SAMS Research Services Ltd

NewDEPOMOD Modelling Report: Loch Long Phase 4

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Loch Long Salmon

[redacted]

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A	First internal draft for review
01	First formal issue to customer

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Contents

Acronyms & Abbreviations

ADCP	Acoustic Doppler Current Profiler
BNG	British National Grid
CFD	Computational Fluid Dynamics
EQS	Environmental Quality Standards
LLS	Loch Long Salmon
SAMS	Scottish Association for Marine Science
SBA	Simply Blue Aquaculture Ltd.
SEPA	Scottish Environment Protection Agency
SFR	Specific feeding rate (% of biomass in kg)
SRSL	SAMS Research Services Ltd.

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1 INTRODUCTION

1.1 Project Background

1.1.1 Loch Long Salmon (LLS) propose the establishment of a new Atlantic salmon (*Salmo salar*) aquaculture site in Loch Long, Scotland. The use of a new semi-enclosed cage technology, designed to recapture a large proportion of salmon aquaculture waste particles (feed and faeces), is proposed.

1.1.2 To better understand the potential environmental capacity in this location, under the Scottish Environmental Protection Agency's (SEPA) regulations (SEPA 2019a), Simply Blue Aquaculture Ltd. (SBA) tasked SAMS Research Services Ltd. (SRSL) to undertake initial NewDEPOMOD modelling exercises in March 2020 (Phase 1) and October 2020 (Phase 2).

1.1.3 LLS wished to investigate that maximum biomass that could be farmed in new semi-enclosed cages at a chosen site in Loch Long, Scotland, using NewDEPOMOD to model the total area and mean intensity of the benthic impacts, given certain levels of waste capture were achieved (Phase 3).

1.1.4 The purpose of this study and report (Phase 4) is to model the impact of the biomass identified in Phase 3, if the waste capture achieved was less than those indicated by computational fluid dynamics (CFD) model results of feed and faeces recapture efficiency.

1.1.5 The following information was requested from LLS in order to undertake the first modelling exercise:

- Site depth (m) for the area to be modelled;
- Current data (from a single ADCP current meter) – 90 days of records;
- Cage information (co-ordinate of cage centre location (per cage), cage dimensions and deployment depth);
- Feed inputs (pellet size, digestibility, and feed input mass over time, or confirmation to use the model defaults);
- Waste feed percentage;
- Faecal settling velocity;
- Required output details.

The following information was requested from SEPA:

- New waste feed capture percentage;
- New faecal waste capture percentage.

1.2 Document Purpose

1.2.1 This report summarises the NewDEPOMOD model setup undertaken and presents the key results from the model outputs.

2 MODEL SETUP

2.1 Model Preparation

2.1.1 A proposed fish farm site was identified for modelling by LLS in Loch Long, Scotland (56.154221°, -4.8105848°).

2.1.2 A standard default model domain size of 2 km^2, split into 25 m^2 grid cells, was confirmed to be appropriate by LLS, in line with SEPA's scoping run requirements.

2.1.3 A flat bathymetry was specified across the domain, in all areas associated with water, again as specified by SEPA. A depth of 51 m was identified as most representative of the proposed fish farm location, as indicated by ADCP data.

2.1.4 The shoreline for Loch Long was extracted from a data set of the UK coastline and this provided the water/land boundary. Within NewDEPOMOD, all land is given a nominal value of +10 m height.

2.1.5 SEPA defaults (SEPA 2019a) were used for all parameters, unless otherwise specified in this report.

2.1.6 The vertical dispersion coefficient for the resuspension phase was calculated using the equation provided by SEPA:

$$\sigma_{z,r} = 0.0003\, u^{-0.762}$$

where u is the mean flow speed at the bed (in m s^{-1}).

2.1.7 The wave exposure index for the site considered here was found using the SEPA specified map provided by Marine Scotland (MS 2015) and found to be 2.23. As this falls below the threshold exposure index (> 2.8) the mean intensity allowed at this location was maintained at 2000 g m^{-2} yr^{-1}.

2.2 Flowmetry Data

2.2.1 ADCP data was provided, as Excel spreadsheets, by LLS. Data was collected by Partrac Ltd, 18/06/2020-30/07/2020 at 56° 9.235', 4° 48.662'. The Nortek AWAC Signature500 (serial number: 102239) was deployed 0.6 m above the seabed, in water of approximately 51 m depth and data were recorded at intervals of 1 m between 2.1 m and 51.1 m height above sea bed. The current data was collected at time intervals of 5 minutes. The ADCP data received from Partrac Ltd. had been corrected for magnetic declination (-2.257°) and recorded as east and north components, in m s^{-1}.

2.2.2 This ADCP data was repaired (see **Appendix A**) to give complete time series, at 3 chosen depths, with 20-minute resolution.

