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Dispersion modelling Firth of Clyde (Delft-3D)

Deposition modelling in the Firth of Clyde

Dawnfresh Farming Ltd

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1 INTRODUCTION

The tidal range in the inner Firth is relatively small at about 1.6 m for mean neap tides and 3.0 m for mean spring tides (UK Hydrographic Office, 2020). The tidal velocities are also weak, in the range 0.1 - 1.1 kts (Millport). This results in small tidal excursions (i.e. the distance water travels during a tide), typically about 3.6 to 3.8 km on a spring tide at Little Cumbrae. The area is sheltered from the prevailing south-westerly winds by Northern Ireland, the Kintyre Peninsula, and the Isle of Arran.

1.1 Overview

The Scottish Environment Protection Agency (SEPA) promotes the use of the AUTODEPOMOD and BathAuto modelling to evaluate deposition of waste from sea cages and the impact of infeed and bath applications of veterinary medicinal products as part of the aquaculture site licence applications.

However, it is acknowledged by SEPA, and demonstrated by site surveys, that for some sites with higher biomass loading in high energy locations the standard modelling does not sufficiently predict the deposition in the far-field and is unable to model cumulative impacts. Therefore, Dawnfresh Farming Ltd. (Dawnfresh) commissioned Xodus Group (Xodus) to develop a Delft3D hydrodynamic model for their aquaculture sites in the Firth of Clyde. The model more accurately predicts and assesses deposition within high energy environments and therefore is better at determining the maximum biomass that sites are capable of supporting without adversely impacting the benthic environment. In addition, the model can be used to simulate fish medicine release at multiple sites to determine whether a combined impact may result from such an activity.

The model was developed by Coastal Science Ltd who were subcontracted by Xodus through an established working partnership, due to their previous modelling experience within the Firth of Clyde. Details of the model development, calibration and validation have previously been reported to SEPA (Xodus, 2020).

1.2 Objectives

The objective of the present study is to use the Delft3D model to simulate the fate of fish faeces, waste feed and bath medicines at three Dawnfresh aquaculture sites in the Firth of Clyde: > Great Cumbrae;

- Isle of Little Cumbrae; and
- South Bute

The key aims of the study were to investigate:

- To what extent may any of the sites cause appreciable impacts at other sites;
- To what extent may the sites, individually or in combination, cause appreciable impacts in the wider marine environment; and
- To what extent are the SSSIs and PMFs situated in proximity to the proposed sites impacted by the discharges.

2 MODELLING

The D-PART module of Delft3D simulates transport and simple water quality processes by means of a particle tracking method using the (2 or 3-dimensional) flow data from the D-FLOW hydrodynamic module. The tracks are followed in three dimensions over time, whereby a dynamic concentration distribution is obtained by calculating the mass of particles in the model grid cells.

The processes are assumed to be deterministic except for a random displacement of the particle at each time step. The particle tracking method is based on a random-walk method since the simulated behaviour is stochastic and the number of particles is finite.

Particle tracking allows water quality processes to be described in a detailed spatial pattern, resolving sub grid concentration distributions. Delft3D-PART is best suited for studies over the mid-field range (200 m to 15 km) of instantaneous or continuous releases, simulation of an effluent plume and modelling of the transport of substances such as salt, bacteria, dye, oil, Biological Oxygen Demand (BOD), or other conservative or decaying chemical substances following first-order kinetics.

The simulations were set up to consider each scenario and each farm location separately. The faeces and feed scenarios were modelled for a period covering a Spring – Neap – Spring (SP-NP-SP) tidal cycle, both with and without wind conditions applied, resulting in a total of 12 SP-NP-SP simulations as described in Table 2.1.

It was decided that the decision to run in-combination dicharge models (i.e. Greater Cumbrae + Isle of Little Cumbrae + South Bute) would be based on the results of the indicidual discharges.

Table 2.1 Modelled feed and faeces discharge scenarios

Location	Substance	Modelled duration
Great Cumbrae	Faeces	SP-NP-SP
Great Cumbrae	Feed waste	SP-NP-SP
Isle of Little Cumbrae	Faeces	SP-NP-SP
Isle of Little Cumbrae	Feed waste	SP-NP-SP
South Bute	Faeces	SP-NP-SP
South Bute	Feed waste	SP-NP-SP
Great Cumbrae	Faeces	SP-NP-SP (No Wind)
Great Cumbrae	Feed waste	SP-NP-SP (No Wind)
Isle of Little Cumbrae	Faeces	SP-NP-SP (No Wind)
Isle of Little Cumbrae	Feed waste	SP-NP-SP (No Wind)
South Bute	Faeces	SP-NP-SP (No Wind)
South Bute	Feed waste	SP-NP-SP (No Wind)

The modelled bath treatment scenarios are shown in Table 2.2. These considered the spring and neap tidal cycles separately, resulting in 18 simulations. Further details of the model inputs are provided in Section 2.1

Table 2.2 Modelled bath treatment scenarios

Location	Substance	Modelled duration
Great Cumbrae	Azamethiphos	Neap tide
Great Cumbrae	Azamethiphos	Spring tide
Great Cumbrae	Cypermethrin	Neap tide
Great Cumbrae	Cypermethrin	Spring tide
Great Cumbrae	Deltamethrin	Neap tide
Great Cumbrae	Deltamethrin	Spring tide
Isle of Little Cumbrae	Azamethiphos	Neap tide
Isle of Little Cumbrae	Azamethiphos	Spring tide
Isle of Little Cumbrae	Cypermethrin	Neap tide
Isle of Little Cumbrae	Cypermethrin	Spring tide
Isle of Little Cumbrae	Deltamethrin	Neap tide
Isle of Little Cumbrae	Deltamethrin	Spring tide
Bute	Azamethiphos	Neap tide
Bute	Azamethiphos	Spring tide
Bute	Cypermethrin	Neap tide
Bute	Cypermethrin	Spring tide
Bute	Deltamethrin	Neap tide
Bute	Deltamethrin	Spring tide

2.1 Model Inputs

Details of the modelled farm setups are provided below.

Table 2.3 Modelled aquaculture site locations and layouts - dicharge locations

Site Name	Site group centre position		Number of Cages	Cage Circumference (m)	Cage group configuration	Net Depth (m)
	E	N				
Great Cumbrae	218162.2	654944.0				16
Isle of Little Cumbrae	214484.1	652622.4				14
South Bute	211692.6	653363.5	10	120	2 x 5	16

2.1.1 Feed scenario model details

Table 2.4 Modelled feed details

Site Name	Concentration (kg/m^3)	Release rate (m^3/s)	Release duration	Particle settling velocity* (m/s)
Great Cumbrae	16.59			
Isle of Little Cumbrae	13.27			
South Bute	16.59	0.001	1 hr per day	0.035

* Values provided within the draft SEPA, 2020

2.1.2 Faeces scenario model details

Table 2.5 Modelled faeces discharges

Site Name	Concentration (kg/m^3)	Release rate (m^3/s)	Release duration	Particle settling velocity* (m/s)
Great Cumbrae	3.456	0.001	Continuous	0.009
Isle of Little Cumbrae	2.765			
South Bute	3.456			

* Values provided within the draft SEPA, 2020

2.1.3 Bath treatment scenario model inputs

Table 2.6 Modelled bath treatment regimes

Site Name	Treatment	Dosage (g)	Schedule
Great Cumbrae	Azamethiphos	206.30	1 pen per day 10 days
	Cypermethrin	138.44	Dosage suitable for 10 pens but treatment over 3 days
	Deltamethrin	51.92	Dosage suitable for 10 pens but treatment over 3 days
Isle of Little Cumbrae	Cypermethrin	69.22	Dosage suitable for 5 pens carried out over 3 days
	Deltamethrin	25.96	Dosage suitable for 5 pens carried out over 3 days
South Bute	Azamethiphos	217.76	1 pen per day 10 days
	Cypermethrin	124.88	Dosage suitable for 10 pens but treatment over 3 days
	Deltamethrin	46.83	Dosage suitable for 10 pens but treatment over 3 days

2.1.4 Wind Scenarios

All the Neap-Spring-Neap simulations described in Table 2.1 were repeated with wind applied in both the hydrodynamic (D-FLOW) and D-PART simulations. The wind was set to 7 m/s from 214° (southwesterly), with wind drag coefficients defined on a site-specific basis in accordance with the values determined and presented in the Hydrodynamic Calibration report.

2.1.5 Year-long Scenarios

All the Neap-Spring-Neap simulations described were repeated for a full year, in order to aid an understanding of the long-term waste patterns on the bed. The hydrodynamics were run for the full year (as opposed to the neap-spring-neap database being rewound and repeated in the D-PART simulation) It should be noted that in order to keep simulation times manageable, the D-PART timestep had to be increased from 1 minute to 30 minutes. The effect of this change is that particles were released by the model in larger simultaneous quantities, thus reducing the accuracy of the modelled settling and sedimentation / resuspension processes. Year-long models were not conduicted for the bath treatment scnearios (Table 2.2).

The year-long scenarios were all modelled with monthly varying wind data, based on yearly averages for Glasgow Airport for the period November 2000 – May 2020 (Windfinder, 2020).

Table 2.7 Wind speed averages and direction (Wavefinder, 2020)

Month	Wind Speed (kts)	Wind Speed (m/s)	Dominant Wind Direction
January	10	5.14	Southwest (SW)
February	9	4.63	Southwest (SW)
March	10	5.14	West-Southwest (WSW)
April	10	5.14	West-Southwest (WSW)
May	10	5.14	Southwest (SW)
June	9	4.63	West-Southwest (WSW)
July	8	4.12	West-Southwest (WSW)
August	9	4.63	West-Southwest (WSW)
September	9	4.63	Southwest (SW)
October	9	4.63	Southwest (SW)
November	8	4.12	Southwest (SW)
December	9	4.63	Southwest (SW)

3 RESULTS

Model results are presented for each aquaculture site for the following models:

> Feed and Faeces deposition – short duration model runs (SP-NP-SP)
> Feed and Faeces deposition – yearly model runs
> Bath treatment chemical (Azamethiphos, Cypermethrin and Deltamethrin) dispersion – Neap tidal period
> Bath treatment chemical (Azamethiphos, Cypermethrin and Deltamethrin) dispersion – Spring tidal period

3.1 Feed and faeces deposition – short duration (SP-NP-SP) scenarios.

The outputs from the feed and faeces models have been combined to present the total seabed deposition. The results are presented in this section for the final model timestep (day 21), thereby providing the maximum deposited material.

3.1.1 Greater Cumbrae

The maximum deposited material (feed and faeces) after 21-days are shown in Figure 3.1 and Figure 3.2, for the wind and no wind scenarios respectively. These indicate that the maximum predicted deposition is approximately 0.8 kg/m^2 and, as expected, is located under the cages. The deposited mass reduces rapidly with distance from the cages, under the influence of the localised currents.

It should be noted that the inclusion of the wind within the model results in minimal variations in the deposition pattern and negligible influence on the maximum deposited mass.

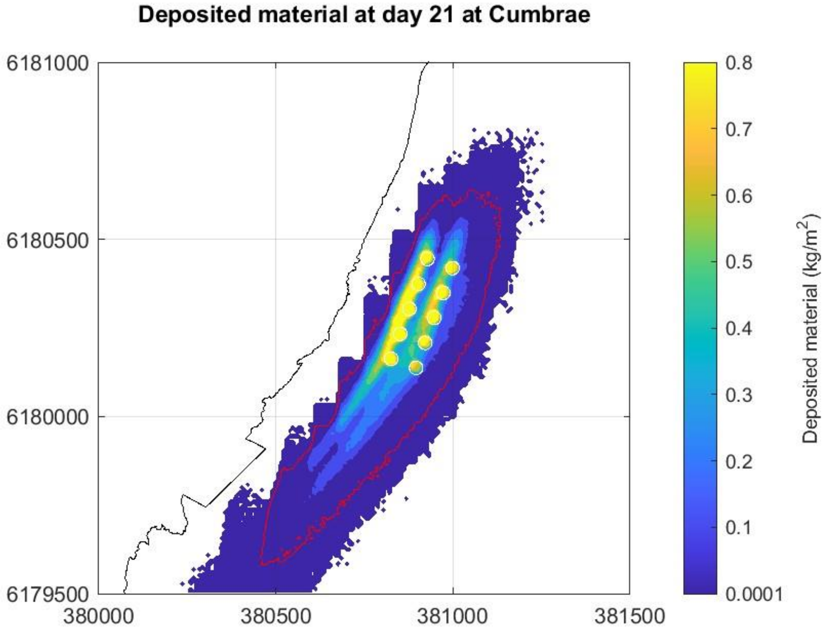


Figure 3.1 Deposited material at Greater Cumbrae after 21 days - Wind applied. The red contour depicts the predicted 20g contour.

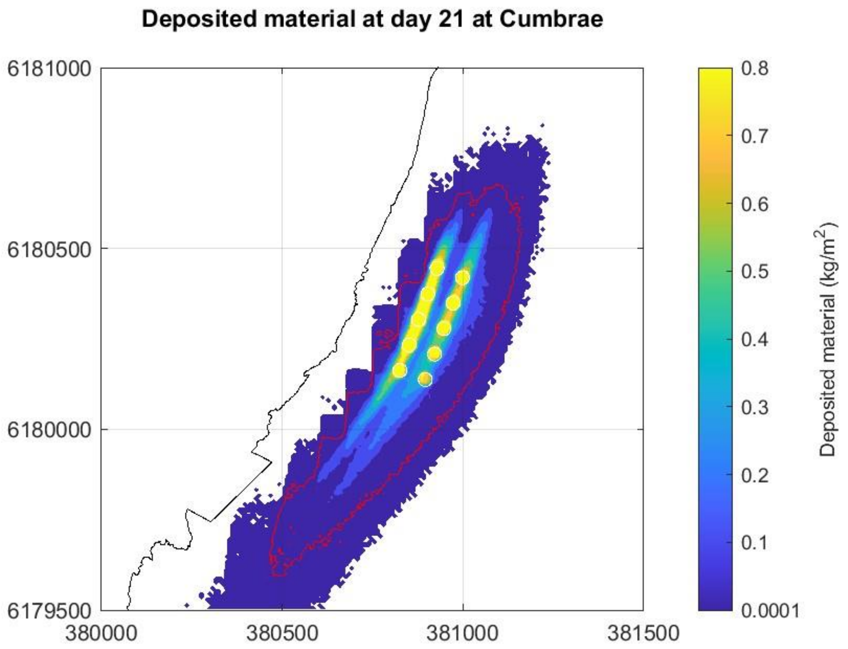


Figure 3.2 Deposited material at Greater Cumbrae after 21 days – No wind applied

3.1.2 Isle of Little Cumbrae

The maximum deposited material (feed and faeces) after 21-days are shown in Figure 3.3 and Figure 3.4, for the wind and no wind scenarios respectively. These indicate that the maximum predicted deposition is approximately 0.8 kg/m^2. The deposited mass reduces rapidly with distance from the cages, under the influence of the localised currents.

The maximum mass deposited is not influenced by the inclusion of wind data, however its inclusion does influence the extents of the deposition contours.

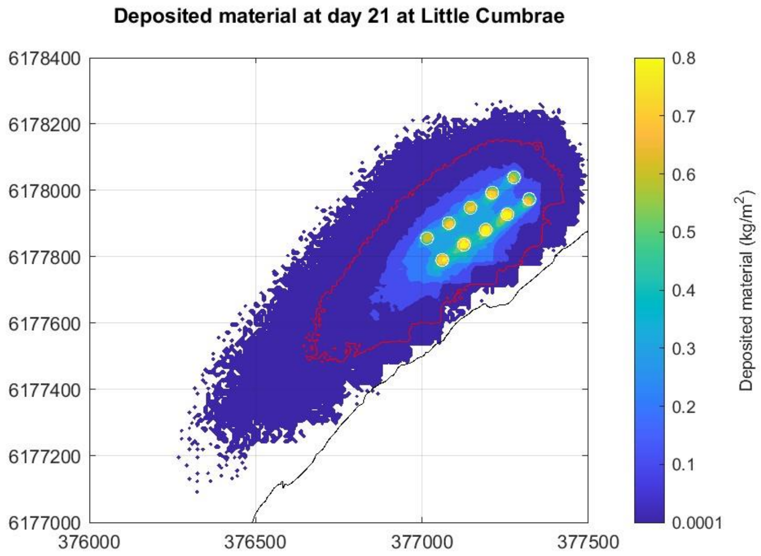


Figure 3.3 Deposited material at Little Cumbrae after 21-days - Wind applied. The red contour depicts the predicted 20g contour.

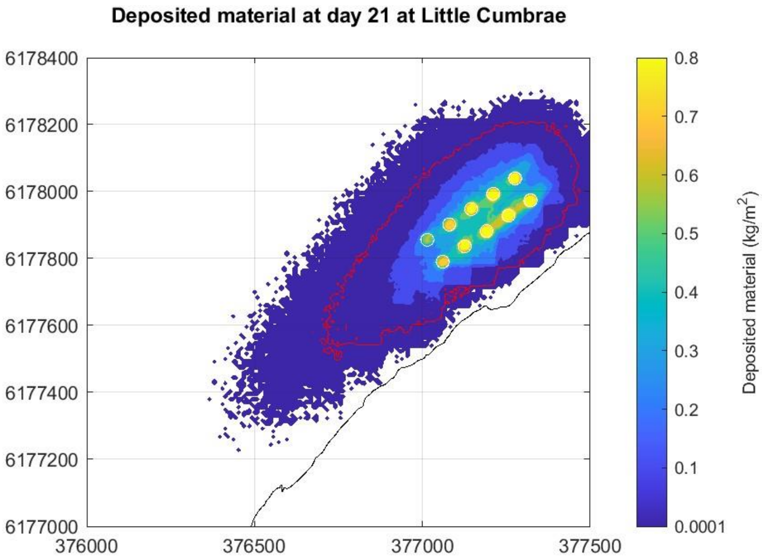


Figure 3.4 Deposited material at Little Cumbrae after 21-days – No wind applied. The red contour depicts the predicted 20g contour.

3.1.3 South Bute

The maximum deposited material (feed and faeces) after 21-days are shown in Figure 3.5 and Figure 3.6, for the wind and no wind scenarios respectively. These indicate that the maximum predicted mass deposited is approximately 0.8 kg/m^2. The deposited mass reduces rapidly with distance from the cages, under the influence of the localised currents. The inclusion of the wind data is shown as influencing the westerly extent of the deposit contours above 0.1kg/m². The figures would suggest that the model results are also influenced by the bathymetry at this location.

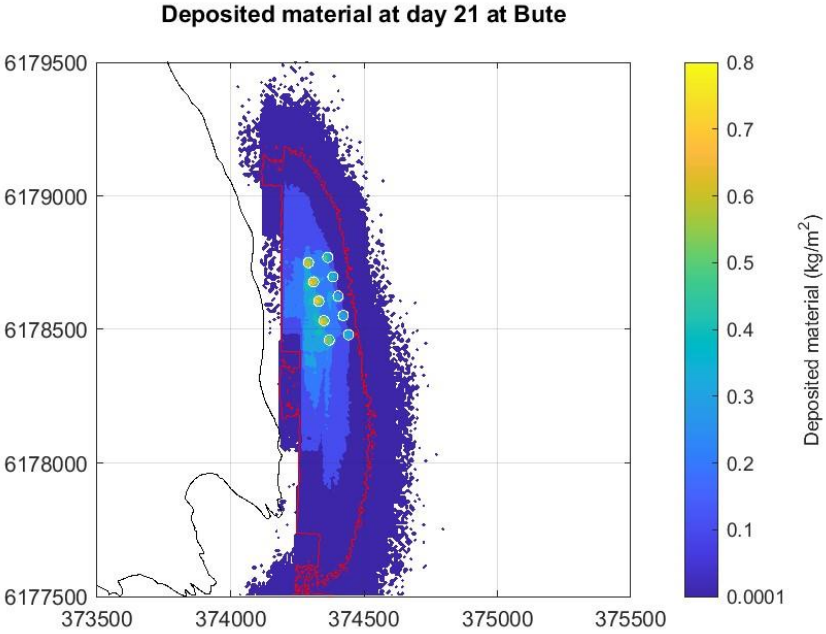


Figure 3.5 Deposited material at Bute after 21-days - Wind applied. The red contour depicts the predicted 20g contour.

