Trilleachan Mor, Loch Seaforth

Bath Medicine Dispersion Modelling Report

CAR/L/1013016

February 2025

	OFFICE	PHONE	FAX
› Mowi Scotland	Mowi, Farms Office, Glen Nevis Business Park PH33 6RX Fort William	+441397715021	-
		MAIL environment@mowi.com	
	POSTAL Mowi, Farms Office, Glen Nevis Business Park PH33 6RX Fort William	WEB http://mowiscotland.co.uk	

CONTENTS

List of Figures

List of Tables

QUALITY ASSURANCE

Mowi Scotland Ltd is ISO9001 and ISO14001 accredited and all project management follows policies designed to ensure that the collection, collation and reporting of information produced in the course of our operations is done to a consistently high standard meeting the requirements of the end user.

EXECUTIVE SUMMARY

Dispersion model simulations have been performed to assess whether bath treatments, specifically those using the active ingredient azamethiphos, at **Trilleachan Mor** salmon farm in Loch Seaforth will comply with pertinent environmental quality standards. Realistic treatment regimes, with one pen treatment a day for five days were simulated. Each pen required 1.018 kg of azamethiphos (the active ingredient in Salmosan, Salmosan Vet and Azure) for treatment, resulting in a daily release of 1.018 kg and a total discharge over 5 days of 5.093 kg. Simulations were performed separately for neap and spring tides, and the sensitivity of the results to key model parameters was tested.

The model results (Table 1) confirmed that the treatment scenario proposed, with a daily release of no more than 1.018 kg, should comfortably comply with the EQS. The peak concentration during the baseline simulation after 168 hours (72 hours after the final treatment) was less than 0.1 μg/L, the maximum allowable concentration, and the area where concentrations exceeded the EQS of 0.04 μg/L was substantially less than the allowable 0.5 km^2. The baseline simulation presented here was designed to be relatively conservative.

Table 1. Summary of Results

Site details	
Site Name:	Trilleachan Mor
Site Location:	Loch Seaforth
Peak Biomass (T):	2,130
Pen details	
Number of Pens:	5
Pen Circumference (m):	160
Working Depth (m):	20.0
Pen Group Configuration:	2 x 2 + 1
Azamethiphos consent to be applied for	
Recommended 3-hour (kg):	1.018
Recommended 24-hour (kg):	1.018

1 INTRODUCTION

This report has been prepared by Mowi Scotland Ltd. to meet the requirements of the Scottish Environment Protection Agency (SEPA) for an application to use topical sealice veterinary medicines at the **Trilleachan Mor** marine salmon farm in **Loch Seaforth** (Figure 1). The report presents results from coupled hydrodynamic and particle tracking modelling to describe the dispersion of bath treatments to determine EQS-compliant quantities for the current site biomass and equipment. The modelling procedure follows as far as possible guidance presented by SEPA in December 2023 (SEPA, 2023).

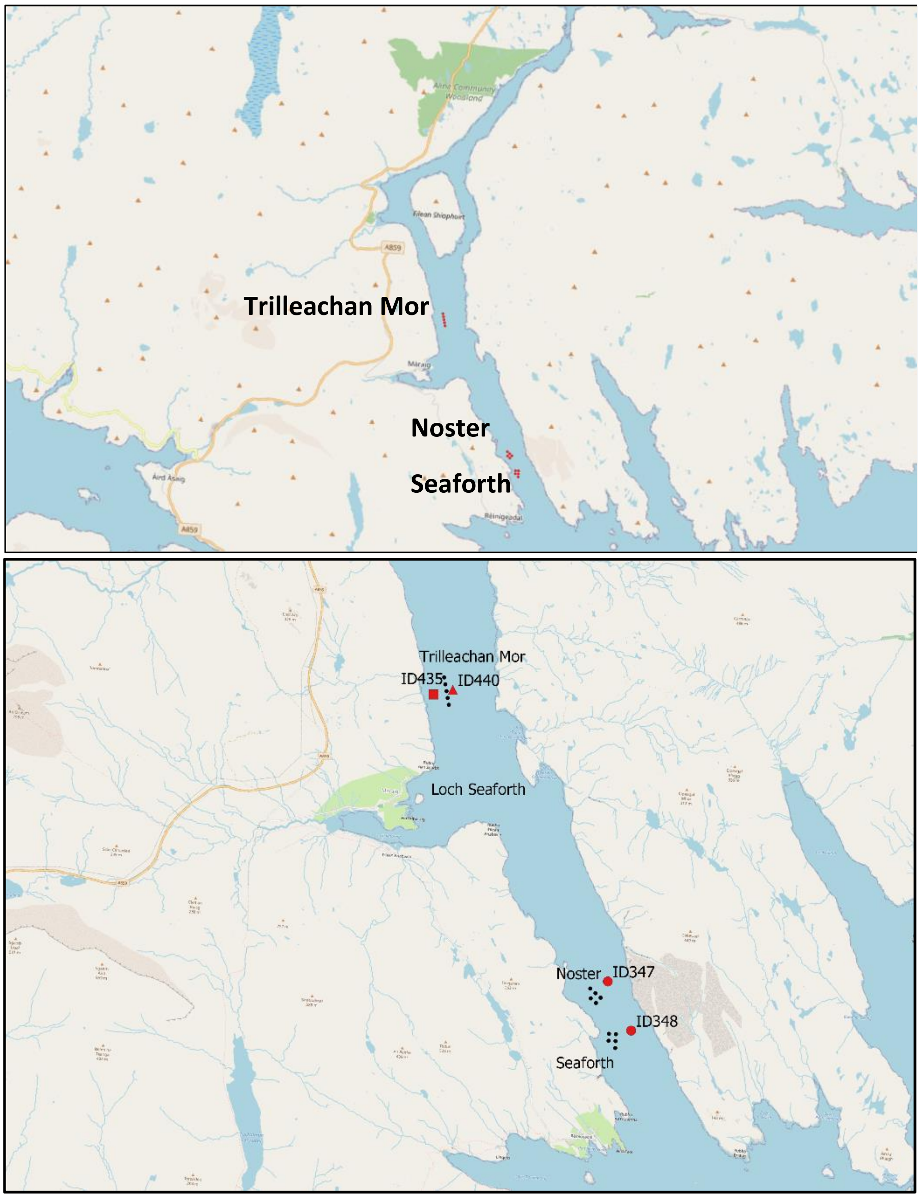

Figure 1. Locations of the Mowi sites in Loch Seaforth (top) and (bottom) the pen locations (●) and current meter deployments (red markers) used in this application.

1.1 Site Details

The site is situated in central Loch Seaforth (Figure 1). Details of the hydrographic data collected at the site are provided in Table 2. Additional hydrographic data collected adjacent to the site at Trilleachan Mor (ID435) and also at Seaforth (ID348) were used in the calibration and evaluation of the hydrodynamic model (Mowi, 2025) but are not used here. The ID435 deployment at Trilleachan Mor was felt to be too short (15 days) for dispersion modelling and did not contain a small neap tide. The receiving water is Loch Seaforth.

Table 2. Hydrographic Information

Hydrographic Data	ID347	ID440
Site:	Noster	Trilleachan Mor
Current Meter Position:	123097E 903757N	121091E 907540N
Depth of Deployment Position (m):	68.3	49
Surface Bin Centre Height Above Bed (m):	50.68	45.5*
Middle Bin Centre Height Above Bed (m):	34.68	44.0*
Bottom Bin Centre Height Above Bed (m):	4.68	42.0*
Duration of Record (days):	72	94
Start of Record:	16:00 25.06.2020	15:10 18.06.2024
End of Record:	09:00 06.09.2020	07:10 21.09.2024
Current Meter Averaging Interval (min):	20	20#
Magnetic Correction to Grid North (°):	0.31	1.35

* *Estimated (mid-water deployment)*
# *Post-processed from raw 5-minute average data.*

2. MODEL DETAILS

2.1 Model Domain and Boundary Conditions

The modelling approach adopted a coupled hydrodynamic and particle tracking method. The hydrodynamic model used was FVCOM (Finite Volume Community Ocean Model), an unstructured mesh, finite volume model (Chen et al, 2003). The unstructured mesh used in the modelling covered Loch Seaforth and adjacent coastal waters (Figure 2). Model resolution was enhanced within Loch Seaforth, particularly around the Mowi sites at Trilleachan Mor (Figure 3), Noster and Seaforth. The spatial resolution of the model varied from about 10 m in some inshore waters to about 500 m along the open boundary. The mesh was refined down to about 15 – 20 m in the area of the pens. In total, the model consisted of 30,147 nodes and 57,668 triangular elements.

Model bathymetry was taken from the UK Admiralty Seabed Mapping Service (https://www.admiralty.co.uk/access-data), supplemented by a multibeam survey undertaken around the Seaforth and Noster sites in December 2020 (Figure 4).

The model was forced along its open boundary by time series of sea surface height (SSH) at each boundary node for the relevant simulation periods; FVCOM appears to perform better when boundary forcing is applied as a time series rather than when tidal constituents are used. The SSH time series were generated using the RiCOM hydrodynamic model (Walters and

Casulli, 1998; Gillibrand et al., 2016) on the Scottish Shelf Model ECLH grid (Marine Scotland, 2016), which was, in turn, forced by eight tidal constituents (O_1, K_1, Q_1, P_1, M_2, S_2, N_2, K_2) taken from the full Scottish Shelf model (SSM).

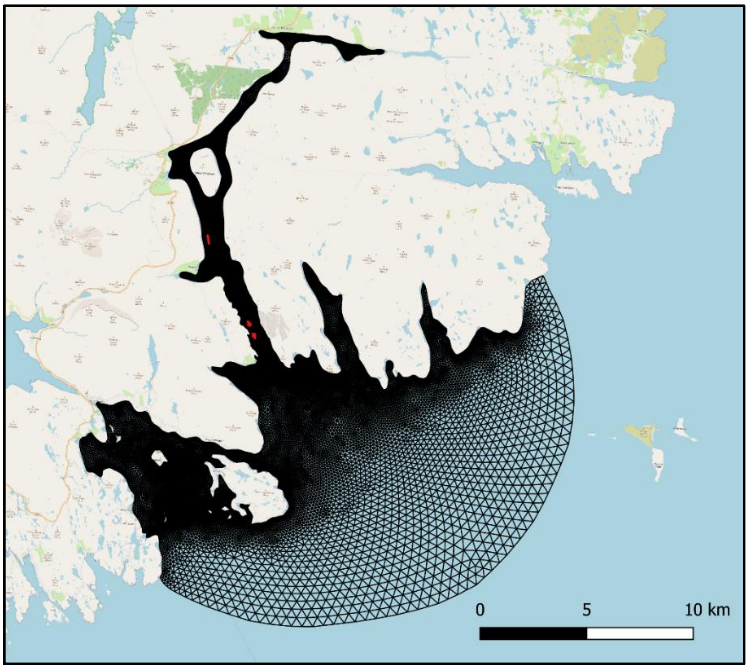

Figure 2. The mesh and domain of the Loch Seaforth model. The pen locations marked (●).

