Noster, Loch Seaforth

Hydrographic Data Report: Deployment ID347

25th June to 6th September 2020

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QUALITY ASSURANCE

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

1. Introduction

Mowi Scotland Ltd is preparing an application to the Scottish Environmental Protection Agency (SEPA) for a medicine consent increase at the marine salmon farm Noster, situated in Loch Seaforth (Figure 1). Hydrographic surveys were undertaken at Noster and the neighbouring site Seaforth in 2020. Hydrographic data at both sites was gathered between 25th June 2020 – 6th September 2020. The purpose of this report is to assess the suitability of the collected hydrographic data at Noster (ID347) for input into a hydrodynamic model of the Loch Seaforth region. The data collected at Seaforth (ID348) has been assessed for suitability in a separate report.

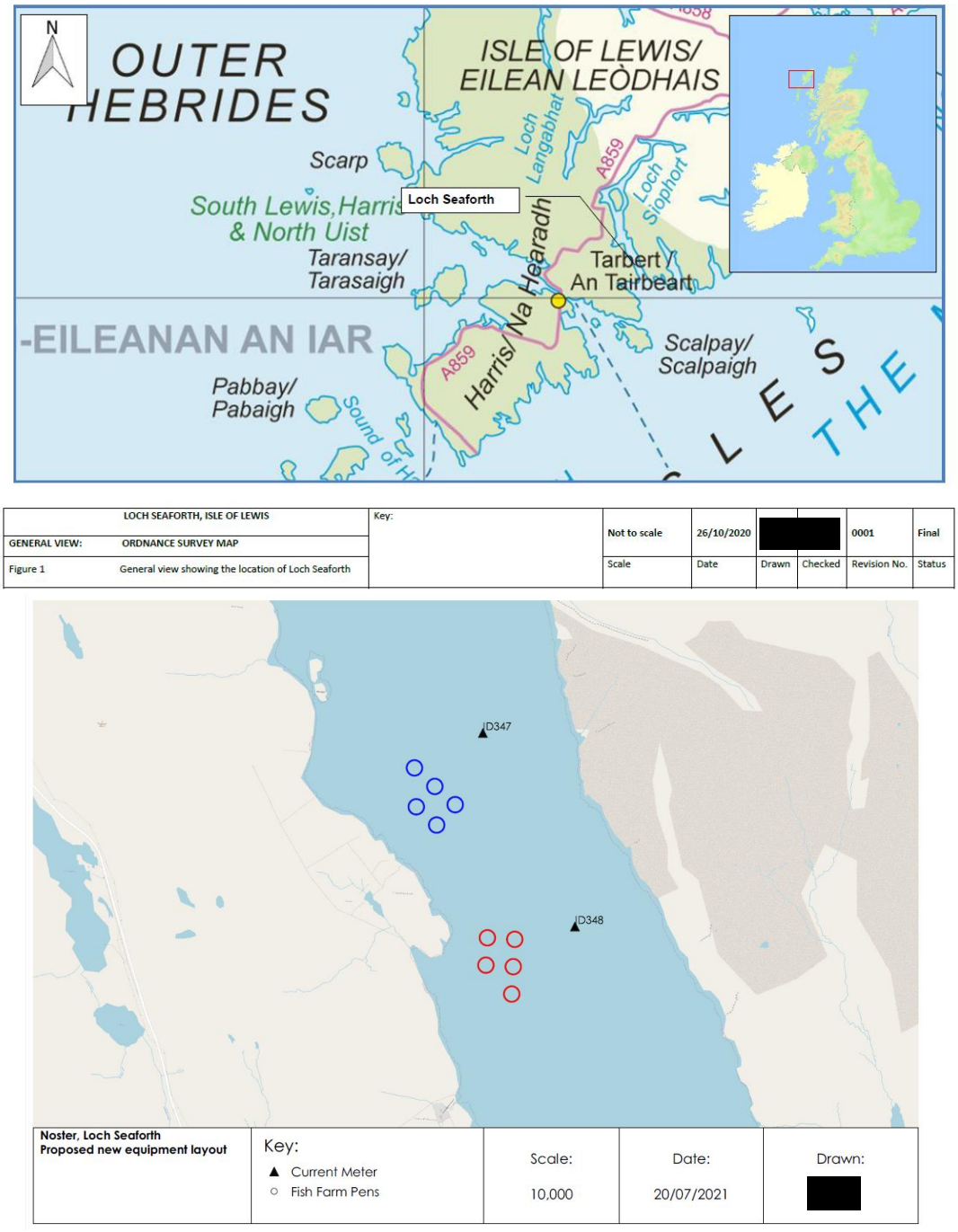


Figure 1. Site location (top) and layout (bottom) of the fish pens at Noster (blue) and Seaforth (red). The deployment locations are marked by a black triangle (▲).

2. Materials & Methods

2.1 Depth Survey

Bathymetry data for the study area was obtained from the UK Hydrographic Office which utilises a variety of source (e.g. digital bathymetry datasets, Admiralty charts, and multibeam surveys). Further information about this data source can be found at:

https://www.gov.uk/government/news/ukho-data-archiving-centre-inspire-portal-data-refresh

http://aws2.caris.com/ukho/mapViewer/map.action

A multibeam bathymetric survey was commissioned by Mowi Scotland Ltd. In December 2020 for the immediate vicinity of the pens (Annex 1). An R2Sonic 2022 multibeam system was used and the data corrected to chart datum. The UKHO and multibeam bathymetric data were combined and interpolated (Figure 2).

