
# NewDepomod Modelling Report Chalmers Hope

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# 1. Summary

Cooke Aquaculture Scotland Ltd. (CAS) has undertaken biomass and in-feed chemotherapeutant modelling for the proposed Chalmers Hope site. The pen layout uses 12, 120m circular pens, moored within 70m grids. The site was modelled using NewDepomod to determine the maximum biomass and in-feed chemical treatments. A summary of these values is shown in Table 1. Transects quantifying benthic footprints are presented, where predominant deposition occurs along transect 1 (T1) on a bearing of 315°G. The benthic impact shows very small accumulations under the northwest pens, with no further impact, this complies with all benthic EQS. In-feed chemical modelling complies with environmental standards when using 250 g of Emamectin Benzoate. Due to the close location of the existing site, the new impacted benthic area was quantified. This identified 14.7% new area of impact. This permits a treatable biomass of 714.3 tonnes, when using Emamectin Benzoate.

**Table 1. Summary of the recommended consent limits for the Chalmers Hope site.**

| | | | |
|---|---|---|---|
| Maximum Biomass | 2,500t | Stocking density | 15.15 kg/$m^3$ |
| | **Biomass modelling** | | |
| 100m Mixing Zone Area ($m^2$) | 167,628 | | |
| Impact area ($m^2$) | 10,625 | | |
| Percentage of 100m mixing zone (%) | 6.34 | | |
| Cage edge threshold (g $m^2$ $yr^{-1}$) | 262.1 | | |
| | **In-Feed Treatments** | | |
| | **Emamectin Benzoate** | | |
| Chemical Quantity (g) | 250 | | |
| 100m Mixing Zone Area ($m^2$) | 167,628 | | |
| Predicted Impact area ($m^2$) | 6,678,125 | | |
| Percentage of 100m mixing zone (%) | 3984 | | |
| New Area of impact ($m^2$) | 1,021,651 | | |
| Percentage of new area impact (%) | 14.7 | | |

# 2. Introduction

## Site Details

Chalmers Hope is an existing, consented site (CAR/L/1003062/V6) operated by CAS with a maximum consented biomass of 1000 tons. The site is situated towards the western entrance to Scapa Flow, on the north-east coastline of Hoy, Orkney (Figure 1).

The proposed development replaces all existing infrastructure and repositions the site 250m to the NNE (328735 E, 1001311 N). A pen circumference of 120m, with 12m net depths, and 70m mooring grids are proposed. This provides a stocking density of 15.15kg/$m^3$ during peak biomass. Further information on the existing and proposed site infrastructure and pen layout is presented in Table 2.

