EDCON-PRJ Specifications

Marine Gravity and Magnetic Services

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December 2009

SPECIFICATIONS
MARINE GRAVITY AND MAGNETIC SERVICES

I) Marine Gravity Data Acquisition

The following specifications are applicable for the LaCoste & Romberg Model S marine gravity meter, and assume with a state-of-the-art instrument with and computerized control system. The system should be provided with a full-function digital data acquisition system capable of recording the gravity meter signals as well as peripheral data, as required.

A) Contractor shall ensure that the marine gravity meter meets manufacturer specifications and shall carry out all the manufacturer's recommended tests of the marine gravity meter system prior to start of work. The results of these tests will be available for inspection by Company. The Contractor shall have adequate consumables, test equipment, tools, software, manuals, and spare parts to operate and maintain the gravity meter system.

B) Failure of the marine gravity meter system shall not be cause to suspend the Work on a Line nor cause to delay commencing Work on a new Line. Contractor shall make best efforts to rectify the situation.

C) Contractor shall designate and identify to Company at least one gravity engineer. This engineer shall be trained and competent to:
   a) Operate and monitor the gravity system including the digital acquisition system and all recorded data.
   b) Perform still readings and land gravity base ties (if required).
   c) Perform any standard gravity meter field repair or maintenance.
   d) Understand gravity data processing requirements sufficiently to identify problems with the gravity meter, navigation, bathymetric, vessel or other systems that might impact the final gravity results.
   e) The gravity engineer shall be computer literate.

D) The stabilized platform carrying the gravity meter sensor shall be mounted:
   a) As near as practicable to the point of intersection of the pitch, roll, and yaw axes of the vessel.
   b) With the long axis of the gravity sensor parallel with the long axis of the vessel.
   c) To avoid extremes in ambient temperature.
   d) To avoid bumps, vibration, RF, strong magnetic fields, or other interference to the stabilized platform and gravity meter sensor performance.

E) Gravity meter outputs required to compute gravity values will generally be recorded continuously, both on-line and off-line, on appropriate digital media at a sampling interval of one second or better. Gravity meter recording may be interrupted while off-line to accommodate data archive functions, daily checks or calibrations, system reconfiguration, testing and maintenance.
   a) At a minimum the following data channel outputs of the marine gravity meter are required:
      (1) Meter gravity
      (2) Spring Tension
      (3) Beam position (unfiltered)
      (4) Cross accelerometer
      (5) Long accelerometer

b. If available, the following should also be recorded:

The ten (10) "Analog Channels"

B =	Average beam position
CC =	Total cross coupling
TC =	Total correction
VCC =	Inherent cross coupling
AL =	Long imperfection cross coupling
AX =	Cross imperfection cross coupling
VE =	Vertical error (average beam velocity squared)
HAcc =	Cross acceleration
LAcc =	Long acceleration
AX2 =	Second-order imperfection cross coupling

E) Digital gravity field data will be provided on appropriate digital media as agreed with Company. A minimum of two sets of archival digital data records, one master and one copy, will be maintained.

The archival copies shall be updated a minimum of once per 24-hour recording period. All gravity survey data will be delivered to Company or to a destination designated by Company within 30 days of data being transferred from the ship to a shore facility.

F) There shall be continuous on-line and off-line digital navigation data recorded directly to the gravity system data logger at a one second sampling interval. Navigation recording may be interrupted while off-line to accommodate data archive functions, daily checks or calibrations, system reconfiguration, testing and maintenance. The preferred navigation data string should include date, time (recorded to a precision of 0.1 seconds), line number, shotpoint number, DGPS-derived velocity and heading data, and position coordinates, including vertical (z) position. The processed results from the navigation data should yield speed over the ground at a precision of 0.01 knots or better, and heading at a precision of 0.1 degrees or better.

G) There shall be continuous on-line and off-line digital water depth data recorded directly to the gravity system data logger. The water depth data string should include date, time, line number, shotpoint number, and water depth. Water depth data may be included in the navigation data string indicated in i) above.

Analog water depth charts must be annotated at least once every 30 minutes with indicated water depth (indicate units of measurement), shotpoint and time. Any chart scale changes must be clearly annotated.

