Technical Specifications Seabed Mapping

MAREANO Programme

Updated 30.11.2009

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1 Overview

This specification gives the requirements for data to be used in the Mareano project. In addition to product specifications, some equipment and procedure requirements are also presented.

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2 Terms and Definitions

Calibration

Calibrations comprise both the determination of corrections and the use of these corrections.

Complete Dataset

A complete dataset consists of hydrographic data satisfying data coverage requirements in terms of total area, survey area limits, sounding density and restrictions on data gaps.

Field Verification

A field verification of the survey spread calibration is based on analysing overlapping hydrographic data collected in a small area with suitable seabed characteristics. The survey pattern is selected in a way that any calibration error is as visible as possible.

Hydrographic Data

All data gathered during the survey and all the related metadata required for seabed mapping.

Mobilisation and Demobilisation

This includes all activity related to preparation and survey spread setup and dismounting.

The mobilisation is not considered completed until Client has approved the documentation of all calibration and verification activity as described in Section 8.1.

Survey area limit

A closed polygon that surround all measured and QC data in a project. Under certain instances several limits may be needed.

Survey spread

This includes the survey vessel itself and all the equipment required to perform the survey.

Survey vessel reference frame

This is an orthogonal coordinate system with a fixed position and orientation relative to the survey vessel hull.

Verification

Verification determines if a system or a sensor operates within specifications.

Unambiguous dataset

This indicates that every position on the seabed is assigned only one unique depth.

XYZ-data

The term XYZ- data is used to describe georeferenced individual soundings from the MBE.

3 Abbreviations

GNSS	Global Navigation Satellite Systems
IERS	International Earth rotation and Reference system Service
IGS	International GNSS Service
IHO	International Hydrographic Organisation
MBE	Multibeam Echosounder

MVP	Moving Vessel Profiler (used for "continuous" sound velocity or CTD observations)
NHS	The Norwegian Hydrographic Service
OM	Operation Manual
SVP	Sound Velocity Profile
THU	Total Horizontal Uncertainty (defined in IHO-S44)
TVU	Total Vertical Uncertainty (defined in IHO-S44)

4 Informal description of the data product

The Contractor shall deliver complete and unambiguous hydrographic data having the desired accuracy, collected with multibeam echo sounder (MBE) at its highest resolution mode.

In addition to the general seabed topography, all seabed features (like iceberg scour marks, coral reefs, pockmarks, sand waves and boulders, etc.) are very important to the Mareano project. Both the survey and the processing shall be carefully done to preserve all the seabed feature information and removing all the faulty soundings. No smoothing of the XYZ data shall be applied.

5 Equipment Requirements

Positioning

The GNSS antenna positioning uncertainty shall be within 0.3m (95%) for the horizontal component and within 0.1 m (95%) for the vertical component. Post processing of positioning is accepted. The positioning shall be based on a high- quality dual frequency GNSS receiver and a high- quality calibrated GNSS antenna type. All the raw data shall be stored for post processing.

Multibeam Echosounder (MBE)

Minimum water depth range at nadir	1200 metres
Sounding pattern	Equidistant
Maximum across track beam width	1,0°
Maximum along track beam width	0,5°
Input of sound speed measurement at transducer to the MBE	Yes
Roll, pitch and yaw beam stabilization	Yes
Seabed reflectivity (backscatter)	Yes
Water column data	Yes
Use online Absorption Coefficient profile	Yes

Attitude and heading sensor

The sensor requirements are:

Heading (GNSS based)	0.05° RMS
Roll and Pitch	0.02° RMS

Heave	0,05m or 5% of amplitude
Output rate	Min. 100 Hz

Sound Velocity and Absorption Coefficient profiles

The time between measured profiles shall not exceed two hours. Profiles to the full survey depth shall be made at least once every 6 hours. The rest of the profiles may be made to shallower depths in case the deeper layers show insignificant sound velocity variations.

The equipment shall either be a CTD sensor or a carbon fibre based "sing-around" sound velocity + temperature sensor. The sensor requirements are:

Temperature	0,01°C RMS
Sound velocity	0.05m/s RMS
Depth range, full scale	0.05% RMS

Profiles of absorption coefficient shall be calculated from the measured profiles.The profiles shall be calculated and applied without significant delay.

Formulas for calculations from measured CTD:

The formula from [*Chen and Millero*] or [*Del Grosso*] shall be used for calculation of sound speed.

Formula from [*Francois and Garrison*] shall be used for absorption coefficient calculation.

