20th January 2026

Bath Modelling Report

Vementry

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Summary

Cooke Aquaculture Scotland Ltd. (CAS) have developed a particle tracking model, driven by a decoupled hydrodynamic model, to simulate bath medicine release in the Swarbacks Minn region on the west coast of Shetland. This determines the safe medicinal quantities that are permitted to be used on site, based on concentration and area Environmental Quality Standards (EQS) outlined by SEPA.

A calibrated and validated hydrodynamic model and particle-tracking model, using measured dispersion coefficients from drogue surveys, were used to predict medicine advection and dispersion from the proposed Vementry site. A well boat-based treatment method was applied, using realistic multiple treatment schedules. For Azamethiphos, this simulated a single 3hr treatment mass and 10 treatments with a 3-hour treatment interval and a maximum of 3 treatments per 24hrs. For Deltamethrin and Cypermethrin a single 6-hour treatment was applied.

Maps and EQS results are presented to illustrate the predicted footprint of bath treatment medicines. The results of the bath modelling found that the medicine amounts summarised in table 1 complied with all EQS standards. An assessment of the proposed treatment quantities on identified sensitive marine features was completed. This shows minimum interactions between treatment plumes and sensitive marine features.

Table 1. Summary of site details and bath treatment results

Stocking details	
Maximum biomass (Tonnes)	1,350
Pen Layout	
No. pens	10
layout	2 x 5
Circumference (m)	120
Orientation (°)	295.5
Bath Treatments	
Azamethiphos	
Consent mass – 3hr	145g
Consent mass – 24hr	375g

Cypermethrin	
Consent mass – 6hr (Adjusted)	0.0936g
Deltamethrin	
Consent mass – 6hr	10g

1. Introduction

This report details the results of the simulation of bath treatments within a coupled hydrodynamic and particle tracking model. The description of the hydrodynamic model, the calibration and validation, and the methods of simulating bath treatments are presented in the Modelling Methods Statement. The measurement of the dispersion coefficient that is used within the particle tracking model is described in detail within the Drogue Release report. The results of the bath treatment modelling are used to determine EQS compliance with the latest SEPA standards (SEPA, 2024)

1.1 Site description

Vementry is considered a new potential site to be operated by Cooke Aquaculture Scotland. The site is located off the northeast coastline of Vementry, in Swarbacks Minn, Shetland. The proposed site consists of a single group of 10 circular, 120m circumference pens with a net depth of 21m. These are arranged in a 2 x 5 layout with an 85 m separation, housing a maximum consented biomass of 1350T at a maximum stocking density of 5.61kg/m^3. The site is aligned with a bearing of 295.5º and has a wave exposure index of 3.52. The proposed development adds a new site ~0.3 off the north coastline of Vementry with the site centre located at 430285.52 E, 1161466.97 N as shown in figure 1. Further information on the proposed site infrastructure and pen layout is presented in Table 1.

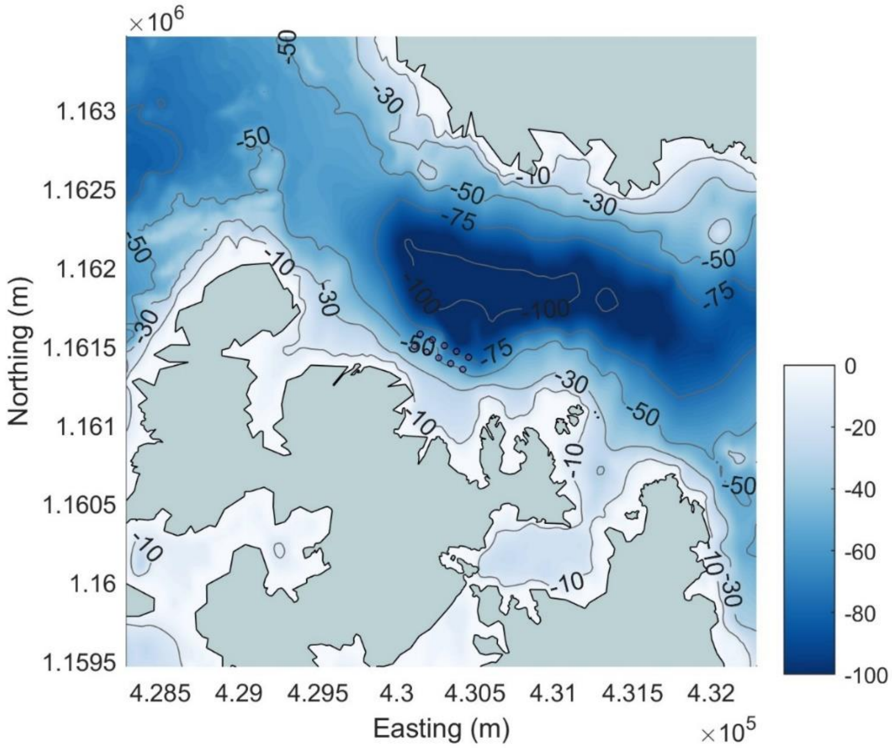


Figure 1. Proposed Vementry site infrastructure and bathymetry.

Table 2 – Existing and proposed site infrastructure and pen layout.

	Vementry (Proposed)
Consent number	-
Company	Cooke Aquaculture Scotland
Receiving water	Swarbacks Minn
Site centre (OSGB36)	430285.52 E, 1161466.97 N
Current meter location (OSGB36)/year of deployment	430307E, 1161464N /2023
Distance to shore (km)	0.3
Average water depth (m)	58.2
Maximum biomass (t)	1350
Total number of pens	10
Number of pen groups	1
Formation	2 x 5
Pen group orientation (°)	295.5
Pen shape	Circular
Pen circumference (m)	120
Mooring grid (m)	85
Net depth	21
Wave exposure index	3.52

1.2 Surrounding Farms and Sensitive Marine Features

The Swarbacks Minn model area hosts 49 shellfish farms and 10 sensitive marine features. Table 3 outlines the additional farms that are included within the cumulative assessment and the marine features that are assessed within this study. These sites were specified in the Screening and Risk Identification Report (SEPA 2024).

Table 3. Sensitive marine features identified within Wide Firth and Shapinsay Sound.

Name	Code	Feature type	Location (OSGB)		Mesh resolution (m)
			East	North	
SS0186 - Westshore	SfF01	Shellfish Farm	429500	1157500	38.6
SS0312 - Bight of Kurkigarth	SfF02	Shellfish Farm	439700	1163500	43.9
SS0500 - Suthra Voe	SfF03	Shellfish Farm	429400	1160400	56.7
SS0588 - North Voe of Clousta	SfF04	Shellfish Farm	430200	1158400	65.2
SS0600 - Bight of Cliffs	SfF05	Shellfish Farm	439100	1164600	51.7
SS0601 - Park Gate	SfF06	Shellfish Farm	438500	1165100	57.0
SS0617 - East of Burki Taing	SfF07	Shellfish Farm	431800	1162700	42.3
SS0641 - Linga	SfF08	Shellfish Farm	435900	1164000	35.3
SS0642 - Quilse	SfF09	Shellfish Farm	438500	1164300	42.7
SS0650 - Seggi Bight	SfF10	Shellfish Farm	429700	1159400	65.6
SS0651 - Papa Little, Aith Voe	SfF11	Shellfish Farm	434100	1160100	37.0
SS0670 - Lee, Busta Voe	SfF12	Shellfish Farm	434500	1164900	38.7
SS0671 - Busta Voe	SfF13	Shellfish Farm	434600	1166200	63.2
SS0672 - Holm of East Burra Firth	SfF14	Shellfish Farm	435300	1157800	54.1
SS0677 - Foula Wick	SfF15	Shellfish Farm	437000	1164800	41.3

SS0679 - Wrawick	SfF16	Shellfish Farm	432700	1167000	37.9
SS0696 -West Side of Aith Voe	SfF17	Shellfish Farm	434400	1157000	42.9
SS0698 - Grunigill	SfF18	Shellfish Farm	428800	1156700	70.6
SS0699 - Pynch Dyke	SfF19	Shellfish Farm	436600	1164700	38.9
SS0704 - Point of Sletta Aith Voe	SfF20	Shellfish Farm	434200	1158800	33.7
SS0715 - Uyeasound, Vementry	SfF21	Shellfish Farm	428900	1159200	62.9
SS0723 - Treawick	SfF22	Shellfish Farm	433500	1161600	34.2
SS0724 - The Ham, Papa Little	SfF23	Shellfish Farm	433200	1163100	36.2
SS0725 - Boat Geo	SfF24	Shellfish Farm	431900	1160600	35.8
SS0726 - Braganess	SfF25	Shellfish Farm	435400	1162400	37.9
SS0727 - Cole Ness Shellfish	SfF26	Shellfish Farm	434800	1158600	33.5
SS0757 - Slyde (Aith Voe)	SfF27	Shellfish Farm	434400	1164200	37.9
SS0758 - North Knowe	SfF28	Shellfish Farm	430500	1160800	28.5
SS0768	SfF29	Shellfish Farm	433300	1159500	32.0
SS0769 - North East of Aithness	SfF30	Shellfish Farm	428700	1158300	58.3
SS0778 - Longa Ness	SfF31	Shellfish Farm	434100	1163600	48.8

SS0781 - Budda Scord	SfF32	Shellfish Farm	435700	1165800	57.3
SS0782 - Hevden Ness	SfF33	Shellfish Farm	435500	1164500	41.0
SS0783 - North Linga	SfF34	Shellfish Farm	435800	1164700	40.5
SS0784 - Wetherstaness	SfF35	Shellfish Farm	431200	1160700	33.1
SS0808 - Holms of Uyeasound	SfF36	Shellfish Farm	428500	1157500	79.4
SS0838 - Brindister Inshore	SfF37	Shellfish Farm	431200	1160000	40.6
SS0843 - Mill Bight	SfF38	Shellfish Farm	434200	1160900	41.5
SS0855 - Bight of Warwick	SfF39	Shellfish Farm	434700	1162300	36.9
SS0856 - Houbanster	SfF40	Shellfish Farm	434700	1160600	35.6
SS0857 - Millburn	SfF41	Shellfish Farm	433000	1160200	33.1
SS0864 - Moo Ness	SfF42	Shellfish Farm	428500	1159800	58.7
SS0869 - Gruna	SfF43	Shellfish Farm	429100	1161400	28.7
SS0870 - Northra Voe	SfF44	Shellfish Farm	429500	1158500	63.2
SS0903 - Crossroads	SfF45	Shellfish Farm	428400	1158700	77.8
SS0904 - Skewart Holm (Linga)	SfF46	Shellfish Farm	434500	1156800	52.4
SS0906 - Aith Voe West	SfF47	Shellfish Farm	436600	1163400	42.7
SS0914 - West of Grobsness	SfF48	Shellfish Farm	434400	1156000	41.2
SS0915 - Brakkatun Beach	SfF49	Shellfish Farm	428900	1159200	62.9

Kelp Beds	KB01	PMF	429492	1164721	53.8
	KB02	PMF	430730	1162602	31.9
	KB03	PMF	429092	1162142	30.8
	KB04	PMF	431190	1160396	36.8
	KB05	PMF	430527	1167164	66.9
Horse Mussel	HM01	PMF	434994	1163509	39.0
	HM02	PMF	435549	1162602	36.9
Kelp and Seaweed Communities	KaSC01	PMF	435062	1163672	28.4
	KaSC02	PMF	434994	1163496	38.5
	KaSC03	PMF	435299	1163340	34.4

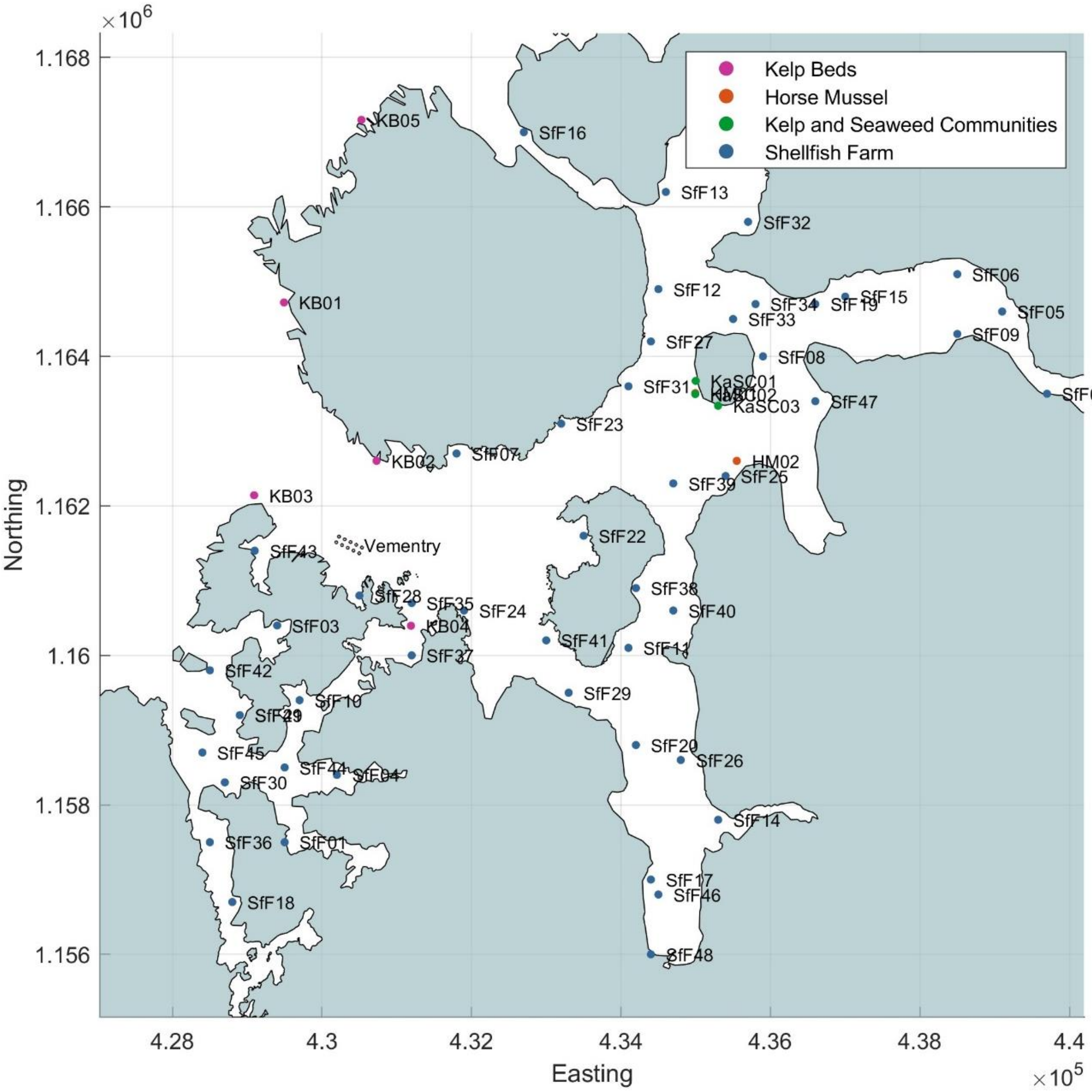


Figure 2. Farm location and sensitive marine features identified within Swarbacks Minn and surrounding waters.

2. Model Description

This study uses DHI's MIKE3 flexible mesh model to simulate free-surface flow in a coastal environment. The model uses an unstructured mesh to replicate tidal hydrodynamics, wind and wave-driven currents, and storm surges.

2.1 Hydrodynamic model

DHI's MIKE3 flexible mesh model solves the three-dimensional incompressible Reynolds averaged Navier-Stokes equations, using the Boussinesq and hydrostatic pressure assumptions to simulate 3D hydrodynamics over the coastal domain of interest. Continuity of momentum, temperature, salinity and density are applied alongside the k-epsilon turbulent closure scheme. A cell centred finite volume approach is applied for the spatial discretisation of the momentum equations over an unstructured triangular mesh.

2.1.1 Model domain

The model domain is created using the Cartesian Ordnance Survey of Great Britain 1936 coordinate system (OSGB 1936). Coastline data is imported from Ordnance Survey (2024) and is used to define the land boundaries within the domain. Bathymetry data are taken from the UK Hydrographic Office (UKHO 2021). A flexible mesh is applied where the peripheries of the model domain have a coarse resolution, with an approximate cell spacing of 250m. The mesh resolution for all identified farms and sensitive marine features is specified in table 1, where the area within Swarbacks Minn has a maximum mesh resolution of 1225-2000m^2 (35-45m). Due to the close proximity of finfish, shellfish and marine features in Swarbacks Minn, an extended area of increased mesh resolution was used. The computational mesh is shown in figure 2, with an enlarged view of the identified areas of interest.

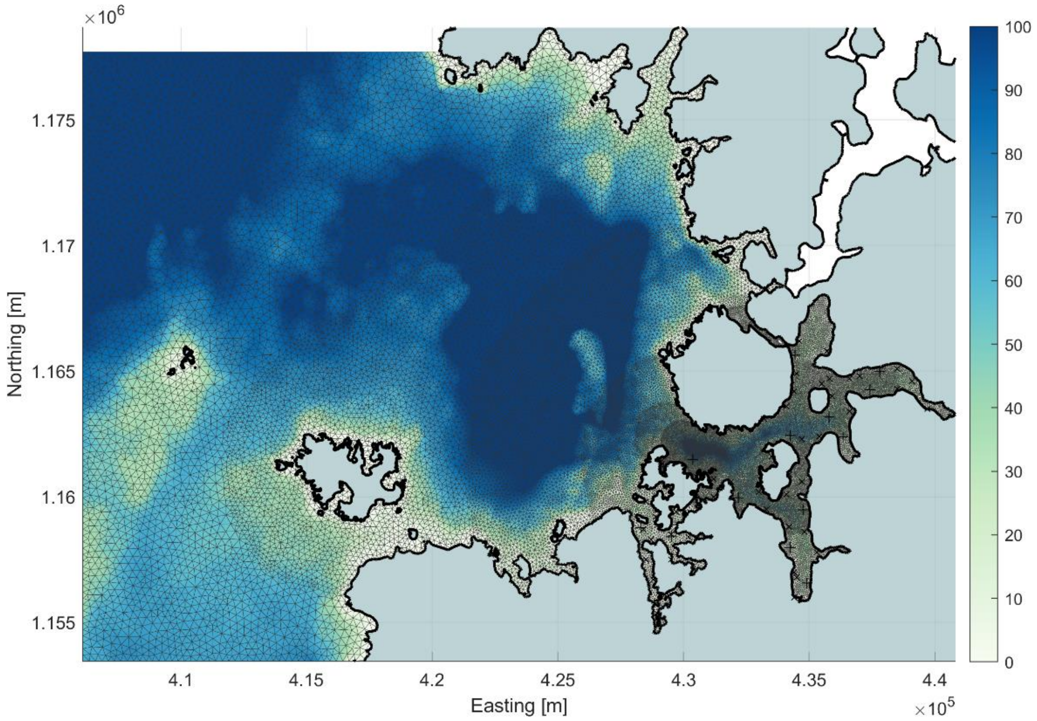


Figure 2. Hydrodynamic model mesh around the proposed Vementry site and wider Swarbacks Minn area.

2.1.2 Configuration and boundary forcing

Boundary conditions are taken from E.U Copernicus Marine Service Atlantic - European North West Shelf - Ocean Physics Analysis and Forecast (CMEMS, 2025). This is taken from a larger scale domain consisting of 50 depth layers and a horizontal resolution of 0.027° at a 15-minute time step. Surface elevation output was interpolated onto boundary nodes on the smaller-scale mesh shown in figure 3. Wind data was taken from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 model (ECMWF 2025). This provides wind velocity in U and V components, as well as surface pressure, with a resolution of 0.25°x. 0.25° at a 3-hourly interval.

A 2-dimensional domain is proposed with a time step interval of 60 s. Outputs are specified with point data frequency of 10 min (600s) and area data outputs at 60 min (3600s) intervals. The model is run for 365 days, plus an additional 5 days to allow the hydrodynamic model to stabilise. The governing equations use the shallow water equations with high order time integration and spatial discretisation. Minimum and maximum timesteps were relaxed to 0.01s and 60s with a critical CFL number of 0.95. This has minimal effects to the output values but reduces computational time. Flooding and drying were included, with a drying depth of 0.005 and a wetting depth of 0.1. The horizontal eddy viscosity applies Smagorinsky’s formulation with a constant value of 0.15.

Bed roughness is specified in the form of the Manning number and is used as the main calibration term for the HD model. The best result applies a uniform value of 20 $m^{1/3}/s$ over the entire domain.

2.2 Particle tracking model

Particle release is simulated using DHI’s MIKE 3 particle tracking model. This is run offline from the hydrodynamic model to reduce computational time. The time step remains identical to that used within the hydrodynamic model. However, the simulation start time is located out with the hydrodynamic model warm-up period and coincides with bath treatments finishing on the user-defined spring and neap tides. A 3D domain is applied with 10 sigma layers in the vertical plane.

2.2.1 Particle Configuration

As treatment chemicals decay when dissolved in aqueous solution, particle decay is included within the model. This decay is specified as the chemical half-life ($t_{1/2}$). This is used to calculate the mean lifetime of the chemical (τ), which is specified within the model as the maximum particle age.

$$\tau = \frac{t_{1/2}}{\ln(2)}$$

To specify the particle decay within the model, the half-life must be converted to decay rate (λ). This is calculated as

$$\lambda = \frac{0.693}{t_{1/2}}.$$

For Azamethiphos, a half-life of 5.6 days is specified. This corresponds to a mean particle lifetime of 8.08 days with a decay rate of $1.43x10^{-6}$ /s. For Cypermethrin and Deltamethrin, no chemical half-life is available, no chemical decay is simulated for these treatments.

As chemical treatments are dissolved, particle settling within the model was switched off and the erosion critical shear stress was set to 0 N/m^2. The horizontal dispersion coefficients used the measured value of $0.0531m^2/s$ calculated in the Drogue Release report. The vertical dispersion coefficient used the default value of $0.001m^2/s$.

2.2.2 Particle Source

For each bath treatment option, a series of model runs was carried out using a tarpaulin-style treatment.

2.2.2.1 Tarpaulin Release

To simulate a tarpaulin-based treatment method, particles are emitted instantaneously from an area source. This is similar to the real treatment process, where once the treatment is complete, the tarpaulin is removed from the reduced volume pen, and the treatment solution is immediately released. To account for the variability in the treatment release location associated with each individual pen treatment, all treatments are released from the site centre. Particles are released at a depth of 2.5m below the surface with a layer thickness that extends from the surface to a depth of 5m.

To realistically simulate the tarpaulin treatment process, particles were released instantaneously from a volume source within the particle tracking model. A diagram of this is shown in figure 3. For the assessment of the long-term treatment program where multiple treatments are considered, particle releases were simulated at a 3hr interval with a maximum of 3 treatments per day. At the end of each treatment, the treatment solution is instantaneously released into the environment over a single model timestep. The number of particles assigned to each treatment is constant, this uses 30,000 particles per treatment. Outputs of particle concentration are assessed using particles within the top 5m of the water column.

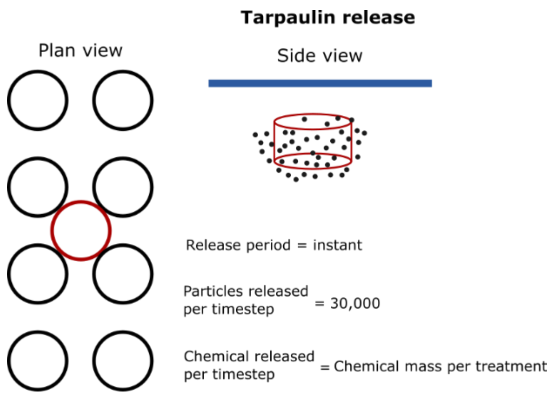


Figure 3. Tarpaulin release schematic. Open black circles represent pen locations, particle source location is shown in red, the blue line represents the sea surface, and small black dots represent particles.

2.2.3 Treatments

The maximum number of treatments is restricted to three per working day (9-hour window). This is the maximum number of treatments that could feasibly be conducted during a single representative day. Each treatment within a day is separated by a 3-hour treatment interval. This allows time for treatments to take place, waste medicine discharge and resetting of equipment ready for the next treatment.

For Azamethiphos, the chemical plume area exceeding the EQS threshold for 72 hours after the final treatment was used to explore the site's potential environmental capacity. For Cypermethrin and Deltamethrin, the chemical plume area exceeding the EQS threshold for 6-hours after the initial treatment was assessed. To monitor the likely most and least dispersive cumulative EQS scenarios, the final treatment for Azamethiphos and the initial treatment for Deltamethrin and Cypermethrin were chosen to coincide with highwater of the smallest neap tide and the largest spring tide. This provides a treatment time of 20/03/2024 05:45:00 during a neap tide and 12/03/2024 10:05:00 during a spring tide. Timings of each bath model run are shown in figures 4 and 5 and outlined in table 3.

Table 3. Simulation times for particle tracking model for bath treatments.

	Simulation start date	Last treatment date	Simulation end date	Time after final treatment (hrs)
Azamethiphos (3hrs)				
Neap	19/03/2024 05:45:00	20/03/2024 05:45:00	24/03/2024 06:45:00	97
Spring	11/03/2024 10:05:00	12/03/2024 10:05:00	16/03/2024 11:05:00	97
Azamethiphos (72hrs)				
Neap	17/03/2024 10:00:00	20/03/2024 05:45:00	24/03/2024 06:45:00	97
Spring	09/03/2024 10:00:00	12/03/2024 10:05:00	16/03/2024 11:05:00	97
Cypermethrin/Deltamethrin				
Neap	19/03/2024 05:45:00	20/03/2024 05:45:00	21/03/2024 12:45:00	31

Spring	11/03/2024 10:05:00	12/03/2024 10:05:00	13/03/2024 17:05:00	31

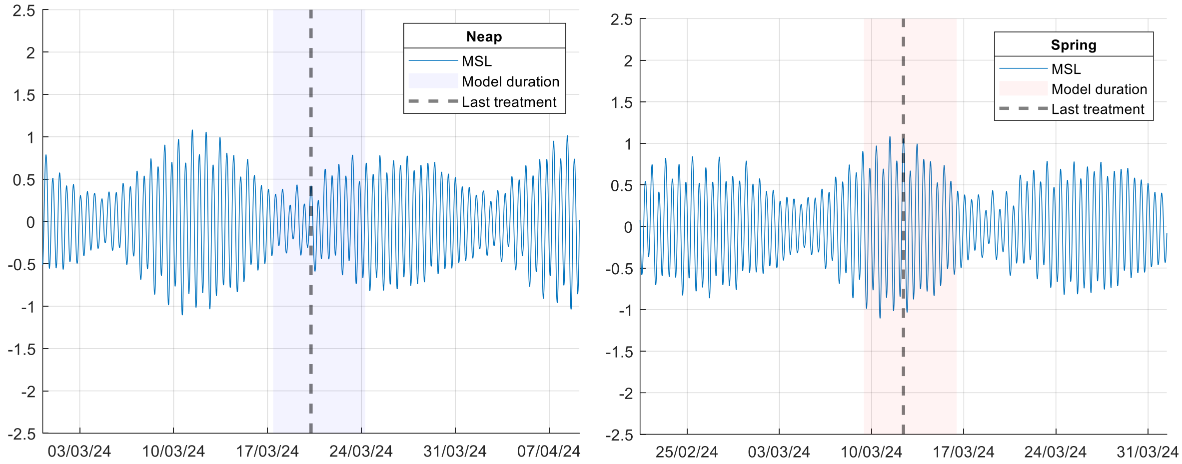


Figure 4. Mean sea level for Neap (left) and Spring (right) tides, indicating model simulation duration for Azamethiphos (72hrs) with the final treatment time indicated using the dashed line.

To assess the short-term risk of Azamethiphos, a single release of the 3-hour treatment mass was modelled. The areal extent of the chemical plume captured 3-hours after the first release time was used to determine short-term EQS compliance. To assess long-term risks from Azamethiphos, an entire treatment regime was modelled, encompassing the treatment of all pens within the proposed farm. The maximum chemical concentration and areal extent of the chemical plume captured 72-hours after the final release time was used to determine long-term EQS compliance.

To assess the risk of Deltamethrin and Cypermethrin, a 6-hour treatment mass was modelled. The areal extent of the chemical plume captured 6-hours after the release time was used to determine EQS compliance.

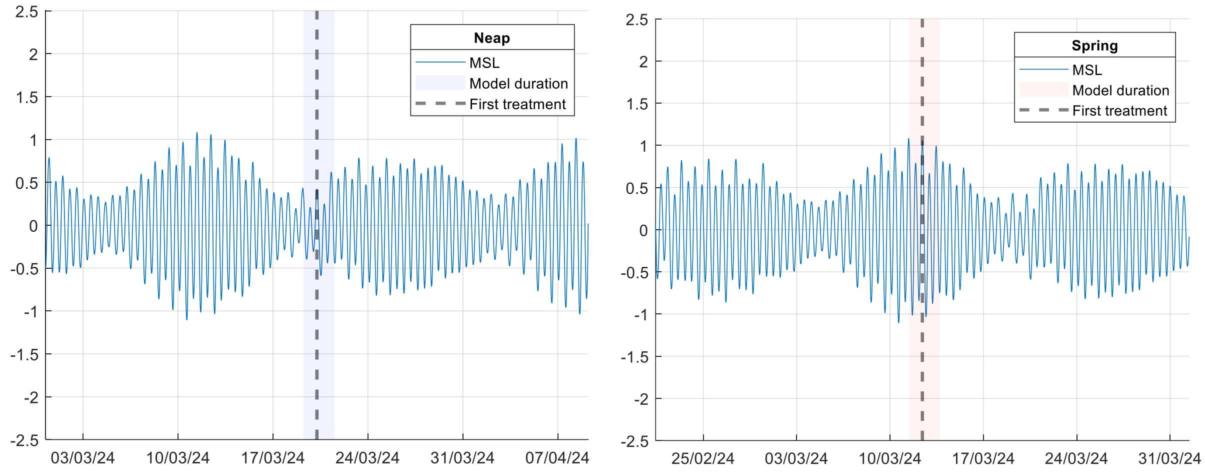


Figure 5. Mean sea level for Neap (a) and Spring (b) tides indicating model simulation duration for Cypermethrin and Deltamethrin with the initial treatment time indicated with the dashed line.

The particle tracking model was run for the treatment period, plus an additional 24 hours after the last EQS time – i.e., 96 hours after the last treatment for Azamethiphos and 30 hours after the last treatment for Deltamethrin and Cypermethrin. This ensures no further EQS standards are exceeded.

2.2.4 Environmental Standards (EQS)

To determine the quantity of chemical used, a hydrodynamic and particle tracking model simulates the chemical release and plume advection. The area coverage and concentration are then monitored to ensure they remain within acceptable tolerances. These environmental quality standards are outlined in SEPA (2024) for Azamethiphos, Cypermethrin and Deltamethrin treatments (table 4). The EQS determines the concentration of the plume area, that must not exceed a site-specific mixing area (A). For the 3- and 6- hour EQS this area is defined as a function of mean current speed (U), time (t) and the horizontal dispersion coefficient (K_X). Mathematically, this is represented as:

$$A = 2\pi \frac{Ut}{2} \sqrt{(2K_x t)}$$

Current meter data from Vementry reveal a mean near-surface current speed of 0.045m/s over the period 31/10/2023 to 29/01/2024, which gives a 3-hour EQS area of 0.0517km^2 and a 6-hour EQS area of 0.1463km^2. The 72-hour EQS area is not site specific and is assigned a constant value of 0.5km^2.

Additionally, for Azamethiphos a Maximum Allowable Concentration (MAC) is applied. This restricts the peak chemical concentration within the domain after the given time interval. This is not required for Cypermethrin and Deltamethrin.

The 3- and 6- hour EQS restrictions are applied to ensure the short-term compliance of a chemical release. Therefore, these times are referenced to the hours after the chemical discharge of a single, initial treatment event. The 72-hour EQS ensures the long-term compliance of bath chemical use, therefore is applied 72 hours after the final treatment of a full site treatment cycle.

Table 4. Environmental standards for chemical treatments.

	EQS (ng/l)			MAC (ng/l)
	3hrs	6hrs	72hrs	72hrs
Azamethiphos	250	-	40	100
Cypermethrin*	-	16	-	-
Deltamethrin	-	6	-	-
*Quantities of Cypermethrin passing EQS, as shown above, will be reduced by a factor of 267 to comply with SEPA (2018).				

3. Results

3.1 Bath Treatments

The simulation of bath treatments from the proposed site was considered. This looks at the release of Azamethiphos, Cypermethrin and Deltamethrin and the dilution of the chemical plume in relation to the EQS standards. The individual EQS parameters are summarised in table 5. This indicates compliance is achieved with all proposed chemical treatments.

Table 5. Environmental standards for tarpaulin treatment release MAC and area EQS for all treatments at Vementry.

	Treatment Quantity (g)	**MAC 72 hrs (µg/l)**	**EQS 3hrs - Single Treatment (km^2)**	**EQS 6hrs (km^2)**	**EQS 72hrs (km^2)**
Azamethiphos (3hrs)					
Neap	145	-	0.036 (69.7%)	-	-
Spring	145	-	0.031 (59.0%)	-	-

Azamethiphos (24hrs)					
Neap	375	0.0779 (77.9%)	-	-	0.428 (85.7%)
Spring	375	0.0911 (91.1%)	-	-	0.030 (0.59%)
Cypermethrin					
Neap	25	-	-	0.078 (53.1%)	-
Spring	25	-	-	0.073 (50.2%)	-
Deltamethrin					
Neap	10	-	-	0.078 (53.1%)	-
Spring	10	-	-	0.075 (51.01%)	-

3.1.1 Azamethiphos

Compliance was achieved at the proposed Vementry site using 145g of Azamethiphos within 3 hours or 375g within 24 hours. This equates to 125g per pen, assuming three treatments per day with a 3-hour interval. This corresponds to a repeated treatable volume of 1250 m^3 per 3 hours.

3.1.1.1 Neap tides

3hr Consent Limit
To assess the short-term compliance for Azamethiphos, a single release of a 3-hour mass (145g) is modelled in isolation. The size of the 3-hour EQS plume following this initial release (0 hours on the x axis) is shown in figure 6. The size of the chemical plume after a single treatment always remains less than the calculated mixing area of 0.051708km^2.

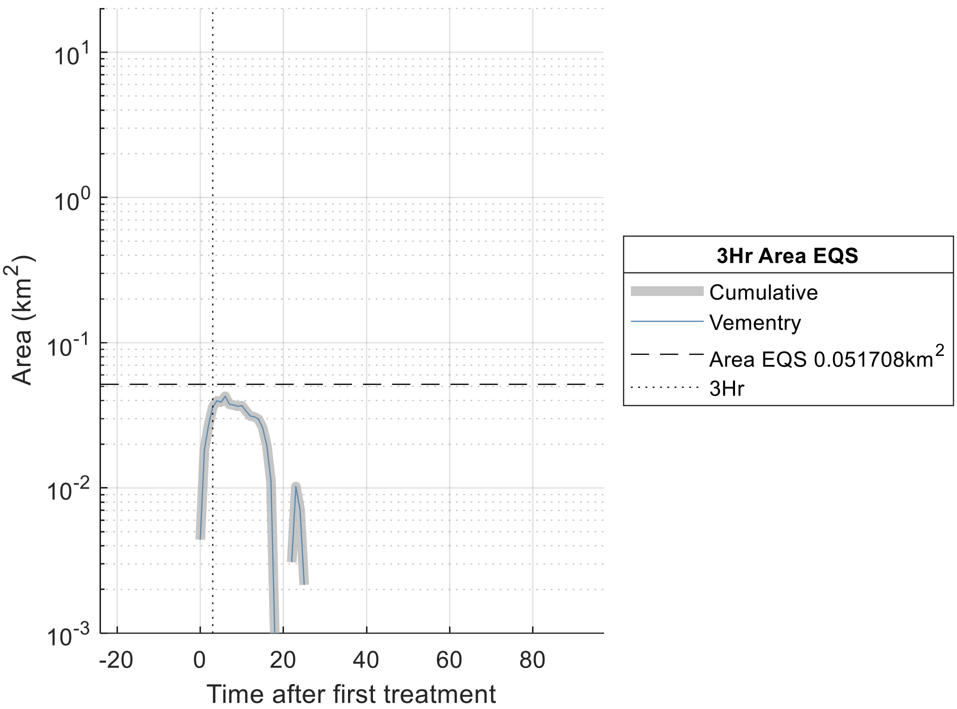


Figure 6. Chemical plume area exceeding the 3-hour (250 ng/l) EQS value after the initial 3-hour mass release of Azamethiphos during neap tides. The size of the 3-hour EQS mixing zone is shown by the horizontal dashed line. 3 hours after the initial treatment is marked by the vertical dotted line.

24hr Consent Limit

To determine the 24-hr treatment mass (375g), repeated treatments are considered using a realistic treatment pattern where compliance is assessed against the 72hr MAC and area EQS. This uses a repeated treatment mass of 125g. The MAC for the neap tidal cycle is plotted in figure 7. Time, on the x-axis, is referenced as hours since the final treatment event, aiding the interpretation of EQS times. Immediately following the introduction of chemical particles into the model domain, decay and dispersion cause a rapid reduction in concentrations, resulting in sharp peaks of chemical quantity as individual pens are treated. At 72 hours after the final treatment, the concentration from the proposed Vementry site is 0.0779µg/l, which is 77.9% of the EQS value. Following this, the concentration continues to steadily decline, as the treatment plume decays and disperses. A general decline in concentration is observed over the remainder of the model run period.