H) Company to provide a stripped P1/90 format tape containing header and vessel records should be provided for gravity data processing. The tape should include line number, time, date, shotpoint, latitude, longitude, X coordinate, Y coordinate, and bathymetry data.

I) Gravity system drift should be nominally less than three mGal per month for a stabilized instrument. The drift may be considerably higher than three mGal per month following instrument shipment or after a period when the instrument is off heat. Gravity meter drift shall be monitored by one of the following methods:

a) Collecting and comparing gravity still readings at each dock or anchorage occupied and reoccupied during the work. Gravity still readings will be available for inspection by Company.
b) Statistical analysis of survey line intersections during the data processing sequence. It is essential that gravity tie lines be acquired to facilitate gravity system drift evaluation. Tie lines may be acquired during periods of seismic down time, when the vessel transits the prospect and may be run at full vessel speed. Tie lines should not be acquired during periods when the gravity instrument performance is significantly degraded due to extreme weather conditions.

J) Gravity Base Ties
a) Contractor shall identify and inform Company, prior to the start of the survey, of any suitable gravity base stations within reasonable proximity of docking locations that may be used during the survey. Reasonable proximity is 500 m.
b) Wherever suitable gravity base station data are available, a gravity meter base constant, corrected to mean sea level, must be calculated

c) If no suitable gravity base station exists within reasonable proximity of gravity still reading locations occupied during the survey, then Company may choose to have Contractor establish a new gravity base station at the gravity still reading location at the expense of Company. Alternatively, an acceptable substitute for an established gravity base, in most cases and at the option of Company, is to tie the survey to the gravity grid derived from satellite gravity or EGM08 (Earth Gravitational Model 2008).

K) Daily Underway Sea Checks

The following Daily Sea Checks shall be logged each day by the gravity operator:

a) Check the synchronization of the spring tension counter and the control computer
b) Check the synchronization of the clocks on the gravity recording system and the survey master time source.
c) Check the performance of the heaters on the gravity meter.
d) Check the power supply voltages.
e) Check the ac input voltage and frequency.
f) Check the gravity meter pressure.
g) Check the gravity sensor temperature
h) Check the operational condition of any vibration isolation equipment

L) In-port Check List

Whenever the vessel is stationary, at a dockside or at anchor, the following checks should be performed, in addition to the Daily Underway Sea Checks:

a) Check the beam position zero and gain
b) Acquire and record a still reading.
c) Acquire and digitally record a K-check; check total correction and average beam readouts.
d) Check the level of the gravity sensor.
e) Check the performance of the stable platform.
f) Check the oil level in the shock absorbers about once a month.

M) Contractor will use autopilot controlled steering as much as possible:

a) Course changes will be made by a series of small incremental changes.
b) The rate of course changes should not exceed two degrees per minute.
c) Change of vessel speed should not exceed one knot per minute.

N) Positioning data shall be recorded at a one-second or better sample rate. In any event, the time lapse between recorded positions to be used in processing the gravity data shall not exceed 10 seconds.

O) The Contractor shall maintain an accurate, continuously up to date and legible log of all events pertinent to the SURVEY including: operating status of all sensors and records, weather and sea state conditions, and all events that may adversely affect the gravity data quality.

P) Data Evaluation

Contractor shall evaluate a minimum two-hour sample of gravity data with corresponding position data at least once each week. Water depth data shall also be evaluated for completeness and quality.

Q) Weekly Status Report

Contractor shall provide client with a weekly status report specific to the acquisition and processing of marine gravity data. The report shall include:

a) General survey information
b) Production statistics
c) Listing of significant survey events
d) Disclosure and evaluation of problems
e) Weekly data evaluation
f) Data processing status

II) Marine Magnetic Data Acquisition

The following specifications are not unique to any particular marine magnetometer system, but assume a current, state-of-the-art instrument.

A) Contractor shall ensure that the marine magnetometer meets manufacturer specifications and shall carry out all manufacturers recommended tests of the marine magnetometer system prior to the start of the work. The results of these tests will be available for inspection by Company. Contractor shall have adequate consumables, test equipment, tools, software, manuals, and spare parts to operate and maintain the magnetometer system. Contractor shall have at least one spare tow cable and sensor.