Sound velocity at transducer head

The sound velocity shall continuously be measured close to the sonar head(s) and automatically be applied by the MBE. This sensor shall utilize "sing around" sound velocity observations over a carbon fibre distance base. Accuracy requirements are the same as for the sound velocity profiles.

6 Reference Systems

Horizontal

The horizontal reference system for the data shall be EUREF89. ITRF positions must be transformed to EUREF89. The transformation formulas shall be approved by the Client.

Vertical

All depths shall be given as ellipsoidal depths in the EUREF89 datum.

Timing

All registrations of time shall be given in Co-ordinated Universal Time (UTC).

7 Data Quality Requirements

7.1 Resolution

The sounding distance (both along track and abeam) shall not exceed the limits given by the following 2nd order polynomial:

d_max = 0.048 + 0.0092*D - 0.000003567 *D*D

where **d_max** is the maximum accepted sounding distance and **D** is the depth

This polynomial is valid for depths between 100 m and 1200 m. For shallower areas, the sounding distance requirements for 100 m depth shall be used.

The maximum nadir angle for the swath shall also not exceed the following values:

Depth	Max nadir angle [°]
0-300	60
300-600	55
600-900	50
>900	45

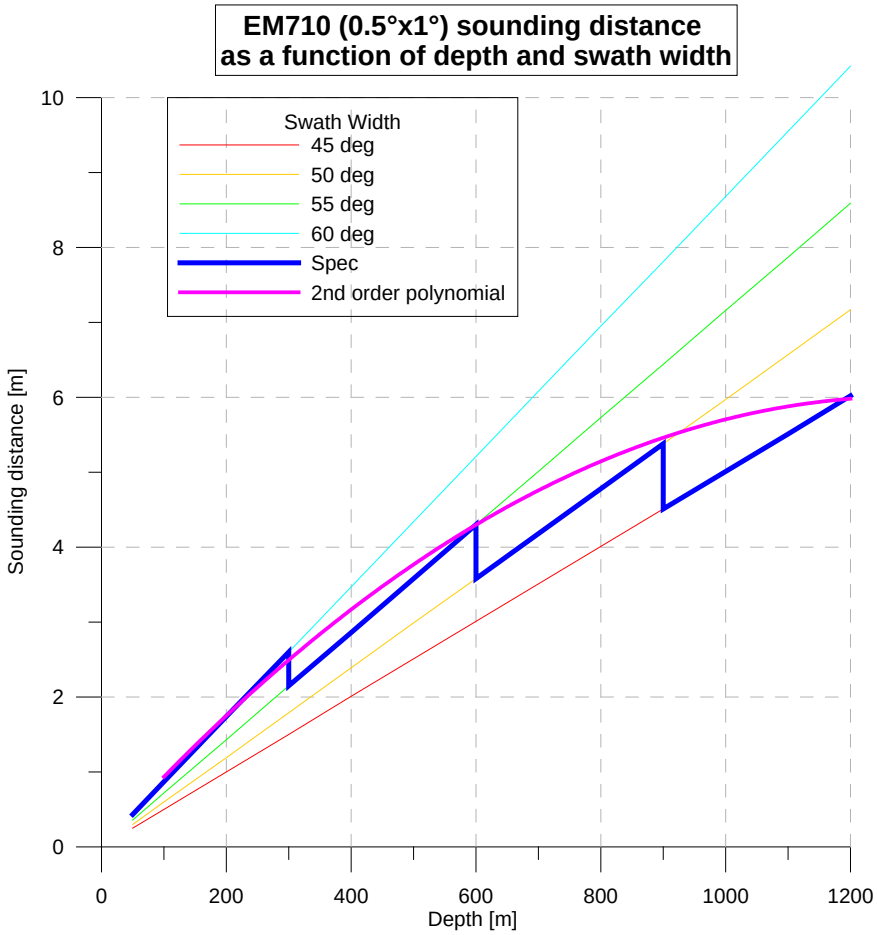

Figure 1 Example showing the EM710 sounding distance

7.2 Positional Uncertainty

Uncertainty limits are related to every individual sounding. 100% of the soundings shall comply with these requirements. No soundings shall have an error exceeding the 99% uncertainty level.

Positional uncertainty of the soundings on the seabed

The 95% total Vertical Uncertainty (**TVU**) shall be better than **0.25m + (0.004 * depth)**.

The 95% total Horizontal Uncertainty (**THU**) shall be better than **0.5m + (0.016 * depth)**.

