

## **Enclosure 2:**

# **Acquisition and Processing of Multibeam and gravity data off the Faroe Islands:**

## **Technical requirements**

### **Objectives**

The Geological Survey of Denmark and Greenland (GEUS), on behalf of the Danish Government, has a requirement to carry out surveys in specific regions on the continental margin and adjacent slope and rise south and southwest of the Faeroe Islands, in order to obtain multibeam bathymetry and backscatter data. These data are required to support a potential claim for extended jurisdiction by Denmark under the United Nations Convention on the Law of the Sea (UNCLOS) Article 76. There is a requirement for collection and processing of high quality, full-coverage multibeam data in water depths of approximately 1000 to 4000 meters in the Atlantic Ocean, in order to precisely define the location of the foot of the slope as defined under Article 76.

### **Requirements**

1. Provision of a survey vessel capable of acquiring deep-water multibeam swath bathymetry, multibeam sonar backscatter data and gravimetric data in the designated areas north and northeast of the Faeroe Islands. Accommodation for at least one representative from GEUS.
2. Provision of a hull mounted deep-water multibeam system(s) and topside electronics aboard the survey vessel. The multibeam system shall collect full-coverage bathymetry and backscatter and be optimized to work in depths between 1000 and 4000 meters. The multibeam package shall include:
  - differential GPS and navigation system.
  - vessel motion sensing system.
  - capability to collect and process data needed for water column speed of sound and refraction corrections. Capability to collect and process on-line sound speed corrections collected at transmit point.
  - the ability to process data underway and produce onboard plots suitable for real-time quality control.
3. The contractor will provide a complete survey system, including vessel, multibeam sonar system, operators and engineers, on-board data processing and QC capability and ancillary office capacity to support the survey program. The officer in charge will hold a IHO category A

surveyors license or equivalent. CV's from relevant personnel will be included in the tender.

4. The contractor, in consultation with GEUS, will take responsibility for survey planning.

## **Deliverables**

### **1. Raw data**

All of the digital output from the multibeam sonar during data acquisition, and ancillary data not already integrated into the multibeam data stream including full orientation and position data, sound velocity profile information, tidal information and the integration parameters used including (but not limited to) installation offsets, misalignment angles and clock time differences. Positional information will include, at least: number and geometry of satellites used in position computations; age of pseudo-range corrections used in position computation, and; horizontal dilution of precision associated with each position computation. In addition to data provided with sonar data recordings, separate files containing the tide data and sound speed data applied to all multibeam soundings will also be provided. Tidal data will be supplied by GEUS prior to the survey. The data format and all data elements (e.g., date/time referenced to UTC, tide relative to MLWS to nearest cm, etc.) will be described.

### **2. Processed full density data.**

Aboard ship, during the data acquisition phase, all the raw data, including multibeam and ancillary integrated sensors must be examined and errors removed. Data will be corrected for position, elevation, orientation, water column sound speed and refraction effects and provided in a cleaned fully integrated form. All soundings and ancillary raw and reduced data must be provided with quality flags, indicating whether the data has been rejected or deemed to be outside deliverable survey specifications. Cleaned, reduced data will be provided on appropriate media in FAU format (Appendix 2) WGS84/UTM zone 30.

### **3. Reduced data set.**

A set of gridded data will be produced from the processed sounding data, from which two color-coded shaded relief maps will be delivered. The shaded relief models will be illuminated from orthogonal directions with a sun elevation no greater than 45 degrees. Data will be gridded at a grid size that is approximately twice the mean horizontal footprint of the beam at nadir (e.g., a 1.5 degree system at 1000 m would be gridded at ~50 m). This implies that the data set will be divided into regions of common depth and gridded at different scales depending on depth. The number of gridding regions will be determined in consultation with GEUS. Other representations that achieve the same resolution limits may also be acceptable. Gridded data will be delivered in digital files on appropriate media as both FAU grids and ASCII XYZ format.

### **4. Backscatter data**

For all multibeam data, raw backscatter data and reduced estimates of the seabed backscatter strength will be provided. The methods used to reduce the backscatter data will be fully documented. Geo-referenced maps of backscatter shall be provided at same scale as shaded relief maps described above.

## 5. Gravimetric observations

Gravity data shall be collected on all straight-line bathymetric tracks of at least 5 km length and constant speed. The raw marine gravity data shall be collected and stored at 10 sec intervals or less. The contractor shall provide GPS coordinates from the ship navigation system and bathymetric data depth vertically below ship extracted from multi-beam data at a similar interval for the processing of gravity data into marine free-air and Bouguer anomalies.

