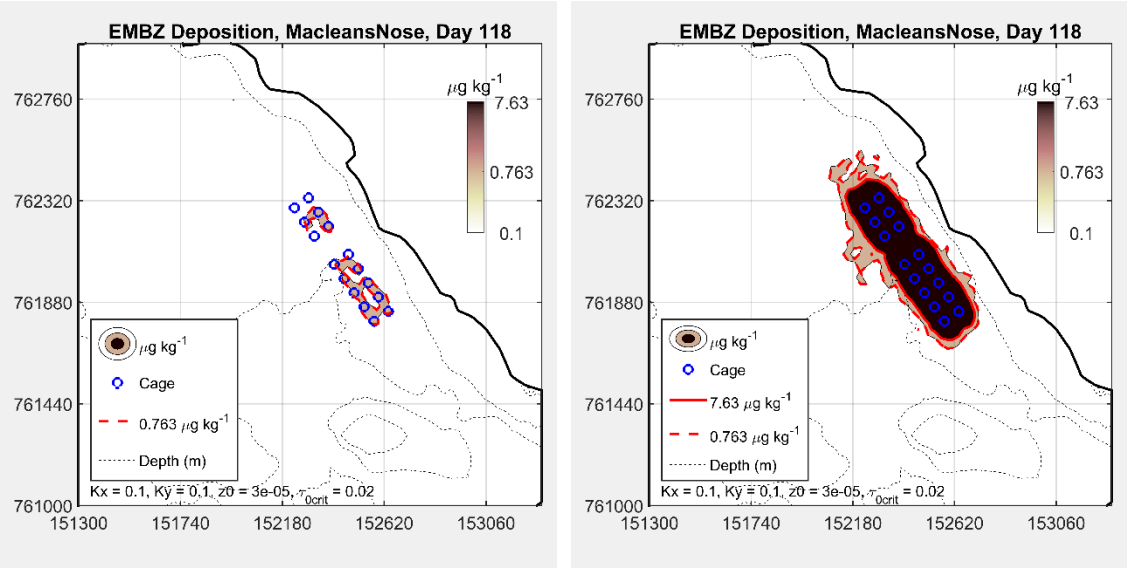


**Figure 11.** Predicted EmBZ concentrations after 118 days with full flow from Run 1 ("Screening") for minimum (left) and maximum (right) treatment biomasses, 30 tonnes and 3500 tonnes respectively.