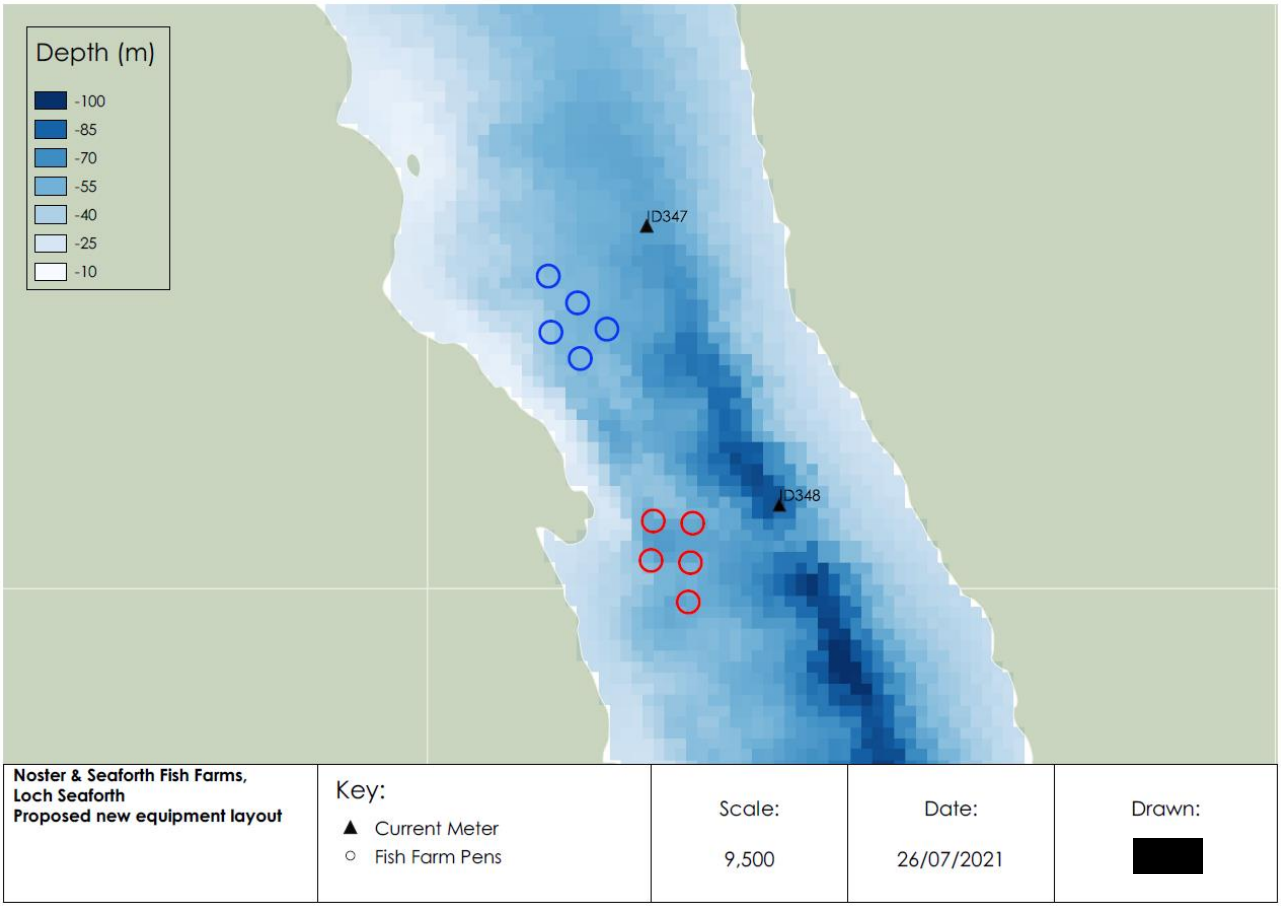


Figure 2. Interpolated bathymetry from the UK Hydrographic Office and multibeam survey. Location of the ADCP deployments (▲) are shown. Noster (blue) and Seaforth (red).

2.2 Current Data

The purpose of this hydrographic report is to assess the suitability of the collected hydrographic data for use within a hydrodynamic model for the Loch Seaforth region. The data contained in this report were recorded at the site from 25th June to 6th September 2020 (72 days and 17 hours of data;

deployment ID347). In addition to current data, bathymetry data were also collected to support this report in the form of a multibeam bathymetric survey.

Data collection using traditional ADCP deployments was challenging at the Noster and Seaforth sites. Deploying instruments close to the pens led to interference on the ADCP beams, compromising data quality. Deploying further away from the pens, in open water undisturbed by the farm pens, led to challenges with water depth which increased rapidly to the East. Since 2015, there have been 13 ADCP deployments undertaken at Noster & Seaforth (Table 1) in an attempt to get good quality data records, but most have suffered either interference or water depth issues. The deployments above (ID347 and ID348), and previous deployments not reported here, were made in water depths approaching 100m. Since data from the upper ~15% of the water column may be affected by acoustic reflection off the sea surface, deploying in these deeper depths led to no data being collected in the top 20m. In the associated Marine Modelling report, this lack of data in the surface 20m is compensated by using tracks of dye releases to calibrate the surface currents of the hydrodynamic model.

The Sentinel V100 (Wide) ADCP (Table 2), within its mooring frame, was positioned at 57.93678N, -6.68017W (123097E 903757N), which was approximately 294m from the nearest shoreline and approximately 280m from the centre of the cage group (Figure 1). The transducer head was 70 cm from the base of the mooring frame. The mean depth (derived from the pressure sensor) at the Sentinel V100 ADCP position was 70.74 m.

No initial soundings were taken before the deployment of the ADCP due to the hand held sounder used being unable to read depths of > 60m. The cell size was set to 2.0 m to accommodate the deep depths found in Loch Seaforth. The number of cells was set to 50. Data was automatically written and stored to the internal memory within the Sentinel V100 ADCP main body and then downloaded to computer after completion of the deployment period via WiFi.

Table 1: ADCP deployments at Noster and Seaforth from 2015 onwards

ID	Site	Deployment Date	Depth (m)	Deployment Length (days)	Useful days	Latitude	Longitude
50	Seaforth	23/07/2015	70	21	21	57 55.765N	006 40.608W
51	Seaforth	23/07/2015	70	21	0	57 55.727N	006 40.608W
52	Noster	23/07/2015	65	22	0	57 56.057N	006 40.905W
121	Seaforth	07/10/2016	66	72	0	57 55.760N	006 40.628W
122	Noster	07/10/2016	59	80	0	57 56.100N	006 40.926W
138	Seaforth	18/01/2017	62	20	0	57 55.760N	006 40.628W
139	Noster	18/01/2017	56	20	0	57 56.100N	006 40.926W
313	Seaforth	20/11/2019	83	91	0	57 55.852N	006 40.490W
314	Noster	20/11/2019	66	91	0	57 56.172N	006 40.857W
325	Seaforth	19/02/2020	104	72	17	57 55.769N	006 40.376W
326	Noster	19/02/2020	76	76	41	57 56.143N	006 40.709W
347	Noster	25/06/2020	70	73	73	57 56.207N	006 40.810W
348	Seaforth	25/06/2020	109	73	73	57 55.876N	006 40.461W

2.3 Magnetic Variation

No magnetic variation correction was made to the Sentinel V100 ADCP during deployment, this was undertaken to the data after the instrument was recovered and data downloaded. The magnetic variation used was -3.66; this was determined using the World Magnetic Model, produced jointly with the US National Oceanographic and Atmospheric Administration's National Geophysical Data center. Further details can be found at http://www.geomag.bgs.ac.uk/navigation.html

2.4 Data Processing

Upon retrieval of the Sentinel V100 ADCP current meter, all data was downloaded to a computer for analysis. The raw data file was opened in Teledyne's "Velocity" software and Matlab. Deployment diagnostic data (beam intensity, correlation, pitch and roll) were analysed to confirm that the deployment was successful with the instrument orientated upright. The heading data were also examined to identify any movement of the Sentinel V100 ADCP mooring frame during the deployment.

The diagnostic data suggested that velocities from the first 24 bins were valid (Figure 3). Calculations were undertaken to identify the cells to be used for surface and middle currents. Surface data was taken at an average depth (derived from the pressure sensor) of 17.63 m (cell 24), and cage-bottom data at 33.63 m (cell 16). Surface and middle cell heights above the seabed were 50.68 m and 34.68 m respectively. The bottom cell (cell 1) was at a depth of 63.63 m and 4.68 m above the seabed.

Table 2: Sentinel V100 ADCP Specifications.