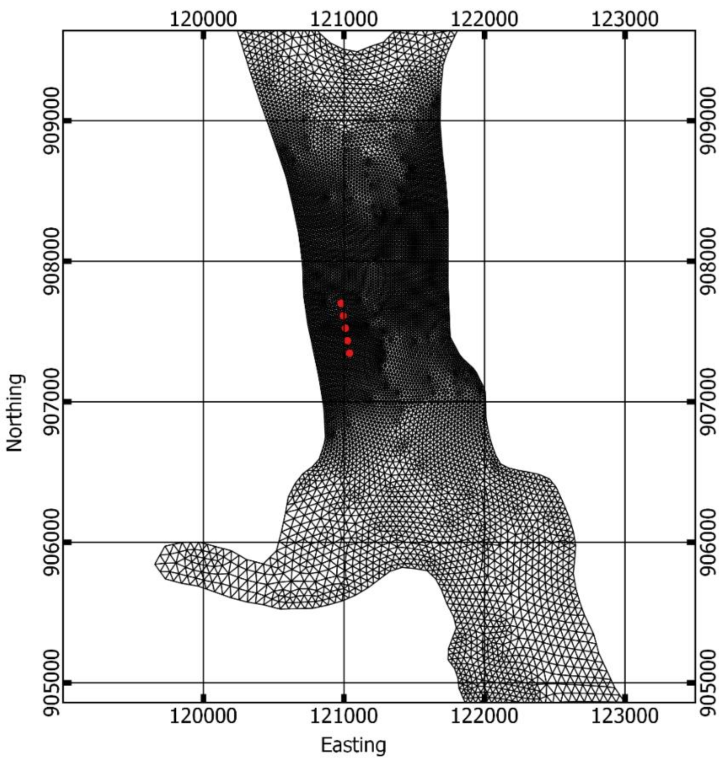

Figure 3. *The unstructured mesh around the Trilleachan Mor site, with the cage locations indicated (●).*

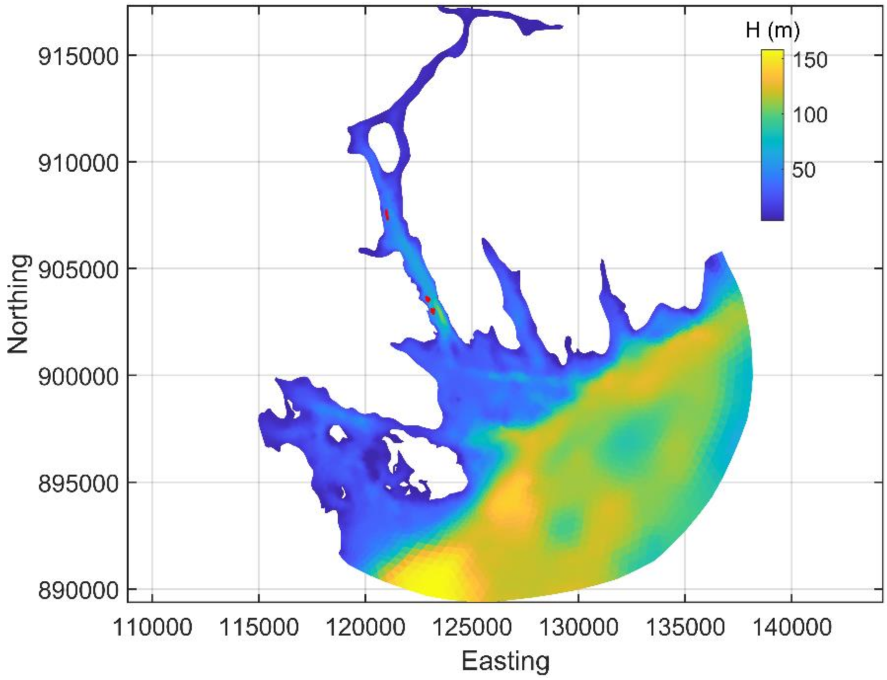

Figure 4. Model water depths (H, m) in the model domain (right), incorporating multibeam data around the Seaforth and Noster sites. The pen locations at the three Mowi sites are indicated (●).

Spatially- and temporally-varying wind speed and direction data were taken from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 global reanalysis dataset (https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5) for the required simulation periods and interpolated spatially onto the model mesh element centre locations.

Stratification was expected to be moderate in this location and the model was run in 3D baroclinic mode. Fourteen layers in the vertical (fifteen sigma levels) were used in the simulations, with layers concentrated near the surface and seabed. The sigma levels used were:

σ = [0 -0.01 -0.04 -0.09 -0.16 -0.26 -0.37 -0.50 -0.63 -0.74 -0.84 -0.91 -0.96 -0.99 -1.0]

Climatological river flow data were used, taken from the Marine Scotland Scottish Shelf Model climatology (Marine Scotland, 2016). Two freshwater discharges into the model domain were specified, discharging directly into Loch Seaforth and Loch Claidh. Climatological river flows were used. The annual-mean flows are comparable to the annual runoff discharges given by Edwards and Sharples (1986).

Full details of the hydrodynamic model configuration, calibration and validation are given in Mowi (2025).

2.2 Medicine Dispersion Modelling

The medicine dispersion modelling, performed using the UnPTRACK particle tracking model (Gillibrand, 2021), simulates the dispersion of patches of medicine discharged from pens following treatment using tarpaulins. The treatment scenario assumed one pen can be treated per day.

To simulate the worst-case scenario, the dispersion modelling was initially conducted using flow fields over a period of six days centred on a small neap tidal range taken from the hydrodynamic model simulations. This is assumed to be the least dispersive set of ambient conditions, when the quantity of medicine able to be discharged and meet the required EQS is least. Later simulations tested dispersion during spring tides.

A treatment depth of 5.0 m was chosen as a realistic net depth during application of the medicine for 160 m pens. The initial mass released per pen was calculated from the reduced pen volume and a treatment concentration of 100 µg/L, with a total mass of 5.093 kg of azamethiphos released during treatment of the whole farm (5 pens). Particles were released from random positions within a pen radius of the centre and within the 0 – 5.0 m depth range. Each numerical particle represented 10 mg of azamethiphos.

Each simulation ran for a total of 193 hours. This covered the treatment period (96 hours), a dispersion period to the EQS assessment after 168 hours (72 hours after the final treatment), and an extra 25 hours to check for chance concentration peaks. At every hour of the simulation, particle locations and properties (including the decaying mass) were stored. Medicine concentrations were calculated from these archived results. Concentrations were calculated on a grid of 50 m x 50 m squares over a depth range of 0 – 5.0 m. Using a regular grid for counting makes calculating particle concentrations and presenting the results easier, and provides a known resolution of the calculated concentrations.

From the calculated concentration fields, time series of two metrics were constructed for the whole simulation:

(i) The maximum concentration (µg/L) anywhere on the regular grid;
(ii) The area (km^2) where the EQS was exceeded;

These results were used to assess whether the EQS or the maximum allowable concentration (MAC) was breached after the allotted period (72 hours after the final treatment).

Sensitivity analyses were conducted to assess the effects of:

(i) Horizontal diffusion coefficient, K_H
(ii) Vertical diffusion coefficient, K_V
(iii) Time of release

The dispersion simulations were performed separately over neap and spring tides during 2024 (Figure 5). Further sets of simulations were performed at neap tides in 2020 to confirm the adequacy of dispersion during the weakest tides (Figure 6).

2.3 Medicine Dispersion Simulations

The pens locations and details of the medicine source are listed in Table 3. The time of release is relative to the start of the neap or spring period highlighted in Figure 5 and Figure 6.

The simulations performed are listed in Table 4. All simulations used the release schedules and quantities outlined in Table 3. In Runs 6 – 11 and 17 – 22, the release schedule was set forward/back by a number of hours to investigate the effect of tidal state at the time of release on the results. Results for these simulations are still presented in terms of time relative to the first release.

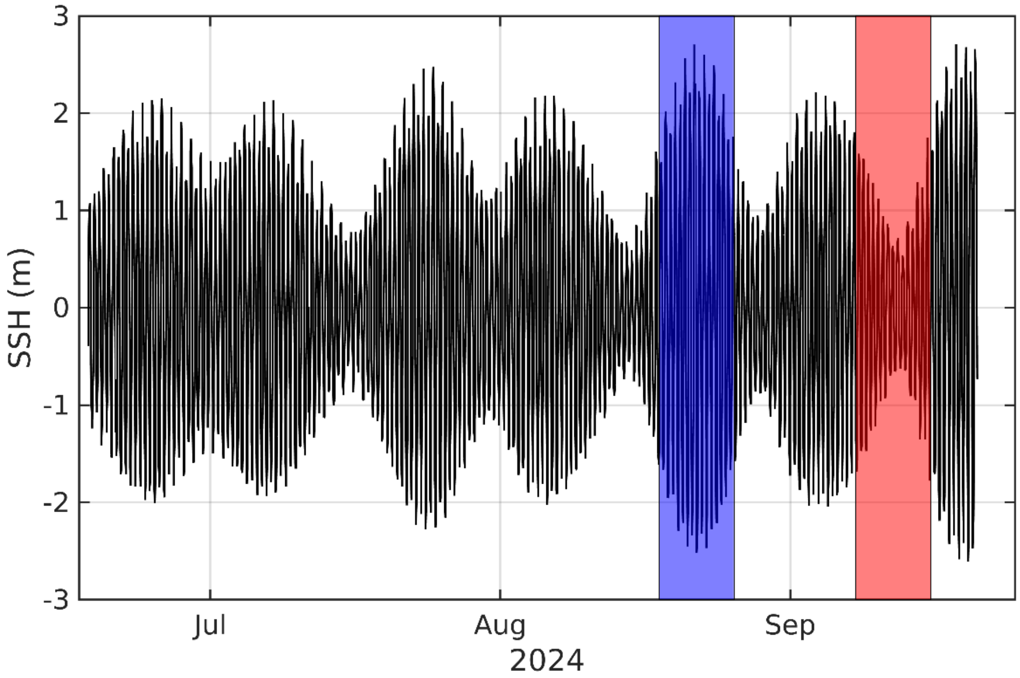

Figure 5. Sea surface height (SSH) at Trilleachan Mor from 18th Aug – 21st September 2024. Dispersion simulations were performed over periods of neap tides (highlighted in red) and spring tides (blue).