2.2.3 The mean depth of the water is 53.3 m. The port depths on the cages are at 30 m and 42 m. At mean depth the ports are 23.3 m and 11.3 m above the seabed.

2.2.4 The closest bin to the seabed is the 3.1 m bin, so this was chosen as the deepest data set. For the remaining depths the bins nearest the ports were chosen, namely 11.1 m and 23.1 m, as middle and near-surface data respectively.

2.2.5 All velocities were recorded in m s^{-1} and provided as a velocity component to the east (u) and north (v).

2.2.6 The mean current velocity at the seabed was recorded as 3.4 cm s^{-1}.

2.2.7 SEPA require modellers to consider the percentage contribution of residual current to the total current recorded. Following analysis, it was found that the deepest data showed a contribution of 32% from residual current. As this is below the 35% threshold, no removal of residual current was carried out.

2.3 Cage Layout

2.3.1 A cage layout was provided by LLS consisting of 4 cylindrical cages, 45 m in diameter and 42 m high (see **Figure 1**). The position of these cages, provided by LLS, are given in **Table 1**, converted to British National Grid (BNG; m) for compatibility with NewDEPOMOD.

2.3.2 In order to simulate how waste leaves the cages via ports in the side and bottom of the cage, a novel cage layout was designed.

2.3.3 Each cage was modelled as 9 small cages, each representing a port in the cage through which waste leaves, see **Figure 2**.

2.3.4 In order to represent the ports on the side of each cage eight spherical cages of 2 m diameter were set at a depth of 30 m below the surface. To represent the port at the bottom of each cage a spherical cage 1.5 m diameter was set at a depth of 42 m below the surface.

2.3.5 The flow through the ports, and thus the proportion of waste from each port, is proportional to the cross-sectional area of the port. In order to simulate this 11.679% was to be present in each 'side-port' cage, and 6.568% in the 'bottom-port' cage.

2.3.6 In order to calculate the correct required footprint, and to comply with SEPA's request of a model run with all baseline assumptions including cage design, another model cage layout was created representing the cages as standard open pens (see **Figure 2**).

***Table 1** Cage positions (in BNG).*

Cage Number	Easting (m)	Northing (m)
1	225472	699129
2	225499	699205
3	225527	699280
4	225554	699355

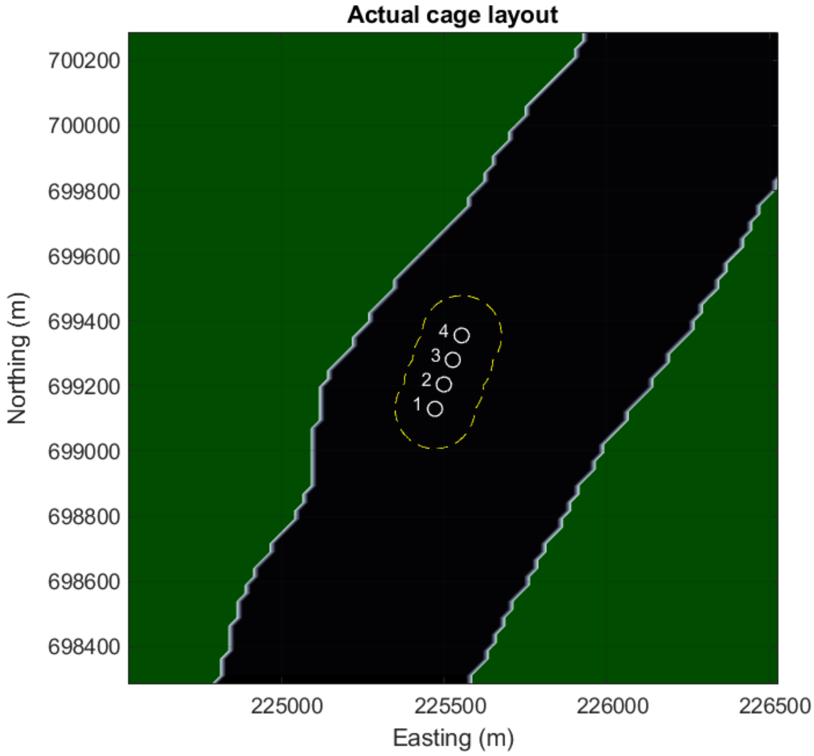

Figure 1 *Actual cage layout in Loch Long (white circles), with allowed mixing zone (yellow dashed line).*

