BAKKAFROST

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The Finest Salmon from
SCOTLAND

Hydrographic Report

West Gigha, Isle of Gigha

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Approved By	

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1. Introduction

This report describes the methods used to collect hydrographic data at the proposed Bakkafrost Scotland Ltd. (BFS) West Gigha fish farm, and presents the outcomes of the survey exercise.

This deployment was carried out by BFS, using a Teledyne RD Instruments Acoustic Doppler Current Profiler (ADCP) Workhorse, mounted in a weighted seabed frame.

Analysis was carried out in accordance with the Scottish Environmental Protection Agency (SEPA) guidelines (Aquaculture Modelling - Regulatory Modelling Guidance for the Aquaculture Sector. Version 1.1, July 2019).

2. Site Description

The hydrographic survey site was located approximately 500 m west of the Isle of Gigha (Figure 2.1). There were no pens on site at the time of the survey. Within the survey area, the seabed sloped westwards to water depths greater than 50 m.

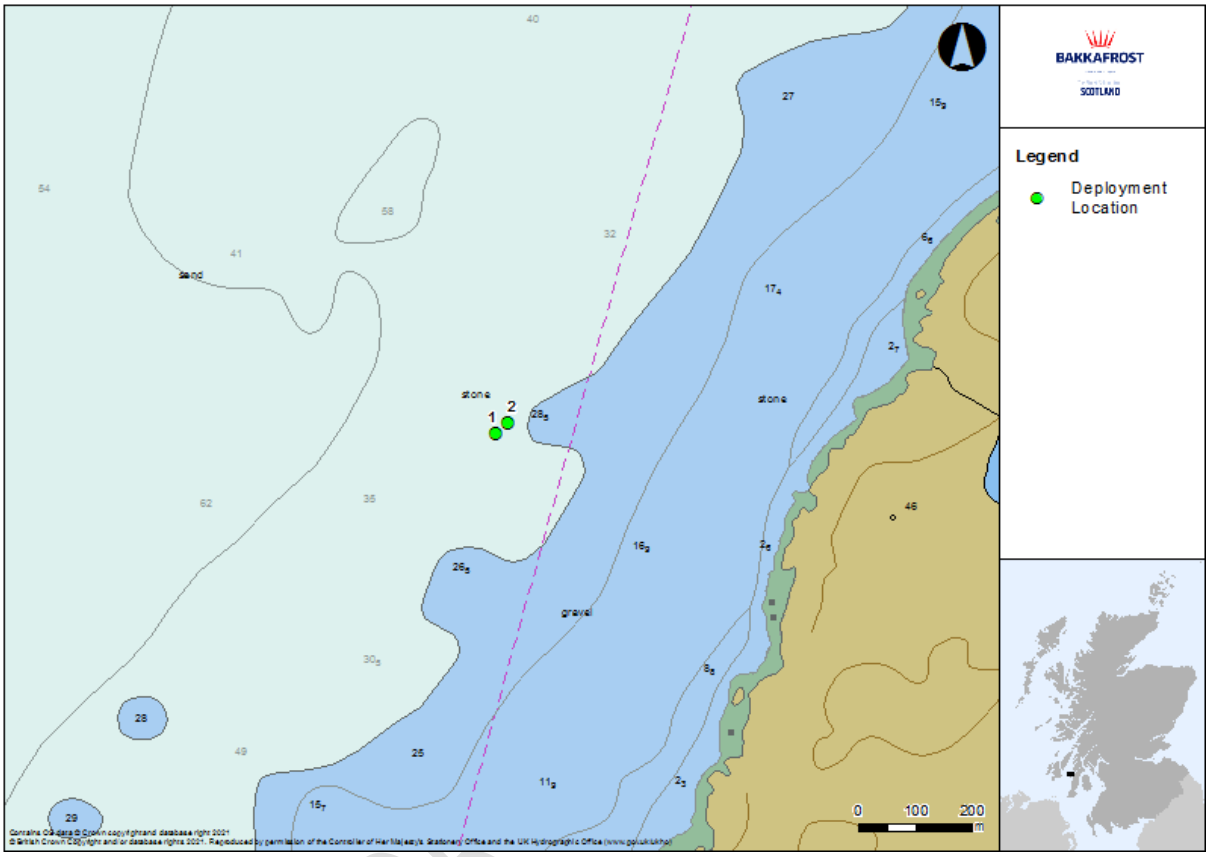

Figure 2.1. Location of the West Gigha current meter deployments (green dots).

3. Materials and Methods

3.1 Bathymetry Survey

BFS conducted a bathymetry survey to collect depth data around the site on 24th July 2020, using a Garmin portable chart plotter with acoustic sounder (Figure 3.1). Boat GPS was used at the start of the survey to verify accuracy to return positional information (WGS84). This device received a minimum of eight satellite coverage throughout the survey. Recorded depths were corrected to Chart Datum (CD) using Admiralty Total Tide software and referenced against tide predictions for the secondary port Sound Of Gigha, Isle of Gigha.

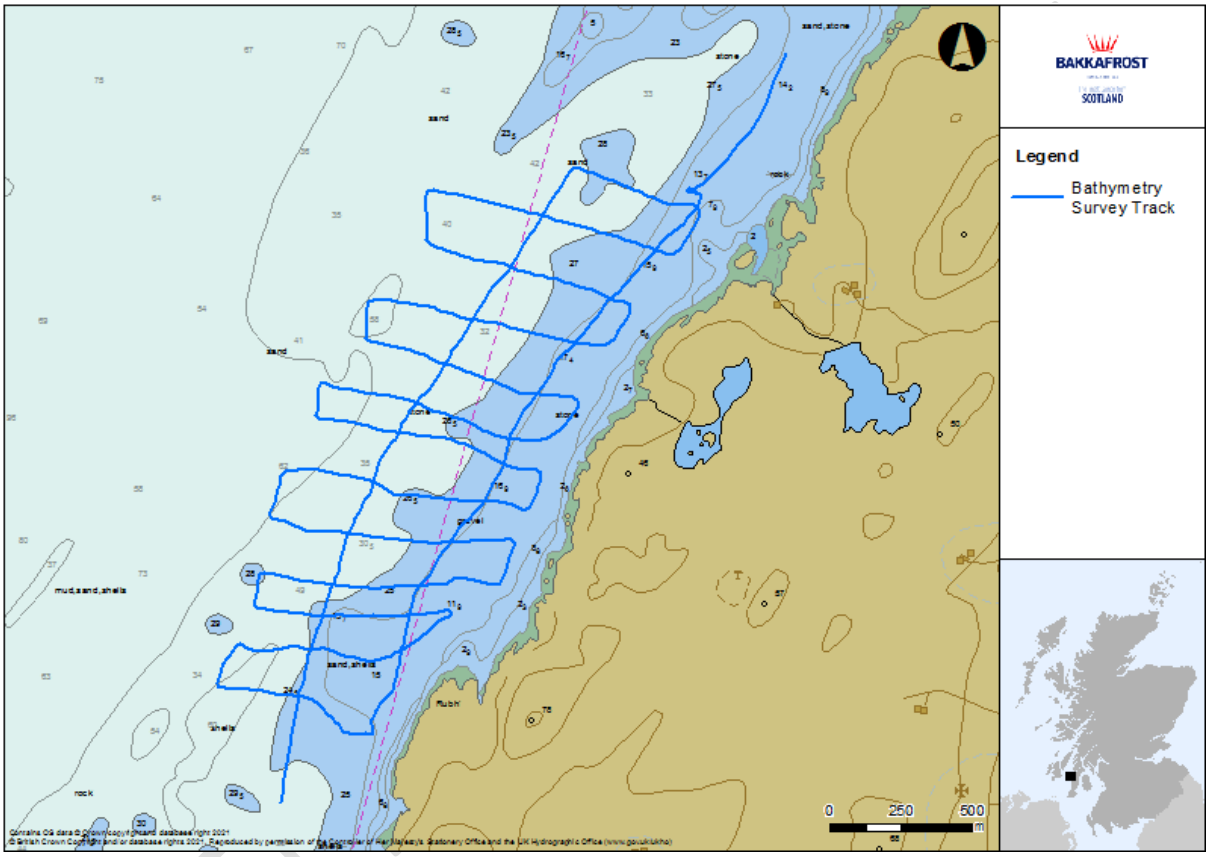

Figure 3.1. Bathymetry track during the survey on 24th July 2020.

