THE CROWN ESTATE

Pentland Firth and Orkney Waters

Enabling Actions Report

Scoping study to identify opportunities for strategic wave and tidal measurements in PFOW area

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Scoping study to identify opportunities for strategic wave and tidal measurements in PFOW area

Version:	1.0
Prepared by:	Dr John Lawrence
Signature:	
Date:	30th May 2012

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1. Introduction

1.1 Background

The Pentland Firth and Orkney Waters (PFOW) Round 1 Development sites were leased by The Crown Estate in 2010. The development of these projects will require an accurate understanding of the wave and tidal resource in the different sites. A number of data collection campaigns have been undertaken by various organisations to date, although these tend to be for site specific purposes.

1.2 Project aims

The aim of this project is to determine whether strategic wave and tidal measurements in the PFOW area offer the prospect of de-risking the development of the 11 PFOW Commercial projects and if so, identify an approach to such measurements. 'Strategic' measurements are measurements which are not primarily or wholly associated with characterisation of a single PFOW project site but which offer the realistic prospect of being useful to multiple projects.

1.3 Approach

The first part of this study is a review of the existing hydrographic data coverage in the PFOW area to identify shortcomings in existing knowledge of the resource available and opportunities to expand this knowledge.

Discussions were held with PFOW developers and the Marine Modelling Enabling Action (MMEA) project manager to gain insight into what data collection would be seen as useful for de-risking PFOW projects and for model validation. These suggestions are focused on wave and tidal data collection because these data types will be the most strategically useful to the PFOW developers as a group.

2. Review of existing data coverage in PFOW

2.1 Data Sources

The following is a list of publicly available data sources explored:

- Centre for Environment, Fisheries and Aquaculture Science (CEFAS) Wavenet
- The British Oceanographic Data Centre (BODC)
- Met office
- System of Industry Metocean data for the Offshore and Research Communities (SIMORC)
- Marine Environmental Data and Information Network (MEDIN)
- National Data Buoy Center (NDBC)
- Aviso
- Environmental Research Institute at the University of Highlands and Islands Thurso

- Physical Oceanography Distributed Active Archive Center (PO.DAAC)
- Marine Scotland
- Orkney Islands Council Marine Services
- United Kingdom Hydrographic Office (UKHO)
- The Crown Estate

The following is a list of developers and private companies contacted for in house data:

- Aquamarine Power*
- Eon*
- Marine Current Turbines
- Meygen
- Open Hydro
- Pelamis Wave Power
- Scotrenewables*
- Scottish Power Renewables*
- SSE Renewables*
- Tidal Generation Ltd
- Voith hydro*

Around 50% of the developer companies (*) contacted replied with either information on their data collection programmes or suggestions regarding future strategic data collection.

Also referred to were reports prepared by Aquatera for Highlands and Islands Enterprise: *Pentland Firth Tidal Energy Project – Data Collection Study, March 2009* and by Natural Power for The Crown Estate: *Baseline Survey of Available Wave Data, February 2008.*

A table containing details of the available tidal data is available in **Appendix 6.1.**

A table containing details of the available wave data is available in **Appendix 6.2**

2.2 Tidal Data

The spatial coverage of tidal data collected in the wider PFOW area is shown in Figure 2.2.1. A version focused on the data gathered in the inter-island and Pentland Firth region can be seen in Figure 2.2.2.

The datasets are marked on the map with colour coded markers according to how useful the data were deemed to be. The usefulness of the data was judged on equipment used, duration of deployment and any additional information available. For tidal data, a duration of over 29 days was deemed as the minimum required to be useful to ensure a full lunar cycle is covered. Acoustic Doppler Current Profilers (ADCPs), either vessel mounted (VMADCP) or bed mounted (BMADCP) and Acoustic Wave And Current Profilers (AWACs), were considered to be more useful than subsurface Eulerian current measurements (SE Currents) because they describe the motion of the water through the whole profile rather than at a single depth point.

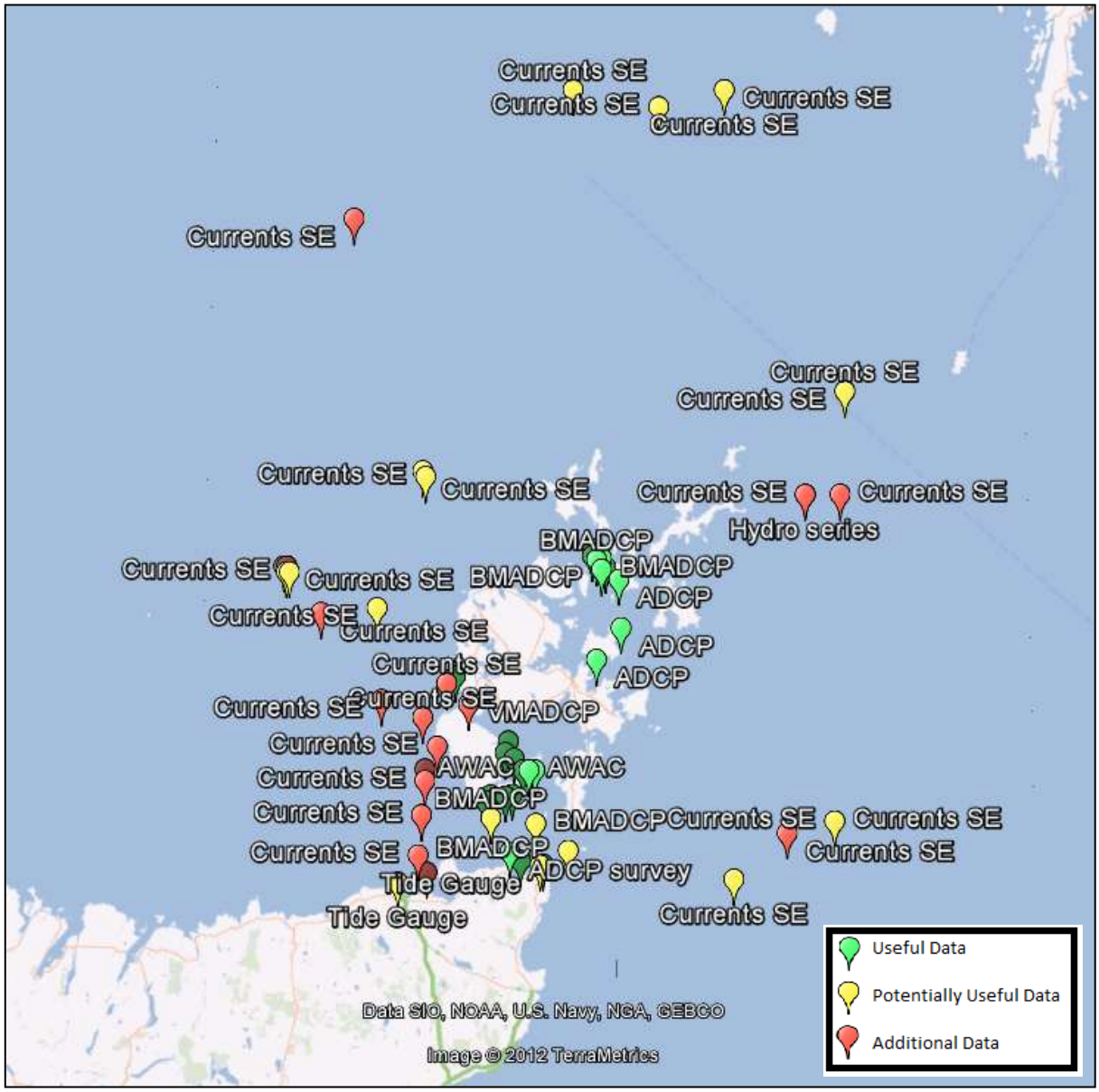

Figure 2.2.1 Tidal Data Distribution (Wide Range)

Anecdotally, good Eulerian measurements within the Pentland Firth are difficult to obtain – the high current speeds causing low instrument stability. Older data sets have accordingly been difficult to interpret.

