GEOSA

الهيئة العامة للمساحة والمعلومات الجيومكانية

General Authority for Survey and Geospatial Information

TECHNICAL GUIDELINES FOR HYDROGRAPHY

V1.0

General Authority for Survey and Geospatial Information

Disclaimer

This document has been developed by the General Authority for Survey and Geospatial Information (GEOSA). The guidelines have been drafted with reference to various standards and guidelines considered to be international best practices, particularly: The International Hydrographic Organization, Land Information New Zealand, the Australian Hydrographic Office, the National Oceanographic and Atmospheric Administration Office of Coast Survey of the United States of America, and the United Kingdom Hydrographic Office and Maritime and Coastguard Agency. Any omissions or errors may please be notified to GEOSA.

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Foreword

The General Authority for Survey and Geospatial Information (GEOSA) is the national mapping agency of the Kingdom of Saudi Arabia (KSA). These guidelines are a vital framework that aligns the Kingdom's geospatial data management practices with international and national standards. This Guideline will help industry, academia, and government bodies in KSA with survey and geospatial data collection and dissemination based on international best practices. The geospatial guidelines are derived from International and National Standards and then applied to develop guidelines and standard operating procedures (SOPs) for various geospatial and remote sensing data forms. This structured approach ensures that geospatial data collected and managed in KSA adhere to international and national standards, leading to data consistency, reliability, and compatibility.

The Guidelines for Hydrography for the Kingdom of Saudi Arabia will be maintained by GEOSA. This guideline is primarily intended to be used towards ensuring safety of navigation, although it may enable a range of other applications within Saudi Arabian waters. The guidelines cover the following areas:

- Hydrographic Surveying Principles and Standards,
- Hydrographic Survey Operations,
- Acoustic and Optical Survey Systems,
- Bathymetric Data Processing,
- Oceanography and Meteorological Observations.

The Guidelines for Hydrography apply to all hydrographic surveying activities and processes. They are developed primarily for surveyors, both in the public and private sectors, undertaking hydrographic surveying projects in the Kingdom of Saudi Arabia. Apart from ensuring safety of navigation, this guideline can be useful for other applications such as environmental protection, marine tourism, recreation, marine science, offshore infrastructure development, coastal engineering, defense, fisheries, and marine boundary determination.

The Guidelines for Hydrography are developed in alignment with the National Geospatial Data Policies and Standards for the Kingdom of Saudi Arabia. Additionally, references to other guidelines within this series, such as the Guidelines for Geodesy and the Guidelines for Remote Sensing (ARD), have been incorporated where relevant throughout this document.

Changes to this Guideline will be instructed by GEOSA, as improvements or amendments become necessary or as required.

1. Introduction

Scope and Objectives of the Guideline

This document provides the guidelines to be applied to the collection of hydrographic survey data and information that may be used by General Authority of Survey and Geospatial Information (GEOSA) to ensure safe navigation within Saudi Arabian sovereign waters and to produce hydrographic data sets compliant with product guidelines of the IHO S-100 Universal Hydrographic Data Model. It is a general guideline that covers a range of hydrographic surveying activities that may be required for nautical charting while also supporting other use-cases such as Coastal Zone Management, environmental protection, marine tourism, recreation, marine science, offshore infrastructure development, coastal engineering, defense, fisheries, and marine boundary determination. This document should be used in conjunction with additional hydrographic instructions or contract guidelines which may detail additional requirements and deliverables for specific survey projects.

Terms and Definitions

Table 1 provides Terms and Definitions used in the guideline.