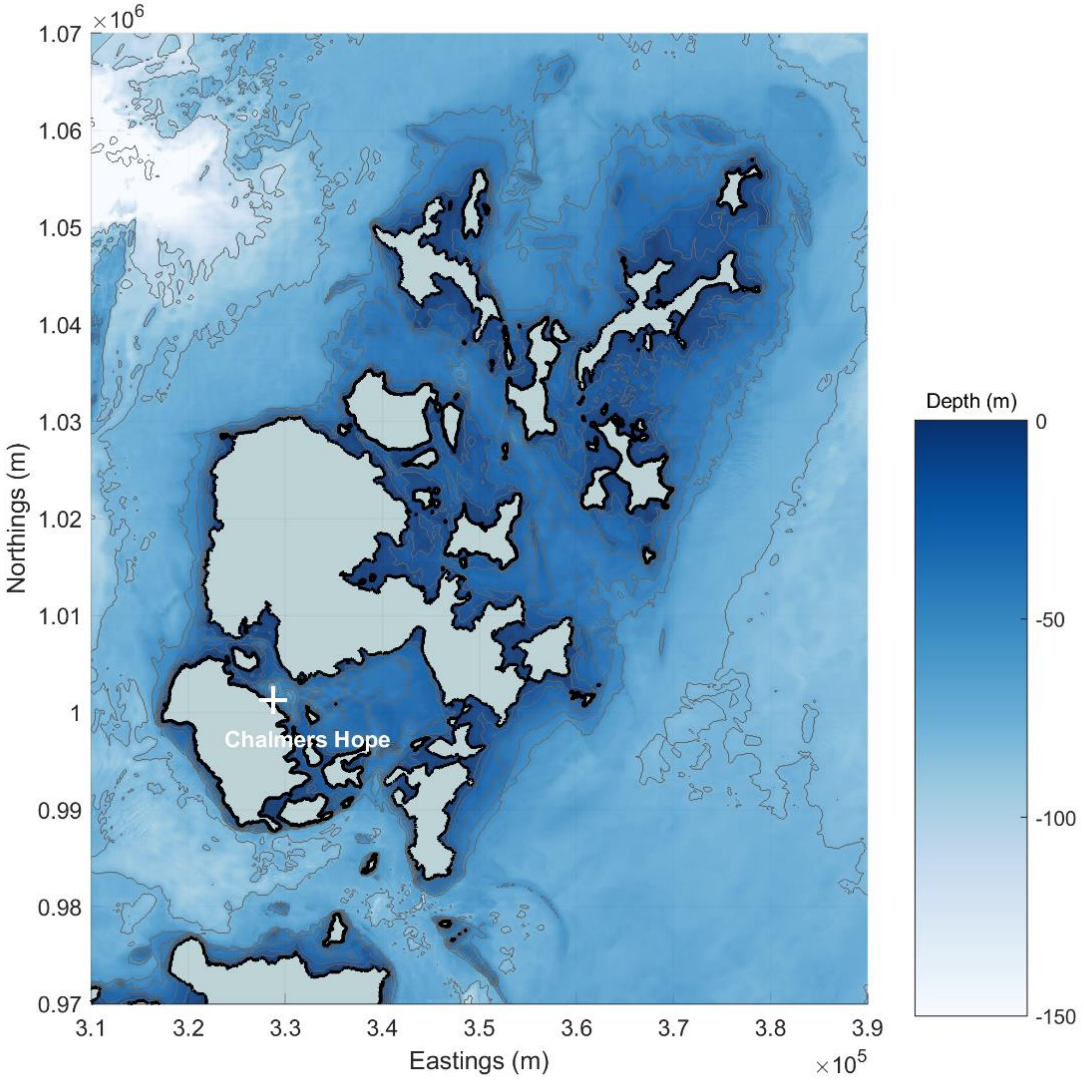


**Figure 1. Site location and bathymetry with depth contours at 10 m intervals.**

**Table 2. Site Infrastructure and pen layout**

| Site name | Chalmers Hope (Existing) | Chalmers Hope (Proposed) |
|---|---|---|
| Consent number | CAR/L/1003062/V6 | N/A |
| Company | Cooke Aquaculture Scotland | Cooke Aquaculture Scotland |
| Receiving water | Scapa Flow | Scapa Flow |
| Site centre - (OSGB36) | 328607 E, 1001109 N | 328735.3 E, 1001310.7 N |
| Current meter location – OSGB36 (year of deployment) | 328750 E, 1001162 N (2003) | 328663.5 E, 1001218.7 N (2016)<br>328688 E, 1001269 N (2018) |
| Distance to shore (Km) | 0.18 | 0.41 |
| Average water depth (m) | 20.9 | 32.9 |
| Total number of pens | 12 | 12 |
| Number of pen groups | 1 | 1 |
| Formation | 2 x 6 | 2 x 6 |
| Pen group orientation (°) | 320 | 315.2 |
| Pen circumference (m) | 90 | 120 |

# 3. NewDepomod modelling methods

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

## 3.1 Benthic – SEPA default model

As the proposed Chalmers Hope site is moving to a new location, no benthic data is available, in this case the SEPA default model is applied. The benthic SEPA default model is used to determine maximum biomass based on Environmental Quality Standards (EQS). These methods and NewDepomod particle dispersion parameters (see Table 5) are outlined in (SEPA 2019a) and (SEPA 2019b).

Peak biomass is simulated for the entire model duration, this is equal to 365 days for the benthic model. This value is used to calculate the feed waste and faecal matter using the following values, see Table 3.

**Table 3. Input feed parameters**

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

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

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

Waste carbon ($w_c$) is calculated as

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

Excreted solids ($e_s$) are calculated as

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

Excreted carbon ($e_c$) is calculated as

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

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

**Table 4. SEPA default model parameters.**

| Parameter | Value |
|---|---|
| TauEcritmin | 0.02 |
| Expansion T50 | 1 |
| Particle release height | 0 |
| Bed roughness | 0.001273 |
| Resuspension dispersion coefficient z | $0.0003\bar{u}^{-0.762}$ |
| Resuspension dispersion coefficient xy | 0.1 |
| Suspension dispersion coefficient z | 0.001 |
| Suspension dispersion coefficient xy | 0.1 |

| | |
|---|---|
| dLayer mass | 3375 |
| Particles per area | 0.0016 |
| Density of mud | 1400 |

### 3.1.1 Benthic EQS

The default model uses the outputs as a risk assessment tool for the benthic environment. The EQS values and descriptions are provided in Table 5. Benthic impact is determined using Infaunal Quality Index (IQI), where a relationship between sediment flux and IQI is used as a proxy for environmental impact. This states that a solid flux of 250g/$m^2$ is equivalent to an IQI of 0.64. Therefore, any deposition above the 250g/$m^2$ is defined as having a significant impact on the seabed. The 100m composite mixing zone is defined as the pen area plus an additional 100m buffer zone. An additional intensity standard is applied that restricts the mean concentration of the impacted area, where the permitted average is based on the sites wave exposure.