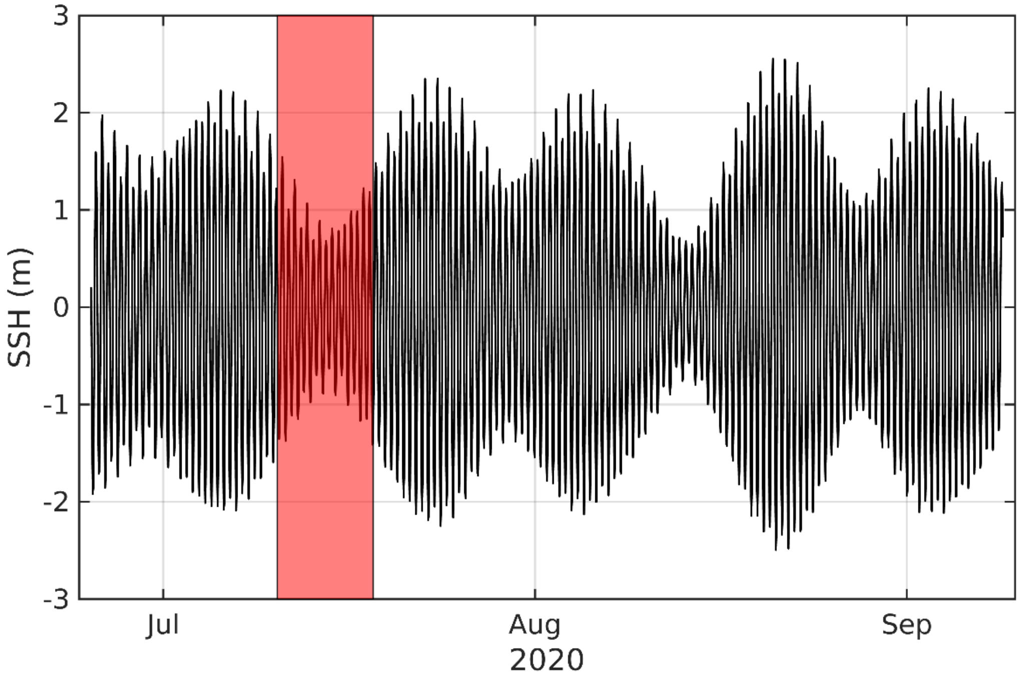

Figure 6. Measured sea surface height (SSH) at Noster from 25th June – 6th September 2020 (ID347). Dispersion simulations were performed over the period of neap tides highlighted in red.

Table 3. Details of the treatment at Trilleachan Mor simulated by the dispersion model. The release time is relative to the start of the neap or spring periods highlighted in Figure 5 and Figure 6.

Pen	Easting	Northing	Net Depth (m)	Treatment Mass (kg)	Release Time (hr)
1	120979	907700	5.0	1.018	0
2	120995	907611	5.0	1.018	24
3	121010	907522	5.0	1.018	48
4	121025	907434	5.0	1.018	72
5	121040	907345	5.0	1.018	96

Table 4. Dispersion model simulation details for the treatment simulations of 5 pens at Trilleachan Mor.

Set	Run No.	$T_{1/2}$ (h)	K_H ($m^2 s^{-1}$)	K_V ($m^2 s^{-1}$)	Start Time
Neap Tides, Start day = 83 (8th Sept 2024, ID440)					
Baseline	1	134.4	0.1	0.001	00:00
1	2	134.4	0.05	0.001	00:00
	3	134.4	0.20	0.001	00:00
2	4	134.4	0.1	0.0025	00:00
	5	134.4	0.1	0.0050	00:00
3	6	134.4	0.1	0.001	00:00 -6h
	7	134.4	0.1	0.001	00:00 -4h
	8	134.4	0.1	0.001	00:00 -2h
	9	134.4	0.1	0.001	00:00 +2h
	10	134.4	0.1	0.001	00:00 +4h
	11	134.4	0.1	0.001	00:00 +6h
Spring Tides, Start day = 62 (18th Aug 2024, ID440)					
4	12	134.4	0.1	0.001	00:00
5	13	134.4	0.05	0.001	00:00
	14	134.4	0.20	0.001	00:00
6	15	134.4	0.1	0.0025	00:00
	16	134.4	0.1	0.0050	00:00
7	17	134.4	0.1	0.001	00:00 -6h
	18	134.4	0.1	0.001	00:00 -4h
	19	134.4	0.1	0.001	00:00 -2h
	20	134.4	0.1	0.001	00:00 +2h
	21	134.4	0.1	0.001	00:00 +4h
	22	134.4	0.1	0.001	00:00 +6h
Neap Tides, Start day = 16 (10th July 2020, ID347)					
8	23	134.4	0.1	0.001	00:00
9	24	134.4	0.05	0.001	00:00
	25	134.4	0.20	0.001	00:00
10	26	134.4	0.1	0.0025	00:00
	27	134.4	0.1	0.0050	00:00

2.4 3-hour EQS

In addition to the main simulations described above to assess compliance with the 72-hour EQS, simulations were also performed to assess compliance with the 3-hour EQS (SEPA, 2023). The 3-hour EQS is applied as a mixing zone EQS, whereby the area where concentrations exceed the EQS of 250 ng L^{-1} after 3 hours must be less than the 3-hour mixing zone. The 3-hour mixing zone is primarily a function of mean near-surface current speed at the site, and has traditionally been calculated by the BathAuto Excel spreadsheet. For calculation of the mixing zone, a mean surface current speed of 9.3 cm s^{-1} was used from the near-surface currents at 3.5 m below the sea surface from ID440 (Table 5).

For the 3-hour EQS assessment, the baseline runs for neap and spring tides were repeated, but with results output every 20 minutes and the runs were truncated, lasting only until 3 hours after the final treatment. The area of the medicine patch for each individual treatment was then calculated over the 3-hour period following its release, and the area exceeding 250 ng L^{-1} determined. Concentrations from these simulations were calculated on a 10 m x 10 m grid (rather than a 25 m x 25 m grid) in order to more accurately calculate the smaller areas of medicine over the initial 3-hour period.

Table 5. Parameter values used in the calculation of the 3-hour mixing zone area. The mean current speed is taken from ID440.

Parameter	Value
Mean current speed (m s^{-1})	0.093
Area of 160 m pen (km^2)	0.002037
Horizontal diffusion coefficient (m^2 s^{-1})	0.1
Distance from shore (km)	0.265
Mean water depth (m)	41.5
Treatment Depth (m)	5.0
3-hr Mixing zone area (km^2)	**0.146650**

2.5 Interactions with Special Features

Five near-by features of interest have been identified (SEPA, 2024), two mussel farms and three kelp bed Priority Marine Features (PMFs), which are thought to be at potential risk from medicine influence and hence must be considered when modelling the treatment releases from Trilleachan Mor. Table 6 shows details of the features of interest, and the locations are indicated in Figure 7.

Predicted concentrations of azamethiphos at the PMF locations during the simulation periods were extracted from the model results. For the mussel farm polygons, the peak concentration is presented; for the kelp bed PMFs, concentrations were calculated using a 200 m radius circule centred at the PMF location. For all features, concentrations were calculated over the surface 5 m thick layer.

Table 6: Table of identified features. The labels A – E relate to Figure 7.

No.	Feature Name	Feature Type	Location (E, N)
1	Seaforth Island East mussel farm	Mussel Farm A	121643, 910789
2	Seaforth South mussel farm	Mussel Farm B	121477, 907987
3	Kelp Beds	PMF C PMF D PMF E	122108, 906299 121700, 905300 122902, 904891

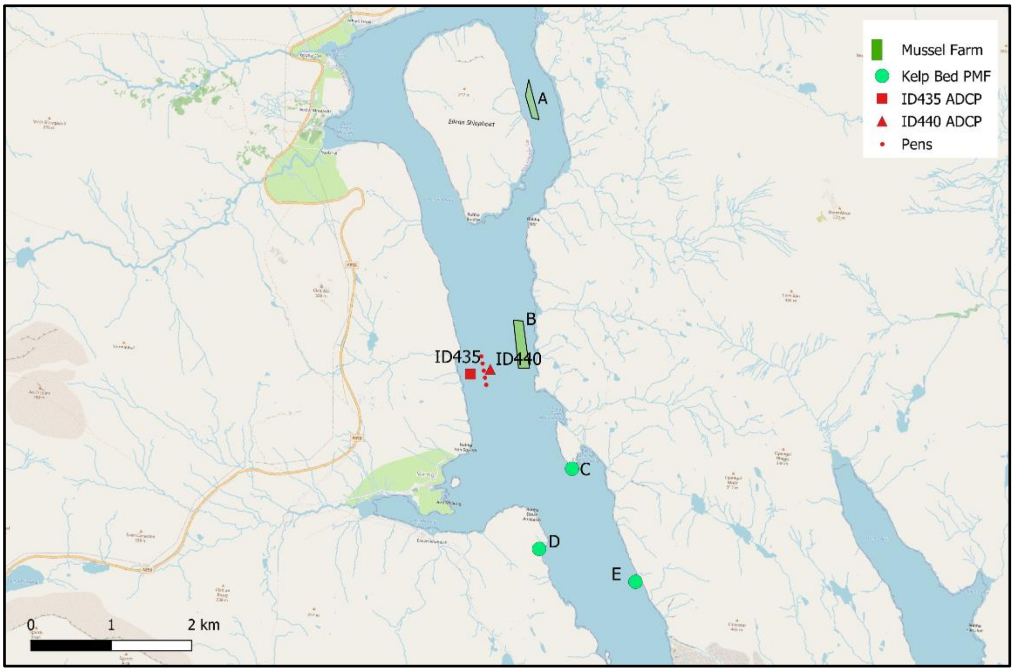

Figure 7. Locations of identified features near Trilleachan Mor: mussel farms and kelp bed PMFs. The various features are labelled A – E for easy identification.

3 RESULTS

3.1 Dispersion During Neap Tides, September 2024

A standard treatment of 5 x 160 m pens, with a reduced net depth of 5.0 m (the mean depth of the 15 m cone) and treatment concentration of 0.0001 mg L^{-1}, resulted in a treatment mass per pen of azamethiphos of 1.018 kg and a total treatment release of 5.09 kg over 96 hours. The dispersion of the medicine during and following treatment from Run001 is illustrated in Figure 8. After 24 hours following the first treatment, the medicine has already largely dispersed. The maximum concentration at this time was 100 µg/L, due to the release of the second treatment. After 48 hours, the discharged medicine had dispersed to low concentrations less than the EQS (0.04 µg/L). The maximum concentration at this time was again about 100 µg/L, due to the release of the third treatment at 48 hours.

The treatment schedule completed after 96 hours (4.0 days). At this stage, the medicine released on earlier days was still present in the loch at low concentrations, mostly lower than the EQS. Dispersion of the medicine does not happen in a gradual “diffusive” manner, but is largely driven by eddies and horizontal shear in the spatially-varying velocity field, which stretches and distorts the medicine patches and enhances dispersion. Over the three days following the final treatment (96 – 168 hours), the medicine steadily disperses, until after 168 hours (72 hours after the final treatment), the discharged medicine was largely dispersed.