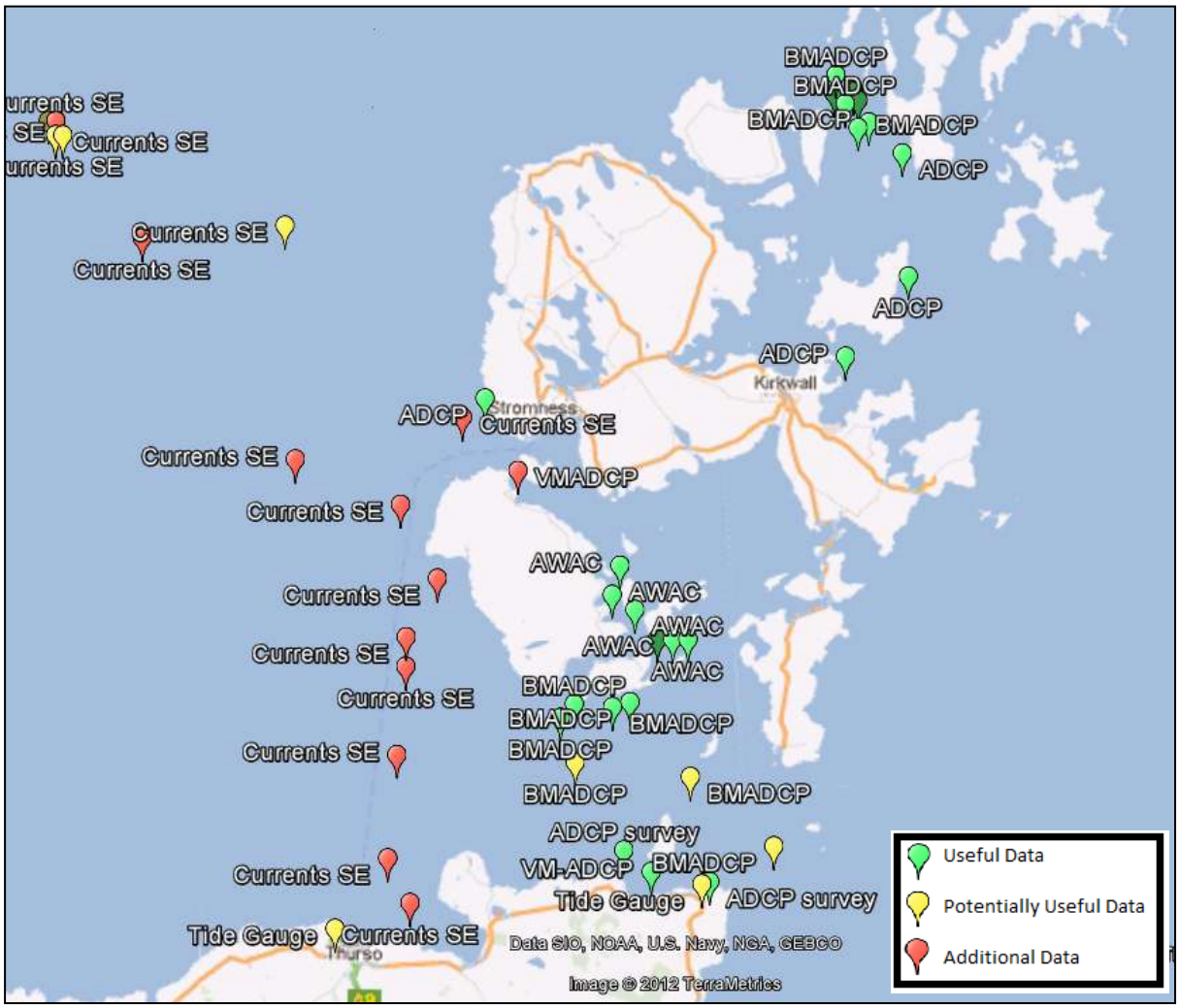

Figure 2.2.2 Tidal Data Distribution (Detailed Range)

2.3 Wave Data

The following figures show the spatial coverage of wave data collected in the PFOW area.

Figure 2.3.1 shows all of the datasets including the Metoffice K7 buoy for completeness.

Figure 2.3.2 focuses on the data within the strategic area.

The datasets are marked on the map with colour coded markers according to how useful the data were deemed to be, as shown in Figure 2.3.1.

For wave data, a duration of one year was deemed as the minimum required to be useful, to ensure that data across all seasons are available. Directional Waverider buoys were considered to be more useful than non-directional Waveriders.

