



19th March 2024

Modelling Data Collection Report

Quanterness

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Summary

A hydrographic survey was carried out by Cooke Aquaculture Scotland for a proposed variation to an existing marine caged fish farm site, Quanterness, located in the bay of Kirkwall on the Orkney mainland.

An acoustic profiling current meter was deployed at the proposed site for 102 days, from the 2nd of September 2021 to the 15th December 2021, from which a 90-day subset was selected. The meter recorded 102 days of usable data with no significant errors. The data presented is considered representative of the period sampled and suitable for determining the impacts due to solid and solute wastes arising from farm operations.

Sensor records confirm that there were minor disturbances around the mooring during the deployment that resulted in pitch and roll changes, however these were all <5 degrees. These variations are well within the normal operational range and do not cause any deterioration in the data.

1. Quality assurance statement

Cooke Aquaculture Scotland confirms the collection, analysis and reporting of all information is attested by a suitably qualified person and is completed to a consistently high standard, to ensure the data presented is representative of the conditions at the site. This is in line with the current SEPA standards outlined in the 2019 Regulatory Guidance documents (SEPAa & SEPAb).

2. Site description

Quanterness is an existing, consented site (CAR/L/1001931) operated by Cooke Aquaculture Scotland. The site is located in the Bay of Kirkwall, on the coastline of Orkney mainland (Figure 1). Currently, the site has a maximum consented biomass of 600 tonnes across 8 pens of circumference 90m and net depth 8m arranged in 2 x 4 pattern on 50m mooring grids. This provides a stocking density of 14.55kg/m³ during peak biomass.

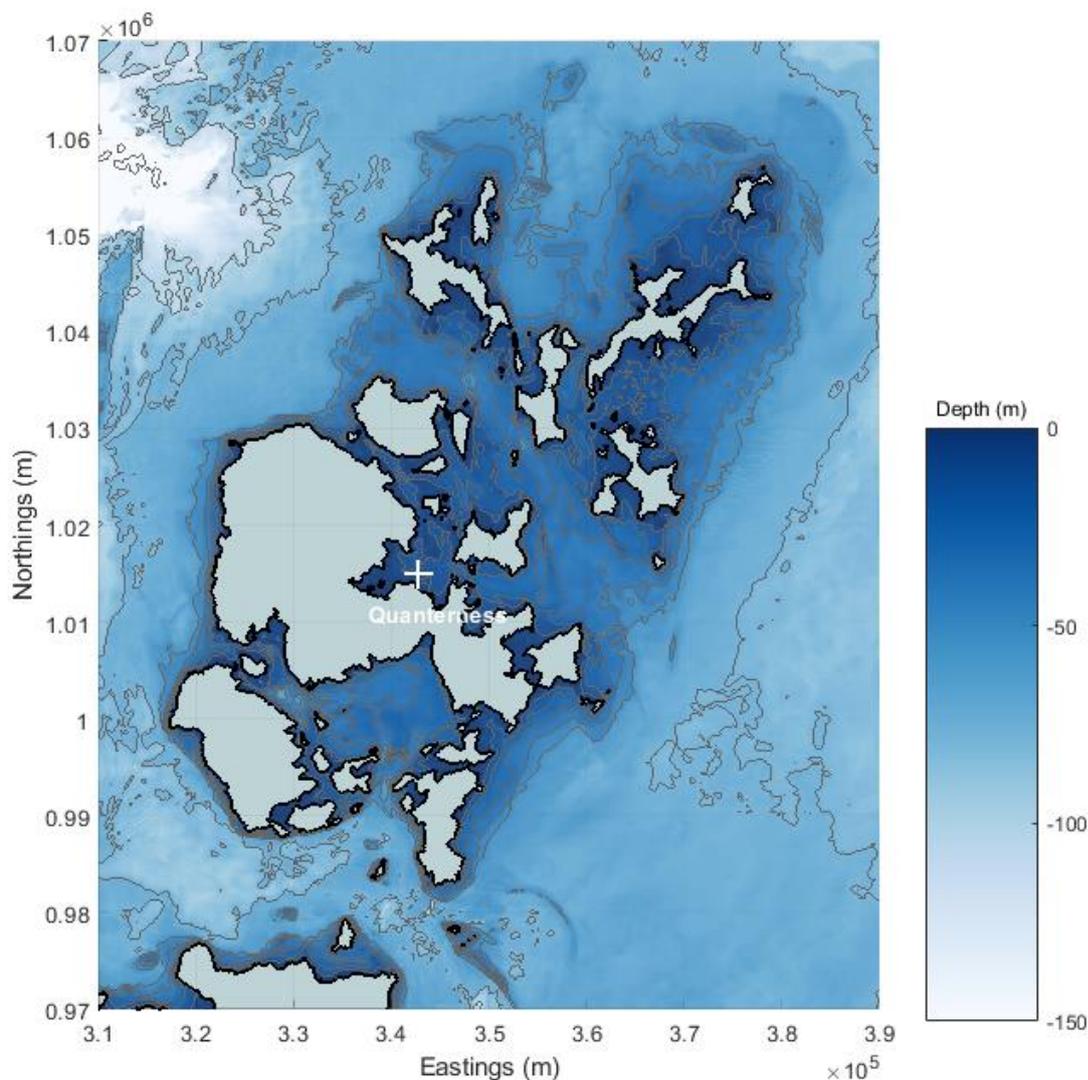


Figure 1. Site location (white cross) and bathymetry with depth contours at 20m intervals.