The time series of maximum concentration from the simulation is shown in Figure 9. The five peaks in concentration of ~100 µg/L following each treatment event over the first 4 days are evident. Following the final treatment after 96 hours, the maximum concentration fell steadily away (Figure 9). With a default half-life of 134.4 h (5.6 days), the maximum concentration seventy-two hours after the final treatment (time = 168 hours) was below the MAC of 0.1 µg/L.

The area of the loch where the EQS of 0.04 µg/L was exceeded peaked at about 1.24 km^2 following the final, but had fallen well below the allowable mixing zone of 0.5 km^2 within 15 hours of the final treatment; by 72 h after the final treatment, the exceeded area was less than 0.1 km^2 (Figure 8 and Figure 9).

These results indicate that environmental quality standards were comfortably achieved with this treatment scenario, particularly given that the half-life used in the modelling (134.4 hours) is considered conservative. In the following sections, the sensitivity of the model results to the horizontal and vertical diffusion coefficients and tidal state are examined.

3.2 Sensitivity to Diffusion Coefficients

The model results were tested for sensitivity to the horizontal and vertical diffusion coefficients used. The horizontal diffusion coefficient used for the standard runs was K_H = 0.1 m^2 s^{-1}. Simulations were also performed with lower and higher values of K_H, specifically K_H = 0.05 m^2 s^{-1} and K_H = 0.2 m^2 s^{-1} (Figure 9). The time series of maximum concentration and area exceeding the EQS are shown in Figure 9. The time series show that all runs achieve concentrations below the MAC after 168 hours, although there is a very minor breach shortly afterwards when K_H = 0.2 m^2 s^{-1} (Figure 9). The area limit of 0.5 km^2 was comfortably met in all cases.

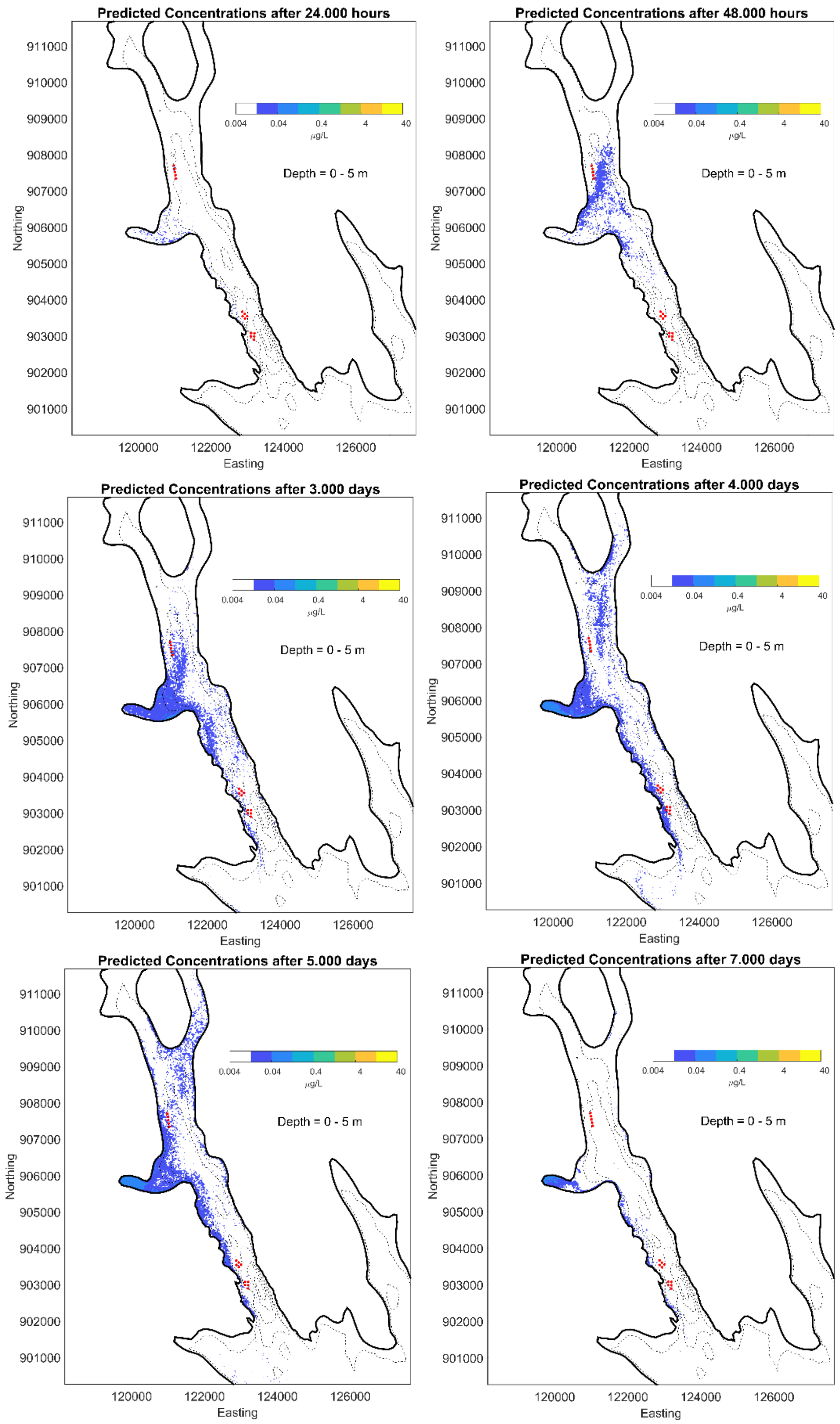

Figure 8. Predicted concentration fields (µg/L) for a dispersion simulation at neap tides in September 2024 after 24 hours (top left), 48 hours (top right), 72 hours (middle left), 96 hours (middle right), 120 hours (bottom left) and 168 hours (bottom right). Pen locations for the Seaforth, Noster and Trilleachan Mor sites are indicated (•).

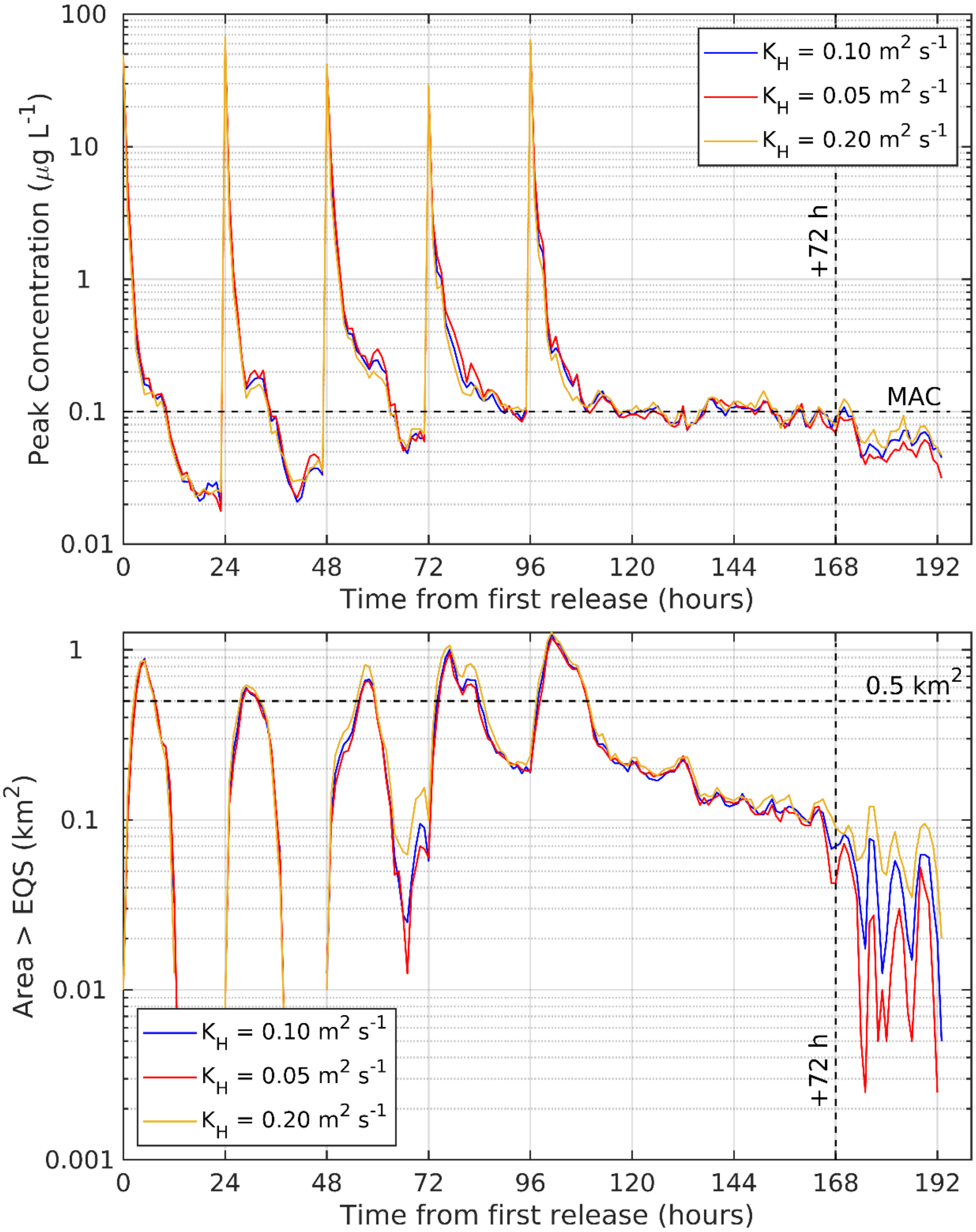

Figure 9. Time series of maximum concentration (top) and area exceeding the EQS (bottom) from the first two sets of model runs (Table 4). The model was run during neap tide in September 2024, and included sensitivity runs with varying horizontal diffusivity K_H. The MAC and area limit 72 hours after the final treatment (Time = 168 h, vertical dashed line) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

Similarly, sensitivity to the vertical diffusion coefficient, K_V, was tested (Figure 10). The model results are not particularly sensitive to the vertical diffusion rate, but all three runs achieved the MAC and EQS after 168 hours.