Surveyed bathymetric data was then combined with land form data and charted bathymetry from the survey area, to provide a comprehensive overview of bathymetry within the area around the fish farm location.

3.2 Current Meter Set-up

An ADCP was used to record current data at the West Gigha site during two seperate deployments. The ADCP was installed in a mooring frame with 20° free gimbal movement that automatically levels the instrument when deployed on the seabed. The Workhorse ADCP is a 500kHz medium range, acoustic Doppler current profiler, which allows multiple, simultaneous sampling strategies with site specific cell size. This allows for current measurements throughout the water column, up to 80 m depths. Further information on the ADCP can be found at:
http://www.teledynemarine.com/adcps/marine-measurements

The ADCP was deployed twice during 2021, in order to collect at least 90 days of current meter data[1]. The details of these deployments are shown in Table 3.1. Further details are available in Appendix 1. The transducer head was 60 cm from the base of the mooring frame.

Table 3.1 West Gigha deployment details

	Deployment	Start date/time	End date/time	Location (OSGB36)	Location (WGS 84)
West Gigha 1	1	17/03/2021 12:50	07/05/2021 08:50	162909E, 650209N	55°41.235'N, 005°46.413'W
West Gigha 2	2	07/05/2021 12:00	17/06/2021 09:20	162931E, 650228N	55°41.246N, 005°46.393W

Initial depth soundings were taken at the deployment site, in order to determine the depth the ADCP would be situated in during high tide and in order for the appropriate column range to be determined. The ADCP was configured at the time of deployment, having established the water depth and expected tidal range on site. This was carried out on the instrument settings using a laptop with wireless connectivity.

3.3 Magnetic Variation

No magnetic variation correction was made to the ADCP during the deployment, this was undertaken after the instrument was recovered and data downloaded. A convergence value of -3.12° was applied. The grid magnetic angle applied was 0.68° for the first deployment and -0.14 for the second deployment. This gave an overall declination of -2.44° and -2.41°, respectively.

This was determined using the World Magnetic Model, produced jointly by the United States National Oceanographic and Atmospheric Administration's National Geophysical Data centre. Further details can be found at:

http://www.geomag.bgs.ac.uk/data_service/models_compass/wmm_calc.html

3.4 Data Processing

Data was downloaded and viewed using 'Velocity', a bespoke software for use with Teledyne instruments. Initial checks were done on the data to determine if the deployments were successful. In particular, pitch and roll, and heading were analysed to confirm that the deployment was successful, with the instrument orientated upright, and no unexpected movement. From the software, the data was extracted to text files and then later further processed in MATLAB and Microsoft Excel.

SEPA specifies that data should be presented for specific depths, therefore the data was selected against the following requirements:

- Sub-surface: from a depth of 5 m below the lowest predicted spring tide during the deployment period;
- Cage-bottom: at a depth corresponding to the bottom of the pens at mean sea level (+/- 1 m);
- Near-bed: as close to the bed as predictable (<3 m).

For both deployments, the near-bottom cell chosen was cell 1, giving a height above the seabed of 2.39 m, with depths ranging from 37.68 m to 40.23 m. Each cage-bottom and sub-surface cell for each deployment was calculated based on recorded depths. The calculated cell number and their depths are shown in Table 3.2.

[1] These datasets, including the final 90+-day stitched dataset, have been sen to SEPA. SEPA confirm, in email correspondence on 20/08/2021, that the data is of good quality and can be used in an application.

Table 3.2 Summary of the cell number and their depths for each dataset.

Deployment		Near-bottom Cell	Cage-bottom Cell	Sub-surface Cell
West Gigha 1	**Cell Number**	1	28	33
	Distance from seabed (m)	2.39	29.39	34.39
	Distance from surface (m)	38.78	9.99	4.99
West Gigha 2	**Cell Number**	1	27	32
	Distance from seabed (m)	2.39	28.39	33.39
	Distance from surface (m)	37.68	9.89	4.89

The distance to the near-bed cell is automatically calculated based on the configuration settings of the instrument. This is the distance from the transducer to the centre of the first cell, which equated to 1.79 m for both deployments. This number is then added to the height of the transducer head from the seabed, to give the actual height of the centre of the first cell, 2.39 m, which is within the remit of the SEPA criteria of 3 m.

Standard deviation has been assessed throughout the deployment to identify accurate and reliable data for near-bed, cage-bottom and sub-surface cells. The instrument standard deviation is determined using the deployment settings when the meter is programmed. Standard deviation for both deployments were within the SEPA criteria of 0.02 cm/s.

4. Results and Discussion

4.1 Bathymetry Survey

Bathymetry data was gathered on 24th July 2020, using a Garmin portable chart plotter with acoustic sounder. This data was used to validate Admiralty chart data for the area. The surveys concluded that chart data was reliable throughout the survey area. A combination of the collected depth data and Admiralty chart data was used to represent the bathymetry around the proposed West Gigha site (Figure 4.1). The mean wetted depth for the 2 x 2 km area was 32.23 m.

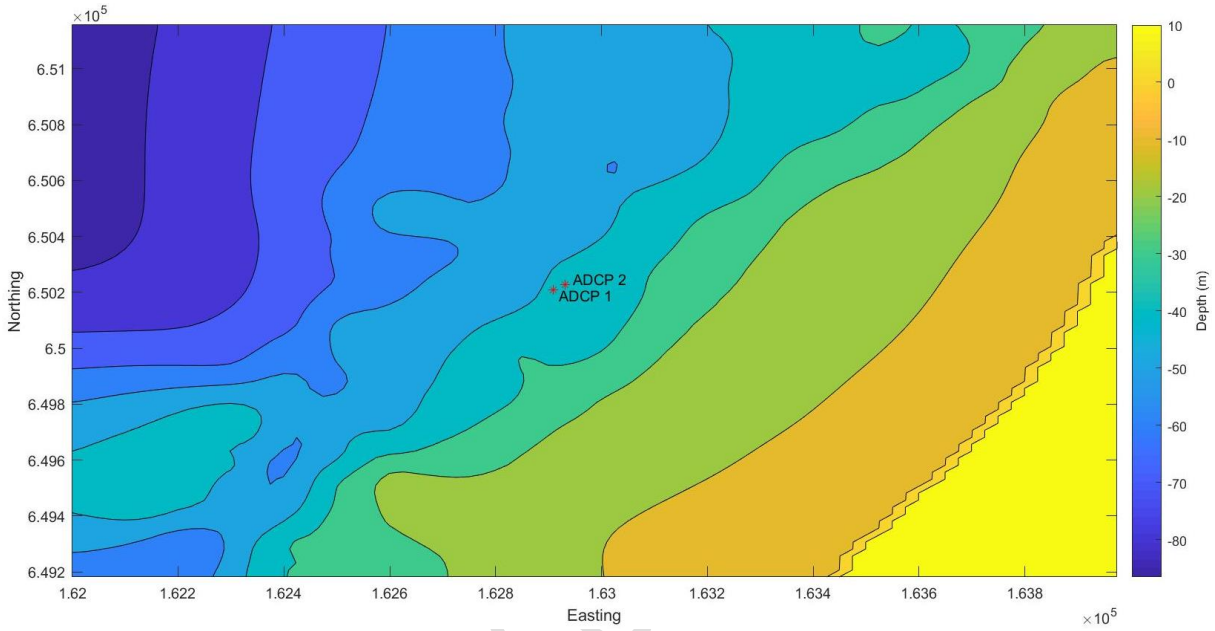

Figure 4.1. Representation of bathymetry in a 2 x 2 km grid around the proposed West Gigha site. The two current meter locations are shown (ADCP1 and ADCP2).

4.2 Current Data

During the initial processing stages, pitch, roll and heading were analysed to ensure the deployments were successful. This is presented in

Table 4.1, Figure 4.2 and Figure 4.3. These values are within the accepted range for successful deployments.

Table 4.1. Pitch, roll and heading range for thetwo West Gigha deployments.