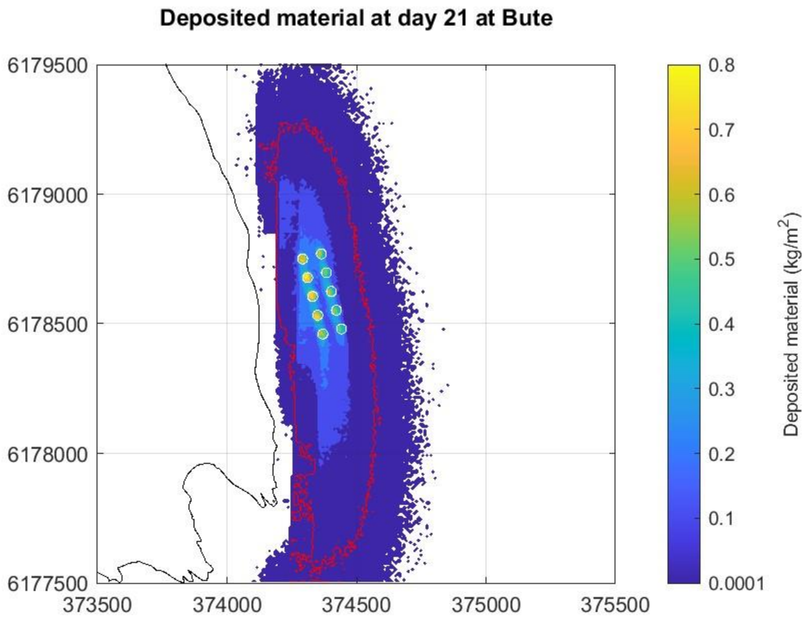


Figure 3.6 Deposited material at Bute after 21-days - Wind applied. The red contour depicts the predicted 20g contour.

3.1.4 Mean mass of deposited material

Figure 3.7 shows the mean mass of the deposited material during modelling for all three aquaculture sites, with and without the inclusion of winds. These indicate that the rate of deposition at the Little Cumbrae site is influenced by the inclusion of wind within the model. The mean mass of the deposited material appears similar at both the Greater and Bute sites with and without the inclusion of wind within the model.

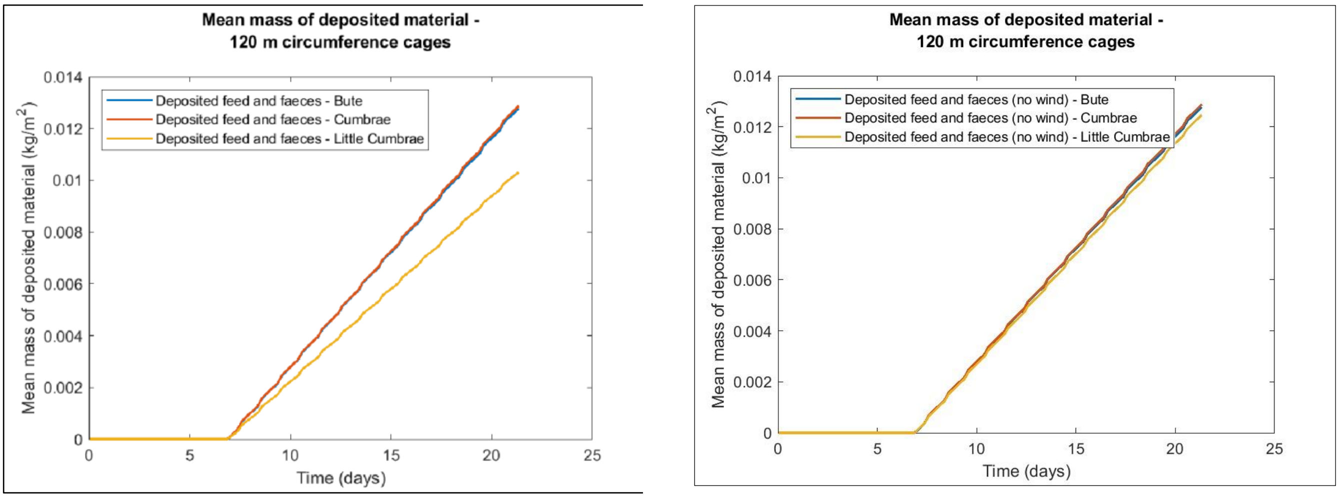


Figure 3.7 Mean mass of deposited material throughout the modelling period for wind (left) and no wind (right) scenarios.

3.1.5 Discussion

The modelling indicates that at all three sites the maximum predicted deposited mass is approximately 0.8 kg/m^2, with the maxima between located either under or between the cages. The deposition patterns are all influenced by the prevailing currents to some extent, with the Greater Cumbrae site showing the greatest current alignment at the higher contour levels. However, in all cases, the deposited mass decreases rapidly with distance from the cage locations.

All the modelled sites show some degree of sensitivity to the inclusion of wind data, with the Little Cumbrae site showing the greatest variation in terms of the mean mass deposition throughout the modelled period.

3.2 Feed and faeces deposition – yearly scenarios.

Figures 3.8 – 3.10 show the predicted deposited material for Greater Cumbrae, Isle of Little Cumbrae and South Bute respectively, after 390 days (the end of the model run period). These indicate that the maximum mass of deposited material does not exceed 25 kg/m^2. However, it is important to note that the model doesn't include processes such as decay and biodegradation. Therefore, once a particle has been deposited it will remain in-situ and subsequent discharges will add to the mass. Hence the model outputs represent an extreme estimation of the potential deposited mass.

3.2.1 Greater Cumbrae

Figure 3.8 shows the predicted deposited mass of feed and faeces at Greater Cumbrae after 390-days (end of model run); down to the 0.01 kg/m^2 contour. The deposits are predicted to have a maximum mass of approximately 25 kg/m^2; located under and between the landward cages. As with the shorter (SP-NP-SP runs) the deposited mass quickly reduces with distance from the cages and the contours are strongly aligned with the predominant currents. The mean mass of the deposited material is predicted to be reach a mass of approximately 0.35 kg/m^2 at day 390 (Section 3.2.4).

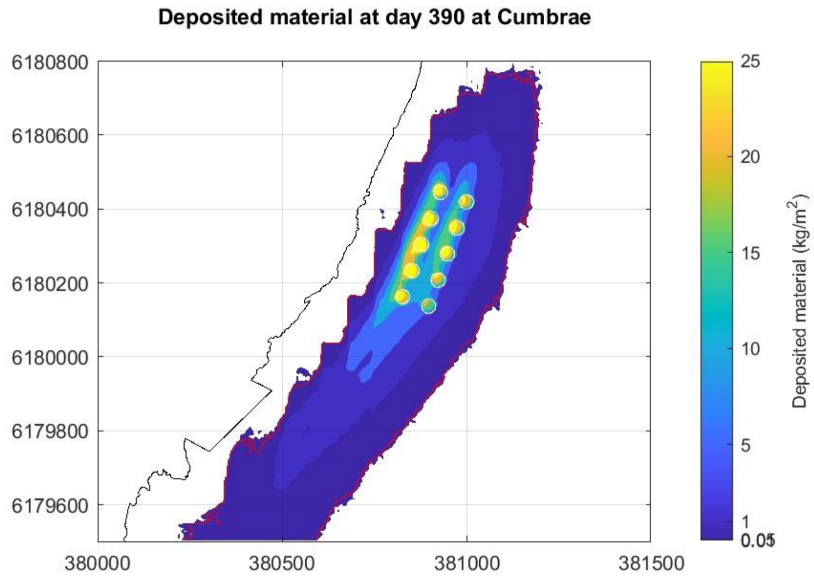


Figure 3.8 Predicted deposited mass of feed and faeces at Greater Cumbrae - yearly scenario. The red contour depicts the predicted 20 g contour.

3.2.2 Isle of Little Cumbrae

Figure 3.9 shows the predicted deposited mass of feed and faeces at Greater Cumbrae after 390-days (end of model run); down to the 0.05 kg/m^2 contour. The deposits are predicted to have a maximum mass of approximately 28 kg/m^2; located in small patches under some of the cages. The mean mass of the deposited material is predicted to have a maximum of approximately 0.27 kg/m^2 (Section 3.2.4).

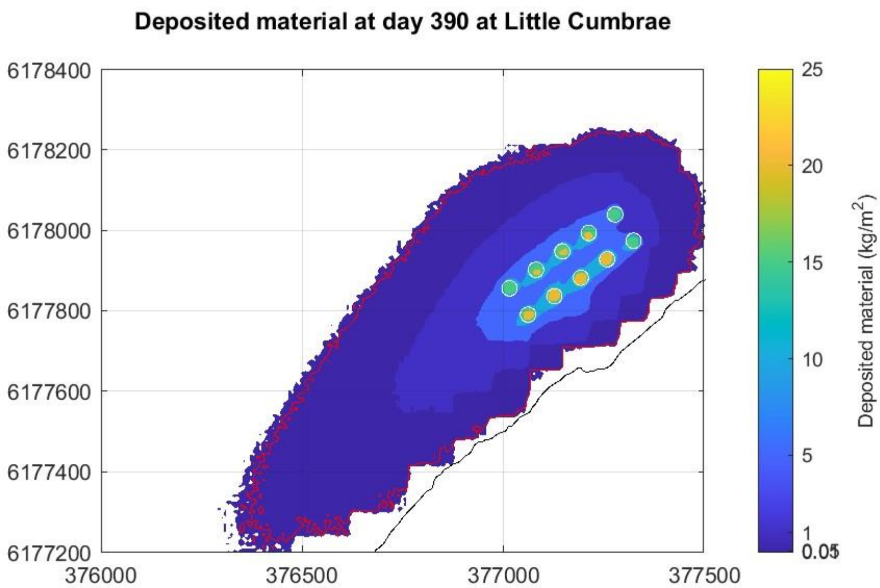


Figure 3.9 Predicted deposited mass of feed and faeces at Isle of Little Cumbrae - yearly scenario. The red contour depicts the predicted 20 g contour.

3.2.3 South Bute

Figure 3.9 shows the predicted deposited mass of feed and faeces at Bute after 390-days (end of model run); down to the 0.05 kg/m^2 contour. he deposits are predicted to have a maximum mass of approximately 0.06 kg/m^2. The deposited mass decreases rapidly form the cages, with contours greater than 0.05 extending south from the cage locations. The mean mass of the deposited material is predicted to be reach a mass of approximately 0.35 kg/m^2 at day 390 (Section 3.2.4).

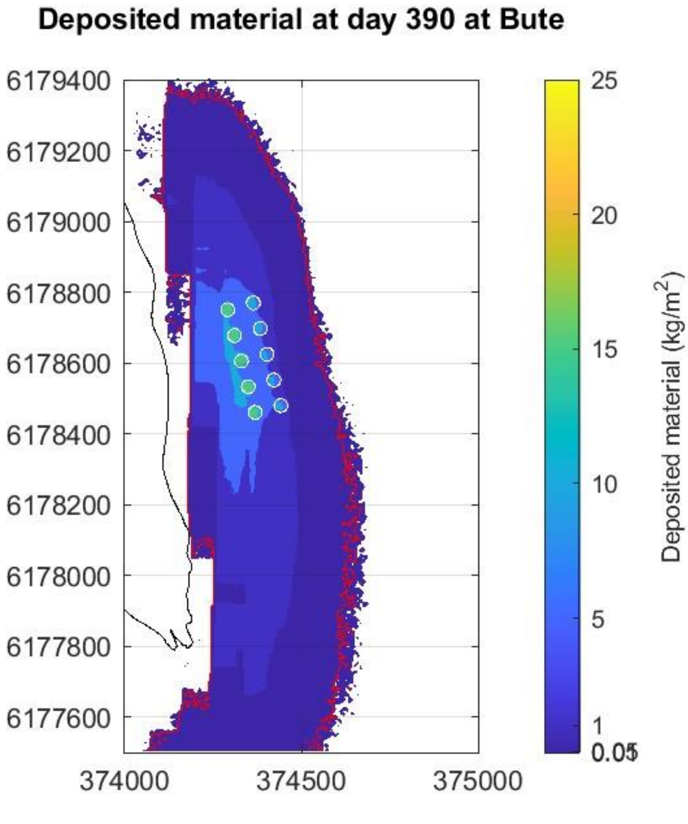
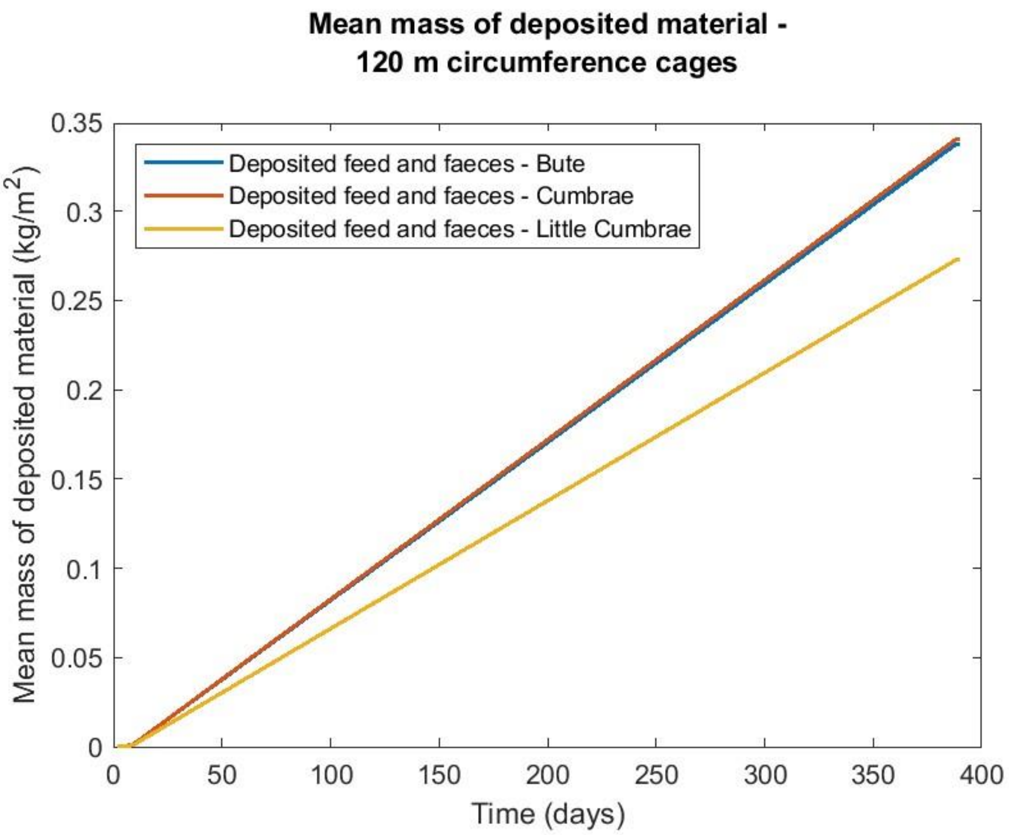


Figure 3.10 Predicted deposited mass of feed and faeces at South Bute - yearly scenario. The red contour depicts the predicted 20 g contour.

3.2.4 Mean mass of deposited material – yearly models

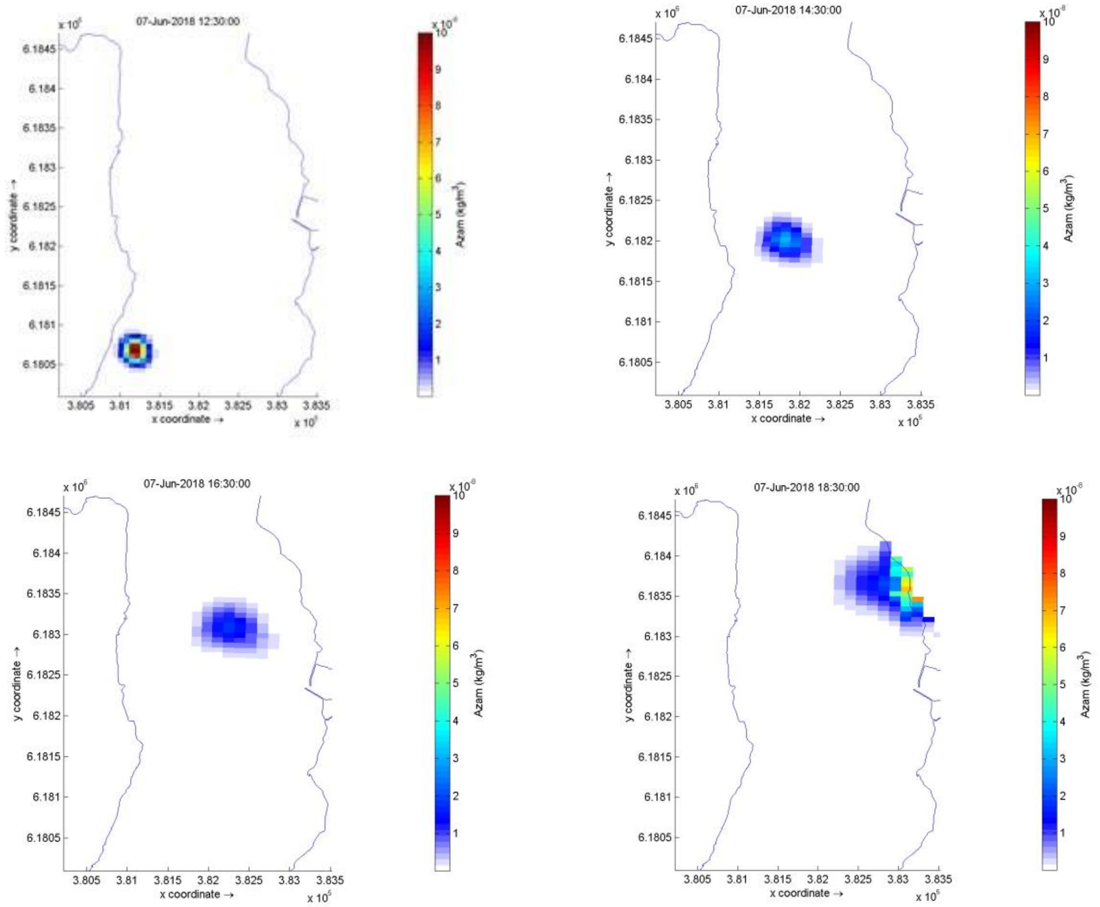


3.3 Bath treatments – Neap and Spring tide model runs

The model results for the chemical dispersion model runs are presented below. In all models the maximum concentration of approximately 0.0000001 kg/m^3 (0.0001 ppm). These densities are generally evident in the initial releases (7th June 2020 12:30 (Neaps) and 2nd June 2020 0800 (Springs)) and were chemicals are shown to accumulate at the coastline. However, it should be remembered that in the Delft3D model the particles are not acted upon once they interact with the coastline. This includes processes such as decay and bioturbation, and therefore the predicted coastal chemical densities should be considered as worst case.

Following the initial release, the chemicals are generally predicted to reduce rapidly (within 1 model timestep (1 hour)) to densities of less than 0.00000004 kg/m^3, on both the Spring and Neap tide.