Depth Cell Size[1]		**V20 (1000kHz)**		**V50 (500kHz)**		**V100 (300kHz)**	
	Depth Cell Size[1]	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow	Range (m)[2,3] Wide/Narrow	Std Dev (cm/s)[3,4] Wide/Narrow
	0.25m	18.0/22.6	19.2/36.5				
	0.3m	19.3/24.0	11.1/20.8				
	0.5m	20.2/24.9	7.1/13.4	44.1/57.6	19.2/36.5		
	1.0m	22.1/26.9	3.6/6.7	50.5/64.6	7.1/13.5	94.5/120.6	10.9/20.6
	2.0m	24.5/29.4	1.7/3.2	56.0/70.6	3.6/6.7	103.5/130.4	5.5/10.3
	4.0m	26.9/32.0	0.8/1.6	63.1/78.2	1.7/3.2	114.6/142.3	2.7/5.2
	6.0m			67.4/82.8	1.1/2.1	121.7/151.5	1.8/3.3
Communications and Recording	Wireless	802.11b/g/n					
	Internal memory	One 16GB Micro SD Card included					
Profile Parameters	Velocity accuracy	V20/V50: 0.3% of the water velocity relative to the ADCP ±0.3cm/s V100: 0.5% of the water velocity relative to the ADCP ±0.5cm/s					
	Velocity resolution	0.1cm/s					
	Velocity range	±5m/s (default); ±20m/s (maximum)					
	Ping rate	Up to 4Hz					
Echo Intensity Profile	Vertical resolution	Depth cell size					
	Dynamic range	80dB					
	Precision	±1.5dB					
Transducer and Hardware	Beam angle	25°					
	Configuration	4-beam, convex; 5th beam vertical					
	Depth rating	200m					
	Materials	Transducer, housing, and end cap: plastic Connector: metal shell					
Standard Sensors	Temperature (mounted on transducer)	Range -5° to 45°C, precision ±0.4°C, resolution 0.1°					
	Compass (magneto-inductive sensor)	Accuracy 2° RMS, resolution 0.1°, max. dip angle 85°					
	Tilt (MEMS accelerometers)	Pitch range ±90°, roll range ±180°, accuracy 2° RMS, precision 0.05° RMS, resolution 0.1°					
	Pressure sensor (mounted on transducer)	Range 300m, accuracy 0.1%FS					
Power	External DC input	12–20VDC					
	Internal battery voltage	18VDC new					
	Battery capacity; over-the-counter @0°C	100 watt hours (typical)					
	Battery pack @5°C	510 watt hours					
Software	Teledyne RDI's new software included	ReadyV—Pre-deployment (testing, planning, and data recovery)[5] Velocity—Post-processing (data handling, display, and export)[6]					
Environmental	Standard depth rating	200m					
	Operating temperature	-5° to 45°C					
	Storage temperature (without batteries)	-30° to 60°C					
	Weight in air	7.5kg – 16.0kg					
	Weight in water	1.6kg – 6.0kg					
Available Options	External battery case • AC/DC power converter • 5th beam (at time of order only) • Waves processing • Straight or right-angle metal shell connector						
Dimensions	Special configuration drawing available upon request						

1 User's choice of depth cell not limited to the typical values specified.
2 Ranges specified are typical at temperature of 5°C and salinity of 35psu; longer ranges are possible.
3 User selects the bandwidth mode; wide = 25% or narrow = 6%.
4 Standard deviations (Std Dev) are typical values for single ping data
5 Resident in ADCP accessed via a web browser.
6 Windows™ based software program.

Specifications subject to change without

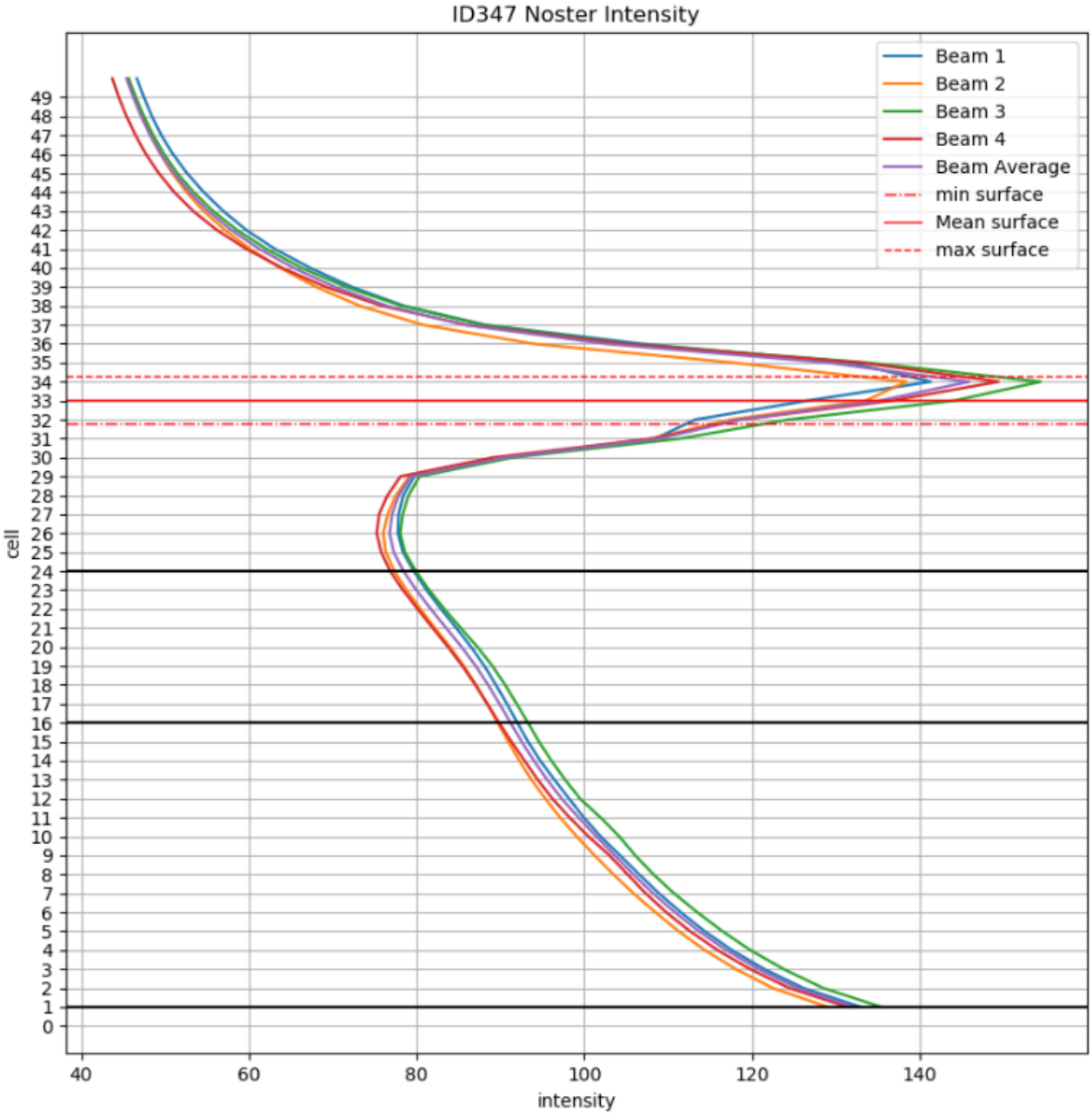


Figure 3. Mean intensity of the ADCP signal for the ID328 dataset plotted by bin number

The distance to the near bed cell is automatically calculated based on the configuration settings of the instrument, using the following equation:

$$Distance\ to\ centre\ of\ first\ cell = (0.5 * cell\ size) + blanking\ distance + (Transmit + \frac{lag}{2}) \quad (1)$$

This is the distance from the transducer head to the centre of the first cell which equated to 3.98 m. For this deployment, and following the manufacturers recommendations to obtain the best quality data, the blanking distance was set to 1.6m, the cell size to 2.0m, the lag to 0.42m and the transmit distance was 1.17m. These values, added to the height of the transducer head, give the actual height of the centre of the first cell above the seabed of 4.68m.