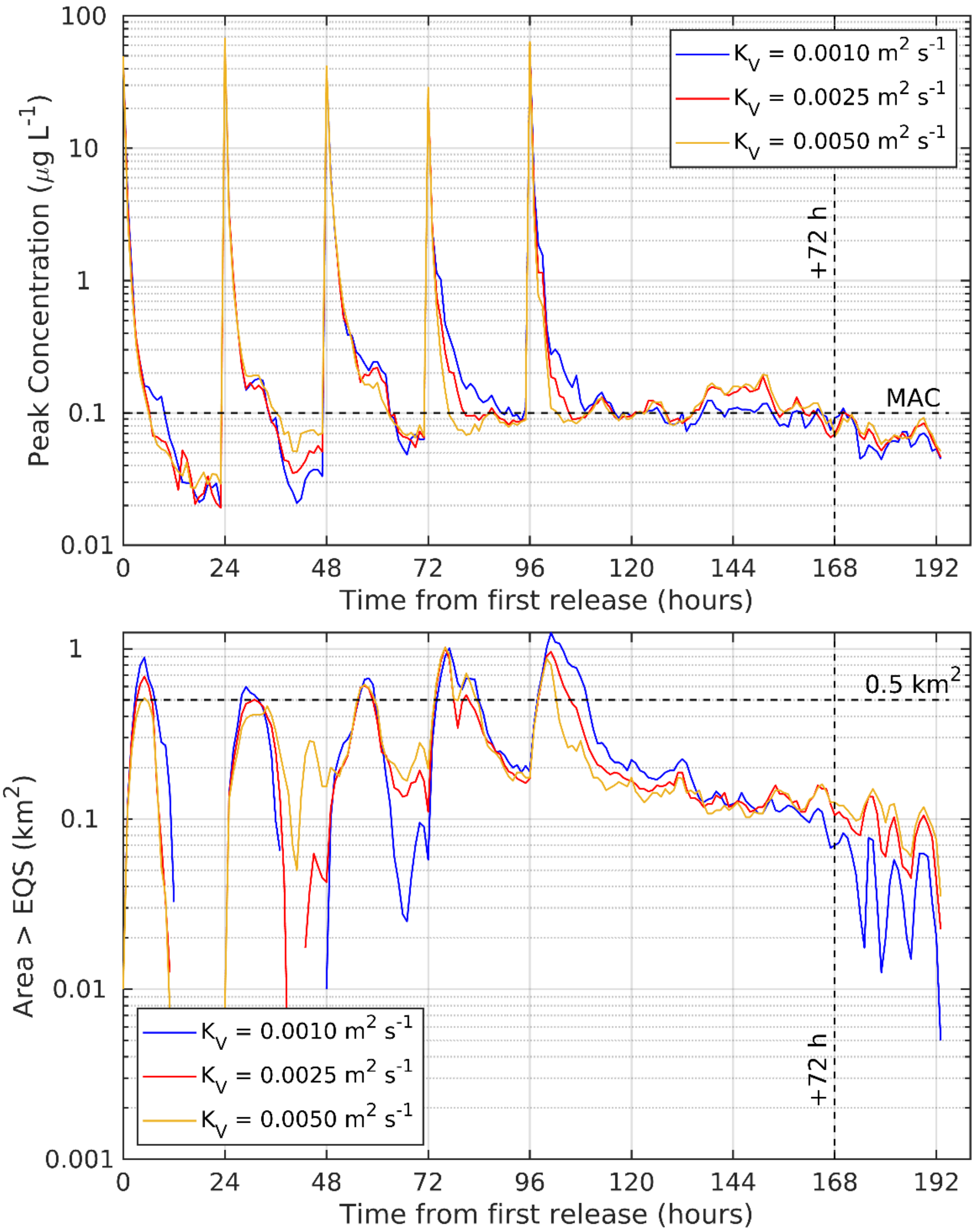

Figure 10. Time series of maximum concentration (top) and area exceeding the EQS (bottom) from the second set of model runs (Table 4). The model was run during neap tides with varying vertical diffusivity K_V. The MAC and area limit 72 hours after the final treatment (Time = 168 h) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

3.3 Sensitivity to Release Time

The baseline simulations were repeated with the time of the releases varied by up to ±6 hours (Runs 6 – 11, Table 4), the purpose being to assess the influence, if any, of the state of the tide on subsequent dispersion. The results show a little variability (Figure 11); however, in all cases the MAC condition was essentially achieved after 168 hours, and the EQS condition was comfortably achieved in all cases.

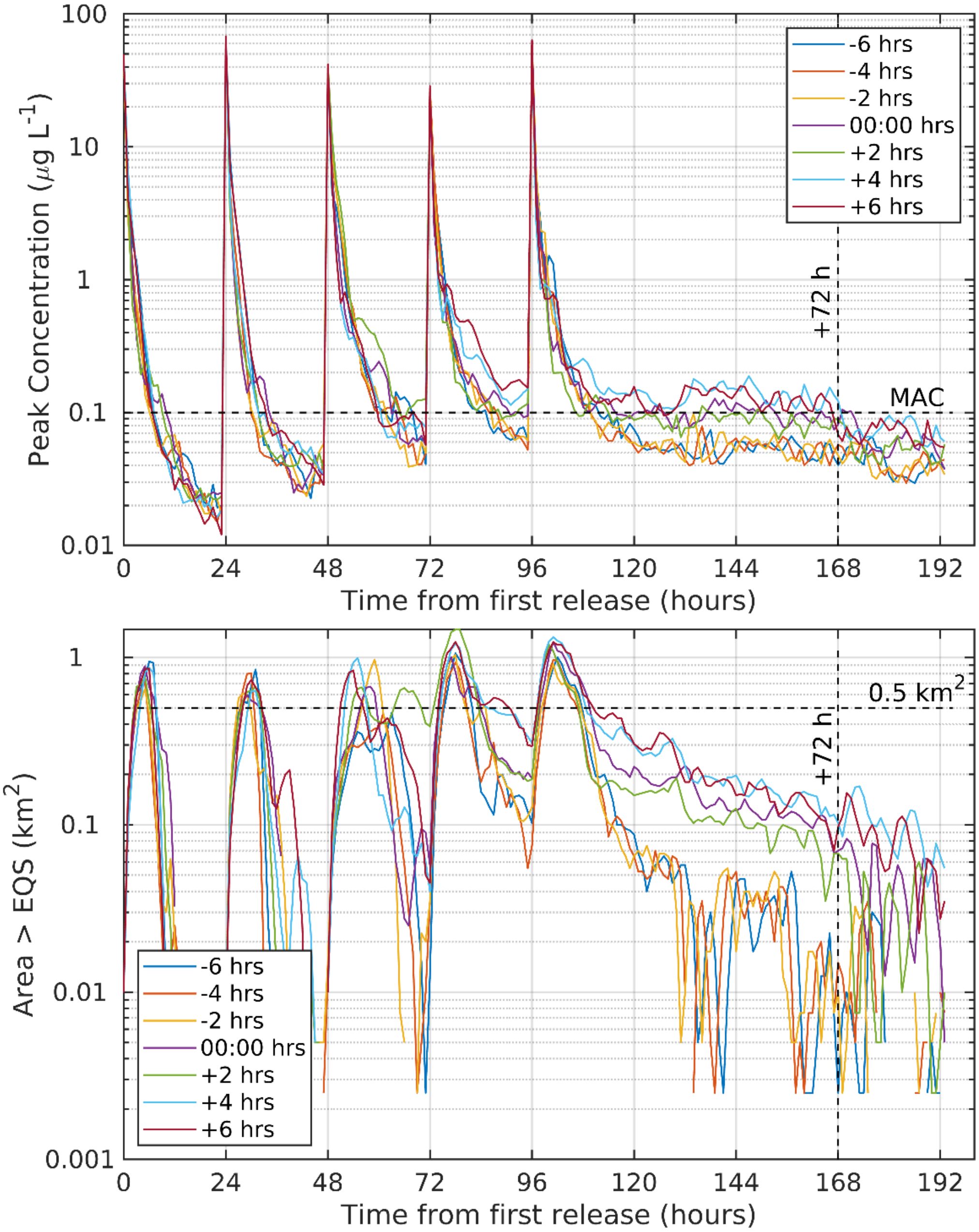

Figure 11. Time series of maximum concentration (top) and the area where concentrations exceeded the EQS (bottom) from the third set of model runs (Table 4). The model was run at neap tides with varying release times relative to the baseline (Start = 0 h). The MAC and area limit 72 hours after the final treatment (Time = 168 h) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

3.4 Dispersion during Spring Tides, August 2024

Dispersion simulations were carried out during modelled spring tides in August 2024 (Figure 5), repeating the main set carried out for neap tides (Table 4). The same treatment scenario of one treatment per day was simulated. For all horizontal and vertical diffusion coefficients (Figure 12) and start times (Figure 13) simulated, both the MAC and area EQS were comfortably achieved.

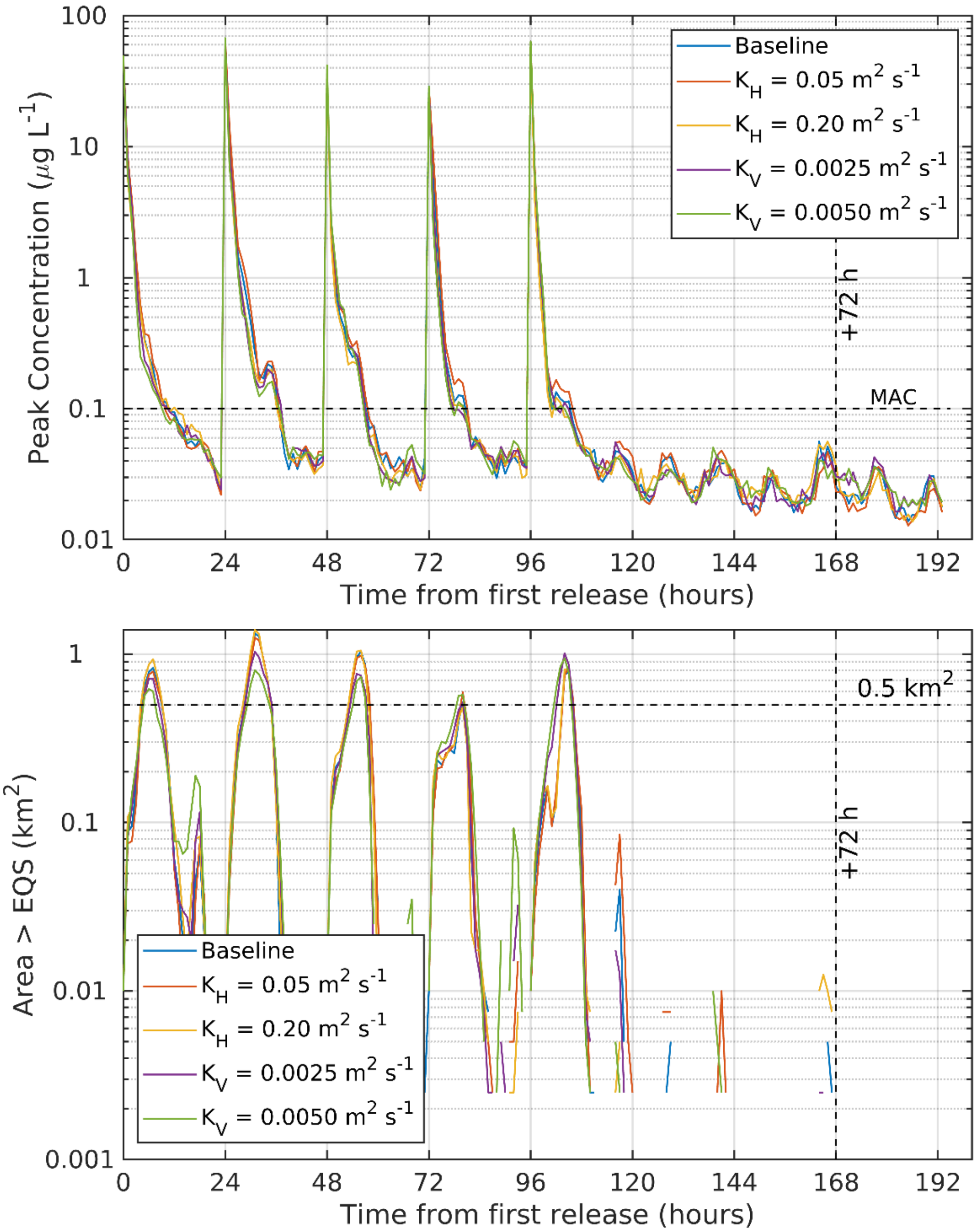

Figure 12. Time series of maximum concentration (top) and area exceeding the EQS (bottom) from simulations during spring tides in 2024 (Runs 12 – 16, Table 4). The model was run with varying horizontal diffusivity (K_H) and vertical diffusivity (K_V). The MAC and area limit 72 hours after the final treatment (Time = 168 h, vertical dashed line) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