Precision

Experiences from surveys conducted with EM710, indicates that the vertical deviation between overlapping lines can be kept smaller, provided that both the survey and the processing are carefully performed.

The 95% level of this deviation shall be better than **0.15m + 0.0018*depth**.

7.3 Timing

All data are to be time-stamped to **UTC** within **1ms (95%)**.

The Contractor shall read and timestamp all sensor data, and the Contractor is urged to document the timestamp uncertainty. Preferably all survey data (observations) shall be time stamped at source.

7.4 Data gaps

Data gaps are caused by missing soundings or by soundings rejected in the data processing. The accepted data shall be checked for data gaps by defining a data gap grid (DGG). The DGG grid size is 2.5 times the sounding distance calculated from the polynomial defined in Section 7.1.

Depth [m]	Sounding distance[m]	DGG grid size
0-50	0,50	1,5
50-100	0,93	2,5
100-200	1,75	4,5
200-300	2,49	6,0
300-400	3,17	8.0
400-500	3,77	9,5
500-600	4,30	10,5
600-700	4,75	12.0
700-800	5,14	13.0
800-900	5,46	13,5
900-1000	5,70	14,0
1000-1100	5,87	14,5
1100-1200	5,98	15.0

A DGG cell with less than **4** accepted soundings is defined as a gap.

The number of gaps shall not exceed 0.1% of the DGG cells.

More than three adjacent (i.e. cells sharing one side) DGG gap-cells is not accepted.

8 Survey control

The Contractor shall document that all requirements given in this specification have been met. The Contractor shall continuously carry out Quality Control during data collection and processing. The Client shall have access to these procedures.

Any modification of the survey spread shall be documented and reported to the Client.

8.1 Calibration and Verification

The calibration and verification delivery (reports and data files) shall contain all the required information for a third party to verify the results. The uncertainty of the calibration and verification results shall be documented.

The Contractor is responsible for maintaining and documenting the total system performance during the survey. This shall be obtained by calibration and verification. A new Field Calibration is required after any modification or reconfiguration of the survey spread.

A verification of all determined calibration parameters is required before the parameters are put into use. This shall be part of the calibration and verification procedure.

Calibration of all equipment in the survey spread

The Contractor shall conduct a calibration of the total survey spread. Calibration reports are to be delivered as a part of the tender.

The Calibrations shall include but not be limited to:

- *Post-installation calibration*:

  Initial determination of system parameters (e.g. position and orientation of new sensors relative to the Body reference frame)

- *Scheduled calibrations*:

  This comprises both laboratory calibration of instruments according to service interval requirements, and onboard calibration of composite systems

- *Calibration after incidents or after equipment configuration changes*:

  This comprises the calibration of all equipment affected by an incident, as well as calibration after remounting or replacement of essential parts of a system.

Verification

Documentation of verification procedures shall be delivered as a part of the tender.

The continued validity of the survey spread must be confirmed at relevant intervals during each survey season. Verification schedules shall be presented as a part of the tender.

If the verification determines discrepancies of the installation parameters, additional calibration of the system is required.

As part of the survey mobilisation, the Contractor shall perform a Field Verification to document that the complete survey spread with all equipment systems operates within specifications. This test shall be performed in an area specified by Client.

8.1.1 Survey vessel reference frame

A reference frame shall be defined for the survey vessel.

A sufficient number of permanently marked points shall be established at suitable locations on the vessel. All points intended for GNSS antenna mounting (e.g. marked by a drilled hole for the antenna attachment bolt) shall be surveyed (it is not sufficient to only survey the antenna itself). Surface vessels shall additionally have a minimum of 4 dedicated GNSS antenna mounts permanently marked in suitable locations for attitude sensor calibration.

Every sensor outputting data sensitive to sensor position or sensor installation angles, shall have these values determined in the survey vessel reference frame.

Sensor positions as well as sensor installation angles shall (as a minimum) be determined to the accuracy level specified in the equipment installation manual. The position and installation angle accuracy requirements for every system component must be carefully judged, so that the accuracy of the final product is kept within the specified range.

The uncertainty of all surveyed reference points on the vessel must be sufficient to satisfy the accuracy requirement related to the use of the points (i.e. often related to sensor calibration requirements).

The installation survey report shall contain a full description of the survey and a clear presentation of the results. The procedure for the determination of sensor position and installation angles, as well as the uncertainty of the determined values, shall be well documented.