Table 1: Terms and Definitions

Term	Definition
Bathymetric coverage	*"Extent to which an area has been surveyed using a systematic method of measuring the depth and is based on the combination of the survey pattern and the theoretical area of detection of the survey instrumentation."* (IHO, 2022)
Confidence Level	Confidence levels for uncertainty are defined as per paragraph 2.7 of S-44 (6.1.0) (IHO, 2022). In the context of the S-44 (6.1.0) standard, which assumes normal distribution of error, the 95% confidence level for 1D quantities (e.g. depth) is defined as 1.96 x standard deviation, and the 95% confidence level for 2D quantities (e.g. position) is defined as 2.45 x standard deviation.
Data Gap	A data gap is a specified number of adjoining cells in the final bathymetric surface grid which do not contain the required number of soundings.
Deep Water	Depths greater than 200m.
Feature	Any object, whether natural or manmade, which is distinct from the surrounding area. (IHO, 2022)
Feature Search	Extent to which an area has been surveyed using a systematic method of identifying features. (IHO, 2022)
Full Seafloor Search	A systematic method of exploring the sea floor undertaken to detect most of the features' defined in the standards in use. (IHO, 2022)
Grid/Bin Resolution	The grid is a regular grid with equal spacing overlaid over the survey area. The resolution of the grid is the size of each side of the grid. There is no required relationship between features of the bathymetry and the grid. Since the grid is a complete cover of the survey area, every sounding measurement can be assigned to one and only one cell in the set. After all the data has been added to the grid, therefore, each cell (or bin) will contain a collection of co-located data points from one or more passes with the measurement system(s). Grid and Bin resolution are inter-related in that the grid size will determine the bin resolution. (AHO, 2023)
Node (or Grid Node)	The central point of a grid cell to which all grid attributes are allocated.
Significant Feature	Feature that poses a potential danger to navigation or object one would expect to see depicted on a nautical chart or product (IHO, 2022).
Survey Management Plan (SMP)	Is a document prepared before the commencement of a survey that shows how the survey will be conducted, what technologies will be used and how the requirements of the survey will be met. It will include a-priori estimates THU, TVU and calculations showing how seafloor coverage and feature detection requirements will be met (AHO, 2023).

Survey Uncertainty (SU)	The uncertainty of the horizontal and/or vertical coordinates of a survey control mark relative to the survey in which it was observed and is free from the influence of any imprecision or inaccuracy in the underlying datum realisation. Therefore, SU reflects only the uncertainty resulting from survey measurements, measurement precisions, network geometry and the choice of constraint. A minimally constrained least squares adjustment is the preferred and most rigorous way to estimate and test SU. SU is expressed in SI units at the 95% confidence level. (AHO, 2023)
Uncertainty	The interval (about a given value) that will contain the true value of the measurement at a specific confidence level. The confidence level of the interval and the assumed statistical distribution of errors must also be quoted. (AHO, 2023)

2. Normative Elements

National Hydrography Guidelines

2.1 General Principles and Standards

2.1.1 Verification of Charts and Publications

During the execution of the hydrographic survey every opportunity shall be taken to verify the adequacy of existing published charts and documents for those areas in which the survey is being carried out.

When examining the detail on a published chart, attention should be paid to whether land features exist or have become obscured by coastal development, and to the prominence or otherwise of objects described as 'conspicuous', and to whether major changes have taken place in built-up areas.

2.1.2 Survey Management Plan

A Survey Management Plan (SMP) shall be prepared prior to the commencement of survey operations. For contracted surveys the SMP will normally form a major part of the tender documentation.

The SMP shall detail how the survey is to be conducted and how it will comply with the required survey standards, this guideline and any other requirements detailed in the Hydrographic Survey Project Instruction (HI) and contract documents.

As a minimum the SMP shall contain:

a. Key personnel nomination details, qualifications, and rotation plan (if required),
b. Key dates and milestones,
c. Communications,
d. Work health and safety,
e. Environmental management compliance,
f. Detailed list of equipment and software,
g. Data acquisition methodology including system settings,
h. Quality management plan,
i. Data processing methodology,
j. A-priori assessments of Total Horizontal Uncertainty (THU) and Total Vertical Uncertainty (TVU),
k. Sounding density, bathymetric coverage, and feature detection calculations.
l. Risk assessment and mitigation

2.1.3 Hydrographic Survey Project Instruction

A Hydrographic Survey Project Instruction (HI) or contract guideline document(s) shall provide additional requirements which must be complied with. In the event of a conflict between this guideline and the HI, the HI will prevail.