Standard deviation has been assessed throughout the deployment to identify accurate and reliable data for near bed, middle (net depth) and surface cells using the following equation:

$$Cell\ StdDev = Instrument\ StdDev * \sqrt{\frac{\%\ valid\ pings}{100} * 300} \quad (2)$$

The Instrument Standard Deviation (StdDev) in Equation 2 is determined using the deployment settings when the meter is programmed, examples of the StdDev values for different configurations are shown in Table 2. This deployment had a cell size of 2m which equates to an Instrument StdDev of 5.5 cm/s.

The Percentage of valid pings used to calculate Cell StdDev is derived using "Percentage Good" data which allows us to relate the StdDev to the actual data gathered. The percent good data is available for 1, 2, 3 and 4 beams which represent the following:

- Percent good 1 = % of good data computed from 3 Beams
- Percent good 2 = % of bad data due to more than 2 Beams
- Percent good 3 = % of bad data due to error velocity exceeded
- Percent good 4 = % of good data computed from 4 Beams

The method described has been used to calculate the Standard deviation throughout the deployment for the surface, middle and bottom cells; the average StdDev values for the surface, middle and bottom was 0.63cm/s, 0.63cm/s and 0.63cm/s respectively which are all within the SEPA criteria of 2cm/s.

2.5 Meteorological Data

The collection of meteorological data is no longer required to support the assessment process and consequently has not been undertaken. The current data used were collected using mulitple deployments and over a longer period and thus provides a more realistic representation of site conditions than short deployments, thus allowing an assessment of the influence of meterological conditions.

3. Results and Discussion

A summary of the current data is shown in Figure 4 to Figure **10** and in Table 3 to Table 5. Over the period analysed for this report, the near-surface, middle and bottom cells had current speed averages of 5.87 cm/s, 5.86 cm/s and 7.9 cm/s respectively. This gave an overall average of 6.54 cm/s. The orientation of the tidal velocities was northwest to southeast.

Residual currents at the surface and mid-depth were toward the north-west (351°G and 342°G, Figure 7. And Figure 8. respectively); near the seabed, the residual flows during the deployment period were southeast ward (159°G, Figure 9). The magnitude of the residual currents for the surface, middle and bottom cells were moderate, with mean values of 0.059 m/s, 0.059 m/s and 0.079 m/s respectively.

4. Hydrographic Data Summary Sheets

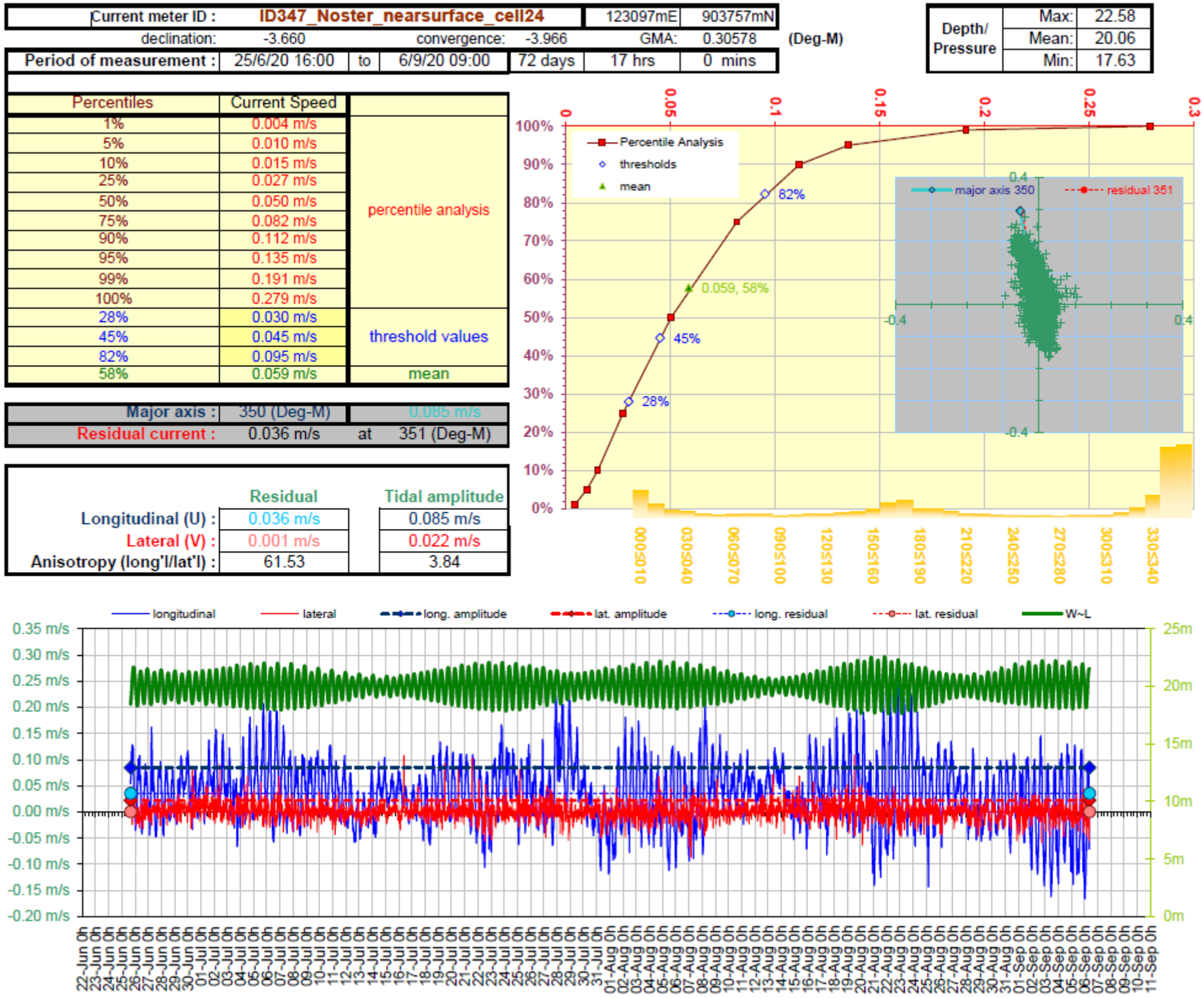


Figure 4. Current Data Summary Sheet for the surface current cell 24, 50.68 m from seabed, 25th June to 6th September 2020 inclusive (ID347).

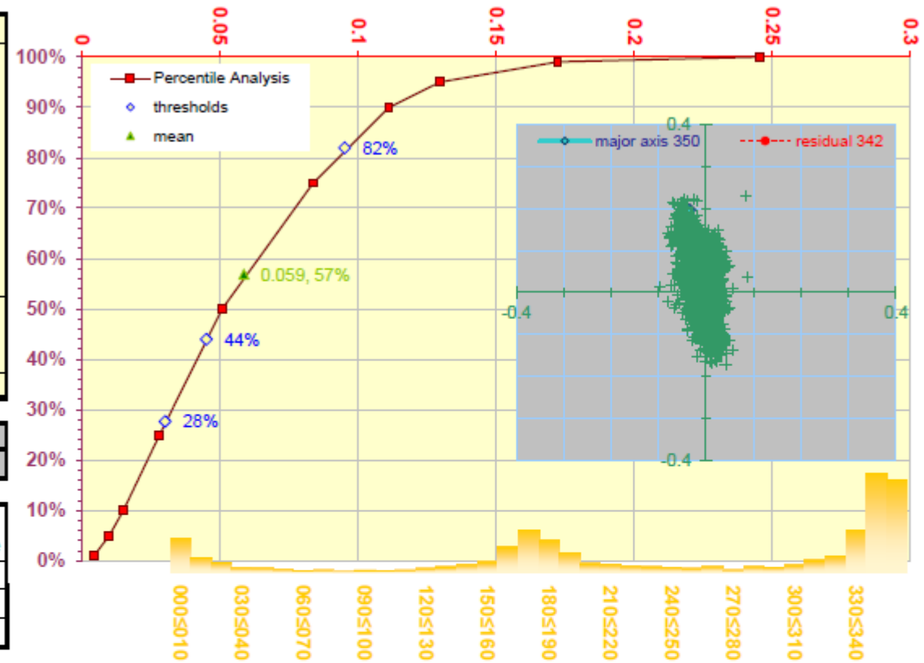
Current meter ID :	ID347_Noster_cagebottom_cell16			123097mE	903757mN
declination:	-3.660		convergence: -3.966	GMA:	0.30578 (Deg-M)
Period of measurement :	25/6/20 16:00	to	6/9/20 09:00	72 days	17 hrs	0 mins