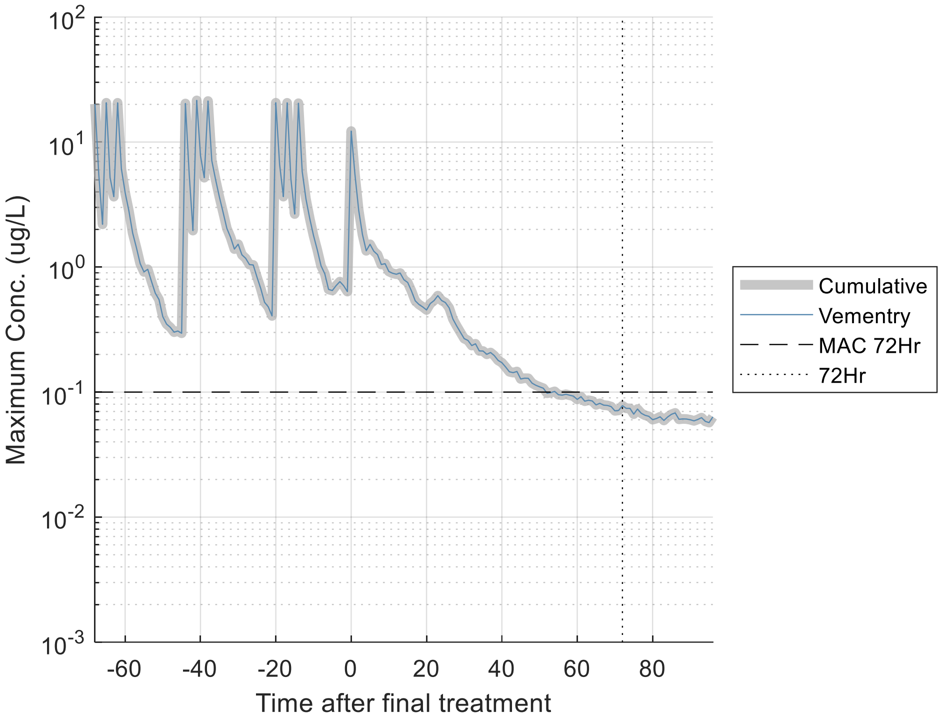


Figure 7. Maximum concentration of Azamethiphos during a neap tide treatment schedule. Cumulative impact plotted as solid grey line and MAC for the 72-hour EQS (100 ng/l) is indicated by the grey dashed line. 72-hours after the final treatment is marked by the vertical dotted line.

The area of the chemical plume exceeding 40ng/l (72-hour EQS) is plotted in figure 8. At the 72-hour EQS time, the area is below the EQS area and continues to decline.

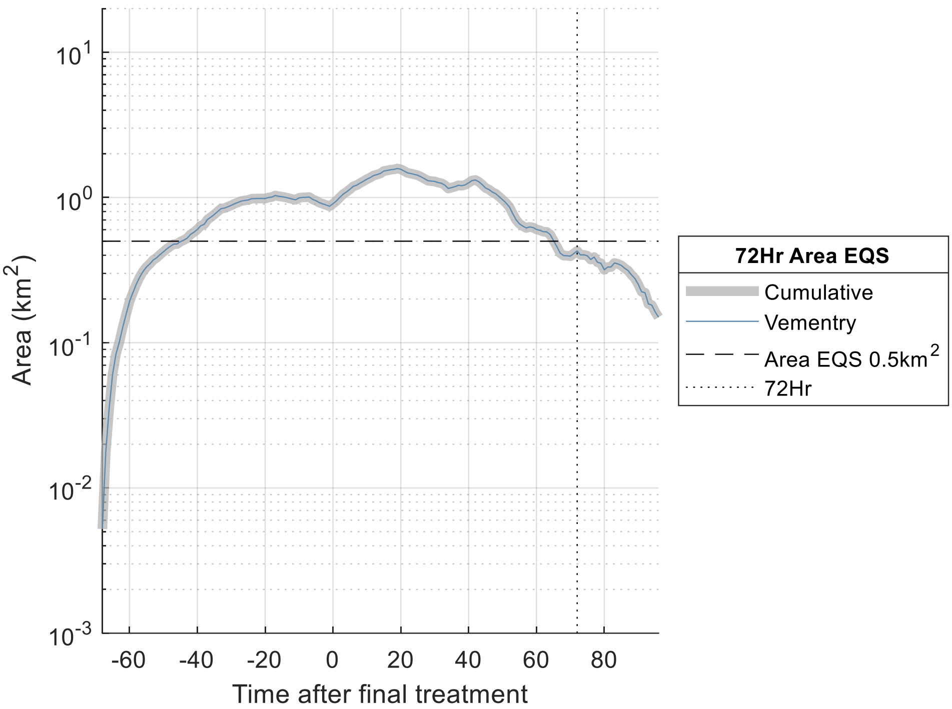


Figure 8. Chemical plume area exceeding the 72-hour (40 ng/l) EQS values after a treatment cycle using Azamethiphos during neap tides. The size of the 72-hour EQS mixing zone is shown by the horizontal dashed line. 72-hours after the final treatment is marked by the vertical dotted line.

The spatial distribution of Azamethiphos after the final release of bath treatment from the proposed site during neap tides is shown in figure 9. The areas where concentrations exceed the 72-hour EQS values are outlined in red. This indicates that the main plume remains relatively localised to the site and is dispersed evenly through the oscillations of the tides over the 72hr window.

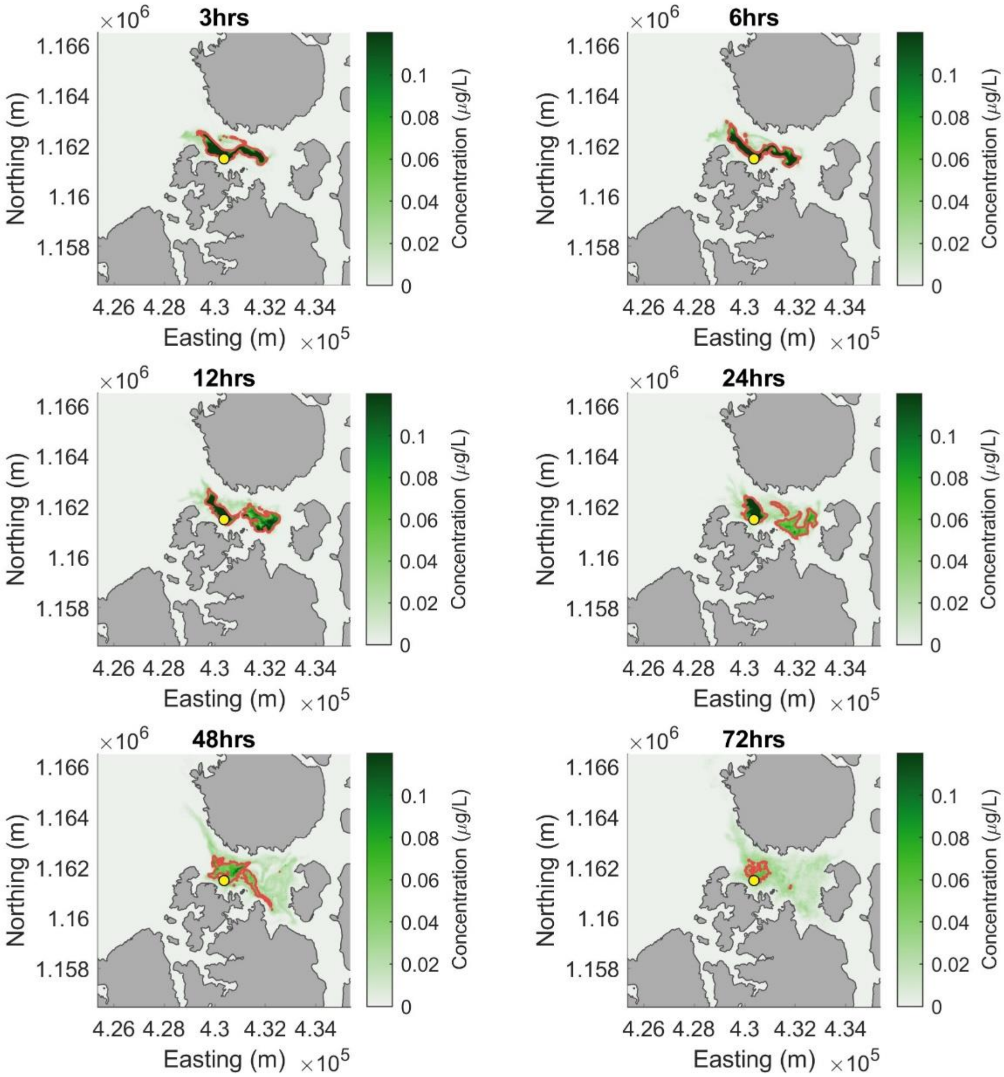


Figure 9. Spatial Azamethiphos distribution for releases during neap tides 3hrs to 72 hrs after the last treatment event. Areas above EQS values are indicated within the red contour and site location is identified using a yellow marker.

3.1.1.2 Spring tides

3hr Consent Limit

To assess the short-term compliance for Azamethiphos, a single release of a 3-hour mass (145g) is modelled in isolation. The size of the 3-hour EQS plume following this initial release (0 hours on the x axis) is shown in figure 10. The size of the chemical plume after a single treatment always remains less than the calculated mixing area of 0.051708km^2.

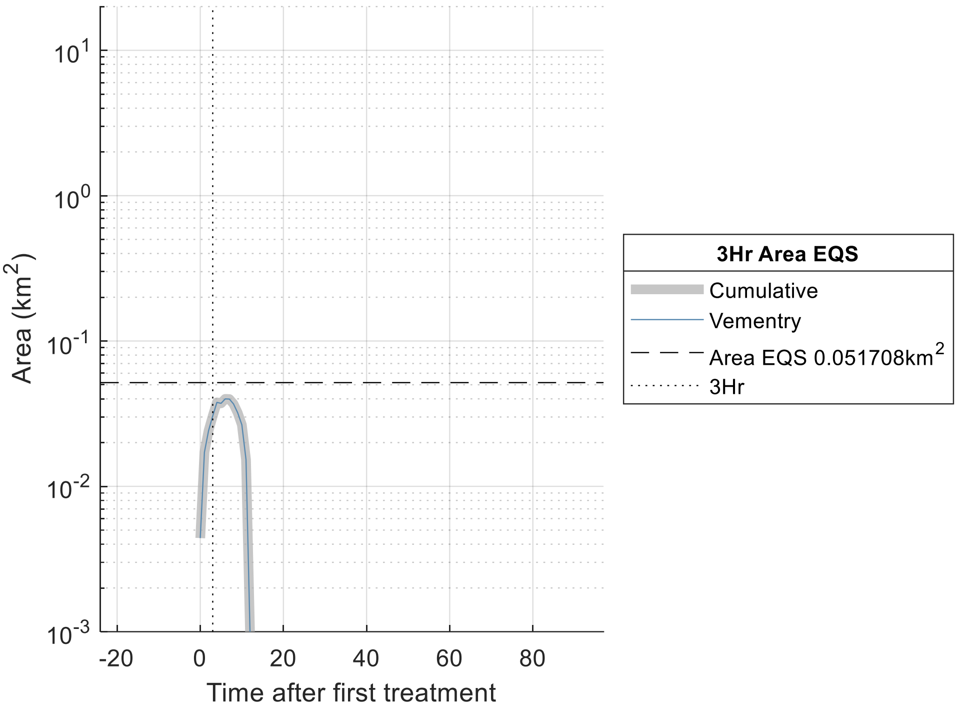


Figure 10. Chemical plume area exceeding the 3-hour (250 ng/l) EQS value after the initial 3-hour mass release of Azamethiphos during spring tides. The size of the 3-hour EQS mixing zone is shown by the horizontal dashed line. 3-hours after the initial treatment is marked by the vertical dotted line.

24hr Consent Limit

To determine the 24-hr treatment mass (375g), repeated treatments are considered using a realistic treatment pattern where compliance is assessed against the 72hr MAC and area EQS. This uses a repeated treatment mass of 125g. The MAC for the neap tidal cycle is plotted in figure 11. Time, on the x-axis, is referenced as hours since the final treatment event, aiding the interpretation of EQS times. Immediately following the introduction of chemical particles into the model domain, decay and dispersion cause a rapid reduction in concentrations, resulting in sharp peaks of chemical quantity as individual pens are treated. At 72 hours after the final treatment, the concentration from the proposed Vementry site is 0.091µg/l, which is 91.1% of the EQS value. Following this, the concentration increases slightly but does not exceed the EQS value of 0.1µg/l. After this peak, a general decline in concentration is observed over the remainder of the model run period.

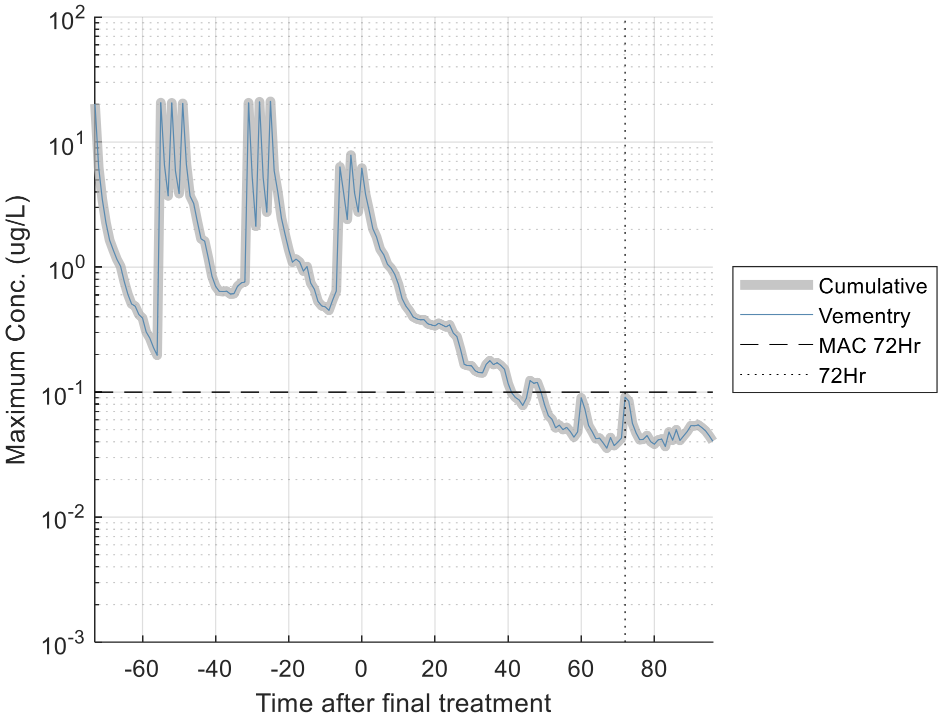


Figure 11. Maximum concentration of Azamethiphos during spring tide releases. Cumulative impact plotted as a solid grey line, and MAC for the 72-hour EQS (100 ng/l) is indicated by the grey dotted line. 72-hours after the final treatment is marked by the vertical dotted line.

The area of the chemical plume exceeding 40ng/l (72-hour EQS) is plotted in figure 12. At the 72-hour EQS time, only very small areas of the treatment plume still exist with concentrations above 40ng/l. By this point, the plume is well dispersed and fragmented and decreasingly exceeds the 40ng/l threshold.

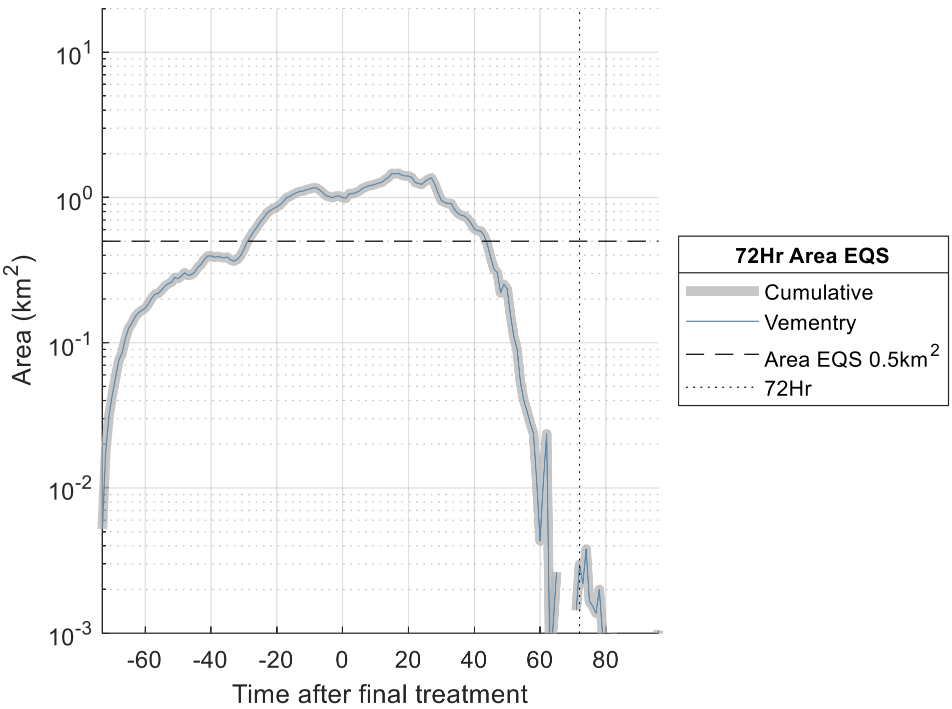


Figure 12. The chemical plume area exceeding the 72-hour (40 ng/l) EQS values after release of Azamethiphos during spring tides. The size of the 72-hour EQS mixing zone is shown by the horizontal dashed line. 72-hours after the final treatment is marked by the vertical dotted line.

The spatial distribution of Azamethiphos during spring tides is shown in figure 13. Within the first 24hrs treatment plumes begin to disperse around the farm location. After 48 and 72hrs, the concentration drops below the threshold value of 0.01µg/l. The distribution of this dispersion occurs to the west of the site and outside of the Swarbacks Minn waterbody.

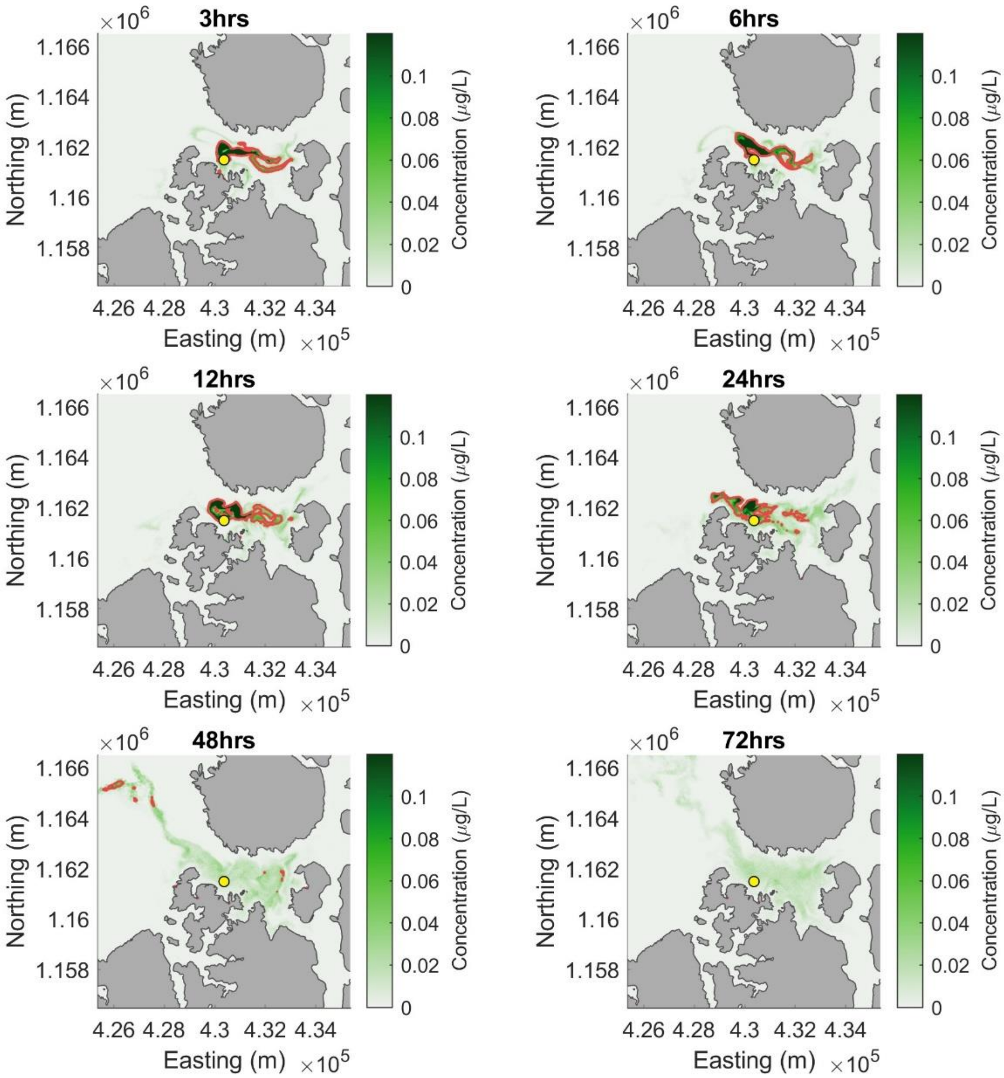


Figure 13. Spatial Azamethiphos distribution for releases during spring tides 3hrs to 72 hrs after the last treatment event. Areas above EQS values are indicated within the red contour and site location is identified using a yellow marker.

3.1.2 Cypermethrin

Environmental compliance was achieved at the proposed Vementry site using 25g of Cypermethrin in a single treatment. A reduction factor of 267 is applied to the compliant chemical quantity to achieve the actual consent mass. This provides a recommended consent mass of 0.0468g. This provides a treatment volume of 9.36 m^3 per 6 hours.

3.1.2.1 Neap tides

The area of the chemical plume, 6 hours after the single treatment release period, that exceeds a concentration of 16ng/l (6hr EQS threshold) is plotted in figure 14. The 6-hour EQS time is applied relative to the first chemical release and is illustrated in the figure by the vertical dotted line. The size of the chemical plume originating from Vementry after a 6-hour mass treatment release remains less than the calculated mixing area 0.60327km^2 throughout the model run.

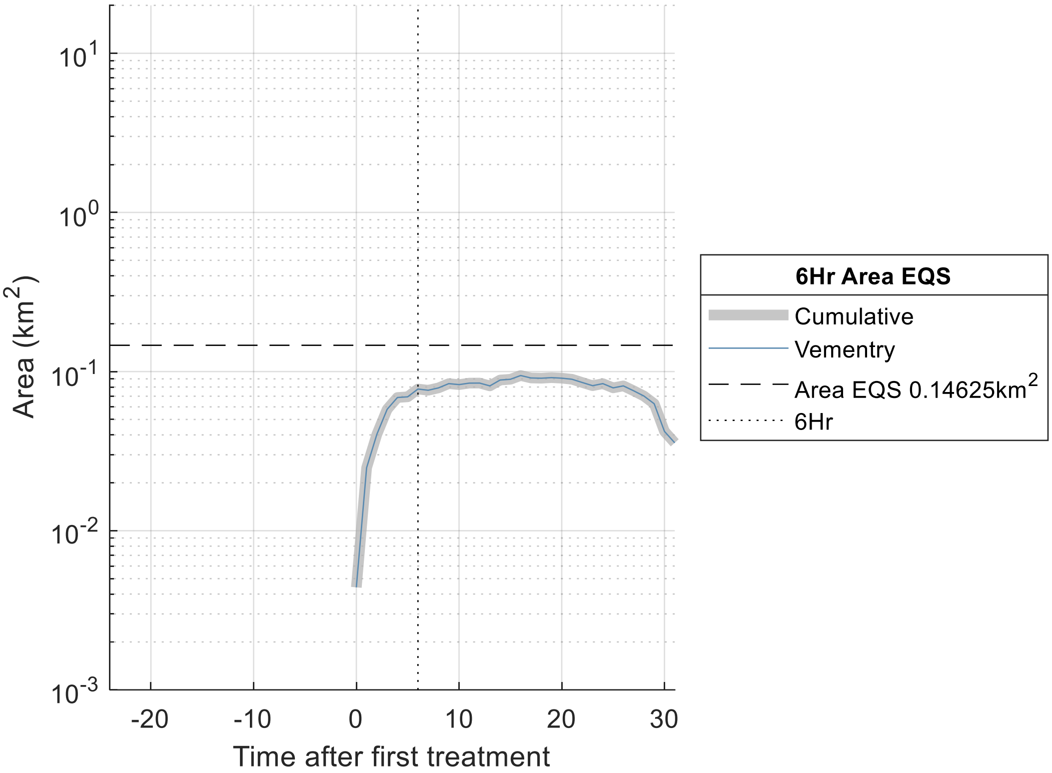


Figure 14. Chemical plume area exceeding the 6-hour (16 ng/l) EQS value after the initial 6-hour mass (25g) release of Cypermethrin during neap tides. The size of the 6-hour EQS mixing zone is shown by the horizontal dashed line. 6-hours after the initial treatment is marked by the vertical dotted line.

The spatial distribution of Cypermethrin 6 hours after the first release of bath treatments during a neap tide is shown in figure 15. The areas where concentrations exceed the 6-hour EQS concentration are outlined in red. After 6-hours, the chemical plume is shown to be heading northwest of the south.

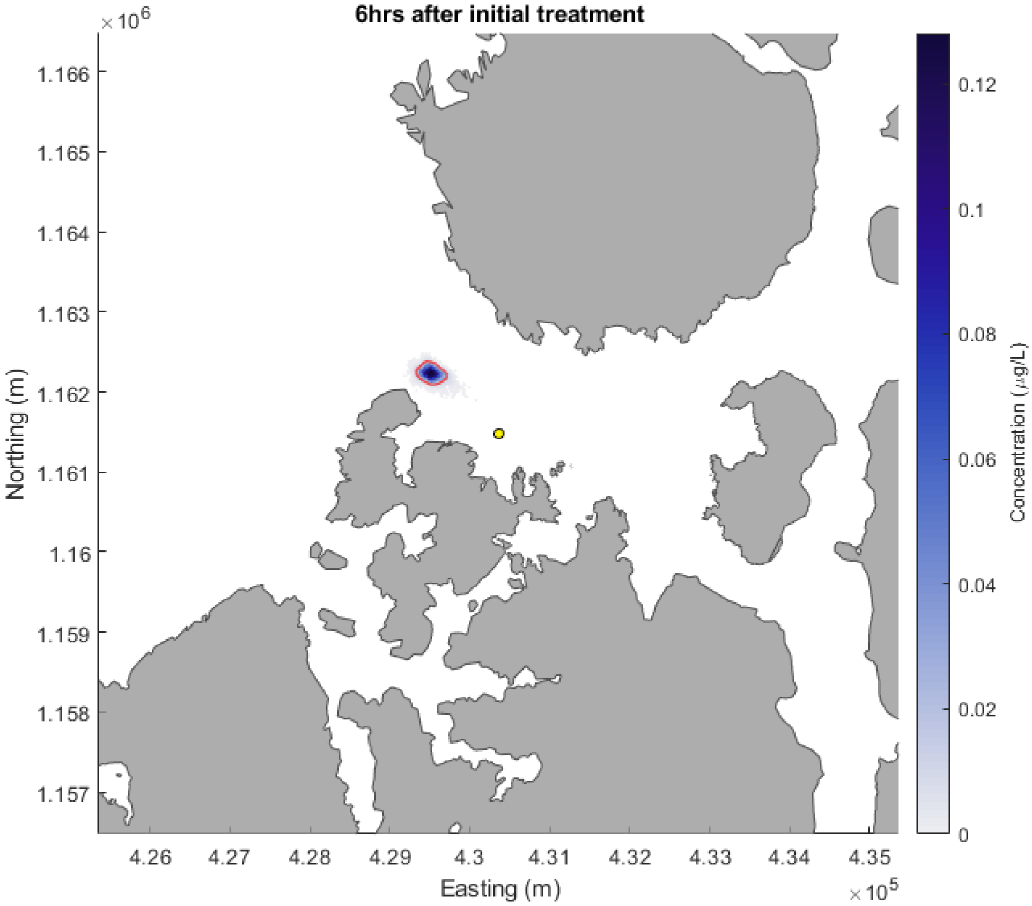


Figure 15. Spatial Cypermethrin distribution for a release during neap tides 6hr after the treatment event. Areas above EQS values are indicated within the red contour, and site locations are identified using a yellow marker.

3.1.2.2 Spring tides

The area of the chemical plume, 6 hours after the treatment release period, that exceeds a concentration of 16ng/l (6hr EQS threshold) is plotted in figure 16. The 6-hour EQS time is applied relative to the chemical release and is illustrated in the figure by the vertical dotted line. The size of the chemical plume originating from Vementry peaks at 0.095km^2 13 hours after the first treatment release period and remains below the 6hr EQS value.

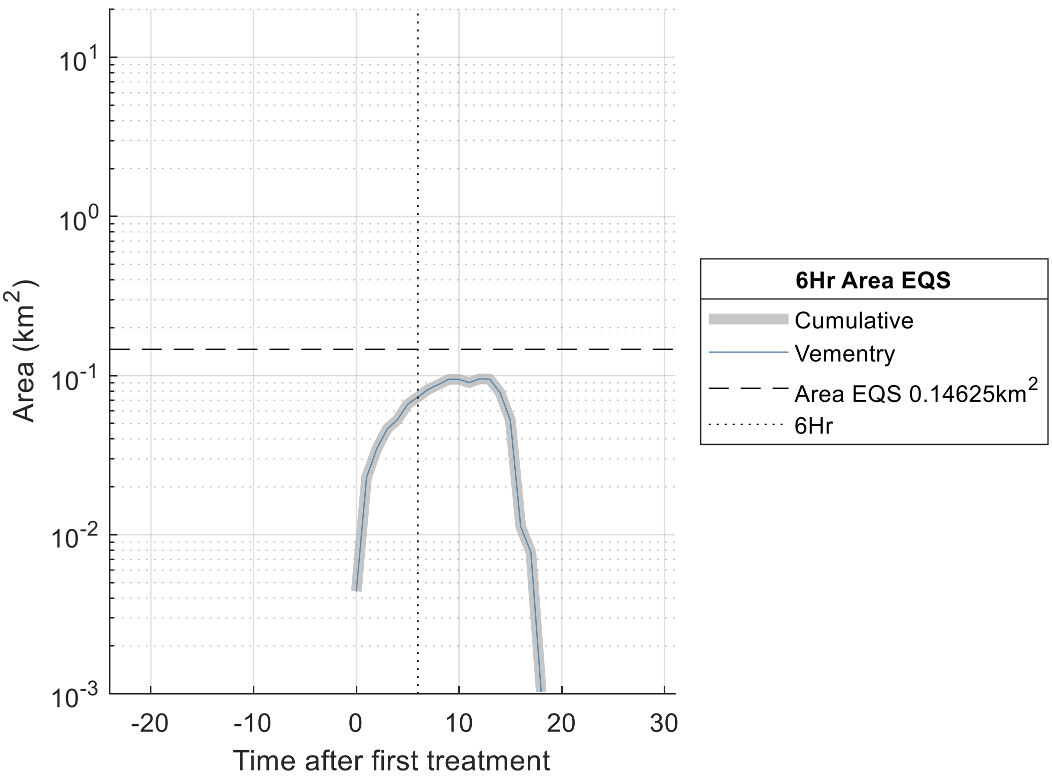


Figure 16. Chemical plume area exceeding the 6-hour (16 ng/l) EQS value after the initial 6-hour mass (25g) release of Cypermethrin during spring tides. The size of the 6-hour EQS mixing zone is shown by the horizontal dashed line. 6-hours after the initial treatment is marked by the vertical dotted line.

The spatial distribution of Cypermethrin 6 hours after the first release of the 6-hour treatment mass during a spring tide is shown in figure 17. The areas where concentrations exceed the 6-hour EQS concentration are outlined in red. In comparison to the neap tide, the spring tide chemical plume is elongated and is located more centrally in the channel. After 18 hours, the plume is dispersed.

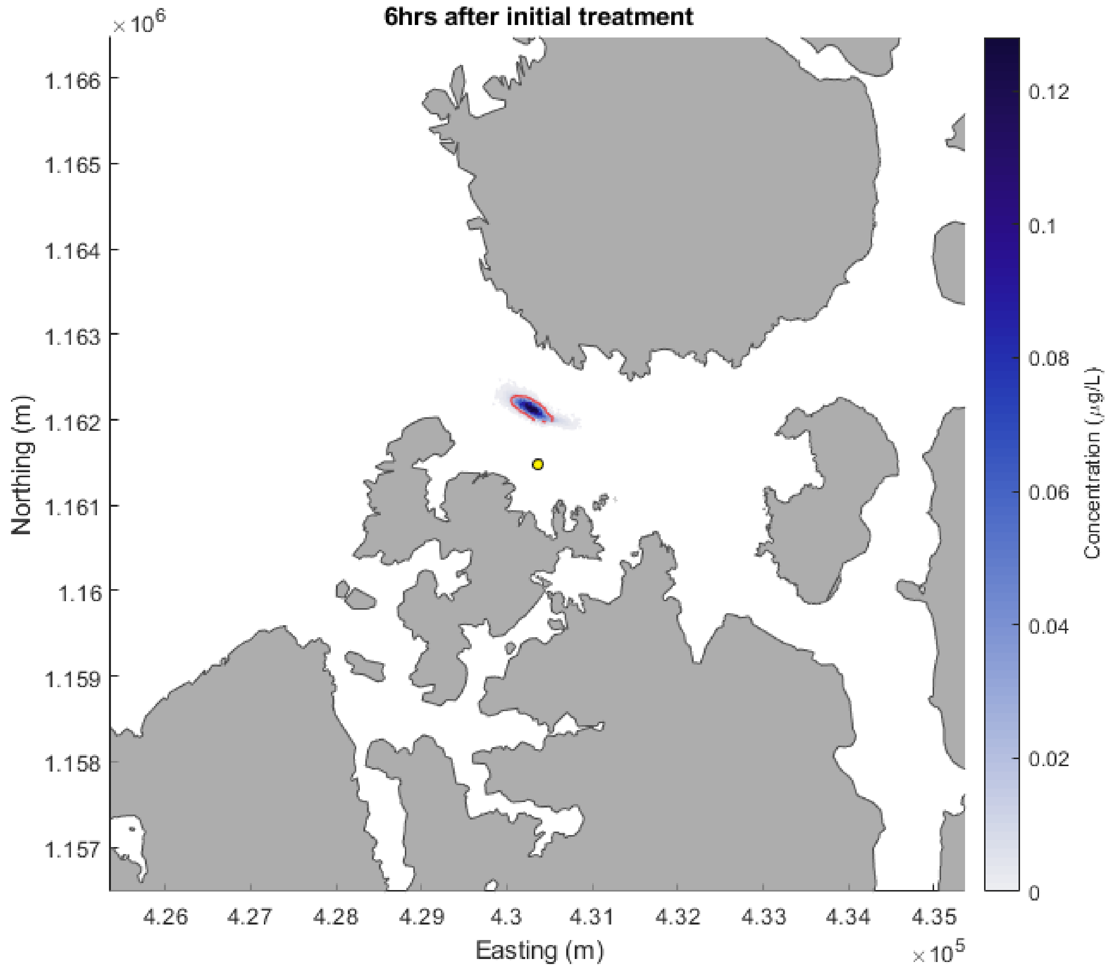


Figure 17. Spatial Cypermethrin distribution for releases during spring tides 6 hours after the last treatment event. Areas above EQS values are indicated within the red contour, and site locations are identified using a yellow marker.

3.1.3 Deltamethrin

Compliance was achieved at the proposed Vementry site using 10 g of Deltamethrin in a treatment plan involving a single treatment. This provides a treatable volume of 5,000 m^3 per 6-hour period.

3.1.3.1 Neap tides

The area of the chemical plume, 6 hours after the first treatment release period, that exceeds a concentration of 16ng/l (6hr EQS threshold) is plotted in figure 18. The 6-hour EQS time is applied relative to the first chemical release and is illustrated in the figure by the vertical dotted line. The size of the chemical plume originating from Vementry after a 6-hour mass treatment release remains less than the calculated mixing area of 0.14625km^2 throughout the model run.

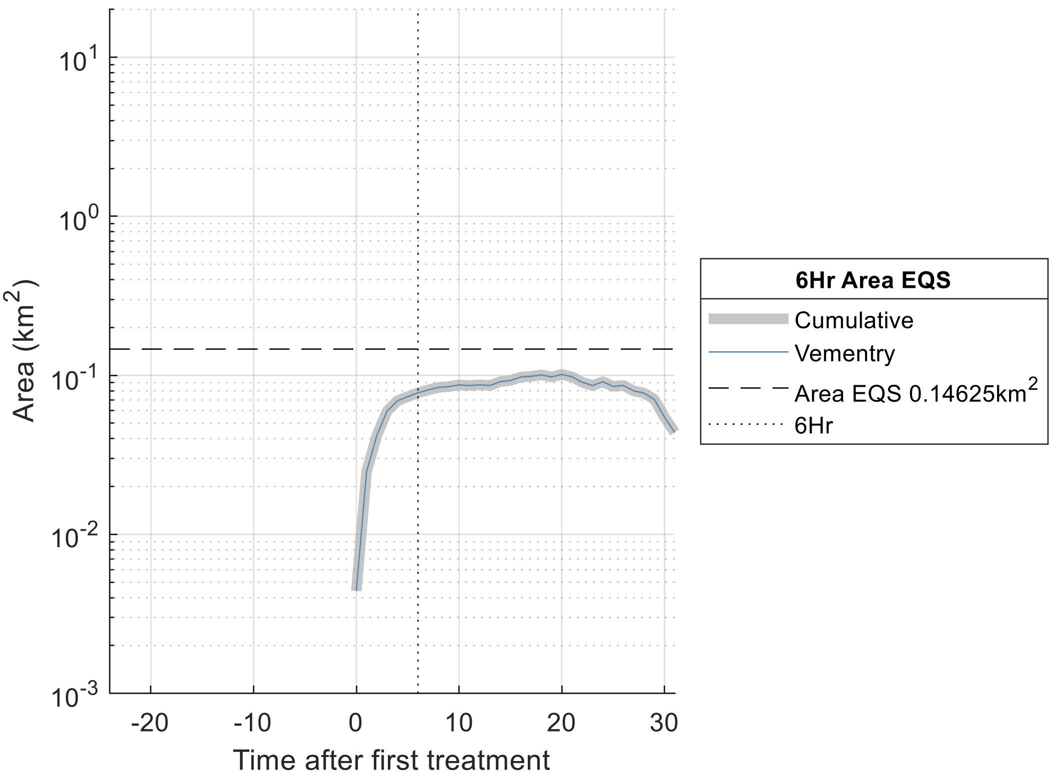


Figure 18. Chemical plume area exceeding the 6-hour (6 ng/l) EQS value after the initial 6-hour mass release of Deltamethrin during neap tides. The size of the 6-hour EQS mixing zone is shown by the horizontal dashed line. 6-hours after the initial treatment is marked by the vertical dotted line.