**Table 5. Benthic EQS parameters**

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

## 3.2 In-feed treatments – SEPA default model

In-feed chemical compliance determines the maximum quantity of Emamectin Benzoate to be used on site. The methods and NewDepomod particle dispersion parameters used for the SEPA default chemical model are outlined in (SEPA 2019a) and (SEPA 2019b). Model settings are identical to the benthic model. Input feed parameters are defined in Table 3, and dispersion parameters are defined in Table 4. For the treatment of Emamectin Benzoate, simulation duration is reduced to 223 days, where the EQS is recorded at 118 days. This is based on the average chemical concentration from the 48 hrs leading up to the 118$^{th}$ day, sampled at a 3hr interval.

### 3.2.1 Emamectin Benzoate EQS

In-feed chemical EQS values are defined using the most recent guidelines from the UK Technical Advisory Group (2019). These values and descriptions are shown in Table 6. This

uses the 100m mixing zone principle, with a chemical contour value of 23.5 ng/kg of dry sediment. This is equivalent to 0.01175 µg/kg of wet sediment.

**Table 6. In-feed chemical EQS parameters**

| **In-Feed (Emamectin Benzoate)** | | |
|---|---|---|
| Mixing zone | Area | Total area which exceeds the pertinent EQS (0.01175 µg/kg) should not exceed the 100 m mixing zone area. |

For existing farms, the previous consented chemical quantity can be used providing very limited impact to new seabed areas. This is quantified using a comparison between the existing and proposed site, where any new area of EmBZ impact area must be below 15% of the existing impact area using the current EQS value (0.01175 µg/kg). If the new area of impact exceeds 15%, then the proposed changes will fail, and the chemical quantity should be reduced until this area is below the maximum new area percentage.

# 3. Input data

### Hydrographic Data and Marine Modelling

Hydrographic data was collected from 18/09/2016 to 03/12/2016 and from 04/07/2018 to 18/07/2018, these datasets were merged to form a single 90-day dataset in order to comply with guidance stated in SEPA (2019a). In order to minimize simulation error from instabilities, the datasets were merged accounting for high and low waters as well as spring and neap cycles. This used 76.1 days from the 2016 deployment and 13.9 days from the 2018 deployment. Three depth cells are provided, this represents flow characteristics from the near surface, pen bottom and near bed layers. This has weighted depth cell values for the surface, pen bottom and near bed cells of 27.7m, 22.7m and 2.7m, with a mean weighted depth of 34.16m. Flow directional data has been corrected to Grid North using a reference deviation of 04° 14’ W in 2005 with an annual rate of change of 12”. The hydrographic inputs are shown in Table 7 below:

**Table 7. Hydrographic input information.**

| | **Near Surface (27.7m, cell 25)** | **Cage Bottom (22.7m, cell 20)** | **Near Bed (2.7m, cell 0)** |
|---|---|---|---|
| Mean Speed (m/s) | 0.133 | 0.138 | 0.122 |
| Ranked Percentage at 0.03 m/s (%) | 6.47 | 5.22 | 5.93 |
| Ranked Percentage at 0.045 m/s (%) | 12.58 | 10.90 | 11.85 |
| Ranked Percentage at 0.095 m/s (%) | 38.04 | 34.32 | 40.79 |
| Maximum Speed (m/s) | 0.46 | 0.49 | 0.43 |

| | | | |
|---|---|---|---|
| Residual Speed (m/s) | 0.014 | 0.016 | 0.022 |
| Residual direction (degrees) | 187.2 | 238.5 | 325.8 |

Current velocities near the seabed of the 90-day joint dataset record a residual speed of 0.022 m/s, with a mean bed speed of 0.122 m/s. This provides a residual flow speed of 18% of the mean bed speed. As this is below the 35% threshold stated in SEPA's modelling guidance, no adjustments to the hydrographic data are required.

The vertical (z) resuspension dispersion coefficient used in the default model is calculated based on the mean bed velocity ($\bar{u}_z$). For the joint dataset, this equates to a value of 0.00149.

For the SEPA default model, a uniform bathymetry is applied based on the weighted depth of the joint dataset. This produces a uniform depth value of -34.16m. The model domain is shown in Figure 2. A regular structured grid with a 25m resolution is used to represent bathymetry and coastlines. Coastline data is taken form the ordinance survey (Ordnance Survey, 2021).