The proposed development at Quanterness expands and repositions the existing site. This proposed site consists of 14 120m circumference, 8m deep pens arranged in 70m mooring grids. The expanded site is relocated 1,341m to the NW of the existing site in a deeper, more exposed waters as well as moving further away from Hatson pier. Benthic modelling using the SEPA default NewDepomod model revealed a maximum biomass of 1,925 tonnes at the newly proposed site was compliant with all EQS rules. This provides a stocking density of 14.99kg/m³ during peak biomass. Further information on the existing and proposed site infrastructure and pen layout is presented in Table 1.

Table 1 – Site infrastructure and pen layout.

	Quanterness (Existing)	Quanterness (Proposed)
Consent number	CAR/L/1001931	
Company	Cooke Aquaculture Scotland	Cooke Aquaculture Scotland
Receiving water	Bay of Kirkwall	Bay of Kirkwall
Site centre (OSGB36)	343533 E, 1013813 N	342733 E, 1014921 N
Current meter location (OSGB36)/year of deployment	343476 E, 1013814 N/2009	342733 E, 1014921N /2021
Distance to shore (km)	0.74	0.92
Average water depth (m)	-11.1	-15.73
Maximum biomass (t)	600	1925
Total number of pens	8	14
Number of pen groups	1	1
Formation	2 x 4	2 x 7
Pen group orientation (°)	8	0
Pen circumference (m)	90	120
Mooring grid (m)	50	70

3. Scope of report

3.1 Required data

Benthic sampling will be carried out to measure Infaunal Quality Index (IQI). This can then be used to assess the environmental performance of the site along with the calibration of future modelling work.

3.2 Existing data

Hydrographic data collected in 2021 has been assessed with a 90-day subset of data being selected for analysis. UK Hydrographic Office data (UKHO, 2021) was used to create the bathymetry around the site for future modelling work.

4. Methods

4.1 Hydrographic measurements

A hydrographic survey was undertaken for the proposed site. A Nortek Signature 500kHz (serial no. 101510) Acoustic Doppler Current Profiler (ADCP) was deployed between 15th September 2021 and the 5th January 2022 at 342733E, 1014921N, ~100m for the proposed site centre. This deployment provided ~112 days of useable data.

The sensor was mounted in a weighted mooring frame with a gimble and deployed in a specific location to avoid interference from existing site infrastructure or other potential risks to data validity. The transducer head is located 0.62m from the seabed. More detail on sensor configuration is given in table 2.

Table 2. Sensor configuration for the deployment.

Signature 500 – Serial no. 102441	
Site name	Quanterness
Measurement interval (minutes)	10 (600 secs)
Average interval (minutes)	5 (300 secs)
Number pings	480
Orientation	Up looking
Salinity (ppt)	35
Cell size (m)	1
Number cells	21
Coordinate system	BEAM
Blanking distance (m)	0.5
Vertical precision (cm/s)	0.27
Measurement load (%)	40

4.2 Hydrographic data: 02/09/2021 – 15/12/2021

The data recorded by the ADCP allows the calculation of flow profiles every 600 seconds. These results were logged on an internal memory card. The specific parameters logged by the ADCP, alongside their accuracy, resolution and range are outlined in table 3.

Table 3. ADCP data collection parameters and specifications.

	Accuracy	Resolution	Range
Speed	0.3% of 0.3cm/s	0.1cm/s	2.5m/s
Compass	2° tilt <30°	0.01°	-
Tilt	0.2° tilt <30°	0.01°	-
Pressure	0.1% full scale	-	0-100m
Heading	± 3° (dynamic)	0.01°	360° all axes
Pitch/roll	± 2° (dynamic)	0.01°	± 90° (p) ± 180° (r)
Temperature	0.1°	0.01°	-4-+40°

4.3 Data processing

Raw data recorded on the Signature500 was downloaded as binary data files using the Nortek AS Signature Deployment programme. The Deployment programme was then used to convert and export the binary files into a .mat file format, suitable for reading into MATLAB.

The averaged current data was assessed in Signature Viewer, a post processing software programme, to ensure the data was of high quality. The data was then imported into MATLAB, where in-house scripts performed quality control (QC) and post processing. These QC checks included assessment of:

- Heading, Pitch and Roll (°) – checking the meter has an upward orientation and limited frame movement during the survey using a threshold exceedance method with a range of $\pm 20^\circ$.
- Pressure record (m) – comparing the depth recorded by the meter with the bathymetry for the area. Clear spring and neap tides observed in the pressure record with no unusual increases or decreases in the record.
- Amplitude (Signal Strength - dB) – should be decreasing with distance from the sensor. Be aware of any unusual spikes, large increases or the amplitude becoming constant. Dramatic increases in amplitude will be seen when the signal meets a boundary such as the surface or seabed. Minimum amplitude threshold = 30dB.
- Correlation (%) – quality measure of velocity data, a decrease in correlation means a decrease in data accuracy. Minimum correlation threshold = 50% of the maximum correlation.

Any data out with the QC parameters were removed and replaced with NaN values. These were later interpolated to repair any missing values. Only depth cells with less than 5% missing/repaired data are considered for use in further modelling work.