The spatial distribution of Deltamethrin 6 hours after the first release of bath treatments from the site during a neap tide is shown in figure 19. Regions with chemical concentration exceeding the EQS threshold are illustrated by the red contour. At the 6hr EQS, the plume is distributed to the northwest of the site and is initiating the dispersal process.

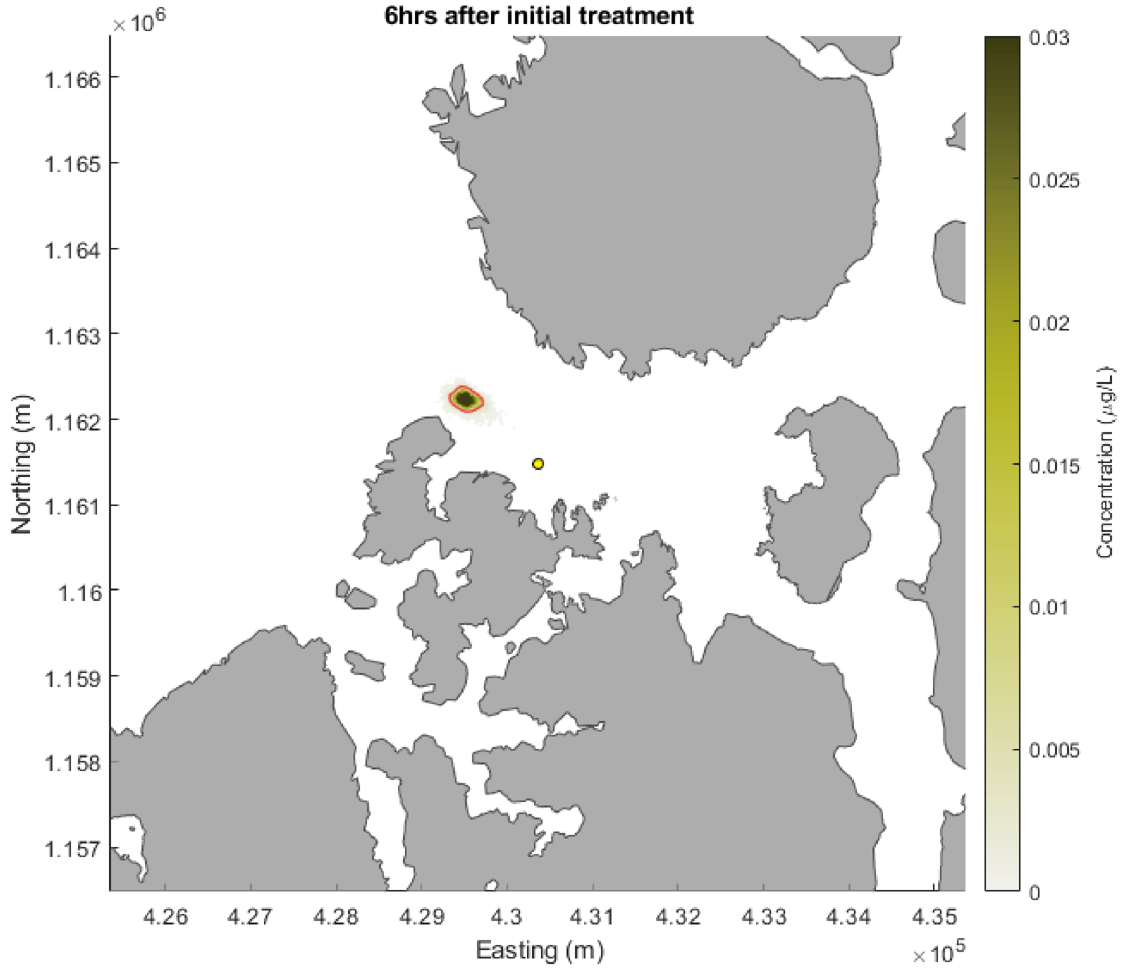


Figure 19. Spatial Deltamethrin distribution for releases during neap tides, 6 hours after the last treatment event. Areas above EQS values are indicated within the red contour and the site location is identified using a yellow marker.

3.1.3.2 Spring tides

The area of the chemical plume, 6 hours after the first treatment release period, that exceeds a concentration of 16ng/l (6hr EQS threshold) is plotted in figure 20. The 6-hour EQS time is applied relative to the first chemical release and is illustrated in the figure by the vertical dotted line. The size of the chemical plume originating from Vementry after a 6-hour mass treatment release remains less than the calculated mixing area of 0.14635km^2 throughout the model run.

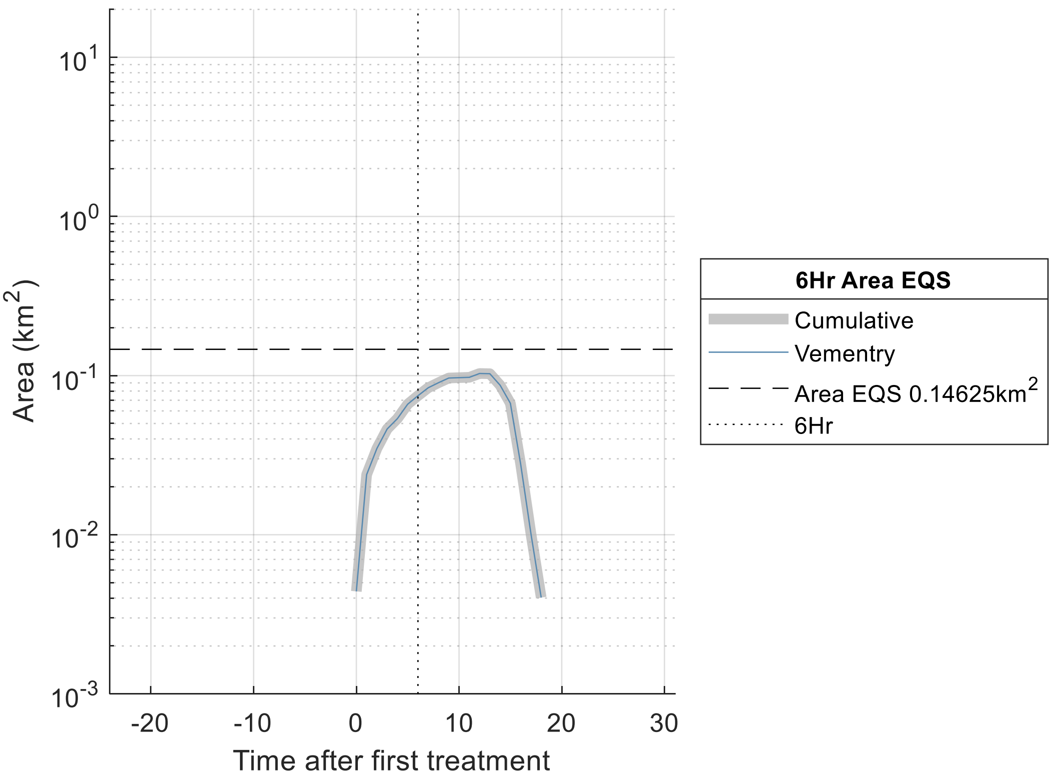


Figure 20. Chemical plume area exceeding the 6-hour (6 ng/l) EQS value after the initial 6-hour mass release of Deltamethrin during spring tides. The size of the 6-hour EQS mixing zone is shown by the horizontal dashed line. 6-hours after the initial treatment is marked by the vertical dotted line.

The spatial distribution of Deltamethrin 6 hours after the first release of the 6-hour treatment mass from the site during a spring tide is shown in figure 21. The regions in which chemical concentration exceeds the EQS threshold are illustrated by the red contour. This shows an area extent less than the permitted EQS area. After 6 hours, the plume area increases up to 13 hours after treatment. After this, rapid dispersion occurs, and concentrations fall below 6ng/l after 18 hours.

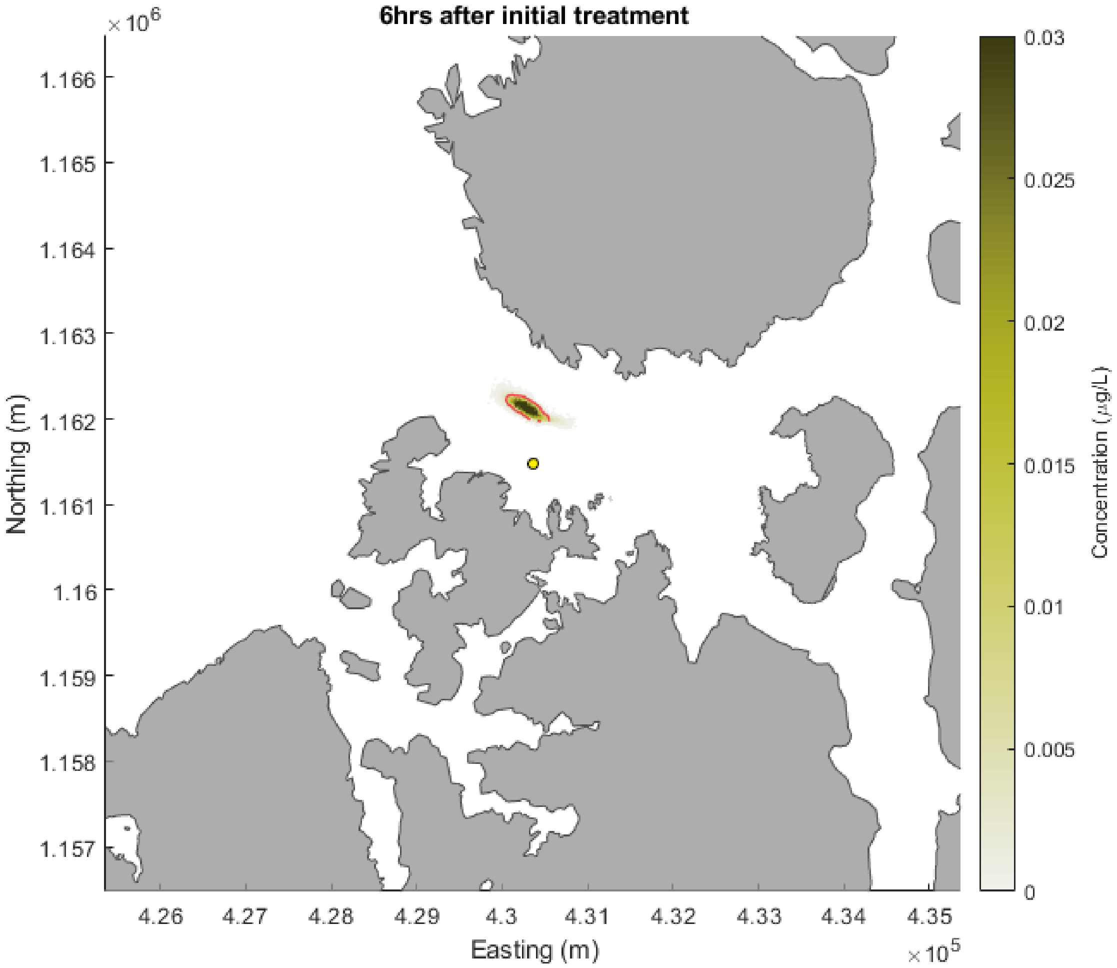


Figure 21. Spatial Deltamethrin distribution for releases during spring tides, 6hr after the last treatment event. Areas above EQS values are indicated within the red contour and the site location is identified using a yellow marker.

4. Interactions with Sensitive Marine Features

The results of the modelled distribution of the bath treatment plumes are used to assess potential interactions with identified sensitive marine features. Treatment-specific EQS parameters are used to determine potential risk to each feature. As there are currently no environmental standards for bath treatment exposure to sensitive marine features, the treatment-specific EQS parameters are used as a guide. It should be noted that the EQS parameters used are area-based measurements and not MACs, and therefore any exceedance in these values is permitted within a reasonable magnitude.

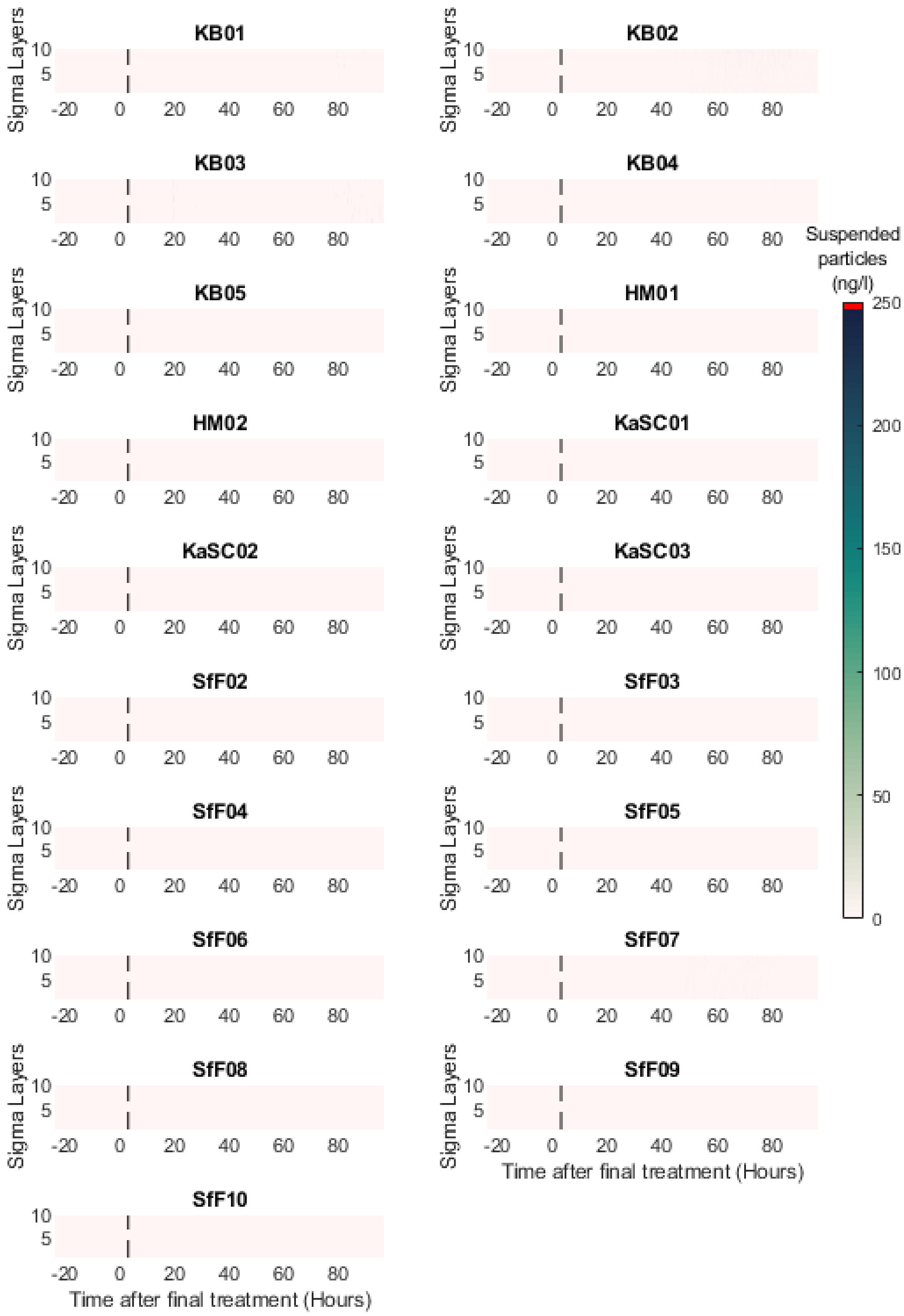
4.2 Point Features

4.2.1 Azamethiphos

4.2.1.1 Neap tides

3hr EQS

Short-term exposure during the neap tide is assessed using a single release of the 3hr treatment mass, 145g of Azamethiphos. Treatment concentrations at sensitive features are identified in figure 22. All features show no interaction with the treatment.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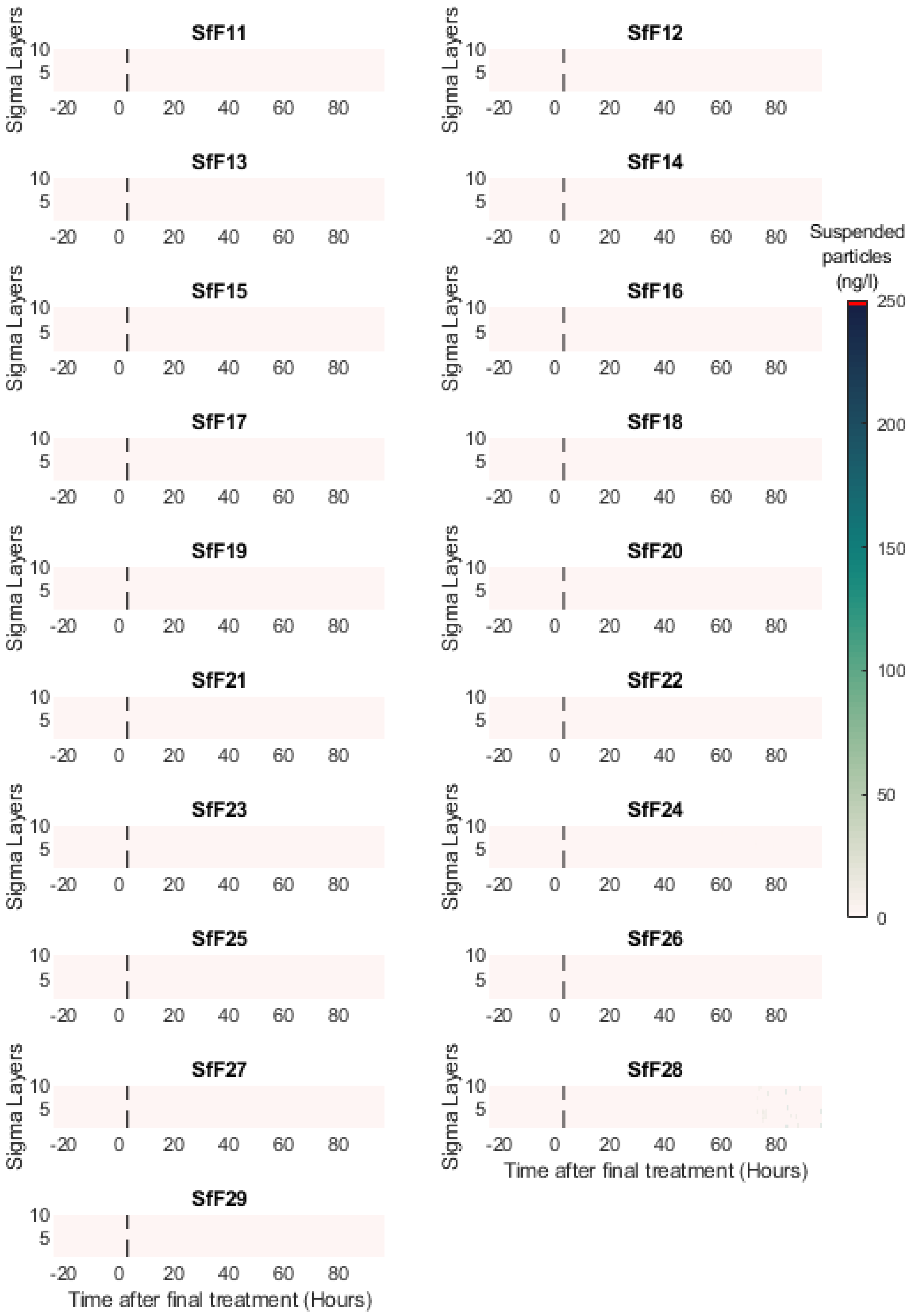
KB02
KB03
KB04
KB05
HM01
HM02
KaSC01
KaSC02
KaSC03
SfF02
SfF03
SfF04
SfF05
SfF06
SfF07
SfF08
SfF09
SfF10
Sigma Layers
10
5
-20
0
20
40
60
80
Time after final treatment (Hours)
Suspended particles (ng/l)
250
200
150
100
50
0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SfF22
SfF23
SfF24
SfF25
SfF26
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SfF28
SfF29
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)
0
50
100
150
200
250

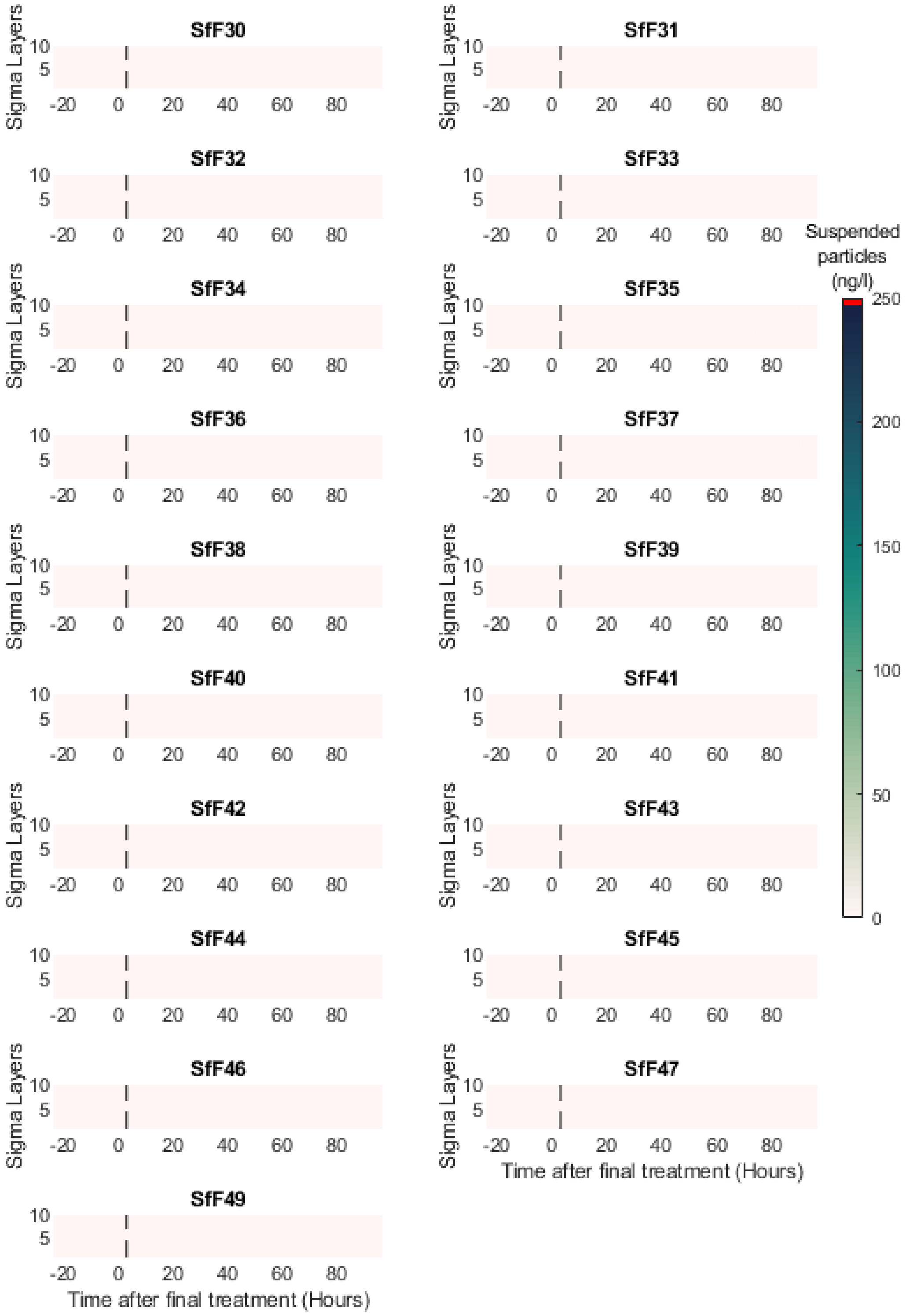
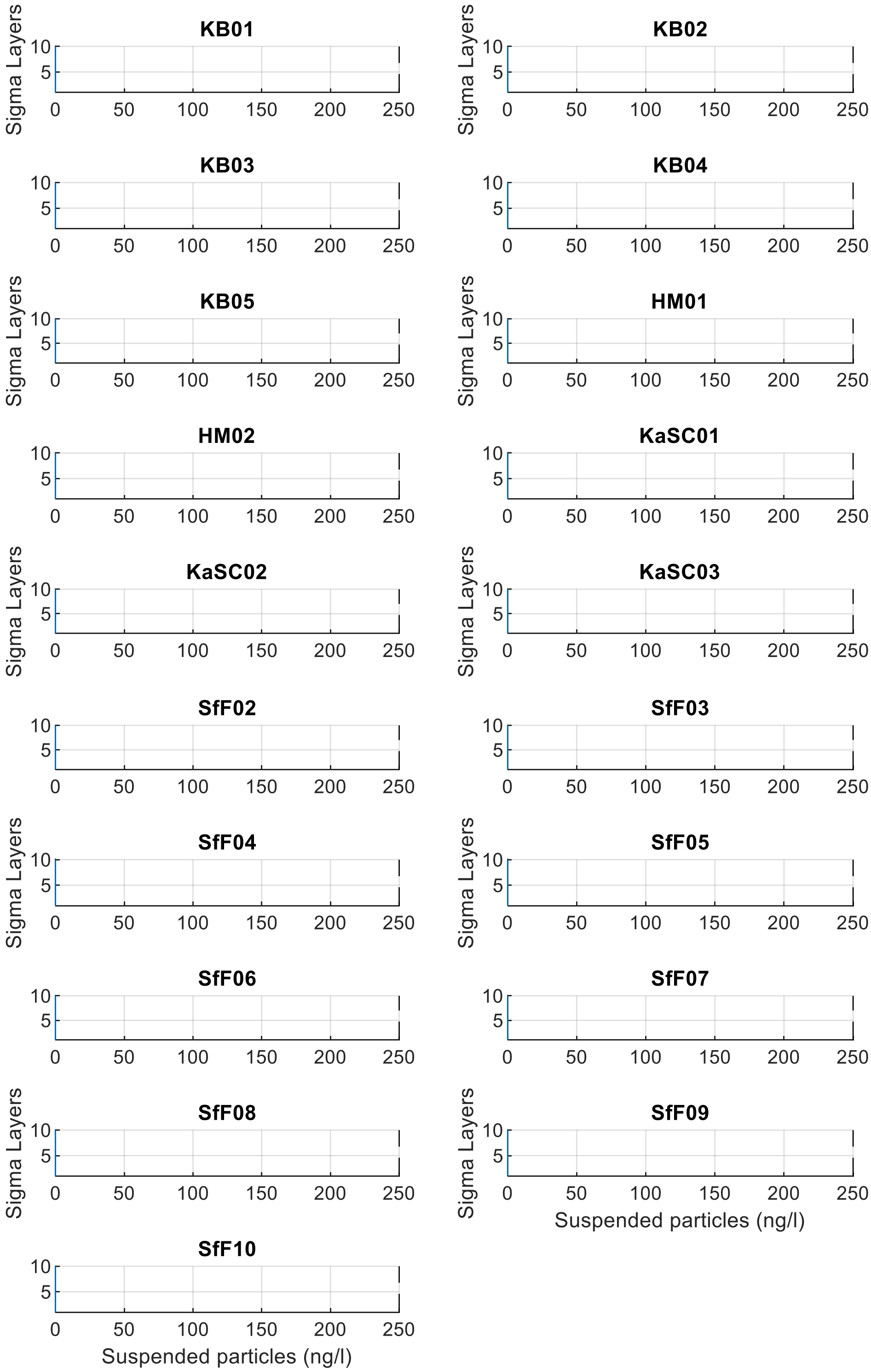


Figure 22. Neap tide Azamethiphos concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar with any values indicated in red that exceed the 3hr EQS value. Water depth is defined in model sigma layers

where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

Vertical concentration profiles for each feature are shown in figure 23 for the 3hr EQS time. After 3hrs of a single treatment, all features show no interaction with the plume.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SfF06
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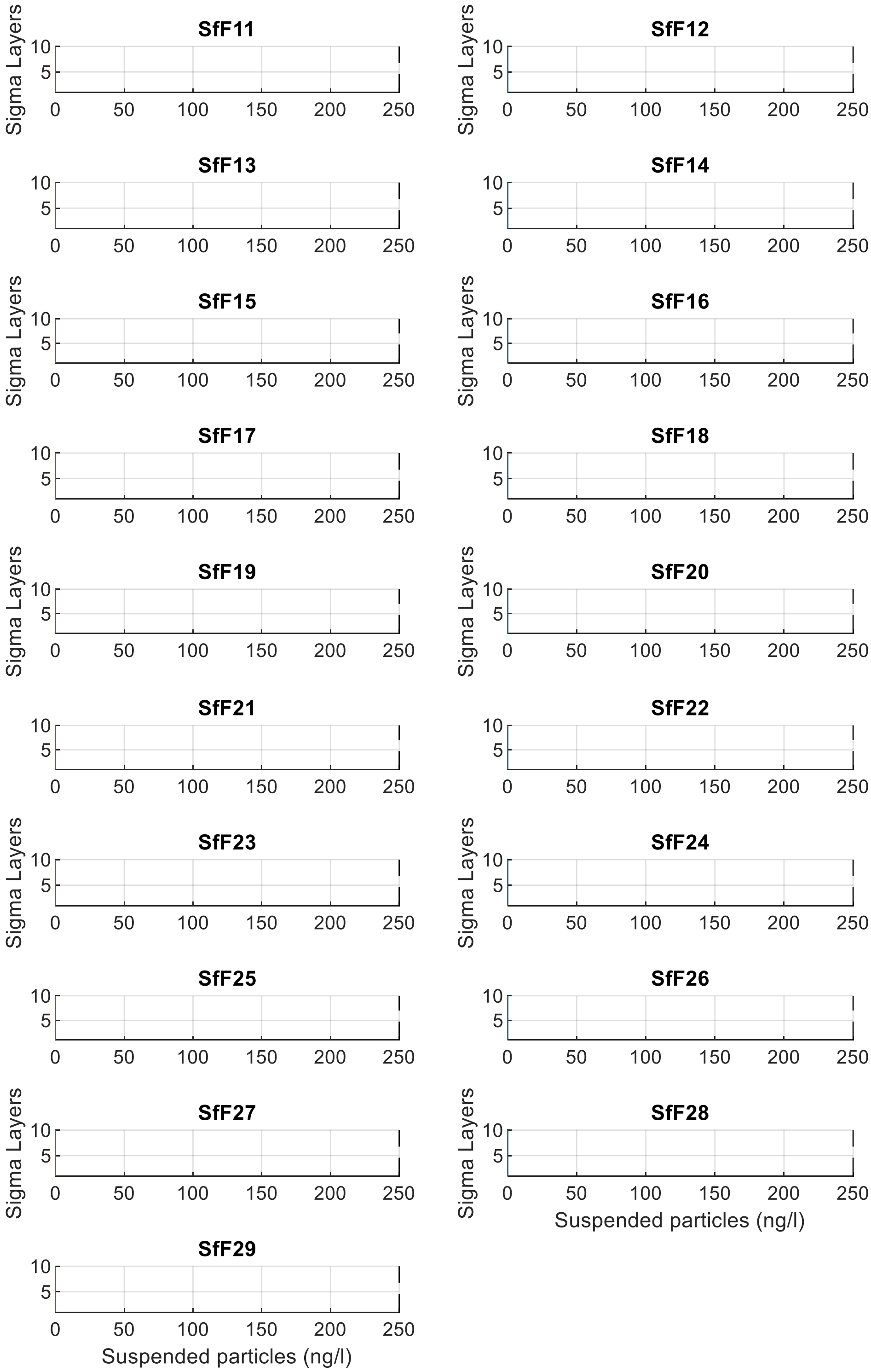
Sigma Layers
10
5
0
50
100
150
200
250
Suspended particles (ng/l)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Sigma Layers
Suspended particles (ng/l)

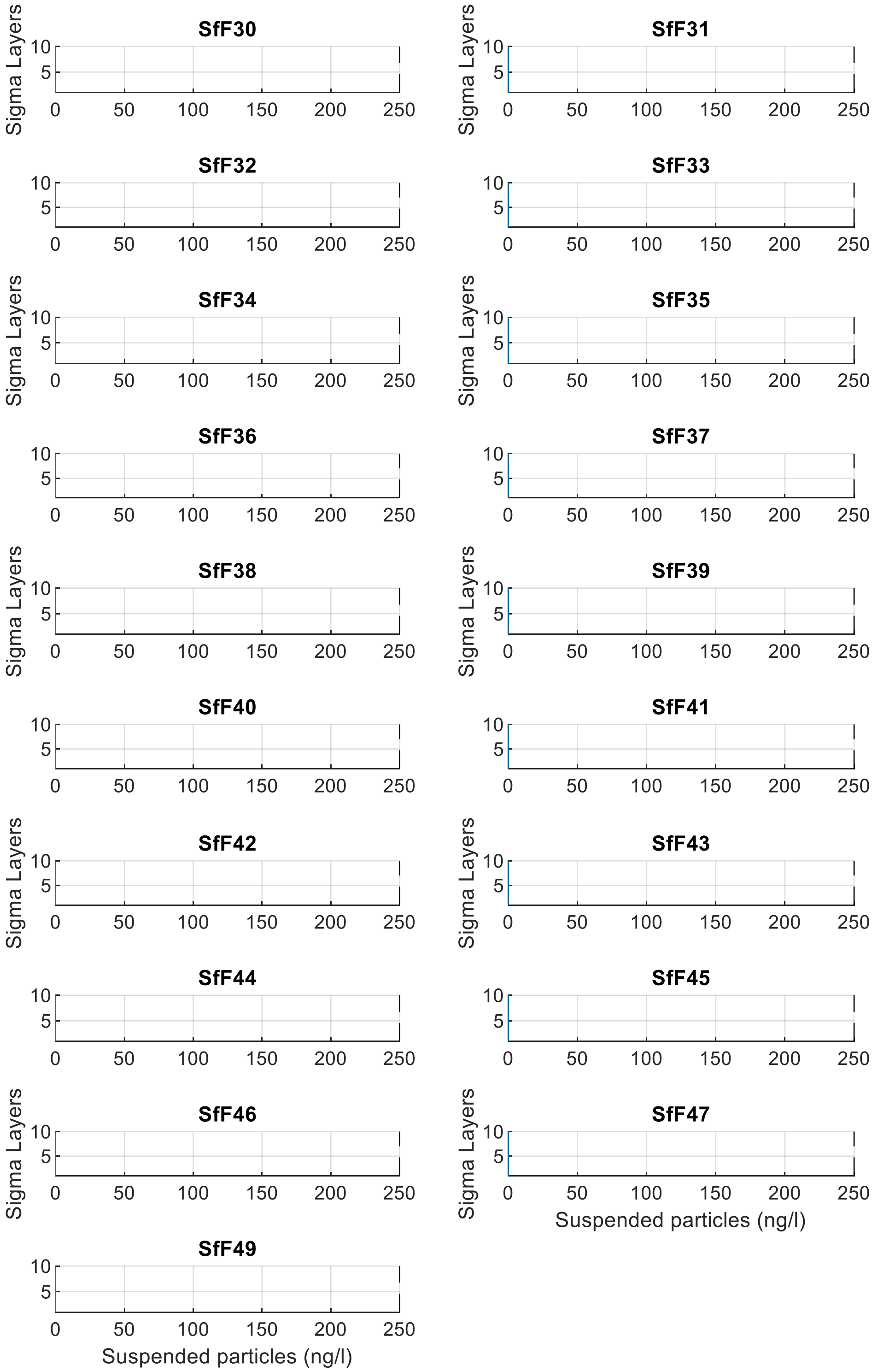
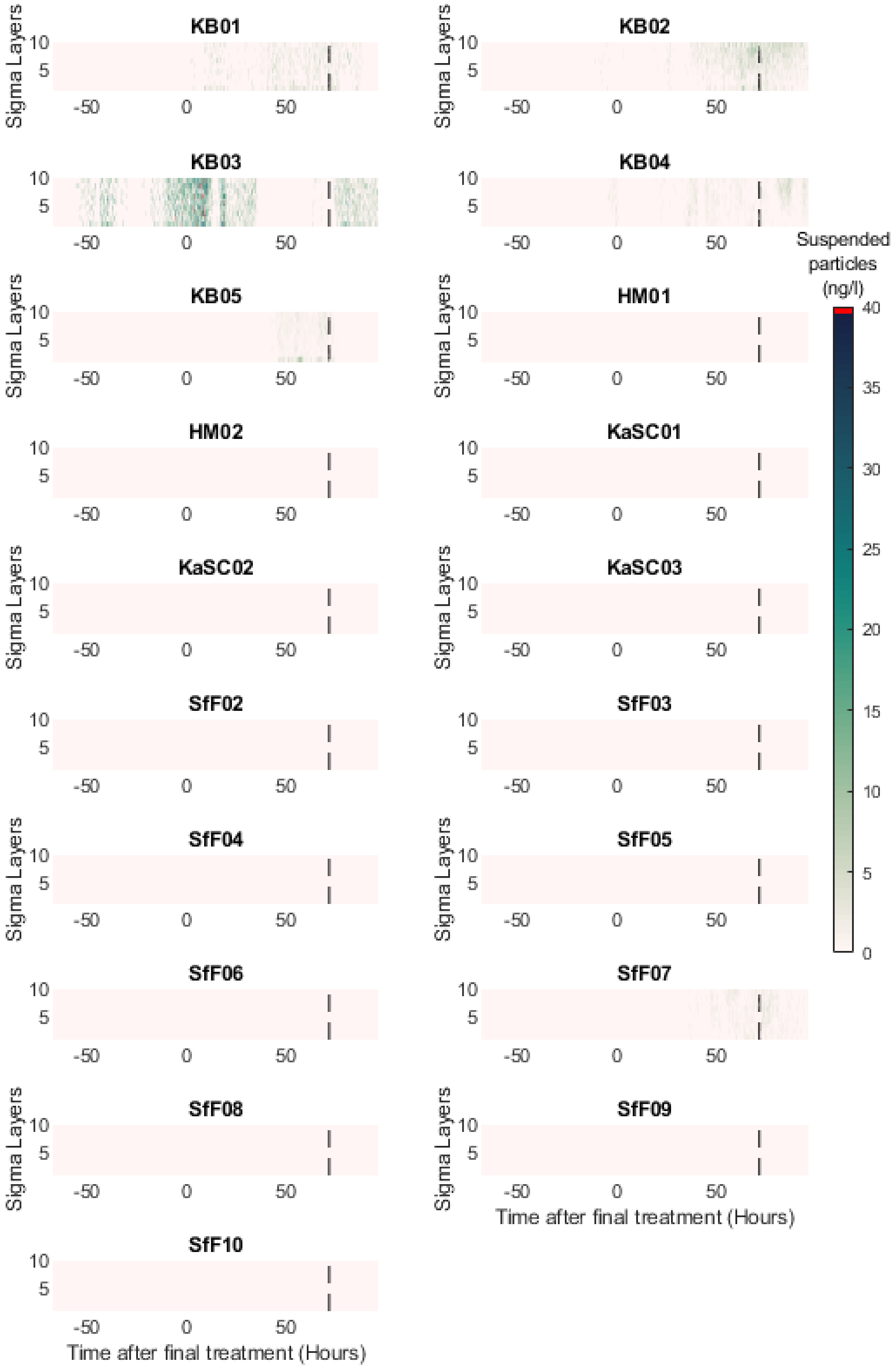