Deployment	Pitch (°)	Roll (°)	Heading (°)
West Gigha 1	0.45	0.35	12.84
West Gigha 2	0.24	0.08	3.17

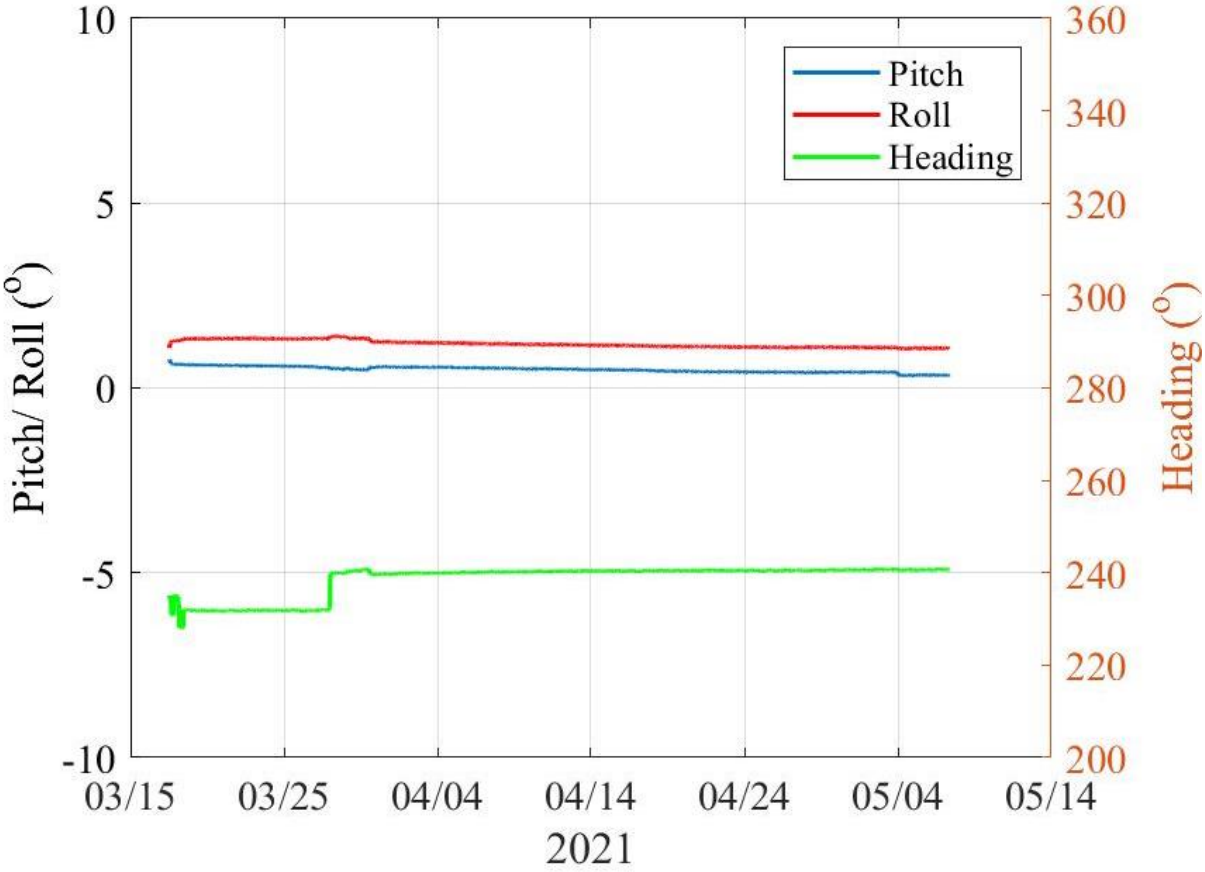

Figure 4.2. Pitch, roll and heading for West Gigha deployment 1, from 17/03/2021 - 07/05/2021.

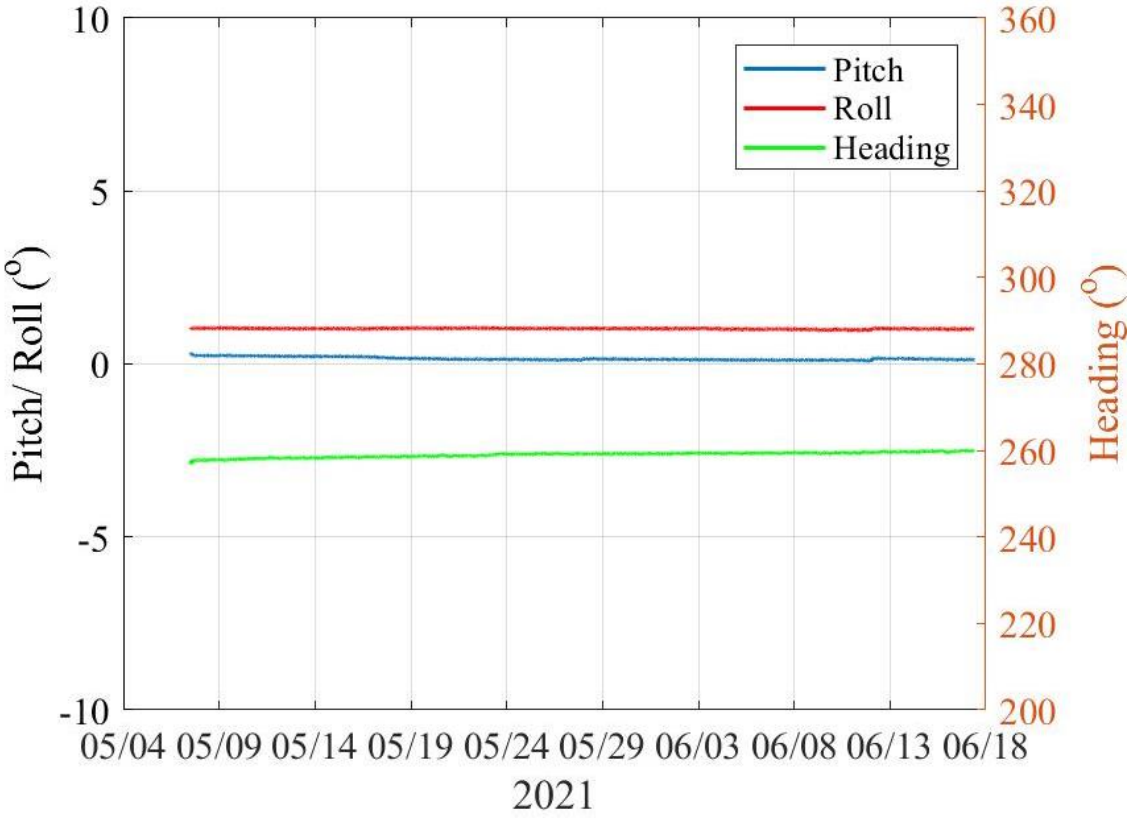

Figure 4.3. Pitch, roll and heading for West Gigha deployment 2, from 07/05/2021 - 17/06/2021.

A summary of the current data is shown in Appendix 1, and the SEPA HG analysis summary details are provided in Appendix 2.

A summary of the current data is shown in Table 4.2 and Table 4.3. During the first deployment, the sub-surface, cage-bottom and near-bed cells had averages of 22.3 cm/s, 21.7 cm/s and 15.4 cm/s respectively. This gave an overall average of 19.8 cm/s. During the second (final) deployment, the sub-surface, cage-bottom and near-bed cells had averages of 23.0 cm/s, 22.2 cm/s and 15.4 cm/s respectively. This gave an overall average of 20.2 cm/s. The orientation of the velocities was 025° to 035° (north-northeast to north-east) at the sub-surface and cage-bottom, and along the north-east and south-west axis at the near-bed. These orientations are all consistent with a parallel flow to the shoreline. Further details on hydrographic meter deployment results are provided in Appendix 1.