Depth/ Pressure		
	Max:	38.58
	Mean:	36.06
	Min:	33.63

Percentiles	Current Speed	
1%	0.004 m/s	percentile analysis
5%	0.010 m/s	
10%	0.015 m/s	
25%	0.028 m/s	
50%	0.051 m/s	
75%	0.084 m/s	
90%	0.111 m/s	
95%	0.130 m/s	
99%	0.172 m/s	
100%	0.246 m/s	
28%	0.030 m/s	threshold values
44%	0.045 m/s	
82%	0.095 m/s	
57%	0.059 m/s	mean

Major axis :	350 (Deg-M)		0.090 m/s
Residual current :	0.026 m/s	at	342 (Deg-M)

	Residual	Tidal amplitude
Longitudinal (U) :	0.025 m/s	0.090 m/s
Lateral (V) :	-0.004 m/s	0.022 m/s
Anisotropy (long'l/lat'l) :	6.85	4.06



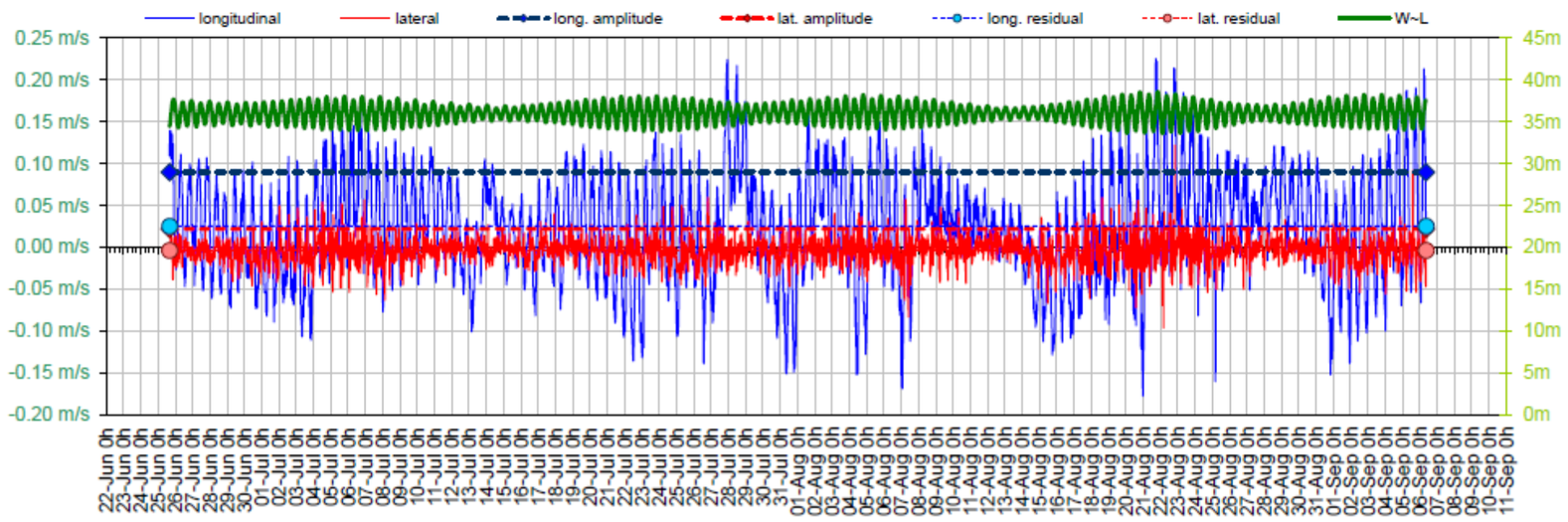


Figure 5. Current Data Summary Sheet for the cage bottom current cell 16, 34.68 m from seabed, 25th June to 6th September 2020 inclusive (ID347).

Current meter ID :	ID347_Noster_nearbottom_cell1			123097mE	903757mN
declination:	-3.660	convergence:	-3.966	GMA:	0.30578 (Deg-M)

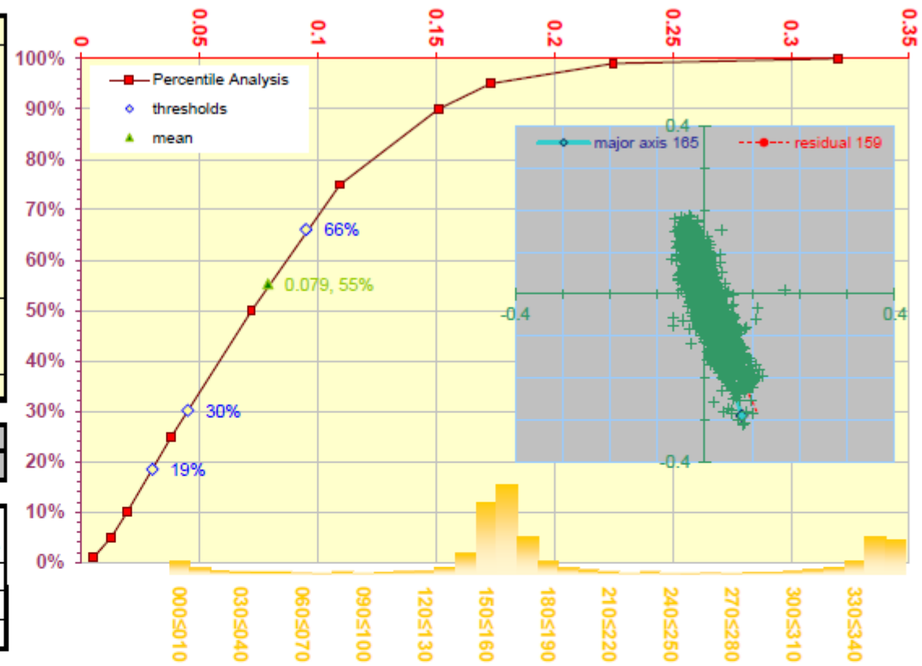
Period of measurement :	25/6/20 16:00	to	6/9/20 09:00	72 days	17 hrs	0 mins

Depth/ Pressure	Max:	68.58
	Mean:	66.06
	Min:	63.63

Percentiles	Current Speed	
1%	0.005 m/s	percentile analysis
5%	0.013 m/s	
10%	0.019 m/s	
25%	0.038 m/s	
50%	0.072 m/s	
75%	0.109 m/s	
90%	0.151 m/s	
95%	0.173 m/s	
99%	0.225 m/s	
100%	0.320 m/s	
19%	0.030 m/s	threshold values
30%	0.045 m/s	
66%	0.095 m/s	
55%	0.079 m/s	mean