B) Failure of the marine magnetometer system shall not be cause to suspend the Work on a Line nor cause to delay commencing Work on a new Line. Contractor shall make best efforts to rectify the situation

C) Contractor shall designate and identify to Company at least one magnetometer engineer. This engineer shall be trained and competent to:
   a) Operate and monitor the magnetometer system including the digital acquisition system and all recorded data.
   b) Perform any standard instrument calibrations or tests
   c) Perform any standard magnetometer field repair or maintenance.
   d) Understand magnetic data processing requirements sufficiently to identify problems with the magnetometer, magnetic monitor station, navigation, vessel or other systems that might impact the final magnetic results.
   e) The magnetometer engineer shall be computer literate

D) The magnetometer sensor shall be towed astern of the vessel at a position chosen to provide optimum results. Nominally, this position should be:

   a) A minimum of 2.5 times the length of the vessel astern of the vessel
   b) Far enough from other towed equipment to prevent magnetic data quality degradation due to:
      (1) Physical contact with other towed equipment
      (2) Electrical noise from other towed equipment
      (3) Data bias from proximity to magnetic fields from other towed equipment
   c) At a nominal tow depth of three meters.

E) Magnetometer outputs will generally be recorded continuously, both on-line and off-line, on appropriate digital media at a sampling interval of ten seconds. or better.

   Magnetometer recording may be interrupted while off-line to accommodate data archive functions, system reconfiguration, testing and maintenance.

F) Some vessel towing configurations may require full or partial retrieval of the magnetometer tow system during turns or shallow water operations to avoid equipment damage.

G) The following information shall be digitally recorded at 10 second intervals or better:
   a) Total Magnetic Intensity
   b) Date and Time
   c) Position data

   Magnetometer data may be recorded on a gravity meter, navigation system or other digital data logger.

H) Records will be kept such that digital and printed magnetometer recordings can be clearly identified and tied to concurrent recorded seismic data and/or fiducial points from positioning systems. A stripped P1/90 format tape containing header and

vessel records should be provided for magnetic data processing. The data should include line number, time, date, shotpoint, latitude, longitude, X coordinate, Y coordinate, and bathymetry data.

I) Magnetometer noise shall not exceed +/- 3 nT.

J) Data Evaluation

Contractor shall evaluate a minimum two-hour sample of marine magnetometer data with corresponding position and magnetic monitor data (if available) at least once each week. Data shall be spike edited and the IGRF correction applied. Filtering consistent with the data quality shall be applied as necessary. Data evaluation shall indicate noise content, spike density, and general data character.

K) Weekly Status Report

Contractor shall provide client with a weekly status report specific to the acquisition and processing of marine magnetic data. The report shall include:

a) General survey information
b) Production statistics
c) Listing of significant survey events
d) Disclosure and evaluation of problems
e) Weekly data evaluation
f) Data processing status

This report may be combined with the gravity Weekly Status Report

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III) Base Station Magnetic Data Acquisition

Observatory Magnetic Station Option:

Contractor shall identify and inform Company, prior to the start of the survey, of any suitable observatory magnetic monitor stations within reasonable proximity to the survey. Company shall inform Contractor if the observatory is acceptable to provide magnetic monitor data for the project.

Dedicated Base Station Magnetometer

If no acceptable observatory magnetic monitor station is available, Contractor will provide a dedicated base station magnetometer station. The following specifications are not unique to any particular magnetic monitor station system, but assume a current, state-of-the-art instrument.

A) Contractor shall ensure that the base station magnetometer meets the manufacturer's specifications and shall carry out any manufacturer recommended tests of the magnetic monitor station system prior to the start of the work. The results of these tests will be available for inspection by Company. Contractor shall have adequate consumables, test equipment, tools, software, manuals, and spare parts to operate and maintain the magnetic monitor station equipment. Contractor shall have one complete spare base station magnetometer system including sensor, cables and control electronics.