3.3.1 Greater Cumbrae - Azamethiphos



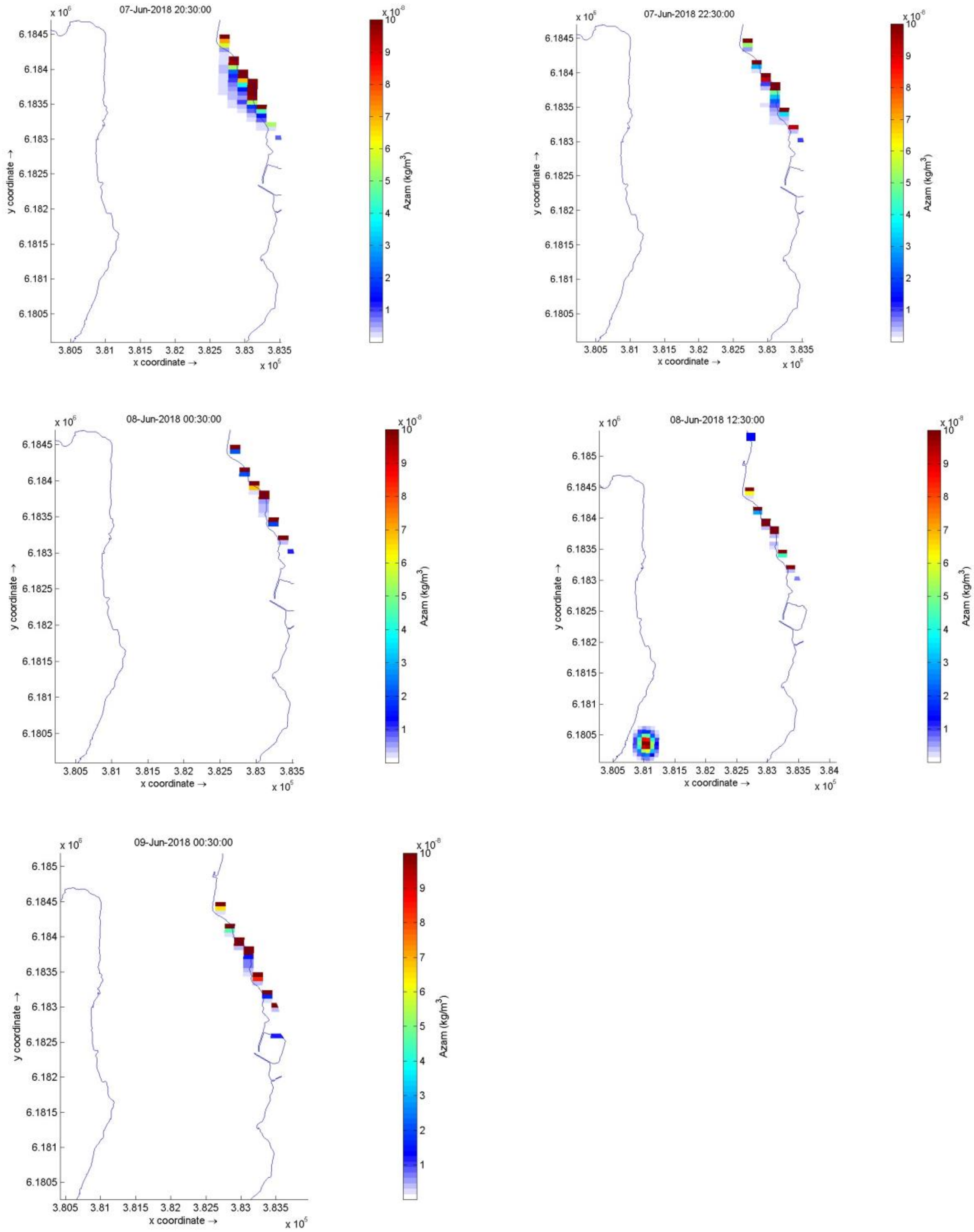
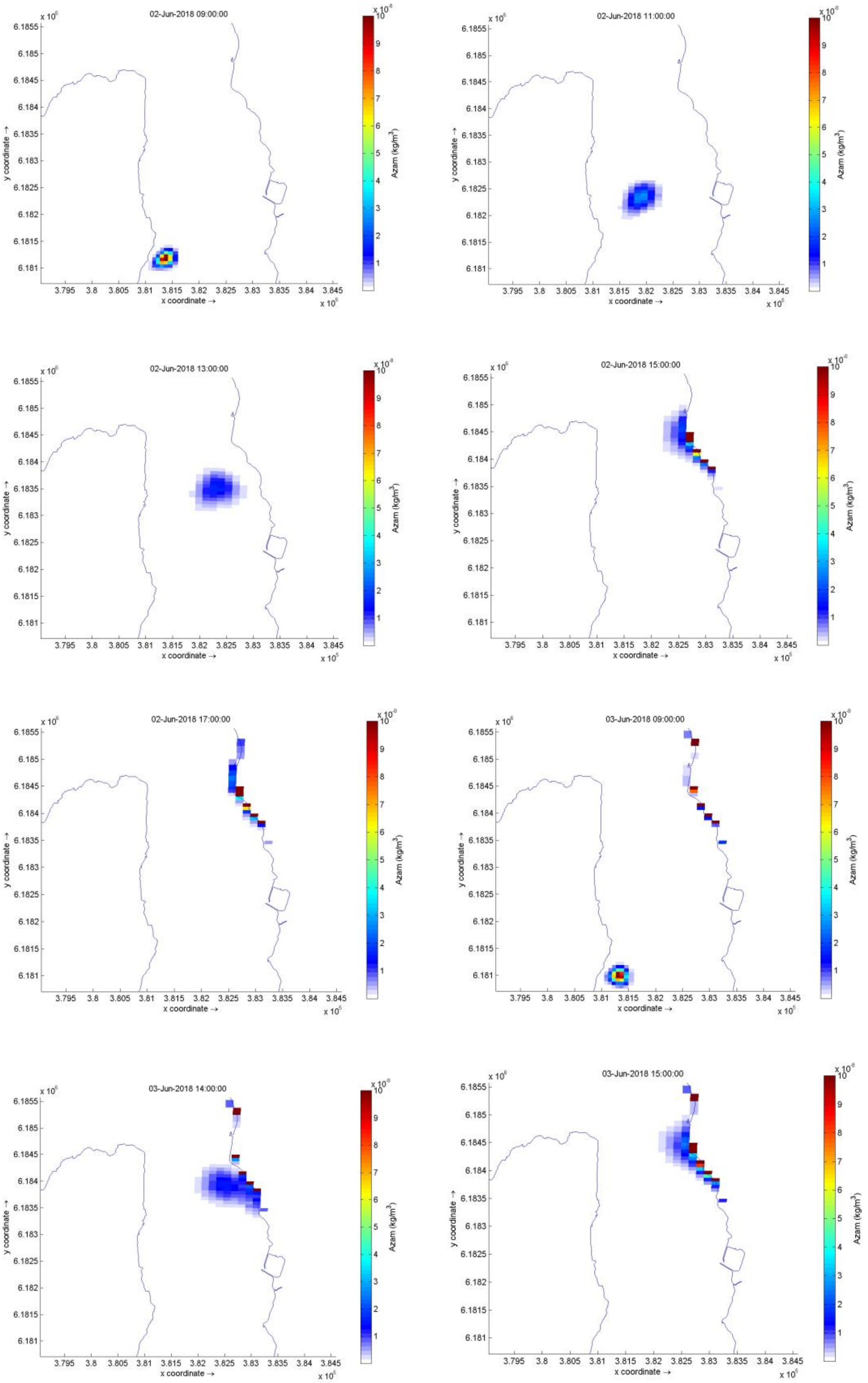


Figure 3.11 Greater Cumbrae - Azamethiphos Neap discharge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02-Jun-2018 11:00:00
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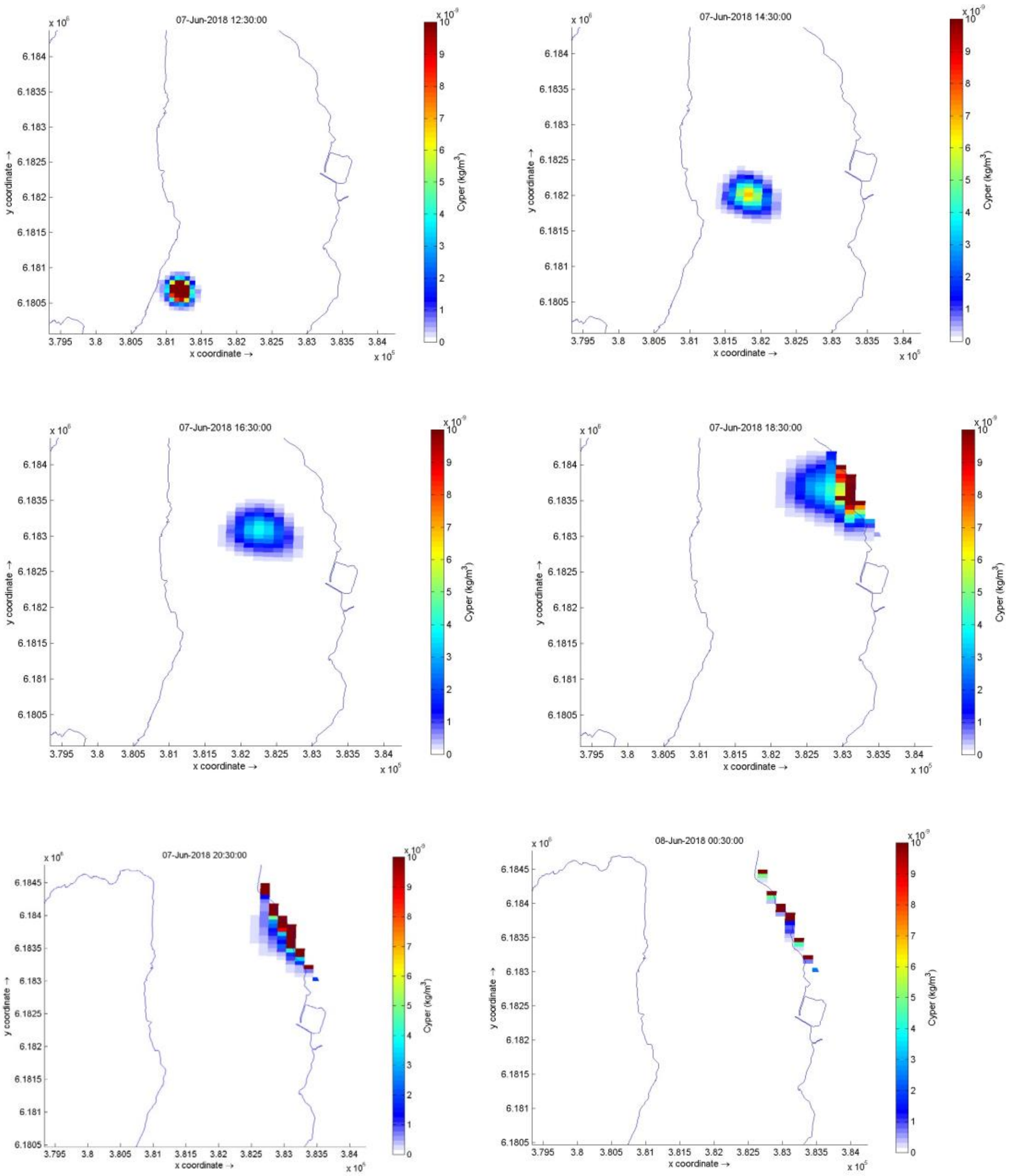
03-Jun-2018 09:00:00
03-Jun-2018 14:00:00
03-Jun-2018 15:00:00
x coordinate →
y coordinate →
Azam (kg/m3)

Figure 3.12 Greater Cumbrae - Azamethiphos Spring discharge

3.3.2 Greater Cumbrae - Cypermethrin



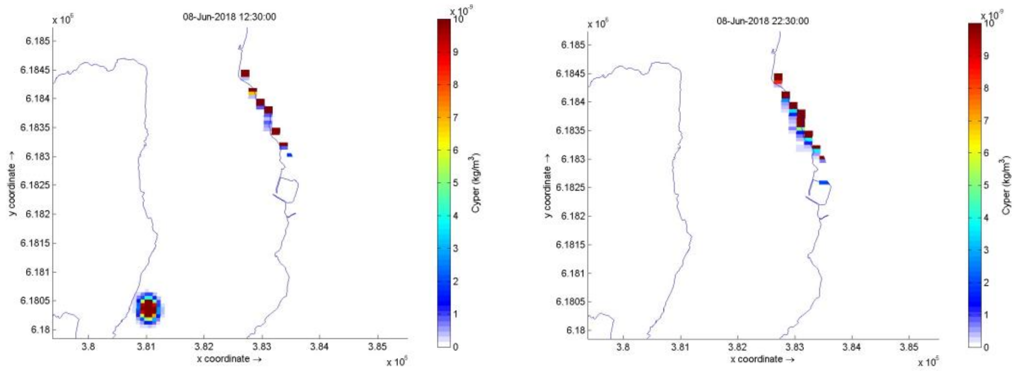


Figure 3.13 Greater Cumbrae - Cypermethrin Neap discharge

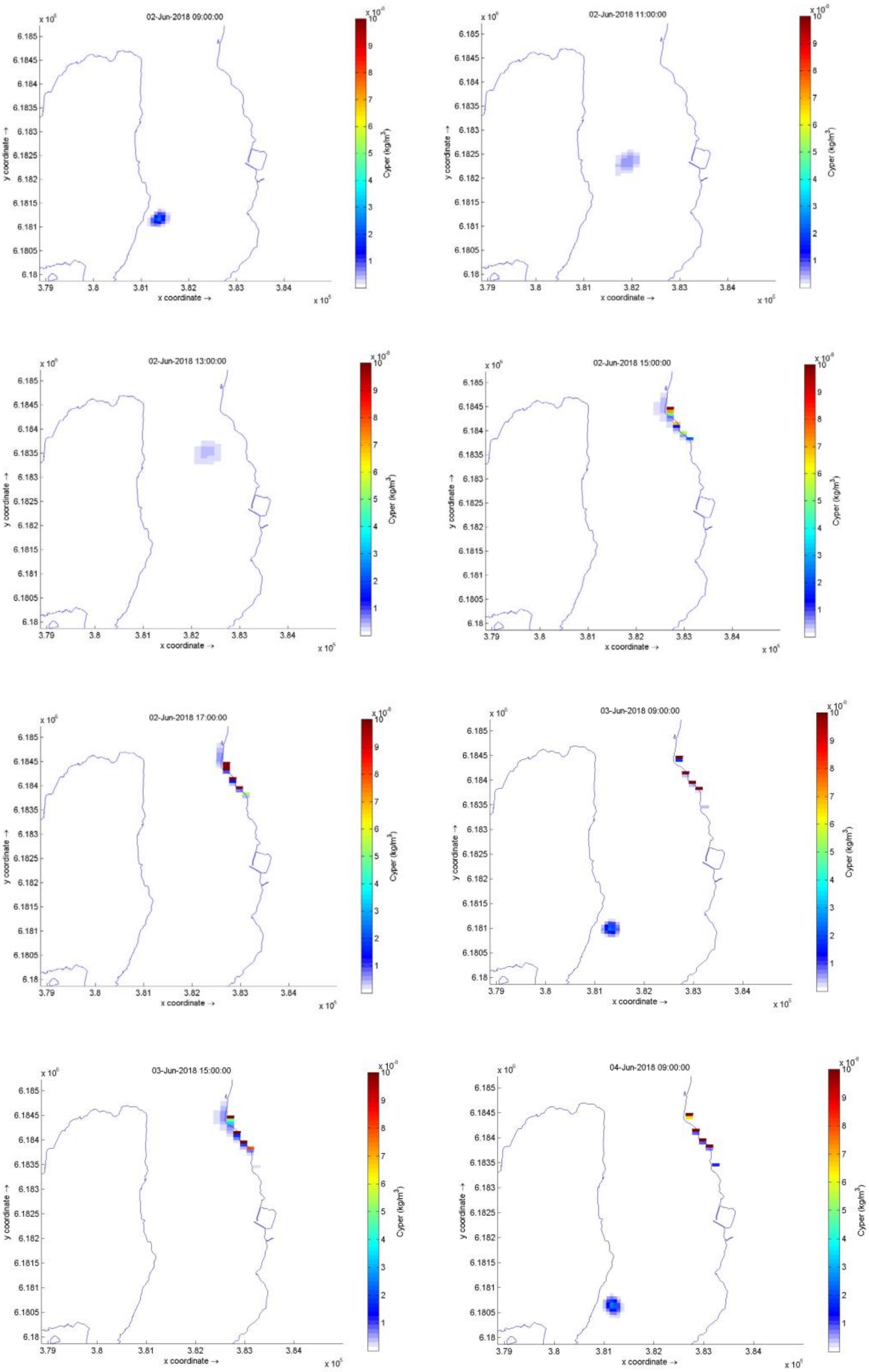
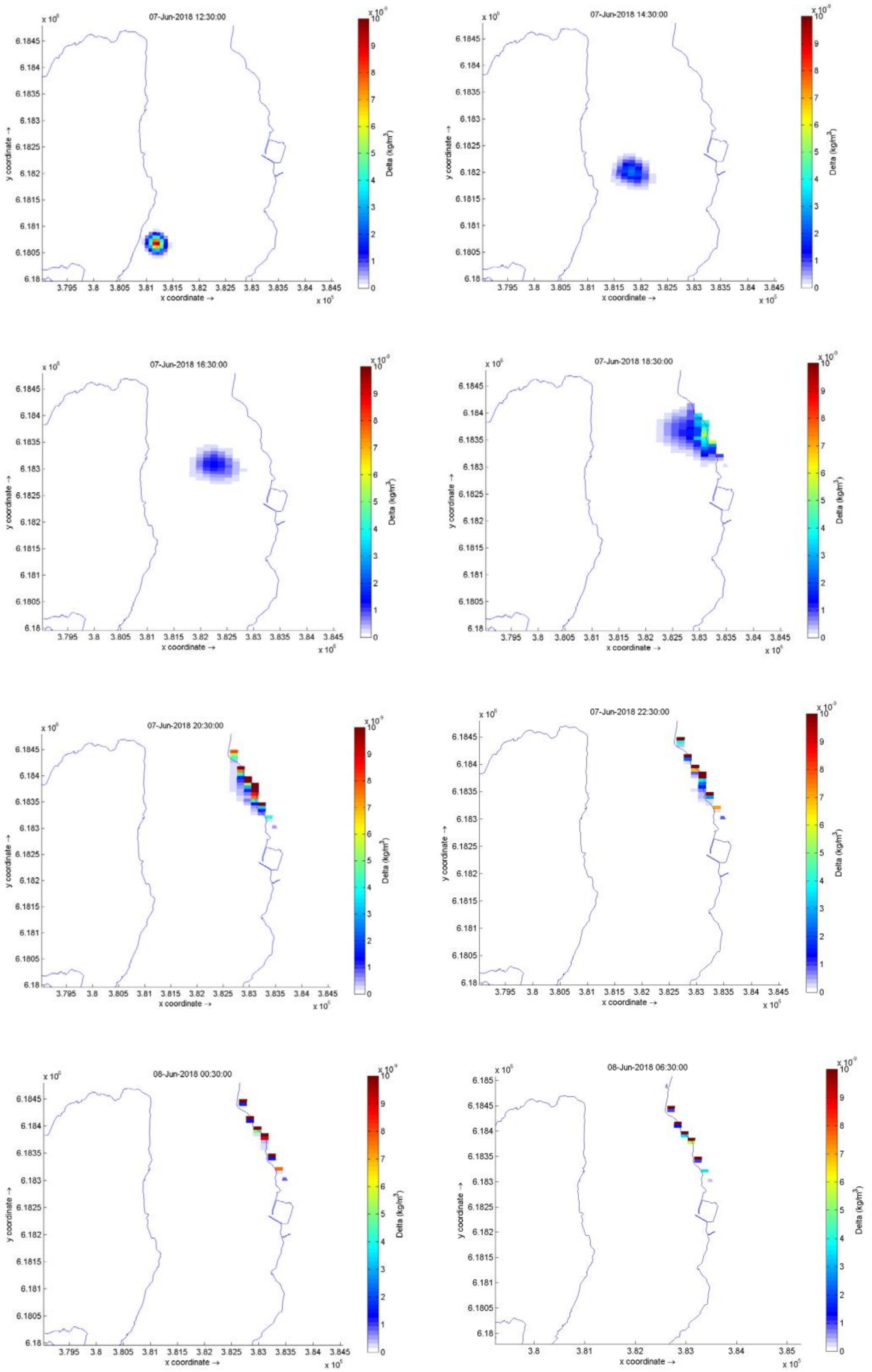


Figure 3.14 Greater Cumbrae - Cypermethrin Spring discharge

3.3.3 Greater Cumbrae - Deltamethrin



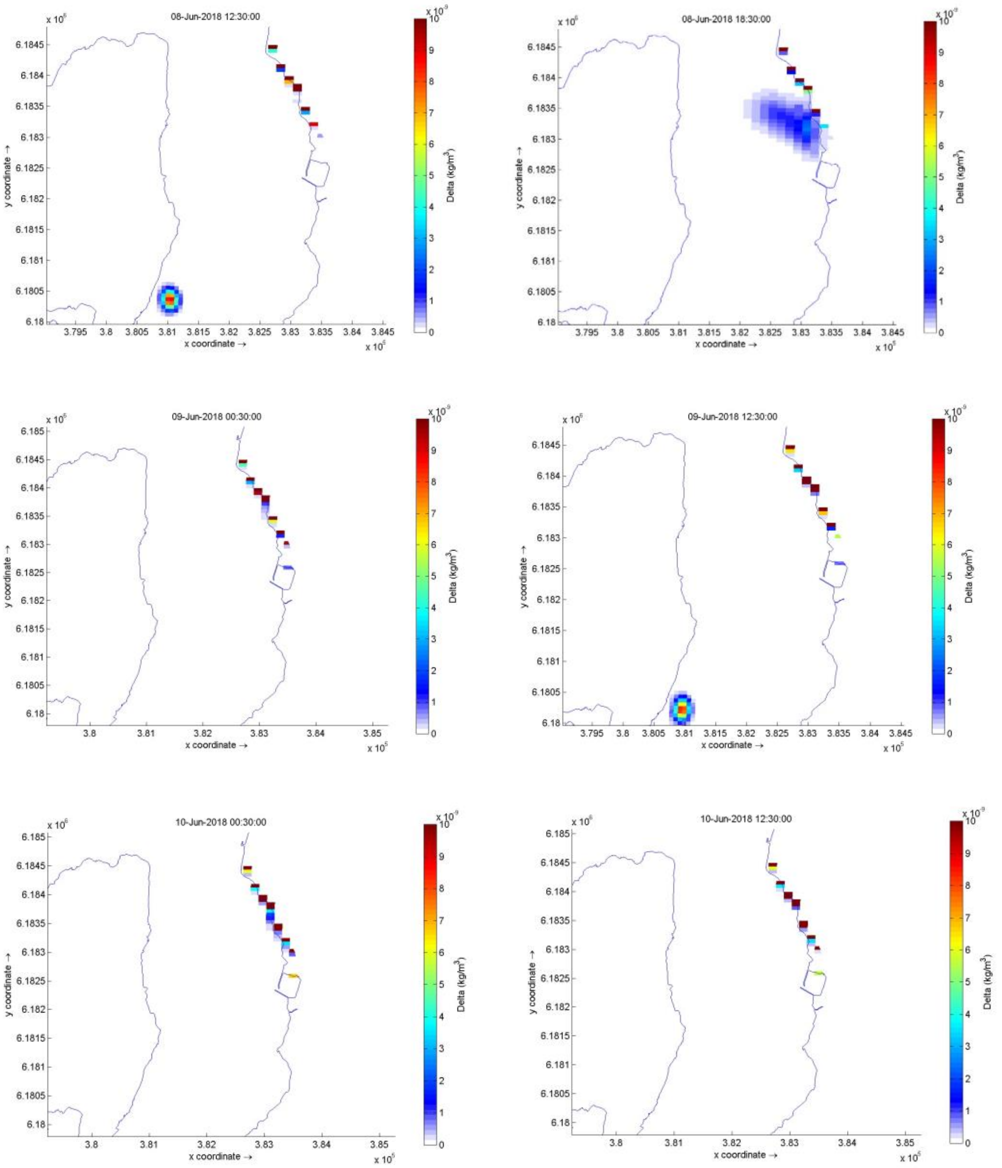
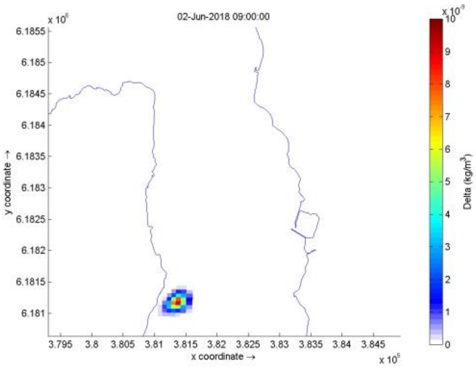