The mean residual currents for the sub-surface, cage-bottom and near-bed cells are 1.6 cm/s, 1.9 cm/s and 1.3 cm/s for the first deployment, with an overall average of 1.6 cm/s; and 2.2 cm/s, 2.3 cm/s and 1.3 cm/s for the second deployment, with an overall average of 1.9 cm/s. Similar to the combined velocity, the direction of the residual current at the subsurface and cage bottom depths was north-east to east-northeast, whereas at the near-bed cell it was east-southeast and south-southeast. The residual currents recorded during the first deployment indicate that there is minimal wind influence in the upper water column and tidal flow is the dominant flow.

Table 4.2. Summary of currents recorded at West Gigha deployment 1.

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	22.3	1.6	036	025
Cage-bottom	21.7	1.9	041	025
Near-bed	15.4	1.3	113	025

Table 4.3. Summary of currents recorded at West Gigha deployment 2.

	Mean Speed (cm/s)	Residual Speed (cm/s)	Residual direction °T	Major axis °T
Sub-surface	23.0	2.2	042	035
Cage-bottom	22.2	2.3	059	035
Near-bed	15.4	1.3	164	215

The data collected was consecutive, meaning data ‘stitching’ was straightforward. Data was ‘stitched’ together to form a 92-day dataset in such a way as to minimise error between Spring-Neap cycles. Table 4.4 shows the two datasets and their Spring-Neap cycles, in the order in which they were ‘stitched’ together. To fill the hour gaps between the datasets, the velocity and direction data has been selected from the appropriate time in the Spring-Neap cycle and replicated.

Table 4.4. West Gigha current meter tidal cycles.

Dataset	Deployment	Start	Tide	Spring Time (days)	End	Tide	Spring Time (days)
West Gigha 1	1	17/03/2021 12:50	1 hr after low	2 after	07/05/2021 08:50	0.5 hrs before low	6 before
Fill gap	1	08/04/2021 08:50	0.5 hrs before low	6 before	08/04/2021 15:10	0.5 hrs after high	6 before
West Gigha 2	2	07/05/2021 12:00	0.5 hrs after high	6 before	17/06/2021 09:20	3.5 hrs before low	5 after

The depth records shown by the current meter pressure sensor cells corresponded to the rise and fall of the tide, as checked with Total Tide software for the deployment periods; high and low tides corresponded with small variations of +/- 9 minutes.

The SEPA HG analysis spreadsheet for the 92 days of current data is shown in Appendix 2. For the 92-day dataset the sub-surface, cage-bottom and near-bed cells had averages of 22.6 cm/s, 21.9 cm/s and 15.4 cm/s respectively. This gave an overall average of 20.0 cm/s. The orientation of the velocities was south-southwest at the nearbed cell and north-northeast at the cage-bottom and sub-surface. Similar to the individual deployments this orientation of the flow is parallel to the shoreline. The mean residual currents for the sub-surface, cage-bottom and near-bed cells are 1.9 cm/s, 2.1 cm/s and 1.2 cm/s, with an overall average of 1.7 cm/s. The direction of the residual current was south-east at the nearbed cell and north-east at the cage-bottom and sub-surface cells.

5. Summary of Meteorological Data

SEPA have determined that meteorological data is no longer required in the assessment of site hydrographic conditions, due to the use of 90-days of hydrographic data. This longer deployment schedule has been achieved through multiple deployments, an extended time period and likely represents different seasons of the year. This provides a more realistic representation of conditions experienced at the site, compared with the previous methodology of short current meter deployments. Through post-processing, the hydrographic data has been used to analyse full flow and tide only flow conditions for the deployment periods, thus assessing the influence of meteorological conditions on the site.

6. Conclusion

Bathymetry and hydrographic data have been collected at the proposed West Gigha site. The results from two deployments, totalling 92 days of data collection, have been presented in this hydrographic report. Due to the successful deployments and good quality of data, these measurements are believed to be reliable and representative of the location of the site.

Overall, the recorded data are indicative of a well flushed site and are considered suitable for further use in modelling. These datasets are considered to provide a good basis for hydrodynamic and bath treatment modelling.

Meteorological data was not collected.

7. Appendices

7.1 Appendix 1: Summary of current meter data for West Gigha deployments

Table 7.1. Summary of currents recorded at West Gigha 1st deployment.

No. of records	3661		
Start date / time	17/03/2021 12:50:08		
End date / time	07/05/2021 08:50:08		
	Near-bed	**Cage-bottom**	**Sub-surface**
Cell Number	1	28	33
Mean speed (m/s)	0.154	0.217	0.223
Residual speed (m/s)	0.013	0.019	0.016
Residual direction °T	113	041	036
Major axis °T	025	025	025
Residual parallel (m/s)	0.000	0.018	0.015
Residual normal (m/s)	0.013	0.005	0.003
Amplitude parallel (m/s)	0.244	0.357	0.365
Amplitude normal (m/s)	0.049	0.048	0.064
Resuspension Threshold (9.5cm/s)	71%	78%	79%

Table 7.2. Summary of currents recorded at West Gigha 2nd deployment.

No. of records	2945		
Start date / time	07/05/2021 12:00:50		
End date / time	17/06/2021 09:20:50		
	Near-bed	**Cage-bottom**	**Sub-surface**
Cell Number	1	27	32
Mean speed (m/s)	0.154	0.222	0.230
Residual speed (m/s)	0.013	0.023	0.022
Residual direction °T	164	059	042
Major axis °T	215	035	035
Residual parallel (m/s)	0.008	0.022	0.022
Residual normal (m/s)	-0.010	0.009	0.003
Amplitude parallel (m/s)	0.239	0.360	0.371
Amplitude normal (m/s)	0.056	0.048	0.055
Resuspension Threshold (9.5cm/s)	72%	80%	81%