5. Site infrastructure

The proposed site infrastructure at Quanterness consists of 14 (2x7) 120m circumference, 8m deep pens arranged on a 70m mooring grid. This pen layout, alongside the ADCP deployment location, is illustrated in figure 2.

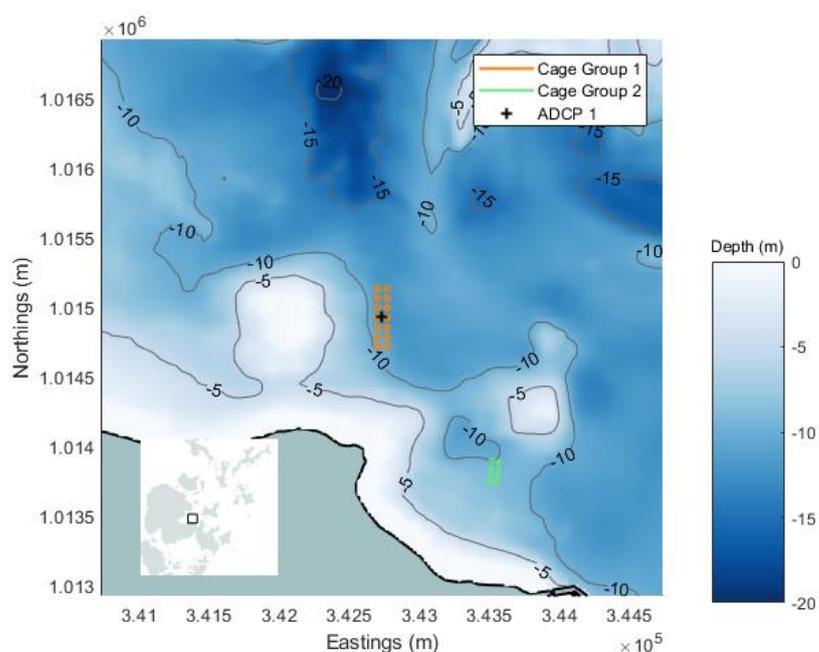


Figure 2. Existing pen layout (green), proposed pen layout (orange) and ADCP location (black +) at Quanterness.

The modification to the existing Quanterness site, moves the farm further away from Hatston Pier and out into deeper water with increased flushing. This creates more dispersive conditions at the proposed site, compared to the existing, likely resulting in a more sustainable operation.

6. Bathymetry

The bathymetry around the site is shown in figure 2, this uses data collected for UKHO (UKHO, 2021). The site is located close to two shoaling reefs, to the west, the reef breaks the surface forming skerries, and the southeast, the reef sits just below the surface. The proposed site places the farm in more exposed waters where the seabed gradually gets deep into Kirkwall Bay in the northeast. Average water depth at the site centre are 15m, with a similar depths around the site.

7. Flow data

The profiling device was deployed on the seabed at (OSGB 1936) 342733 E, 1014921N (figure 2) for 103 days from the 2nd of September 2021 to 15th December 2021, with usable data recorded across the full deployment. During the recording period a mean water depth of 15.7m was recorded. The quality control process identified 0 pitch and roll exceedances and 0 water column errors (0%) within the full data set.

To comply with SEPA’s NewDepomod regulatory modelling guidelines, a total of 90 days of current meter data must be used. Applying a timestep of 600 seconds, this provides a total number of 12,960 timesteps forming 90 days of data. The length of the usable data set exceeds the 90-day minimum by ~13 days. The 90-day period selected was from 02/10/2021 15:40 to 01/12/2021 15:40. Within this 90-day subset, no pitch and roll exceedances or water column errors were identified.

The sensor heading, pitch and roll for the 90-day period are shown in figure 3. There are several minor disturbances in the sensor variables occurring on the 09/10/21, 09/11/21 and 21/11/21. However, at these times the variations in pitch, roll and heading suggests the ADCP gimble remained stable with only small fluctuations recorded that were well within the operating constraints advised by SEPA. These measurements suggest it is unlikely that any significant frame movements occurred.

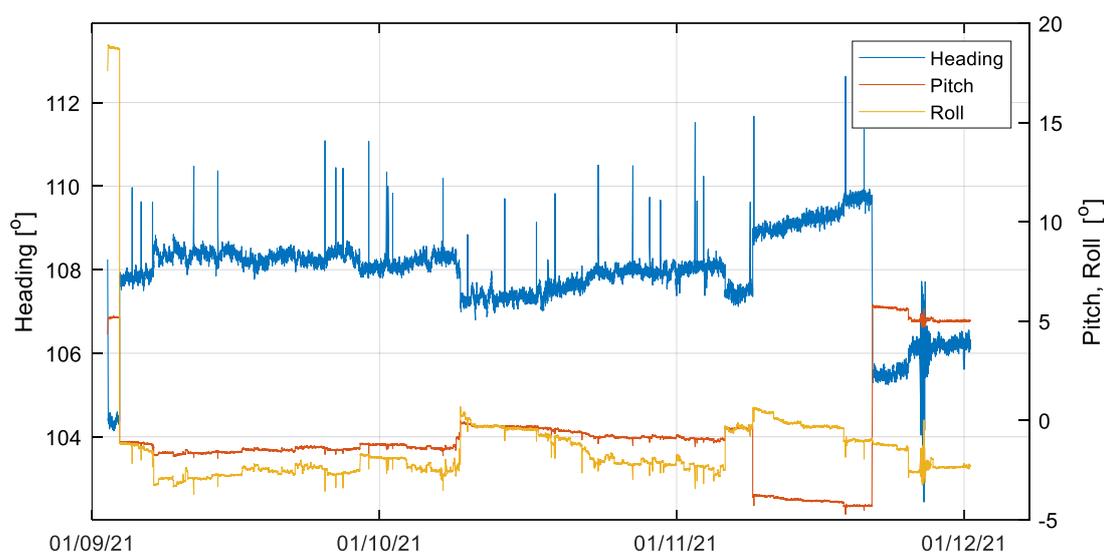


Figure 3. Sensor heading, pitch and roll for the 90-day period.