2.1.4 Personnel

All non- Kingdom of Saudi Arabia (KSA) nationals must hold appropriate visas for the duration of survey operations in KSA. Security clearance from the competent authorities in the KSA must be obtained prior to the deployment of personnel in survey activities.

2.1.4.1 Surveyor in Charge (SIC)

A SIC shall be nominated in the Survey Management Plan (SMP).

The SIC shall be a hydrographic surveyor who has completed an International Hydrographic Organization (IHO)/ Federation International Geographic (FIG)/ International Cartographic Association (ICA) International Board for Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC) recognized Category A course and has a minimum of 10 years hydrographic surveying experience including surveying for international navigation charting purposes, using the full range of equipment to be used for the survey. Alternatively, professional hydrographic surveyors certified at the highest level by regional hydrographic certification schemes recognized by the FIG/IHO/ICA IBSC may also be considered. For safety of navigation surveys, the SIC is to be approved by the Saudi Arabian Government/The General Authority for Survey and Geospatial Information (GEOSA) prior to commencement of the project.

The SIC shall have the authority and experience to make and implement operational decisions and must be available as required for consultation with the tasking authority to assess progress and modify the survey management plan if necessary.

The SIC must be dedicated to the conduct of the survey in a full-time capacity and be in the field for mobilization, system setup and calibration. The SIC shall be responsible to oversee technical hydrographic surveying matters and ensure compliance with the standards and guidelines.

2.1.4.2 The Survey Party Chief (SPC)

The SPC is the senior surveyor on board the survey vessel in charge of field operations. They shall be on board during all survey operations and will normally also be the SIC. However, for complex, multi-unit or extended duration surveys, additional SPCs who may lead the field operation in absence of the SIC may be nominated in the SMP. SPCs are to have similar qualifications and experience as the SIC.

Where survey operations are conducted remotely by un-crewed vessels or aircraft, the SIC shall be located in the support vessel or operational headquarters from where the survey assets are deployed, and the survey data received and processed.

2.1.4.3 Survey Team

Survey teams shall include adequately qualified and experienced personnel capable of supporting all aspects of hydrographic survey operations in complex offshore areas and to undertake processing, data compilation and quality assurance.

2.2 Standards for Bathymetry, Seafloor Coverage and Feature Detection

The required standards for hydrographic surveys will normally be expressed as IHO Orders of Survey selected directly from IHO S-44 (6.1.0) (IHO, 2022). Such orders of survey specify five main defining parameters: Total Horizontal Uncertainty (THU), Total Vertical Uncertainty (TVU), feature detection, feature search and bathymetric coverage requirements. The factors relating to bathymetry and feature detection are described in S-44 (6.1.0), Table 1. In addition, S-44 (6.1.0), Table 2 specifies the uncertainty allowances relating to other survey measurements, such as coastline, overhead clearances etc.

In special cases GEOSA may decide to specify individual criteria to meet specific product outcomes. Where individual criteria are to be specified, GEOSA will utilize the guideline matrix at Section 7.6 of IHO S-44 (6.1.0).

2.2.1 Classification of Bathymetry – Orders of Survey

2.2.1.1 IHO Exclusive Order

IHO Exclusive hydrographic surveys are of the highest accuracy and are intended to cover small-scale shallow water surveys in areas where there is an optimal use of the water column and/or critical areas of under-keel clearance. This can include dredging surveys, harbor surveys with critical clearance heights under bridges, berthing areas and critical channels with minimum under-keel clearances or surveys requiring in-depth knowledge of the seabed to aid the management of the marine environment, marine resources or infrastructure (e.g., pipelines or wind farms). This order requires high precision surveying where all error sources must be minimized, and high precision positioning and vertical control is achieved. This survey order will require the use of technology and methodologies capable of detecting all features greater than 50cm cube in less than 40m of water and 200% feature search and bathymetric coverage. IHO S-44 (6.1.0) (IHO, 2022) recommends that the use of Exclusive Order should be limited to areas with exceptional conditions and specific requirements.