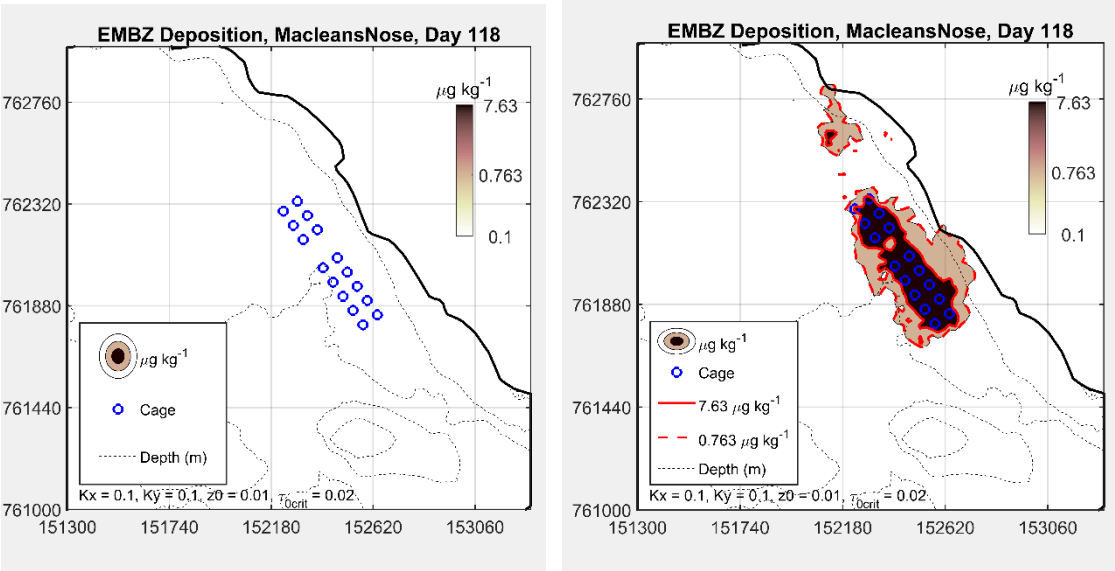


**Figure 12.** Predicted EmBZ concentrations after 118 days with full flow from Run 2 ("Calibrated") for minimum (left) and maximum (right) treatment biomasses, 30 tonnes and 3500 tonnes respectively.

### *4.2.2 TIDE-ONLY MODELLED FLOW*

Results from the tide-only flow simulations are shown in Figure 13 and Figure 14. In the discussion below, summarised in Table 15, we refer to the values for the maximum predicted deposition from Run 2 (results from Run 1 are also presented in Table 14).

A successful pass was achieved with an Over Treatment Factor of 0.9, with a released mass of emamectin benzoate of 971.2 g. The predicted area inside the 0.763 µg/kg contour was smaller than the predicted far-field area limit of 245,552 $m^2$ by 19,927 $m^2$. The mass of emamectin benzoate exported from the model domain after 119 days was zero. After 118 days, the peak concentration of EmBZ in the near-field are did exceed the EQS trigger value of 7.63 µg $kg^{-1}$ by 189.7 µg $kg^{-1}$; thus enhanced monitoring will be required at the site if Slice is used.

A model pass was achieved for a minimum biomass of 30 tonnes, with an over-treatment factor of 1.2 and a released quantity of emamectin benzoate of 11.3 g. Predicted emamectin benzoate concentrations above 0.763 µg $kg^{-1}$ were predicted over a small area of 10,625 $m^2$ (Figure 14).

Table 14. NewDepomod EmBZ simulation results after 118 days with tide-only flow for Run 1 ("Screening").

| | Minimum Biomass | Maximum Biomass |
|---|---|---|
| OverTreatment Factor applied | 1.2 | 5.0 |
| Biomass of fish (tonnes) | 30 | 3500 |
| Mass of EmBZ released (g) | 11.3 | 5506.2 |
| Mass of EmBZ exported* (g) | 0.0 | 0.0 |
| Far-field Area Limit ($m^2$) | 245,552 | 245,552 |
| Area > 0.763 µg $kg^{-1}$ ($m^2$) | 42,500 | 181,250 |
| Area > 7.63 µg $kg^{-1}$ ($m^2$) | 0.0 | 147,500 |
| Peak concentration (µg $kg^{-1}$) | 1.7 | 851.2 |

* The exported mass refers to the end of the simulation at 119 days.

Table 15. NewDepomod EmBZ simulation results after 118 days with tide-only flow for Run 1 ("Calibrated").

| | Minimum Biomass | Maximum Biomass |
|---|---|---|
| Over Treatment Factor applied | 1.2 | 0.9 |
| Biomass of fish (tonnes) | 30 | 3500 |
| Mass of EmBZ released (g) | 11.3 | 971.2 |
| Mass of EmBZ exported* (g) | 0.0 | 0.0 |
| Far-field Area Limit ($m^2$) | 245,552 | 245,552 |
| Area > 0.763 µg $kg^{-1}$ ($m^2$) | 10,625 | 225,625 |
| Area > 7.63 µg $kg^{-1}$ ($m^2$) | 0.0 | 95,625 |
| Peak concentration (µg $kg^{-1}$) | 1.9 | 197.3 |

* The exported mass refers to the end of the simulation at 119 days.