Processing of data will be done with zero-phase filtering, providing track no, UTC, latitude, longitude, filtered gravity, free-air anomalies (GRS80 ellipsoid) and marine Bouguer anomalies (standard density 2.67 g/cm<sup>3</sup>). A detailed processing report should include details on filtering and harbour gravity ties.

Gravity harbour ties are required at every port call. If interval between port call exceed approximately 14 days, GEUS may be willing to accept the substitution on one or more harbour ties with ties (cross-overs) with existing marine surveys, providing such surveys are recent (i.e., GPS navigation has been used), demonstrated to have an accuracy of 1.5 mgal r.m.s. or better, and a well-defined and well-described gravity reference system. It is up to the GEUS to verify the quality of such data, and GEUS will give its consent for the substitution of harbour ties in advance. GEUS will be willing to help in providing information on suitable tie-in data sources from the national Danish gravity data base.

6. Metadata shall be provided for all bathymetric, backscatter and gravity data files.

7. All data and digital plot files shall be provided on appropriate digital media in a completely documented format. The contractor shall also provide a detailed listing of all files submitted, their size, and format.

8. An interim report, including raw and processed data and draft color shaded relief maps and backscatter maps, shall be delivered to GEUS within one week of completion of operations.

9. A final report documenting equipment, procedures and survey operations shall be delivered to GEUS within 60 days of the completion of the survey. This report will include a full description of the bathymetric data collection procedures as required under UNCLOS Article 76 and outlined in the Scientific and Technical Guidelines of the UN Commission on the Law of the Sea ([http://www.un.org/Depts/los/clcs\\_new/commission\\_guidelines.htm](http://www.un.org/Depts/los/clcs_new/commission_guidelines.htm)) unless otherwise specified.

## Survey specifications

1. The multibeam sonar will have an effective beam width of no greater than 2 degrees in both the along-track and cross-track directions and lateral coverage of at least 3 km for depths greater than 1000 m. Maximum cross-track swath opening angle  $\pm 60$ deg for bathymetric data. For backscatter data cross-track swath opening angle may be opened to  $\pm 75$ deg.

2. Depth errors (at the 95% confidence level) will be less than 1% of the observed water depth. The contractor will document the procedures used to assure that data meets these specifications as well as providing an error budget for the complete survey setup.
3. Prior to commencing operations, the contractor shall conduct system accuracy tests to quantify the accuracy, precision and alignment of the multibeam sonar system in water depths and conditions equivalent to those found in the survey area. Testing shall include determination of residual biases in roll, pitch, heading and navigation timing error and transducer draft. A description of these values as well as the methodology used to determine these values will be delivered to GEUS.
4. Data from turns shall be excluded from the delivered products. Line numbers will be changed with each turn.
5. All depths shall be referenced to Mean Low Water Spring (MLWS).
6. Coordinated Universal Time (UTC) shall be used for all times recorded.
7. The sound speed profile in the survey areas must be measured and monitored at sufficient frequency and to an appropriate depth to assure that the bathymetric data provided meets the required depth accuracy specification. The sound speed profile should be determined with a calibrated system capable of measuring the speed of sound with errors no greater than 2 m/sec (at the 95% confidence level). A calibrated sound speed measuring system capable of measuring the sound-speed profile to at least 95% of the deepest anticipated depth in the survey area must be available, though collection of sound speed data to 95% of the full depth of the survey area shall only be required at beginning and end of the surveys. The on-line sound speed collected at transmit point shall be merged on time basis with the sound speed profile.
6. The draft, settlement and squat of the vessel will be measured, monitored, applied, and recorded with sufficient frequency to ensure that the bathymetric data provided meets the required depth accuracy specification.

7. The system must be capable of achieving bottom coverage at all survey depths such that no less than 3 beam footprints, center-to-center fall within a lateral distance of 10% of the water depth in the along-track dimension. It is understood that occasionally there may be brief periods of data degradation that are too short to justify resurveying. Occasional gaps of up to 5 consecutive ping cycles will be acceptable.

8. Cross-lines will be run at a frequency determined by the contractor as a continuing check on data quality as indicated in enclosure 2. Tie lines must agree at the acceptable depth error level (1% of depth at 95% confidence level) to at least +/- 45 degrees from nadir. The full swath width to which the tie lines demonstrate that data collected meet or exceed the acceptable depth error (1% of depth at 95% confidence level) will be the swath width used to determine line spacing and overlap. The contractor will decide numbers of cross-lines to be run prior to the general survey lines.