Figure 3.15 Greater Cumbrae - Deltamethrin Neap discharge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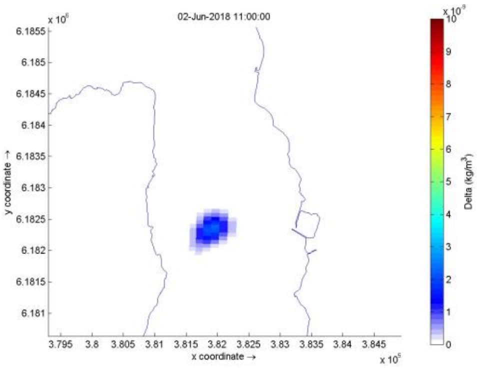
y coordinate →
Delta (kg/m3)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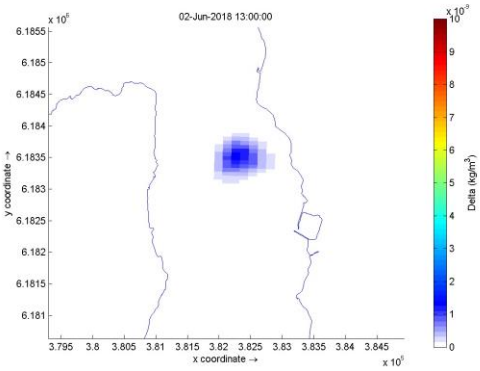
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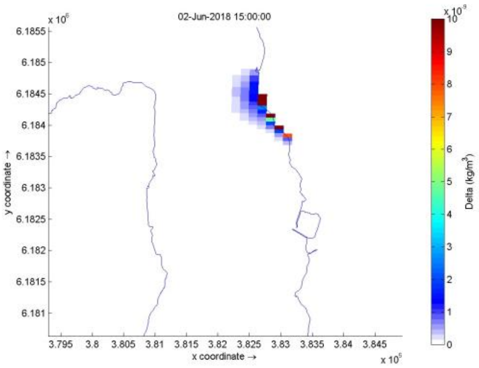
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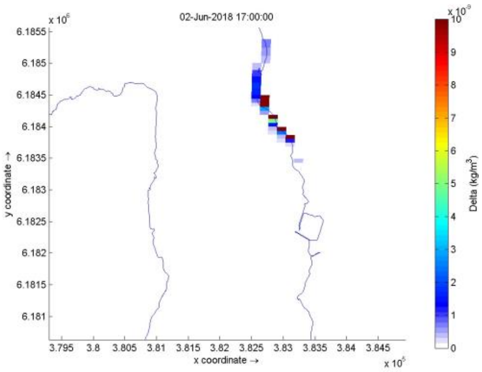
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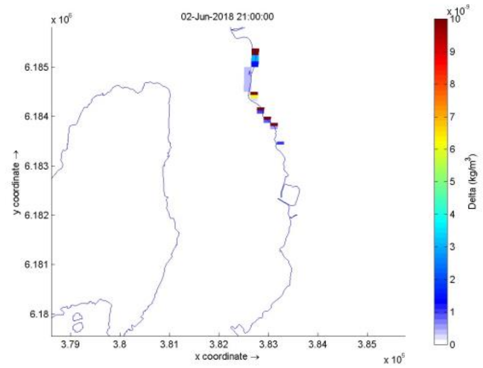
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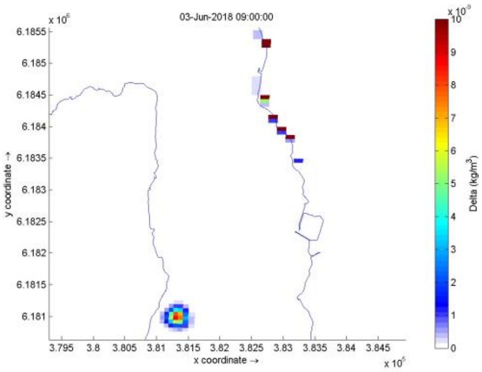
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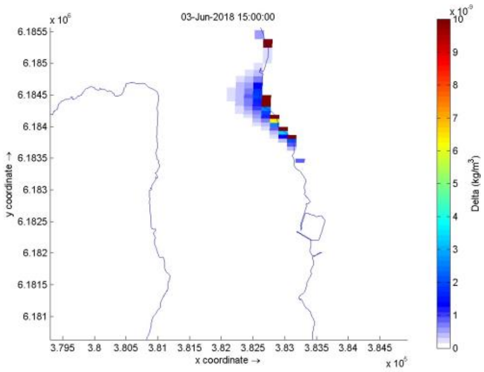
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y coordinate →
Delta (kg/m3)

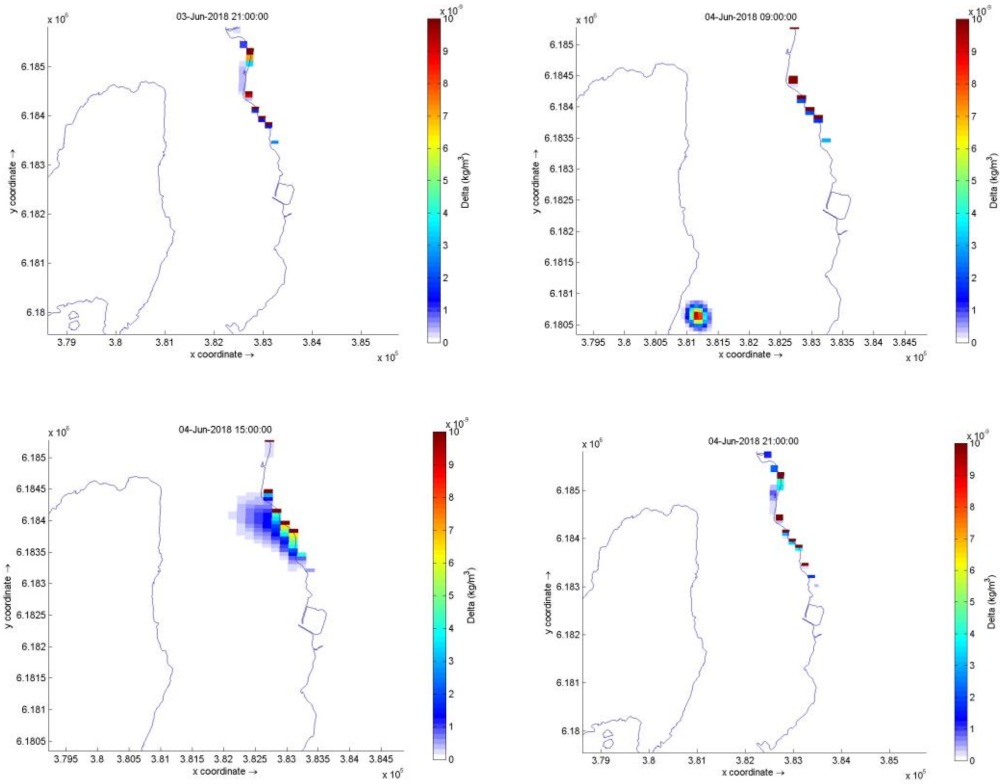
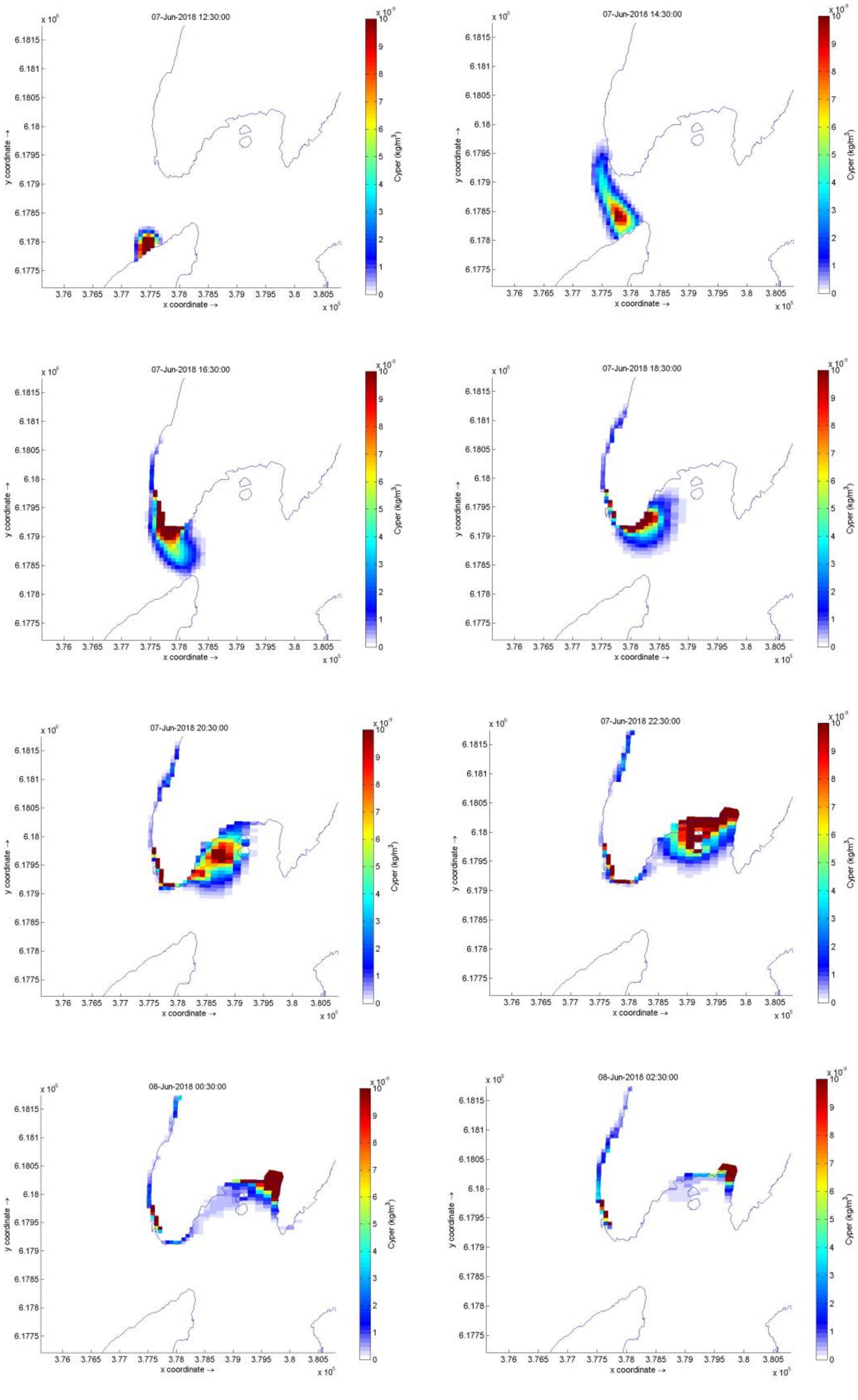


Figure 3.16 Greater Cumbrae - Deltamethrin Spring discharge

3.3.4 Isle of Little Cumbrae - Cypermethrin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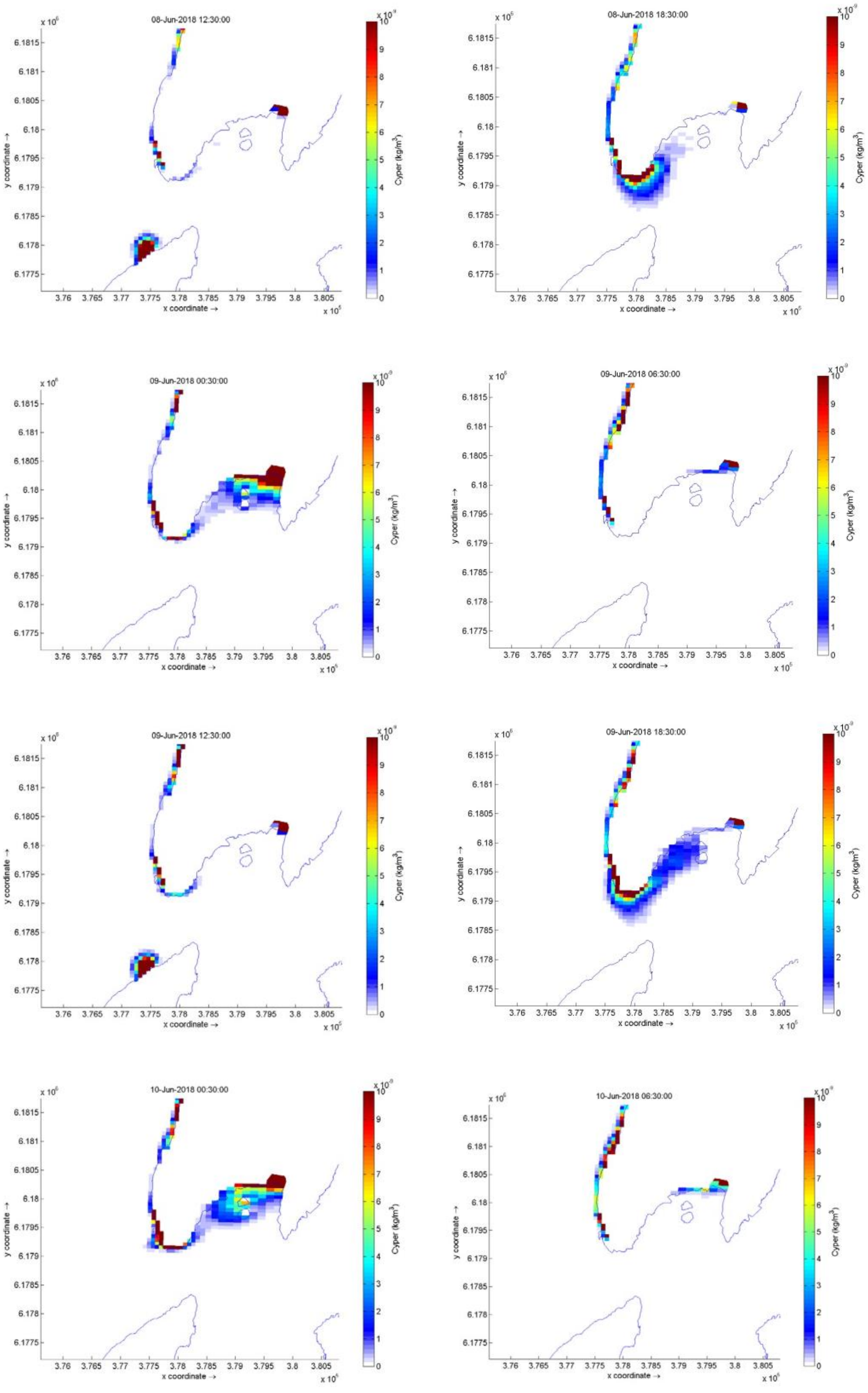
07-Jun-2018 14:30:00
07-Jun-2018 16:30:00
07-Jun-2018 18:30:00
07-Jun-2018 20:30:00
07-Jun-2018 22:30:00
08-Jun-2018 00:30:00
08-Jun-2018 02:30:00
x coordinate →
y coordinate →
Cyper (kg/m^3)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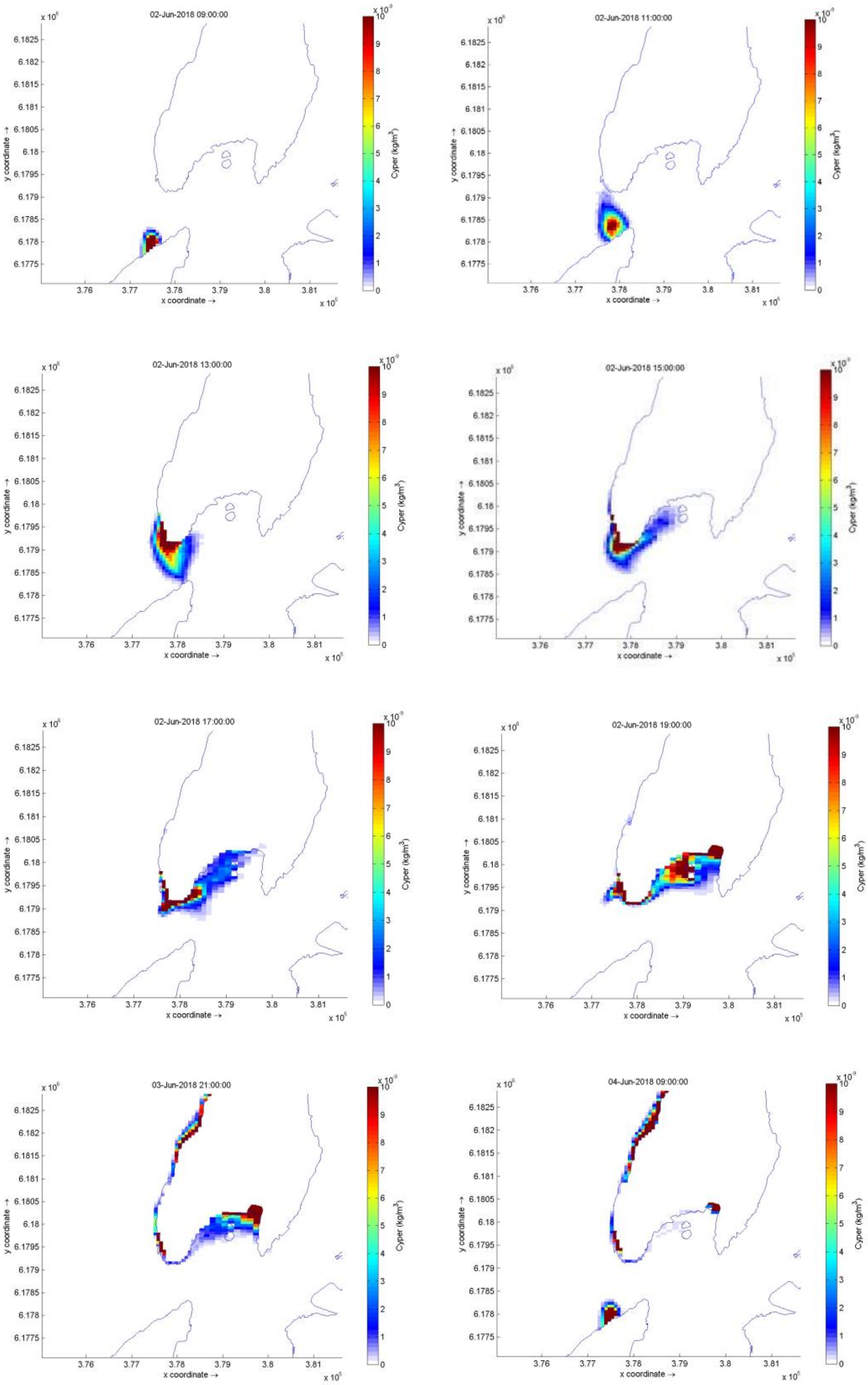
09-Jun-2018 06:30:00
09-Jun-2018 12:30:00
09-Jun-2018 18:30:00
10-Jun-2018 00:30:00
10-Jun-2018 06:30:00
y coordinate →
x coordinate →
Cyper (kg/m³)