Figure 23. Neap tide vertical concentration profile of Azamethiphos after the single treatment at the 3hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

72hr EQS

Bath treatment exposure during the neap tide is assessed using a 24-hr treatment mass of 375g of Azamethiphos. Treatment concentrations at features are identified in figure 24, where the concentration scale is adjusted to 40ng/l, in line with the 72hr EQS value. Plume concentration at feature locations all remains at very low levels. Features KB01, KB02, KB03, SfF22, SfF24, and SfF28 show more visible variations in passing plume concentrations. These small increases in concentration have a short duration and are generally weak in strength.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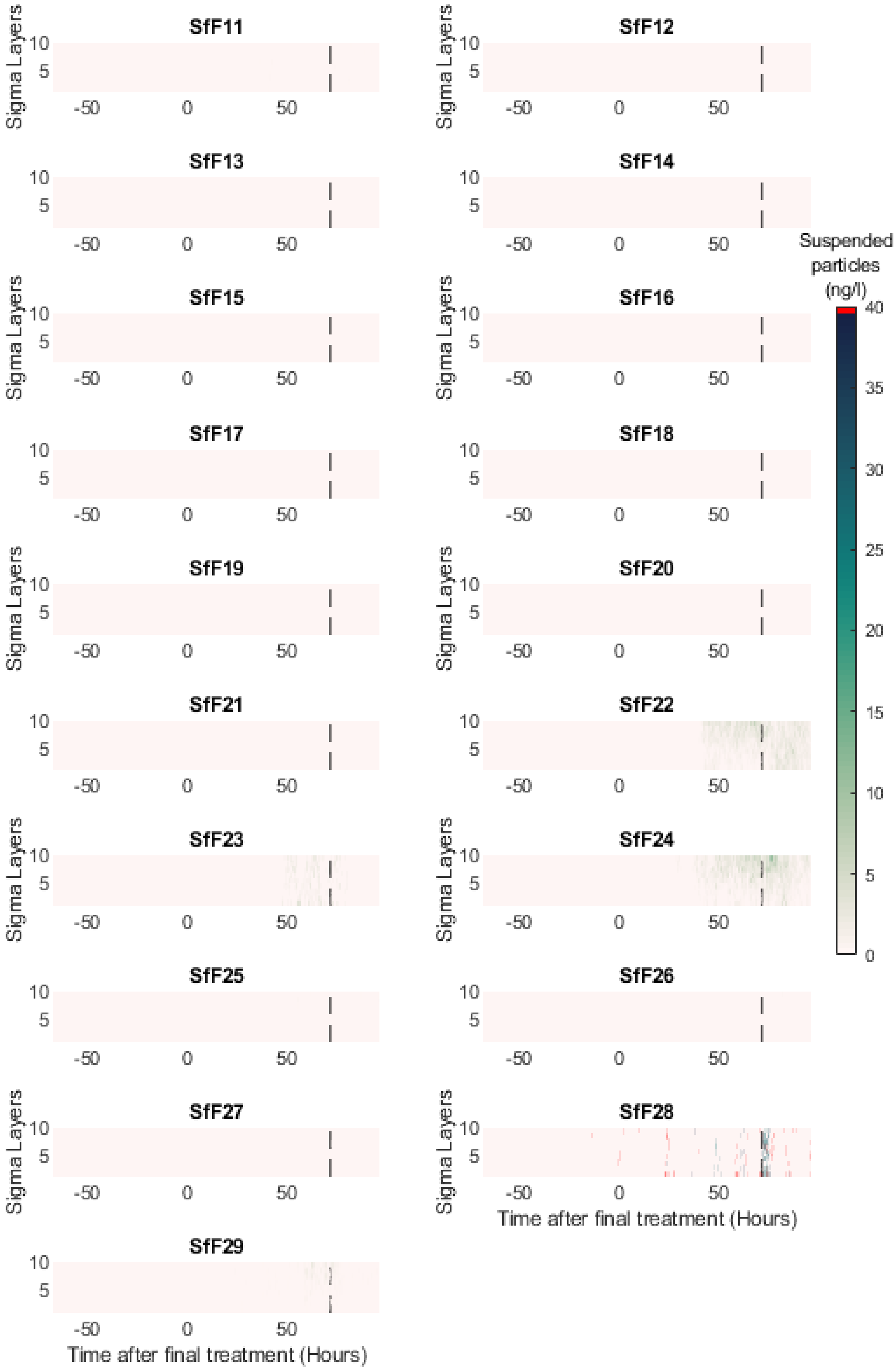
Time after final treatment (Hours)
Suspended particles (ng/l)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SfF23
SfF24
SfF25
SfF26
SfF27
SfF28
SfF29
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)
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0
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10
5
40
35
30
25
20
15
10
5
0

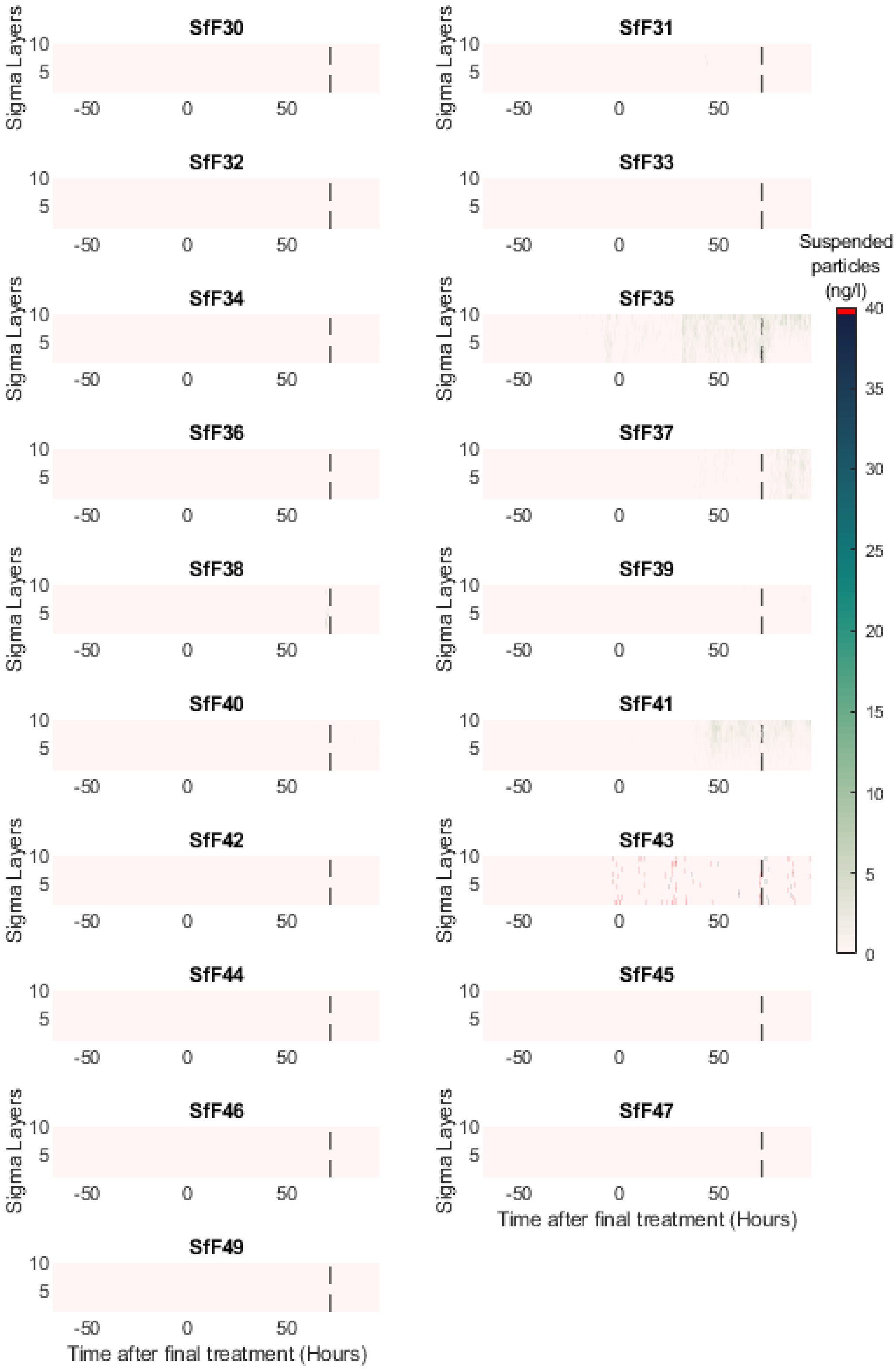
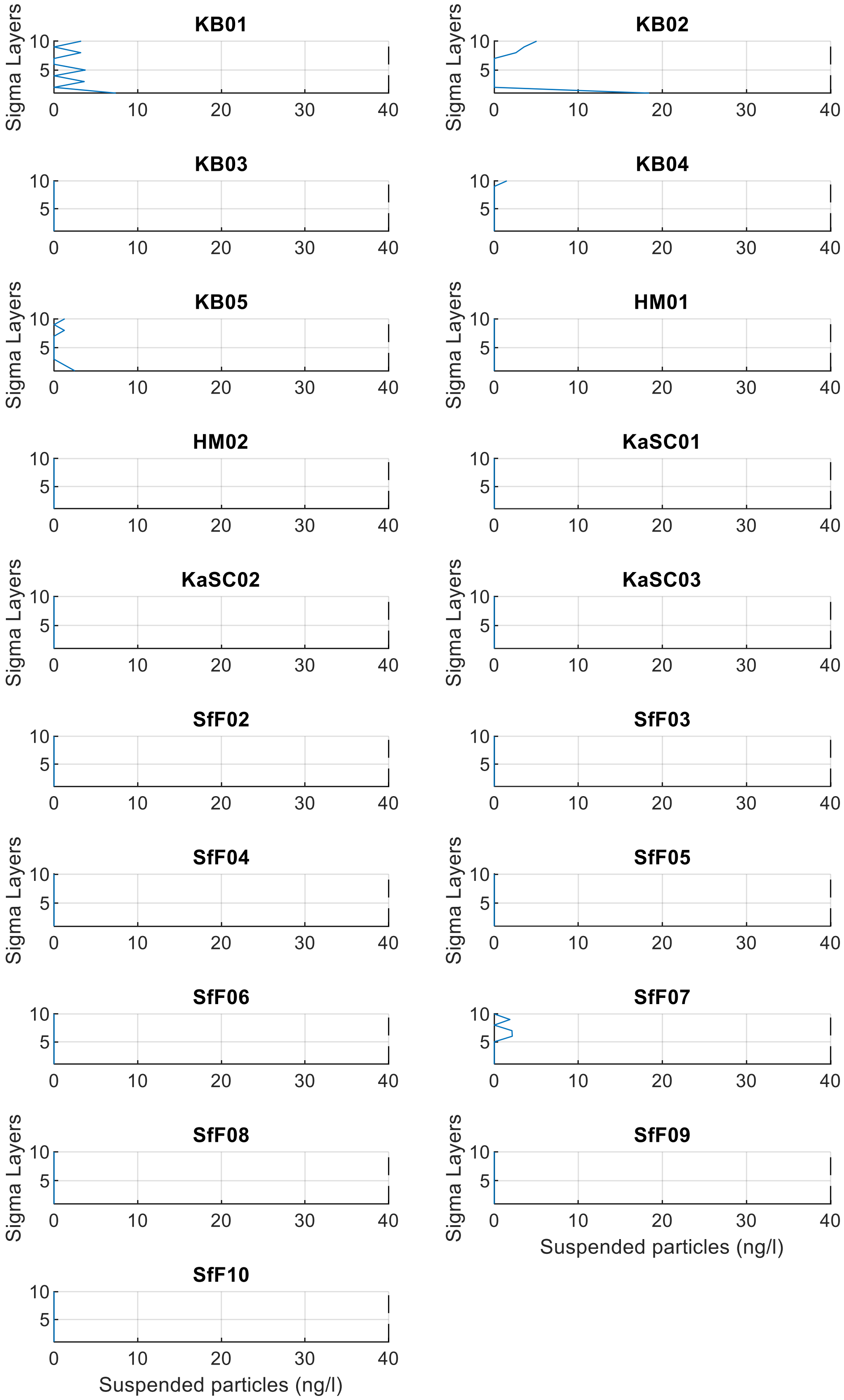


Figure 24. Neap tide Azamethiphos concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar, with any values indicated in red that exceed the 72hr EQS value. Water depth is defined in model sigma

layers where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

After 72 hours, the concentration of Azamethiphos is less than 40ng/l for all features, with most locations recording concentrations of 0ng/l. Feature SfF28 shows the largest concentration of around 40ng/l, however, this interaction is only present for a short duration, and the concentration remains low.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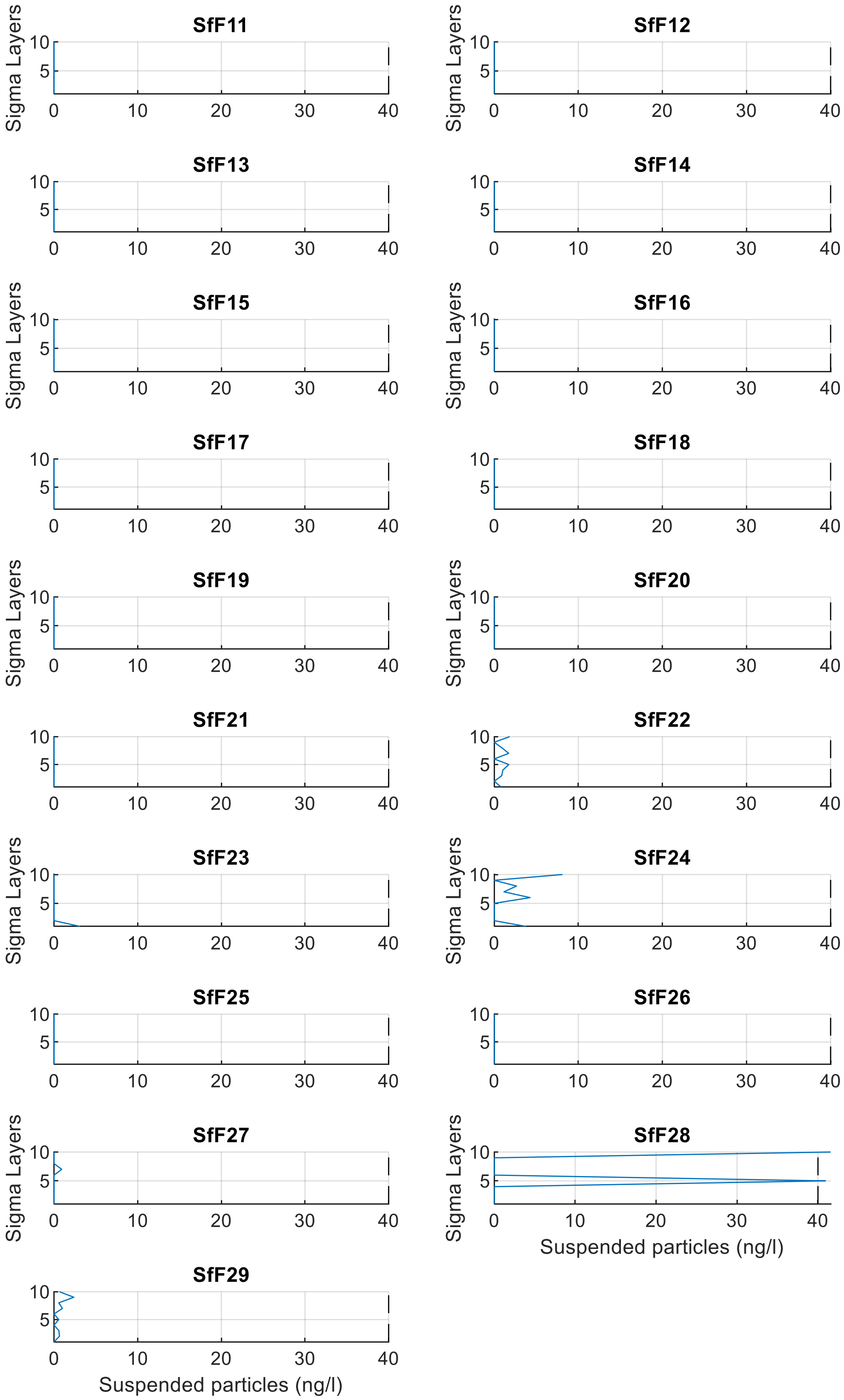
Sigma Layers
Suspended particles (ng/l)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Sigma Layers
Suspended particles (ng/l)

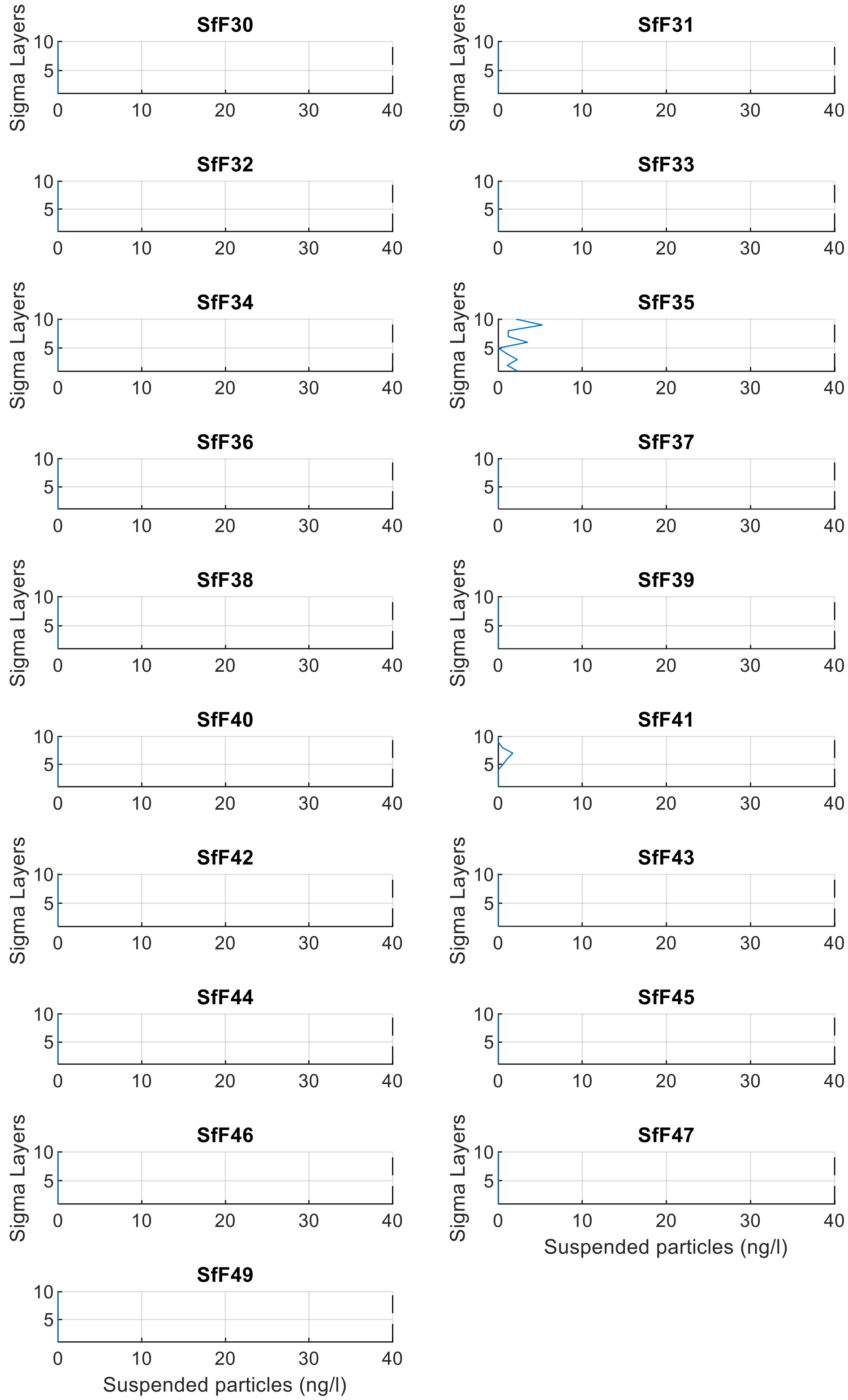


Figure 25. Neap tide vertical concentration profile of Azamethiphos after a treatment plan with a 24-hr treatment mass of 375g at the 72hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

The spatial distribution of Azamethiphos is shown relative to the feature locations in figure 26. Several time steps are shown, ranging from 3 to 72 hours, and red contour lines are shown for treatment concentrations of 100 ng/l. Treatments are shown to be widely distributed and separated into fragmented plumes with no accumulations. Interactions with features are uncommon and occur only with diluted plumes. The largest concentration occurs around 6 to 12 hours after the final treatment and is located in the centre of the channel. Previous concentration plots show minimal plume interaction with features.

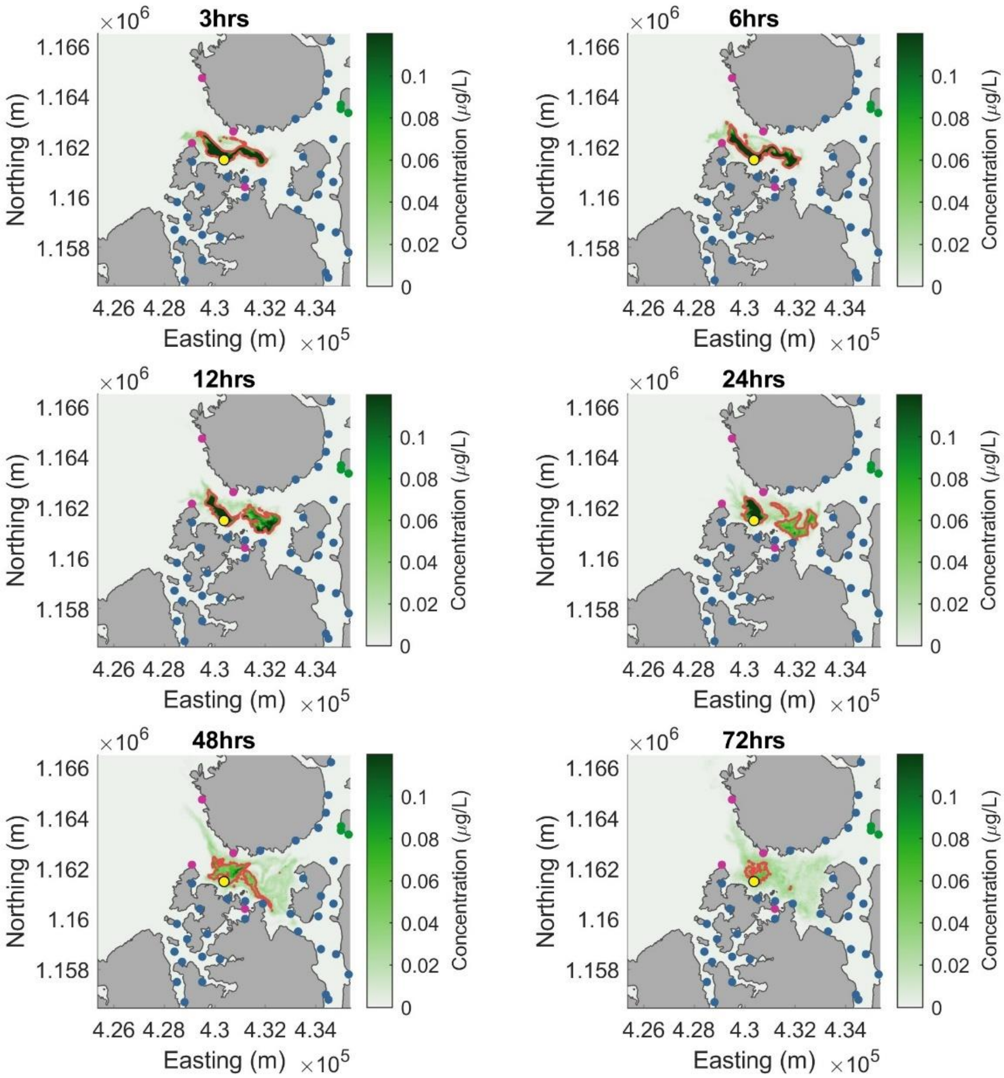
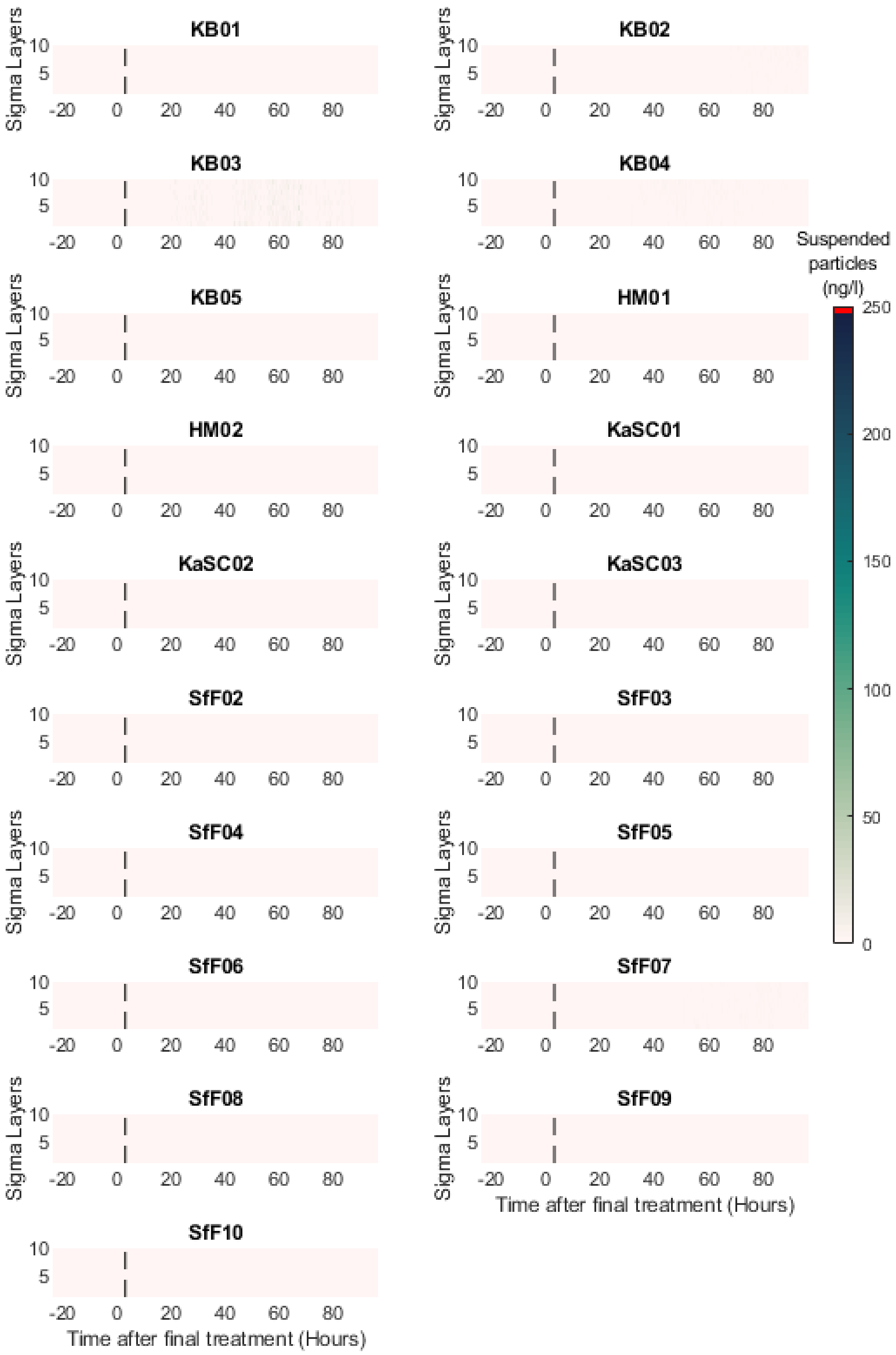


Figure 26. Spatial Azamethiphos distribution for bath treatment releases during neap tides 3hrs to 72 hrs after the last treatment event. Areas above EQS values are indicated within the red contour, the site location is identified using a yellow marker and PMF locations are shown as points.

4.2.1.2 Spring tides

3hr EQS

Short-term exposure during the spring tide is assessed using a single release of the 3hr treatment mass, 145g of Azamethiphos. Treatment concentration at features is identified in figure 27. SfF28 is the only location to show any interaction with the dispersing treatment plumb. Concentrations at this location are very low and only occur very briefly.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SfF06
SfF07
SfF08
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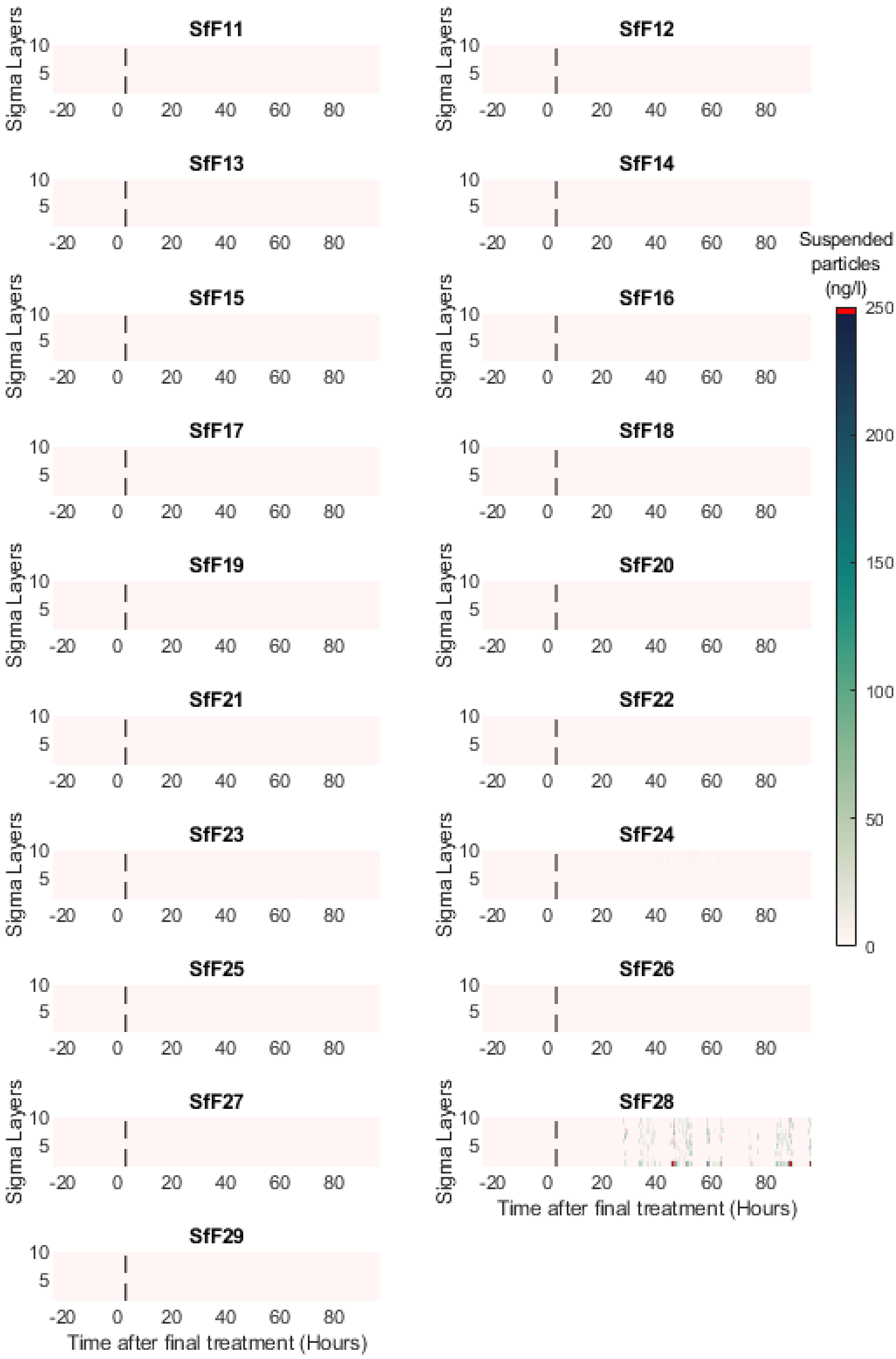
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)
250
200
150
100
50
0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Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)
250
200
150
100
50
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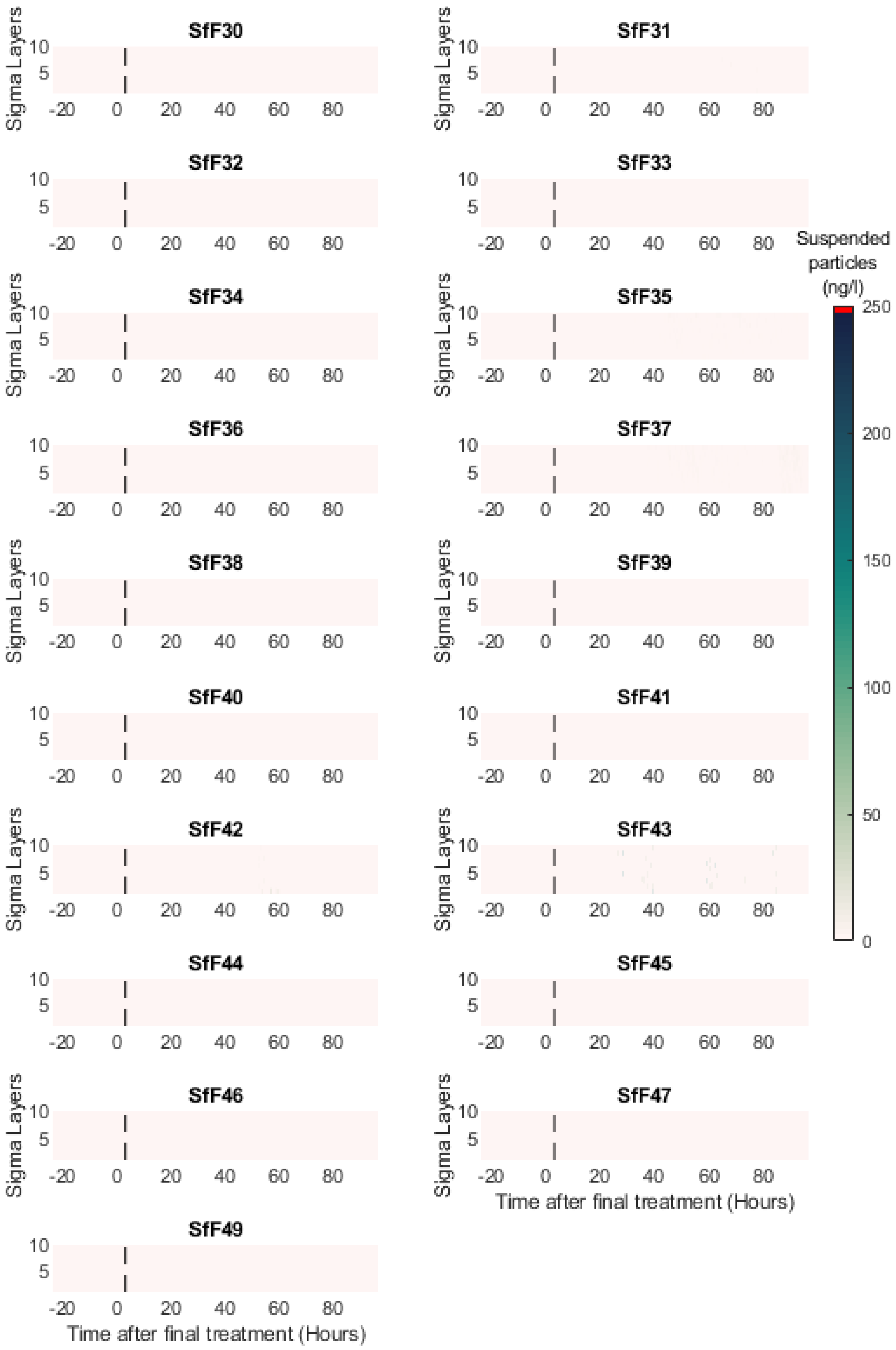
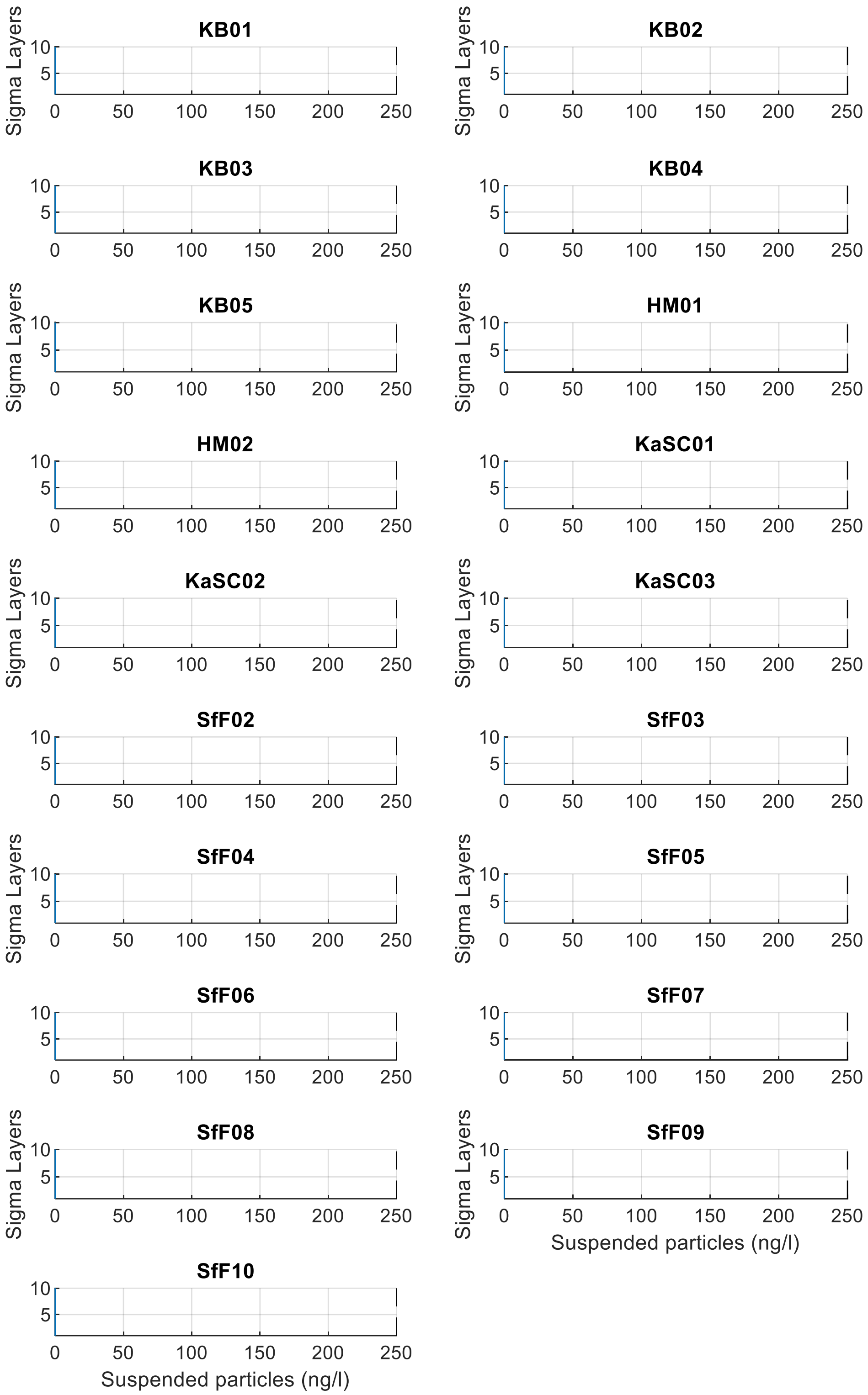