Major axis :	165 (Deg-M)	0.121 m/s
Residual current :	0.036 m/s	at 159 (Deg-M)

	Residual	Tidal amplitude
Longitudinal (U) :	0.036 m/s	0.121 m/s
Lateral (V) :	-0.004 m/s	0.021 m/s
Anisotropy (long'l/lat'l) :	9.09	5.65



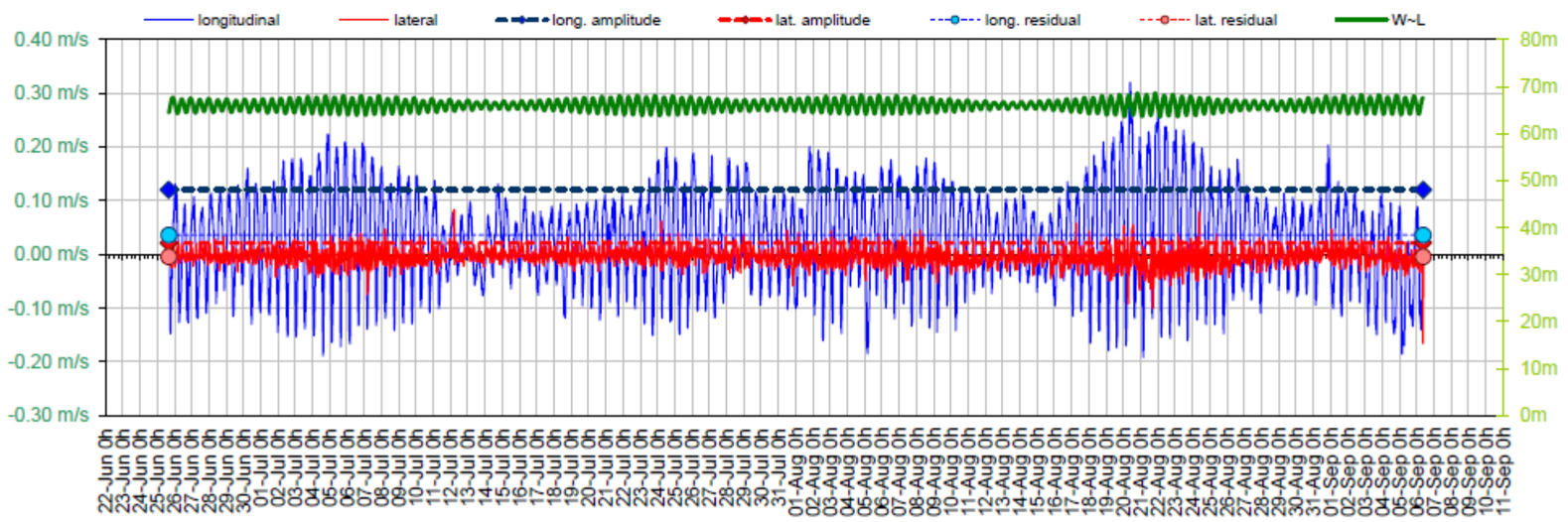


Figure 6. Current Data Summary Sheet for the near bottom current cell 1, 4.68m from seabed, 25th June to 6th September 2020 inclusive (ID347).

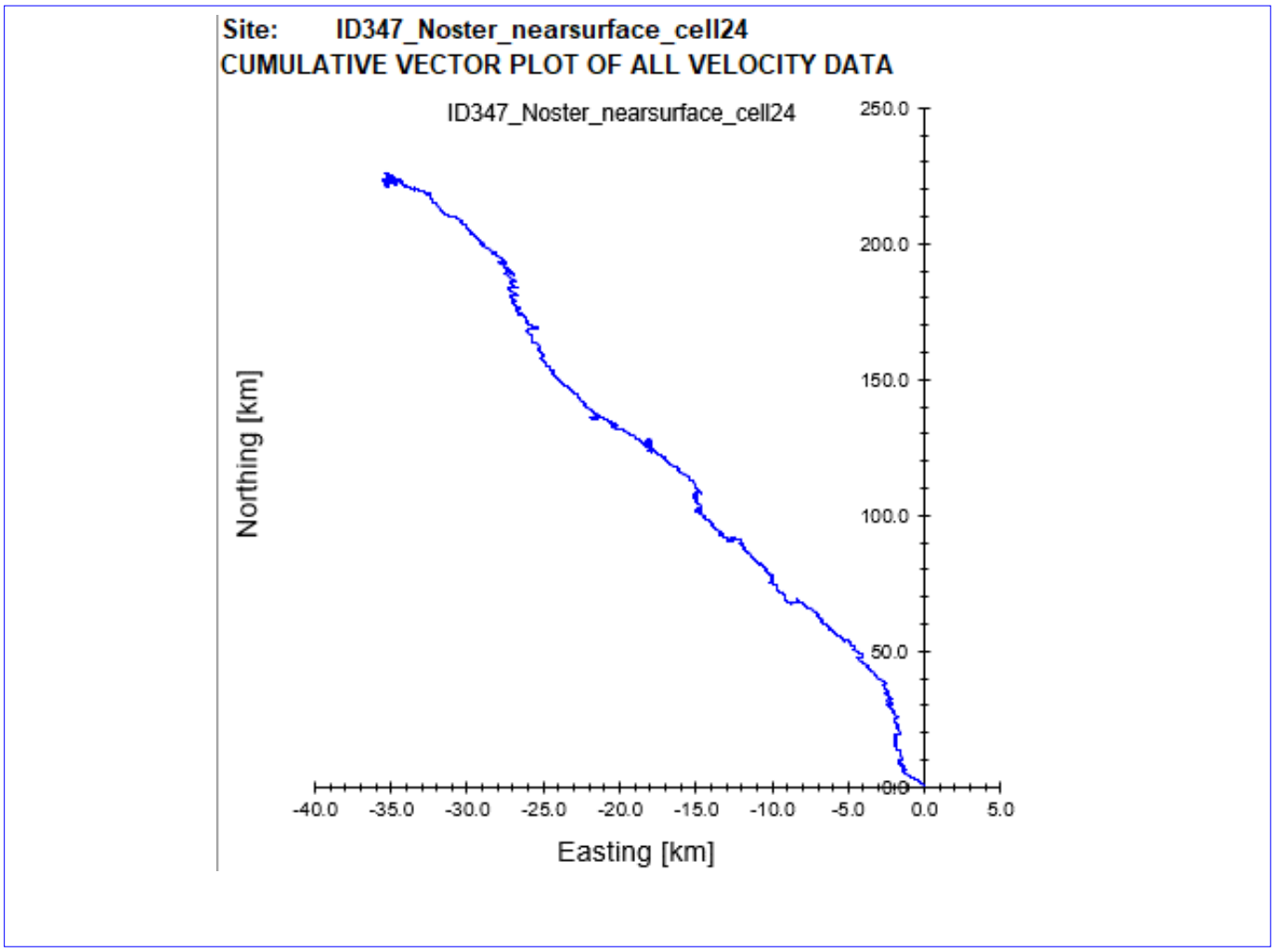


Figure 7. Cumulative Vector Plot of all velocity data from near surface cell for ID347.