2.2.1.2 IHO Special Order

IHO Special Order hydrographic surveys are intended to be restricted to specific critical areas with minimum under-keel clearance and where bottom characteristics are potentially hazardous to surface navigation. These areas will usually be associated with Under Keel Clearance Management systems, Recommended Tracks and Two-Way routes where depths are critical, and Multibeam Echo Sounder (MBES) Reference Areas. This order requires high precision vertical and horizontal control, and all error sources are to be minimized. This survey order will require the use of technology and methodologies capable of detecting all features greater than 1m cube in less than 40m of water and 100% feature search and bathymetric coverage.

2.2.1.3 IHO Order 1a

IHO Order 1a hydrographic surveys are intended to cover high risk coastal areas. These could include berthing areas, harbour approaches, recommended tracks, and coastal areas with high traffic density and where under-keel clearance is less critical than IHO Special areas but features on the seabed may be a concern for vessels expected to transit the area, thus a full seafloor search is required. Seafloor search technologies must be able to detect all features greater than 2 m cube in depths less than 40 m and all features greater than 10% of depth in water deeper than 40 m. 100% feature search but less than 100% bathymetric coverage.

2.2.1.4 IHO Order 1b

IHO Order 1b hydrographic surveys are intended to cover other coastal survey areas where seafloor feature detection is not so critical. As a minimum, an evenly distributed bathymetric coverage of 5% is required for the survey area. For this order of survey, the HI may specify feature search requirements.

2.2.1.5 IHO Order 2

IHO Order 2 hydrographic surveys are intended for areas generally deeper than 200 metres where a general description of the sea floor is considered adequate. These are areas where a general description of the bathymetry is sufficient to ensure there are no obstructions on the seafloor that will endanger the type of vessel expected to transit or work the area. As a minimum, an evenly distributed bathymetric coverage of 5% is required for the survey area. Further details of coverage requirements may be provided in the HI.

2.2.1.6 Passage Sounding Order

IHO S-44 (6.1.0) does not specify which survey order should be applied to passage sounding. Unless otherwise specified in the HI, where passage sounding is required, it is to achieve the following IAW the guideline matrix table at paragraph 7.6 of IHO S-44 (6.1.0): Ba8, Bb8, Bc7, Bd4, Bf3.

2.2.2 Total Horizontal Uncertainty (THU)

THU is a two-dimensional quantity with all contributing horizontal measurement uncertainties included. THU is the horizontal dimension component of total Propagated Uncertainty (TPU)

In determining horizontal uncertainty, all sources of uncertainty shall be quantified as an interval of ± the stated value and a statistical method used to combine all uncertainty values.

All uncertainty is to be stated to 2 Points of Decimals (POD) of a meter.

The SIC shall provide an a-priori assessment of the THU at the 95% confidence level during the planning phase to demonstrate that the planned survey operation can fulfil the THU guidelines required by the HI.
The a-posteriori uncertainty at 95% confidence level is to be recorded in the Report of Survey (ROS) and all associated digital datasets. Where THU has varied spatially or temporally, full details shall be given in the ROS including area boundaries and the typical values for the different areas.

2.2.3 Total Vertical Uncertainty (TVU)

Total Vertical Uncertainty (TVU) is a one-dimensional quantity with all contributing vertical measurement uncertainties included. THU is the vertical dimension component of TPU.