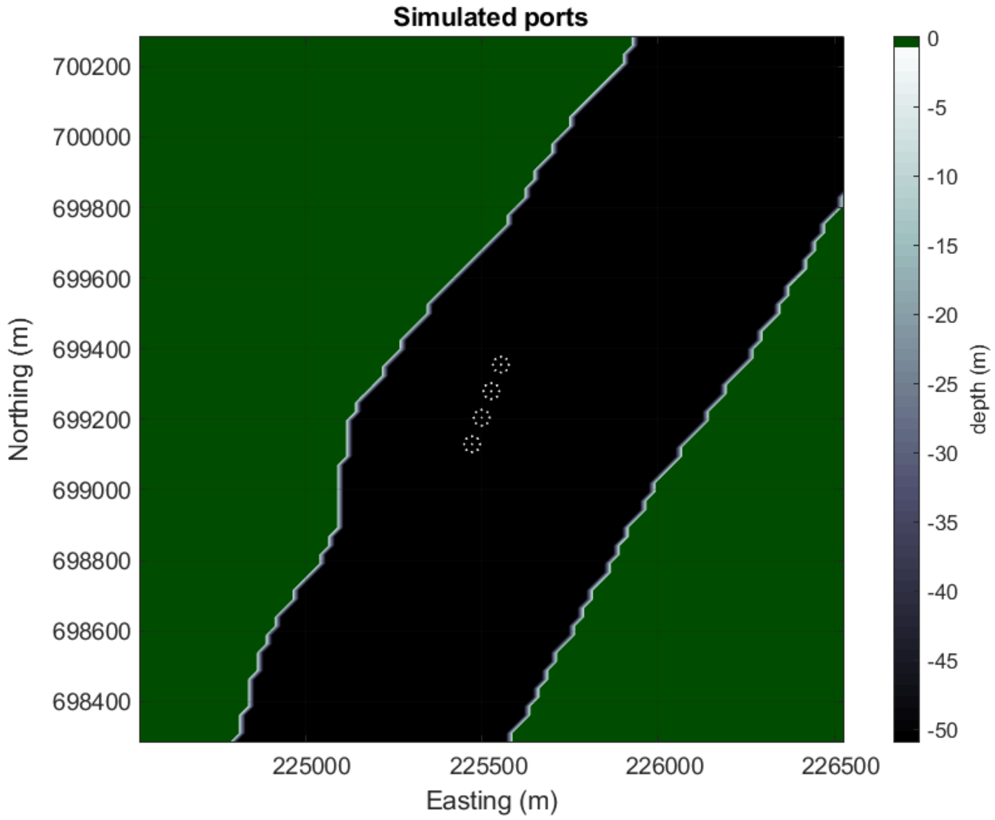

Figure 2 *Cages to simulate waste release via ports.*

2.4 Model configuration

2.4.1 SEPA defaults assume a specific feeding rate (SFR) of 0.7, that is 7 kg of feed per tonne of fish per day, a feed waste percentage of 3% and a feed absorption rate of 85%. That is, for every 7 kg of food given 6.79 kg is eaten, 0.21 kg is wasted and 1.0185 kg of faeces is produced.

2.4.2 In Phase 3 it was modelled that 100% of the feed waste is captured. Thus, we required that if 6.79 kg of feed is eaten then 0 kg is wasted, leading to an SFR of 0.679. In order that the correct amount is eaten and wasted the feed waste percentage used was 0%. It was modelled that 85% of faeces is captured. Thus, we required that if 6.79 kg of feed is eaten then 0.152775 kg of faeces is produced. To do this the feed absorption rate was increased to 97.75%.

2.4.3 SEPA requested that a new model was to be run, where it was simulated that 88.3% of the feed waste is captured. Thus, we required that if 6.79 kg of feed is eaten then 0.02457 kg is wasted, leading to an SFR of 0.681457. In order that the correct amount is eaten and wasted the feed waste percentage used was 0.36055%.

2.4.4 SEPA also requested that the faeces capture percentage was reduced to 75%. Thus, we required that if 6.79 kg of feed is eaten then 0.254625 kg of faeces is produced. To do this the feed absorption rate was changed to 96.25%.

2.5 Model runs

2.5.1 A model with the new waste capture simulated was run 20 times.

2.5.2 For each model run the aggregate surface was calculated from snapshots taken every 3 hours for the last 90 days of the run, as per SEPA guidelines (SEPA 2019b).

2.6 SEPA's EQS requirements

2.6.1 The aggregate surface for the last 90 days of the modelled time frame was compared to the two SEPA standards used to assess sites:

- Mixing-zone – the total area (m^2) with a deposited mass in excess of 250 g m^{-2} yr^{-1} should not exceed the 100 m composite mixing zone area.
- Cage-edge – the mean deposited mass within the 250 g m^{-2} yr^{-1} impacted area should not exceed 2000 g m^{-2} yr^{-1}.

3 RESULTS

3.1.1 Due to the random processes within the model an identical model run can give different footprints – an increase in the size of the 250 g m^{-2} yr^{-1} contour will lead to a decrease in the intensity within this contour, and vice versa.