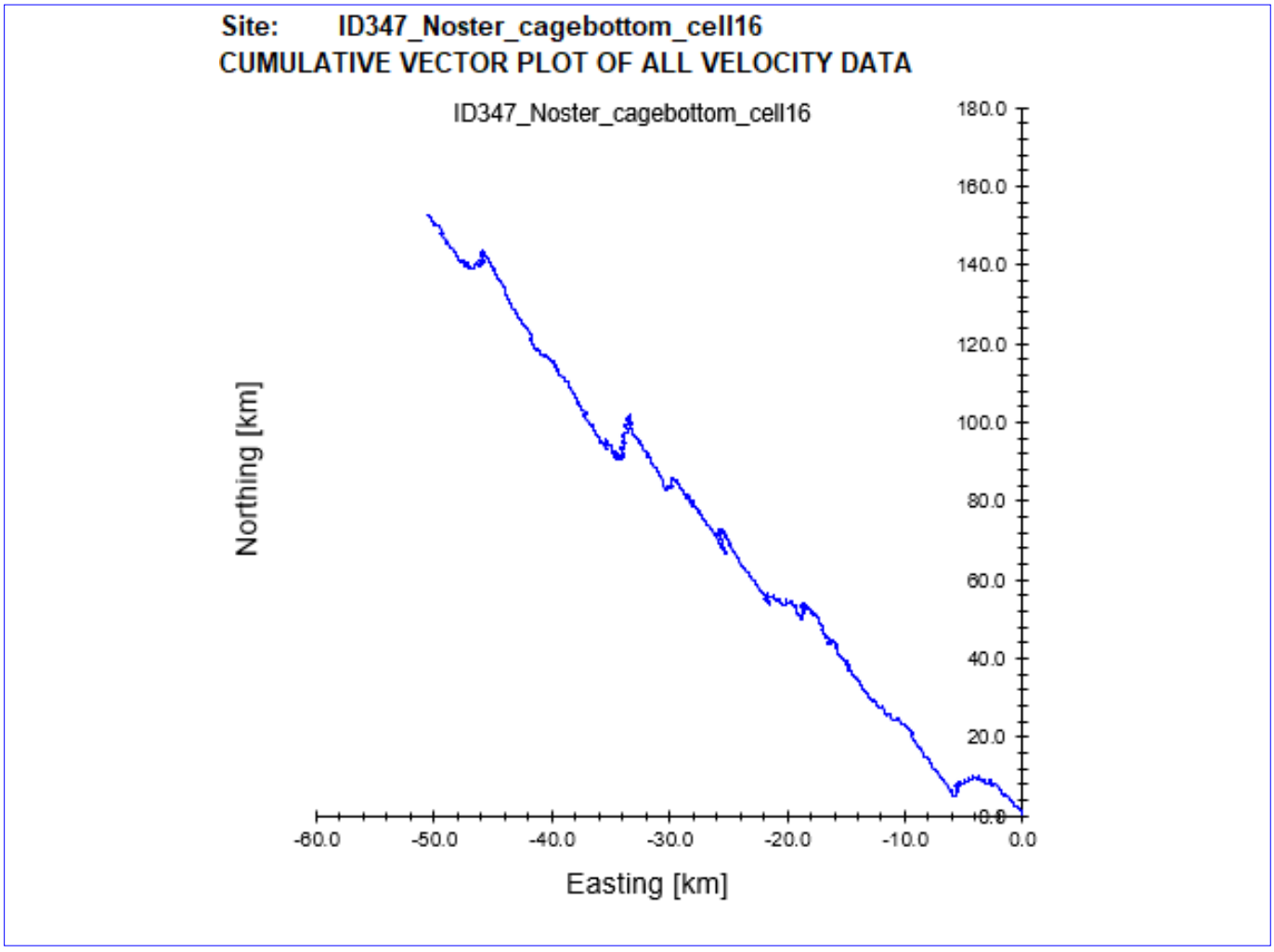


Figure 8. Cumulative Vector Plot of all velocity data from cage bottom cell for ID347.

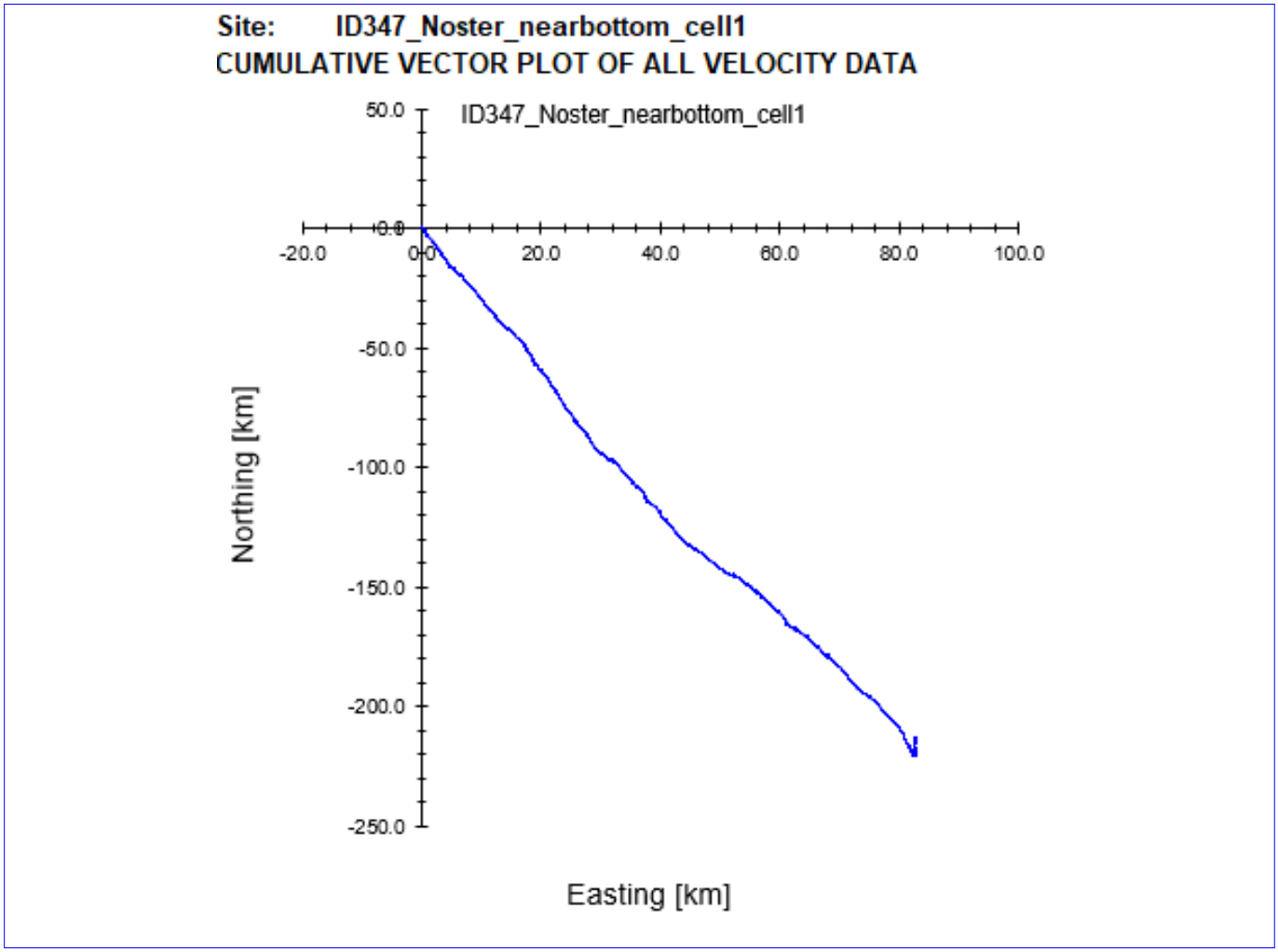


Figure 9. Cumulative Vector Plot of all velocity data from near bottom cell for ID347.