The SIC shall provide an a-priori assessment of the TVU at the 95% confidence level during the planning phase to demonstrate that planned survey operation can fulfil the TVU guidelines required by the HI.

At the completion of the survey, to provide a definitive TVU assessment, a crossline comparison shall be made against the final surface. The ROS shall detail the methods used to conduct the assessment and how a final TVU value was derived.

The TVU assessment may be broken up into individual areas, this may be relevant where different sensors are used or where different tidal regimes occur. Ideally the assessment shall be done using uncleaned crosslines to give the best assessment of the accuracy of the data.

2.2.4 Total Propagated Uncertainty (TPU)

TPU is comprised of THU and TVU elements, the assessment of these uncertainties is key to assessing the quality of the survey; verification processes during and post the survey are to be undertaken to provide assurance that the estimated THU and TVU achieved the survey order standards. These uncertainties are specified at the 95% confidence level.

Such estimates shall be conducted using an appropriate model (such as Hare-Godin-Mayer model or any other model which accurately accounts for the covariance of factors in the sounding equation) and takes into account all the individual sources of uncertainty from the positioning and sounding systems as well as the expected prevailing sea and weather conditions.

The SIC shall graph the two components of TPU (THU and TVU) across the whole expected depth range of the survey area. The tolerance of the relevant survey order shall also be plotted to prove the system/methodology is capable of theoretically meeting the guideline.

As the survey standards are defined by the TVU and THU tolerances, a-posteriori uncertainty analysis at 95% confidence level of both TVU and THU is to be conducted to show the survey standard has been met. The most reliable method of a-posteriori assessment is comparison with an established reference surface which has been surveyed using multiple independent systems. Where this is not possible crossline comparisons and comparisons with other survey vessel overlaps are valuable.

TPU is critical to the generation of a Combined Uncertainty and Bathymetry Estimator (CUBE) surface and the contributing factors are to be fully documented, including an assessment of the uncertainty of tidal observations and model and analysis of the TPU layer to support the claimed order of the final derived bathymetric surface.

2.3 Geodetics and Tides

2.3.1 Introduction

All surveying activities to establish and extend survey control are to be conducted using established industry practices and guidelines detailed in Guidelines for Geodesy for the Kingdom of Saudi Arabia.

2.3.2 Time Datum

All observations and digital data shall be time stamped and reported in terms of Coordinated Universal Time (UTC). Descriptive text used in reporting of incidents and events may refer to local time.

2.3.3 Horizontal Datum

Horizontal positions shall normally be referenced to the World Geodetic System 1984 (WGS 84) Ellipsoid (KSA-GRF17, EPSG:9331) with parameters:

Semi major axis radius a = 6,378,137.000 m
Semi minor axis radius b= 6,356,752.314 m
Relative flattening f=1/298.257 223 563

By prior agreement, other International Terrestrial Reference Frame (ITRF) realizations may be approved.

2.3.4 Horizontal Control

Details of geodetic control marks may be included in the HI. The existing control point network shall be used as far as possible.

When extension of the existing geodetic control and establishment of new stations is required, it shall be fully documented. All new survey control marks are to be tied into the National Gravity Network (NGN) and Continually Operating Reference Station (CORS) network in accordance with the GEOSA guidelines and positioned to achieve Survey Uncertainty (SU) <15mm for horizontal position and SU <20 mm for vertical height.

All geodetic control marks established during a survey shall be monumented IAW Guidelines for Geodesy for the Kingdom of Saudi Arabia. A full station record including photographs and diagrams to aid recovery shall be recorded.

All raw and RINEX files and final Global Navigation Satellite System (GNSS) processing reports are to be included in the geodetic section of the ROS.

Grid positions, if used, shall be referenced to the WGS 84 Universal Transverse Mercator (UTM) Grid as specified in the HI.

2.3.5 Vertical Datum

The KSA Vertical Reference Frame (KSA-VRF14) is the ellipsoidal reference frame. This frame is coincident with the WGS 84 ellipsoid (GRS80) for epoch 2017.