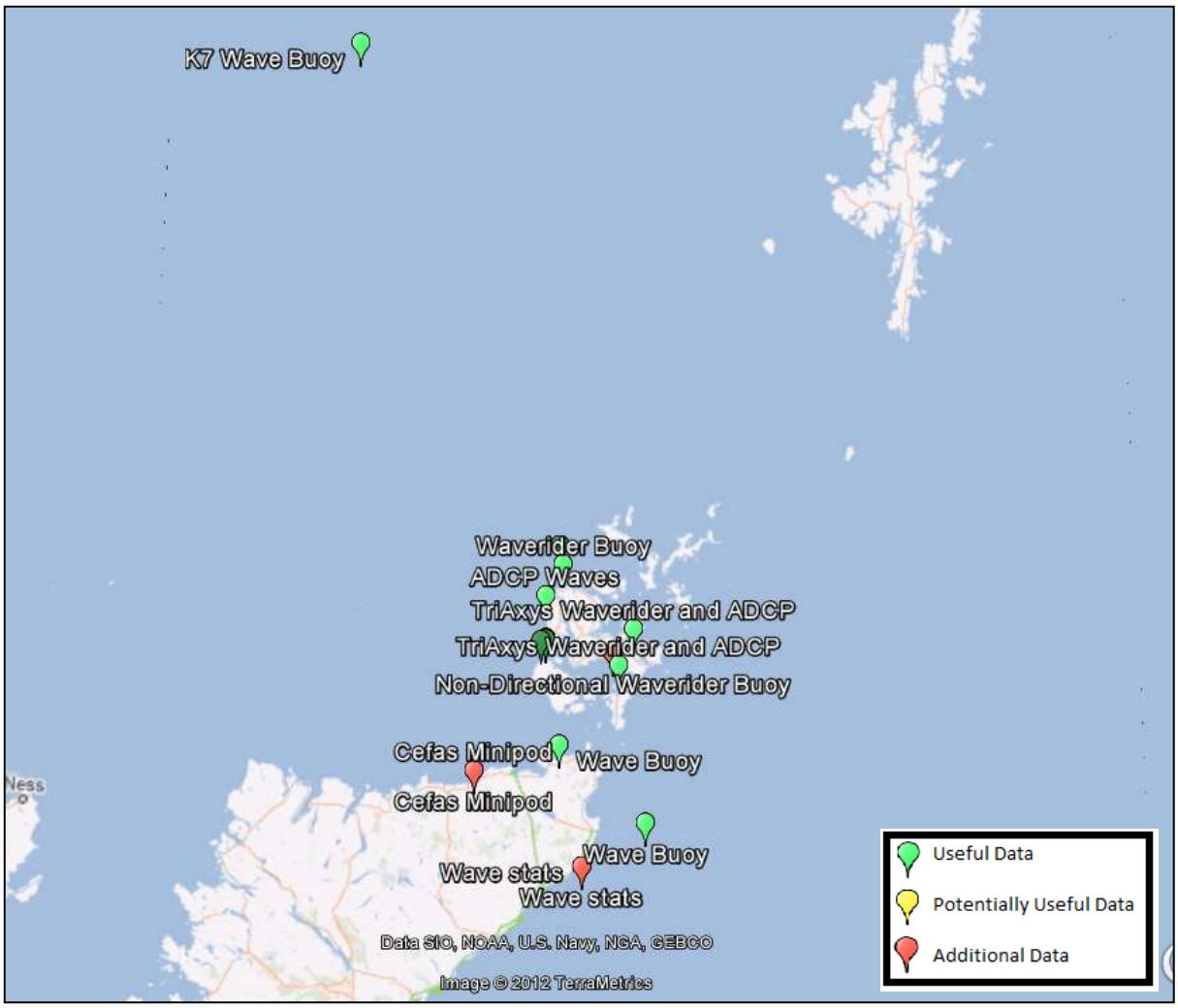

Figure 2.3.1 Wave Data Distribution (Wide Range)

Most wave measurements to date in the region may be categorised as inshore. A few buoys have been located as much as 10km offshore. Other than the Metoffice K7 buoy, there is no offshore wave measurement in the region.

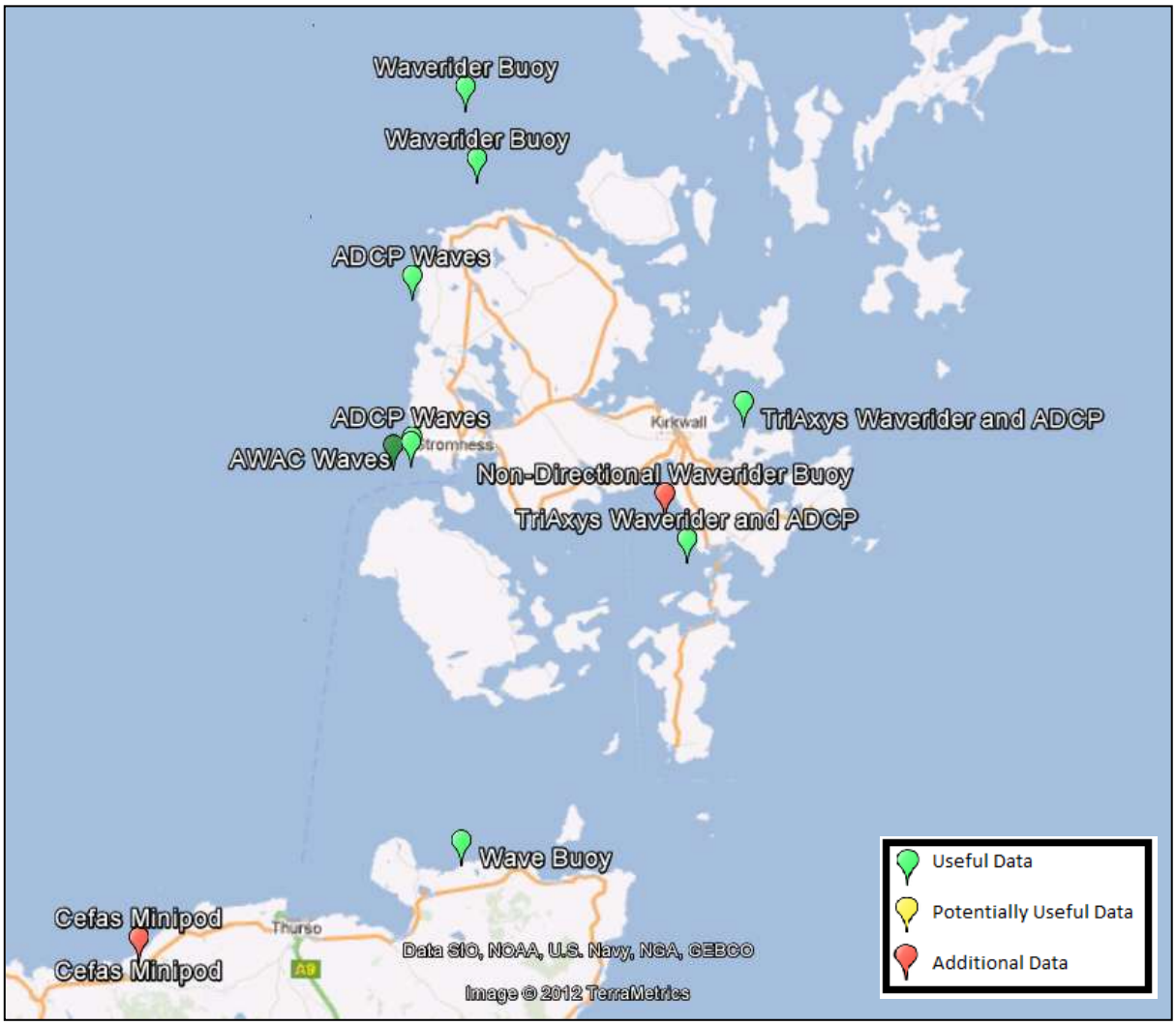

Figure 2.3.2 Wave Data Distribution (Detailed Range)

3. Options for future strategic data collection

The Crown Estate has been developing a strategy for exploiting PFOW for commercial wave and tidal developments. The options for strategic data collection relate to the data gathering equipment and the nature of the resource being measured. Wave resource data measured at a regional level can be used directly, while modelling will clearly enhance any strategic project. Since ADCP measurements are very site specific within complex tidal environments, a strategic approach will require either a large number of current measurements (>30) or an associated modelling exercise. In this report it has been assumed that the modelling route is preferable. The following recommendations in this section have been framed in the context above.