3.2 Biomass achieved with LLS waste capture levels

3.2.1 Phase 3 indicated that, with waste feed capture of 100% and faeces capture of 85%, that a biomass of 3452T would consistently pass SEPA EQSs, see **Figure 3** and **Figure 4**.

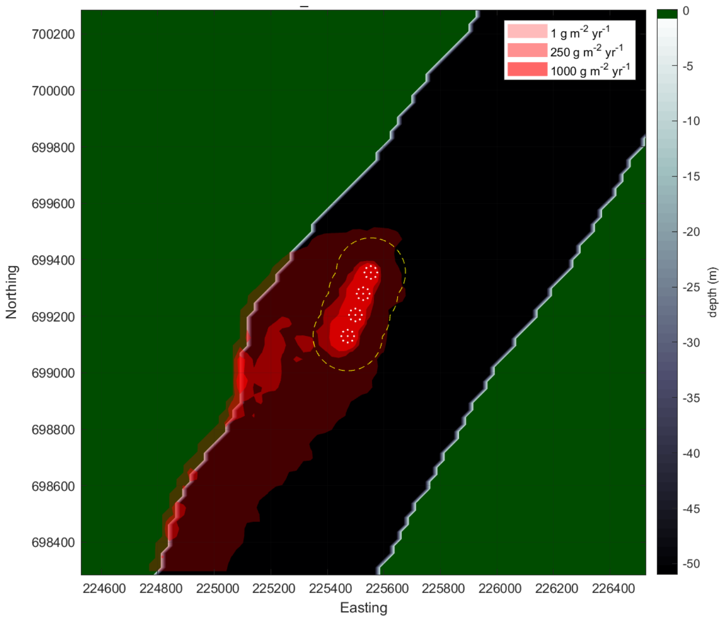

***Figure 3** Model simulating 3452T, result with smallest footprint (89.0%).*

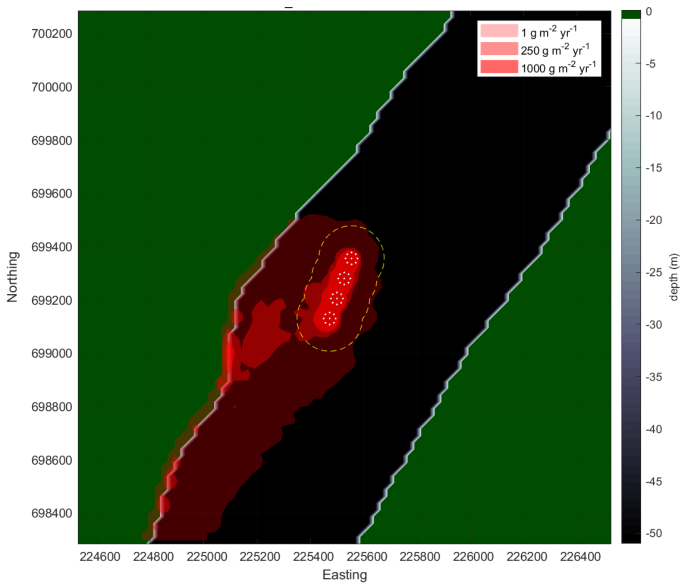

***Figure 4** Model simulating 3452T, result with largest footprint (99.5%).*

3.3 SEPA requested run with reduced waste capture

3.3.1 A model with biomass 3452T, where 88.3% of feed waste and 75% of faeces was ‘captured’ was run. The resulting footprint was compared to the allowed mixing zone calculated using a model that used cages in a standard layout (as in Phase 3). This was repeated 20 times.

3.3.2 This model was found to use 105-120% of the allowed mixing zone (see **Figure 5** and **Figure 6**), with mean impact of 1801-2080 g m^{-2} yr^{-1}.