Figure 27. Spring tide Azamethiphos concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar with any values indicated in red that exceed the 72hr EQS value. Water depth is defined in model

sigma layers, where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

Vertical concentration profiles for each feature are shown in figure 28 for the 3hr EQS time. After 3hrs no treatment concentrations are shown for any of the identified sensitive marine features.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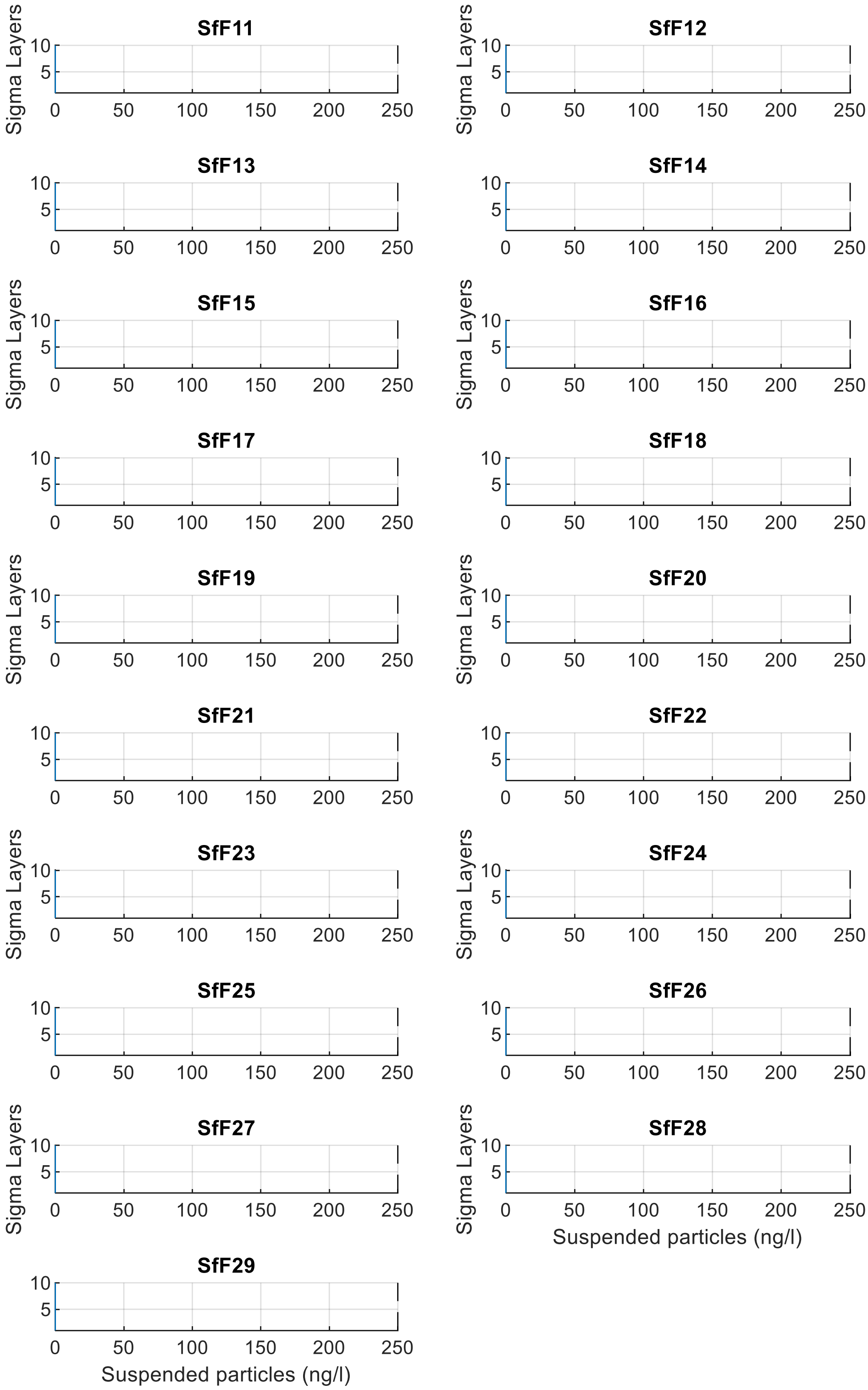
Sigma Layers
Suspended particles (ng/l)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SfF26
SfF27
SfF28
SfF29
Sigma Layers
10
5
0
50
100
150
200
250
Suspended particles (ng/l)

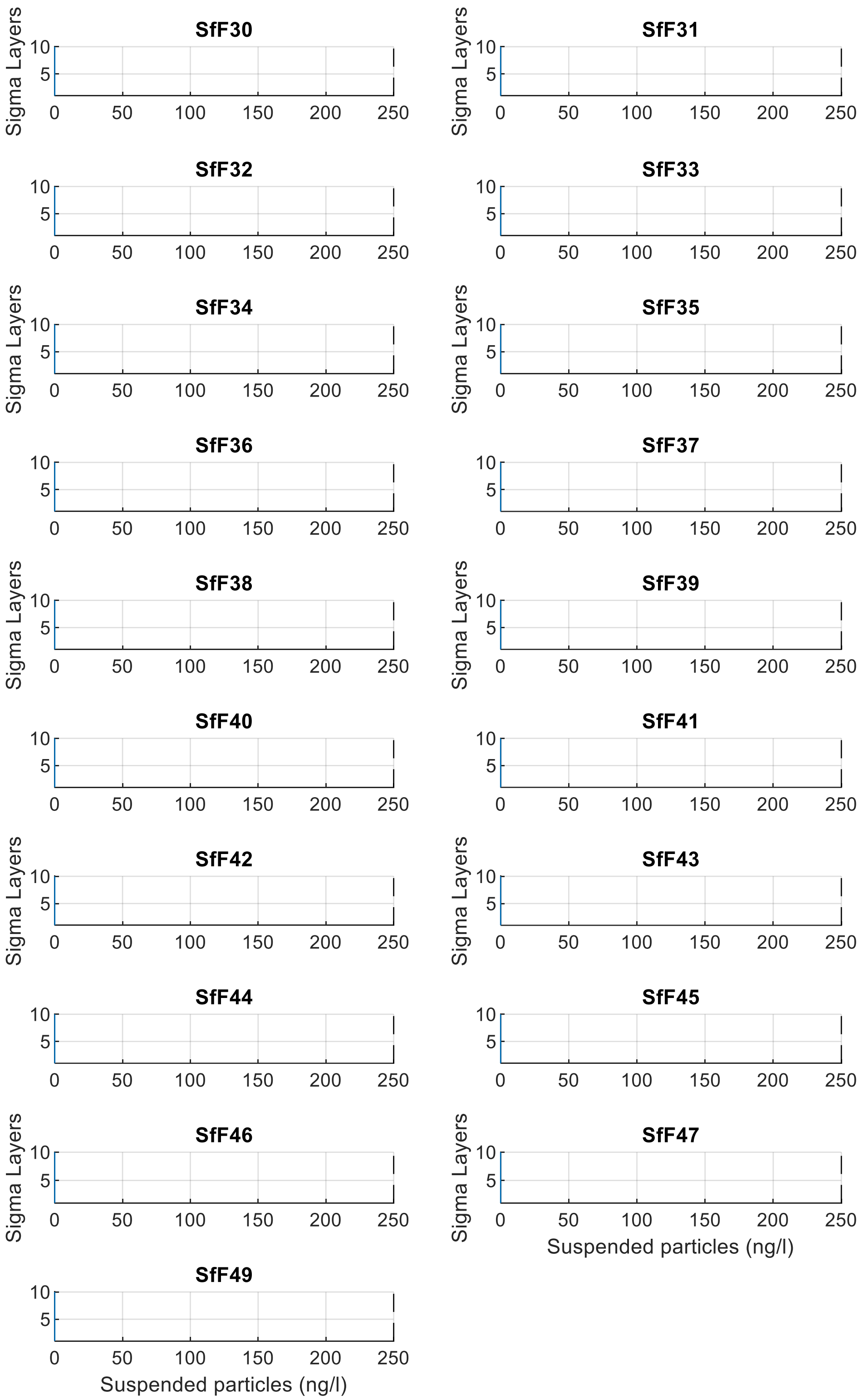
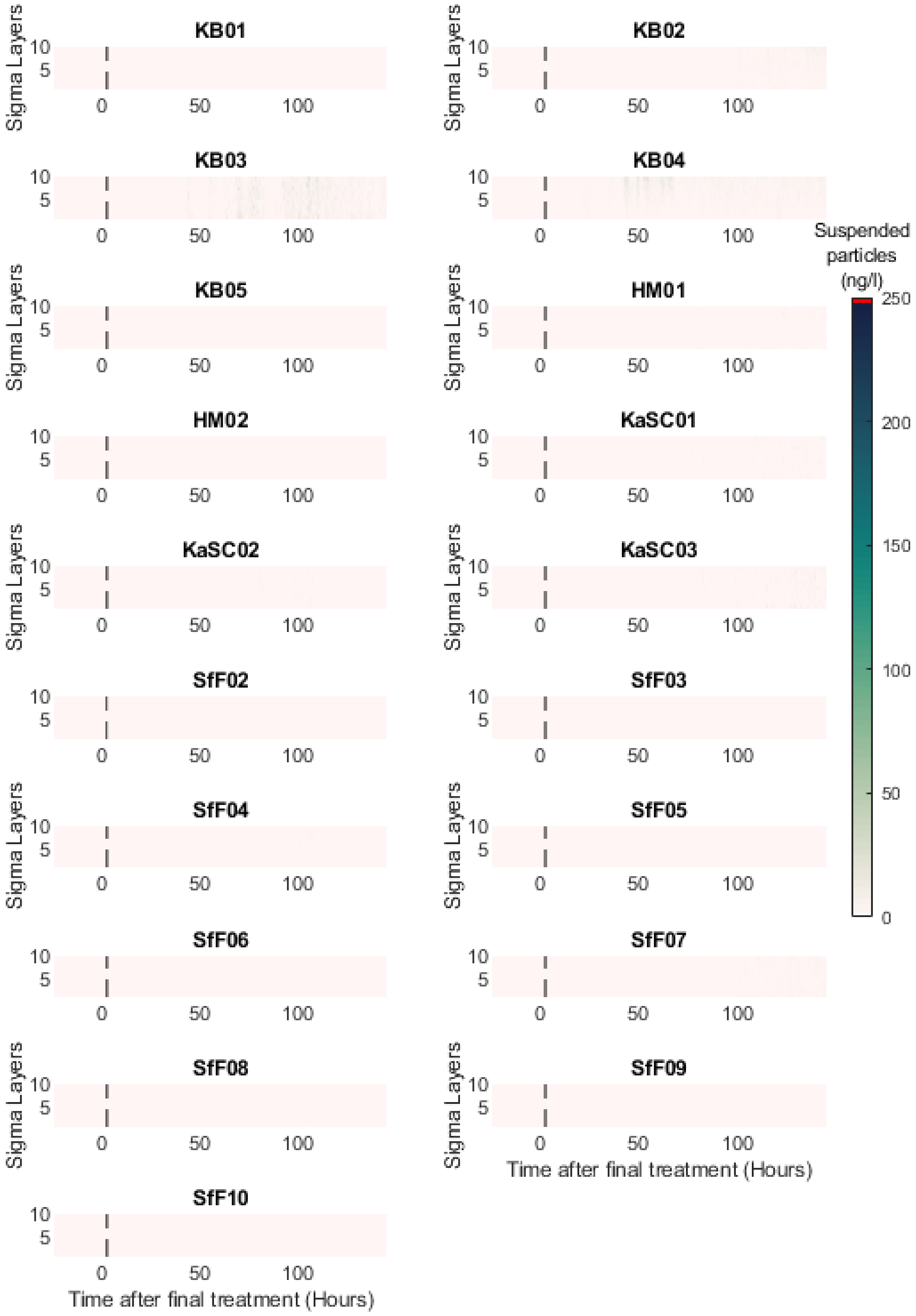


Figure 28. Spring tide vertical concentration profile of Azamethiphos after the single treatment at the 3hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

72hr EQS

Bath treatment exposure during the spring tide is assessed using a 24-hr treatment mass of 375g of Azamethiphos. Treatment concentrations at features are identified in figure 29, where the concentration scale is adjusted to 40ng/l, in line with the 72hr EQS value. Plume concentration at feature locations all remains at very low levels, with only SfF28 showing any sign of plume interaction. At this location, very low infrequent concentrations occur.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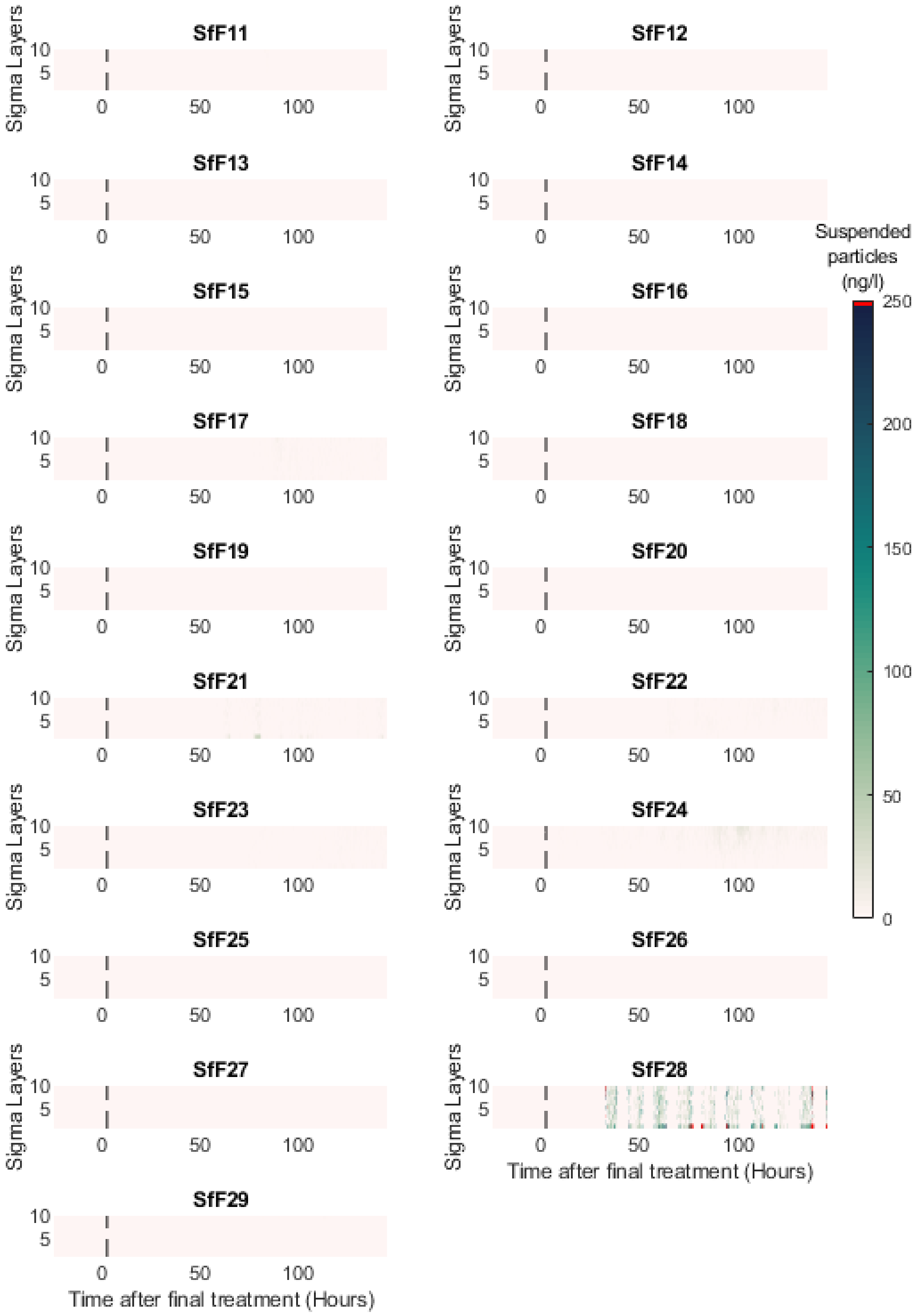
SfF06
SfF07
SfF08
SfF09
SfF10
Sigma Layers
10
5
0
50
100
Time after final treatment (Hours)
Suspended particles (ng/l)
250
200
150
100
50
0



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SfF22
SfF23
SfF24
SfF25
SfF26
SfF27
SfF28
SfF29
Sigma Layers
10
5
0
50
100
Time after final treatment (Hours)
Suspended particles (ng/l)
250
200
150
100
50
0

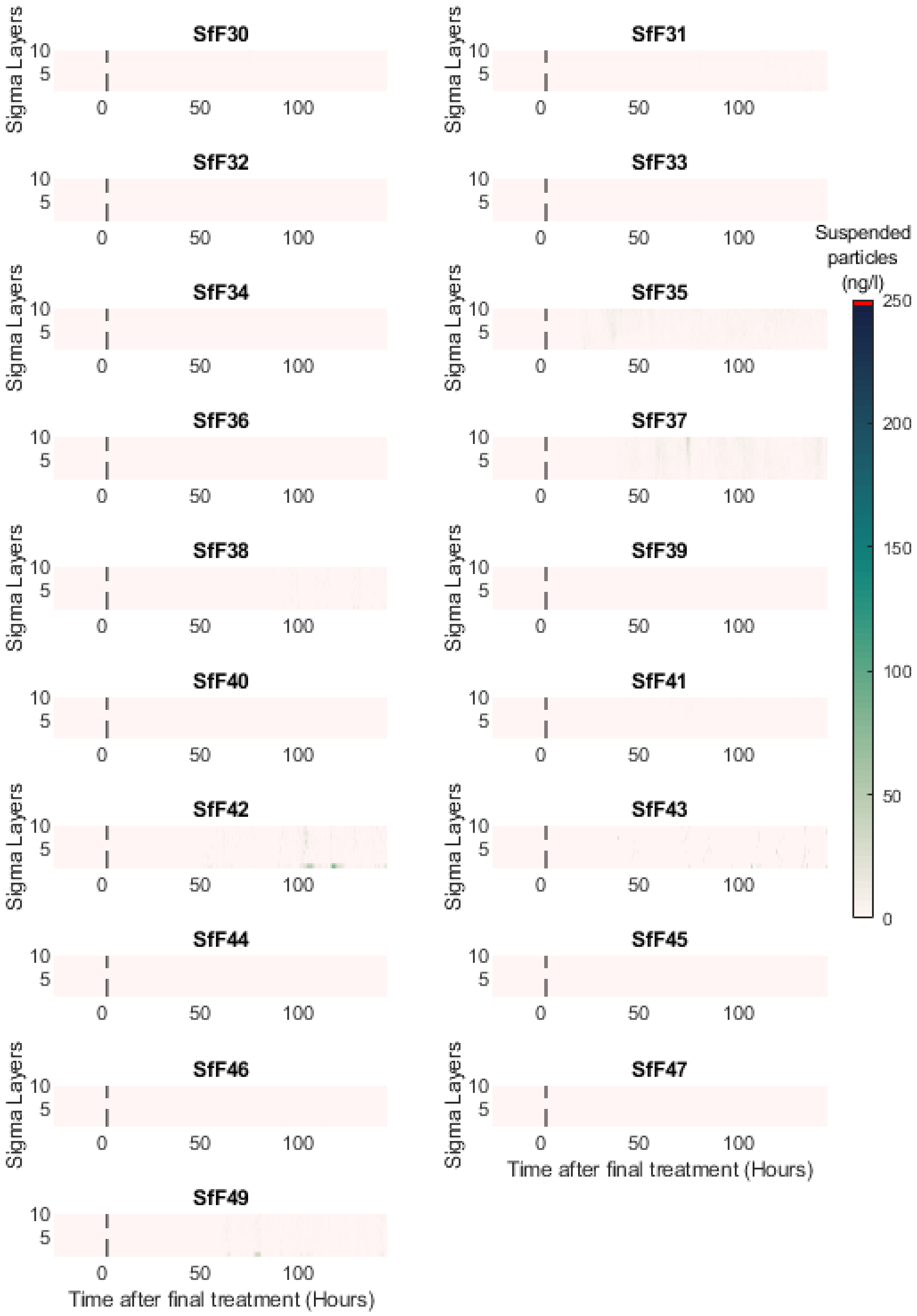
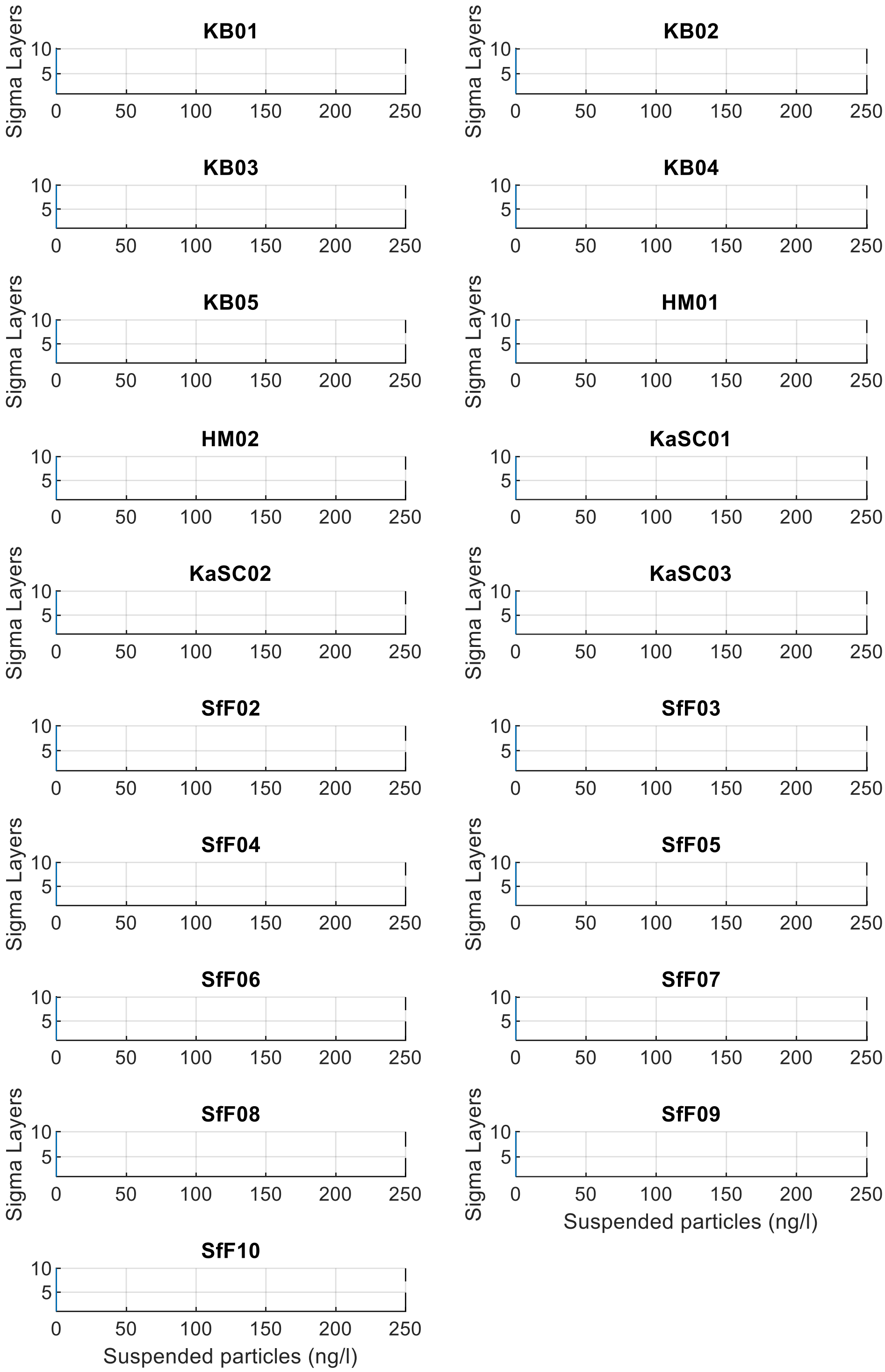
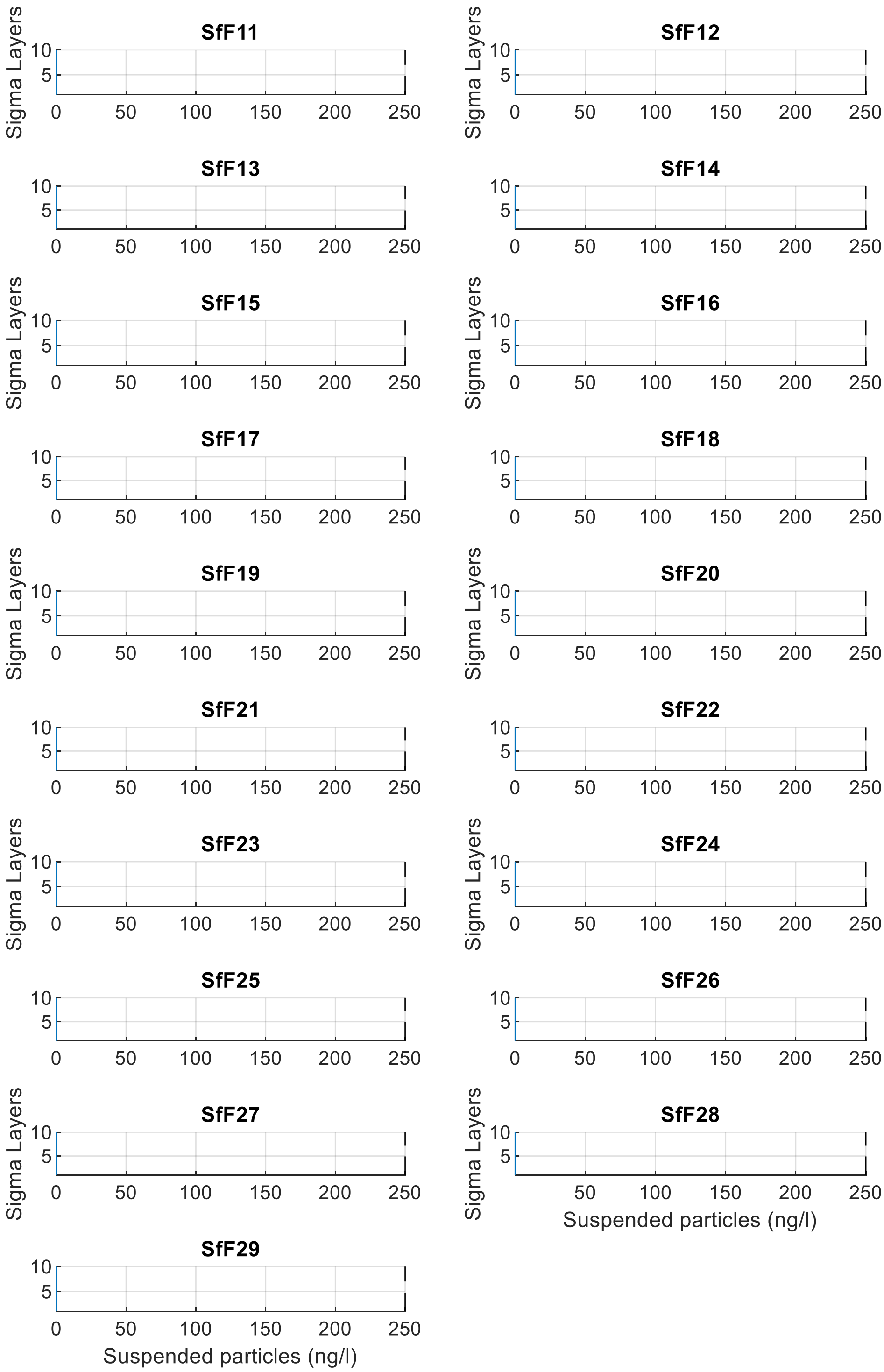


Figure 29. Spring tide Azamethiphos concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar with any values indicated in red that exceed the 72hr EQS value. Water depth is defined in model sigma layers, where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

Vertical concentration profiles for each feature are shown in figure 30 for the 72hr EQS time. After 72hrs, treatment concentrations are shown to be zero at all locations.

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SfF24
SfF25
SfF26
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Sigma Layers
10
5
0
50
100
150
200
250
Suspended particles (ng/l)

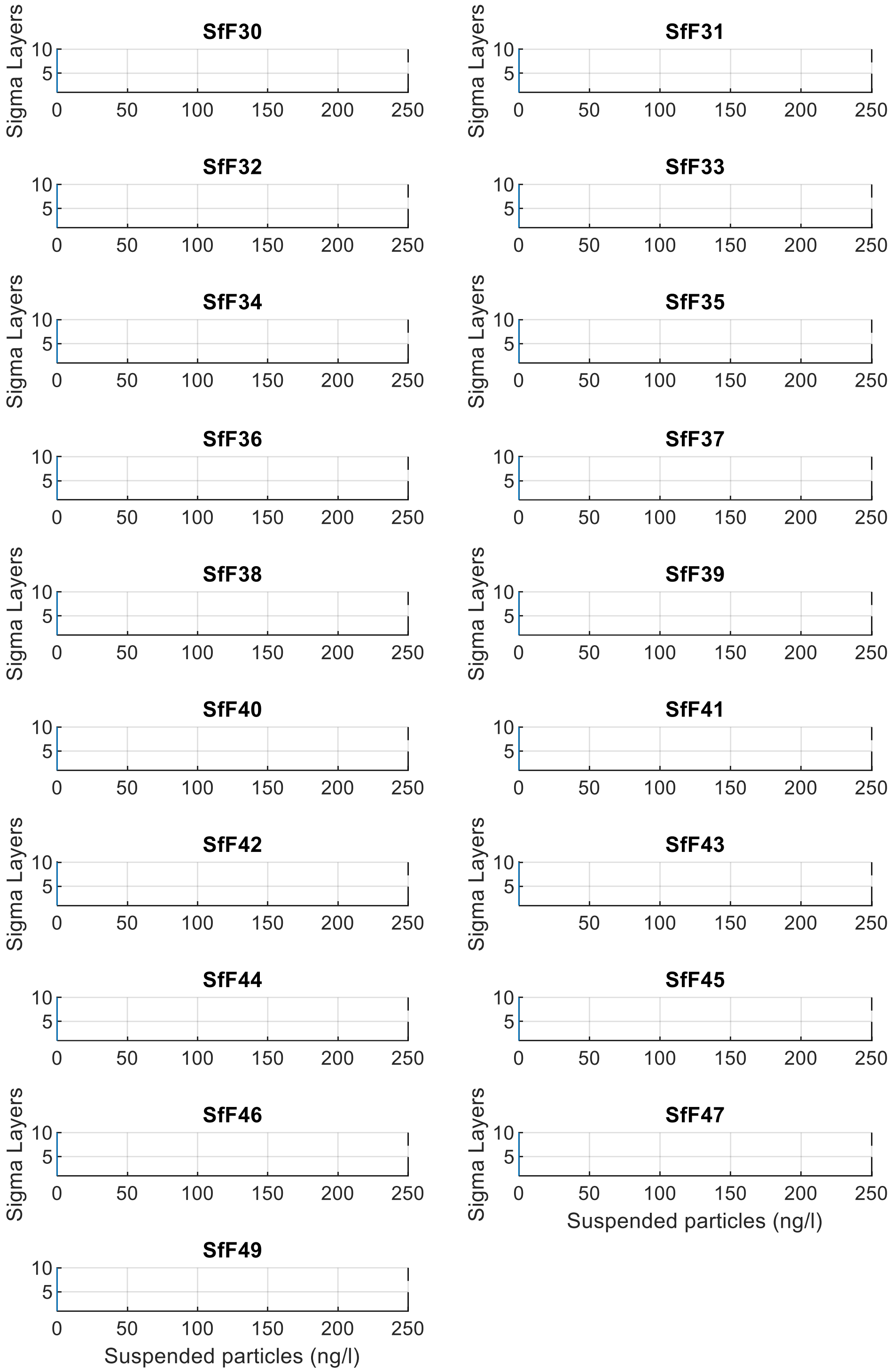


Figure 30. Spring tide vertical concentration profile of Azamethiphos after a treatment plan with a 24-hr treatment mass of 375g at the 72hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

The spatial distribution of Azamethiphos is shown relative to the sensitive feature locations in figure 31. Several time steps are shown, ranging from 3 to 72 hours, and red contour lines are shown for treatment concentrations of 100 ng/l. Treatments are shown to be distributed in a northwestern direction. By 48 hours, the treatment plume has dispersed to very low concentrations with very small pockets remaining above 100ng/l. After 72 hours, no values exceed the EQS.