It is now KSA practice for hydrographic surveys to be referenced to the ellipsoid as well as to Sounding Datum (SD).

For Hydrography: LAT (Lowest Astronomical Tide)

For Topography: MSL (Mean Sea Level)

Geoid KSA:_Geoid 17&Geoid21 or the most recent one available

2.3.6 Sounding Datum (SD)

Sounding datum is the low water plane to which soundings are reduced and above which drying height are referred to in the survey records. The sounding datum is to be set to Lowest Astronomical Tide (LAT).

Chart Datum is the low water to which depths are referenced below on the published chart, on modern charts it is normally LAT.

When the relationship between existing benchmarks and sounding datum is provided in the HI, sounding datum is to be recovered from this information.

When sounding datum relationship is not provided in the HI it shall be determined as close as possible to LAT by a proven and accepted method (such as datum transfer or analysis of a minimum of 35 days tidal observations) and that method should be fully described in the SMP.

Sounding datum determined from analysis of offshore tide gauge data must be connected to the vertical reference ellipsoid via a minimum of 72 hours of simultaneous GNSS and tide gauge observations.

2.3.7 Tide Stations

Tide stations are to be established as required by the HI and to ensure that there are sufficient gauges to capture each tidal regime in the survey areas so that an accurate tidal model can be constructed.

Each tide station shall comprise:

- sea level sensor capable of recording averaged sea level height and time,
  - The minimum accuracy of measured tidal height shall be ±0.05% (full scale), and stability ±0.1%. The recorded value shall be the average water height taken at 1Hz over a minimum of 60 seconds centered on the time of recording.
  - The height of tide is to be recorded on the hour (UTC) and at intervals not exceeding 10 minutes. Time accuracy is to be ± 1 minute.
  - The height of tide is to be recorded to the nearest 0.01m.
- a barometer, if non-vented underwater pressure sensors are deployed,
- a tide pole or GNSS buoy (for calibrations). If a GNSS tidal buoy is used in place of a tide staff, levelling runs are to be conducted between all benchmarks. The benchmark being coordinated, and the GNSS tide buoy observations must be simultaneous for a minimum period of 25 hours so that an analysis can be conducted to establish the datum connection.

Detailed guidance on tide gauge installation operation and processing is available in the Special Publication No.9 (Intergovernmental Committee of Surveying and Mapping, ICSM, 2021).

2.3.7.1 Tide Station Connection

Shore connected tide gauge deployments are to be levelled to at least three benchmarks that are to be permanently established, monumented, levelled, documented with diagrams and photographs, and referred to Chart Datum (CD), Mean Sea Level (MSL) and LAT and ellipsoidal height. Levelling and monumentation are to comply with Guidelines for Geodesy for the Kingdom of Saudi Arabia ().

Ellipsoidal heights of any existing or newly established benchmarks shall be determined by GPS classic carrier-phase observations of at least one primary benchmark and transferred to all benchmarks via two-way levelling.

All offshore tide gauge installations must be referenced to the ellipsoid. To achieve this, high accuracy GNSS heights must be observed on the sea surface close adjacent to the gauge using GNSS buoy deployments. A minimum of two sessions of observations must be collected. Each session shall be at least 25 hours in duration.

One session must be collected immediately after deployment of the gauge to seabed and another session must be collected immediately prior to recovery from seabed.

The importance of continuous tidal observations is such that a second sea level sensor is recommended for all deployment to provide redundancy.

2.3.7.2 Benchmark Levelling

Two-way levelling, using either an optical/digital level or total station with backsight and foresight change points for every benchmark is to be conducted between all benchmarks and the tide staff in accordance with Guidelines for Geodesy for the Kingdom of Saudi Arabia (). The maximum allowable misclosure = $12mm*\sqrt{k}$ (km). All height values are to be recorded to 0.001 m.