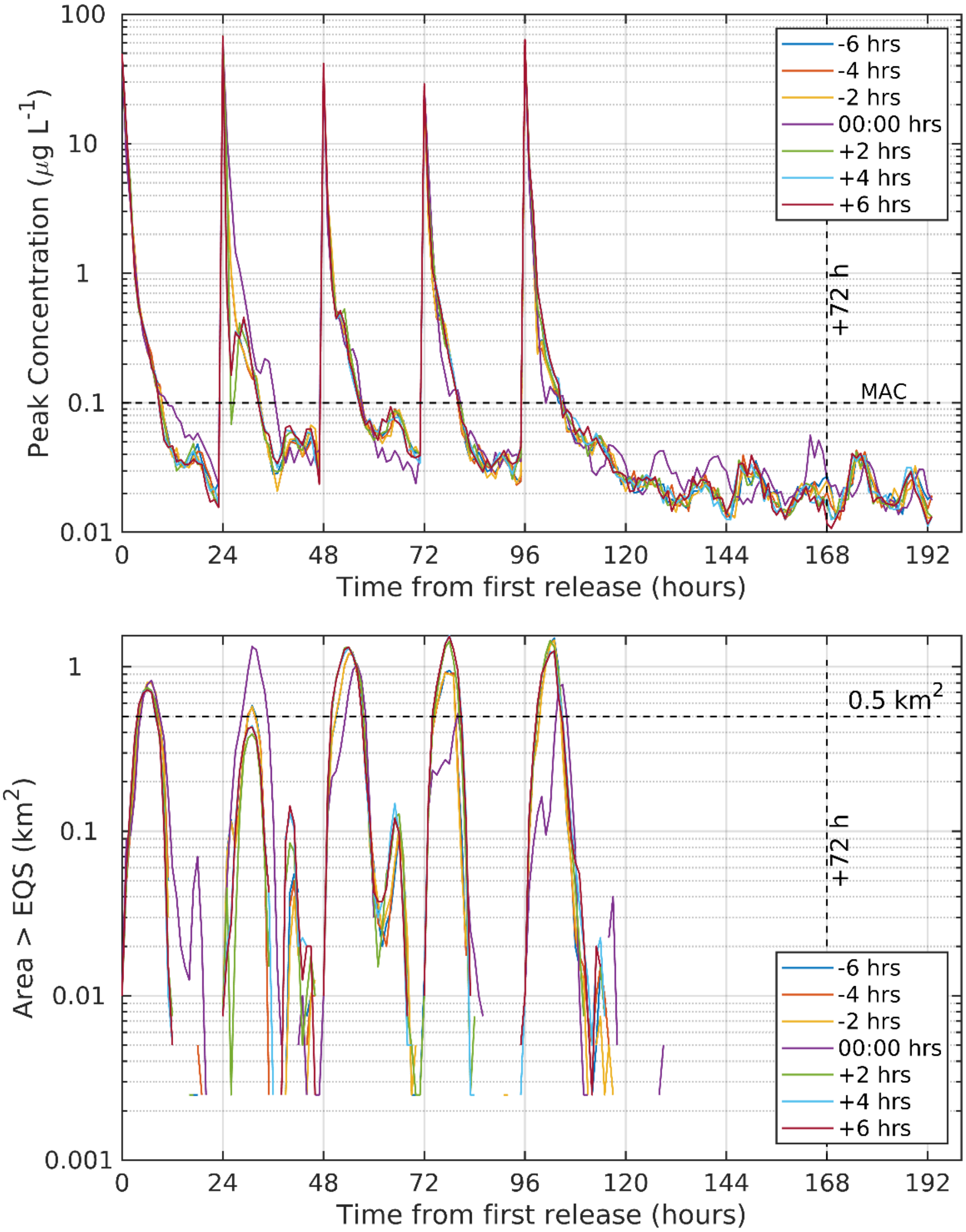

Figure 13. Time series of maximum concentration (top) and the area where concentrations exceeded the EQS (bottom) from the 7th set of model runs (Table 4). The model was run at spring tides with varying release times relative to the baseline (Start = 0 h). The MAC and area limit 72 hours after the final treatment (Time = 168 h) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

3.5 Dispersion During Neap Tides, July 2020

A further set of dispersion simulations during neap tides in July 2020 (Figure 6) were performed, including a sensitivity study for horizontal and vertical diffusivity (Table 4). The same treatment scenario of one treatment per day with each treatment using 1.018 kg of azamethiphos was modelled. For all horizontal and vertical diffusion coefficients simulated, both the MAC and area EQS conditions were achieved (Figure 14).

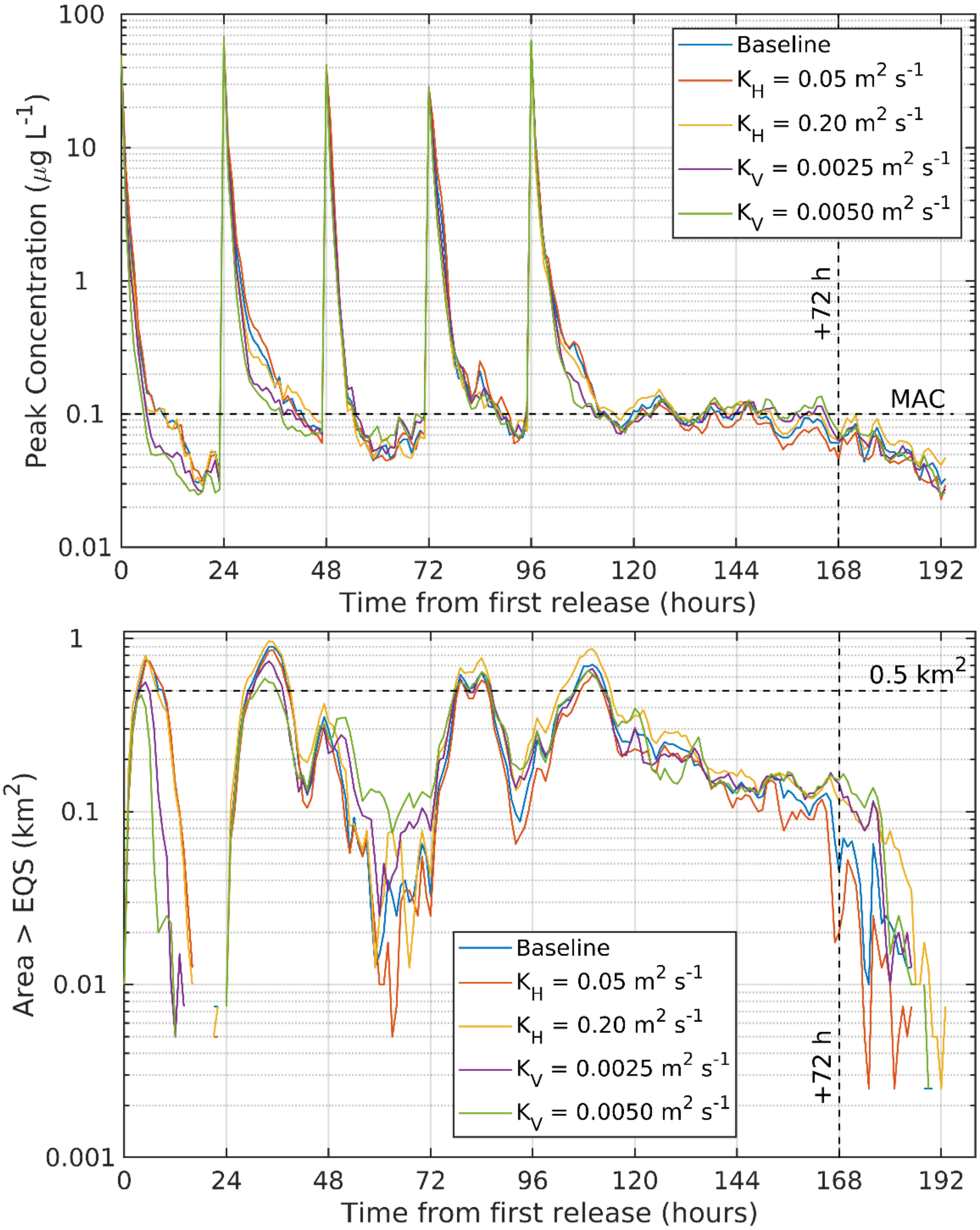

Figure 14. Time series of maximum concentration (top) and area exceeding the EQS (bottom) from simulations during neap tides in July 2020 (sets 8 – 10, Table 4). The model was run with varying horizontal diffusivity (K_H) and vertical diffusivity (K_V). The MAC and area limit 72 hours after the final treatment (Time = 168 h, vertical dashed line) of 0.1 µg/L and 0.5 km^2 are indicated by the horizontal dashed lines.

3.6 3-Hour EQS

The 3-hour mixing zone is primarily a function of mean near-surface current speed at the site, and has traditionally been calculated by the BathAuto Excel spreadsheet. For calculation of the mixing zone, a mean surface current speed of 9.3 cm s^{-1} was used from ID440 (Table 1) which was thought to be a representative value for the surface 0 – 5 m layer at Trilleachan

Mor. The parameter values used in the calculation of the 3-hour mixing zone ellipse area are shown in Table 5.

The time series of the areas where the 3-hour EQS of 250 µg/L is exceeded for pen treatments at neap tide (first release on 8th September 2024) are shown in Figure 15. The area exceeding the EQS was less than the allowable mixing zone (0.146650 km^2) after 3 hours for all treatments.

For spring tide releases (first release on 18th August 2024), the area where concentrations exceeded the 3-hour EQS also complied with the allowable area (Figure 15). This demonstrates that the discharge quantity of 1.018 kg of Azamethiphos from each of the five 160 m pens at Trilleachan Mor should not breach the 3-hour Environmental Quality Standard.