The installation survey delivery shall include the report and the digital observation files. This delivery shall contain all the required information for a third party to verify the results. An example of such a report can be found in “Info_C_alignment_report.pdf”.

8.1.2 Sensor Alignment

Multibeam Echosounder

The MBE transducer installation angles shall be determined by a land-survey operation to obtain a sufficient connection to the survey vessel reference frame.

Attitude and Heading sensors

Attitude sensors shall be mounted on a rigid, machined surface with steering pins to ensure repeatable precision mounting.

The determination of vessel motion sensor and heading sensor installation angles shall be by use of at least four (preferably more) GNSS antennas, to obtain a time series of the “true” orientation of the survey vessel. During calibration, the vessel shall manoeuvre to obtain realistic attitude sensor behaviour. Installation angles are determined from the difference between the GNSS derived attitude values and the attitude sensor readings. Alternative methods will be accepted if they are documented to give better results.

Positioning sensor

GNSS antenna calibration values from the IGS shall be utilized.

Examples of sensor alignment are given in “Info_C_alignment_report.pdf”.

8.1.3 Sensor Calibration

All equipment requiring regular calibrations against standards shall hold a valid calibration certificate from a certified institution. The equipment shall be maintained and handled according to manufacturer's recommendations to make it plausible that the equipment is kept within its accuracy specifications between calibrations.

The Contractor shall keep a historical record all calibration and verification results for all equipment at the serial number level.

8.2 Crosslines and line overlap

Survey line overlap

There shall be at least 10% overlap for survey lines where a swath angle of more than 55° from nadir is used.

Crosslines

There shall be at least one crossline for every sub-survey area. If the sub- survey area size exceeds 500 km^2, there shall be one crossline per 500 km^2. Crosslines may be planned in connection with crew change or infill lines. The crosslines may be split into several parts. Crossline (or crossline segments) shall cover the sub survey area from one side to the other in a direction of at least 70° from the ordinary survey direction.

8.3 Reports

All reports shall be sent by e-mail to the Client.

Daily reports during survey

These are very brief reports indicating daily problems and progress.

Weekly reports during survey

More comprehensive (but still brief) reports indicating survey progress and status related to schedule.

The report shall contain

- The estimated survey completion date
- The surveyed area [km^2] and a plot showing the area.
- Processing and QC progress and status related to schedule
- The estimated final delivery date

Weekly processing reports

Brief reports indicating processing and QC progress and status related to schedule. The report shall include the estimated completion date. Processing reports are requested during the time from survey completion until the data are accepted.

Final report

A final survey report shall be delivered as a part of the documentation. This report is the Contractors summary of the survey, and shall contain documentation of all hydrographical data, data processing, interpretation and information of data quality.

The report shall as a minimum contain:

- Data collection method and their technical specifications and comments on the processes
- Geodetic reference system, positioning-methods and their error budgets

- Date and time for the data collection
- All corrections applied to the data and details of Quality Control Procedures
- Estimates of random and systematic errors concerning the data
- Other data referred to in IHO S44, Chapter 5
- Experiences, comments and findings

Processing parameters should be included digitally together with the project data, or be included in the final survey report.

The final survey report shall be submitted to the Client no later than two weeks after the completion of the quality controlled data set.

Executive summary report
Following all data deliverables, an executive summary report shall be delivered. A template for an Executive Summary Report can be found in *Info_A_Executive Summary_template.doc*

9 Data Processing

Careful processing is required to obtain the specified data quality.

The processing shall focus on removing all faulty soundings at the same time as the seabed feature information is preserved.

Artefacts in the processed XYZ- data shall be kept at an insignificant level not disturbing the seabed image.

Faulty soundings shall be flagged as rejected, and no soundings shall be deleted.

XYZ-data shall not be smoothed.

10 Data Product Delivery

Data types:

- Accepted XYZ-data (observed data)
- Rejected XYZ-data (observed data)
- Horizontal and vertical uncertainty for each depth value (THU and TVU)
- Survey area limits generated from accepted data
- Gridded depths based on accepted data
- Sensor data
    - MBE (depths, backscatter, water column)
    - Motion sensor
    - GNSS data (RINEX)
    - SVP

Data units and resolution:

- Depths shall be given in metric units with 0.01 m resolution.
- Positions shall be given as decimal degrees with 0.0000001° resolution.