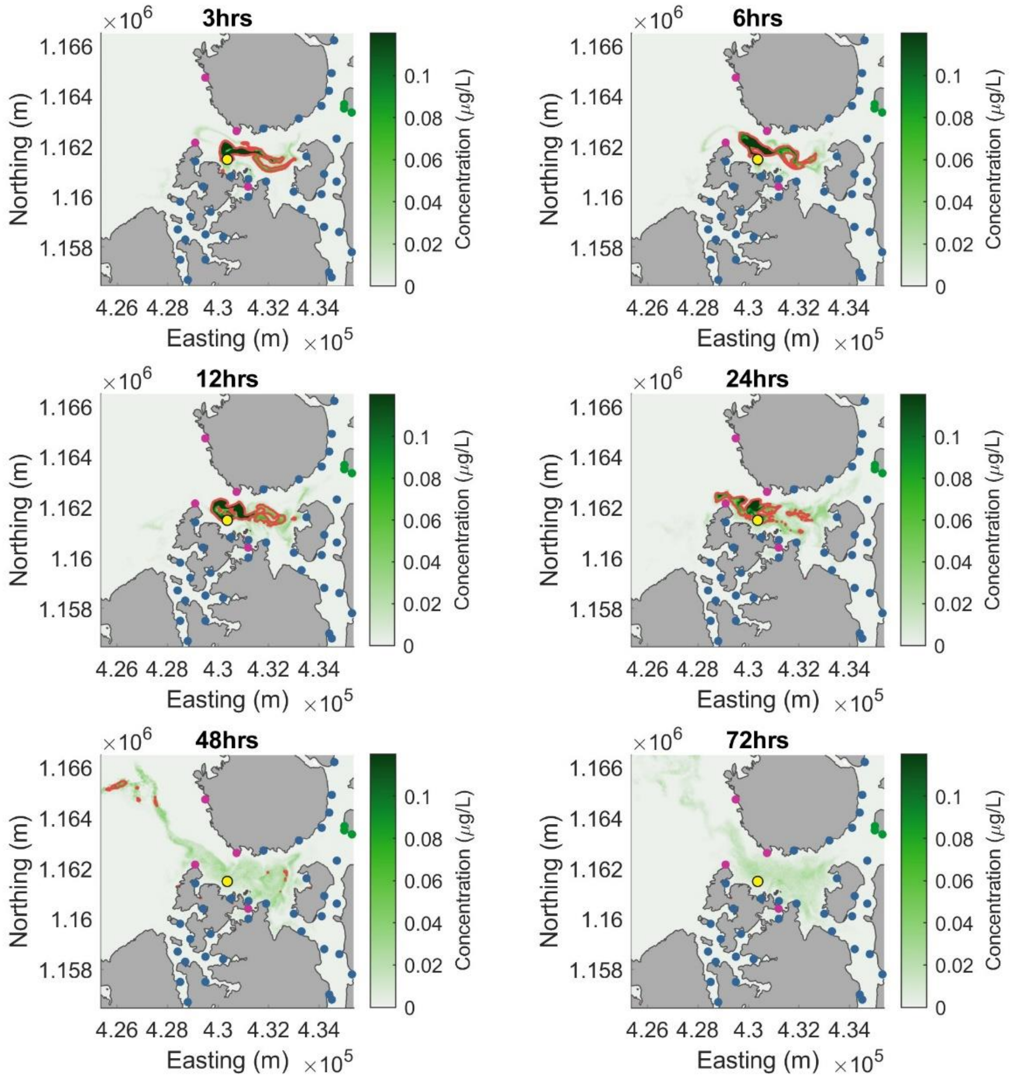
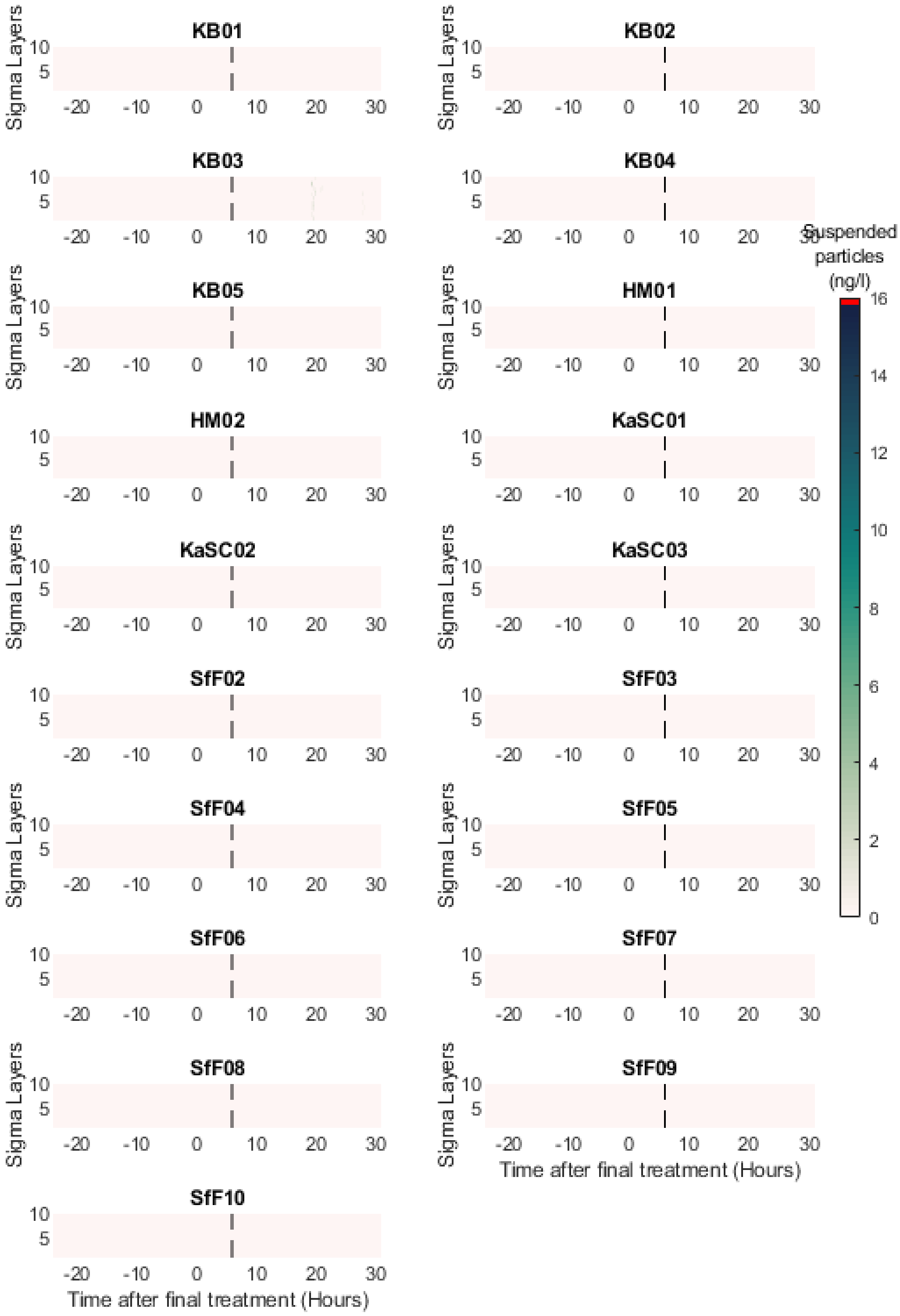


Figure 31. Spatial Azamethiphos distribution for bath treatment releases during spring tides 3hrs to 72 hrs after the last treatment event. Areas above EQS values are indicated within the red contour, site location is identified using a yellow marker and PMF locations are shown as points or polygons.

4.2.2 Cypermethrin

4.2.2.1 Neap tides

Short-term exposure during the neap tide is assessed using a single release of 25g of Cypermethrin. Treatment concentration at features is identified in figure 32, where all features show no observable treatment concentrations.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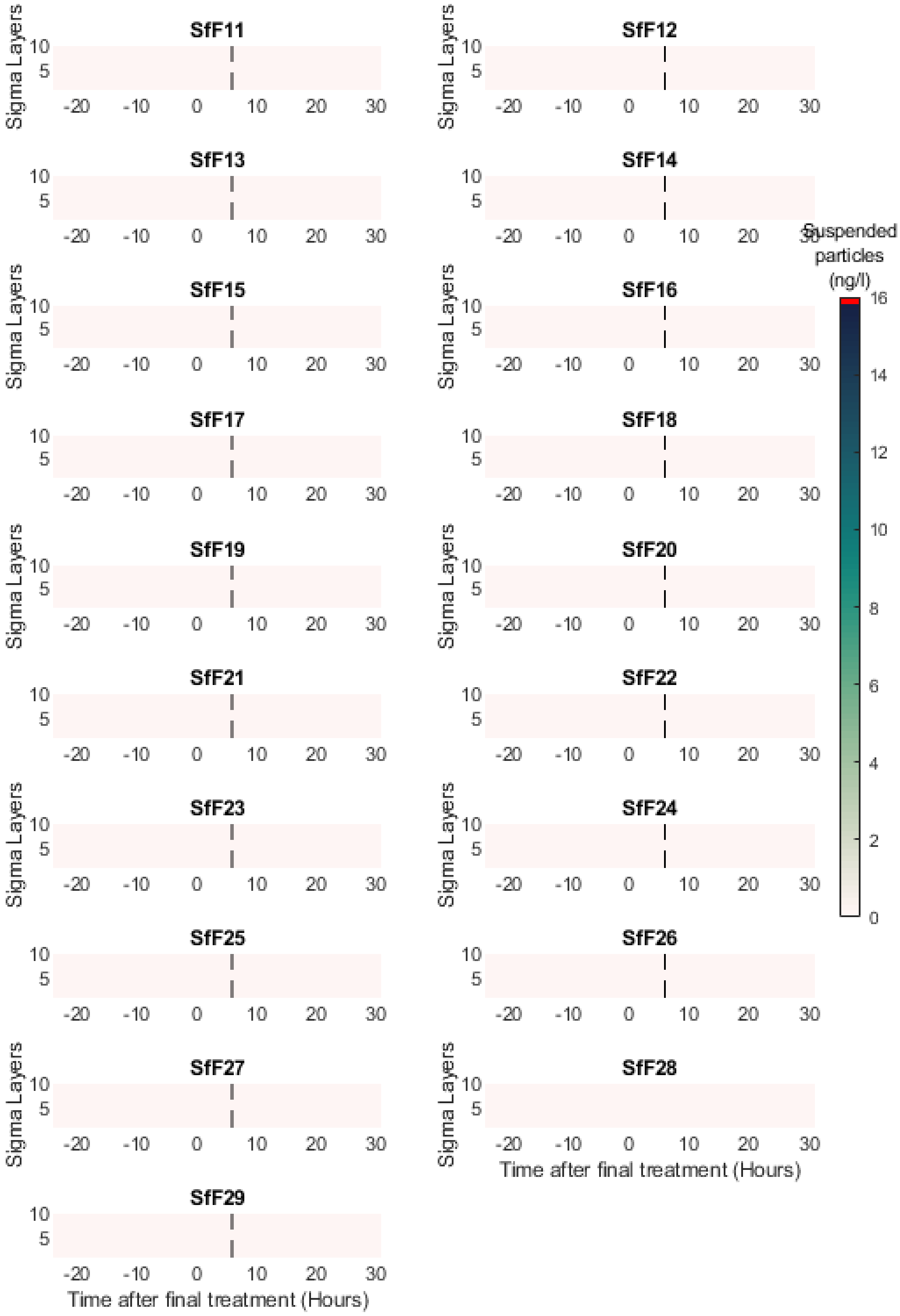
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)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SfF24
SfF25
SfF26
SfF27
SfF28
SfF29
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)
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-10
0
10
20
30

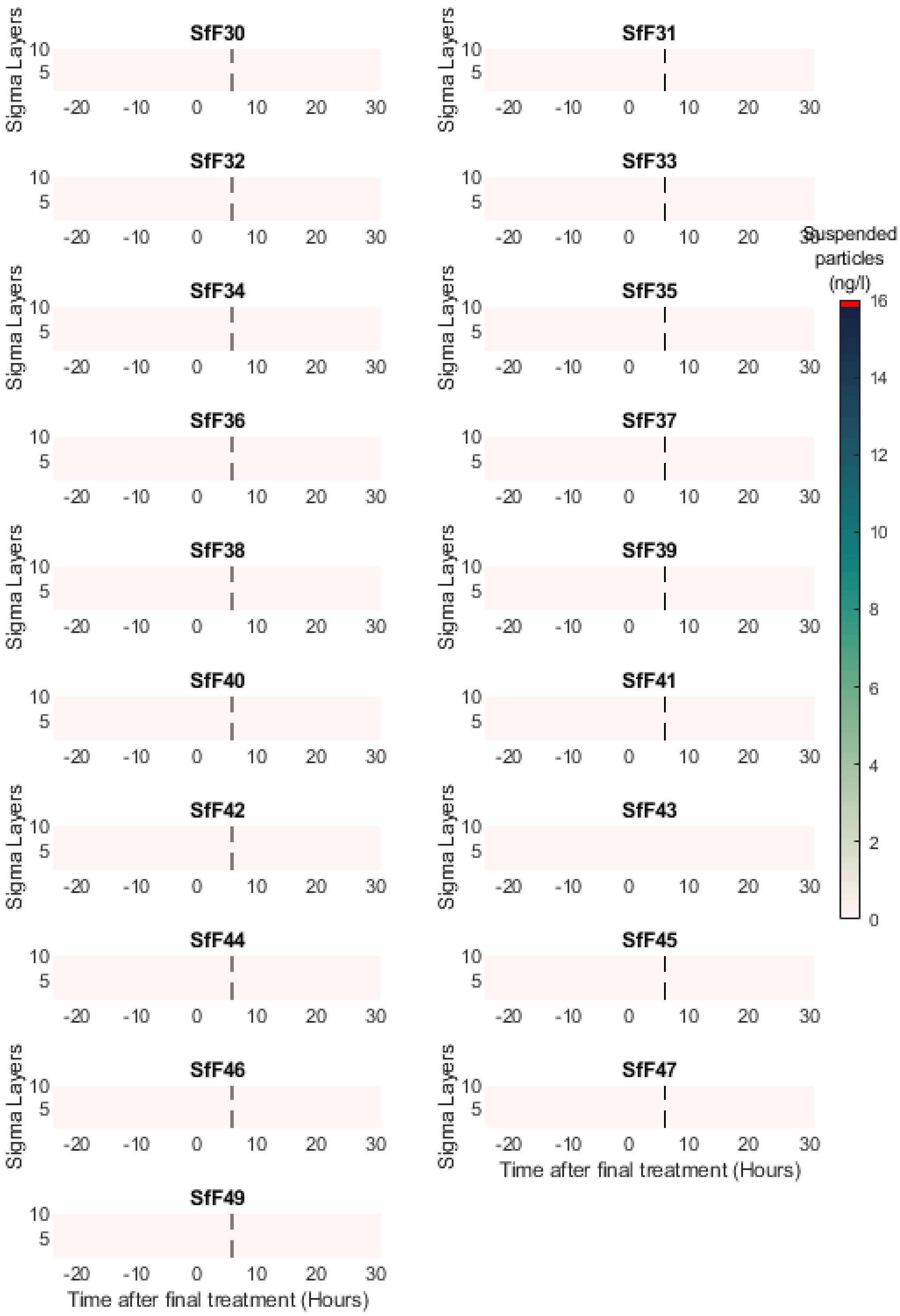
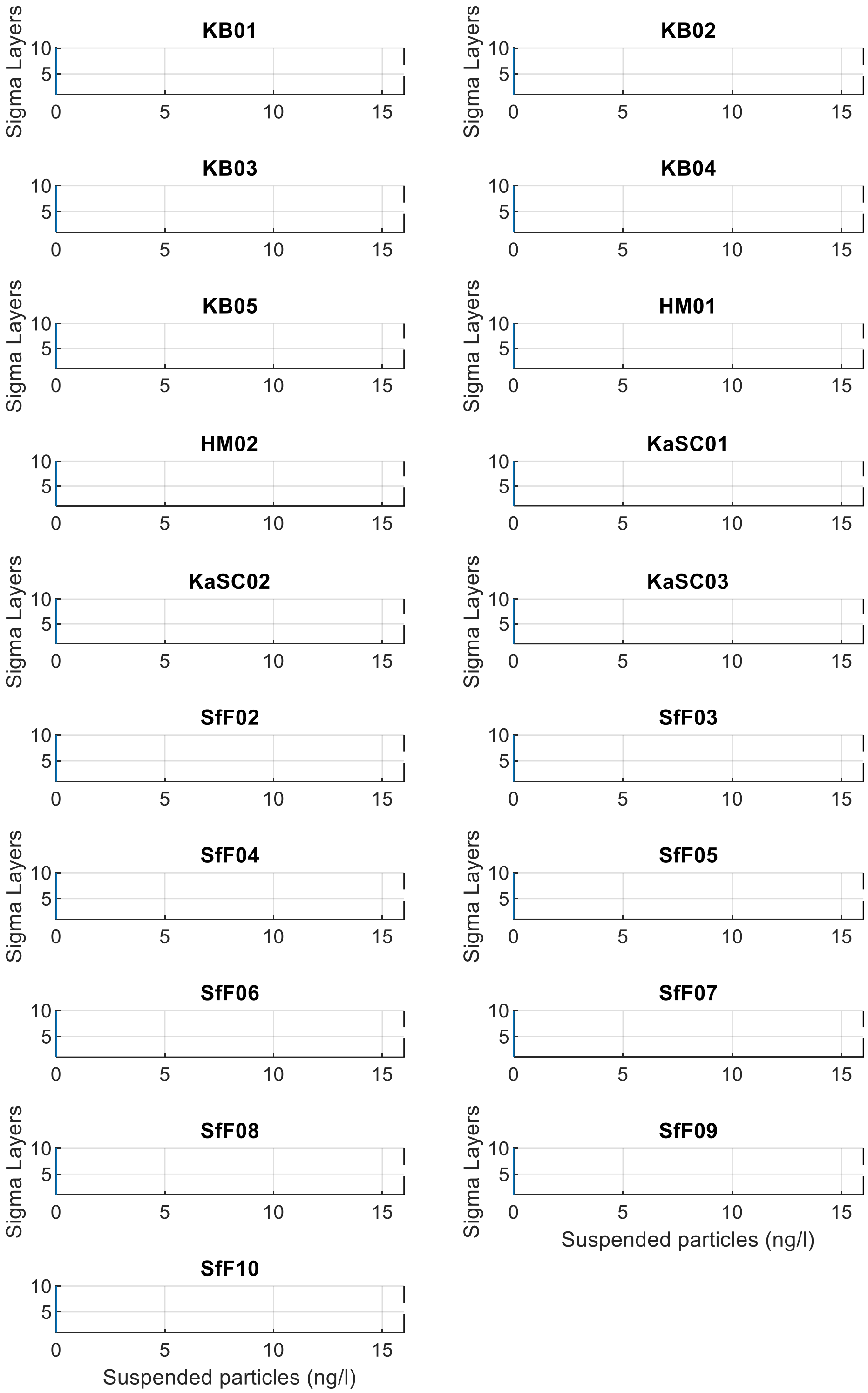
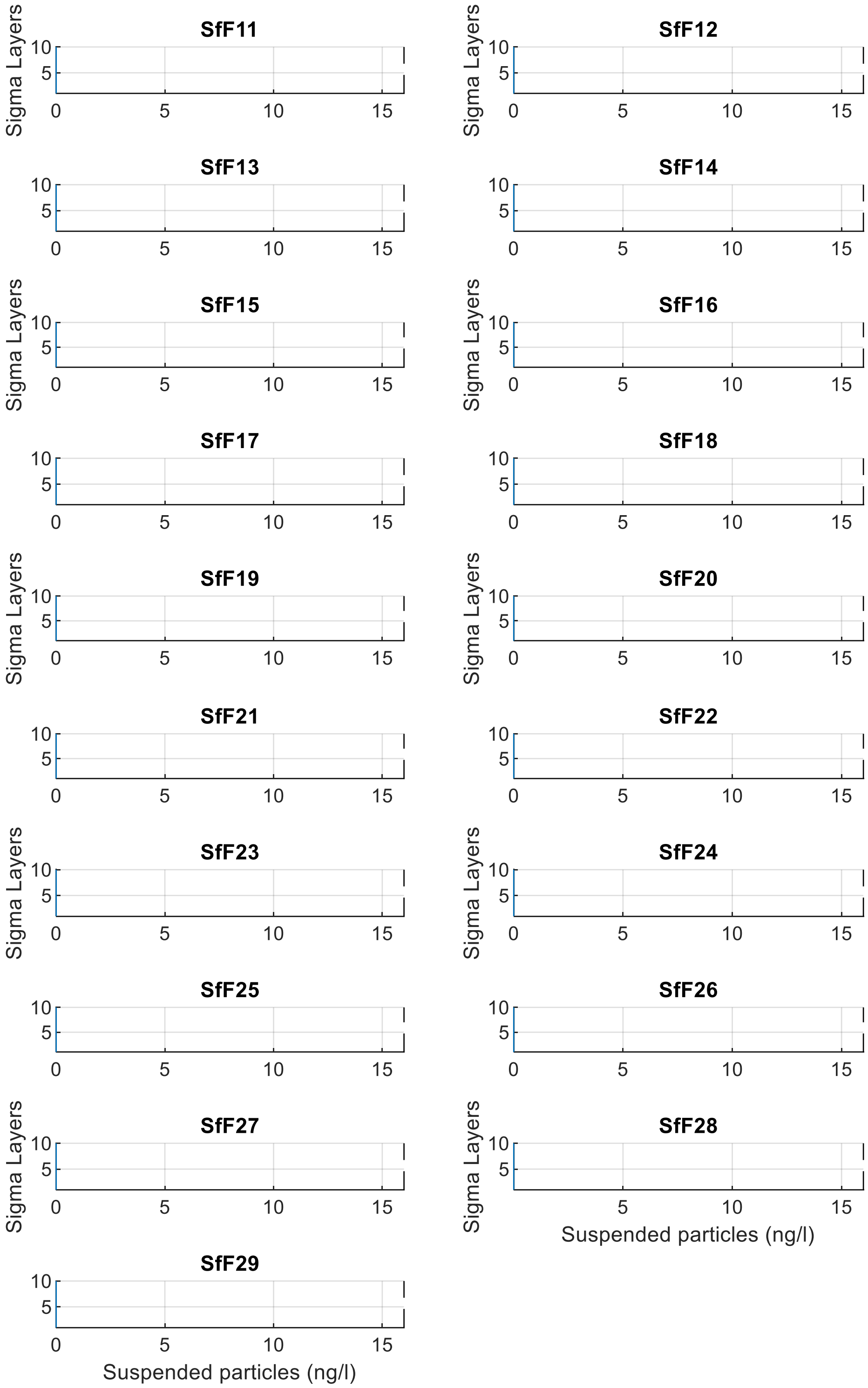


Figure 32. Neap tide Cypermethrin concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar, with any values indicated in red that exceed the 6hr EQS value. Water depth is defined in model sigma layers, where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

Vertical concentration profiles for each feature are shown in figure 33 for the 6hr EQS time. After 6hrs no treatment concentrations are shown for any of the identified features.

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SfF29
Sigma Layers
Suspended particles (ng/l)
0
5
10
15

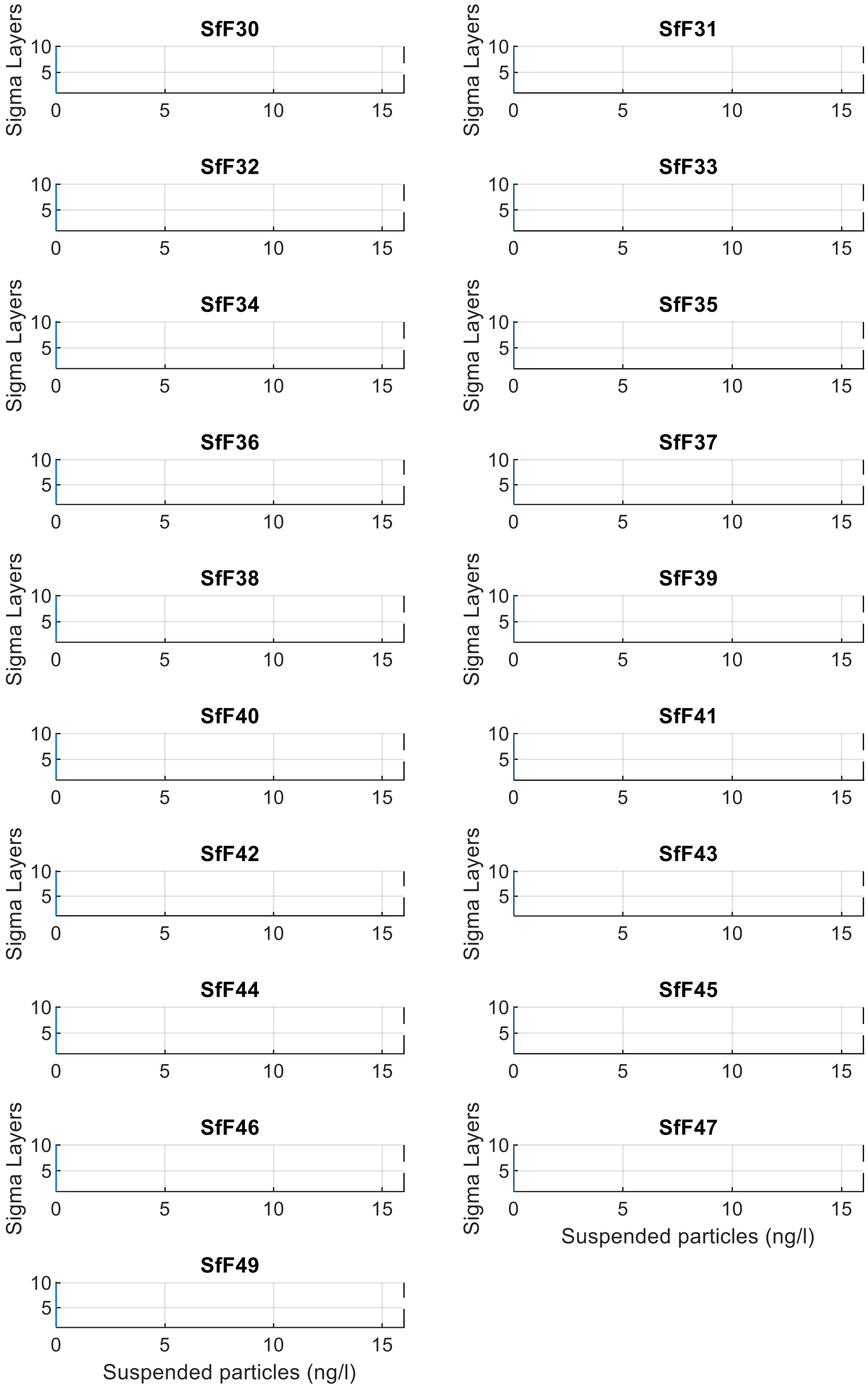


Figure 33. Neap tide vertical concentration profile of Cypermethrin after the single treatment at the 6 hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

The spatial distribution of Cypermethrin is shown relative to the sensitive feature locations in figure 34. Red contour lines are shown for treatment concentrations of 16 ng/l. The treatment plume is shown to be distributed to the northwest and out of the Swarbacks Minn water body.

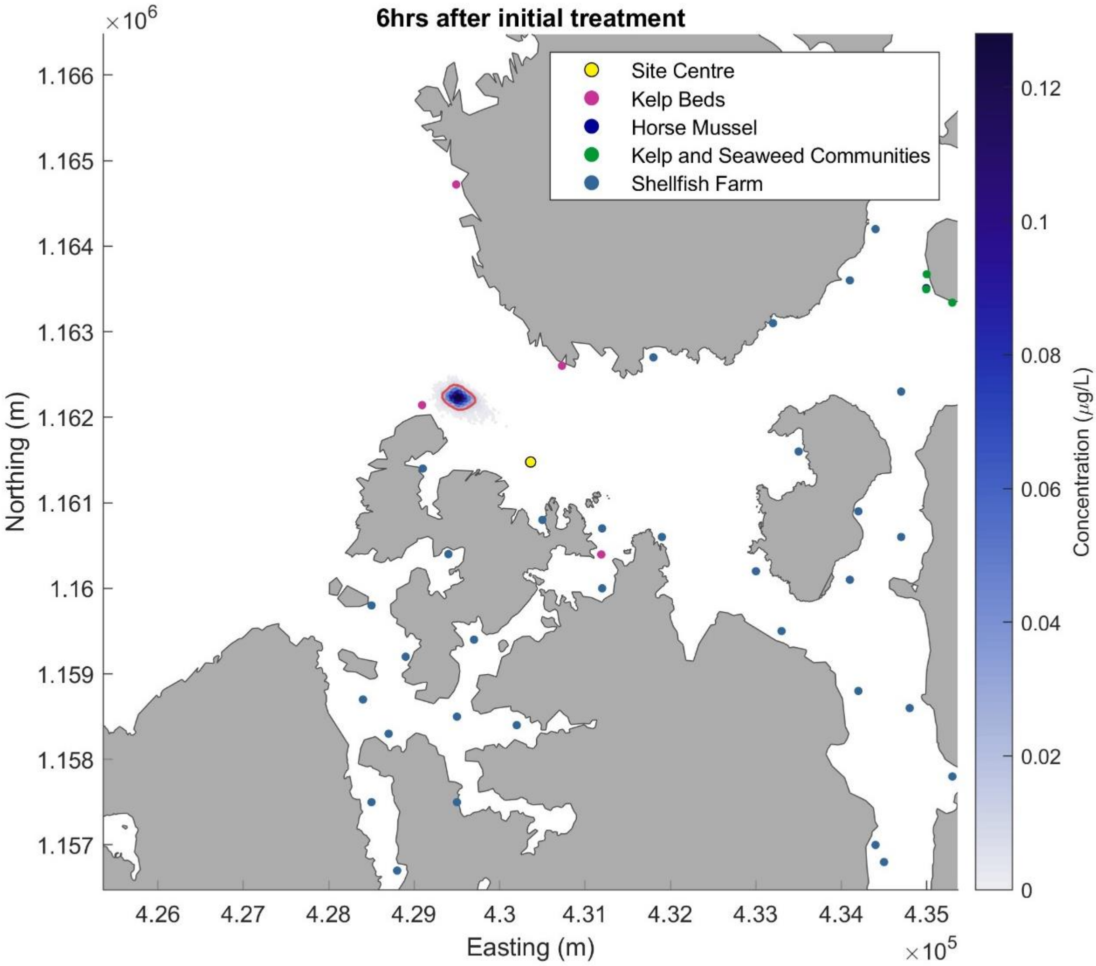
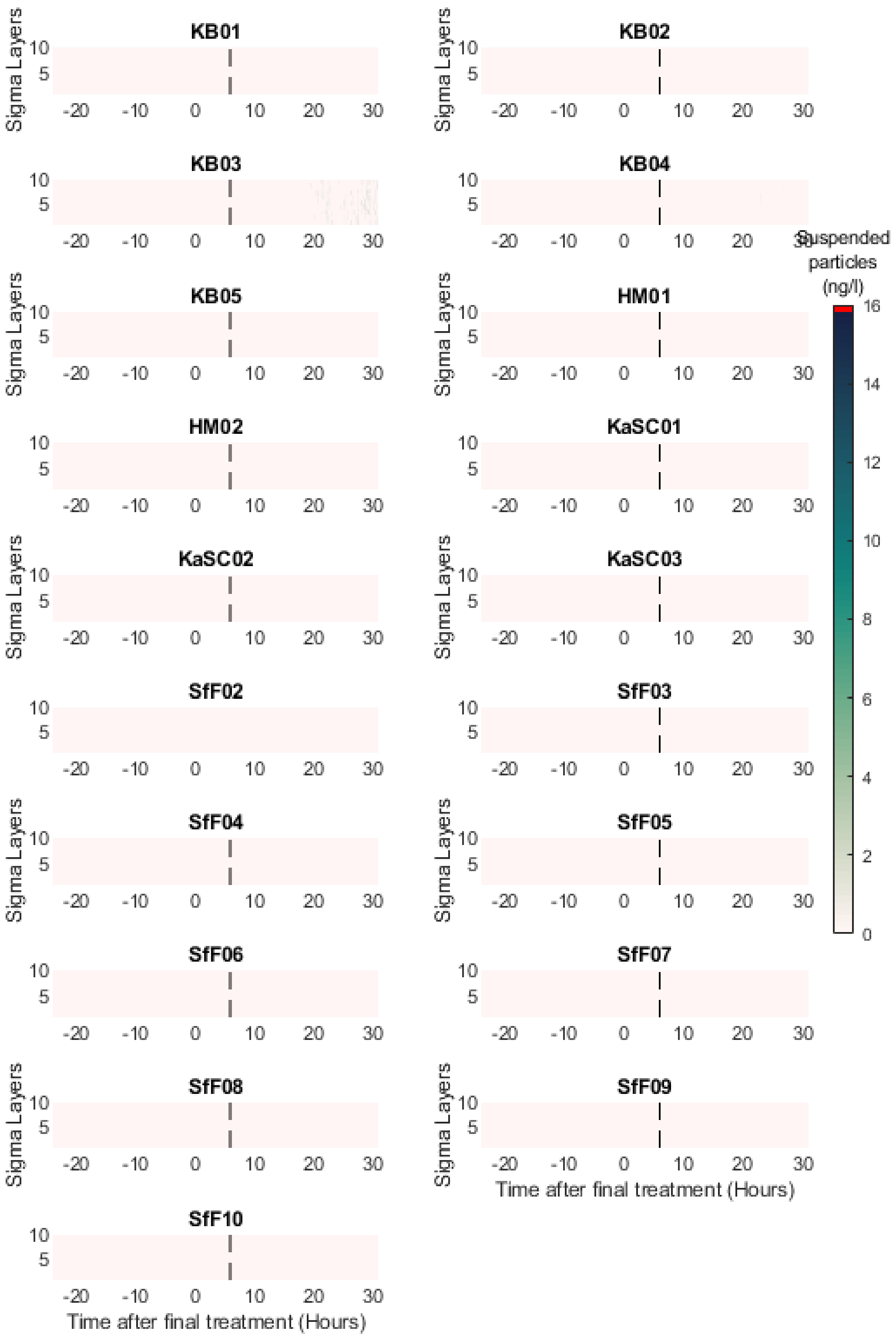


Figure 34. Spatial Cypermethrin distribution for bath treatment releases during neap tides 6 hours after treatment. Areas above EQS values are indicated within the red contour, the site location is identified using a yellow marker and PMF locations are shown as points or polygons.