Figure 3.17 Isle of Little Cumbrae - Cypermethrin Neap discharge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02-Jun-2018 13:00:00
02-Jun-2018 15:00:00
02-Jun-2018 17:00:00
02-Jun-2018 19:00:00
03-Jun-2018 21:00:00
04-Jun-2018 09:00:00
x coordinate →
y coordinate →
Cyper (kg/m³)

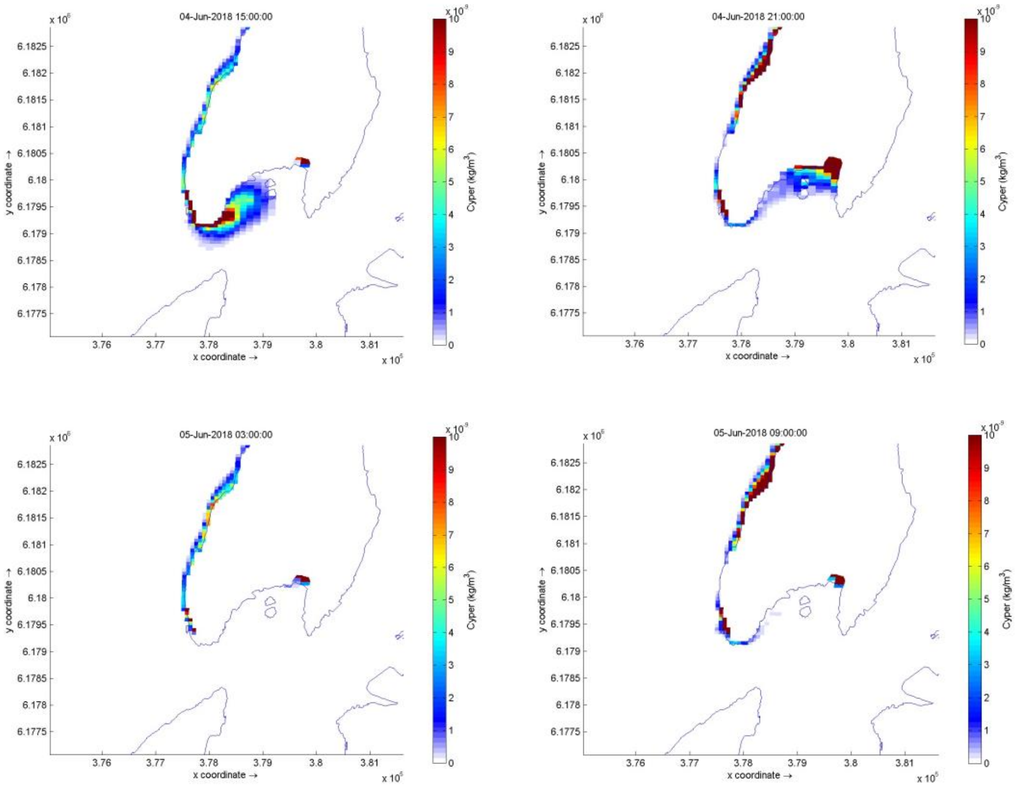
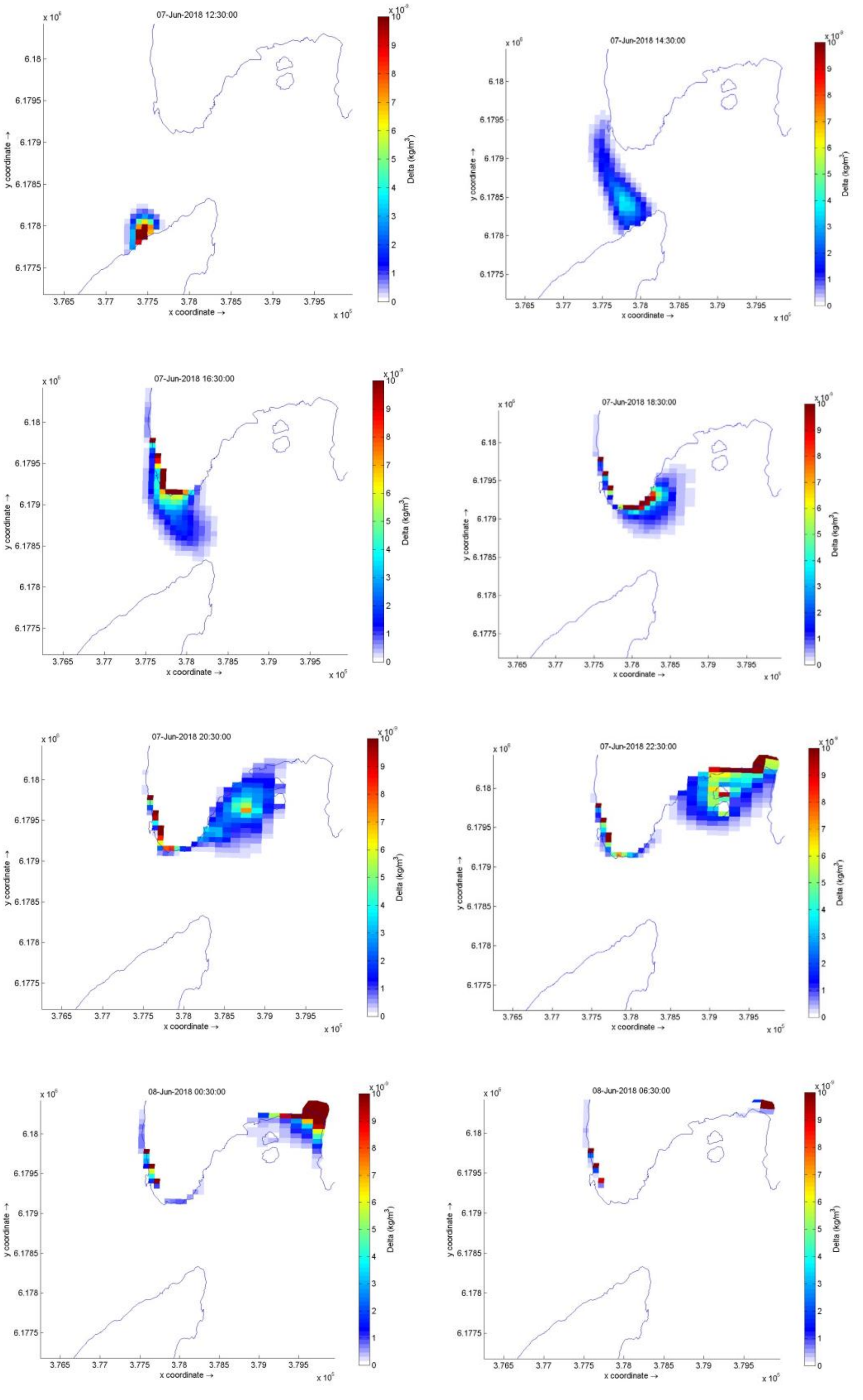


Figure 3.18 Isle of Little Cumbrae - Cypermethrin Spring discharge

3.3.5 Isle of Little Cumbrae - Deltamethrin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07-Jun-2018 14:30:00
07-Jun-2018 16:30:00
07-Jun-2018 18:30:00
07-Jun-2018 20:30:00
07-Jun-2018 22:30:00
08-Jun-2018 00:30:00
08-Jun-2018 06:30:00
x coordinate →
y coordinate →
x 10^5
x 10^6
x 10^-9
Delta (kg/m^3)
3.765
3.77
3.775
3.78
3.785
3.79
3.795
6.1775
6.178
6.1785
6.179
6.1795
6.18

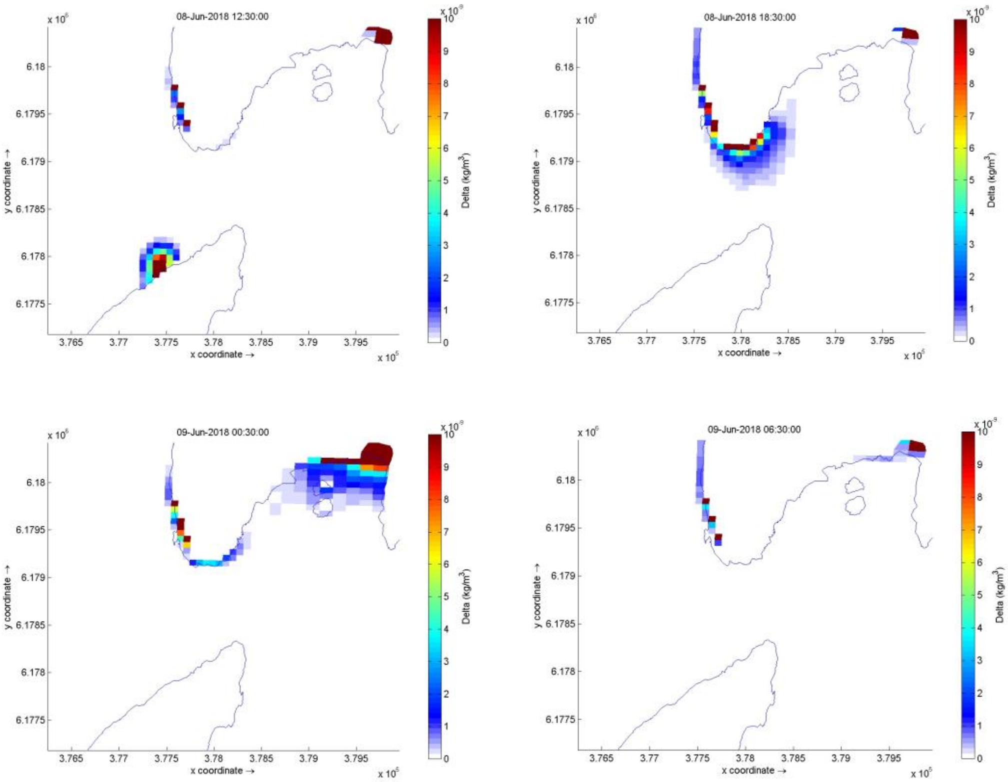
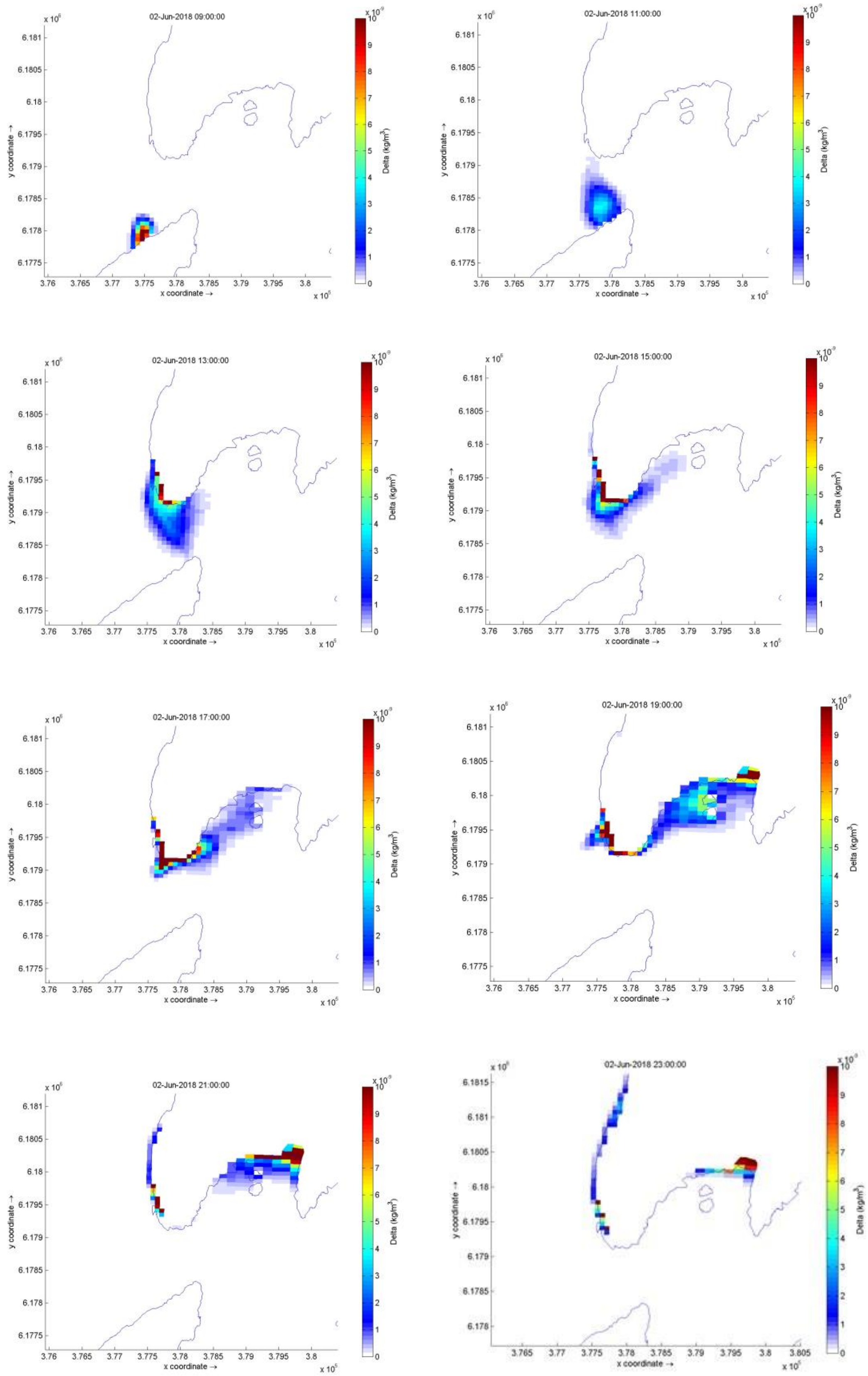
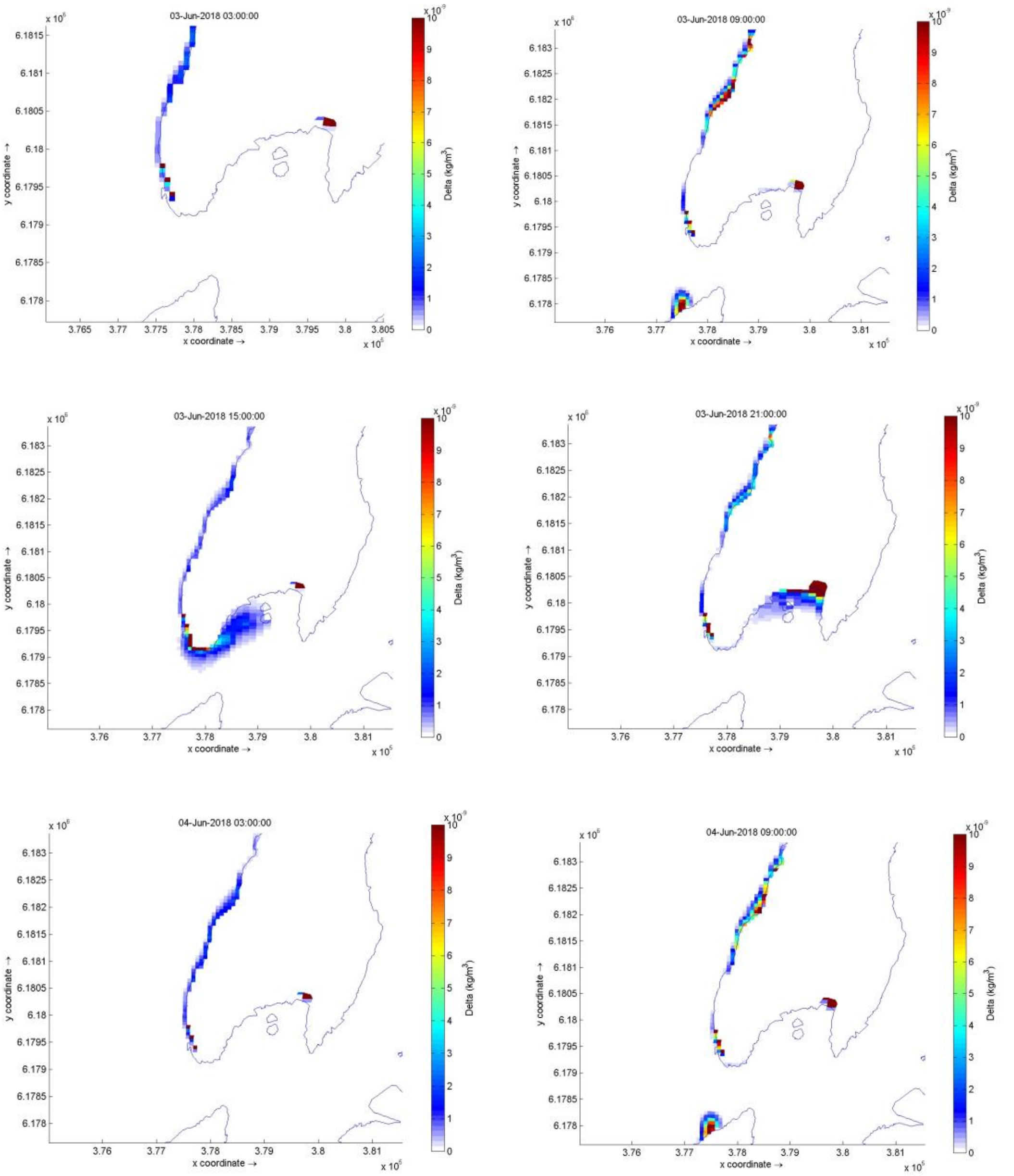


Figure 3.19 Isle of Little Cumbrae - Deltamethrin Neap discharge



02-Jun-2018 09:00:00
02-Jun-2018 11:00:00
02-Jun-2018 13:00:00
02-Jun-2018 15:00:00
02-Jun-2018 17:00:00
02-Jun-2018 19:00:00
02-Jun-2018 21:00:00
02-Jun-2018 23:00:00
x coordinate →
y coordinate →
Delta (kg/m³)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03-Jun-2018 09:00:00
03-Jun-2018 15:00:00
03-Jun-2018 21:00:00
04-Jun-2018 03:00:00
04-Jun-2018 09:00:00
x coordinate →
y coordinate →
Delta (kg/m^3)