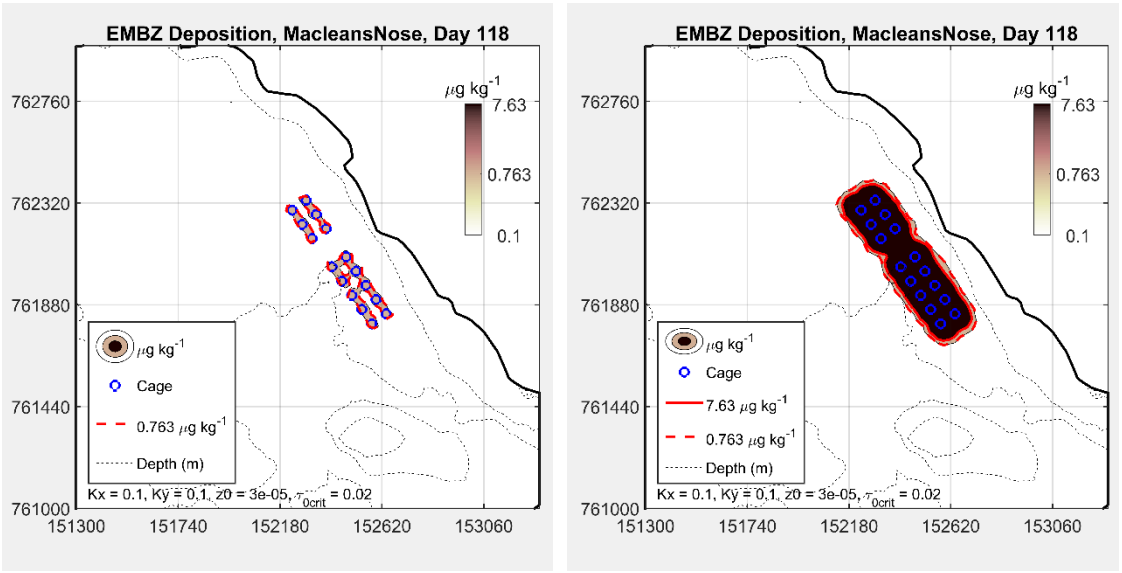


**Figure 13.** Predicted EmBZ concentrations after 118 days with tide-only flow from Run 1 ("Screening") for minimum (left) and maximum (right) treatment biomasses, 30 tonnes and 3500 tonnes respectively.