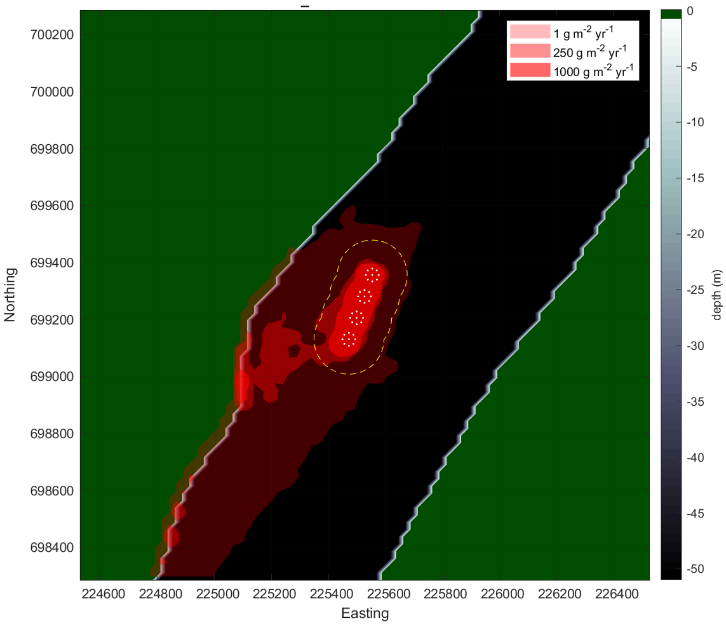

***Figure 5** Model simulating 3452T, result with smallest footprint (105%).*

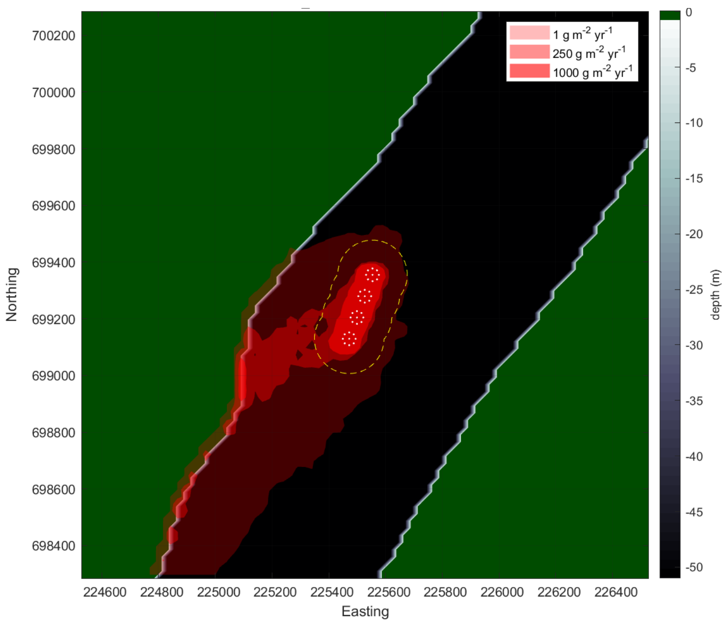

***Figure 6** Model simulating 3452T, result with largest footprint (120%).*

4 DISCUSSION AND CONCLUSIONS

4.1.1 As shown in **section 3.1**, reduction of waste feed by 100%, combined with simulated recapture of 85% of faecal waste, that is released for ports in the side and bottom of the cages, demonstrated that a 3452T salmon farm setup consistently passed SEPA's EQSs in the proposed location within Loch Long, Scotland (95% confidence).

4.1.2 As shown in **section 3.2**, reduction of waste feed by 88.3%, combined with simulated recapture of 75% of faecal waste, that is released for ports in the side and bottom of the cages, demonstrated that a 3452T salmon farm setup would not consistently pass SEPA's EQSs in the proposed location within Loch Long, Scotland. The extent EQS is exceeded by 5-20%, the intensity EQS is sometimes exceeded by up to 80 g m^{-2} yr^{-1}.

5 REFERENCES

MATLAB (2020) interp1 – 1-D data interpolation https://www.mathworks.com/help/matlab/ref/interp1.html

MS (2015) Wave Exposure Index (Wave Fetch Model). Available: http://marine.gov.scot/maps/780

SEPA (2019a) Aquaculture Modelling: Regulatory Modelling Process and Reporting Guidance for the Aquaculture Sector. Available: https://www.sepa.org.uk/media/450279/regulatory-modelling-guidance-for-the-aquaculture-sector.pdf

SEPA (2019b) HGdata_analysis_v7. Available: https://www.sepa.org.uk/regulations/water/aquaculture/pre-june-2019-guidance/aquaculture-environment/modelling/