9. Horizontal positioning of the vessel, as determined via differential GPS, should be accurate to within 5 meters (at 95% confidence) during all surveying. An integrated DGPS/motion sensor solution should be offered to help mitigate navigational problems arising from intermittent transmission of DGPS corrections. All positioning shall be referenced to the WGS84 Datum. The contractor must demonstrate the accuracy prior to the survey, preferable on the Faeroe Islands.

10. The gravity data should be collected with a marine gravimeter, e.g. Lacoste and Romberg or similar type, capable of providing gravity measurements at an accuracy better than 2 mgal r.m.s. (1 mgal =  $10^{-5}$  m/s<sup>2</sup>) after filtering. The filtering length (full width) will be no longer than 5 min. The drift of the gravimeter during marine observations will be less than 5 mgal/month. The contractor will indicate the performance and reliability of the proposed gravity survey system. In case of shorter errors or gaps in the gravimetric data collection, while operating with multibeam bathymetry, GEUS will not request a resurvey. However, as overall objectives 95% of all planned bathymetric survey lines longer than 5 km must have useable gravity data.

The marine gravity measurements will be tied to harbour reference gravity points before and after the bathymetric/gravimetric survey, preferably the Faeroe Islands (GEUS will provide the necessary information). If the tie-ins are more than 1 week prior or after the actual survey, the contractor will demonstrate the performance of the gravimeter to be sufficiently stable to give a bias accuracy of better than 2 mgal during the survey period. The gravity reference point values must be given in absolute gravity system or IGSN71. A land gravimeter will, if necessary, be used to tie into reference gravity points not immediately located at pier.

### **Scope of Work:**

Acquisition of multibeam sonar data is required in the areas described in Appendix 1. Minor adjustments may come during the survey planning.

### **Price quotations**

The tenderer shall use the format below to give a price quotation for the multibeam

acquisition, based on the scope of services given above. Bids not complying with this format may be rejected.

Fixed prices:

Mobilisation/Demobilisation.

Lump Sum DKK

Acquisition of approximately 10.000 or 40.000 km<sup>2</sup> multibeam data offshore Faroe

Islands DKK/Km

Line change

DKK/Km

Transit between areas

DKK/Km

Day rate:

Mobilisation/Demobilisation.

Lump Sum DKK

Acquisition of approximately 10.000 and 40.000 km<sup>2</sup> multibeam data offshore the Faroe

Islands DKK/Day

Line change

DKK/H

Transit between areas

DKK/H

Gravity data acquisition pricing schedule:

Mob-/Demobilisation to the area of operations.