7.2 Appendix 2: HG analysis spreadsheets for the West Gigha deployments.

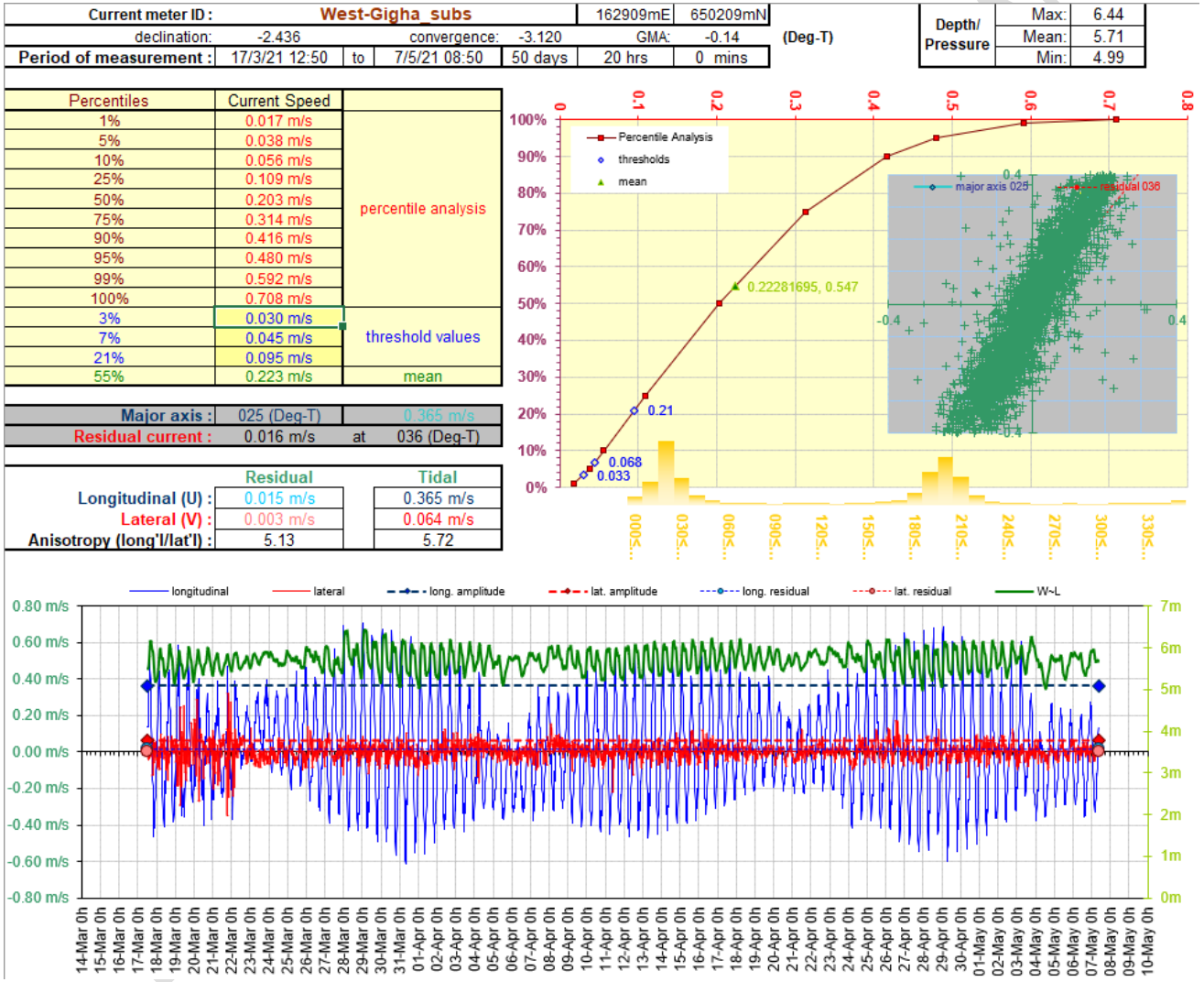

Figure 7.1. HG analysis summary of the sub-surface cell for West Gigha 1st deployment.

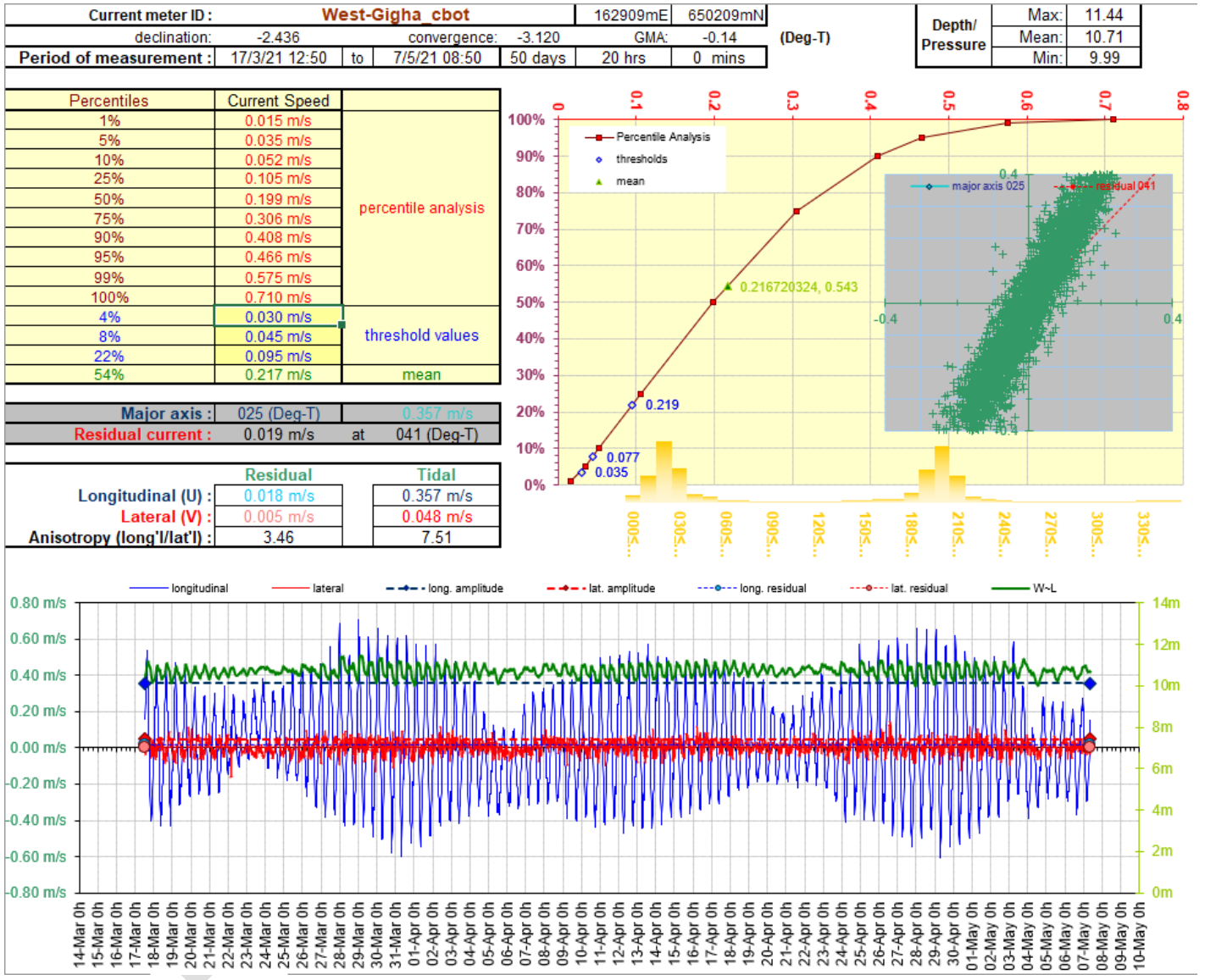

Figure 7.2. HG analysis summary of the cage-bottom cell for West Gigha 1st deployment.

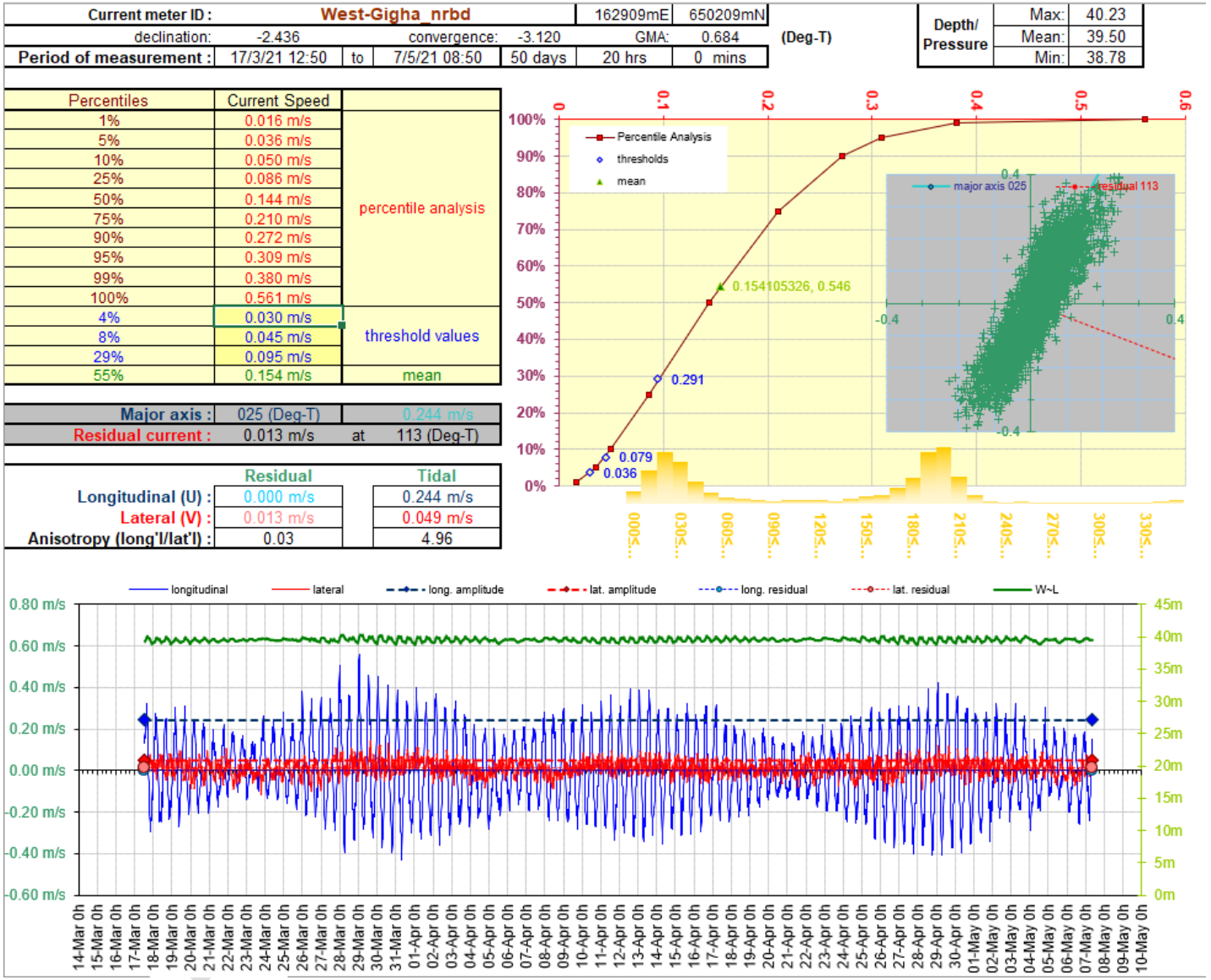

Figure 7.3. HG analysis summary of the near-bed cell for West Gigha 1st deployment.