5. Summary of Current Data – ID347

Site Name: Noster

Data start date: 25/06/2020 **Data end date:** 06/09/2020

Water Depth (mean derived from pressure sensor): 70.74 m

Table 3. Summary of current meter deployment

	Cell	Depth Below Surface (m)	Distance from Seabed (m)	Mean current speed (cm/s)
Near surface	24	17.63	50.68	5.87
Cage bottom	16	33.63	34.68	5.86
Near bed	1	63.63	4.68	7.9
			Average current speed:	6.54

Table 4. Ranked percentiles for current speed at all three depths

Cell	Ranked Percentile (%) for mean speed	≤3cm/s (%)	≥4.5cm/s (%)	≥9.5cm/s (%)
Near surface	58	28	55	18
Cage bottom	57	28	56	18
Near bed	55	19	70	34

Cell	Major Axis (Deg-G)
Near surface	350
Cage Bottom	350
Near bed	165

Table 5. Mean and residual currents

	Mean Speed (m/s)	Residual Speed (m/s)	Residual Parallel (m/s)	Residual Normal (m/s)	Tidal Amplitude Parallel (m/s)	Tidal Amplitude Normal (m/s)
Near Surface	0.059	0.036	0.036	0.001	0.085	0.022
Cage Bottom	0.059	0.026	0.025	-0.004	0.090	0.022
Near Bed	0.079	0.036	0.036	-0.004	0.121	0.121

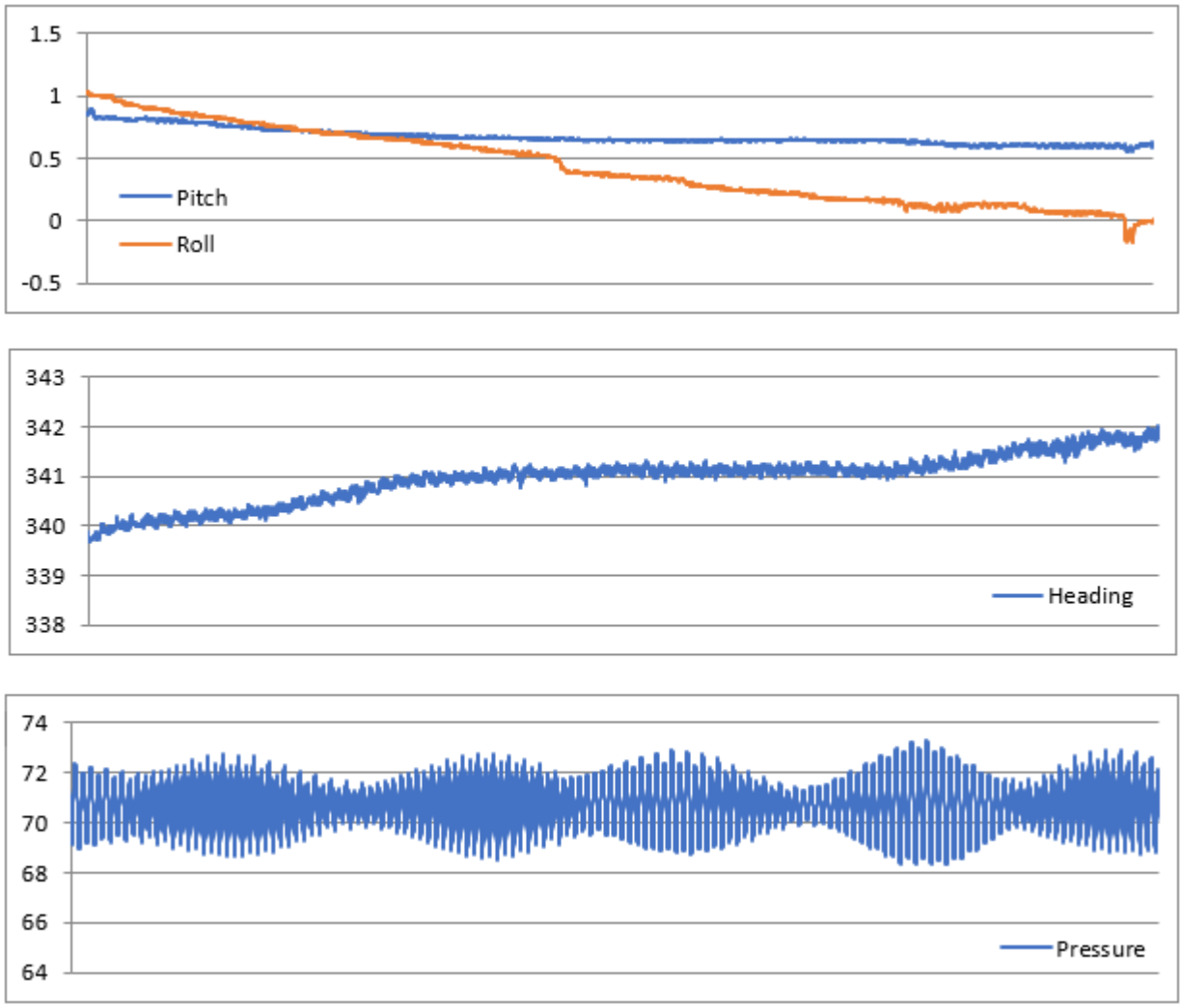


Figure 10. Summary of pitch, roll, heading & pressure data from deployment ID347.

6. Conclusion

MOWI has collected and analysed current and bathymetric data for the proposed new equipment at Noster salmon farm. The analysed current data for the 72 days and 17 hours period are believed to be reliable and representative of the farm location. The local-area multibeam bathymetric data gained from surveying the proposed site, combined with the wider-area UKHO bathymetry data, provided a coherent bathymetric dataset for the site.

Appendix 1. Survey Equipment Deployment Log

Sentinel V (ADCP) Current Meter Record Log

Location: Noster, Loch Seaforth

Nearest tidal port: Stornoway Time zone: UTC

Deployment Details

	Time		Date
Meter switched on.	16:00:00		25/06/2020
Meter deployed.	16:00:00		25/06/2020
Meter lifted.	09:00:00		06/09/2020
Meter switched off.	09:00:00		06/09/2020
Period used for this report.	25/06/2020 16:00:00	to	06/09/2020 09:00:00

ADCP serial number: 24614

Meter position: 57.93678N, -6.68017W

123097E 903757N

Minimum water depth: 68.31m (67.61m measured by ADCP + 0.7m *)

Water depth (Chart Datum): 67.11m (minimum water depth – 1.2 m tide timetable)

Mean water depth: 70.74m (measured by ADCP + 0.7m *)

Depth of meter from surface: 68.28m (below mean low water spring (68.98m))

Depth of meter from seabed: * Meter on seabed 0.7m to transducer head

Sounding at deployment: Depth sounder unable to record >60m

ADCP meter settings:

Reference	Transducer
Bin size	2.0m
Dist to 1st bin	4.68
Number of bins	50
Frequency	307 kHz
Recording interval	20 min
No. pings per ensemble	300
Magnetic correction	0
Ensemble	1200
Standard Deviation	0.63cm/sec
Time/Ping	2 seconds