3.1 Option 1 – ADCP Surveys in Pentland Firth

It was suggested both by developers and the MMEA team that further ADCP drops would be useful for the development of the PFOW tidal sites. As a minimum, two bed mounted ADCPs should be deployed at either end of the main channel of the Pentland Firth, as shown in the indicative areas in Figure 3.1.1. More ADCPs will, however, provide a greater understanding of flow patterns in the region.

Duration – At least a month to cover a full lunar cycle of tides.

Requirement – To validate model data and confirm flow rates in and around the Pentland Firth.

Additional information – The ADCPs should be deployed simultaneously: the final locations for any deployments will need ratifying before any survey campaigns were taken forward.

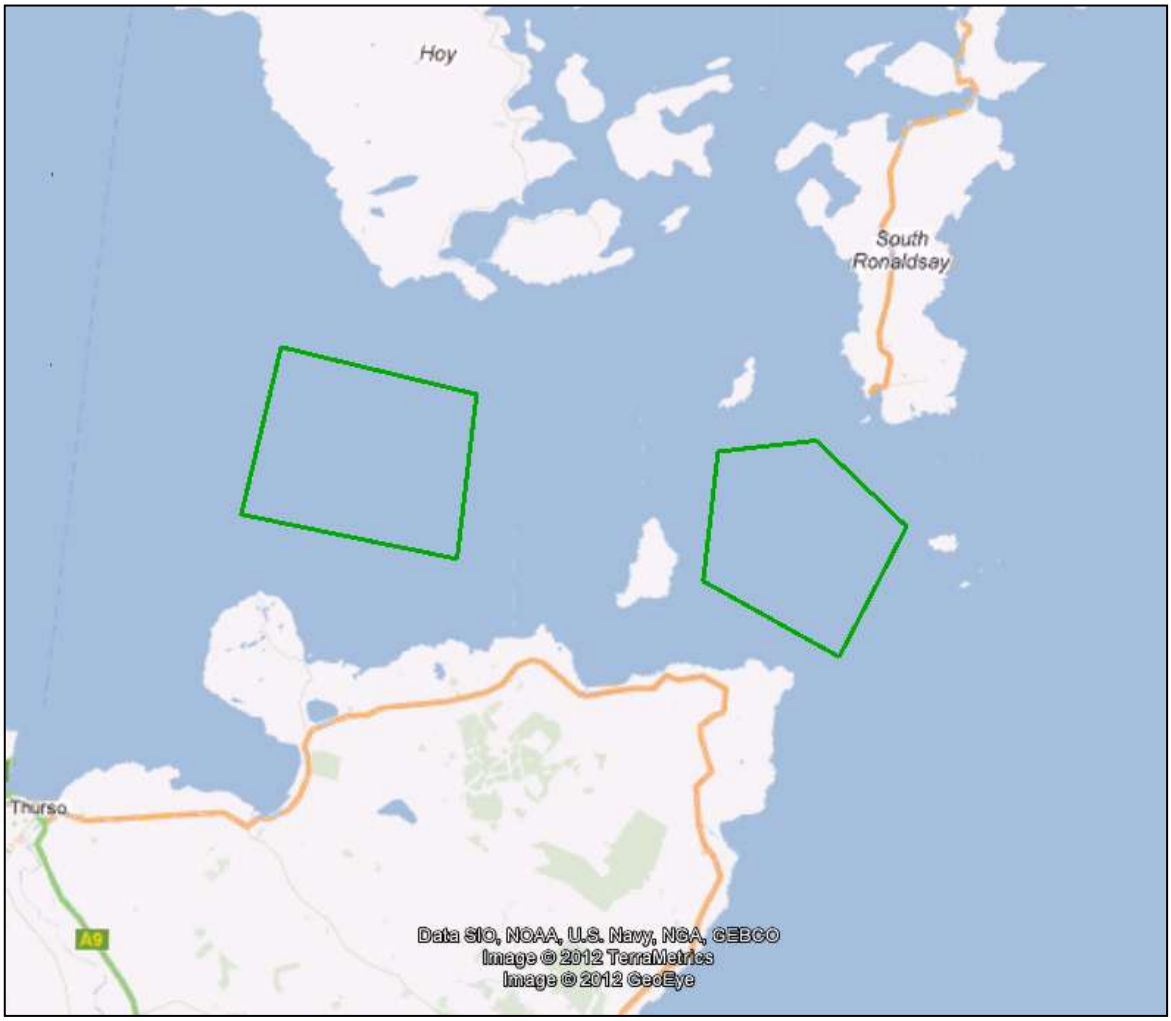

Figure 3.1.1 ADCP Pentland Firth Positions

3.2 Option 2 – ADCP Surveys In Peak Flow Locations

In addition to option one, the ideal situation would be simultaneous deployments of ADCPs at each of the main flow points between the islands as shown in Figure 3.2.1.

Duration – At least a month to cover a full lunar cycle of tides.

Requirement – To validate model data and confirm flow rates in and around Pentland Firth and Orkney Waters.

Additional information – The ADCPs should be deployed simultaneously.