6 APPENDIX A - ADCP DATA PREPARATION

6.1 Raw data

6.1.1 ADCP data was provided, as Excel spreadsheets, by LLS.

6.1.2 Data was collected from 13:20 18/06/2020 to 11:45 30/07/2020, see **Figure 7**.

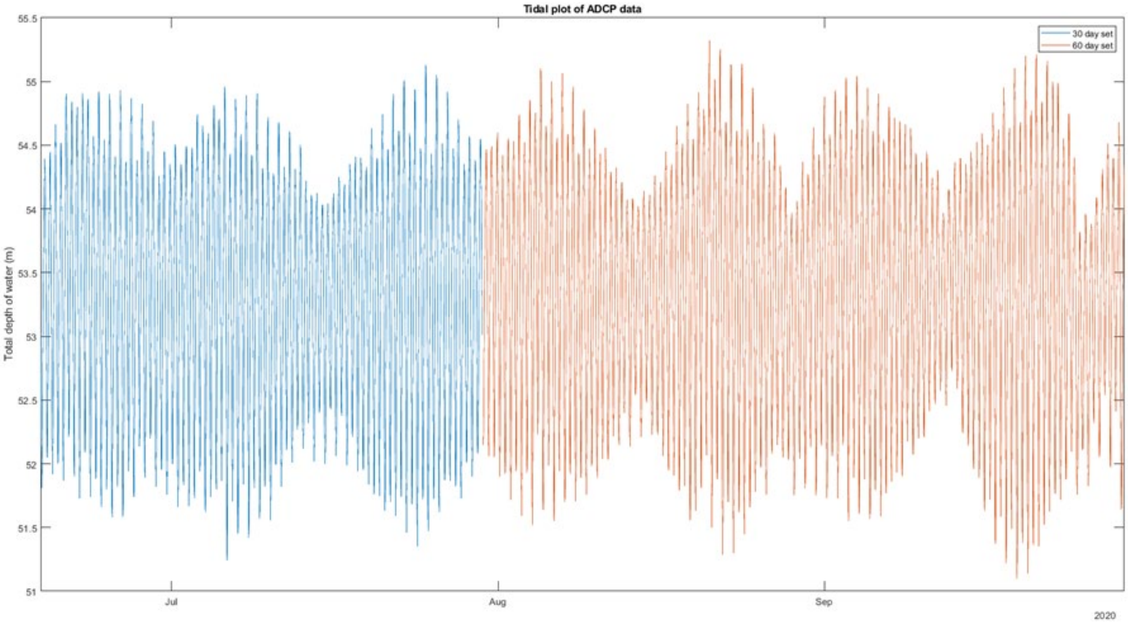

Figure 7: *Height of water; blue - first (30-day) deployment, red - second (60-day) deployment.*

6.2 Repaired data

6.2.1 Data was stitched together by removing the data collected between 08:35 and 11:45, and between 13:20 and 20:55 on 30/07/2020. This allowed data to be joined at the same point in the tidal cycle (~12 hours apart), see **Figure 8** and **Figure 9**.

6.2.2 For the magnitude and direction data a moving average was taken, using MATLAB, with a 20-minte window in order to remove some 'noise'. This also filled in some of the missing data points, see **Figure 10**.

6.2.3 The MATLAB function `interp1` (MATLAB 2020) was then used to fill in all remaining gaps.

6.3 Data checking

6.3.1 The SEPA provided HGdata_anaylsis Excel sheet (SEPA 2019a) was used to check data. As residual flow was <35% at deepest bin, the residual flow was not removed from the data.