- THU and TVU shall be given in metric units with 0.01 m resolution.
- Grids shall be metric in the UTM projection. The grid file size shall not exceed 1Gb. The Contractor shall include information about the utilized gridding algorithm and the parameter settings. The grid cell size is depth dependent.

Depth region	Grid cell size
0-300m	3m
300-800m	5m
800-1200m	10m

Data format:

XYZ-files:

XYZ- data shall be divided into geographical (not projected) sub-areas and should preferably not exceed 2 Gb in size. A file shall contain all accepted XYZ-data within the sub-area. The files (both Rejected and Accepted XYZ-data) shall be ASCII data and use the following record format:

Latitude, longitude, depth, THU, TVU

Sensor data:

Sensor data shall be delivered in a format agreed between the Contractor and the Client. A preliminary image of the backscatter information in the survey area shall be delivered as a tiff or jpg image. The Client shall have access to all data collected during the survey.

Survey area limits:

The Survey area limit shall have the file extension *.irap*. This is a geographical ASCII IRAP format without header.

Example:

16.4877026 71.5047873 0.0

16.4876353 71.5047728 0.0

16.4875556 71.5047557 0.0

999.00 999.00 999.00

16.4871803 71.5048135 0.0

16.4871171 71.5048003 0.0

16.4873026 71.5048173 0.0

999.00 999.00 999.00

Exchange medium and format

The Contractor shall deliver all digital data on External-HHD, DVD or CD-ROM when suitable. All data shall be submitted on ASCII-format if not otherwise agreed between the parties.

File and folder structure of delivery (including naming convention):

By first delivery XYZ files and survey limit files shall have a revision number rev0 in the filename. If first delivery is rejected, later deliveries of the same survey should be named revA, revB, etc.

Vertical reference: Ellipsiod (ell) and Mean Sea Level (msl) or LAT(lat)

Mareano/ “

Survey name/ “vessel name” –“year” – “survey number”(Example: *hydrograf-2009-01*)

- Survey report:

  Executive_report_“vessel name” –“ year” – “survey number”.doc
- Backscatter: Plot of backscatter in image-file.

  BS_“vessel name” –“ year” – “survey number”.tif
- Survey limit:

  SL_“vessel name”_“ year”_“ survey number”_”revision”_”coordinate system”.irap

  Example: *SL_hydrograf_2009_01_rev0_geo.irap*

Mareano/ **Survey name/ XYZ/Accepted_points/**

Filename: “survey number_sub area number”_”vertical reference”_”revision number”.xyz

Example: *01_P1_ell_rev0.xyz*

Mareano/ **Survey name/ XYZ/Rejected_points/**

Filename: Rejected_“survey number”_”revision number”.

Example: *Rejected_01_rev0.xyz*

Mareano/ **Survey name/ XYZ/Gridnodes/**

Filename: GRID_”gridsize”_“number"_”vertical reference”_”revision number”.xyz

Example: *GRID_5m_01_ell_rev0.xyz*

Mareano/ **Survey name/ RAW/ -**

Filename: ”line number”_"date"_"time"_“vessel name”.all

Example: *0001_20090423_103641_hydrograf.all*

Or similar structure which the logging software permits.

Mareano/ **Survey name/RINEX/ -**

GNSS raw RINEX data.

11 Metadata

The metadata shall contain all significant information related to the Hydrographic data and the data processing. The metadata shall be included in the Executive Summary Report.

12 Data Storage

Contractor shall store all collected Hydrographic data for at least 5 years.

13 Support

The Contractor shall provide support regarding the survey and the deliveries for at least 2 years after data acceptance.

14 Documentation

The Contractor shall provide an Operation Manual (OM), which shall contain a complete description of the survey and the processing work. The description shall include calibration, verification, data acquisition, data processing and data delivery procedures. A draft of this OM shall be delivered as part of the Tender documents, and the final OM is to be approved by Client before survey commences.

15 References

Chen and Millero	*Algorithms for computation of fundamental properties of seawater*, Unesco technical papers in marine science 44, page 46.
Del Grosso	*New equation for the speed of sound in natural waters.* *V.A. Del Grosso. J. of Acoustical Soc. of America oct 1974 p1064*
Francois and Garrison	*Francois R. E., Garrison G. R., "Sound absorption based on ocean measurements: Part II:Boric acid contribution and equation for total absorption*", Journal of the Acoustical Society of America, 72(6), 1879-1890, 1982,
IHO S-44	*International Hydrographic Organization Standard for Hydrographic Surveys, Special publication No 44. 5th edition, February 2008.*