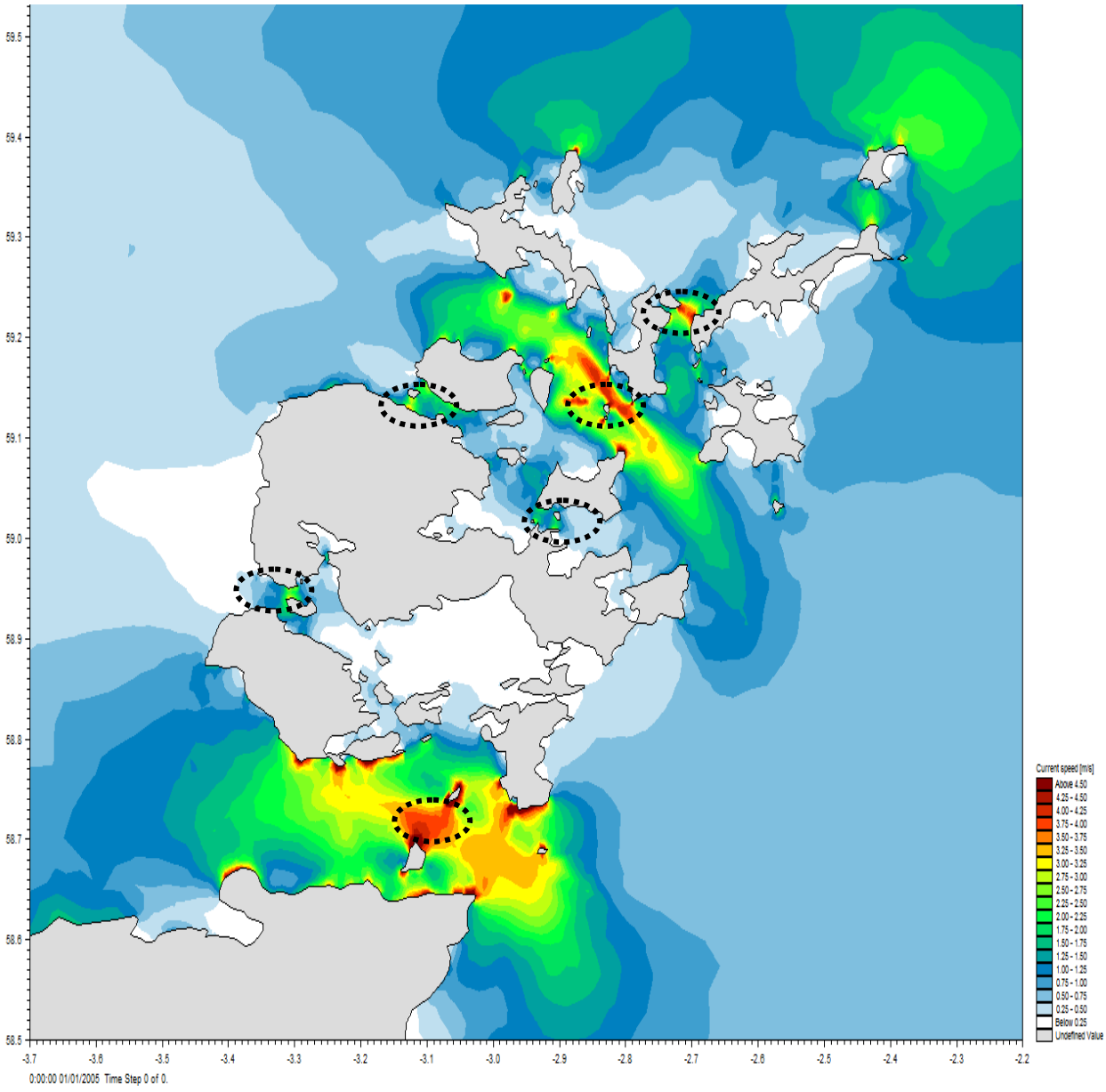

Figure 3.2.1 Peak Flow Locations

3.3 Option 3 – Waverider Surveys

It was suggested by the wave developers that it would be useful to know more about the wave climate some distance off the coast of Orkney before the waves are greatly affected by the bathymetry nearer to the coast. Therefore, suggested is a Directional Waverider deployment at least 30km off the West coast, as shown in the area indicated in Figure 3.3.1

Duration – At least a year to ensure that data for all seasons are collected.

Requirement – To characterise the offshore wave climate

Additional information – More than one buoy may be needed to accurately describe the wave climate offshore. The ideal situation would be for an arc of up to eight wave riders to be deployed from the Western Isles around to Fair Isle with a spacing of 30-50km.

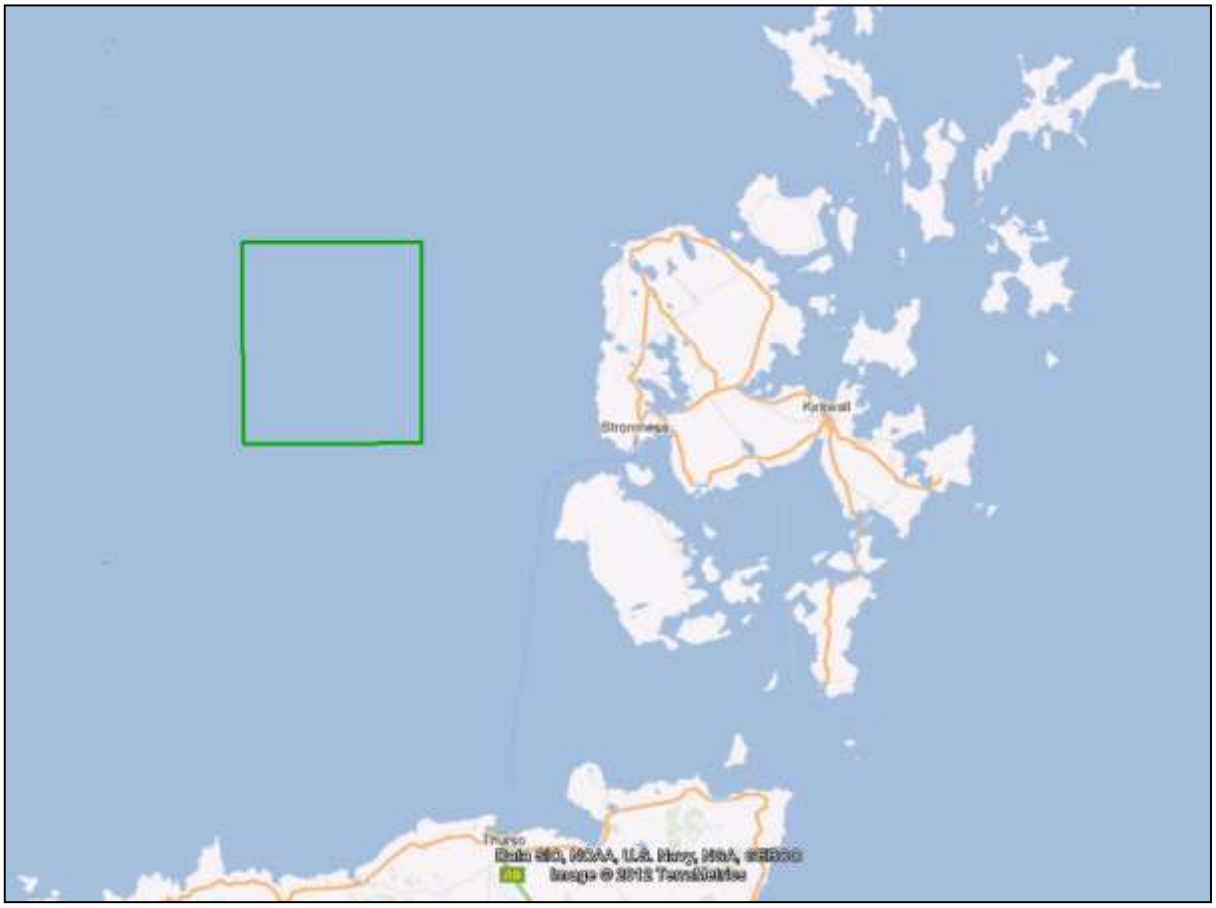

Figure 3.3.1 Waverider Deployment Area

3.4 Option 4 – Ferry Mounted Hull ADCP Surveys

To accurately describe the complicated tidal scheme around the PFOW area many ADCP drops would need to be made. An alternative to this may be to fit a hull mounted ADCP to some of the many ferries that serve the Orkney Islands, both inter-island and across the Pentland Firth. The approximate routes of these ferries are shown in Figure 3.4.1.

Duration – To be determined.

Requirement – To describe tidal schemes across the whole area more accurately.

Additional information – Units could be transferred from ferry to ferry to cover relevant routes, dependent on mode of attachment. For more information on this type of activity see www.ferrybox.org.