The flow statistics over the 90-day deployment are given in Table 4. This shows the site experiences relatively high flow speeds, with mean velocities >0.13m/s. Several higher energy events occur throughout the deployment where flow speeds near the surface exceed 0.47m/s. Due to the increased velocities at the site vertical structure is observed, where bed friction causes turbulence near the seabed resulting in lower current speeds. The ranked percentage of velocity 0.03, 0.045 and 0.095m/s represents the proportion of data below these speeds. This indicates whether a site is quiescent and determines the proportion of resuspension velocities. This data represents a site with high dispersive tendencies, where sediment has a high proportion of resuspensions events. Residual currents are strongest near the surface and reduce in magnitude towards the bed. At the seabed, the residual currents comprise of 87% of the mean current velocity. The direction of the residual currents is predominantly south eastly throughout the water column.

Table 4. Flow statistics

	Near Surface	Cage Bottom	Near Bed
Cell number	10	8	1
Height from seabed (m)	10.62	8.62	1.62
Mean Speed (m/s)	0.176	0.171	0.132
Ranked Percentage at 0.03m/s (%)	3.90	3.83	5.02
Ranked Percentage at 0.045m/s (%)	8.37	8.51	11.15
Ranked Percentage at 0.095m/s (%)	25.68	27.29	37.75
Maximum Speed (m/s)	0.476	0.471	0.387
Residual Speed (m/s)	0.160	0.155	0.115
Residual Direction (°)	149.2	150.3	146.8

The near surface, cage bottom and near bed flow conditions are presented in Figures 4-7. Plot descriptions:

Near Surface: z = 10.62m (Cell = 10)