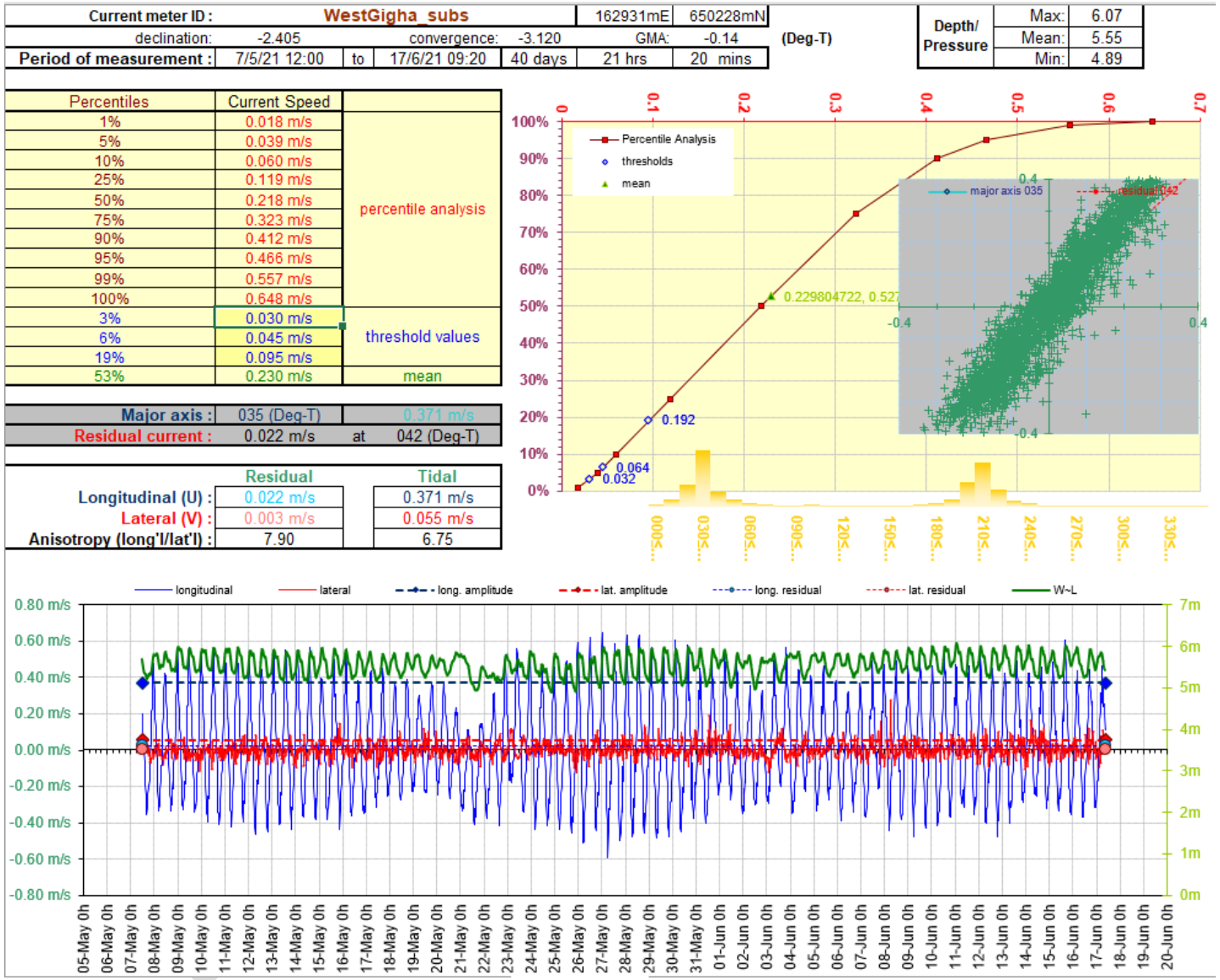

Figure 7.4. HG analysis summary of the sub-surface cell for West Gigha 2nd deployment.

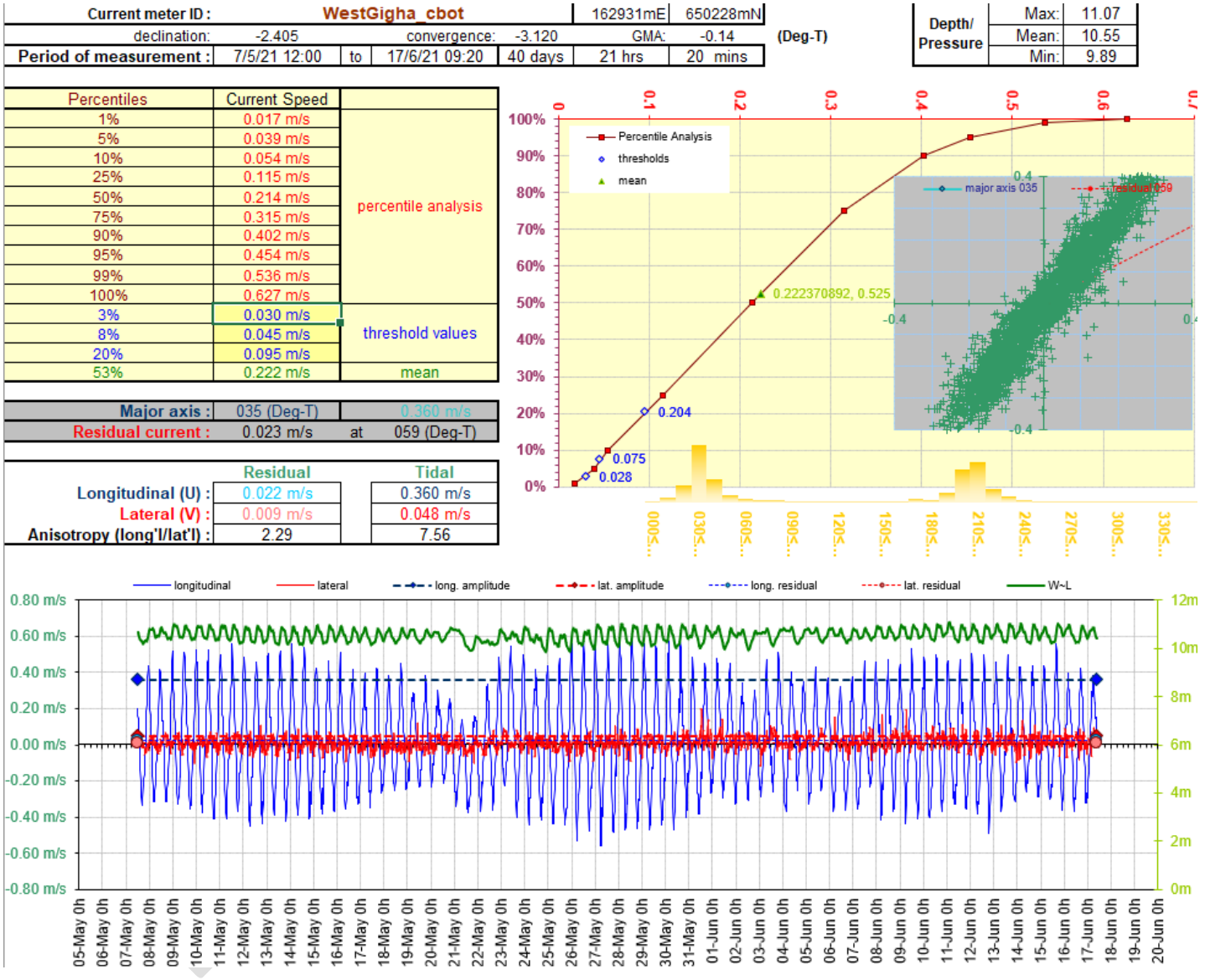

Figure 7.5. HG analysis summary of the cage-bottom cell for West Gigha 2nd deployment.