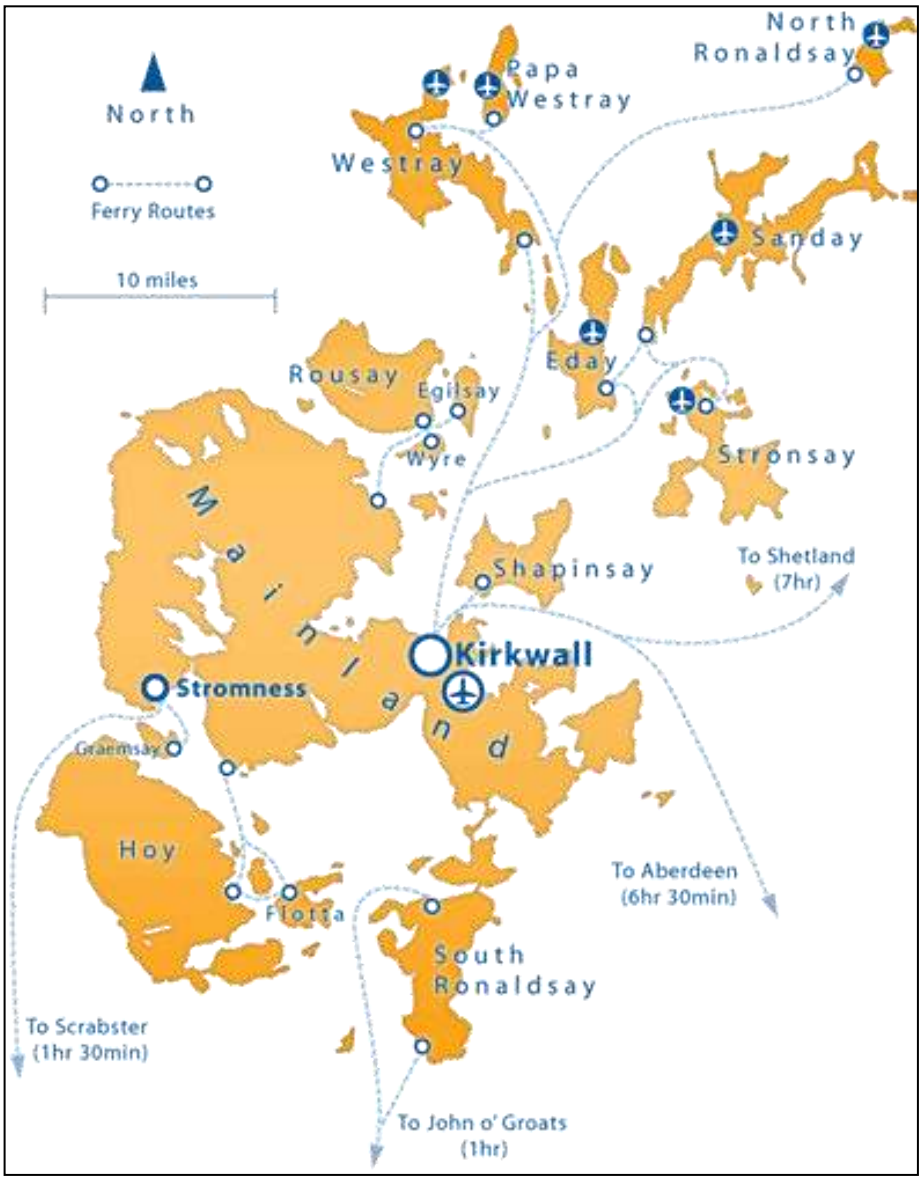

Figure 3.4.1 Ferry Routes Around Orkney

3.5 Option 5 – HF Radar

HF radar systems located at coastal stations have the capacity to provide detailed real-time hydrographic information over large areas. HF Radar is capable of both wave and current measurements. Radio frequency determines maximum range (20-200km going from high to low frequency) with spatial resolution being determined by radio bandwidth and antenna aperture. Data are usually provided on rectangular grids with 500m to 15km resolution. An HF radar system would typically comprise a transmitter and transmit antenna(s), a receiver and receive antenna(s) and radar signal processing computers at each of at least two sites. Coastal antenna locations and operating frequencies will determine the area of coverage.

Duration – Minimum of one year.

Requirement – There are two main applications of radar data: (i) provision of real-time data on wave and current climates for operational management; and (ii) parameterisation and validation of hydrographic models used to assess the detailed nature of energy resources, applied in locational planning, array and device design and specification of tolerances.

Additional information – Coverage would be dependent on location, with a Pentland Firth facing example given below. Figure 3.5.1 indicates a maximum range of 50km and the colour-coding indicates the angle of intersection between the two radar beams with blue being good and red being poor, for measurements that require data from two radars. In order to gather information of the resource to the west, the base stations would have alternative locations.

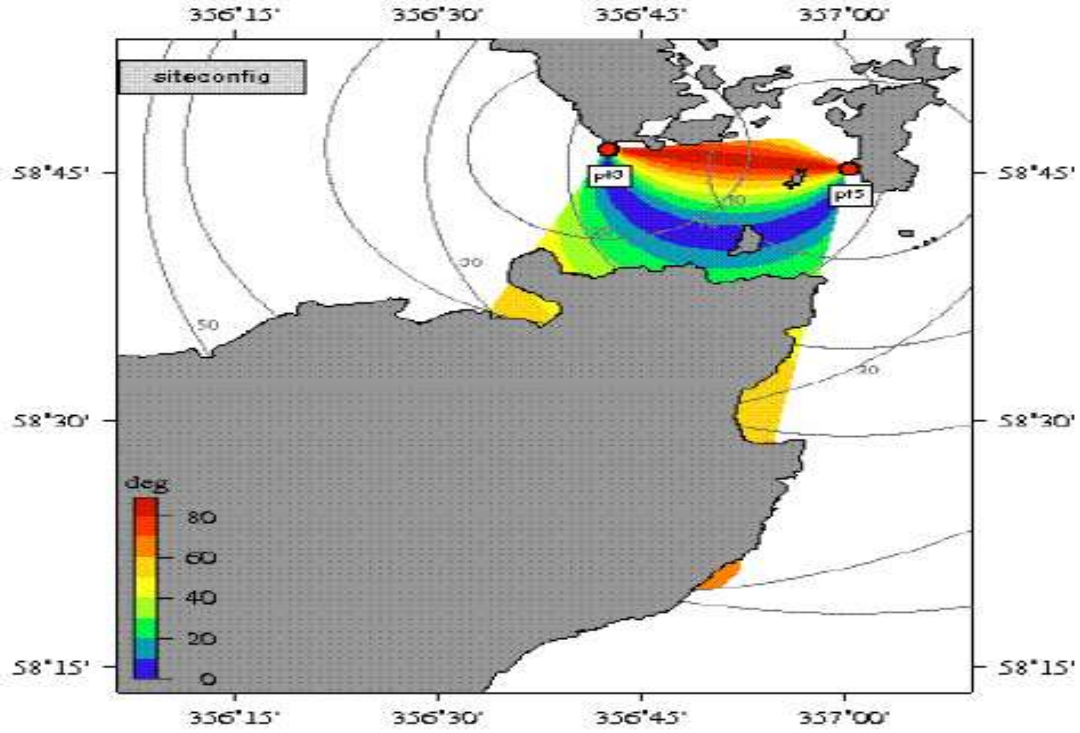

Figure 3.5.1 Example HF Radar Range (Provided by Heriot Watt University)