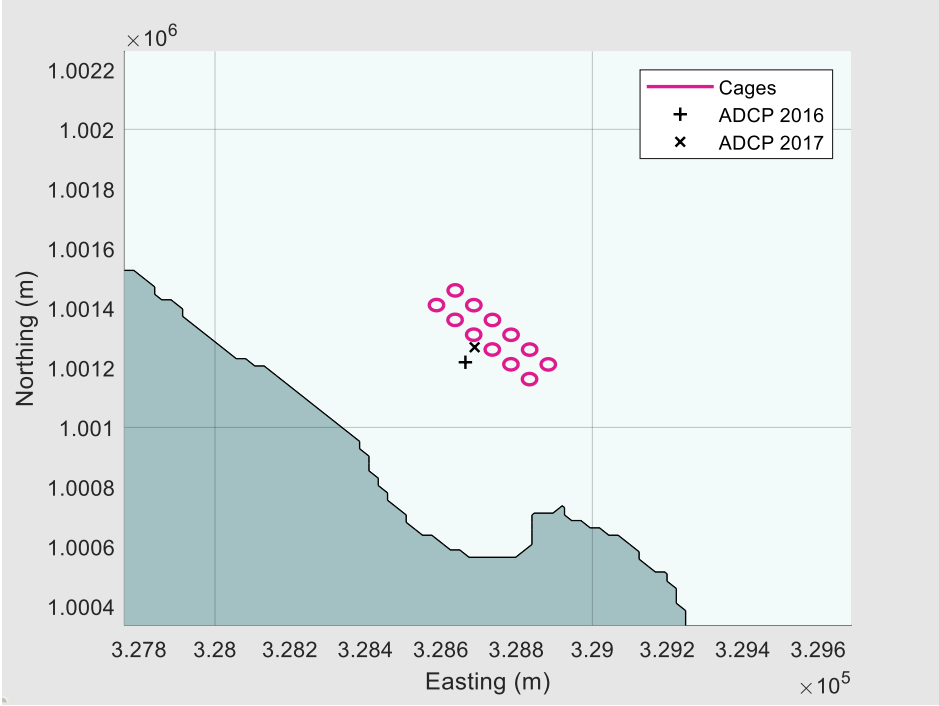


**Figure 2. NewDepomod model domain. Pen layout and ADCP deployment location are shown within the domain.**

# 4. Results

## 4.1 Benthic - Maximum biomass

The SEPA default model was run to indicate the maximum biomass at the site. Compliance was achieved with a biomass of 2500 t, providing a stocking density of 15.15 kg/m$^3$. The

average spatial coverage of the deposited solids is shown in Figure 3. This suggests the majority of sediment flux accumulates towards the north-western pens. However, concentrations of deposited solids in this area remain low. Flux values exceeding 250 g/$m^2$ are only observed directly under 4 pens. This equates to an exceptionally small area, equivalent to 6.3% of the 100m mixing zone. The cage edge EQS experiences a mean deposited flux value of 262.1 g/$m^2$. This is a fraction of the cage edge threshold for a site with low wave exposure (< 2000 g/$m^2$). Using the SEPA default model parameters and EQS values, the proposed site passes all benthic stipulated standards.

**Table 8. EQS results from the benthic SEPA default model.**

| Model type | Default settings |
|---|---|
| Residual currents | Included |
| Project name | ChalmersHope002_1 |
| Biomass (tonnes) | 2,500 |
| Stocking density (kg/$m^3$) | 15.15 |
| 100m mixing zone ($m^2$) | 167,628 |
| Predicted impact area ($m^2$) | 10,625 |
| Area of 100m mixing (%) | 6.34 |
| Mean deposited mass (g $m^{-2}$ $yr^{-1}$) | 262.1 |

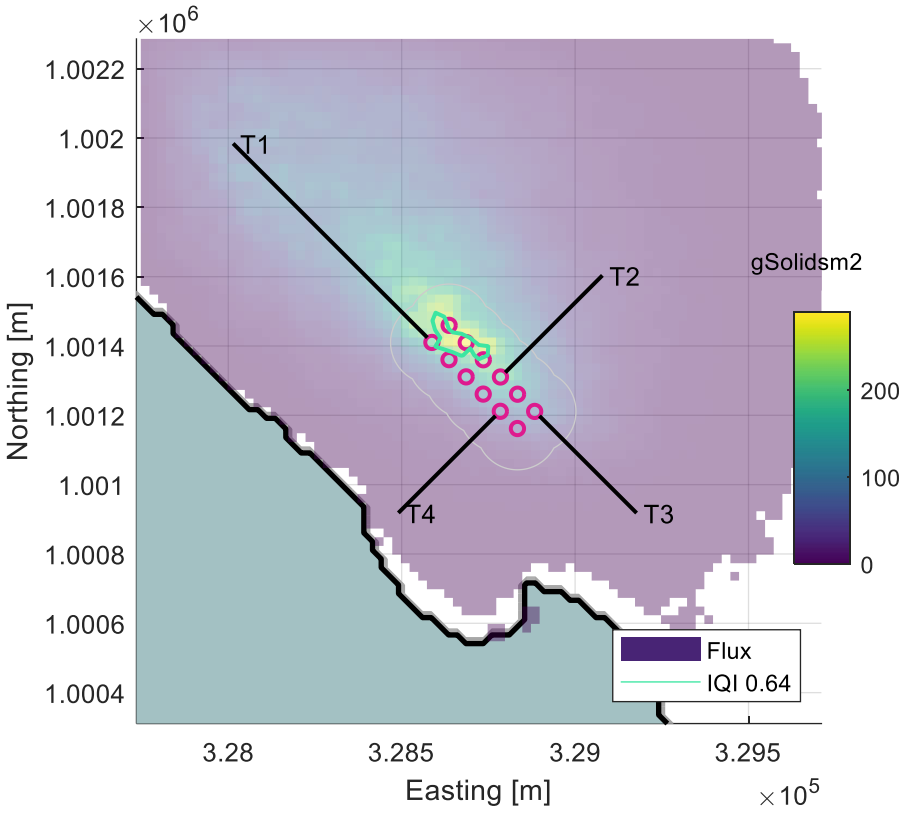


**Figure 3. Solid flux distribution around the farm for the Default model, (inc. residual currents) with a biomass = 2,500t. Transects locations 1-4 are also shown.**