B) Failure of the magnetic monitor station shall not be cause to suspend the Work on a Line nor cause to delay commencing Work on a new Line. Contractor shall make best efforts to rectify the situation

C) In the event of a failure of the dedicated base station magnetometer, Contractor shall acquire observatory magnetic data from the nearest available observatory to cover periods of on-line marine magnetic data acquisition at the expense of Company.

D) Contractor shall designate and identify to Company at least one base station magnetometer engineer. This engineer shall be trained and competent to:
   a) Operate and monitor the base station magnetometer.
   b) Perform any standard base station magnetometer instrument calibrations or tests.
   c) Perform any standard base station magnetometer field repair or maintenance.
   d) Understand magnetic data processing requirements sufficiently to identify problems with the base station magnetometer or other systems that might impact the final magnetic results.
   e) The magnetometer engineer shall be computer literate and able to manipulate data files, work with modem based data transmission systems and otherwise be capable of fulfilling the requirements related to proper operations of the magnetic monitor station system.

E) The station shall be located at the nearest practicable position to the survey area.

F) The base station magnetometer sensor must be located in a secure and magnetically "clean" environment, well away from automobile traffic, power lines, any kind of rotating machinery, any other sources of magnetic noise and in a secure environment.

G) It is also important to avoid positioning the magnetometer sensor in areas of strong local magnetic gradients. A site survey should be conducted to determine the local magnetic gradient. The following site survey procedure should be followed using a portable magnetometer instrument:

a) All site survey activity must be recorded in an activity log that includes: Time, Total Magnetic Field values, and Relative Locations of all site evaluation readings taken with the portable magnetometer. This log should also include a description of all site selection activity including sketches of possible locations.
b) Locate the portable magnetometer sensor at the preferred location for the magnetic monitor station sensor.
c) Take a series of six readings at this location. These readings should repeat to within a few tenths of a nanotesla.
d) Measure the local gradient by moving the portable magnetometer North from the preferred sensor location and taking single readings at approximate five meter intervals to a distance of 30 meters. Ideally the gradient should not exceed two nanoteslas per five meter increment, or a total of 12 nanoteslas at 30 meters from the preferred sensor location.
e) Repeat the check to points 30 meters South, East, and West from the preferred sensor location.
f) If the readings indicate a gradient in excess of ten nanoteslas, then alternate magnetometer sensor locations should be considered and site surveys should be conducted at the alternate locations.

H) If site surveys at all reasonable alternate locations results in no location with less than a ten nanotesla gradient, then the location with the lowest gradient should be utilized.

The primary concerns are selecting a magnetically clean site and security for the equipment. The local gradient is a secondary consideration.

The base station magnetometer sensor should be positioned in a secure location and protected from interference caused by inclement weather. Any directional orientation requirements for proper installation of the sensor should be observed.

I) The base station magnetometer shall be operated at a sensitivity of one nanotesla or better

J) The base station magnetometer will record during all periods of marine magnetic data acquisition by the survey vessel.

K) The operator shall maintain a station log. This log must include all information and activities that may have an impact on the magnetic monitor data set. Time and Total Magnetic Field values should be entered as often as practical but at least once every 12 hours**.**

L) Digital base station magnetometer data shall be recorded at a sampling rate of one minute or better. Digital records shall include Total Magnetic Intensity, Date and Time.

Digital base station magnetometer recording may be interrupted for brief periods, preferably while the marine magnetic survey is off-line, to accommodate data archive requirements.

M) To the extent allowed by communications facilities, digital data will be transmitted to Contractor electronically each day. Contractor shall plot and inspect each daily sample to evaluate data quality and identify any system malfunction.

N) Time synchronization checks between the base station magnetometer system time and a reliable time standard such as GPS time will be made on a daily or more frequent basis. Any time adjustments must be clearly noted in the Magnetic Monitor Log, including the amount of the time offset observed and the exact time the clock is reset.

O) A portable GPS receiver will be provided to record accurate base station magnetometer locations and to synchronize magnetometer system time.