2.3.7.3 Tide Gauge Calibration

Prior to deployment, every sensor used for sea level measurements must have a factory calibration certificate that is within the manufacturer's recommendation for validity, or less than 3 years old. Modern digital sea level sensors shall not be adjusted in the field and shall be returned to the manufacturer for repair if found to be recording erroneous data. The manufacturer's pre-deployment checks standard procedures shall be followed.

Non vented tide gauges and tidal data collected for IHO - Exclusive, IHO Special Order, and IHO Order 1 surveys are to be corrected for atmospheric pressure. Pressure is to be recorded at fixed locations within 20 km of the gauge at a periodicity no greater than 1 hour. If there is no suitable location for pressure recording within 20 km then buoy deployments shall be utilized.

In-situ calibration of each sensor is to be carried out over a period of at least 25 hours (IAW IHO C-13) as soon after deployment as practical by making simultaneous independent observations of sea level using either a tide pole or GNSS buoy as close as possible to spring tide.

The GNSS buoy solution is to be capable of determining the ellipsoidal height to +/- 0.02 m (1 sigma).

Calibrations employing a tide pole shall record with readings (coinciding with the sensor recording schedule) every 10 minutes during the period 30 minutes either side of high and low water, and at intervals no greater than 30 minutes during the remainder of the tide cycle.

The sensor calibration parameters are to be determined from the intercept and gradient of a straight line fitted to the sensor readings plotted against the independent sea level values.

Once established, check leveling of the tide pole, sensor and pole gauge comparisons are to be conducted at least once per month for the duration of the deployment. If a sensor becomes defective and has to be replaced, then a new calibration must be conducted. A final confirmation calibration shall be carried out prior to the gauge being recovered to confirm that sensor/pole relationship has remained valid.

2.3.7.4 Sea Level Observations

Unless otherwise specified in the HI, sea level observations are to be recorded for a minimum of 35 days, or the duration of the survey, whichever is longer, with less than 5% interruption. Sea level observations shall be processed by harmonic analysis to determine vertical datum parameters and relationship between LAT, MHWS, MLWS, MSL and HAT. Ellipsoidal separation is to be determined at each tide gauge location. SD is to be set at LAT.

The following recording requirements are to be met for all sea level observations:

- time of sea level measurements is to be recorded within 5 seconds of UTC,
- sea level height is to be measured to an accuracy not less than ±0.05% of the full scale of the sea level sensor.
- For digital sensors the recorded value is to be an average of height samples taken over a minimum of 51 seconds centered on the recorded time of reading, and averaged sea level height is to be recorded at intervals not greater than 10 minutes with values aligned to the whole hour.

2.3.8 Surveying on the Ellipsoid

When surveying on the ellipsoid an Ellipsoid Separation Model (SEP) is to be developed between LAT, MSL, EGM08 and WGS 84 ellipsoid for the entire survey area with the tide gauge locations fixed and interpolating/extrapolating using the EGM08 1 minute model.

The navigation solution for each survey platform must be capable of <10cm (1 sigma) ellipsoidal height. The quoted uncertainty must be accompanied with observational proof that the system can achieve that level. Post Processed Precise Point Positioning (PPP) data is to be Forward-Backwards processed using final precise ephemerides, clock corrections and an accurate ionosphere model (available in IONEX format), as per FIG Document No 62 (FIG, 2014).

All survey platforms must perform calibration/validations of the vertical positioning component. For ship borne platforms this must include at least 24 hours of continuous height observations while lying by a tide gauge location.
Raw GNSS observations shall be recorded on all survey platforms during all survey operations, even if real-time high-accuracy GNSS techniques are used.

The translation from ellipsoid to chart datum may take place anywhere in the data processing cycle, but must be fully documented. Separation models must have associated metadata to indicate what they translate between, including epochs. Resulting surfaces should also contain this information, such that it is possible to translate back to the original ellipsoid surface if necessary. If separation models are applied in real-time, all data related to that translation must be recorded (including the Real Time Kinematic (RTK) observations).