Four transects are taken from the pen edges and extended well beyond the impact area. The location of these are shown in Figure 3 with individual transect results plotted in Figure 4. Transect information is displayed in Table 9. The flux distribution results show a very small impact to the surrounding area. Transect 1 shows the highest flux values, however no flux values exceed 250 g/m$^2$. As distance from the cage edge increases, flux values are shown to reduce. All other transects record flux values well below 250 g/m$^2$, indicating no significant benthic impact out with the pen area.

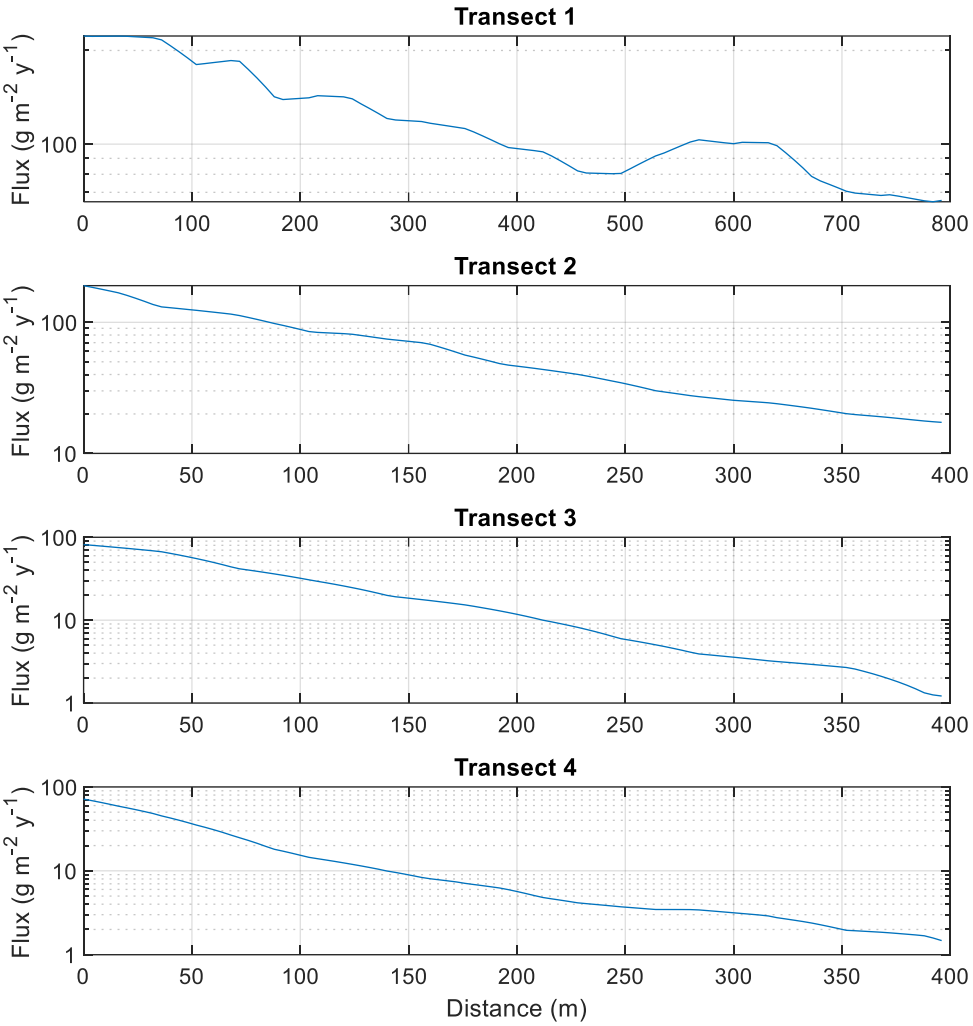


**Figure 4. Transects (T1-T4) of organic solids with distance from cage edge.**

**Table 9. Transect information**

| | Origin | | Length (m) | Bearing (°) | Distance of IQI 0.64 (m) |
|---|---|---|---|---|---|
| | East | North | | | |
| Transect 1 (T1) | 328574 | 1001424 | 792 | 315 | - |
| Transect 2 (T2) | 328799 | 1001324 | 396 | 45 | - |
| Transect 3 (T3) | 328897 | 1001198 | 396 | 135 | - |
| Transect 4 (T4) | 328770 | 1001198 | 396 | 225 | - |

## 4.2 NewDepomod - In-feed treatment (SLICE)

In-feed treatments are used to control sea lice numbers in salmon farms. Slice™, (active ingredient Emamectin Benzoate EmBZ), is applied as a coating to the daily feed quota. To reduce adverse environmental effects from chemotherapeutants, the in-feed chemical default model is applied. Peak biomass was modelled using a biomass of 2,500 t.