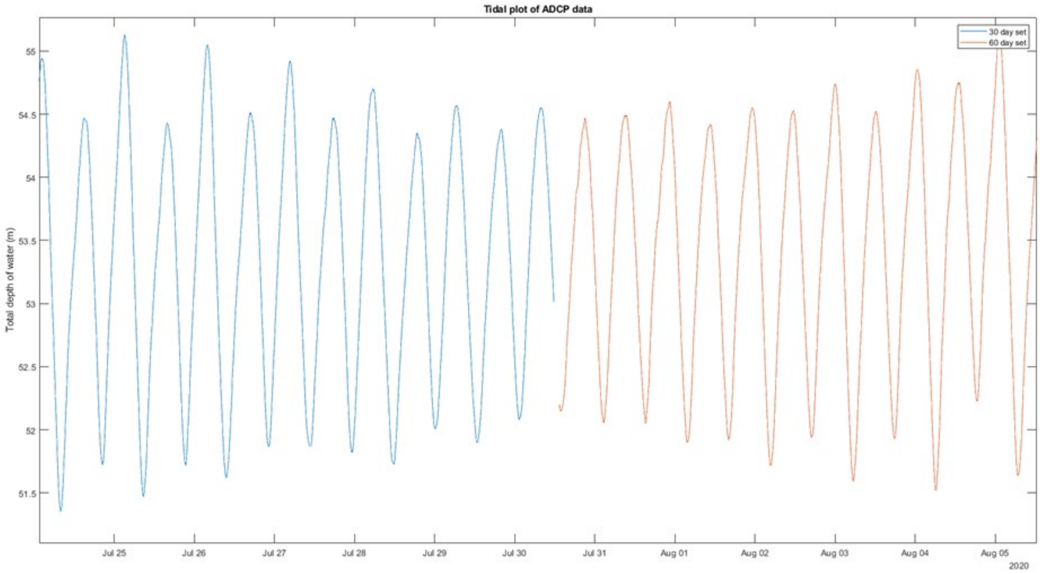

Figure 8: *Unstitched data*

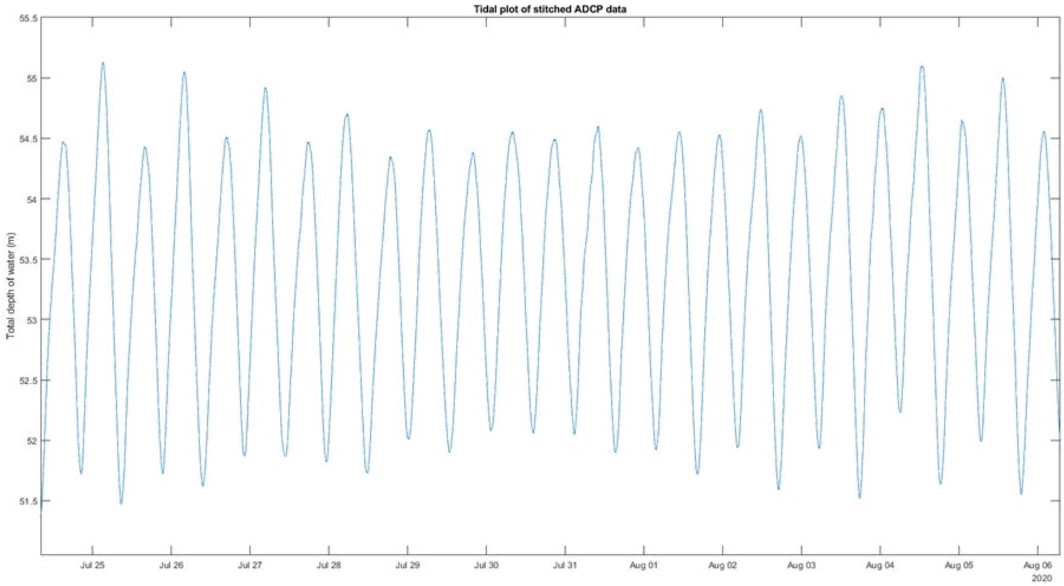

Figure 9: *Stitched data*

Data from 3.1m above sea bed

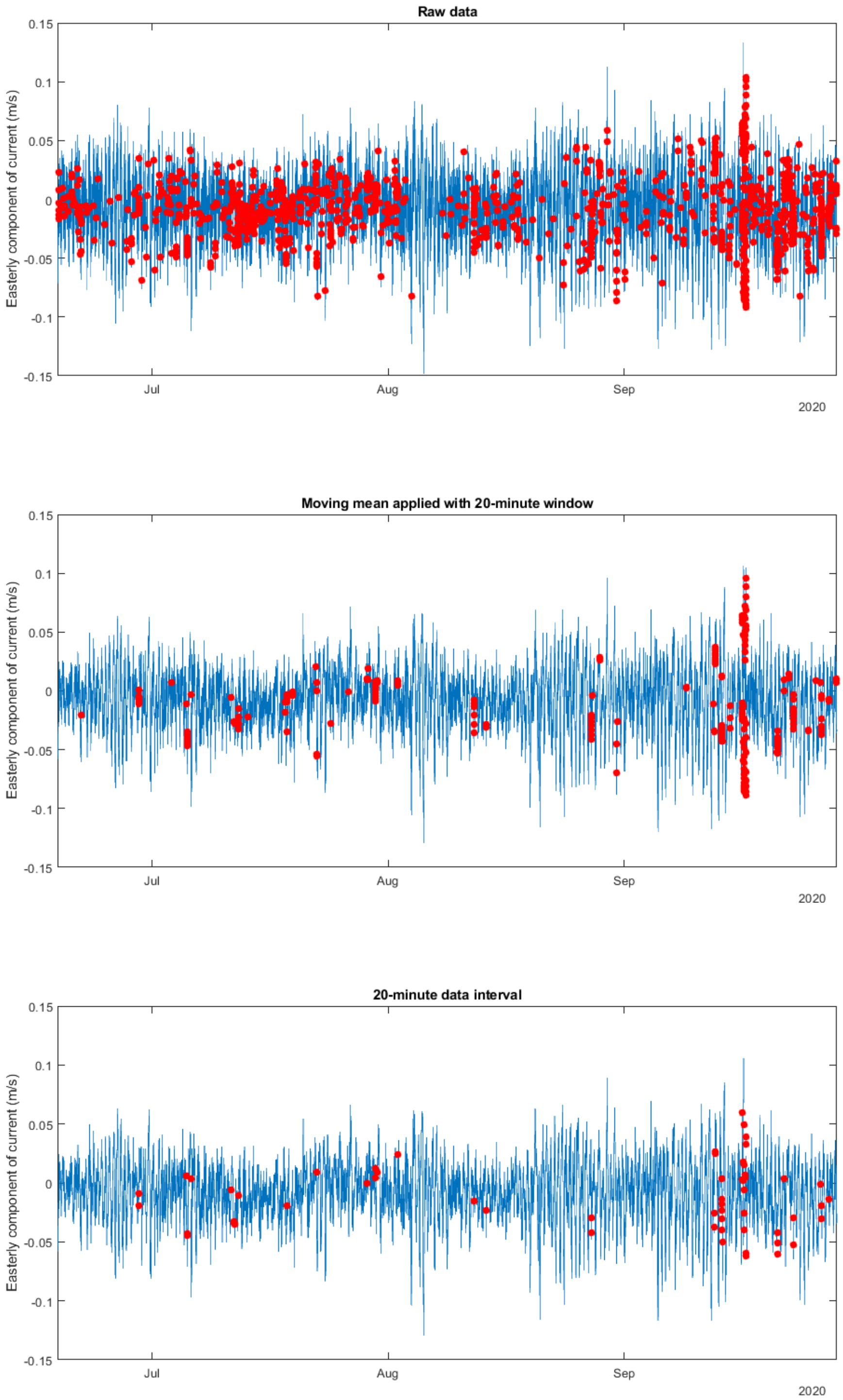

Figure 10: *Comparison of data through repairing process;*
top - raw data (blue), missing points highlighted (red),
middle – data after moving mean applied (blue), missing points highlighted (red),
bottom – 20-minute time series (blue), missing points (if interp1 function not used) highlighted (red).

7 APPENDIX B

7.1 Reduced SFR run

7.1.1 LLS requested that a model be run using all the parameters used in the model in **section 3.1,** with the exception of SFR. SFR was to be reduced to 5.3, a level calculated by LLS to be a better approximation of the actual feeding rate that will be used at peak biomass.