3.6 Option 6 – Alternative Data Sources

The following options were considered for providing additional data, but not deemed suitable for this project:

- Satellite altimetry. This method only provides a low sampling frequency at a regional scale. As an example of its use, the present JASON project samples the same location of the earth's surface once every 10 days.
- Marine X-Band radar. This method is only usable for short distances, of the order of 5km, and is more suitable for site specific purposes.
- LIDAR (Light Detection and Ranging). This method requires mounting a sensor on a suitable aircraft and is not practical or economic for long-term surveys.
- Tidal gauges. Orkney Islands Council has maintained tidal gauges at a number of sites (usually piers). However, since there is generally no direct transform between tidal elevations at one location and tidal speeds at another, the usefulness of such data is limited. Also, sea bed deployed ADCPs usually include tide gauge measurements, so this information should be available via this route if required.
- Temporary vessel mounted ADCP transects. This method of survey is uneconomic for long-term use, although very informative for intensive site assessment. This option was not requested by any consultee for further consideration.

4. Costs

For the purposes of assessing the relative viability of the various options suggested for future data collection, the following table outlines some initial cost estimates.

Option	Description	Cost Estimate	Comments
1	30 day ADCP survey in Pentland Firth	~£15k/deployment	Minimum of two locations.
2	30 day ADCP survey at peak flow locations	~£15k/deployment	Approximately six locations.
3	Single Waverider or Waverider arc - buoy deployment for one year	~£50k each	30 - 100km off the West coast of Orkney Includes equipment purchase (cheaper over long duration)
4	Vessel Mounted ADCPs on Ferries	Costs highly variable, dependent on the vessel access options	Requires negotiation with ferry owners and to be timed with dry dock
5	HF Radar	£1M+	Cost for the minimum of two radar stations.

Please note that the costs estimates do not include any contingency element.

5. Summary

This scoping study has concluded that there are various options that could be considered for strategic data collection.

1. ADCP Surveys: Measurements along the principal axis of the Pentland Firth will provide key information to the tidal developers in that region. At a wider level this could be supplemented by additional surveys at peak current locations in PFOW. Before undertaking additional ADCP data collection, associated modelling requirements should be considered, because ADCP measurements are very site specific.

2. Waverider Surveys: Provision of offshore data will allow estimation of wave resource across the PFOW region, and one or more Waveriders distributed in the western approaches to PFOW should be considered.

3. Vessel Mounted ADCPs on Ferries: This has the potential to provide a cost efficient longer term data set, however this approach has not been trialled in the region so further resource would be required to understand the practicalities of carrying this out.

4. HF Radar: Whilst costly, it will provide good coverage and can substitute for multiple ADCP or waverider deployments. It can also provide joint wave and current measurements, and would be suitable for deployment facing West of Orkney or across the Pentland Firth. Although the setup costs are high, the running costs of radar should be relatively low since marine operations are not required. This renders such a scheme more sustainable in the longer term, if the initial setup costs can be achieved.

In conclusion, this study has presented to The Crown Estate a summary of the existing datasets available in the area of interest, together with options for future additional data collection campaigns. The decision to commission such future data collection campaigns, or additional modelling work to complement a strategic approach, rests with The Crown Estate.

6. References

[Aquatera, 2009] “Pentland Firth Tidal Energy Project – Data Collection Study”, Highlands and Islands Enterprise, (2009).

[Natural Power, 2008], “Baseline Survey of Available Wave Data”, The Crown Estate, (2008).

6. Appendices

6.1 Tidal Data

Date	Data Type	Source	Area	Latitude	Longtitude	Duration	Held by
19-Nov-80	Currents -subsurface Eulerian	Wimpol Ltd (currently known as Fugro GEOS Ltd)		58.63	-3.45	10.00	BODC
17-Nov-80	Currents -subsurface Eulerian	Wimpol Ltd (currently known as Fugro GEOS Ltd)		58.66	-3.48	12.00	BODC
19-Nov-80	Currents -subsurface Eulerian	Wimpol Ltd (currently known as Fugro GEOS Ltd)		58.73	-3.47	10.00	BODC
21-Nov-80	Currents -subsurface Eulerian	Wimpol Ltd (currently known as Fugro GEOS Ltd)		58.79	-3.46	8.00	BODC
15-May-81	Currents -subsurface Eulerian	Offshore Environmental Systems Ltd		58.81	-3.46	10.00	BODC
19-Nov-80	Currents -subsurface Eulerian	Wimpol Ltd (currently known as Fugro GEOS Ltd)		58.85	-3.42	10.00	BODC
15-May-81	Currents -subsurface Eulerian	Offshore Environmental Systems Ltd		58.90	-3.47	10.00	BODC
07-Aug-74	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		58.93	-3.61	19.00	BODC
16-May-81	Currents -subsurface Eulerian	Offshore Environmental Systems Ltd		58.96	-3.39	9.00	BODC
09-Mar-76	Currents -subsurface Eulerian	Institute of Oceanographic Sciences Bidston Laboratory (currently known as National Oceanography Centre, Liverpool)		58.62	-2.42	37.00	BODC
07-Mar-76	Currents -subsurface Eulerian	Deutsches Hydrographisches Institut (currently known as Bundesamt für Seeschiffahrt und Hydrographie)		58.70	-2.24	22.00	BODC
31-Oct-74	Currents -subsurface Eulerian	Institute of Oceanographic Sciences Bidston Laboratory (currently known as National Oceanography Centre, Liverpool)		58.72	-2.08	38.00	BODC
07-Mar-76	Currents -subsurface Eulerian	Deutsches Hydrographisches Institut (currently known as Bundesamt für Seeschiffahrt und Hydrographie)		58.72	-2.08	49.00	BODC
07-Aug-74	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.08	-3.82	19.00	BODC
07-Aug-86	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.09	-3.63	58.00	BODC
21-Jun-88	Currents -subsurface Eulerian	Scottish Office Agriculture and Fisheries Department Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.15	-3.94	89.00	BODC
21-Jun-88	Currents -subsurface Eulerian	Scottish Office Agriculture and Fisheries Department Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.15	-3.94	96.00	BODC
26-Sep-91	Currents -subsurface Eulerian	Scottish Office Agriculture and Fisheries Department Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.15	-3.94	27.00	BODC
26-Jun-89	Currents -subsurface Eulerian	Scottish Office Agriculture and Fisheries Department Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.15	-3.93	86.00	BODC
25-Apr-90	Currents -subsurface Eulerian	Scottish Office Agriculture and Fisheries Department Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.15	-3.94	158.00	BODC
07-Aug-86	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.16	-3.95	59.00	BODC
01-Aug-85	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.16	-3.94	80.00	BODC