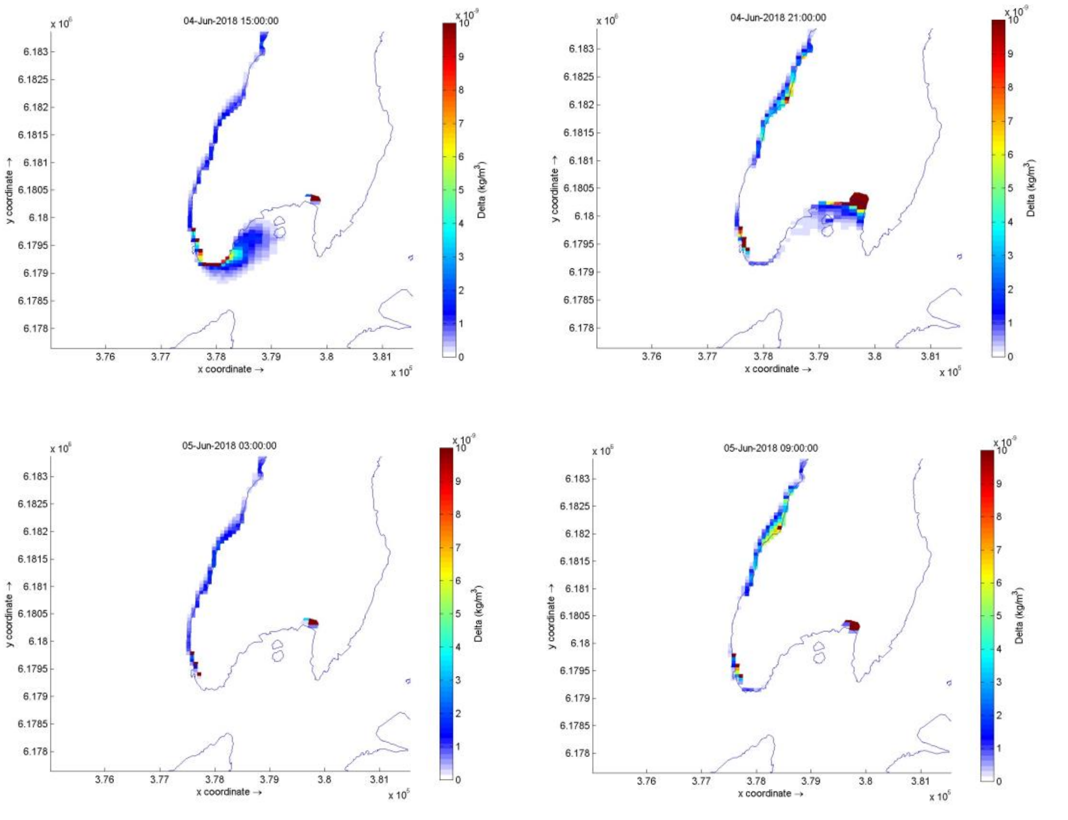
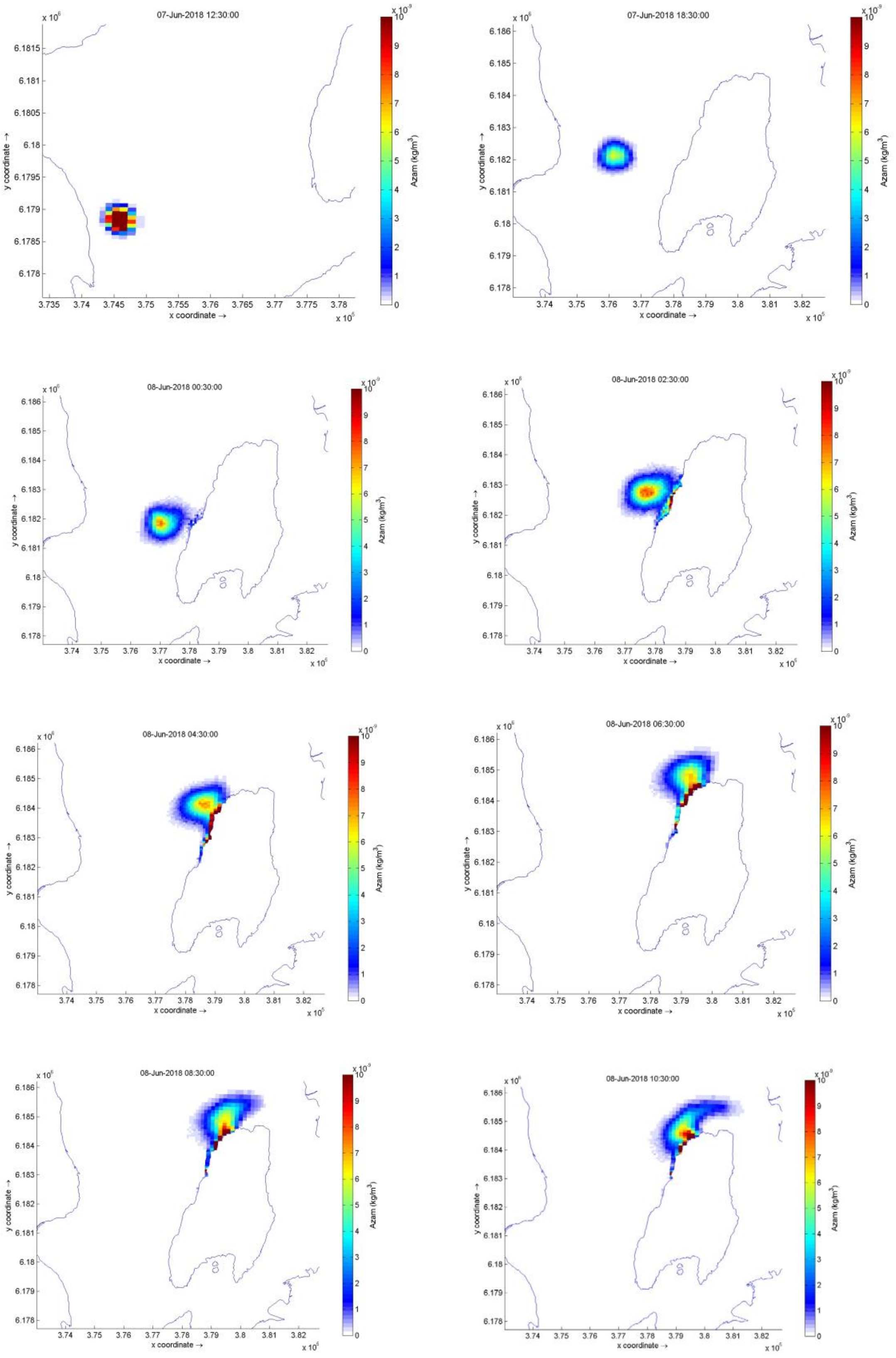


Figure 3.20 Isle of Little Cumbrae - Deltamethrin Spring discharge

3.3.6 South Bute - Azamethiphos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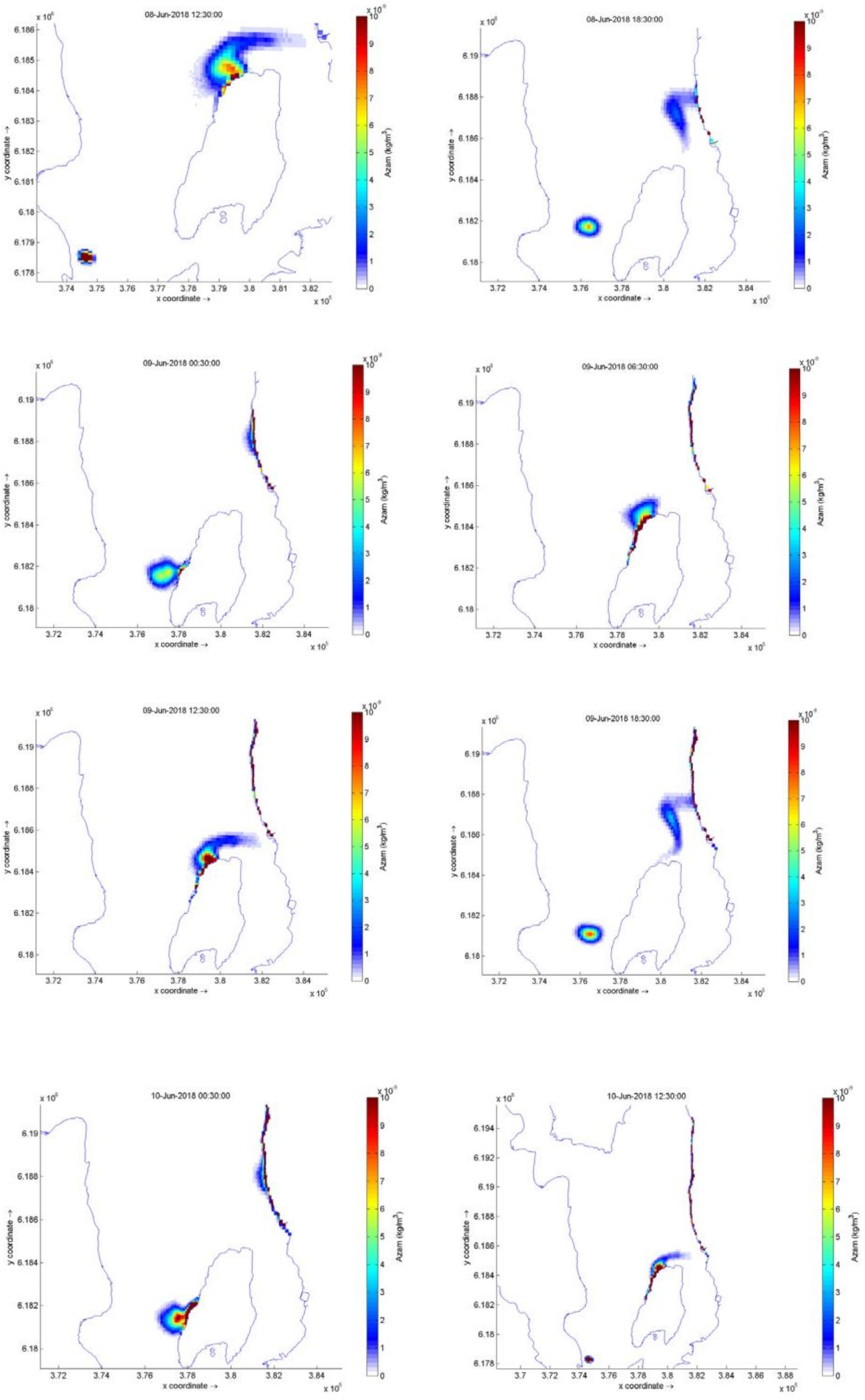
08-Jun-2018 02:30:00
08-Jun-2018 04:30:00
08-Jun-2018 06:30:00
08-Jun-2018 08:30:00
08-Jun-2018 10:30:00
x coordinate →
y coordinate →
Azam (kg/m^3)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08-Jun-2018 18:30:00
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09-Jun-2018 06:30:00
09-Jun-2018 12:30:00
09-Jun-2018 18:30:00
10-Jun-2018 00:30:00
10-Jun-2018 12:30:00
x coordinate →
y coordinate →
Azam (kg/m³)

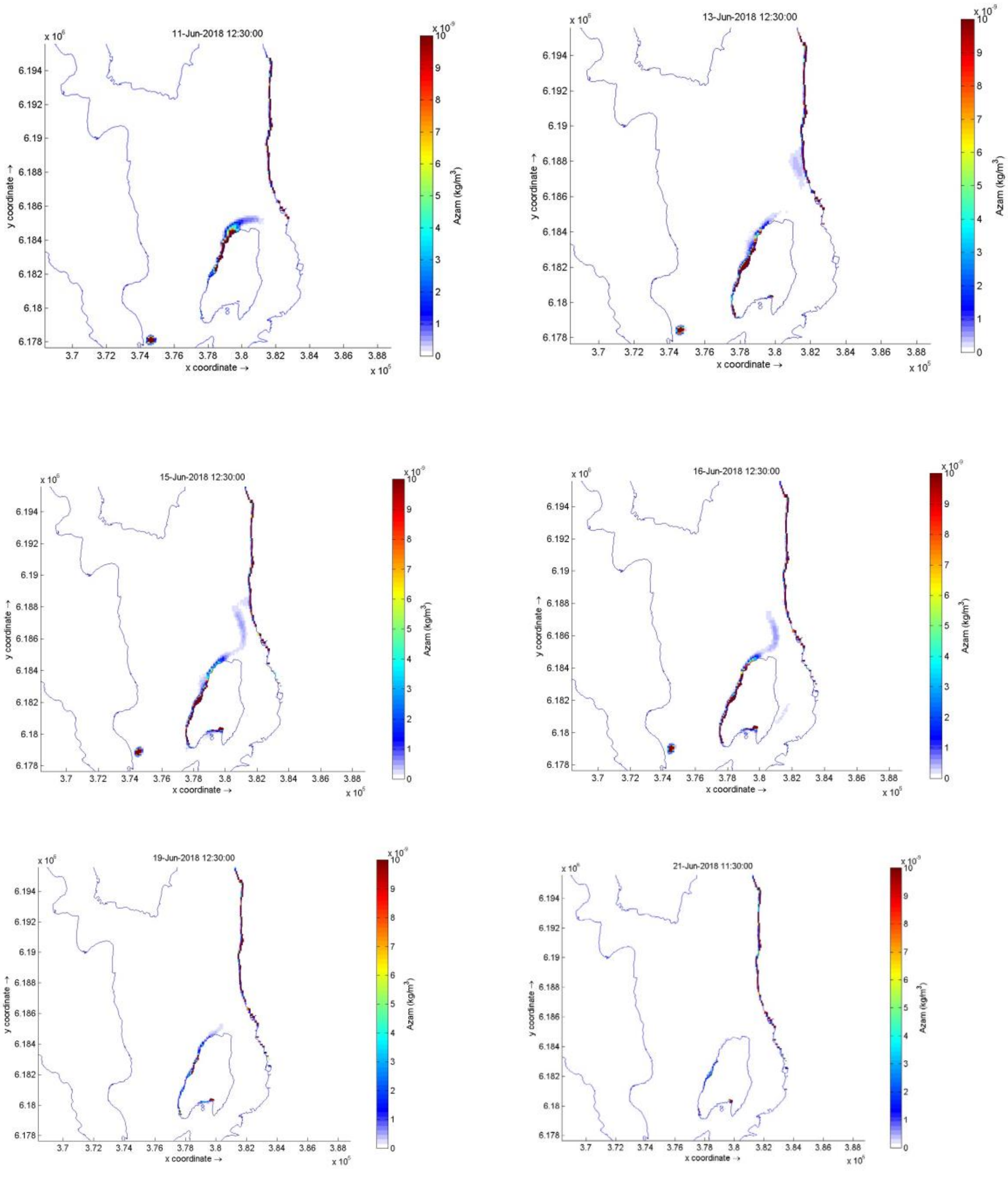
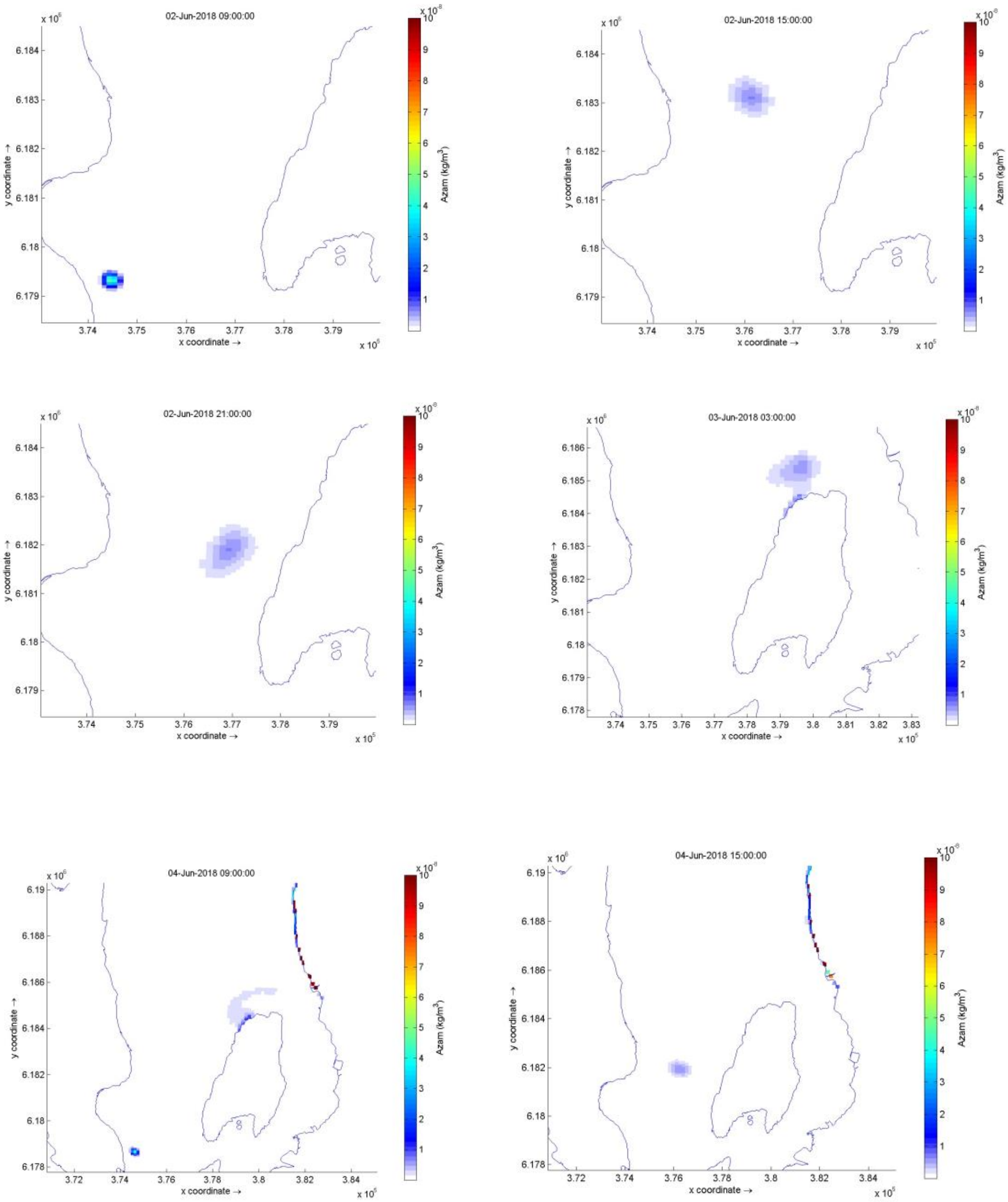


Figure 3.21 South Bute - Azamethiphos Neap discharge



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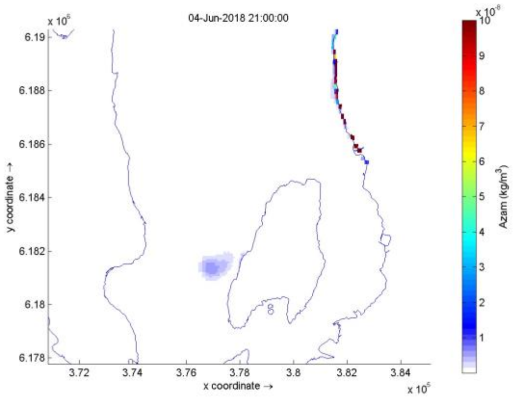
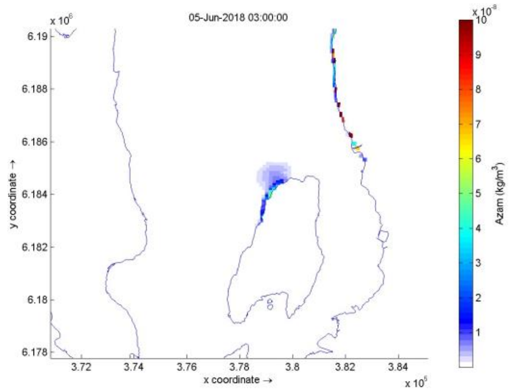
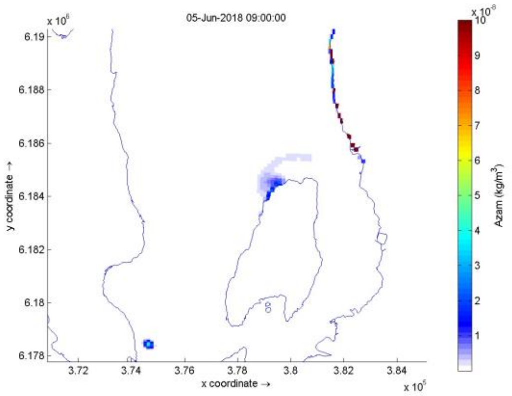
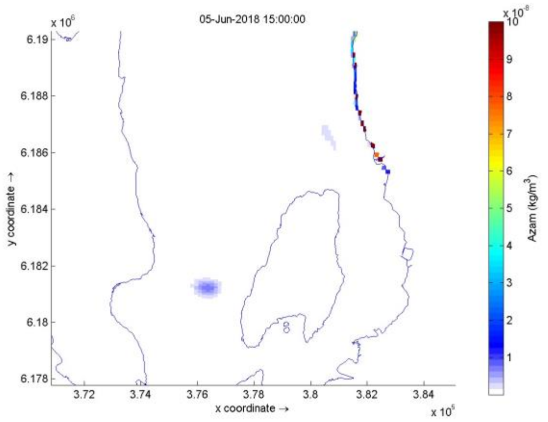
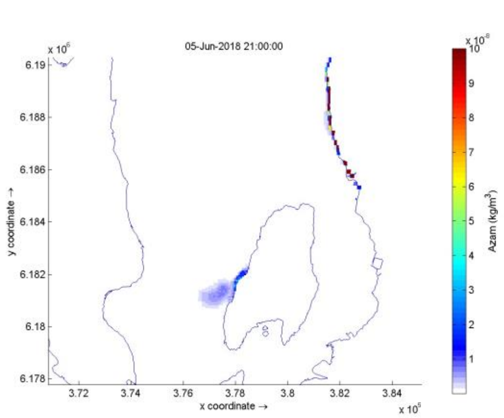
02-Jun-2018 15:00:00
02-Jun-2018 21:00:00
03-Jun-2018 03:00:00
04-Jun-2018 09:00:00
04-Jun-2018 15:00:00
x coordinate →
y coordinate →
Azam (kg/m3)

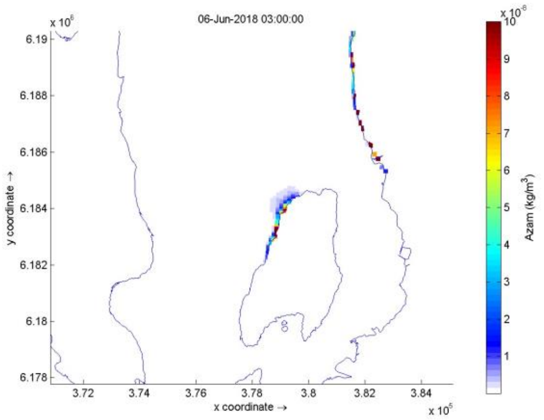

04-Jun-2018 21:00:00
x coordinate →
y coordinate →
Azam (kg/m^3)


05-Jun-2018 03:00:00
x coordinate →
y coordinate →
Azam (kg/m^3)


05-Jun-2018 09:00:00
x coordinate →
y coordinate →
Azam (kg/m^3)


05-Jun-2018 15:00:00
x coordinate →
y coordinate →
Azam (kg/m^3)


05-Jun-2018 21:00:00
x coordinate →
y coordinate →
Azam (kg/m^3)


06-Jun-2018 03:00:00
x coordinate →
y coordinate →
Azam (kg/m^3)