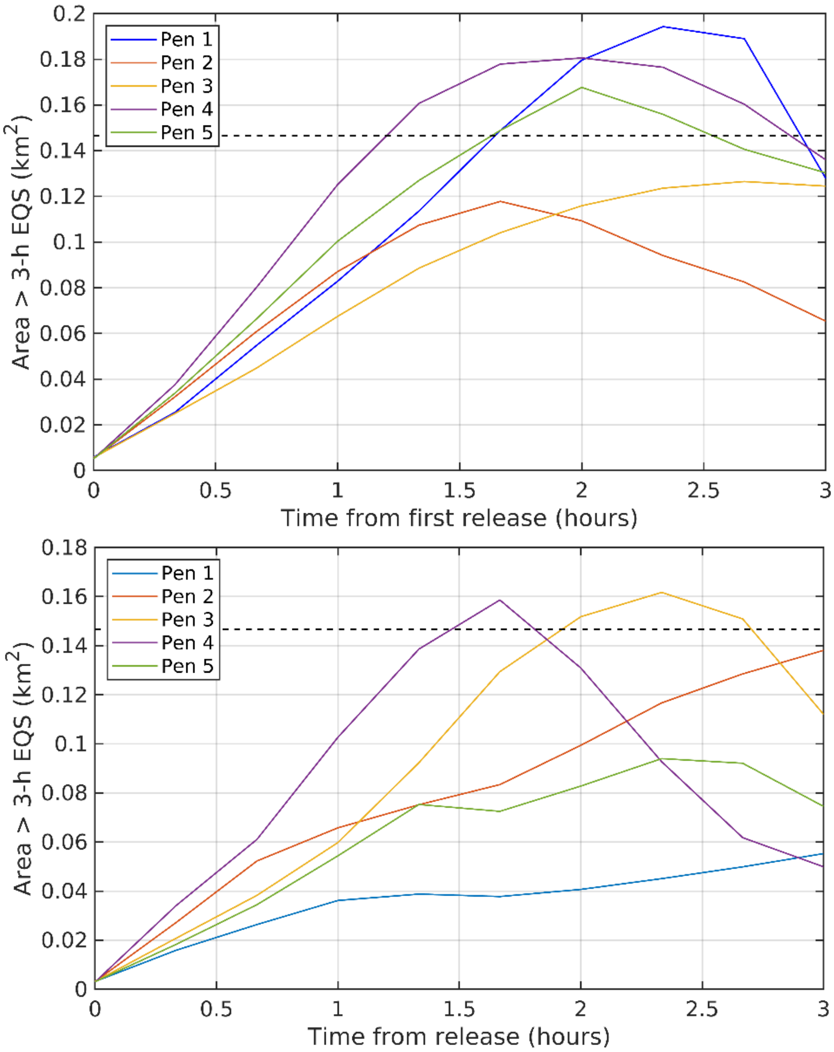

Figure 15. Time series of the area exceeding the 3-hour EQS for five pen treatments during the 3 hours following release at neap (top) and spring (bottom) tide. The 3-hour mixing zone area is indicated (---).

3.7 Interactions with Special Features

Time series of predicted concentrations at the special features locations after a treatment during neap tides are shown in Figure 17. The time series for the mussel farms include the peak concentrations in the polygons (Figure 7). Three hours after the each treatment, residual medicine concentrations were evident but were well below the EQS concentrations. At no time did concentrations exceed the 3-hr MAC of 0.1 µg/L (100 ng/L), and there were only very brief exposures at kelp bed D to concentrations exceeding 0.04 µg/L. Seventy-two hours after the final treatment, concentrations were less than half the EQS concentration.

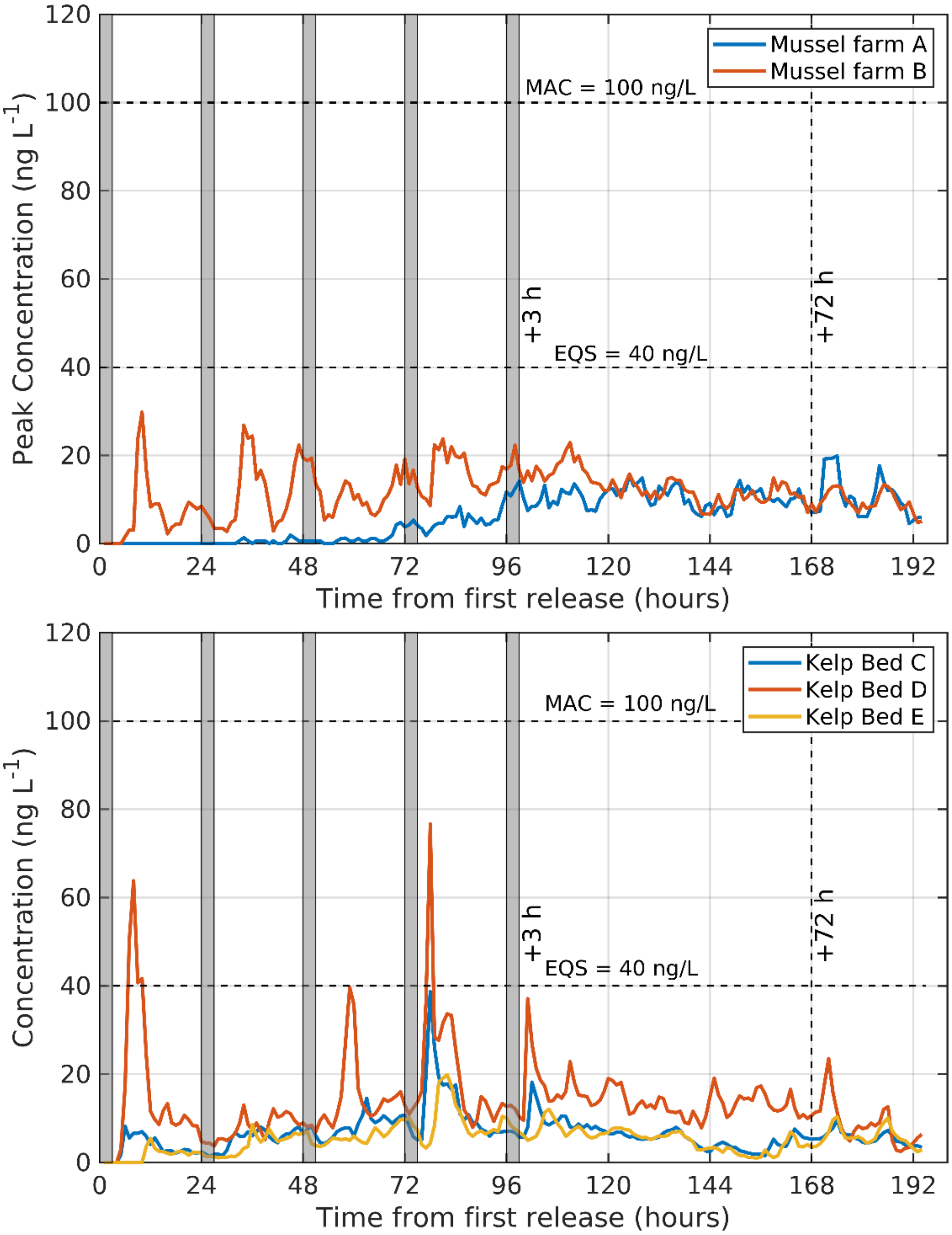

Figure 16. Predicted peak concentrations at the two mussel farm (polygon) locations (top) and predicted concentrations at three kelp bed PMF locations (bottom) at neap tides from the baseline run (Run 1, Table 4).

Medicine concentrations at 3 hours and 72 hours after the final treatment are illustrated in Figure 17. By 72 hours after the final treatment (7 days from the start of the simulation), residual medicine was still evident but at low concentrations and, as evident from Figure 16, not significantly impacting the special feature locations.

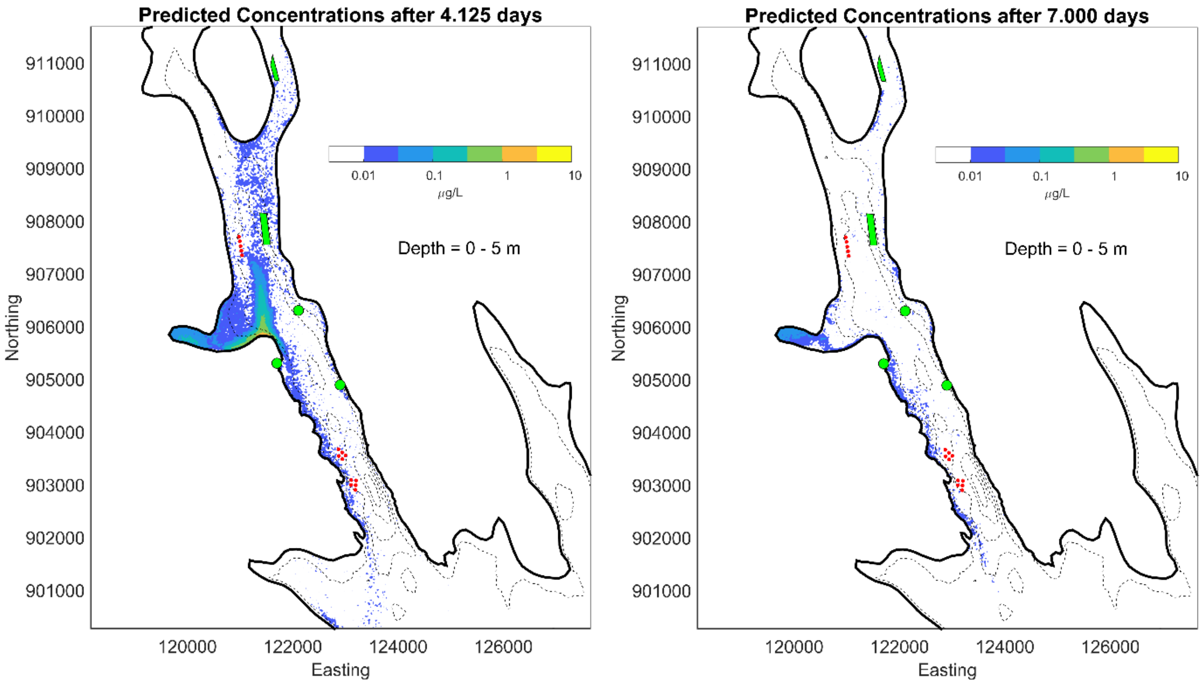

Figure 17. Predicted concentration fields from the baseline run at neap tide (Run 1, Table 4) after 99 hours (3 hours after the final release, left) and after 168 hours (72 hours after the final release, right). The identified special features are marked, including mussel farms (green polygons) and kelp beds (green circles).