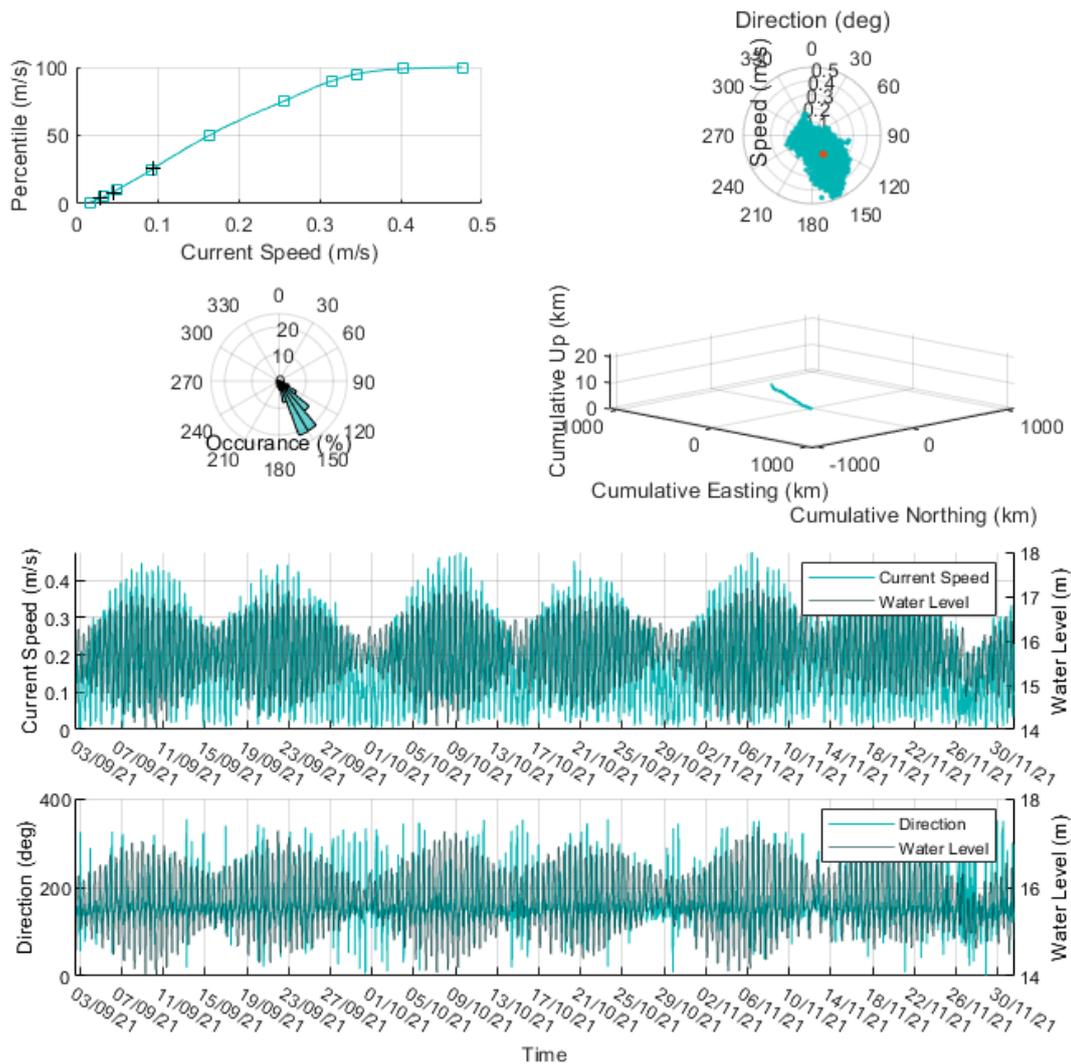


Figure 4. Near surface flow data. Top left: Percentile current speed with 0.03, 0.045 and 0.095m/s indicated by black cross markers. Top right: Polar scatter plot of all speed and direction data points with residual marker in red. Middle left: Percentage occurrence flow direction. Middle right: Cumulative 3-dimensional particle displacement. Bottom upper: Time series of current speed and water level. Bottom lower: Time series of direction and water level.

Cage Bottom: z = 8.62m (Cell = 8)

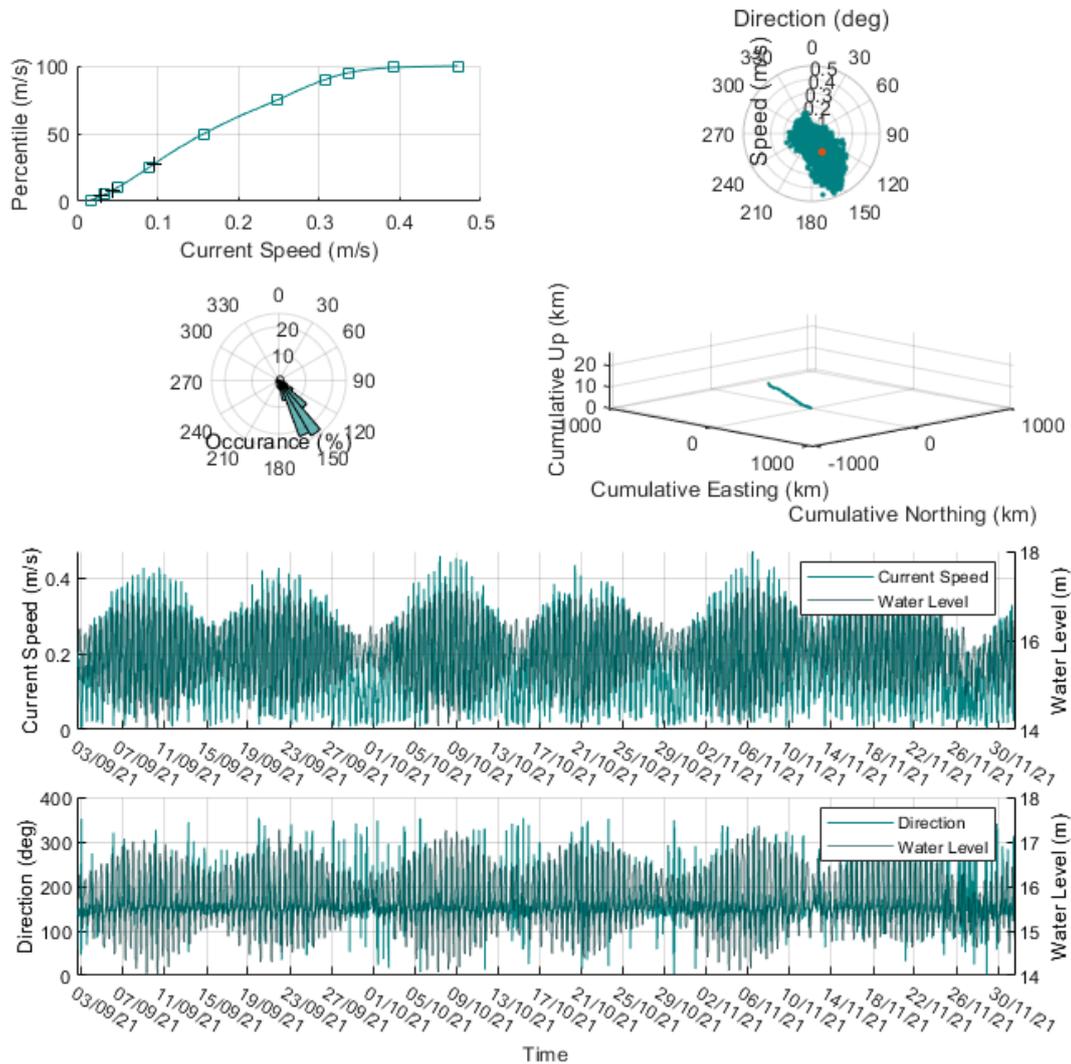


Figure 5. Cage bottom flow data. Top left: Percentile current speed with 0.03, 0.045 and 0.095m/s indicated by black cross markers. Top right: Polar scatter plot of all speed and direction data points with residual marker in red. Middle left: Percentage occurrence flow direction. Middle right: Cumulative 3-dimensional particle displacement. Bottom upper: Time series of current speed and water level. Bottom lower: Time series of direction and water level.