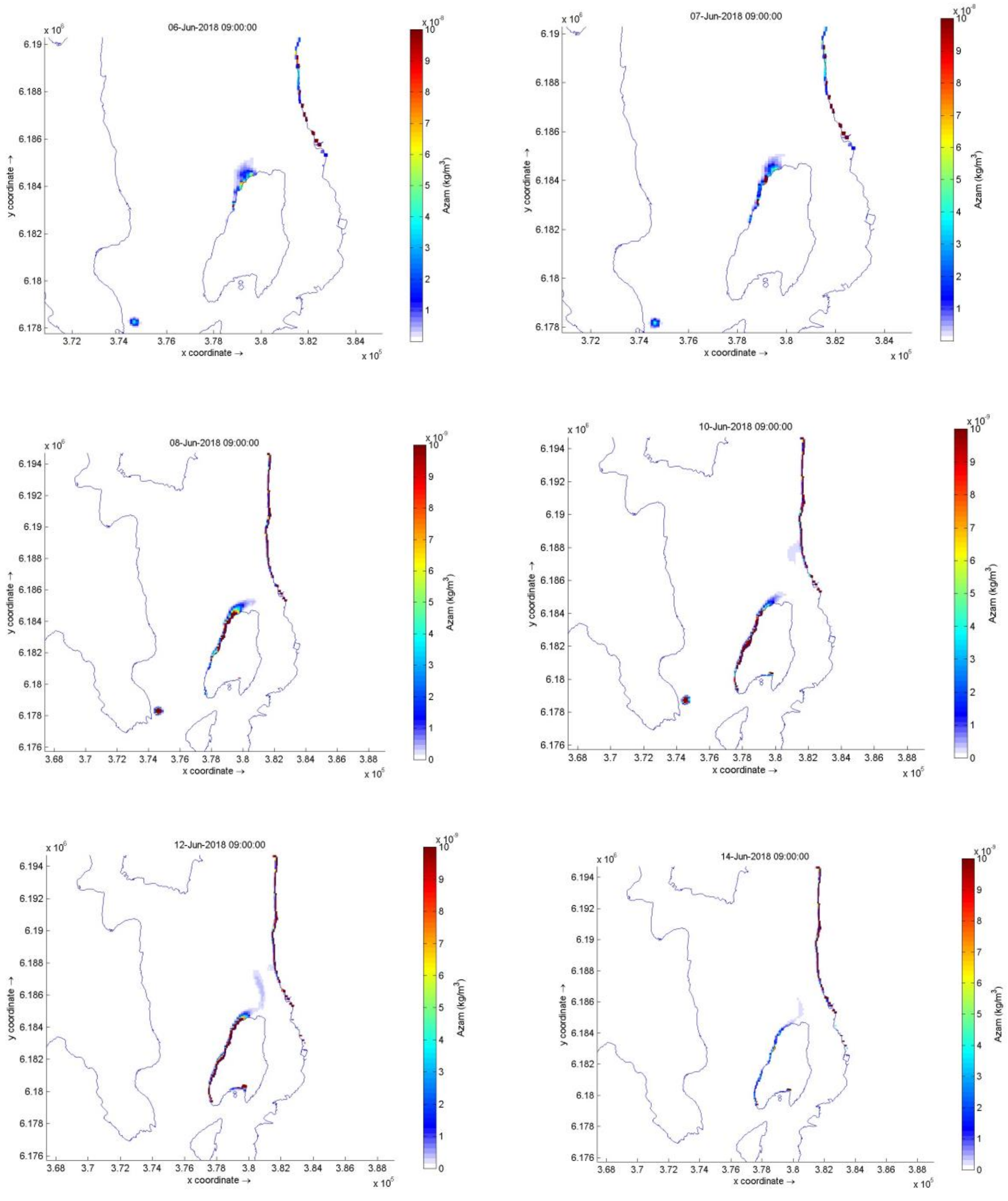
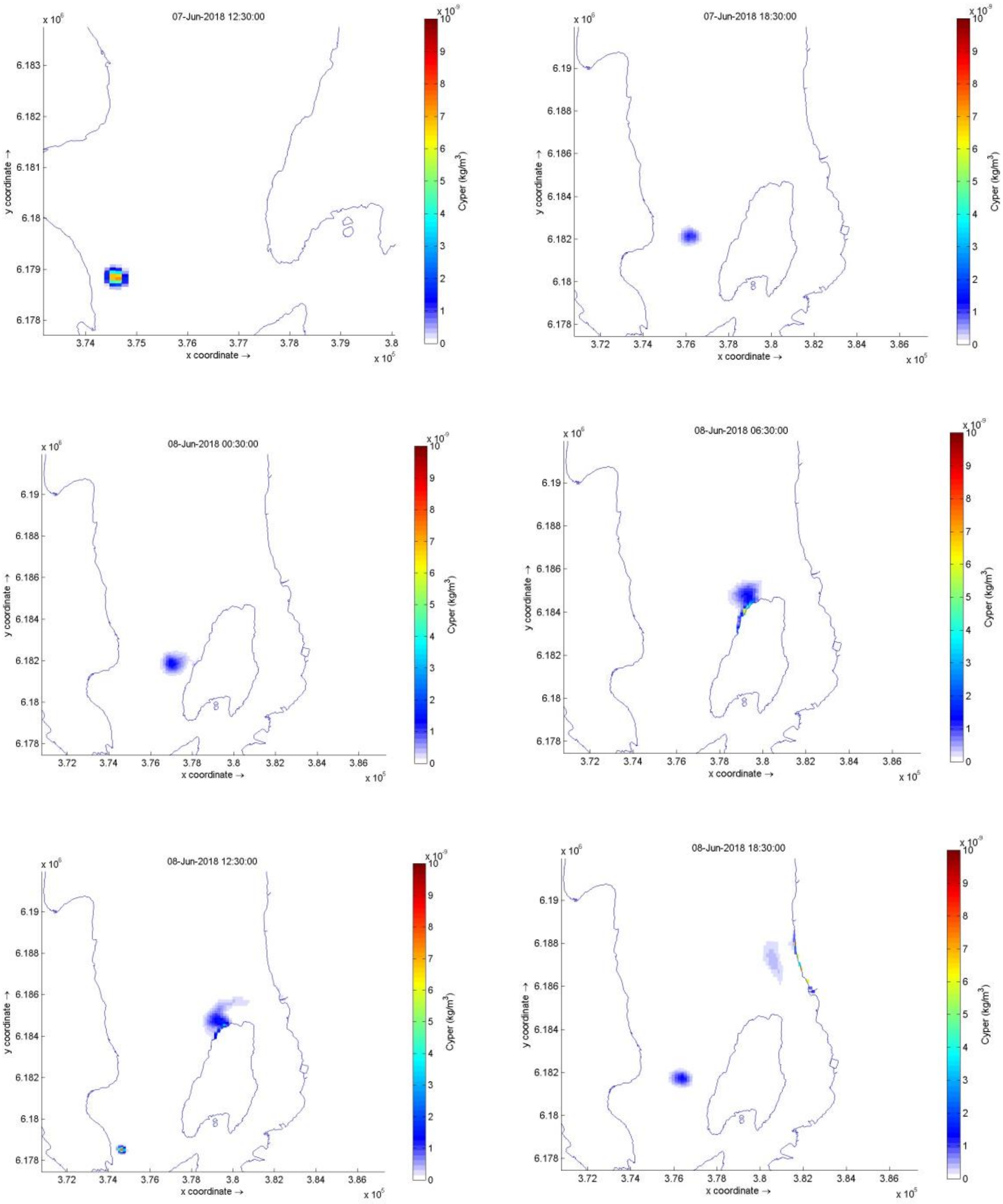
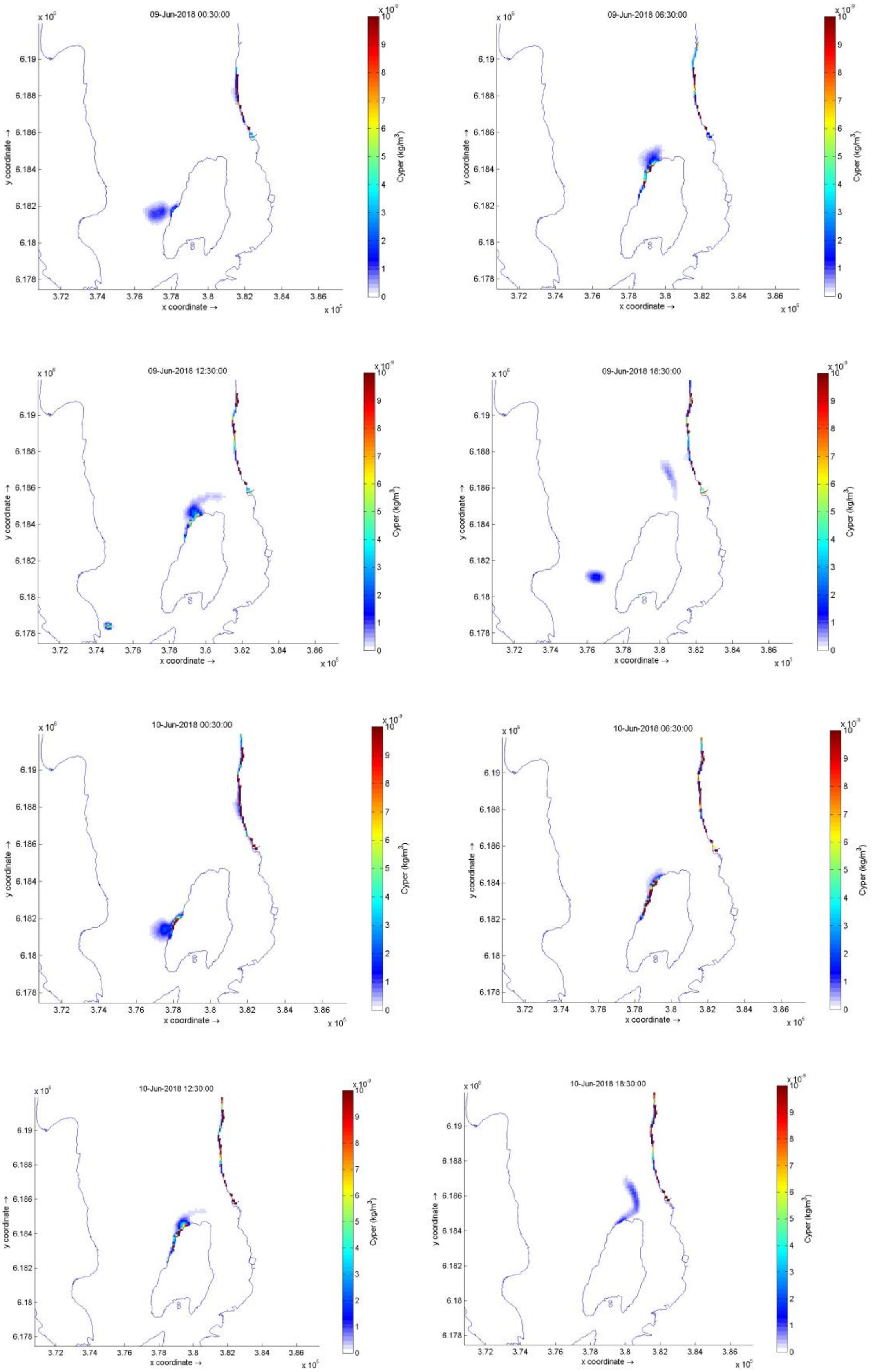


Figure 3.22 South Bute - Azamethiphos Spring discharge

3.3.7 South Bute – Cypermethrin

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09-Jun-2018 06:30:00
09-Jun-2018 12:30:00
09-Jun-2018 18:30:00
10-Jun-2018 00:30:00
10-Jun-2018 06:30:00
10-Jun-2018 12:30:00
10-Jun-2018 18:30:00
y coordinate →
x coordinate →
Cyper (kg/m3)

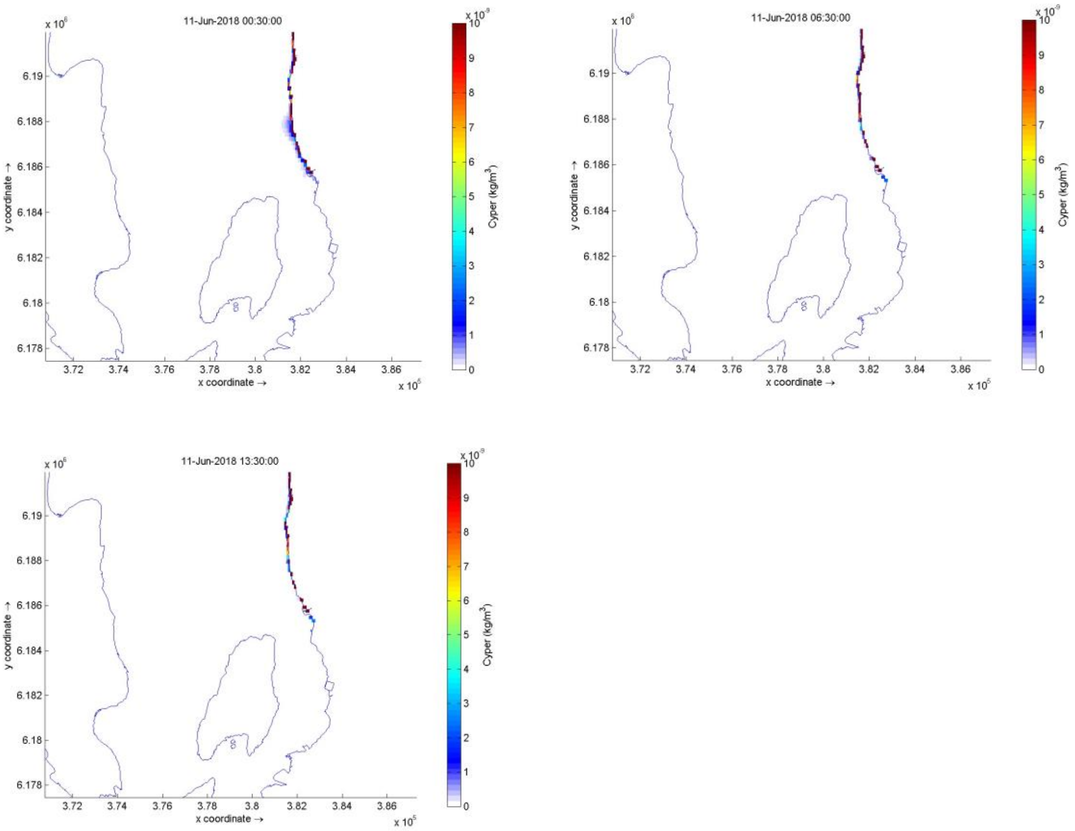
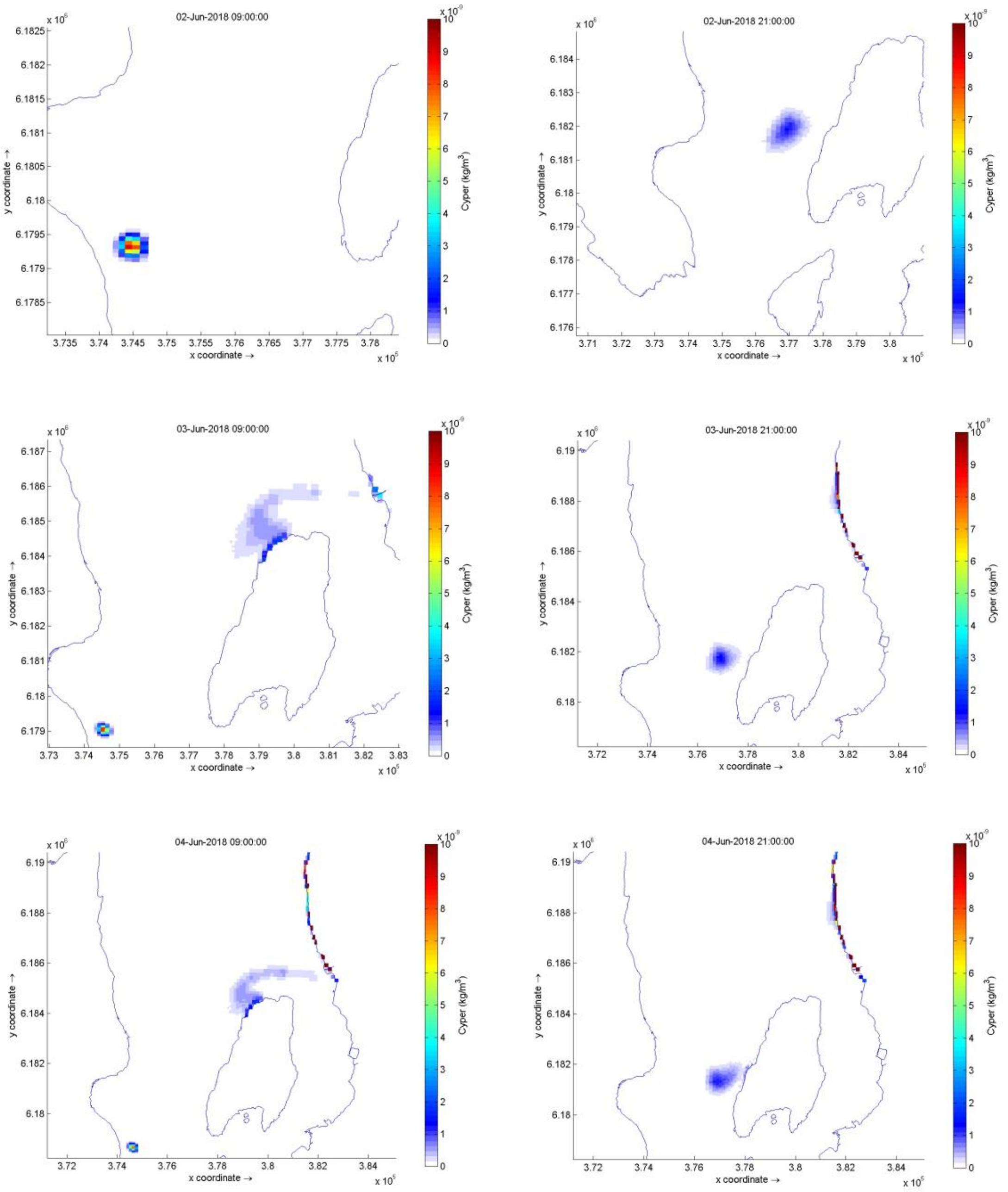


Figure 3.23 South Bute - Cypermethrin Neap discharge


02-Jun-2018 09:00:00
02-Jun-2018 21:00:00
03-Jun-2018 09:00:00
03-Jun-2018 21:00:00
04-Jun-2018 09:00:00
04-Jun-2018 21:00:00
x coordinate →
y coordinate →
Cyper (kg/m3)