4.2.2.2 Spring tides

Short-term exposure during the spring tide is assessed using a single release of 25g of Cypermethrin. Treatment concentration at sensitive features is identified in figure 35. No observable treatment concentrations are shown for any feature, with the exception of SfF28. This shows a grainy presence of treatment around 28 hours after the release.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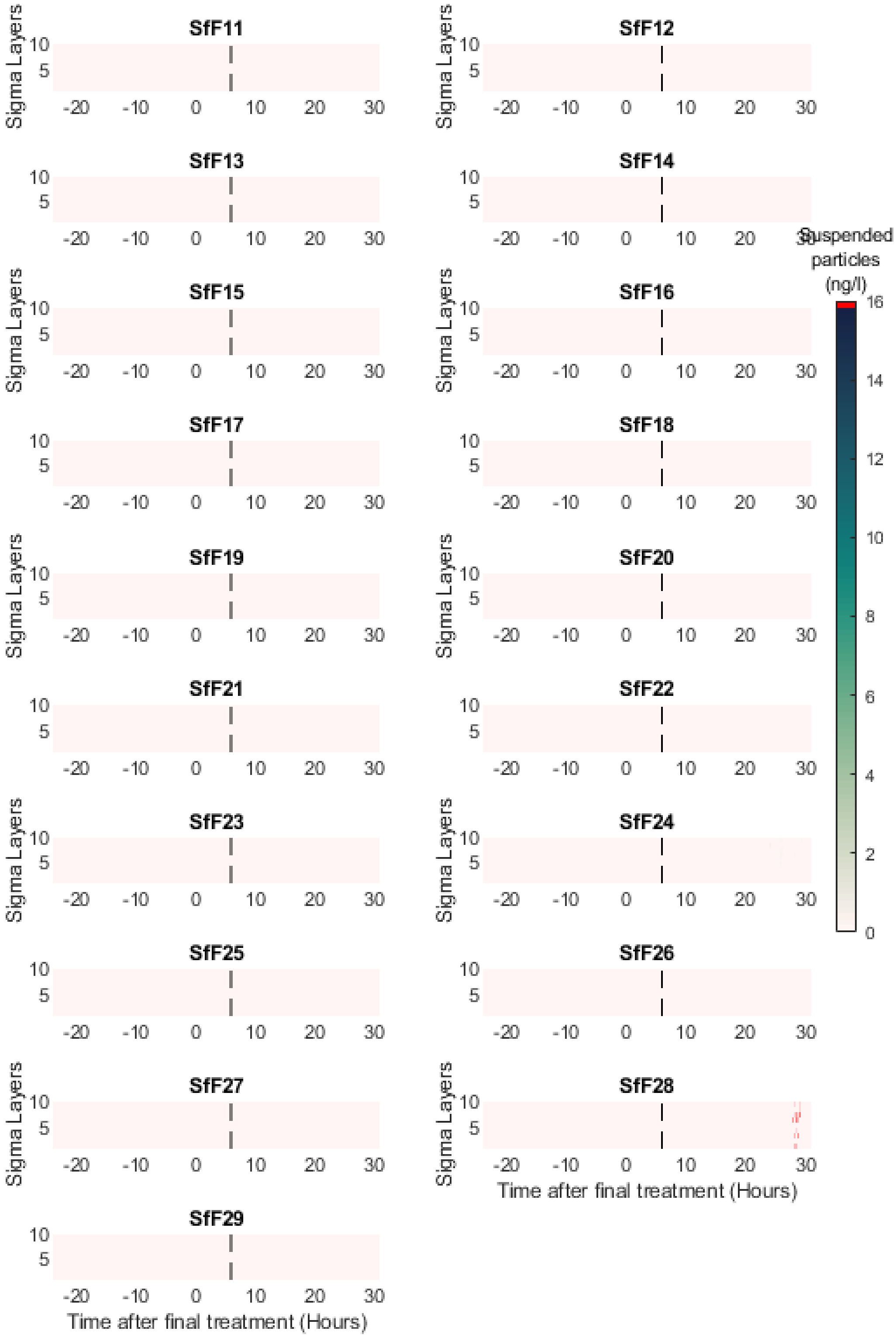
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)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SfF26
SfF27
SfF28
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Suspended particles (ng/l)
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8
10
12
14
16

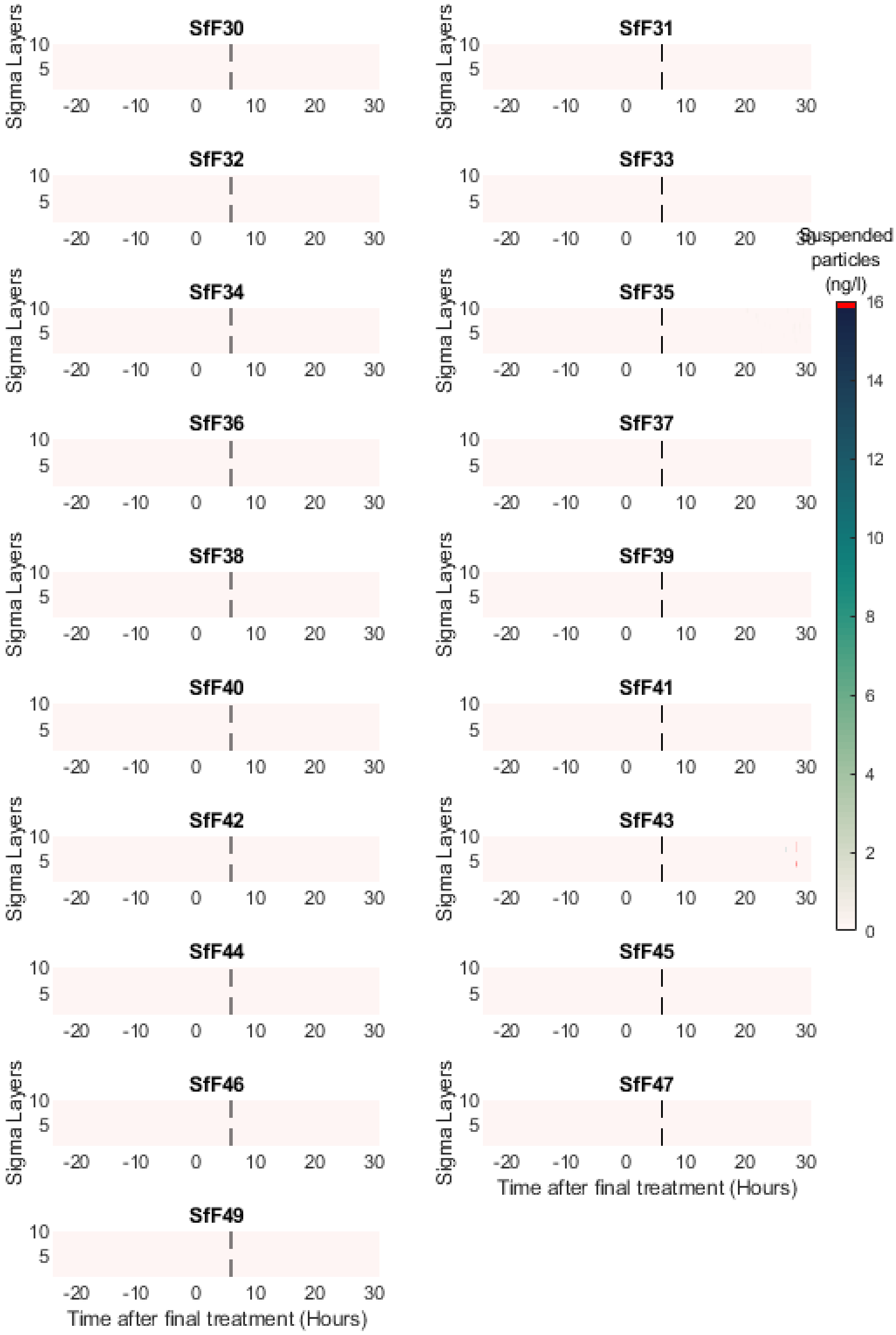
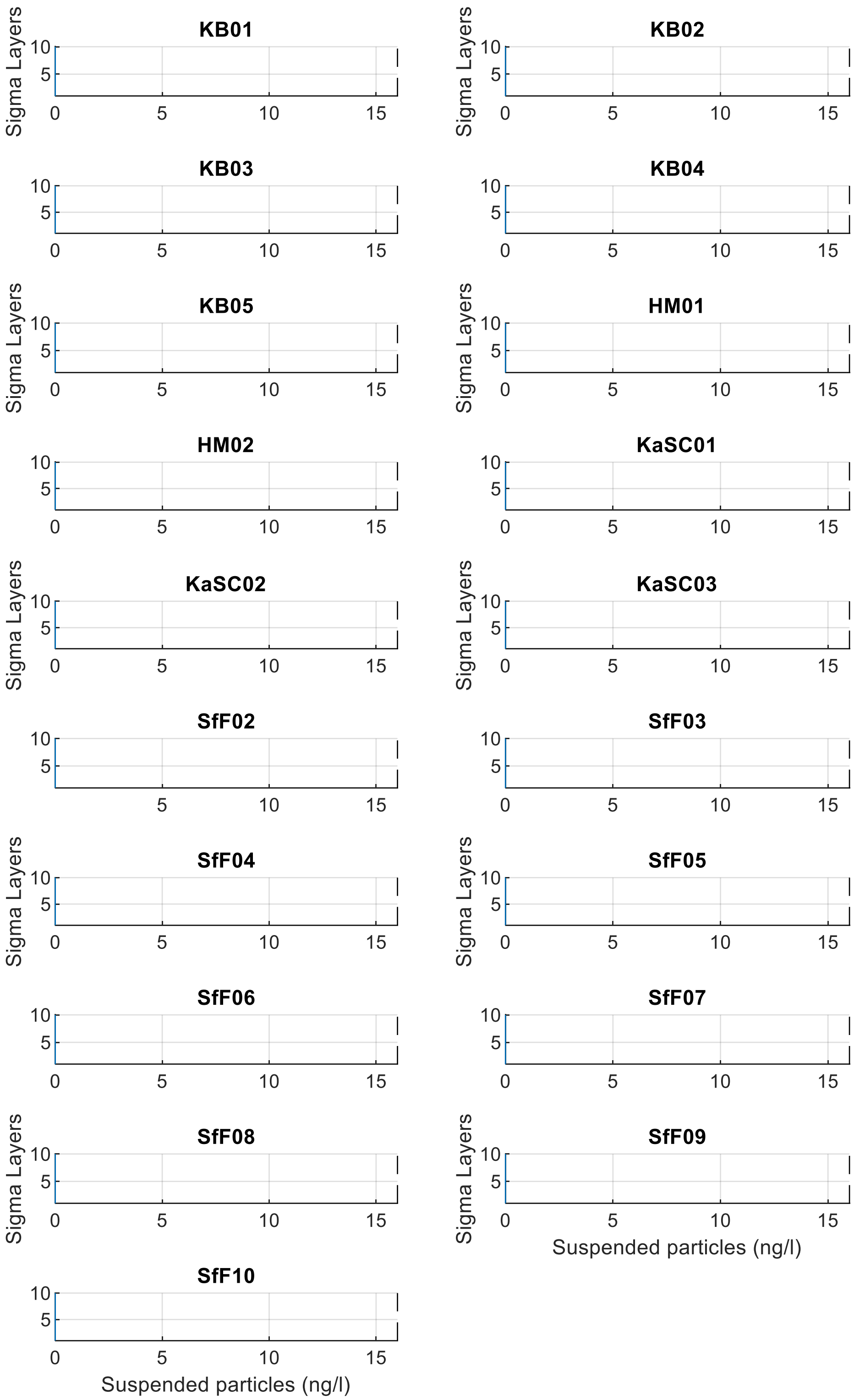
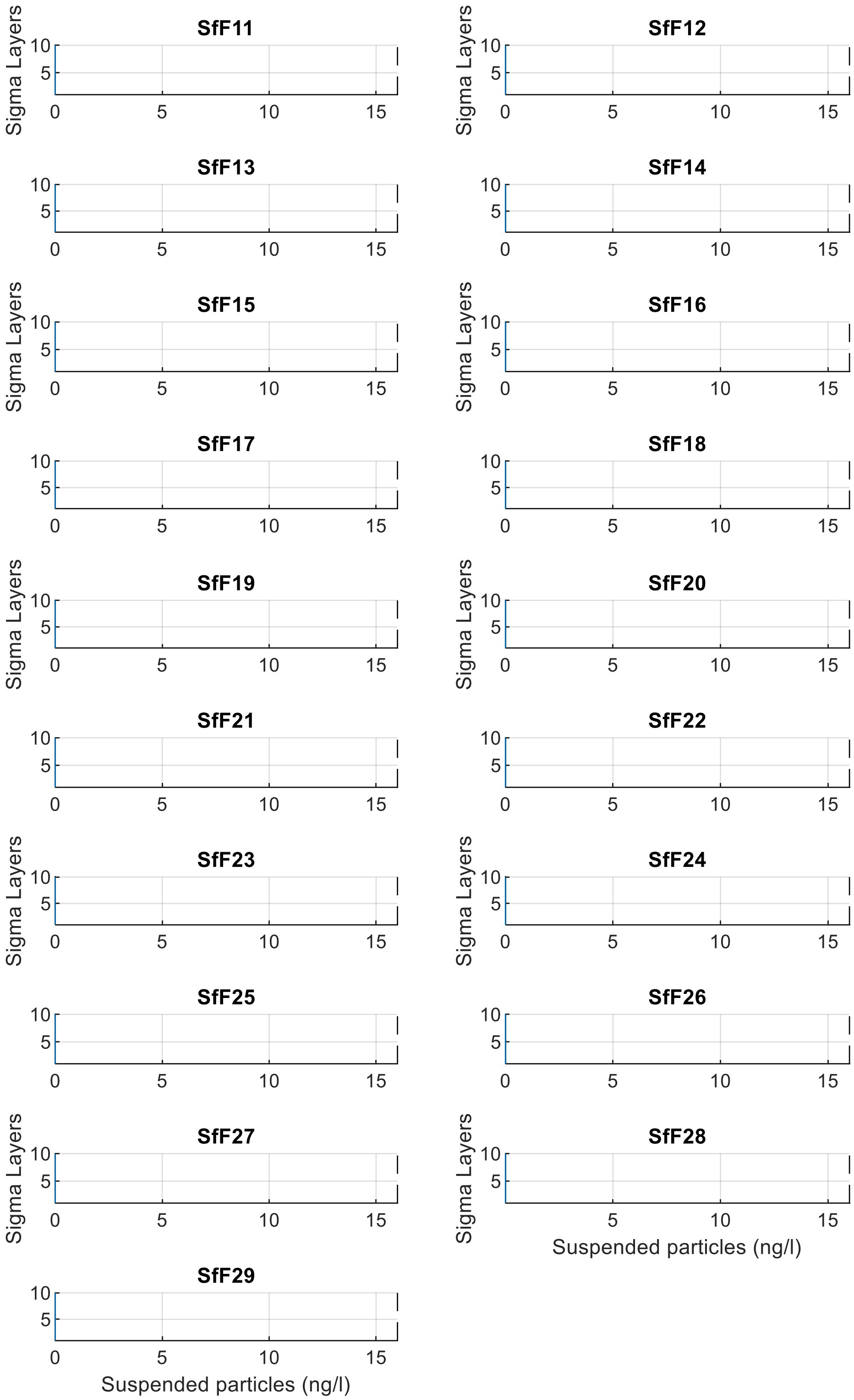


Figure 35. Spring tide Cypermethrin concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar, with any values indicated in red that exceed the 6hr EQS value. Water depth is defined in model sigma layers, where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

Vertical concentration profiles for each feature are shown in figure 36 for the 6hr EQS time. After 6 hours, no treatment concentrations are shown for any of the identified features.

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Sigma Layers
Suspended particles (ng/l)

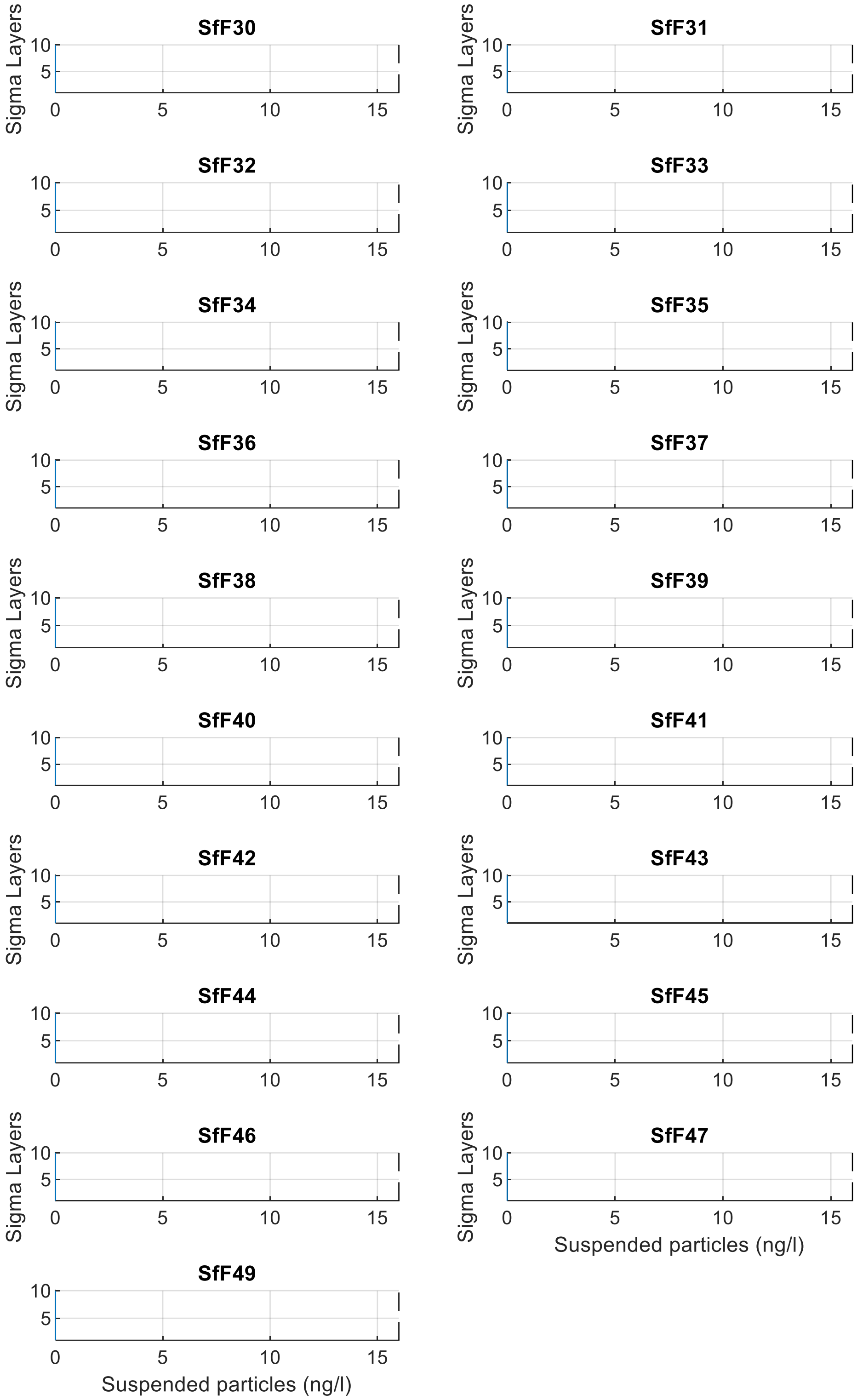


Figure 36. Spring tide vertical concentration profile of Cypermethrin after the single treatment at the 6 hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

The spatial distribution of Cypermethrin is shown relative to the sensitive feature locations in figure 37. Red contour lines are shown for treatment concentrations of 16 ng/l. The treatment plume is shown to be distributed to the north, in the centre of the channel, away from feature locations.

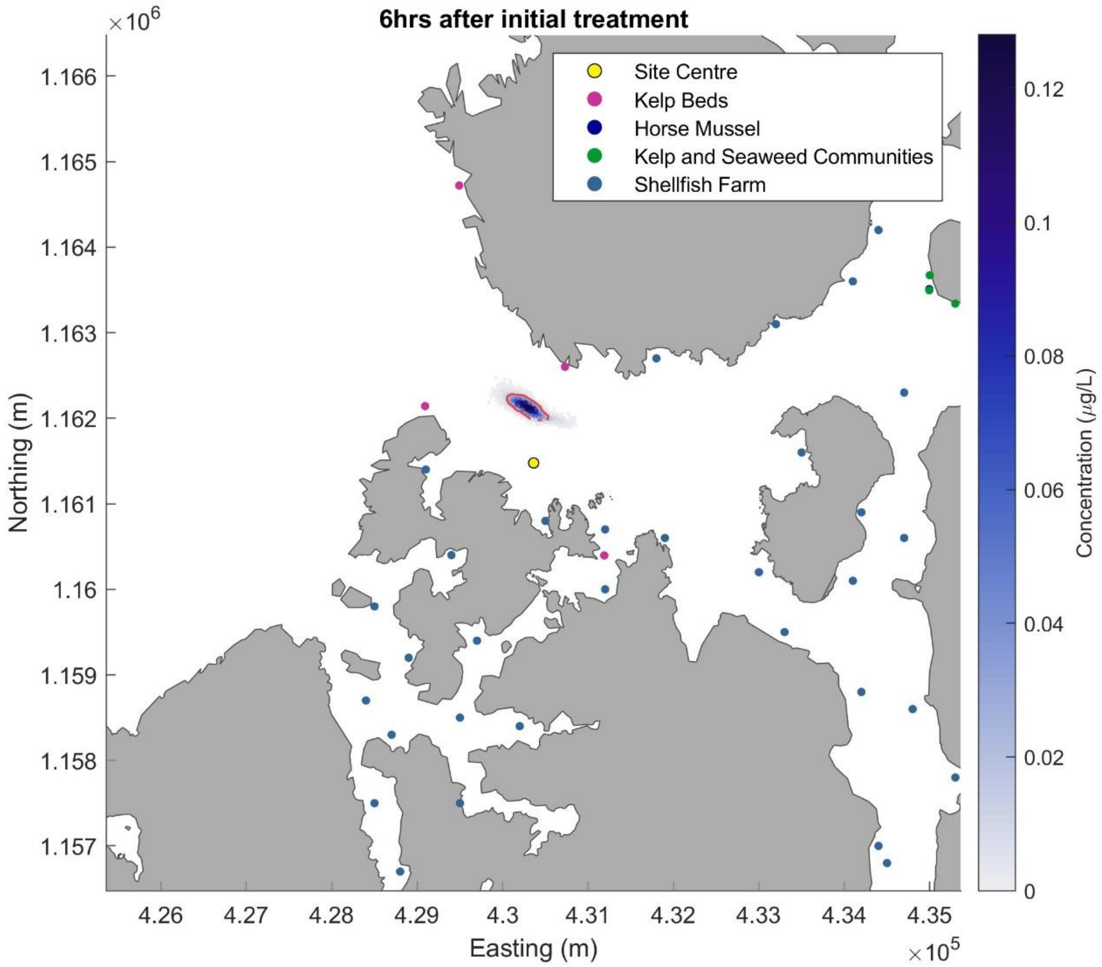
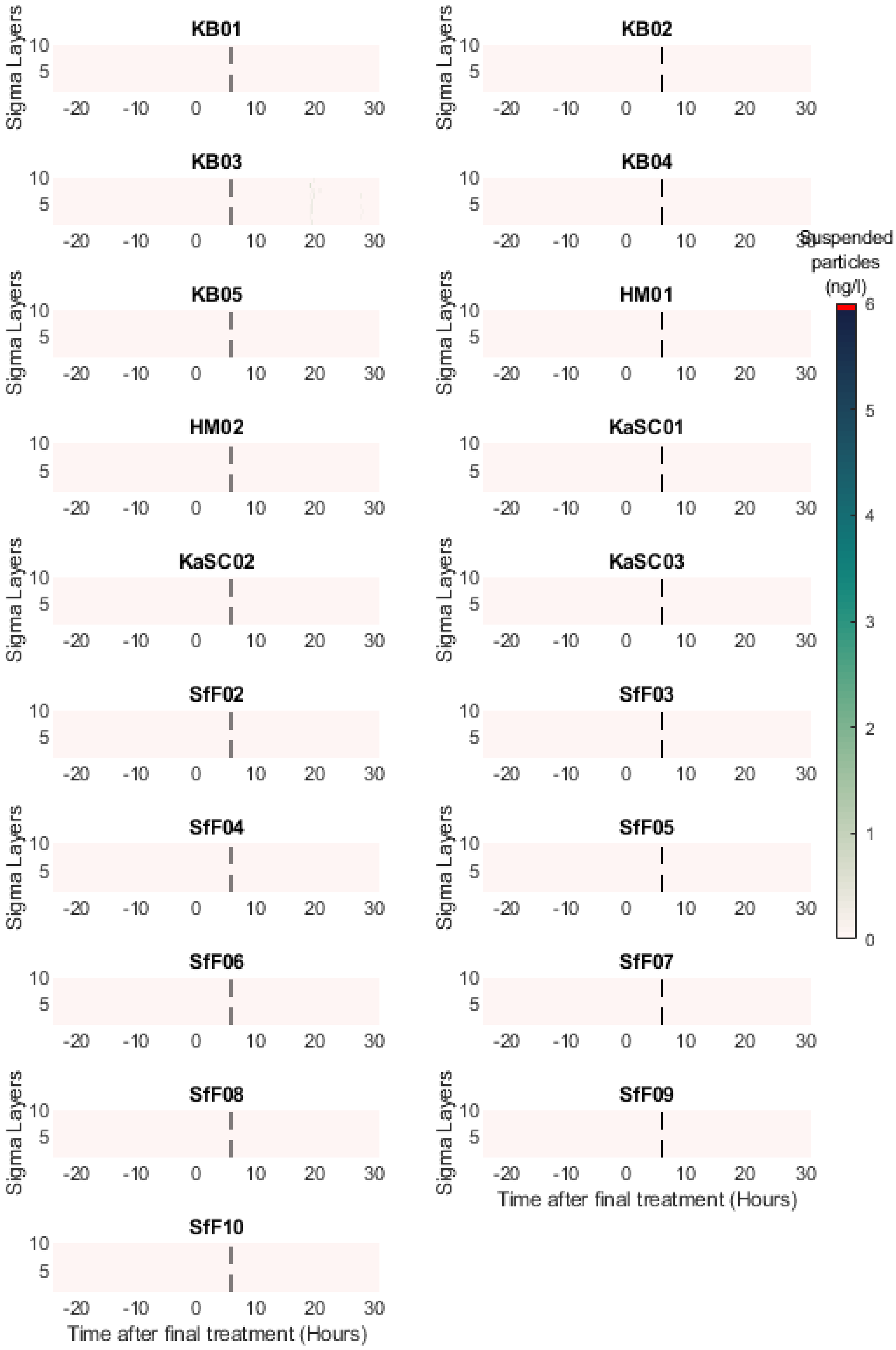


Figure 37. Spatial Cypermethrin distribution for bath treatment releases during spring tides 6hrs after treatment. Areas above EQS values are indicated within the red contour, the site location is identified using a yellow marker and PMF locations are shown as points or polygons.

4.2.3 Deltamethrin

4.2.3.1 Neap tides

Short-term exposure during the neap tide is assessed using a single release of 10g of Deltamethrin. Treatment concentration at features is identified in figure 38. All features show no treatment interaction.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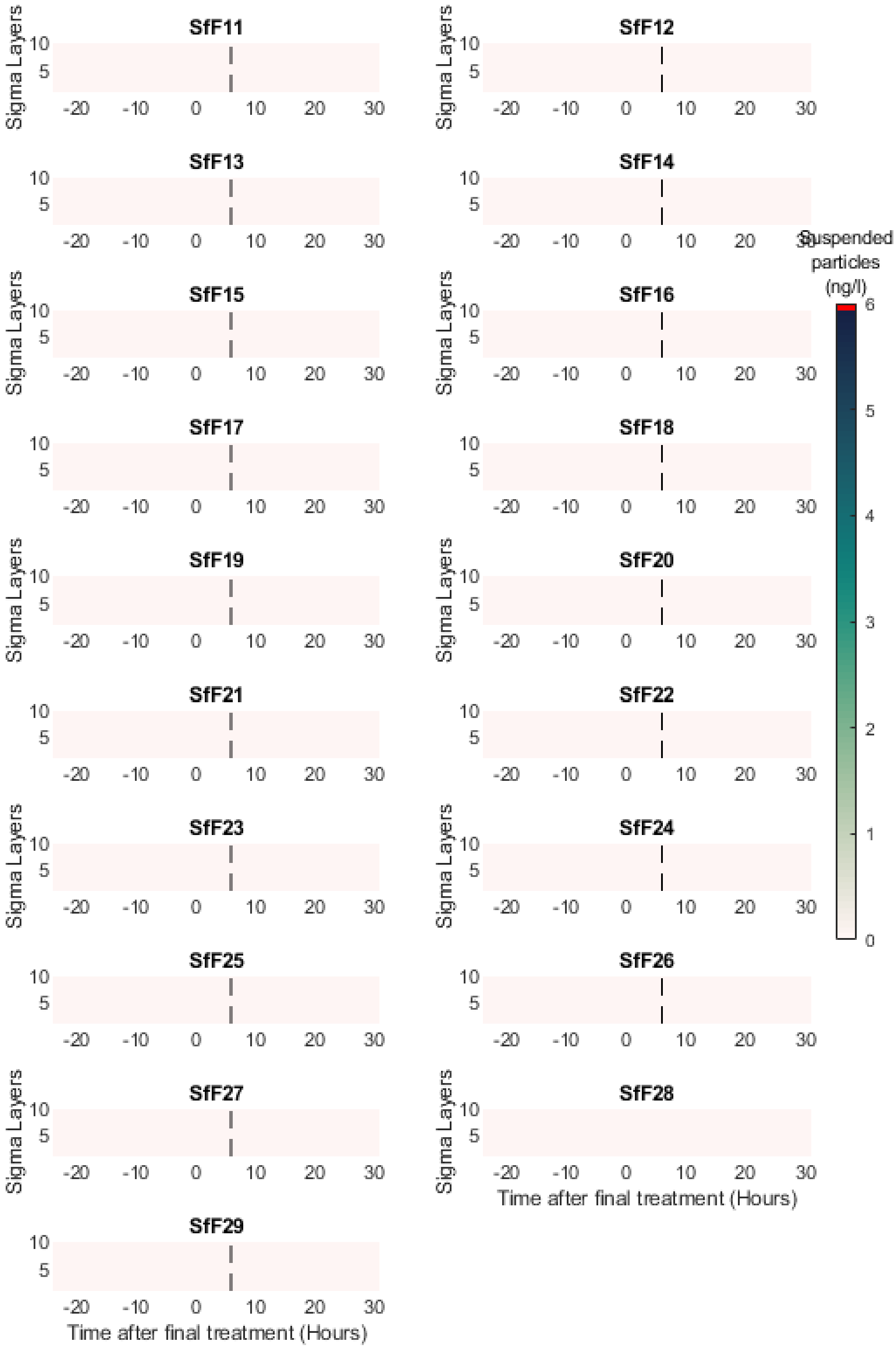
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)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Time after final treatment (Hours)
Suspended particles (ng/l)

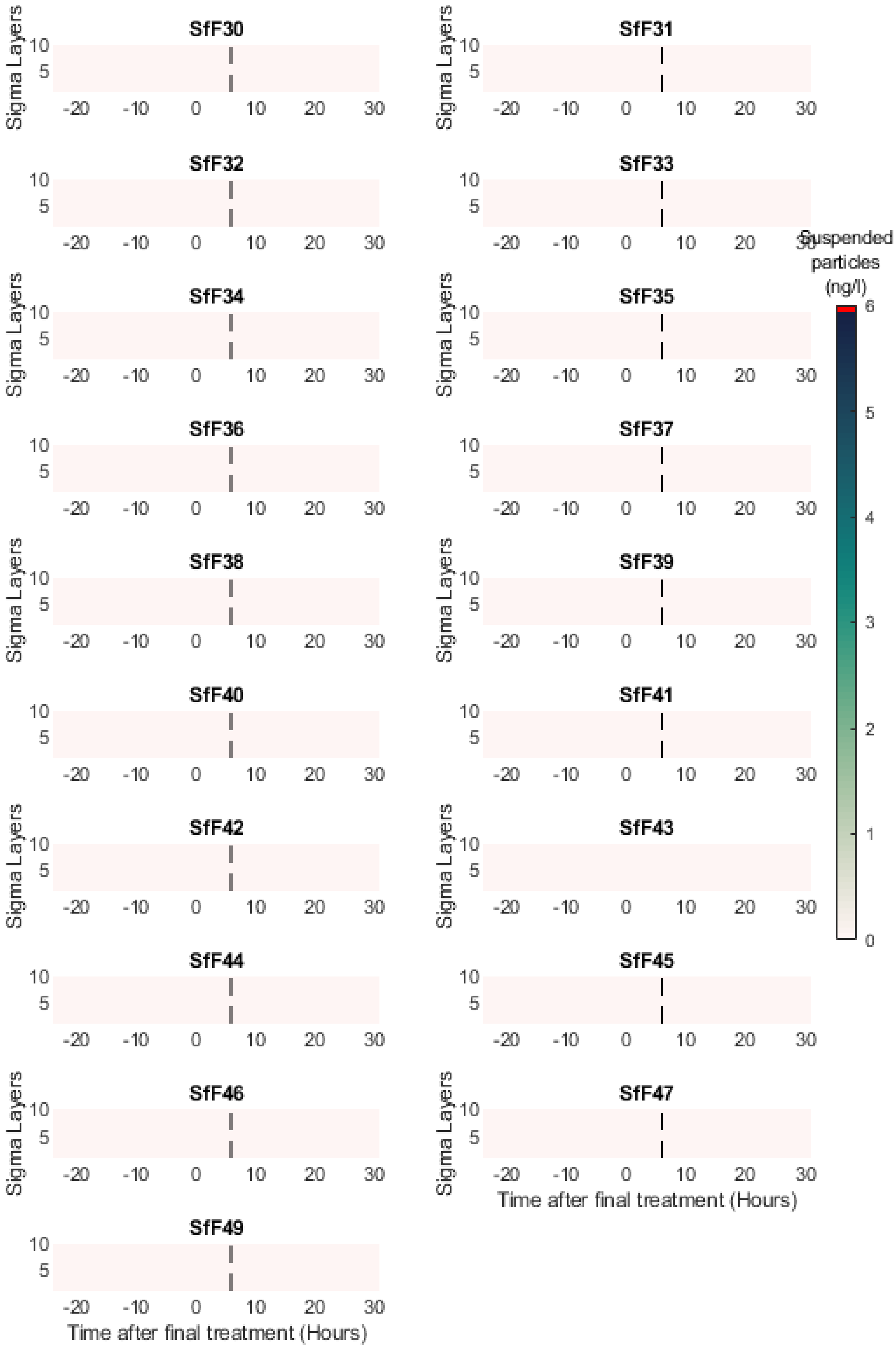
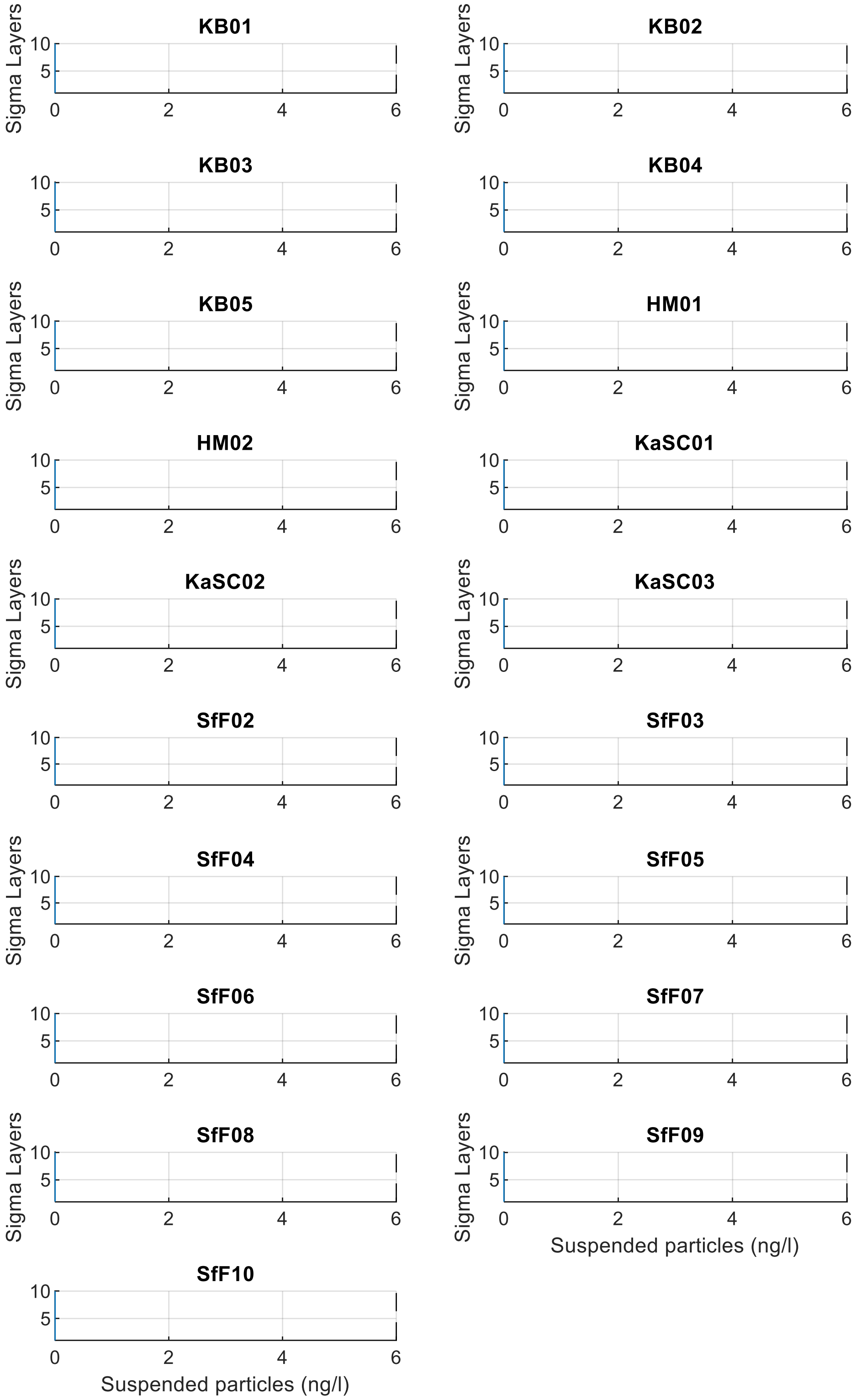
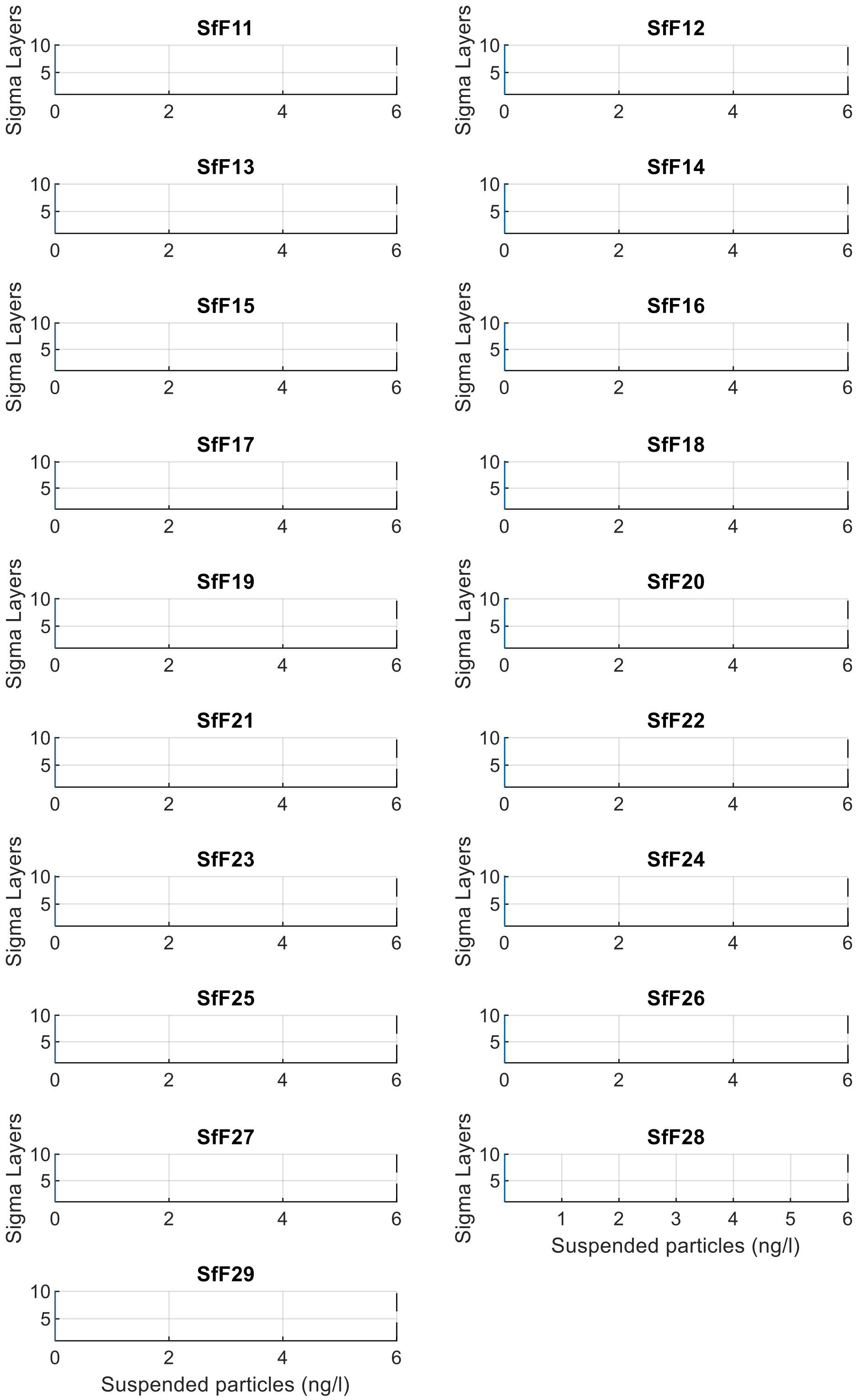


Figure 38. Neap tide Deltamethrin concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar, with any values indicated in red that exceed the 6hr EQS value. Water depth is defined in model sigma layers,

where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

Vertical concentration profiles for each feature are shown in figure 39 for the 6hr EQS time. After 6 hours, no treatment concentrations are shown for any of the identified features.