As Chalmers Hope is an existing site with a licensed chemical quantity of 350 g, a comparison between the existing and proposed impact area is used to determine a compliant chemical quantity. Due to the dispersive currents at the site and the low chemical EQS, the default model boundary was expanded from 2km$^2$ to 7km$^2$.

Compliance with in-feed chemical EQS parameters was achieved with 250 g of EmBZ. The chemical distribution is shown in Figures 5 and 6, with EQS performance values shown in Table 10. This indicates a new area of impact of 14.7% with a proposed impact area of 3,984% of the 100m mixing zone.

**Table 10. EQS results from the EmBZ SEPA default model.**

| | Existing | Proposed |
|---|---|---|
| Model type | Default model - residual currents inc. | Default model - residual currents inc. |
| Project name | ChalmersHope_Existing003_1 | ChalmersHope012_1 |
| Biomass (tonnes) | 1,000 | 2,500 |
| Stocking density (kg/m$^3$) | 12.93 | 15.15 |
| Chemical quantity (g) | 350 | 250 |
| Domain size (km$^2$) | 7 | 7 |
| 100m mixing zone (m$^2$) | 121,591 | 167,628 |
| Predicted impact area (m$^2$) | 7,055,625 | 6,678,125 |
| Area of 100m mixing (%) | 5,802 | 3,984 |
| New Impact Area (m$^2$) | - | 1,021,651 |
| Percentage of new area impact (%) | - | 14.69 |

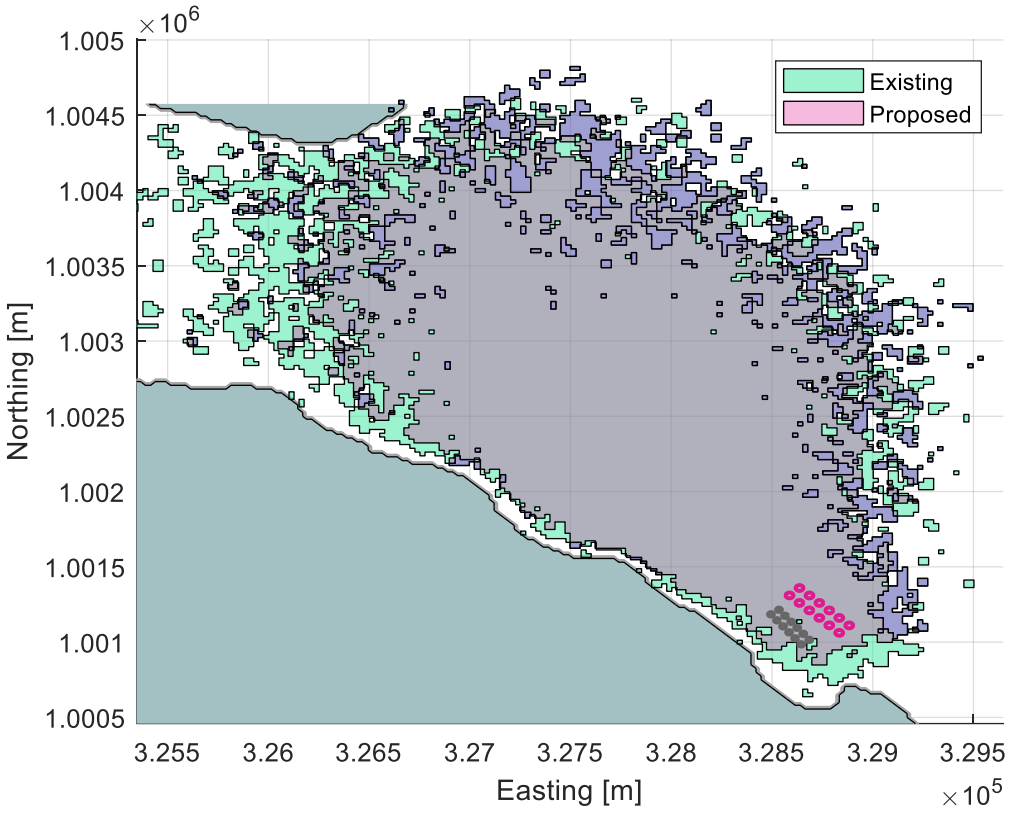


**Figure 5. EmBz footprint and new area of impact for the existing and proposed site using EQS of 0.01175 µg/kg.**

### 4.2.2 Footprint and Transects

The chemical footprint of the compliant proposed model is shown in Figure 6, where transects of the footprint are shown in Figure 7 and Table 11. This indicates large dispersion towards the north-west, where a peak accumulation occurs 950 m from the pen edge on Transect 1. This falls below the EQS value 3,759 m from the pen edge. All other transects show a continual and rapid reduction as distance increases from the pen edge.