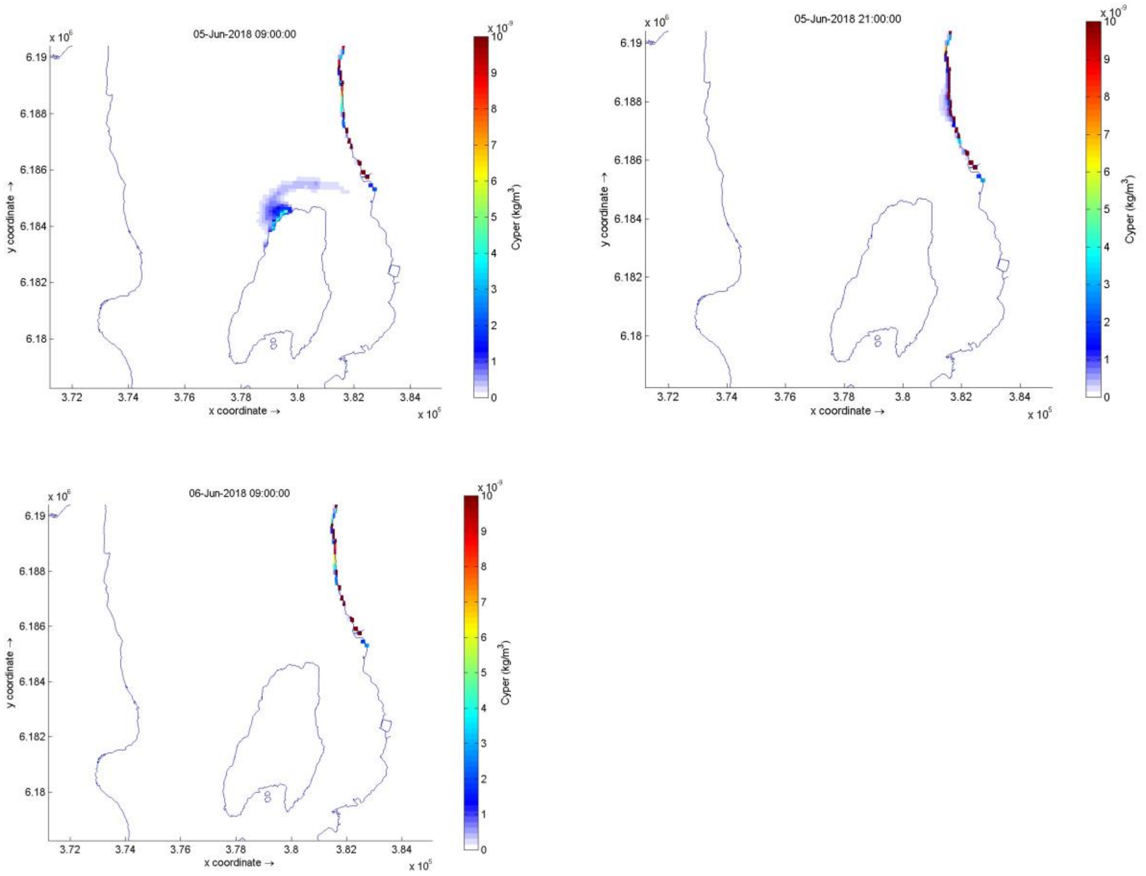
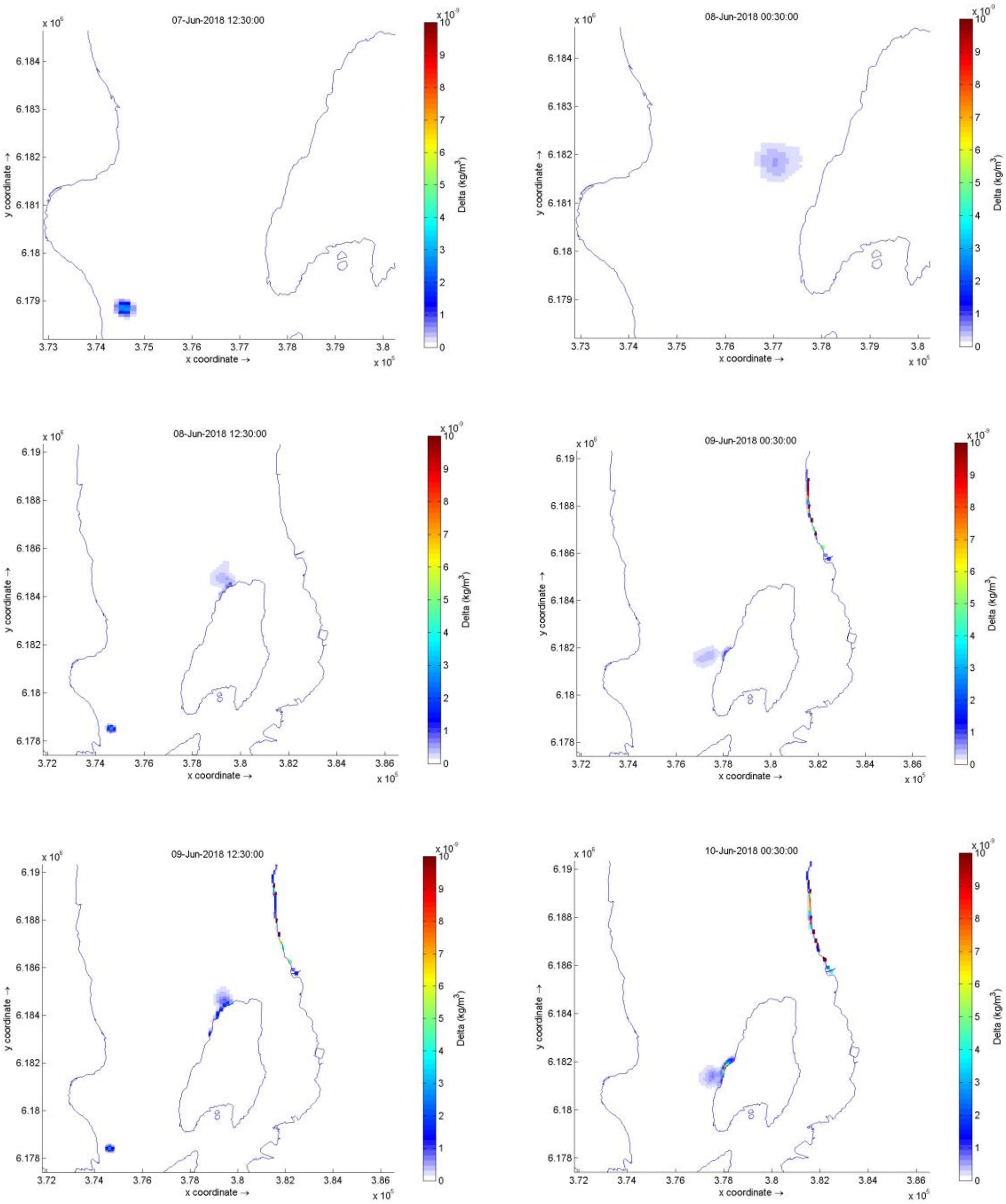


Figure 3.24 South Bute - Cypermethrin Spring discharge

3.3.8 South Bute – Deltamethrin



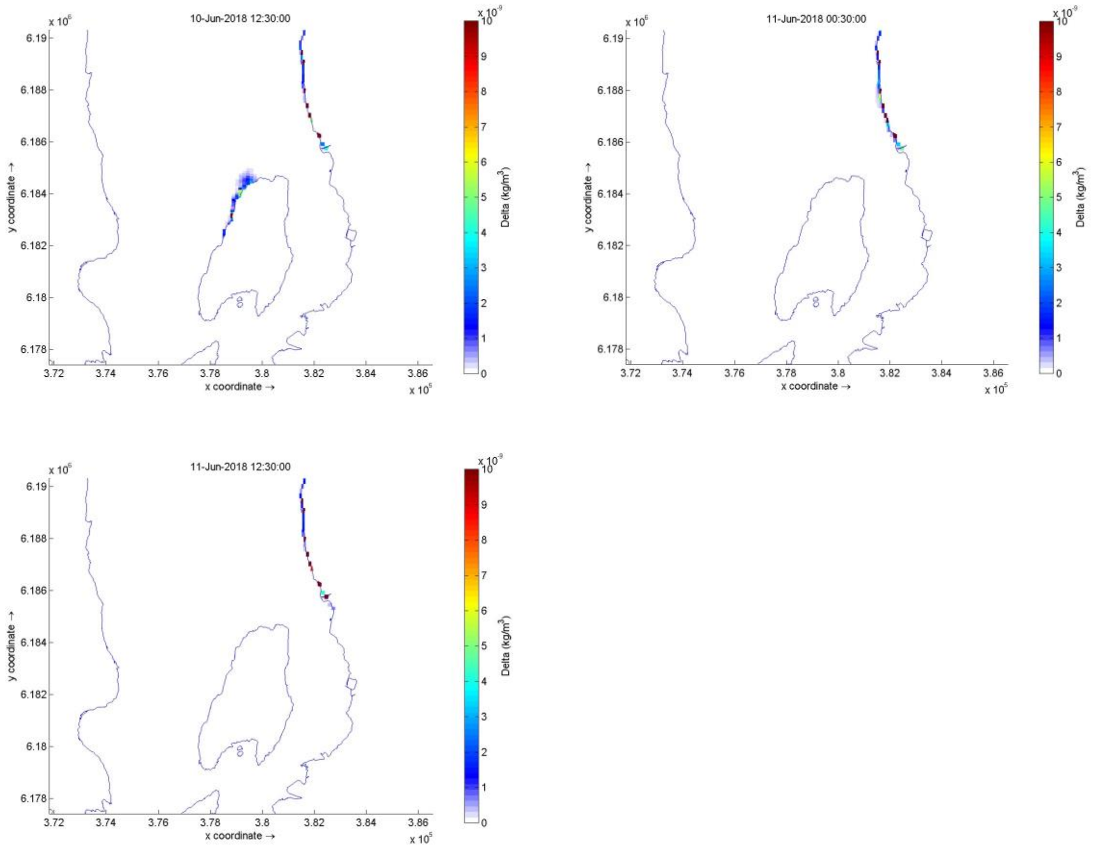
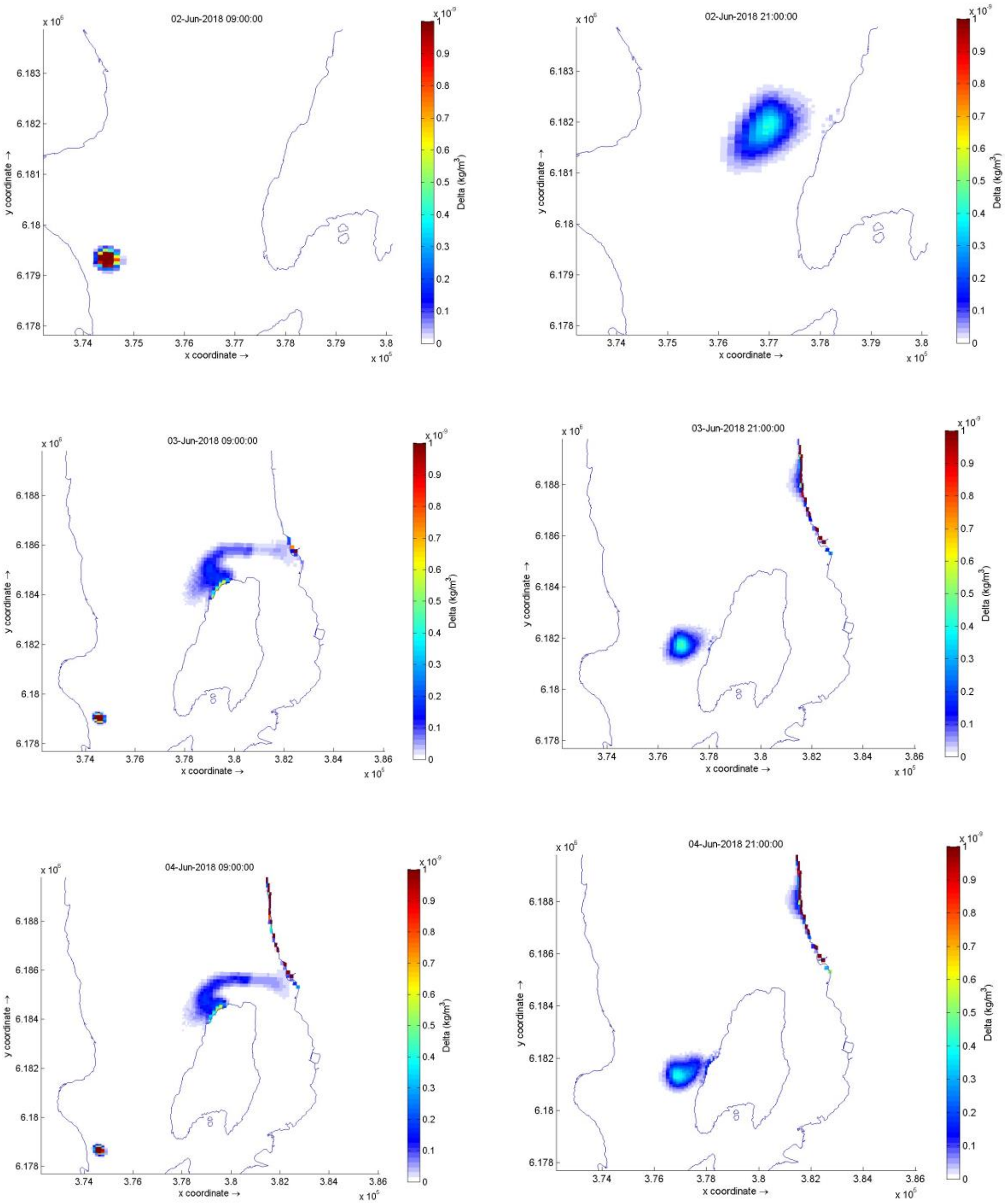


Figure 3.25 South Bute - Deltamethrin Neap discharge


02-Jun-2018 09:00:00
02-Jun-2018 21:00:00
03-Jun-2018 09:00:00
03-Jun-2018 21:00:00
04-Jun-2018 09:00:00
04-Jun-2018 21:00:00
x coordinate →
y coordinate →
Delta (kg/m3)

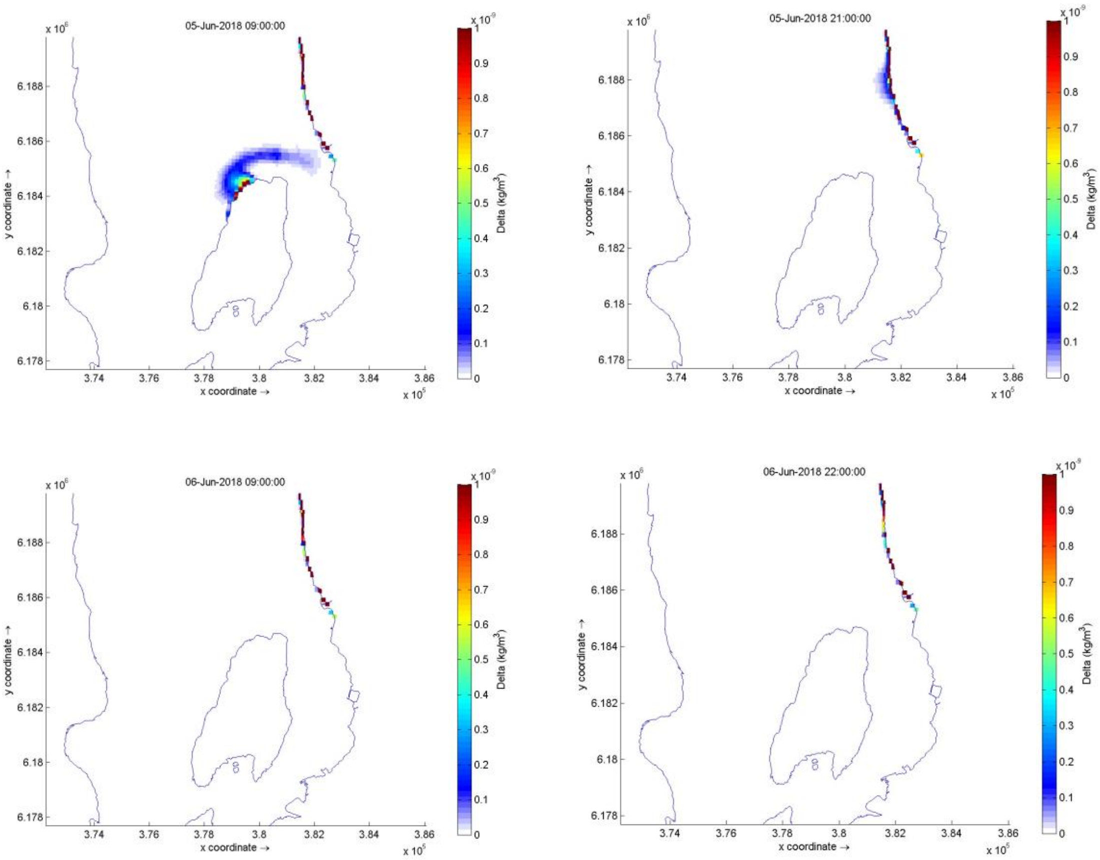


Figure 3.26 South Bute - Deltamethrin Spring discharge

4 CONCLUSIONS

A modelling study has been undertaken to investigate the dispersion of waste feed, faeces and bath medicines from the Dawnfresh aquaculture sites at Great Cumbrae, Isle of Little Cumbrae and South Bute. The key aims of the study were to investigate:

1. To what extent may any of the sites cause appreciable impacts at other sites;
2. To what extent may the sites, individually or in combination, cause appreciable impacts in the wider marine environment; and
3. To what extent are the SSSIs and PMFs situated in proximity to the proposed sites impacted by the discharges.

4.1 Greater Cumbrae

The maximum predicted deposition of feed and faeces for the 21-day (Spring-Neap-Spring) scenario was 0.8 kg/m^2. This maximum was primarily predicted to occur under and between the cages. The deposited mass reduces rapidly to levels around 0.0001 kg/m^2 under the influence of the localised currents. The year long model scenario shows a similar deposition pattern, with an increase in the predicted maximum deposition mass of approximately 25 kg/m^2. As with the short scenario the maximum mass is predicted under, and in between, the cages, with deposited mass decreasing rapidly away from the fish farm.

The chemical medicines are predicted to travel north west in a plume with a concentration of between 0.00000003 kg/m^3 and 0.00000004 kg/m^3. The chemicals are shown to accumulate on the coastline on and around Largs. The discharge of azamethiphos are predicted in the vicinity of Priority Marine Feature (PMF): Fan Mussel site in concentrations of around 0.00000002 kg/m^3 during the spring tidal release. The predicted relative highs in concentration on the coastline are primarily due to particle accumulation, with particles not being decayed or biodegraded.

It is not predicted that the discharges from the Greater Cumbrae will interact with those from the other sites or result in depositions at those sites.

4.2 Isle of Little Cumbrae

The maximum predicted deposition of feed and faeces for the 21-day (Spring-Neap-Spring) scenario was approximately 0.8 kg/m^2. This maximum was primarily predicted to occur under the cages, with slightly lower masses between the cages. The deposited mass reduces rapidly to levels around 0.0001 kg/m^2. The lower mass contours are elongated in the direction of the dominant current in the area. The year-long model shows a similar deposition pattern, with an increased in the predicted maximum deposition mass of approximately 25 kg/m^2. As with the short scenario the maximum mass is predicted under, and between, the cages, with deposited mass decreasing rapidly away from the fish farm.

The chemical medicines are predicted to travel north and north east west under the influence of the currents. The chemicals are shown to accumulate on the south and southwestern coastline of Greater Cumbrae. All the chemical discharges modelled resulted in plumes in the vicinity of Millport and Kames Bay, which is a Site of Special Scientific Interest (SSSI) due to it being the only example of a shore dominated by sand on Great Cumbrae. The sands at Kames Bay are constantly wet and even in summer never experience severe drying, resulting in a high faunal population, including large numbers of the lugworm *Arenicola* marina and the bivalve *Tellina tenuis* (SNH,2000). Therefore, there is a potential for chemicals to impact the fauna within this area. However, chemical concentrations from both sources are predicted to be very low at this location (maximums of approximately 0.000000001 kg/m^3), and therefore jointly only has the potential to produce a similarly low total concentration (a potential total maximum concentration of approximately 0.000000002 kg/m^3). Due to these very low concentrations it was not considered necessary to conduct in-combination model runs. It should also be remembered that the predicted relative highs in concentrations on the coastline are primarily due to particle accumulation, with particles not being decayed or biodegraded.

The modelling indicates that there is the potential for the bath medicines to interact with treatments form South Bute along the western coast of Great Cumbrae, if treatments conducted simultaneously. It is not predicted that the discharges from the Isle of Little Cumbrae will interact with those from Greater Cumbrae.

It is also not predicted that the discharges from the Isle of Little Cumbrae site will result in depositions at either the Greater Cumbrae or South Bute sites.

4.3 South Bute

The maximum predicted deposition of feed and faeces for the 21-day (Spring-Neap-Spring) scenario was approximately 0.8 kg/m^2. This maximum was primarily predicted to occur under the cages, with dispersion towards the coast and in the direction of the primary tides. The deposited mass reduces rapidly to levels around 0.0001 kg/m^2. The year-long model shows a similar deposition pattern, with an increased in the predicted maximum deposition mass of approximately 18 kg/m^2. As with the short scenario the maximum mass is predicted under the fish cages with deposited mass decreasing rapidly away from the fish farm. The mean mass under the cages is approximately 0.35 kg/m^2.

All the chemical discharges modelled resulted in low concentration plumes in the vicinity of the Largs Coast Section SSI. This site was designated for its natural geological features: stratigraphy: Non-marine Devonian. The site comprises of a stretch of intertidal rock exposure, it is considered important for the understanding of the structure of braided-stream deposits. Therefore, the designation is unlikely to be impacted by the presence of the bath chemicals. The predicted highs in concentration on the coastline are primarily due to particle accumulation, with particles not being resuspended or biodegraded.

The modelling indicates that there is the potential for chemical interactions along the western coast of Great Cumbrae with discharges from the Isle of Cumbrae fish farm site. As discussed in Section 4.2 the maximum resulting concentration could be up to 0.000000002 kg/m^3. It is not predicted that the discharges from the Isle of South Bute site will result in depositions at either the Greater Cumbrae or Isle of Little Cumbrae sites.

The predicted relative highs in concentrations on the coastline are primarily due to particle accumulation, with particles not being decayed or biodegraded.

5 REFERENCES

https://www.windfinder.com/windstatistics/glasgow accessed May 2020.

Xodus Group Limited, 2020. Dispersion Modelling Firth of Clyde (Delft3D). Model Calibrations and validation report. 21st January 2020. Document reference: L-300558-SO1-TECH-001.

Scottish Natural Heritage (SNH), 2000. SSSI Management Statement: Kames Bay SSSI. Document Reference Number: 825 (15/02/2000).