Near Bed: z = 1.62m (Cell = 1)

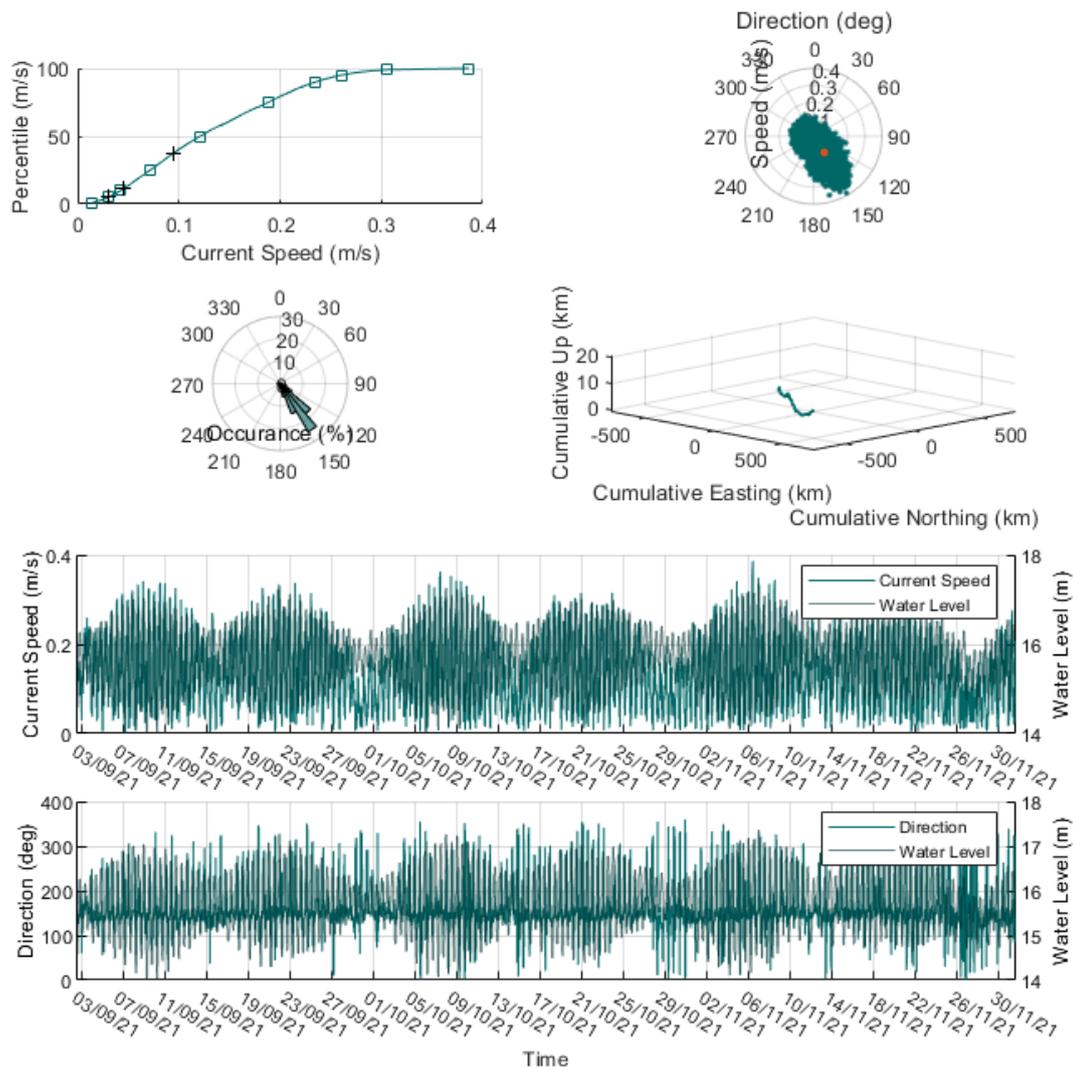


Figure 6. Near bed flow data. Top left: Percentile current speed with 0.03, 0.045 and 0.095m/s indicated by black cross markers. Top right: Polar scatter plot of all speed and direction data points with residual marker in red. Middle left: Percentage occurrence flow direction. Middle right: Cumulative 3-dimensional particle displacement. Bottom upper: Time series of current speed and water level. Bottom lower: Time series of direction and water level.