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Sigma Layers
Suspended particles (ng/l)

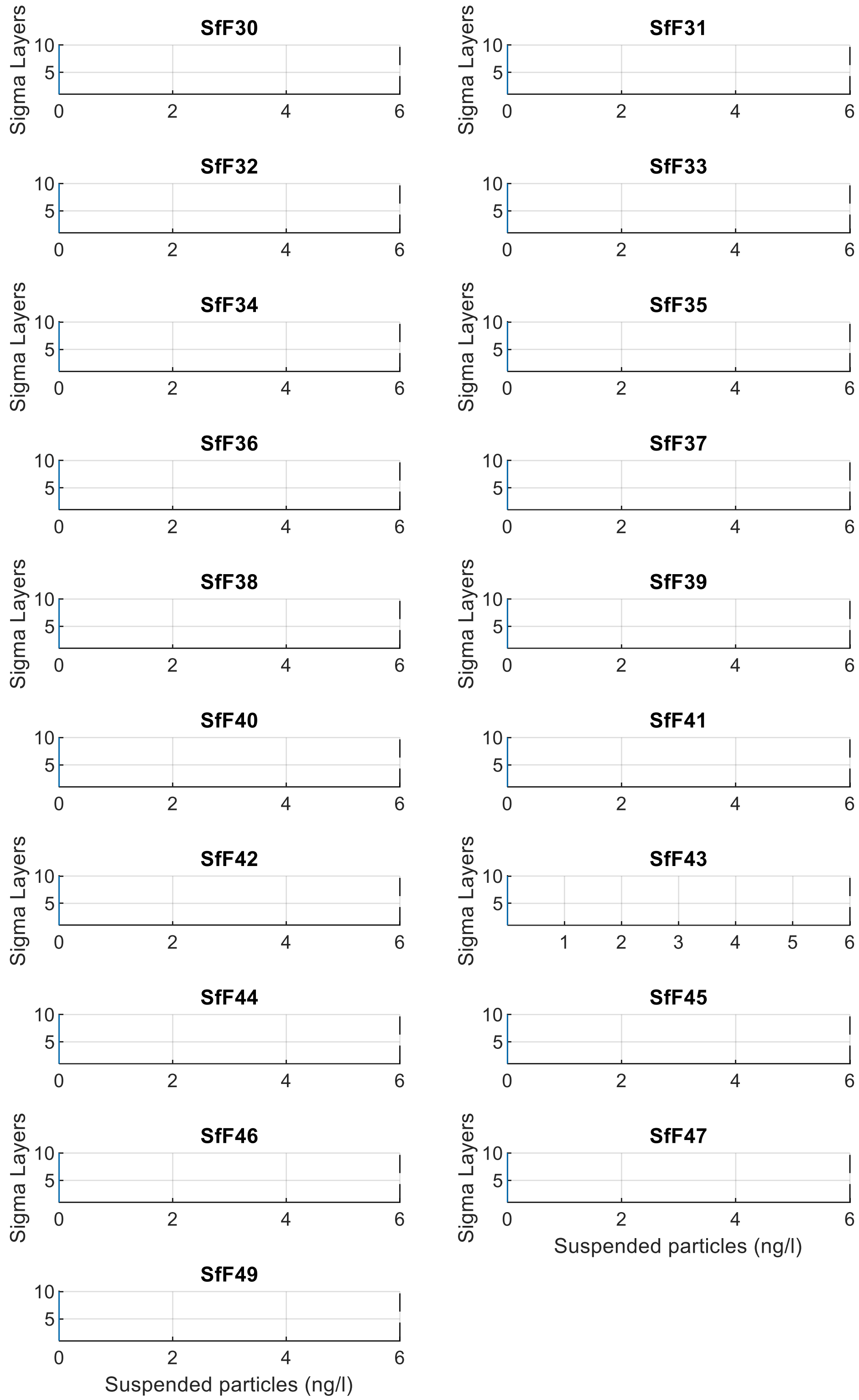


Figure 39. Neap tide vertical concentration profile of Cypermethrin after the single treatment at the 6 hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

The spatial distribution of Deltamethrin is shown relative to the feature locations in figure 40. Red contour lines are shown for treatment concentrations of 6 ng/l. The treatment plume is shown to be distributed northwest of the site.

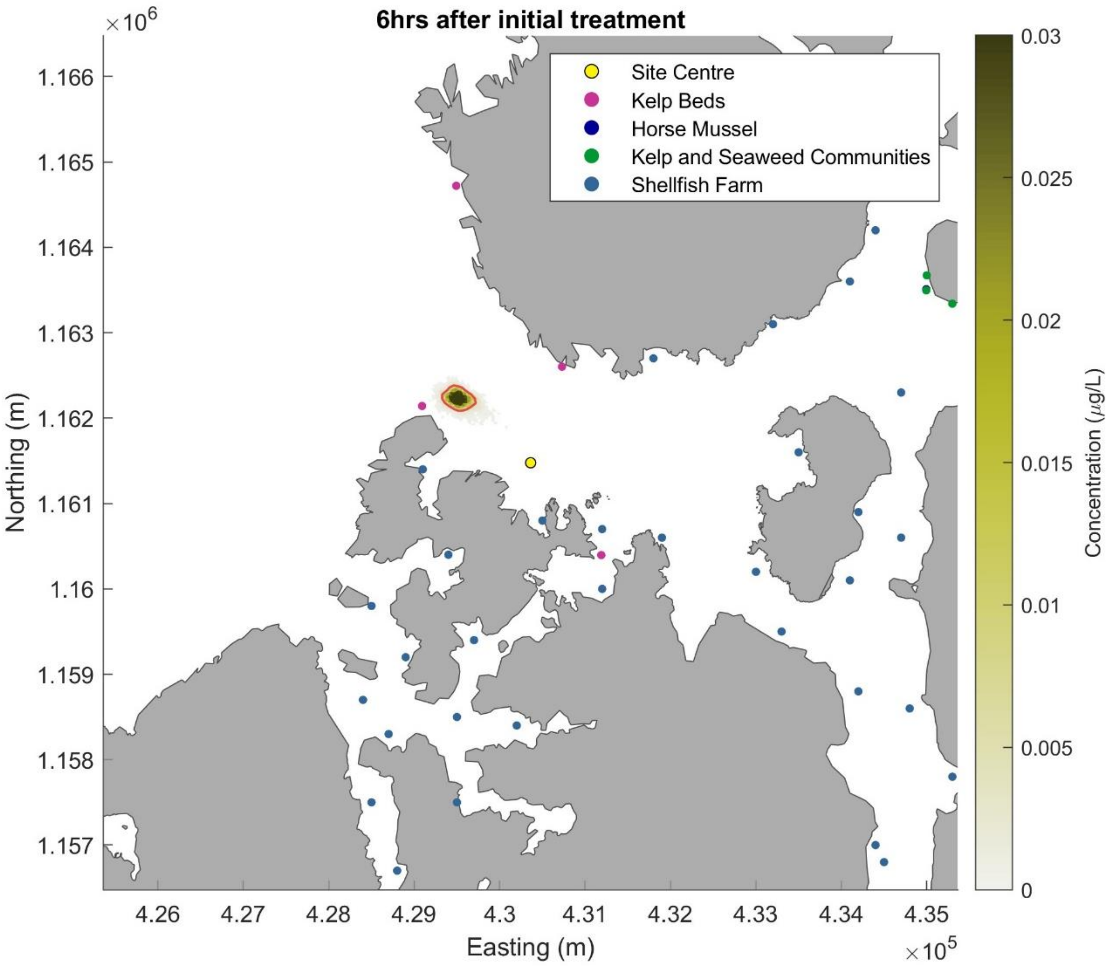
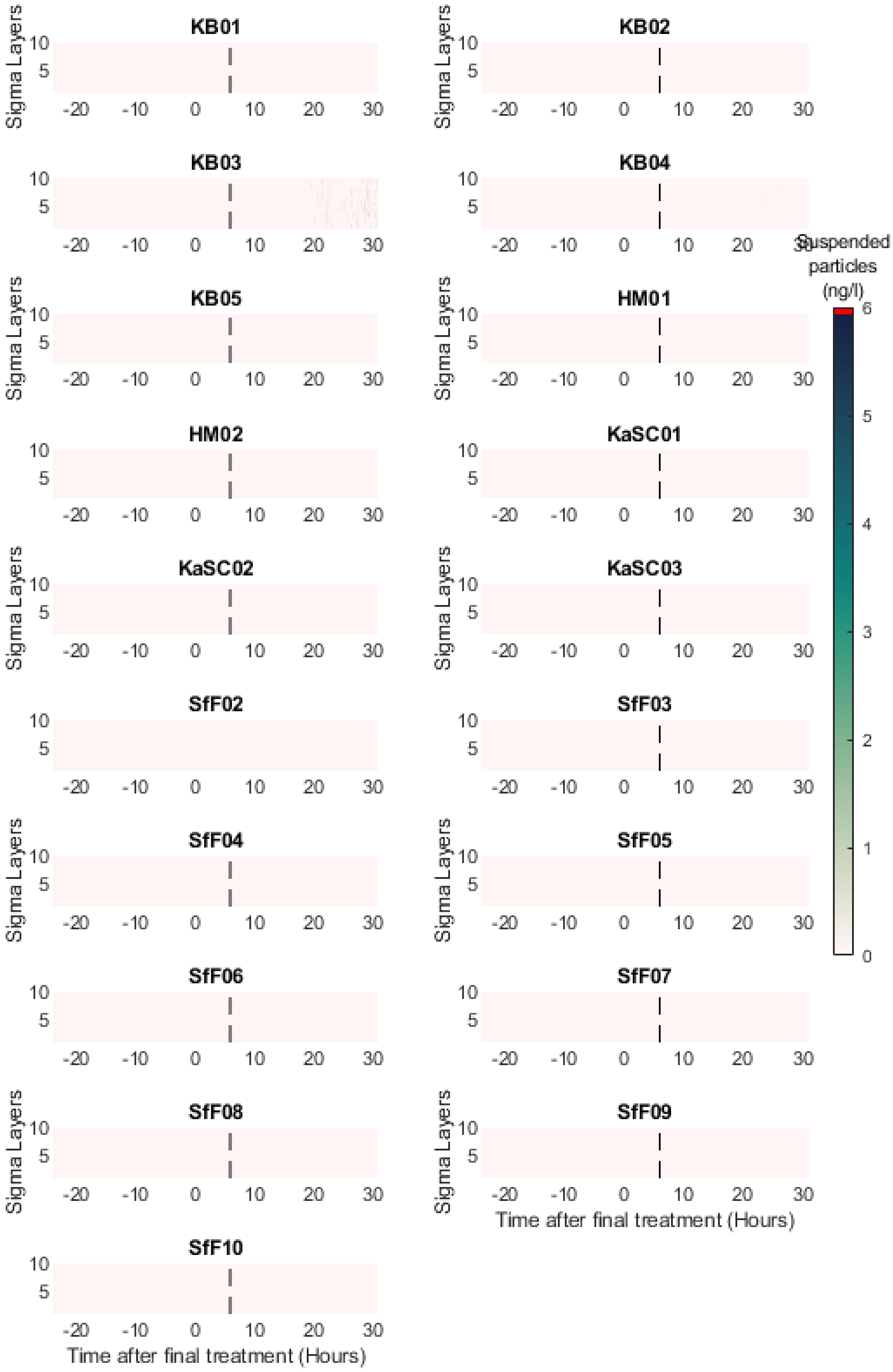


Figure 40. Spatial Deltamethrin distribution for bath treatment releases during neap tides 6 hours after treatment. Areas above EQS values are indicated within the red contour, the site location is identified using a yellow marker and PMF locations are shown as points or polygons.

4.2.3.2 Spring tides

Short-term exposure during the spring tide is assessed using a single release of 10g of Deltamethrin. Treatment concentration at sensitive features is identified in figure 41. Features SfF28 and SfF43 show low concentrations of passing treatments. These occur much later in the simulation, around 30 hours after treatment. No other feature shows any treatment interaction.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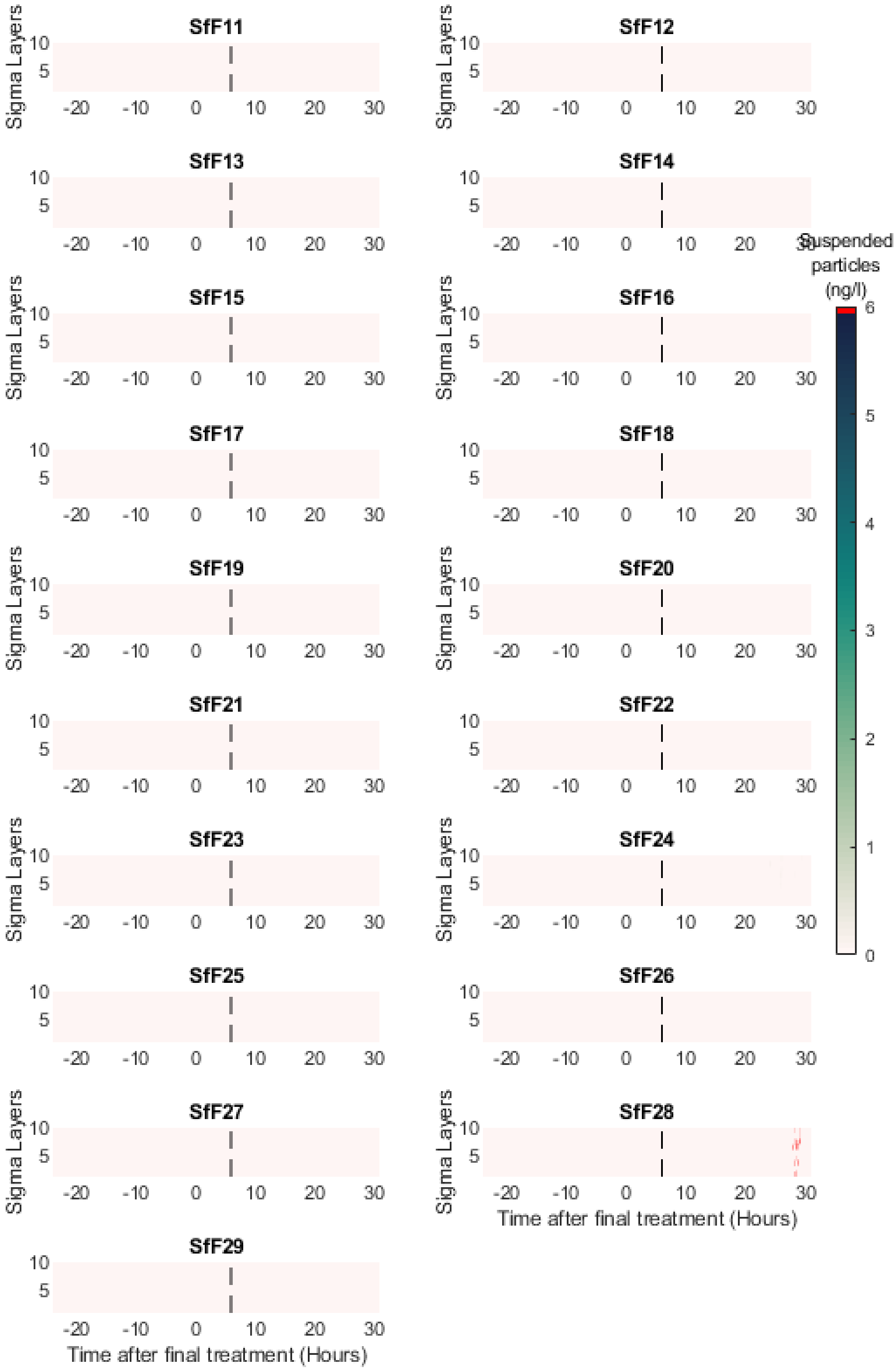
Sigma Layers
Time after final treatment (Hours)
Suspended particles (ng/l)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Time after final treatment (Hours)
Suspended particles (ng/l)

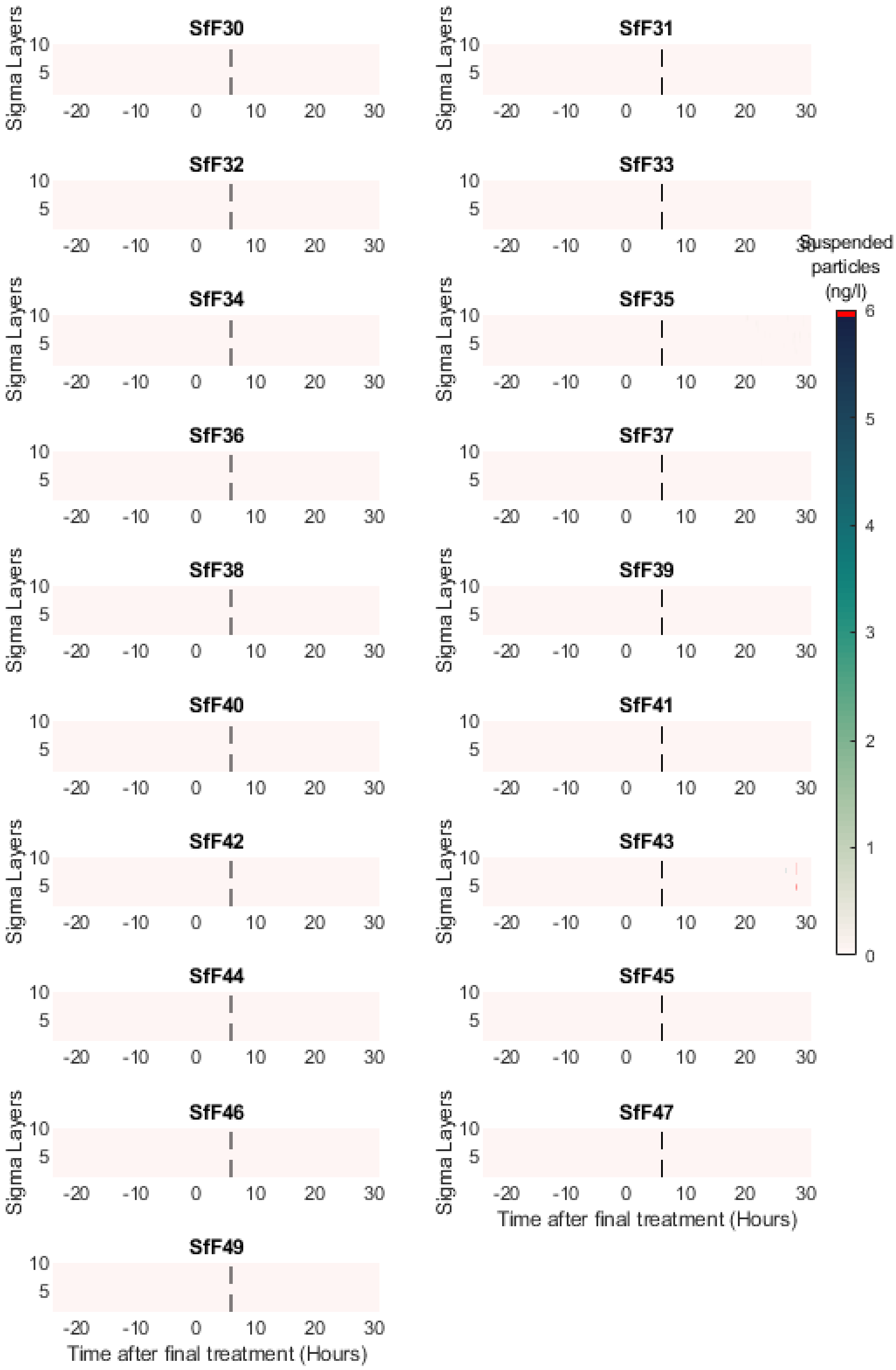
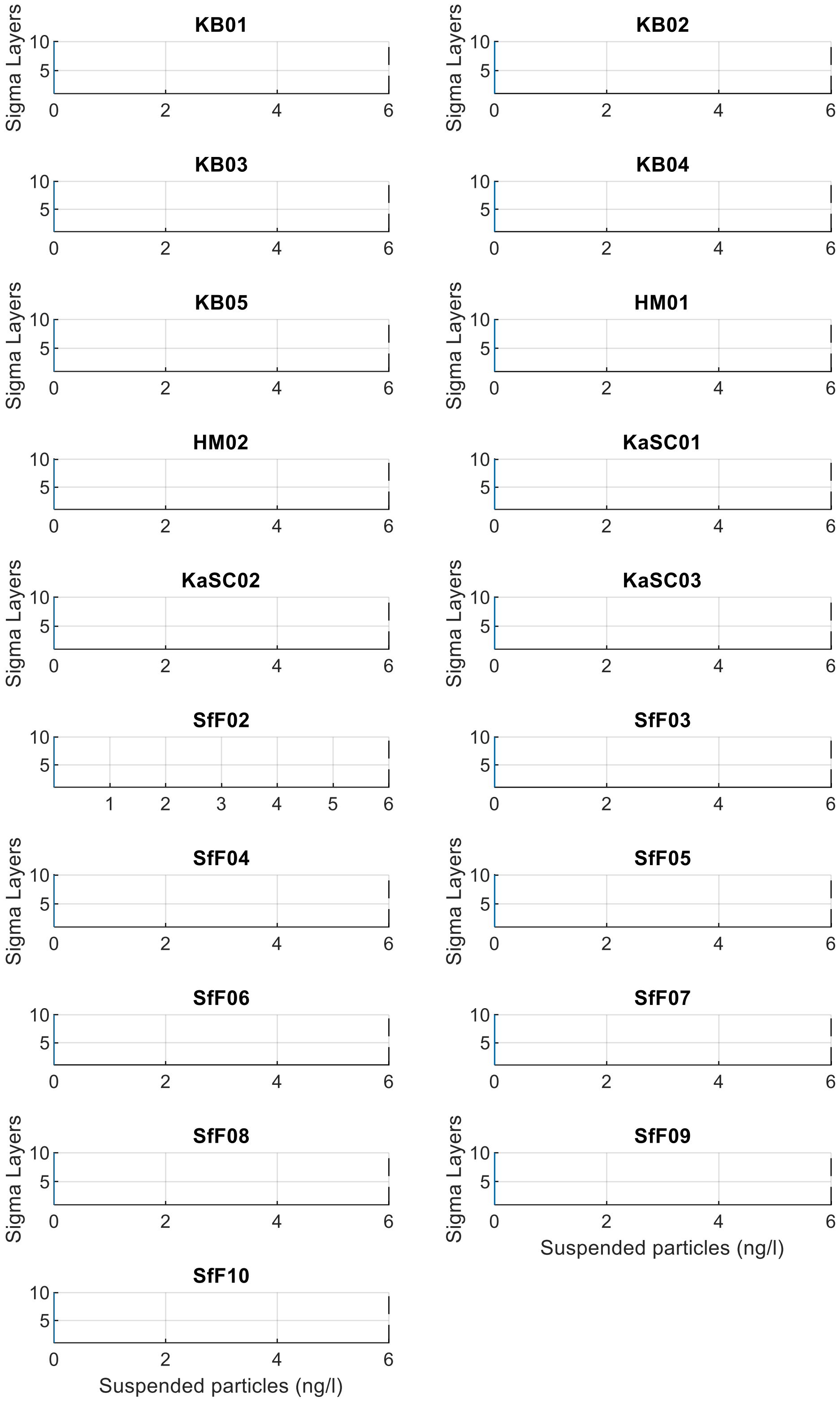


Figure 41. Neap tide Deltamethrin concentration in the water column at identified sensitive marine feature locations. Concentration in ng/l is shown in the colour bar, with any values indicated in red that exceed the 6hr EQS value. Water depth is defined in model sigma layers,

where 1 is the bed cell and 10 is the surface cell and time is shown in hours from the last/single treatment.

Vertical concentration profiles for each feature are shown in figure 42 for the 6hr EQS time. No treatment concentrations are shown for any of the identified features.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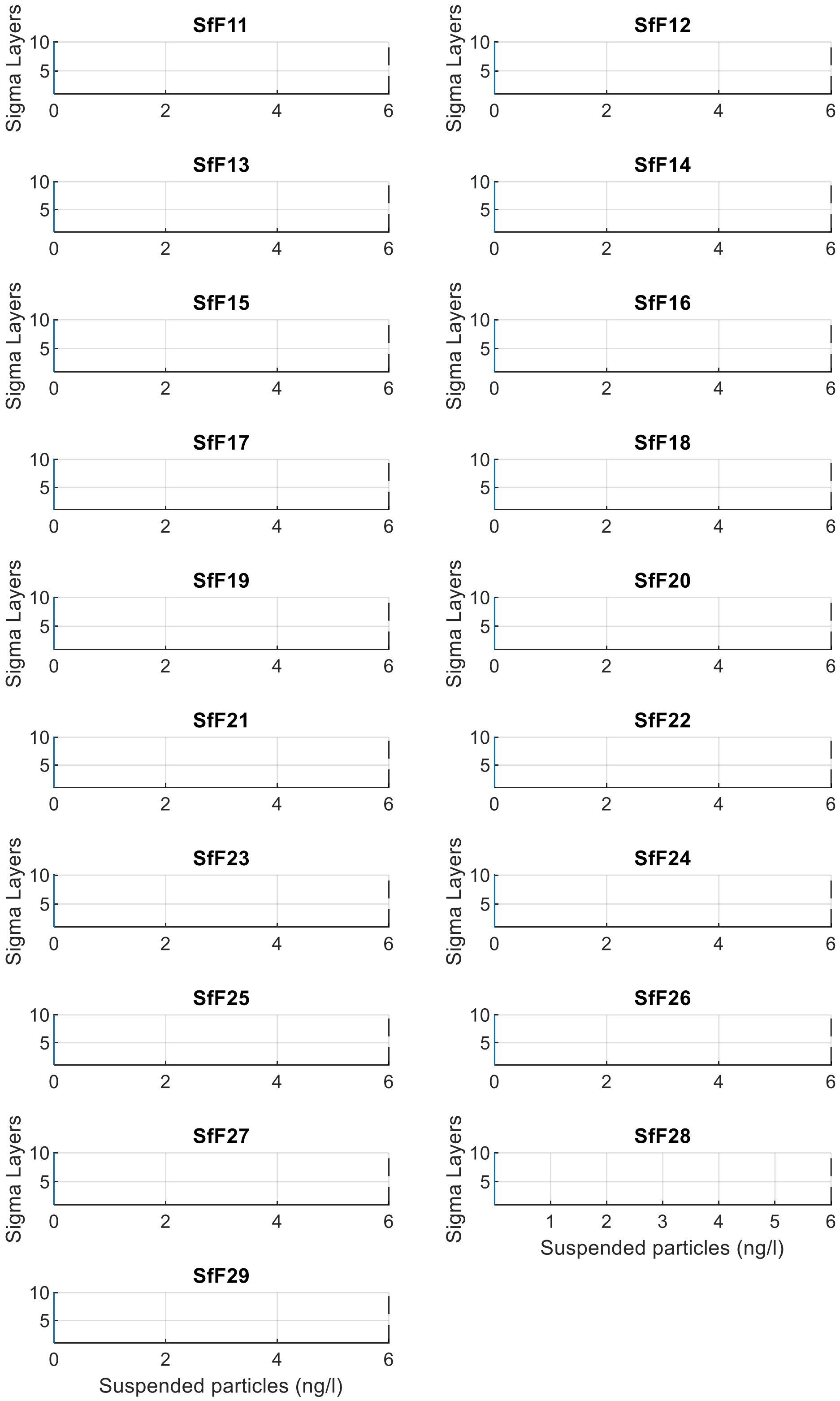
Sigma Layers
Suspended particles (ng/l)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Sigma Layers
Suspended particles (ng/l)

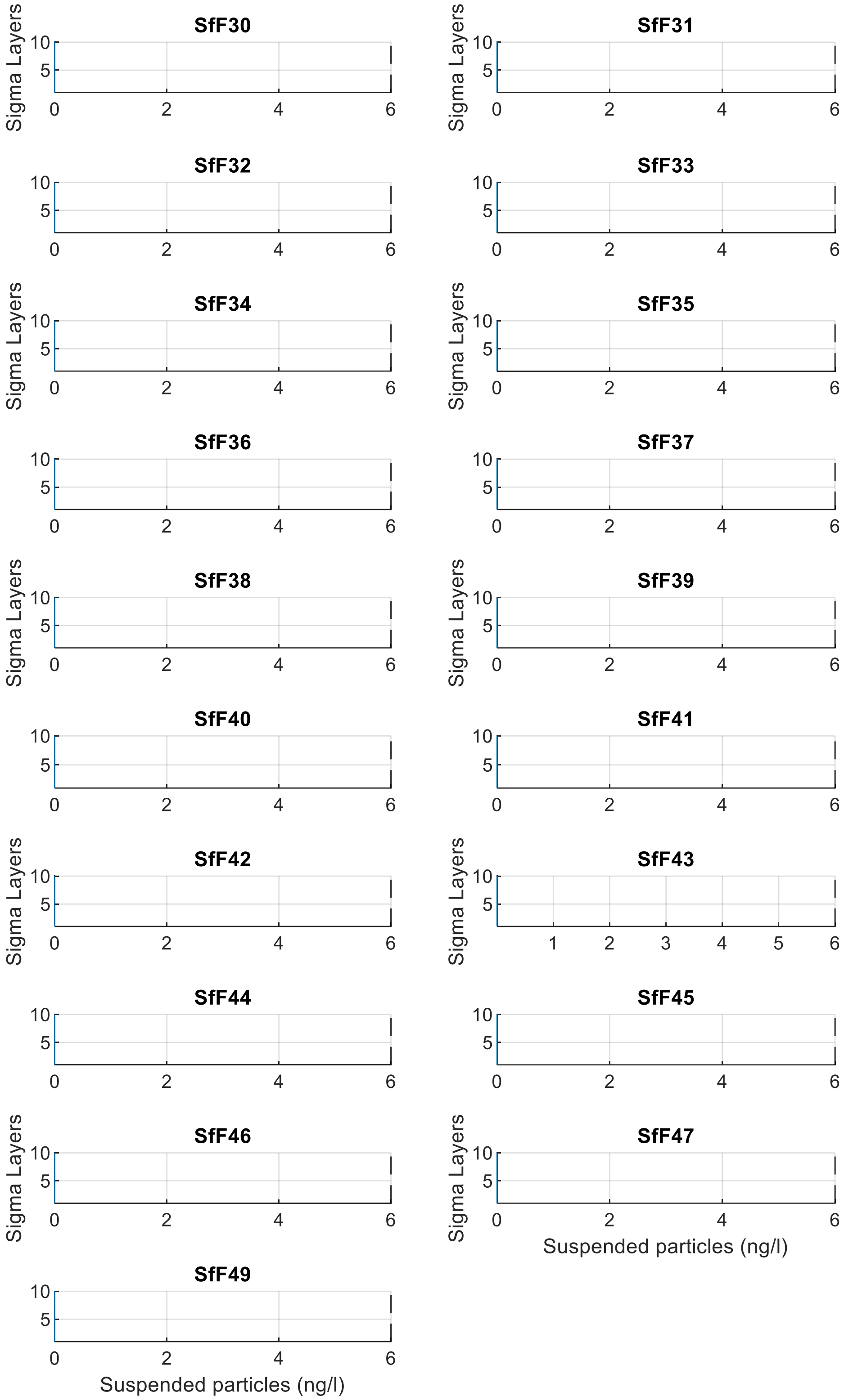

Figure 42. Spring tide vertical concentration profile of Cypermethrin after the single treatment at the 6 hr EQS time. Profiles for all identified sensitive marine feature locations are shown.

The spatial distribution of Deltamethrin is shown relative to the sensitive feature locations in figure 43. Red contour lines are shown for treatment concentrations of 6 ng/l. The treatment plume is shown to be distributed to the north.

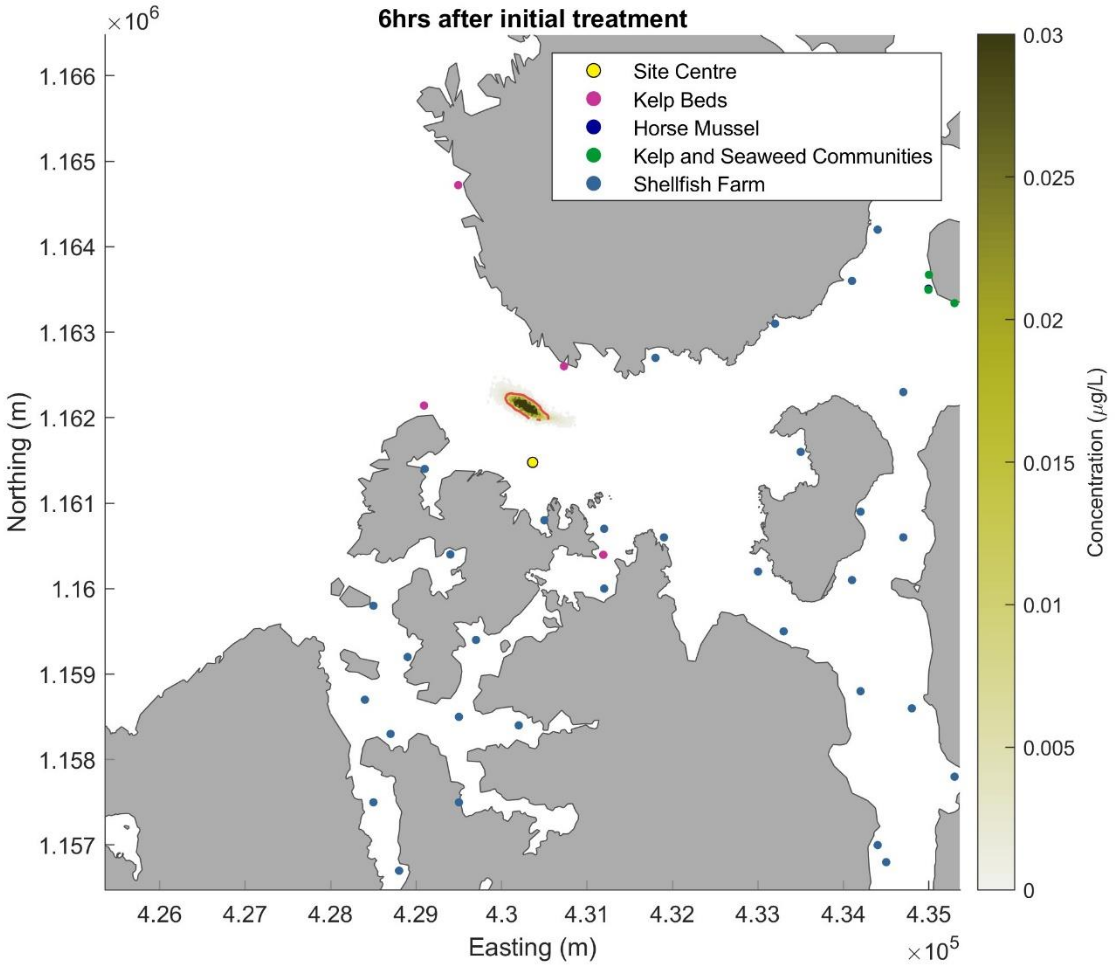

Figure 43. Spatial Deltamethrin distribution for bath treatment releases during spring tides 6hrs after treatment. Areas above EQS values are indicated within the red contour, the site location is identified using a yellow marker and PMF locations are shown as points or polygons.

5. Conclusions

This report outlines the methodology and results for the simulation of bath treatment chemicals at the proposed Vementry site. This informs the safe quantities of treatment chemicals that may be used on site in the event of chemotherapeutic sea lice treatment.

To explore the impacts and determine environmental compliance under a realistic bath treatment plan, bath medicines were released in particle tracking models driven by the calibrated and validated hydrodynamic model. Treatments were split into working days with a maximum of 3 treatments per day, with a treatment interval of 3 hours. For Azamethiphos, modelling of the entire treatment cycle revealed that a recommended consent mass of 375g per 24-hour period, or a single treatment of 145g per 3-hour window, was shown to be compliant with EQS. The 24-hour treatment program equates to a repeatable treatment volume of 1250m^3 per 3 hours. For Cypermethrin, modelling of the 6-hour treatment mass revealed an adjusted treatment mass of 0.0936g per 3-hour period. This chemical quantity is not viable for the effective treatment of sea lice. For Deltamethrin, modelling of the 6-hour treatment mass provided a recommended treatment mass of 10g per 3 hours, while maintaining EQS compliance. This provides a treatable volume of 5,000 m^3, equal to 3.33 wellboat treatments (1,500m^3 capacity) per 3-hours.

Azamethiphos, Cypermethrin and Deltamethrin have been assessed at 59 feature locations. As there are no compliant standards for marine features, EQS time and concentrations were used as reference values. It should be noted that EQS concentrations are used for area assessment and not maximum allowable concentration, it is permitted for EQS concentrations to be exceeded. The results indicate that most identified sensitive marine features experience no interaction with bath chemical treatments. Features KB03 and SfF28 are shown to have infrequent interaction with the treatment plume, but as these experience low concentrations and short-term exposure, this poses very low environmental risk. In addition, SfF28 (Lamba wick) is a lease held by CAS.

The numerical simulation of bath treatments has revealed multiple feasible treatment options for Vementry using Azamethiphos or Deltamethrin. The treatment of sea lice however, is not restricted to medicinal approaches. Thermal or mechanical treatment options can also be used if required. This flexibility provides a diverse range of sea lice treatment options that can be called upon if required, allowing specific treatment plans to be chosen that are best suited for the welfare of the farmed fish, wild salmonids and the wider environment.

5. References

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