**Table 11. EmBZ transect information**

| | Origin | | Length (m) | Bearing (°) | Distance to EQS 0.01175 µg/kg (m) |
|---|---|---|---|---|---|
| | East | North | | | |
| Transect 1 (T1) | 328574 | 1001424 | 3762 | 315 | 3318.9 |
| Transect 2 (T2) | 328799 | 1001324 | 594 | 45 | 252.4 |
| Transect 3 (T3) | 328897 | 1001198 | 990 | 135 | 272.8 |
| Transect 4 (T4) | 328770 | 1001198 | 396 | 225 | 352.3 |

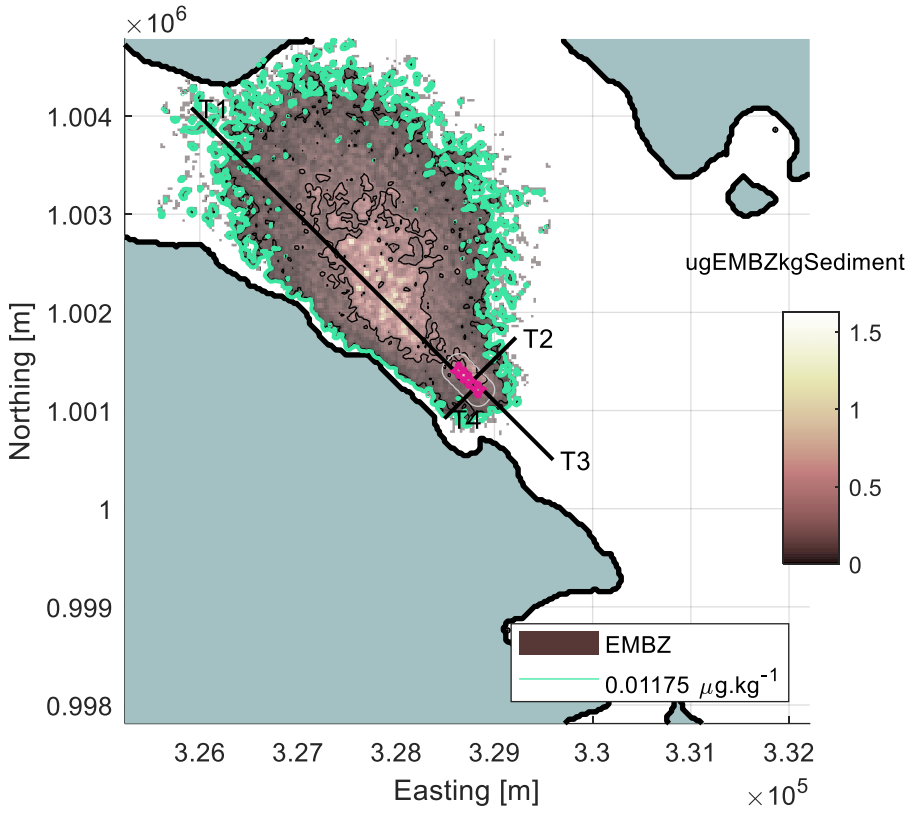


**Figure 6. EmBz impact area for the proposed site using EQS of 0.01175 µg/kg**

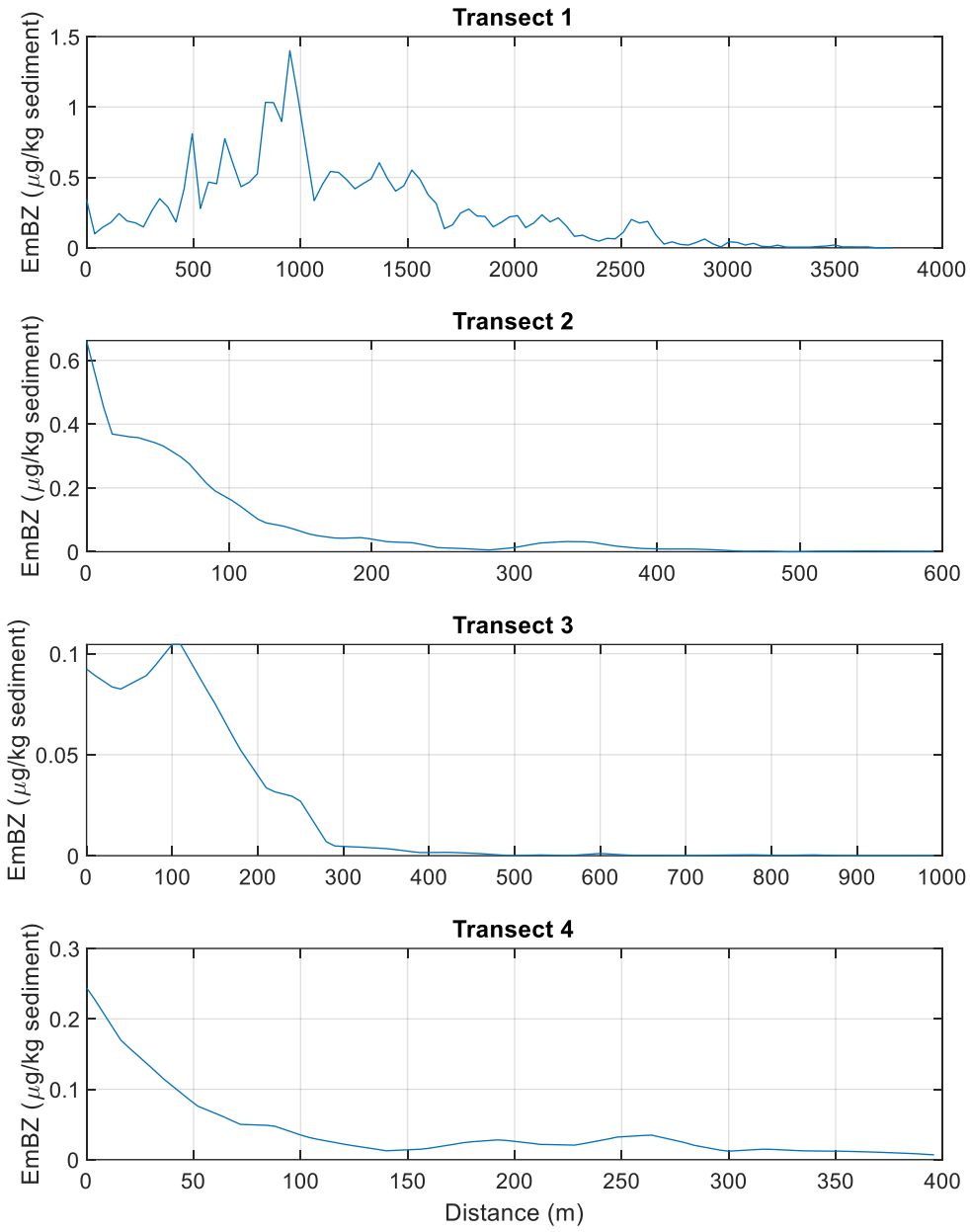


**Figure 7. Transects (T1-T4) of chemical (EmBZ) concentration with distance from pen edge.**

### 4.2.4 Treatable biomass

The compliant treatable chemical mass is used to determine the maximum treatable biomass. The total amount of Slice required is calculated using the chemical quantity multiplied by 0.5. Treatable biomass is calculated by dividing the chemical quantity by 0.35. This provides a treatable biomass of 714.3 T, requiring 125 Kg of SLICE.

# 5. Conclusion

The benthic modelling highlights the dispersive nature of the proposed Chalmers Hope site. The results of the SEPA default model show large particle dispersion leading to very small accumulations directly beneath the north-western pens. This passes all EQS requirements with a maximum biomass of 2,500 T, resulting in the predicted impact area of only 6.3% of the 100m mixing area.