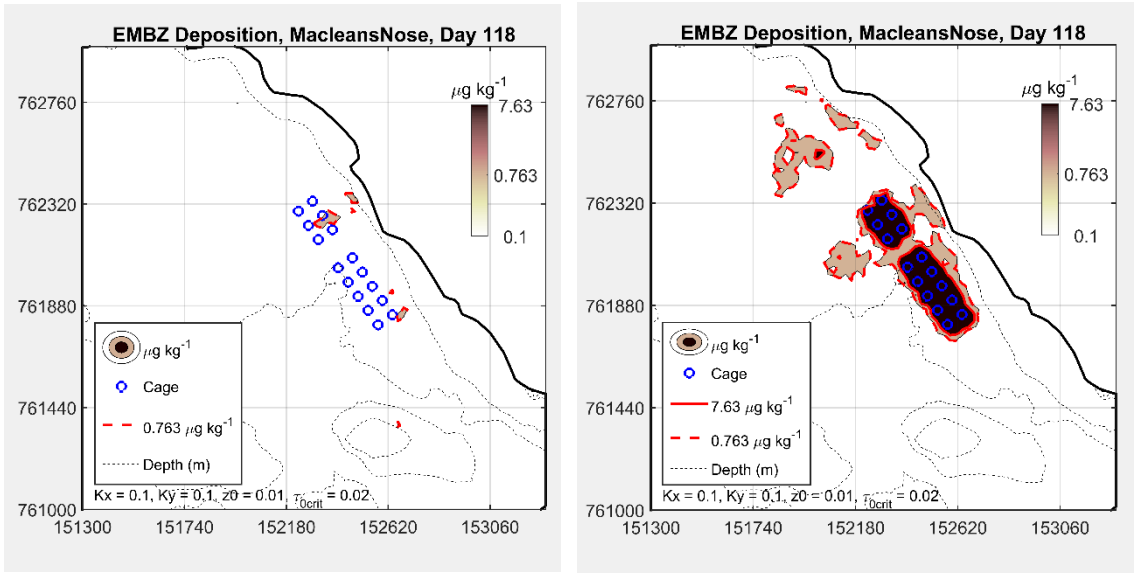

**Figure 14.** Predicted EmBZ concentrations after 118 days with tide-only flow from Run 2 ("Calibrated") for minimum (left) and maximum (right) biomasses, 30 tonnes and 3500 tonnes respectively.

### *4.2.3 SUMMARY*

In-feed modelling results are summarised in **Error! Not a valid bookmark self-reference.**. Given that Run 2 is believed to best represent the dispersion of emamectin benzoate at Macleans Nose, and that the full-flow simulations are appropriate for the location, which has significant wind and wave action, a consent mass of 771 g of emamectin benzoate is proposed as appropriate.

Table 16. Summary of emamectin benzoate masses used in the modelling for the maximum biomass that achieved a pass.

| | Run 1: SEPA Defaults | | Run 2: Site-specific | |
|---|---|---|---|---|
| | **Mass EmBZ (g)** | **Factor** | **Mass EmBZ (g)** | **Factor** |
| Full Flow | 5506 | 5.0 | 771 | 0.7 |
| Tide Only | 5506 | 5.0 | 992 | 0.9 |

### *4.2.4 TRANSECT AND MONITORING STATIONS*

The proposed transects for Slice (Table 17) match those of the benthic monitoring transects (Table 11). Three sample locations are proposed for each transect. The two primary transects are to the northeast and northwest, with a secondary transect to the south, where predicted EmBZ concentrations are low.

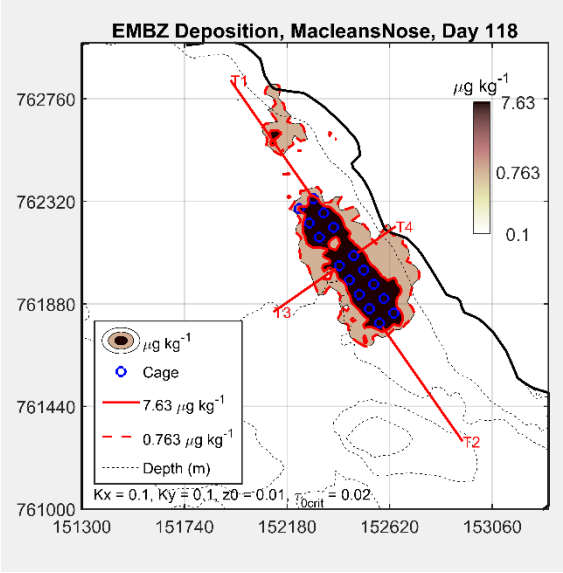


**Figure 15.** Locations of the proposed Slice monitoring transects, superimposed on the maximum modelled concentrations from Run 2 with full flow.

**Table 17.** Slice Transect and Reference Station Coordinates

| **Transect Start Point Coordinates (Cage Centres)** | | | | |
|---|---|---|---|---|
| | **T1** | **T2** | **T3** | **T4** |
| NGR Easting | 152282 | 152589 | 152389 | 152482 |
| NGR Northing | 762348 | 761782 | 762032 | 762099 |
| Bearing (°N) | 325 | 145 | 235 | 55 |
| **Sample Stations (Easting Northing)** | | | | |
| 0 m | 152282 762348 | 152589 761782 | 152389 762032 | 152482 762099 |
| 50 m | 152254 762389 | 152617 761741 | 152348 762004 | 152523 762127 |
| 100 m | 152225 762430 | 152646 761700 | 152307 761975 | 152564 762156 |

| **Reference Positions** | | |
|---|---|---|
| NGR Easting | 151805 | 152891 |
| NGR Northing | 762702 | 761570 |
| Depth (m) | 32.7 | 33.1 |