7.1.2 As it was to be modelled that 100% of waste feed is captured the SFR was further reduced to 5.141 to account for 3% feed not eaten.

A binary search optimisation process used, and a biomass of 4167T was found to pass consistently with 86.4-99.9% of mixing zone allowance used (see **Figure 11** and **Figure 12**), and a mean impact of 1242-1400 g m^{-2} yr^{-1}.

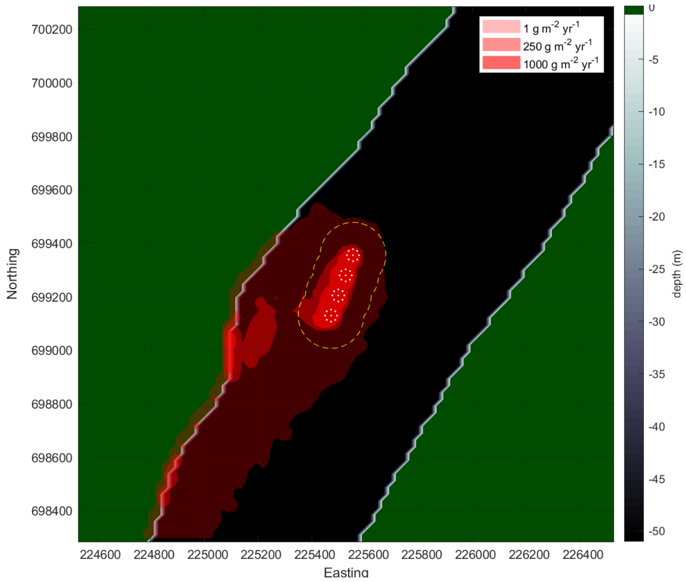

***Figure 11** Model simulating 4167T, result with smallest footprint (86.4%).*

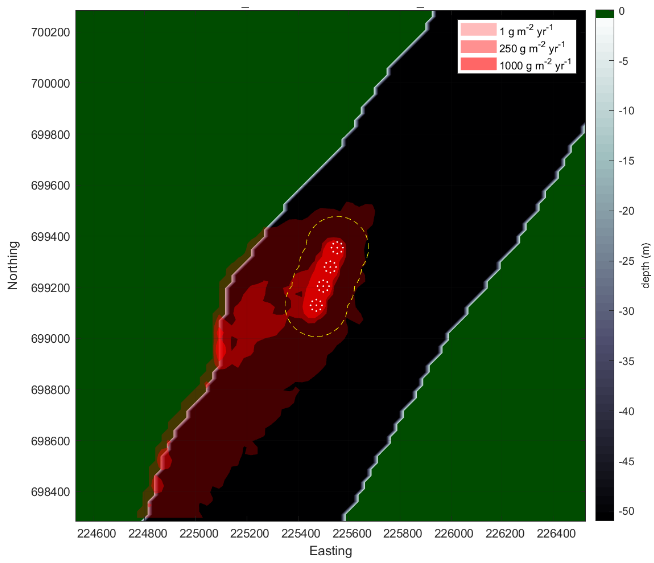

***Figure 12** Model simulating 4167T, result with largest footprint (99.9%).*