In-feed chemical modelling provides a total allowable quantity of 250 g of EmBZ. The majority of the chemical deposition is distributed to the north-west of the farm, where the proposed farm results in 14.7% new area impacted, and a net reduction in the overall impact area.

The results from the benthic and chemical modelling suggest the proposed Chalmers Hope site will improve general environmental performance when compared to the existing development. In-feed chemical modelling suggests a reduction in permitted chemical quantity. If infection occurs when stocking is above the maximum EmBZ treatable biomass, then alternative treatment options are required, this may include bath, Hydrolicer or Thermolicer treatments.

# 6. References

Ordnance Survey (2021) “Boundary-Line” Available at https://osdatahub.os.uk/downloads/open (Accessed 04/05/2021)

Scottish Environment Protection Agency (SEPA) (2019a) “Regulatory Modelling Guidance for the Aquaculture Sector” Version 1.1. Available at https://www.sepa.org.uk/media/450279/regulatory-modelling-guidance-for-the-aquaculture-sector.pdf. (Accessed on 11/12/19).

Scottish Environment Protection Agency (SEPA) (2019b) “Regulatory Modelling Process and Reporting Guidance for the Aquaculture Sector”. Version 1.1. Available at https://www.sepa.org.uk/media/450278/regulatory-modelling-process-and-reporting-guidance-for-the-aquaculture-sector.pdf. (Accessed on 11/12/19).

UK Technical Advisory Group (2019) “UKTAG Standards Consultation May 2019” Available at: https://www.wfduk.org/stakeholders/uktag-standards-consultation-may-2019 (Accessed 19/02/2020)