## 4.3 BATH MODEL RESULTS

Cage details are given in Section 2. The cage treatment depth used for the bath treatments was 1.4 m. Using the results from the analysis of the surface current meter data in the short-term bath treatment model EQS compliance for both Deltamethrin and Cypermethrin at this cage depth was predicted. EQS compliance for Azamethiphos was predicted at a cage depth of 1.4 m.

**Cypermethrin & Deltamethrin Results**:
Cage Treatment Depth = 1.4
Permissible Quantity of Cypermethrin = 46.8 g; 5.8 cages/3 hours
Permissible Quantity of Deltamethrin = 17.5 g; 5.5 cages/3 hours

**Azamethiphos Results:**
Cage treatment depth = 1.4m
Permissible Quantity of Azamethiphos = 258.4 g; 1.6 cages/3 hours
Permissible Quantity of Azamethiphos = 641.8 g; 4.0 cages/24 hours

The permissible quantities mean that full treatment of the 16 pens at the site, would take approximately 2 to 4 days to complete.

The bath treatment model files are saved in the folder Macleans Nose2018vF1*Bath*

## 4.4 CUMULATIVE EFFECTS

Because the modelled export of emamectin benzoate from the NewDepomod model domain was zero for all simulations, and solids export was less than 5%, modelling of the cumulative effects in the northern Sound of Mull and Loch Sunart region has not be undertaken.

# 5 RESULTS AND CONCLUSIONS

The biomass and treatment amounts requested for consent at this site are given below (Table 18).

**Table 18.** Modelling Results Summarised

| | | | |
|---|---|---|---|
| **SITE DETAILS** | | | |
| Site Name: | | Macleans Nose | |
| Site location: | | Macleans Nose, Sound of Mull | |
| Peak biomass (T): | | 3,500 | |
| **CAGE DETAILS** | | | |
| Number of cages: | | 16 | |
| Cage dimensions: | | 120m Circumference | |
| Working Depth (m): | | 16 | |
| Cage group configuration: | | 2x3 & 2x5, 75m matrix | |
| **HYDROGRAPHIC SUMMARY** | | | |
| | | **North** | **South** |
| Surface Currents | Average Speed (m/s) | 0.058 | 0.066 |
| | Residual Direction (°G) | 308 | 320 |
| | Wind-Influence | Moderate | Moderate |
| Middle Currents | Average Speed (m/s) | 0.043 | 0.052 |
| | Residual Direction (°G) | 293 | 323 |
| Seabed Currents | Average Speed (m/s) | 0.046 | 0.050 |
| | Residual Direction (°G) | 261 | 200 |
| **BENTHIC MODELLING** | | | |
| Max fish biomass proposed (T) | | 3,500t | |
| Max Average Stocking Density (kg/m³) | | 11.93 | |
| Direction of transects (˚G) | | 325, 145, 235, 55 | |
| **IN-FEED TREATMENTS** | | | |
| Recommended consent mass EmBZ (g) | | 771 | |
| Equivalent Fish Biomass (T) | | 2450 | |
| Maximum Treatment Amount EmBZ (g) | | 771 | |
| **BATH TREATMENTS** | | | |
| Recommended consent mass in 3hrs Azamethiphos (g) | | 258.4 | |
| Recommended consent mass in 24 hrs Azamethiphos (g) | | 641.8 | |
| Recommended consent mass in 3 hrs Cypermethrin (g) | | 46.8 | |
| Recommended consent mass in 3 hrs Deltamethrin (g) | | 17.5 | |

## REFERENCES

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