IV) Data Processing

A) Standard Procedures

Data processing should produce high-resolution maps, profiles and digital data. The primary objective is to maximize the geologic signal with minimal distortion. The EDCON-PRJ processing sequence is as follows:

a) Gravity meter output is converted from "counter units" to milliGals and corrected for phase and amplitude distortion caused by gravity meter filters.
b) Latitude correction is applied using the WGS 84 International Gravity Formula. Other formulae may be applied if client desires.
c) Meter drift is removed from the gravity data as obtained from still readings. If no still readings are provided, a correction based on line intersection statistics and available historical records is made.
d) Data is edited to identify and correct bad points.
e) An Eötvös correction is computed and applied in such a manner as to minimize Eötvös anomalies. The EDCON-PRJ Eötvös correction algorithm uses a time-varying filter to minimize the correlation between final corrected gravity and the Eötvös correction without over smoothing the basic data. Window lengths and amplitude factors are selected based on the visual inspection of each line segment of data.
f) A two-dimensional Bouguer correction is applied. The bathymetry data are analyzed to determine if a 3-D Bouguer correction is required. Density is computed and tested at several representative locations across the survey area (Nettleton profiles). The best density fit for the overall area is then selected for the Bouguer correction.
g) Position correction for sensor offset is applied.
h) Measured total magnetic intensity is corrected for the Earth's normal field (IGRF) and observatory data, when appropriate.
i) Lines are visually inspected to identify filters that eliminate extraneous noise without loss of meaningful anomalies.
j) If analog data are digitized, the digitizing is done such that the character of the analog data are preserved. Each profile plotted from digitally recorded or digitized data is compared with original analog data to verify the accuracy of the digital data.

B) Extra Processing Procedures

Digitization: Missing or digitally unrecoverable data can be digitized if analog records of sufficient quality are available.

Special Maps: Analytic operators and filters can be applied to the grid if requested.

3-D Bouguer Correction: In areas of severe topographic relief, a 3-D Bouguer correction may provide a more useful Bouguer Gravity map. Water depth data from sources other than the survey may be introduced to provide a more accurate Bouguer correction and to reduce "edge effects".

Virtual Network Analysis -- VNA: VNA processing is a line network analysis procedure designed especially for 3-D surveys. This proprietary EDCON-PRJ procedure ensures that short-wavelength anomalies are accurately mapped and that distortion resulting from the application of conventional line intersection adjustment algorithms is eliminated

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C) Deliverable Products

a) **Processed Digital Data:** All basic and final processed data, is recorded onto CD-ROM. During processing, EDCON-PRJ routinely makes preliminary products available to the client on a secure section of the EDCON-PRJ web site. The digital data will contain samples of the following at one-second intervals along every survey line:

(1) Line number
(2) Julian date
(3) Time
(4) Shotpoint
(5) Water depth (meters)
(6) Latitude (decimal degrees)
(7) Longitude (decimal degrees)
(8) X-coordinate
(9) Y-coordinate
(10) Observed gravity
(11) Eötvös correction
(12) Free-air gravity
(13) Adjusted free-air gravity
(14) Bouguer gravity
(15) Adjusted Bouguer gravity
(16) Observed magnetic total field
(17) Magnetic observatory monitor
(18) Magnetic anomaly (corrected for IGRF and observatory monitor)
(19) Adjusted magnetic anomaly

b) **Maps:** Maps will be prepared for:

(1) Free-air Gravity
(2) Bouguer Gravity
(3) Bathymetry
(4) Magnetic Anomaly

Map scale will be as specified by client. Maps will be written as digital files in Adobe PDF format.

c) **Report:** EDCON-PRJ will submit a complete report containing a description of the processing parameters and procedures. It will include an analysis of the raw and processed data and line intersection statistics and a description of data formats.

Digital data, maps, and the report (in Adobe PDF) will be delivered on CD-ROM. Two copies of the CD will be provided. Additional copies of the CD and paper copies of the maps and report can be delivered at nominal extra cost.

D) Timing

Processing of up to 5000 km of gravity magnetic data typically requires 30 days to complete; larger data sets may require more time. Turnaround time is measured from the date EDCON-PRJ receives all data necessary for processing, including final navigation, digital water depth, and magnetic observatory data.

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