During spring tides, medicine dispersion was more rapid and concentrations were generally lower (Figure 19) relative to the neap tide results. At all times, the predicted peak concentrations within the mussel farm polygons were below the EQS concentration of 40 ng/L. Concentrations at the location of mussel farm A were always less than 10 ng/L. After the final treatment, concentrations at both locations fell rapidly, and by 72 hours later (168 hours after the first release), concentrations at the mussel farms were around 10 ng/L or less. At the kelp bed PMFs, concentrations at no time exceeded the EQS value of 40 ng/L.

The distributions of medicine after 99 and 168 hours (+3 and +72 hours after the final treatment) illustrate the generally rapid dispersion of medicine during spring tides (Figure 19).

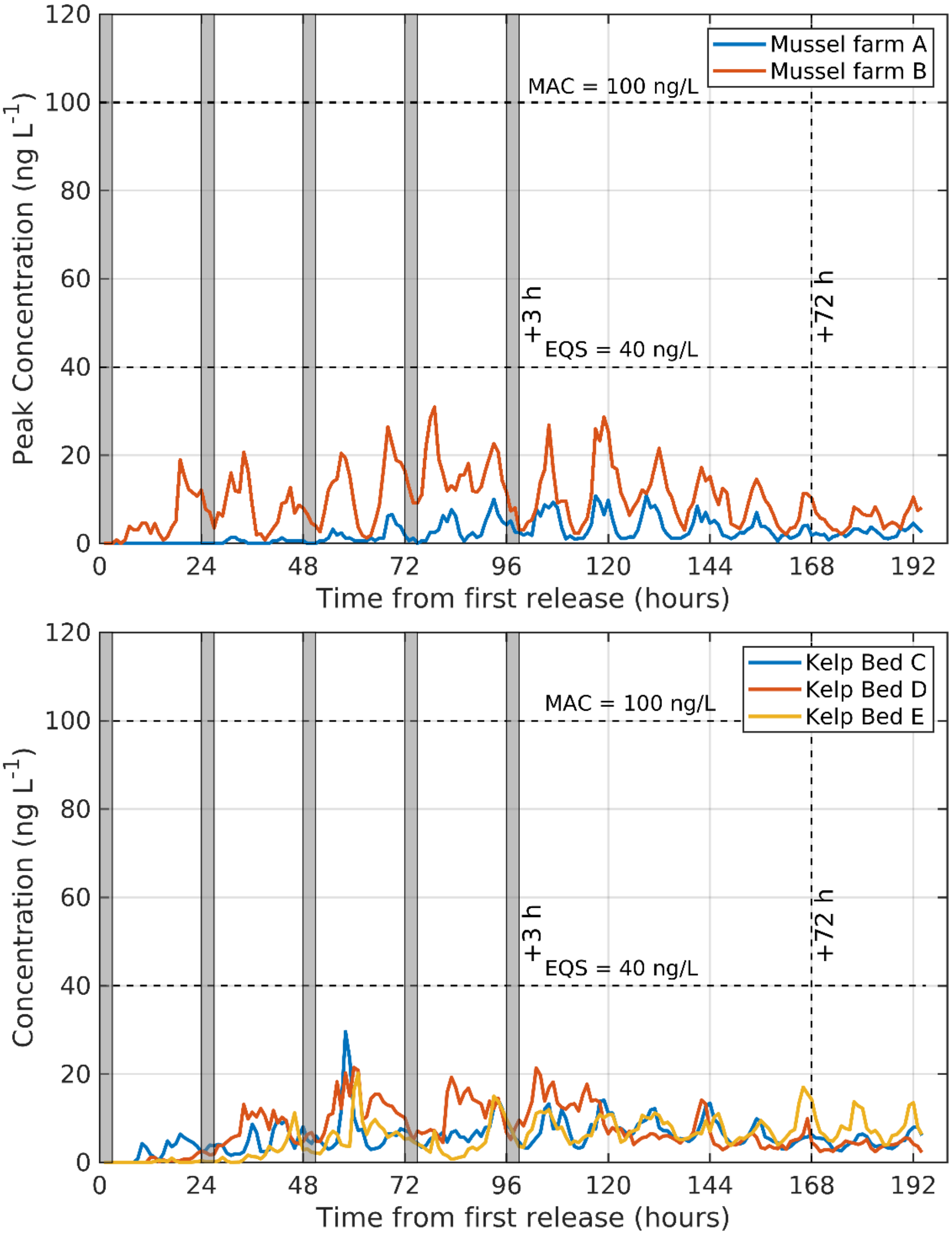

Figure 18. Predicted peak concentrations at the two mussel farm (polygon) locations (top) and predicted concentrations at three kelp bed PMF locations (bottom) at spring tides (Run 12, Table 4).

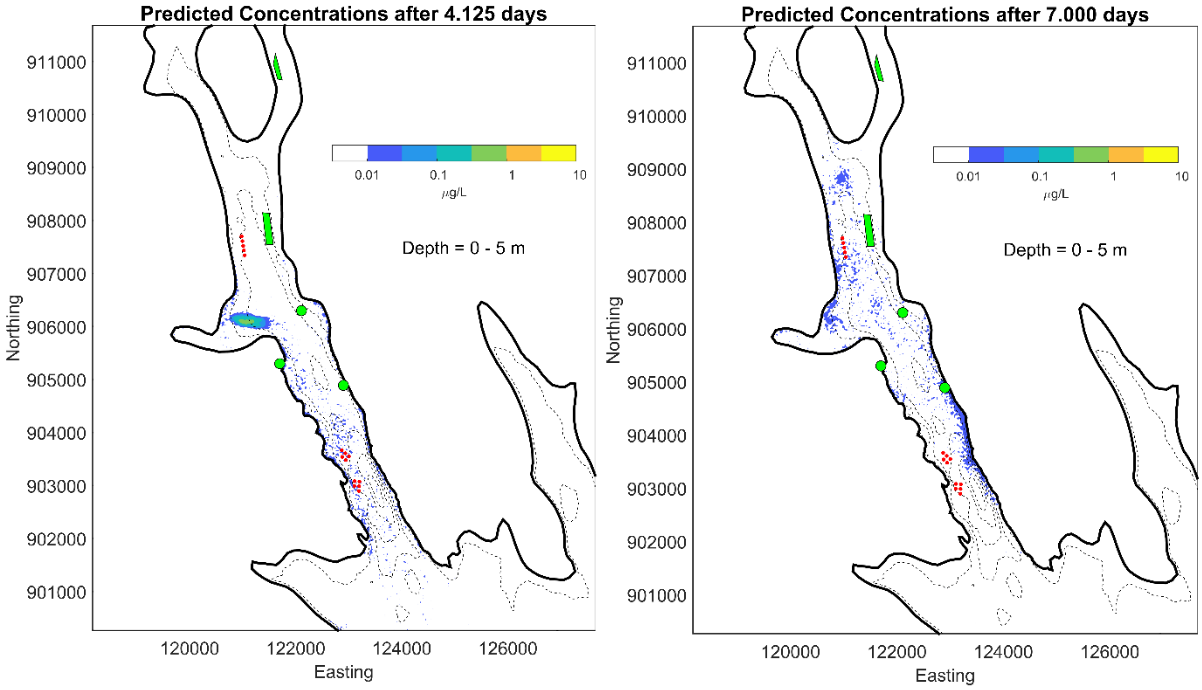

Figure 19. Predicted concentration fields from the run at spring tide (Run 12, Table 4) after 99 hours (3 hours after the final release, left) and after 168 hours (72 hours after the final release, right). The identified special features are marked, including mussel farms (green polygons) and kelp beds (green circles).

4 SUMMARY AND CONCLUSIONS

A total of 27 dispersion simulations have been performed to assess whether bath treatments at Trilleachan Mor salmon farm will comply with pertinent environmental quality standards. A realistic treatment regime, with one pen treatment a day, was simulated. Each pen required 1.018 kg of azamethiphos for treatment, resulting in a maximum daily release from the site of 1.018 kg and a total discharge over 5 days of 5.09 kg. Simulations were performed separately for modelled neap and spring tides, and the sensitivity of the results to key model parameters was tested. Results are summarised in Table 7.

The model results confirmed that the treatment scenario proposed, with a daily release of no more than 1.018 kg, will consistently comply with the EQS. The peak concentration during the baseline simulation after 168 hours (72 hours after the final treatment) was consistently less than 0.1 µg/L, the maximum allowable concentration, and the area where concentrations exceeded the EQS of 0.04 µg/L was substantially less than the allowable 0.5 km^2. In all simulations performed, including some sensitivity testing, the EQS criteria were met. Simulations over two different neap tides from 2020 and 2024 demonstrated that the modelled treatment regime consistently complied with the relevant EQS. For the simulation during spring tides, generally greater dispersion meant that the EQS were met very comfortably. Therefore, we believe that the requested daily quantity of 1.018 kg of azamethiphos per day can be safely discharged without breaching the EQS.

Table 7. Summary of Results

Site details	
Site Name:	Trilleachan Mor
Site Location:	Loch Seaforth
Peak Biomass (T):	2,130
Pen details	
Number of Pens:	5
Pen Circumference (m):	160
Working Depth (m):	20.0
Pen Group Configuration:	2 x 2 + 1
Azamethiphos consent to be applied for	
Recommended 3-hour (kg):	1.018
Recommended 24-hour (kg):	1.018

5 REFERENCES

Chen, C., H. Liu, and R.C. Beardsley, 2003. An unstructured, finite-volume, three-dimensional, primitive equation ocean model: Application to coastal ocean and estuaries. J. Atmos. Ocean. Tech., 20, 159 – 186.

Edwards, A. and Sharples, F., 1986. Scottish Sea Lochs: A Catalogue. Scottish Marine Biological Association, Dunstaffnage, Oban, 242 pp.

Gillibrand, P.A., 2021. UnPTRACK User Guide. Mowi Scotland Ltd., February 2021, 31 pp..

Gillibrand, P.A., Walters, R.A., and McIlvenny, J., 2016. Numerical simulations of the effects of a tidal turbine array on near-bed velocity and local bed shear stress. *Energies*, vol 9, no. 10, pp. 852. DOI: 10.3390/en9100852

Marine Scotland 2016. The Scottish Shelf Model. Marine Scotland. http://marine.gov.scot/themes/scottish-shelf-model

Mowi, 2025. Loch Seaforth Marine Modelling Report. Mowi Scotland Ltd., January 2025, 27 pp.

SEPA, 2023. Interim Marine Modelling Guidance for Aquaculture Applications. Scottish Environment Protection Agency, Air & Marine Modelling Unit, December 2023, 11 pp.

SEPA, 2024. Aquaculture Modelling Screening & Risk Identification Report: TRILLEACHAN MOR (TRM1). Scottish Environment Protection Agency, April 2024, 31 pp.

Walters, R.A.; Casulli, V., 1998. A robust, finite element model for hydrostatic surface water flows. Comm. Num. Methods Eng., 14, 931–940.