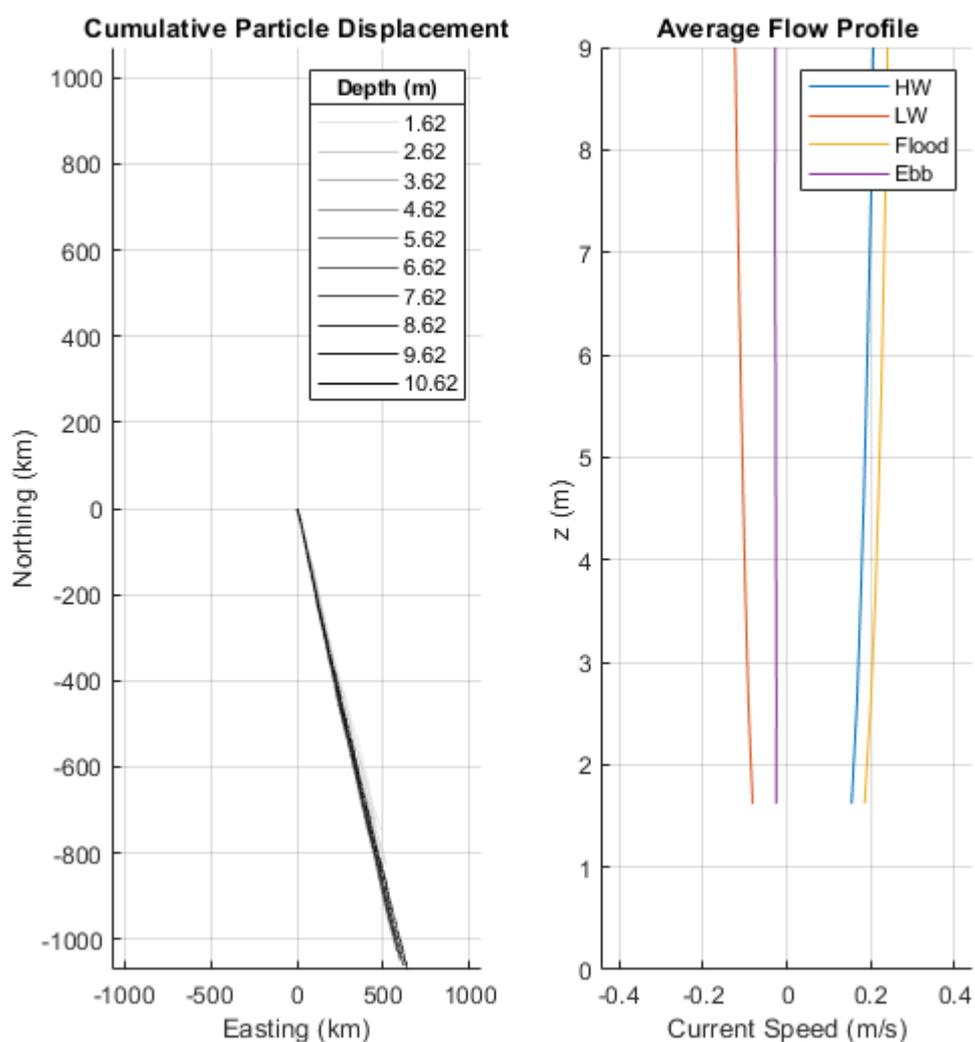


Figure 7 – Left: Cumulative particle displacement with depth. Right: Average velocity depth profile for high water (HW), low water (LW), flood tide (Flood) and ebb tide (Ebb).

8. Discussion

An ADCP was deployed at the site centre of the proposed site for over 90-days. During this time, the sensor recorded several gimbal and heading movements. During this time, no values exceeded SEPA’s 20° pitch and roll threshold. Additional quality control techniques found no additional errors within the full deployment dataset. This suggests a successful deployment with results suitable for use in further applications.

The proposed site shows increased mean current speeds, that are well in excess of 0.095m/s. This indicate the site will be very dispersive, with large amounts of resuspension. The large residual currents indicate any deposition will travel in the south easterly direction.

The hydrographic results can be used to classify the site in terms of flushing, quiescence and resuspension. The mean current speed is slightly greater than 0.13m/s in all depth layers, making Quanterness a Strongly flushed site (table 5).

Table 5. Flushing characteristics based on mean current speed.

Mean Current Speed (m/s)			
>0.1m/s	0.05-0.1m/s	0.03-0.05m/s	<0.03m/s
Strongly flushed	Moderately flushed	Weakly flushed	Quiescent

The quiescent periods of the measured data show values ranging from 3.83% to 5.02%, making the site slightly quiescent.

Table 6. Degrees of quiescence based on percentage current speeds below 0.03m/s.

Quiescent Period (0-0.03m/s)		
>50%	30-50%	<30%
Highly quiescent	Moderately quiescent	Slightly quiescent

Velocities were below 0.095m/s approximately 37.75% of the time, meaning the site is highly resuspensive.

Table 7. Resuspension characteristics based on percentage current speeds below 0.095m/s.

Resuspension (<0.095m/s)		
>95%	80-95%	<80%
Depositional/Quiescent	Partially resuspensive	Highly resuspensive

These parameters classify the site as a very low quiescent and highly dispersive location.

9. Equipment list

- Garmin eTrex 10 handheld GPS
- Nortek Signature 500kHz Acoustic Doppler Current Profiler (Serial no. 102441)

10. Calibration reports

Below are the calibration documents for the Nortek Signature 500kHz ADCP (Serial no. 102441) used in the Quanterness deployment.

Final test checklist AD2CP



Wageningen
N-5301 RD
Hornvliet
Tel: +47 6733 4688
Fax: +47 6733 8739
Inquiry@nortek-nv.com
www.nortek.no

Order number: 45048-1-780	Name: Signature 500
	Instrument serial number: 10-2441
Frequency: 500kHz	Main board: AD2CP-2566
Firmware version: 1.4.5422.2212-11/169	

Label checked <input checked="" type="checkbox"/> OK	Comments: AHRS
Dock test <input checked="" type="checkbox"/> OK	
Baudrate 115200 <input checked="" type="checkbox"/> OK	