Date	Data Type	Source	Area	Latitude	Longtitude	Duration	Held by
07-Aug-74	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.16	-3.94	19.00	BODC
11-Aug-74	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.16	-3.94	15.00	BODC
21-Jun-88	Currents -subsurface Eulerian	Scottish Office Agriculture and Fisheries Department Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.32	-3.47	96.00	BODC
12-Sep-87	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.33	-3.48	126.00	BODC
20-May-71	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.77	-3.73	5.00	BODC
18-Jun-81	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.29	-2.17	13.00	BODC
18-Jun-81	Hydrography time series at depth	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.29	-2.17	16.00	BODC
10-May-72	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.29	-2.05	6.00	BODC
27-Sep-08	Currents -subsurface Eulerian	Fisheries Research Services Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.47	-2.03	223.00	BODC
07-May-08	Currents -subsurface Eulerian	Fisheries Research Services Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.47	-2.03	143.00	BODC
18-Nov-94	Currents -subsurface Eulerian	Scottish Office Agriculture Environment and Fisheries Department Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		59.97	-2.67	49.00	BODC
01-May-85	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		60.00	-2.44	30.00	BODC
01-May-85	Currents -subsurface Eulerian	Department of Agriculture and Fisheries for Scotland Aberdeen Marine Laboratory (currently known as Marine Scotland Aberdeen Marine Laboratory)		60.00	-2.44	99.00	BODC
14-Aug-71	Currents -subsurface Eulerian	Institute of Oceanographic Sciences Bidston Laboratory (currently known as National Oceanography Centre, Liverpool)		60.00	-2.97	29.00	BODC
	AWAC	OIC Marine Services	Hoy/Flotta	58.86	-3.18		OIC
	AWAC	OIC Marine Services	Hoy/Flotta	58.84	-3.19		OIC
	AWAC	OIC Marine Services	Hoy/Flotta	58.83	-3.16		OIC
	AWAC	OIC Marine Services	Hoy/Flotta	58.81	-3.13		OIC
	AWAC	OIC Marine Services	Hoy/Flotta	58.81	-3.11		OIC
	AWAC	OIC Marine Services	Hoy/Flotta	58.81	-3.09		OIC
Multiple Deployments	ADCP	EMEC	Billia Croo	58.97	-3.36	32+	EMEC
Multiple Deployments	ADCP	EMEC	Fall of Warness, Eday	59.14	-2.81	32+	EMEC
	ADCP	EMEC	Shapinsay Sound	59.00	-2.88	32+	EMEC
	ADCP	EMEC	Baas of Linton	59.06	-2.80	32+	EMEC
Oct-Dec 1997	Cefas Minipod	Cefas	Dounreay	58.59	-3.75	50+	CEFAS
Apr-May 2001	Cefas Minipod	Cefas	Dounreay	58.59	-3.75	~30	CEFAS
15-Aug-11 to present	Tide Gauge	ERI at UHI	John O Groats	58.64	-3.07	200+	UHI
6-Dec-11 to present	Tide Gauge	ERI at UHI	Scrabster	58.61	-3.55	150+	UHI
Multiple Deployments	ADCP survey	ERI at UHI	Inner Sound	58.67	-3.17	32+	UHI
Multiple Deployments	ADCP survey	ERI at UHI	Inner Sound	58.65	-3.06	32+	UHI

Date	Data Type	Source	Area	Latitude	Longtitude	Duration	Held by
10-Oct-09	BMADCP	SSE	Westray South AfL	59.19	-2.87		SSE
14-Nov-10	BMADCP	SSE	Cantick Head AfL	58.77	-3.17		SSE
15-Nov-10	BMADCP	SSE	Cantick Head AfL	58.76	-3.19		SSE
12-Mar-11	BMADCP	SSE	Westray South AfL	59.16	-2.85		SSE
12-Mar-11	BMADCP	SSE	Westray South AfL	59.18	-2.90		SSE
11-Jun-11	BMADCP	SSE	Cantick Head AfL	58.77	-3.24		SSE
11-Jun-11	BMADCP	SSE	Cantick Head AfL	58.76	-3.26		SSE
05-Nov-11	BMADCP	SSE	Westray South AfL	59.18	-2.88	36.00	SSE
05-Nov-11	BMADCP	SSE	Westray South AfL	59.20	-2.90	44.00	SSE
06-Nov-11	BMADCP	SSE	Westray South AfL	59.18	-2.87	44.00	SSE
06-Nov-11	BMADCP	SSE	Westray South AfL	59.16	-2.87	37.00	SSE
14-Sep-01	ADCP	UKHO	Pentland Firth Main Channel	58.67	-2.98	36.00	UKHO
19-Sep-01	ADCP	UKHO	Pentland Firth Main Channel	58.72	-3.09	31.00	UKHO
14-Sep-01	ADCP	UKHO	Pentland Firth Main Channel	58.73	-3.24	32.00	UKHO
04-Aug-09	Vessel Mounted ADCP	ERI at UHI	Pentland Firth Inner Sound	58.65	-3.14		BODC
Live	Satellite Altimeter Current Measurements	PO.DAAC	Worldwide				

6.2 Wave Data

Date	Data Type	Source	Area	Latitude	Longtitude	Duration	Held by
1994 onwards	K7 Wave Buoy	Met office		60.70	-4.50	6000+	Met Office
23-Dec-85	Waves (statistics)	Shell International Exploration and Production BV		58.31	-3.15	77.00	BODC
23-Dec-85	Waves (statistics)	Shell International Exploration and Production BV		58.31	-3.15	69.00	BODC
Dec-99	Non-Directional Waverider Buoy	OIC	Scapa Flow	58.93	-2.98	~30	CEFAS
Jan-Mar 2000	Non-Directional Waverider Buoy	OIC	Scapa Flow	58.93	-2.98	80+	CEFAS
2004 onwards	Datawell Waverider Buoy	EMEC	Billia Croo	58.97	-3.39	3000+	EMEC
2010 onwards	TriAxys Waverider and ADCP	EMEC	Scapa Flow (St. Marys)	58.90	-2.95	600+	EMEC
2011 onwards	TriAxys Waverider and ADCP	EMEC	Shapinsay Sound	59.00	-2.87	400+	EMEC
17-Jan-12 to present	Wave Buoy	ERI at UHI	Stroma	58.66	-3.28	150+	UHI
22-Dec-11 to present	Wave Buoy	ERI at UHI	Wick	58.44	-2.80	150+	UHI
14-Mar-12	Waverider Buoy	SSE	Costa Head AfL	59.19	-3.27	365+	SSE
14-Mar-12	Waverider Buoy	SSE	Costa Head AfL	59.24	-3.29	365+	SSE
May-08 to Mar-11	ADCP Waves	Aquamarine Power Ltd	Billia Croo	58.97	-3.36	1000+	APL
Multiple deployments	ADCP Waves	Aquamarine Power Ltd	Marwick Head	59.10	-3.36	~400	APL
May-12 onwards	AWAC Waves	Aquamarine Power Ltd	Billia Croo	58.97	-3.36		APL
Live and historical	Satellite Altimeter Wave Measurements	AVISO	Worldwide				

The Crown Estate
16 New Burlington Place
London
W1S 2HX
Tel: 020 7851 5080

The Crown Estate
6 Bell's Brae
Edinburgh
EH4 3BJ
Te: 0131 260 6070

www.thecrownestate.co.uk

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