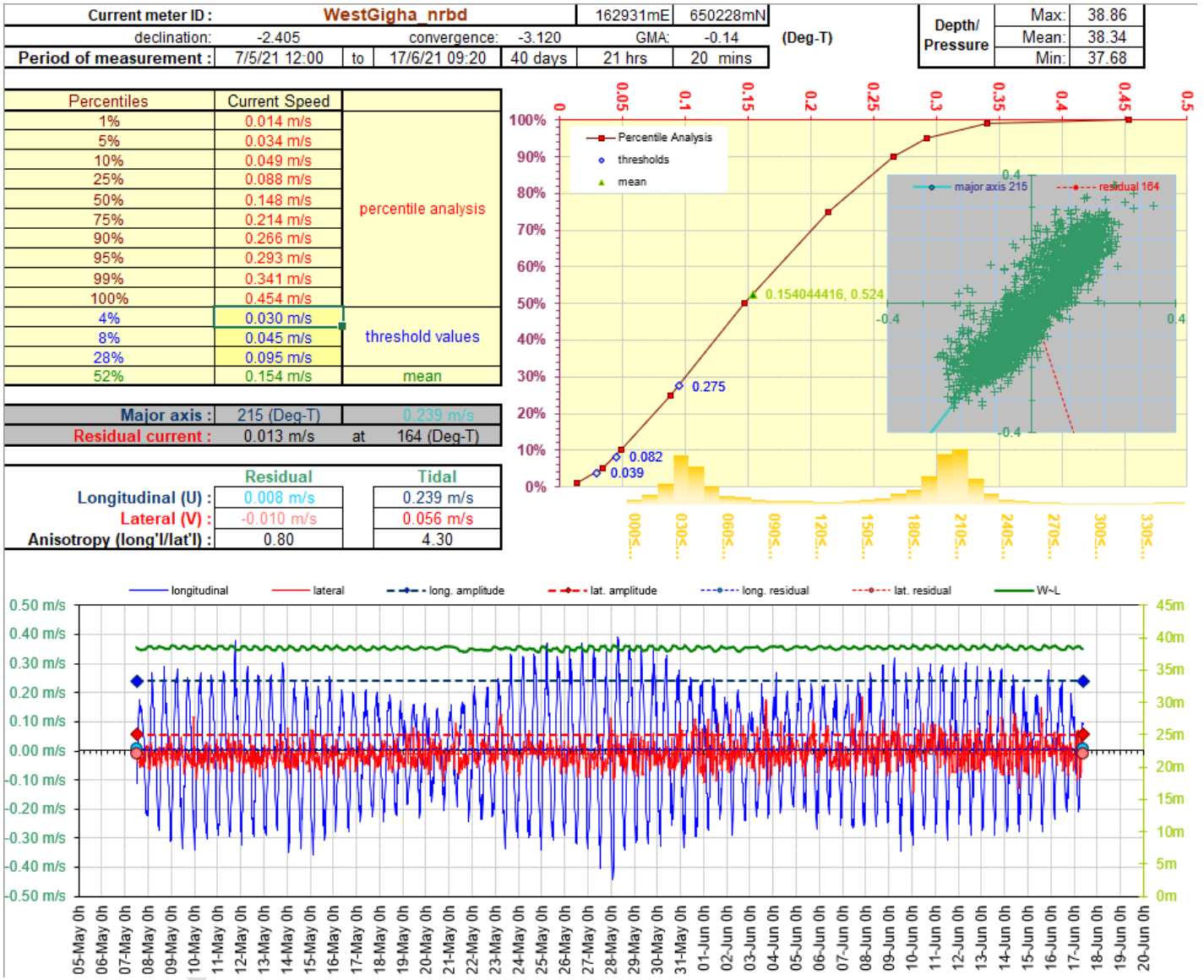

Figure 7.6. HG analysis summary of the near-bed cell for West Gigha 2nd deployment.

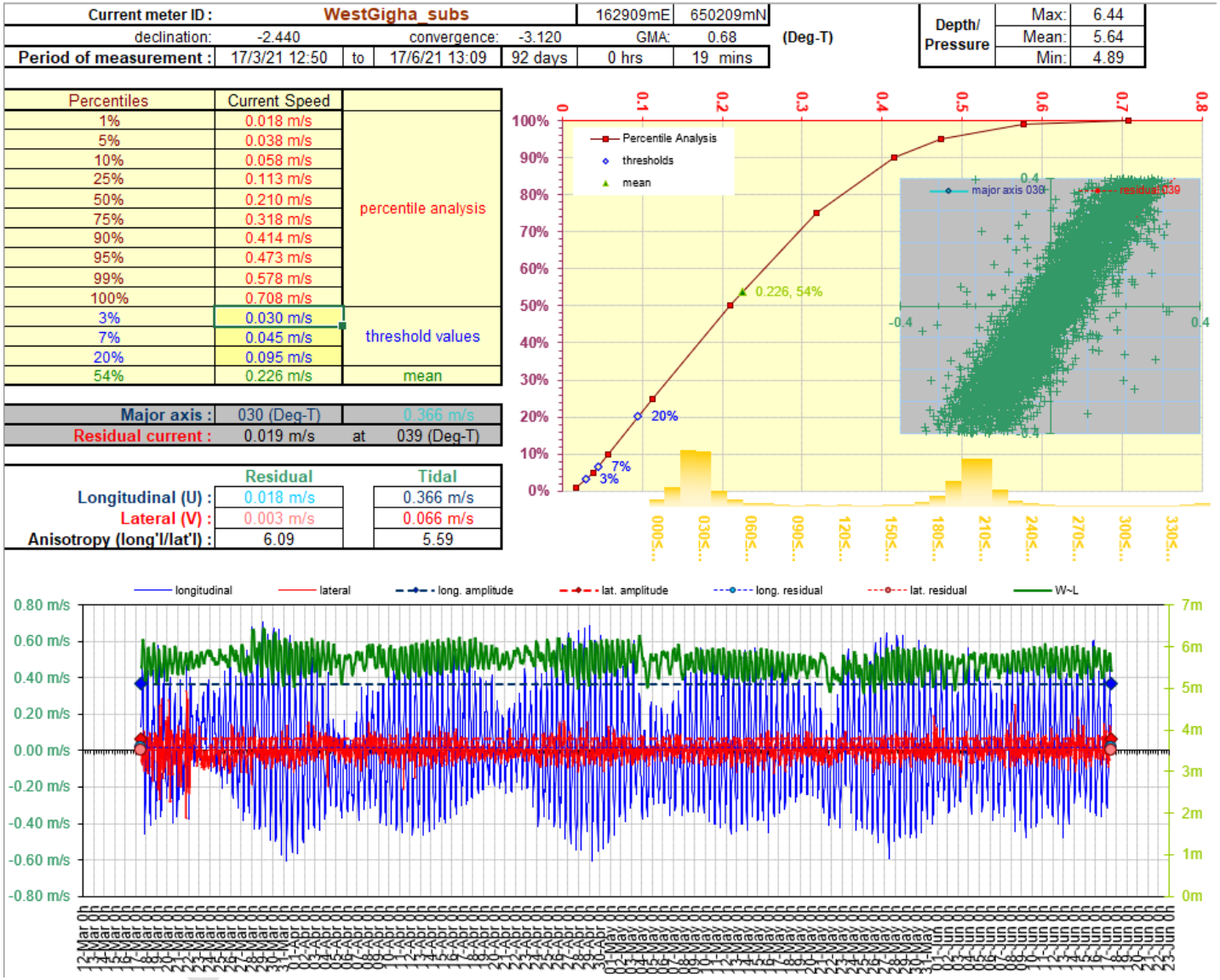

Figure 7.7. HG analysis summary of the sub-surface cell for West Gigha 92 days.