Lump Sum DKK

Acquisition rate

DKK/day

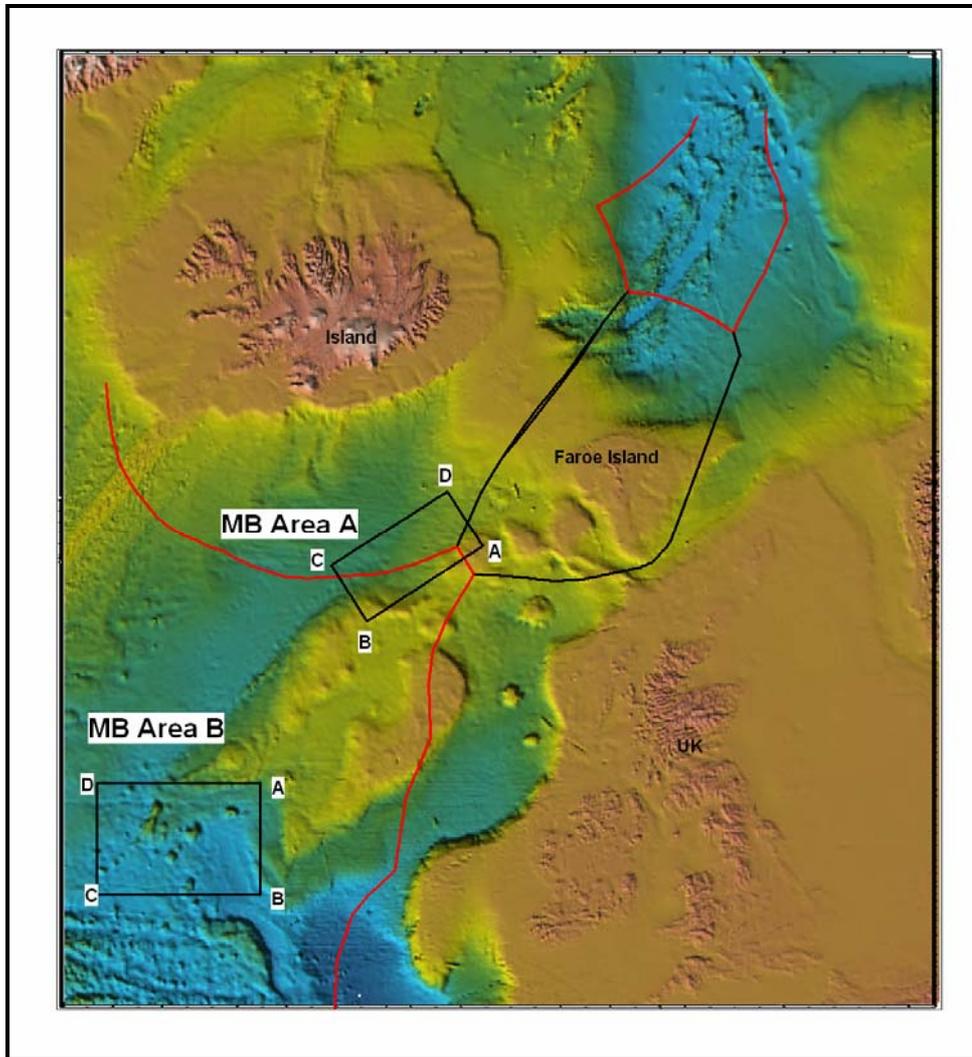


Figure 1 Areas for Multibeam acquisition

Area A		Area B	
A	12° 51' 44,7"W 60° 42' 38,5"N	A	21° 07' 03,5"W 55° 40' 41,4"N
B	17° 38' 12,7"W 59° 10' 07,8"N	B	20° 39' 59,7"W 53° 25' 40,1"N
C	19° 19' 59,3"W 60° 18' 06,0"N	C	26° 24' 37,2"W 53° 05' 18,8"N
D	14° 28' 18,8"W 61° 52' 51,3"N	D	27° 12' 05,8"W 55° 18' 43,8"N

Description of survey area:

The planned survey areas are in the waters south and southwest of the Faeroe Islands.

In Figure 1 two polygons depict the survey area ( to be announced 15 February 2007 on GEUS Website [www.geus.dk](http://www.geus.dk) .

The depth interval in the survey area is estimated from existing surveys to be in the order 1 - 3 km for Area A, and 2-4 km for Area B.

If the weather dictates a general line direction different from practical line direction then the cross-lines must be run perpendicular to this line direction.

## Appendix 2.

### FAU Format

#### General comments to the format.

When data from the hydrographic survey is converted to FAU, it is vital for the further process that the structure in the observations is conserved, i.e. that there is a Survey data structure for each beam in each ping. If, during the conversion, some beam possibly cannot be assigned an observation, a substitute Survey data structure must be inserted at its place and its quality number must be set to 128.

The *int* and the *time\_t* are 4 bytes long each; the *short* is 2 bytes and *char* 1 byte, each byte consisting of 8 bits.

Only quality values between 1 and 15 are valid quality indicators, the other bits in this byte are reserved for additional flagging. A precise description of the quality indicator values will be provided by GEUS.

#### The FAU data format is:

```
typedef struct {
int          N;          /* Northing of depth, in units of centimeter . */
int          E;          /* Easting of depth, in units of centimeter. */
int          depth;     /* observed depth in units of centimeter. */
time_t       sec;       /* UNIX time for the ping */
short        angle;     /* observed beam angle with respect to the Nadir, in units of 1/100 degree; */
char         heave;    /* observed heave for the beam, in units of 2cm */
char         roll;      /* observed roll for the beam: in units of 1/10 degree; */
unsigned char quality;  /* quality of the depth observation */
unsigned char amplitude; /* amplitude of the observation, not used for the moment */
char         pitch;     /* observed pitch for the beam in units of 1/10 degree */
unsigned char centisec; /* fractional ping time in units of 1/100sec. to be appended to sec */
}Survey_data;
```

The only relevant quality allowed for flagging data is: "Deleted by the multibeam system".

```
#define ERRORBIT      128 /* 1000 xxxx set in quality field when obs. is deleted by the multibeam system
*/
```

Other quality values used by customer is:

```
#define MULTIPATH     144 /* 1001 xxxx set in quality field when a multiple path depth is identified */
#define UNVERMSP      160 /* 1010 xxxx bits for flagging observations by parameter settings for MapSpike
*/
#define ERRORSSP      192 /* 1100 xxxx bits for flagging observations by VISE */
```