Tilt check

Pitch up
 Roll up
 Status bit
 Pitch down
 Roll down

pitch & roll within +/- 0.2 °

Clock

Set clock **UTC**

Heading

Up
 Down

tolerance: +/- 2 °

Pressure

Pressure sensor temp
 OK
 tolerance: +/- 0.1 % of
300 m

Temperature

OK

tolerance: +/- 0.1 °

Beam check

Correct order	Beam Imp	Noise floor	Amplitude in tank	Range
Beam 1 <input checked="" type="checkbox"/> OK	<input type="checkbox"/>	<input type="checkbox"/> Ω	26 dB	> 80 dB <input checked="" type="checkbox"/> OK
Beam 2 <input checked="" type="checkbox"/> OK	<input type="checkbox"/>	<input type="checkbox"/> Ω	26 dB	> 80 dB <input checked="" type="checkbox"/> OK
Beam 3 <input checked="" type="checkbox"/> OK	<input type="checkbox"/>	<input type="checkbox"/> Ω	26 dB	> 80 dB <input checked="" type="checkbox"/> OK
Beam 4 <input checked="" type="checkbox"/> OK	<input type="checkbox"/>	<input type="checkbox"/> Ω	26 dB	> 80 dB <input checked="" type="checkbox"/> OK
Beam 5 <input checked="" type="checkbox"/> OK	<input type="checkbox"/>	<input type="checkbox"/> Ω	26 dB	> 80 dB <input checked="" type="checkbox"/> OK

Velocity direction

XYZ coordinate system	ENU coordinate system
X <input checked="" type="checkbox"/> OK	E <input checked="" type="checkbox"/> OK
Y <input checked="" type="checkbox"/> OK	N <input checked="" type="checkbox"/> OK
Z <input checked="" type="checkbox"/> OK	U <input checked="" type="checkbox"/> OK
Zu <input checked="" type="checkbox"/> OK	Uz <input checked="" type="checkbox"/> OK

Head file

Headfile checked.
 Saved as read only

Serial communication

RS422
 RS232 **N/A**

Trigger

TTL
 RS485

Recorder erased

OK
 Rec size: **16GB**

Ethernet

MAC address: **8C:68:78:00:0A:06**

Static IP address:

Set host name: **102441**

DHCP enabled
 FTP OK

Licenses

Averaging mode <input checked="" type="checkbox"/>	Wave mode <input checked="" type="checkbox"/>	Vertical velocity <input type="checkbox"/>	64GB recorder <input type="checkbox"/>	Calibration license erased <input checked="" type="checkbox"/>
Burst Five beams <input checked="" type="checkbox"/>	Echo Sounder <input type="checkbox"/>	Dual frequency low <input type="checkbox"/>	128GB recorder <input type="checkbox"/>	Production license erased <input checked="" type="checkbox"/>
Bottom track <input type="checkbox"/>	Ice Measurement <input type="checkbox"/>	Dual frequency high <input type="checkbox"/>	256GB recorder <input type="checkbox"/>	Default configuration set <input checked="" type="checkbox"/>
High Resolution <input type="checkbox"/>	Altimeter <input type="checkbox"/>	16GB recorder <input checked="" type="checkbox"/>		

Cable/Harness

Cable Communication <input checked="" type="checkbox"/>	Harness Communication <input checked="" type="checkbox"/>
Battery <input checked="" type="checkbox"/>	Battery <input checked="" type="checkbox"/>

Electrical isolation test

SGV OK **N/A**

External sensors

Power down

OK

Date

Day **19** Month **10** Year **2020**

8294-02-288-01



Certificate of Calibrations and Tests

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Instrument Information

Customer Reference No.	45048-1-780
Instrument Type	Signature500
Instrument Frequency	500 kHz
Instrument S/N	102441
Head S/N	D-2441
Interface Board S/N	2566
Interface Board Mfr. S/N	4M00749310046
Digital Board Mfr. S/N	4M00771900038
Analog Board Mfr. S/N	4M00766610026
Sensor Board Mfr. S/N	4M00776610015
Interface Board Rev.	H-4
Digital Board Rev.	I-3
Analog Board Rev.	G-1
Sensor Board Rev.	D-1(AHRS)

Calibrations and tests performed

Pressure	Passed
Tilt and Compass	Passed

All the tested values are within Nortek AS specifications

October 19, 2020

Date

11. List of data files and description

Hydrographic data sheets (NS, CB, NB)

- CurrentMeterData_Quanterness_Bottom2021
- CurrentMeterData_Quanterness_Middle2021
- CurrentMeterData_Quanterness_Surface2021

Raw instrument files

- S102441A005_Quanterness.cfg
- S102441A005_Quanterness.ad2cp
- S102441A005_Quanterness_avgd.ad2cp

12. References

Scottish Environment Protection Agency (SEPAa) (2019) “Regulatory Modelling Process and Reporting Guidance for the Aquaculture Sector”. Version 1.1. Available at: <https://www.sepa.org.uk/media/450278/regulatory-modelling-process-and-reportingguidance-for-the-aquaculture-sector.pdf>

Scottish Environment Protection Agency (SEPAb) (2019) “Regulatory Modelling Guidance for the Aquaculture Sector” Version 1.1. Available at: <https://www.sepa.org.uk/media/450279/regulatory-modelling-guidance-for-theaquaculture-sector.pdf>

UK Hydrographic Office (2021) Marine Data Portal (Accessed 05/2021) Available at: <https://datahub.admiralty.co.uk/portal/apps/sites/#/marine-data-portal>