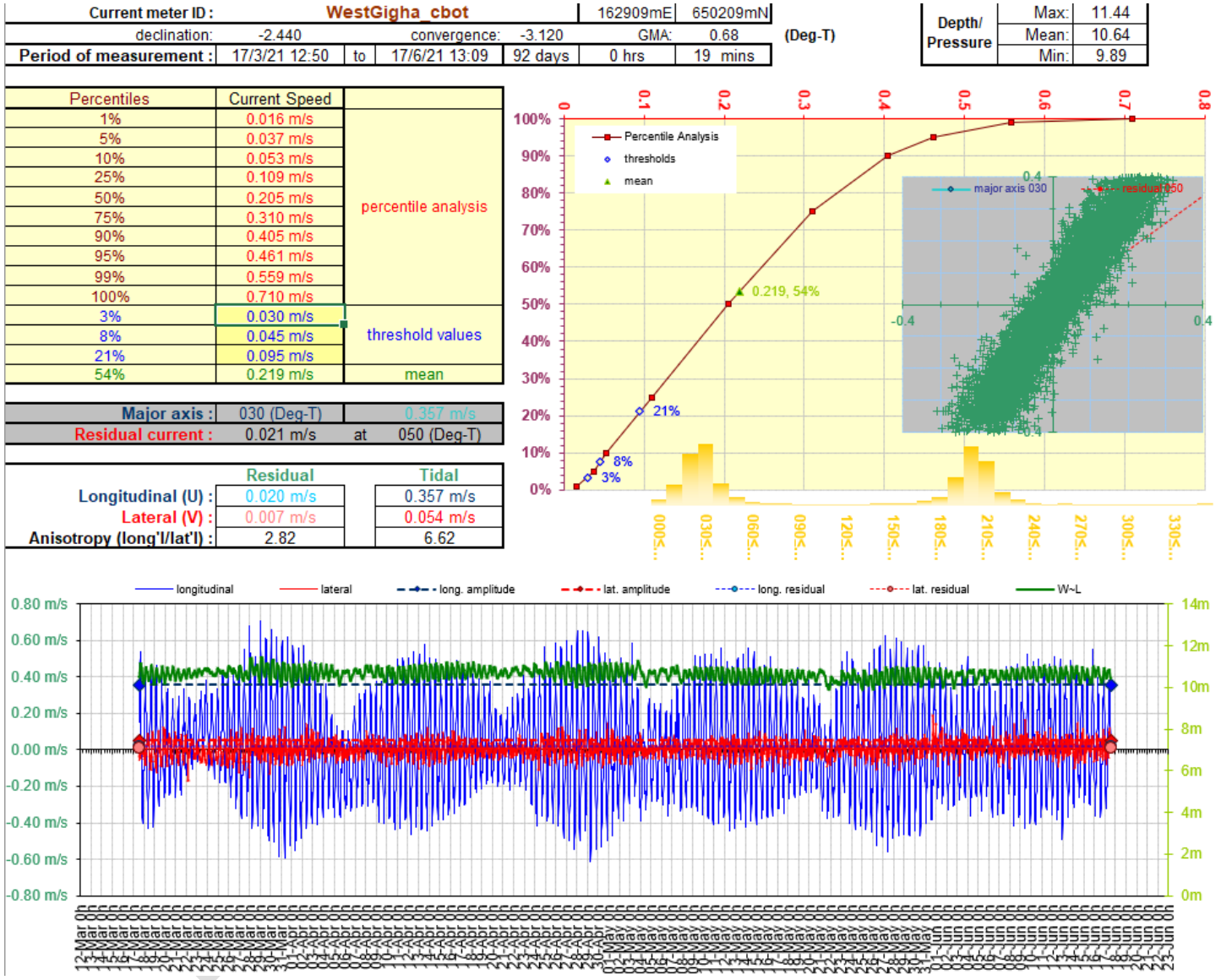

Figure 7.8. HG analysis summary of the cage-bottom cell for West Gigha 92 days.

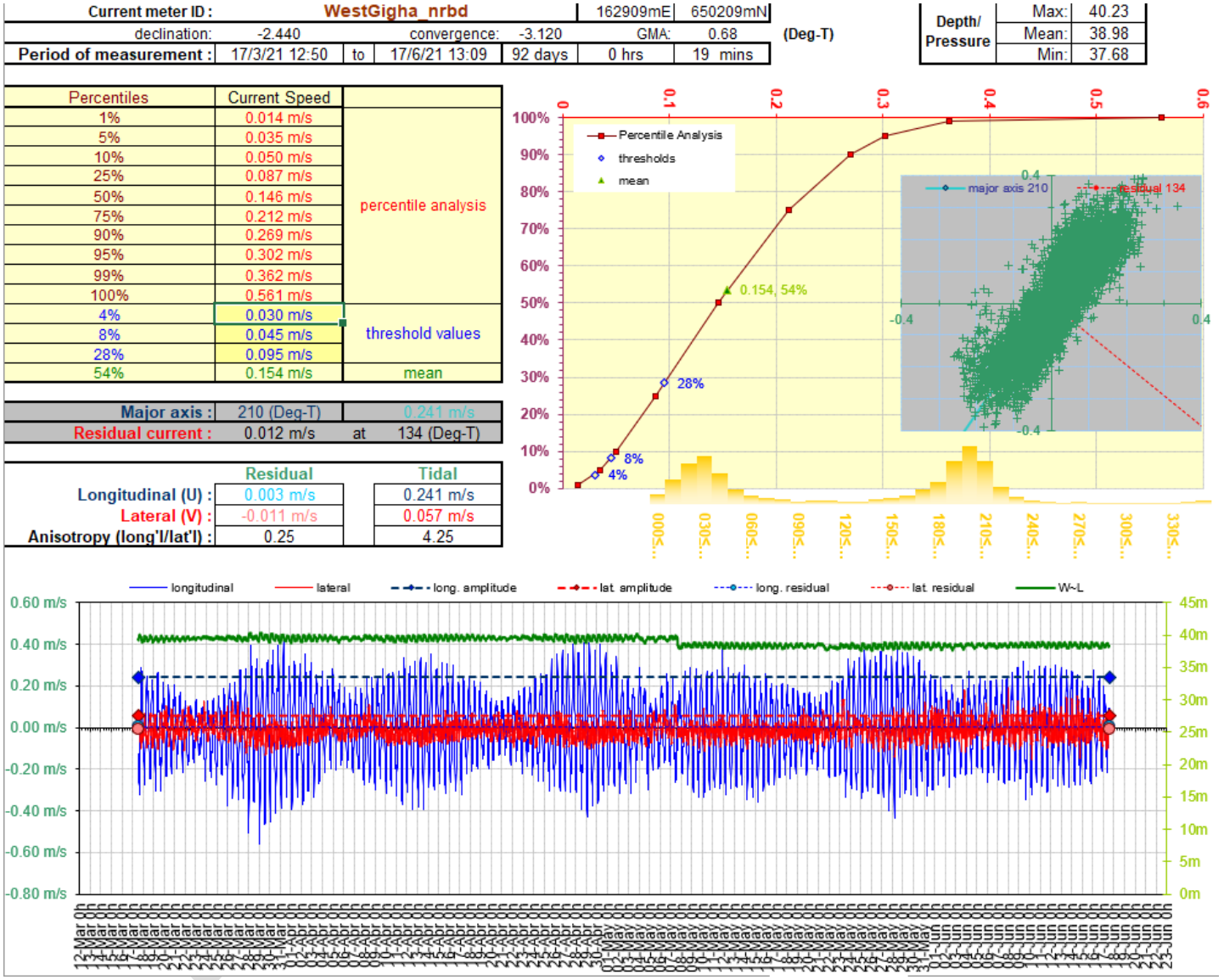

Figure 7.9. HG analysis summary of the near-bed cell for West Gigha 92 days.