2.3.9 Datum for Elevations and Overhead Clearances

Elevations are referenced to Mean High Water Springs (MHWS) or Mean Higher High Water (MHHW). Reference INT1 (Symbols, Abbreviations and Terms used on Charts (IHO)), Section H.20 (UKHO, 2020).

Overhead clearances (e.g., bridges) are referenced to Highest Astronomical Tide (HAT).

2.4 Survey Operations

2.4.1 Bathymetric Coverage

Bathymetric coverage is to be achieved as specified in S-44 (6.1.0) (IHO, 2022) unless otherwise required in the HI.

A 100% bathymetric coverage should be interpreted as “full” bathymetric coverage. To achieve this coverage adjacent lines shall be planned with sufficient overlap to account for roll and the rejection of outer beams that do not meet the required TPU.

Where greater than 100% bathymetric coverage is required, including 200% for Exclusive Order, this shall be achieved by overlapping collection or acquiring more than one independent dataset over the area. To account for greater uncertainty in both the nadir and outer beams, where 200% coverage is required, lines should be planned such that the outer beams meet the nadir beam of the adjacent line.

In areas where less than 100% bathymetric coverage is required, surveys must be performed systematically and the horizontal distance between registered position of depth shall be no greater than 3 times the depth of water or 25m whichever is greater.

2.4.2 Gaps in Swath Systems Data Acquisition (MBES and LiDAR)

A cell in the bathymetric surface sounding grid which does not contain the required number of soundings as specified in the sounding resolution is a data gap.

No data gaps are to exist over any shoals or significant features.

Minor data gaps are permitted in other areas but shall not account for more than 5% of the total area and shall be random in nature. The SIC shall review Water Column Data (WCD) and any rejected data to assess the likelihood of any features existing within the gaps. If significant features are probable, then the gap is to be filled. The SIC is to certify in the ROS that data gaps contain no significant features.

For the 100% bathymetric coverage an unacceptable data gap would be a 3 by 3 grid of cells in the bathymetric surface, not populated to the required resolution, as shown in Figure 1(a).

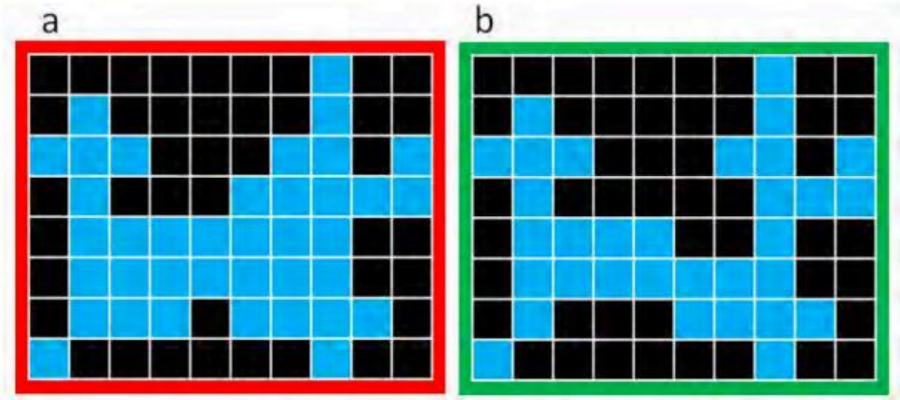

Figure 1: Figures 1(a) and 1(b) Represent Unacceptable and Acceptable Data Gaps for 100% Bathymetric Coverage Respectively. Source: AHO HIPP SOR 2023

For 200% bathymetric coverage an unacceptable data gap would be 3 or more collinear contiguous cells as shown in Figure 2(a) and 2(b), the bathymetric surface sharing adjacent sides not populated at the required resolution.

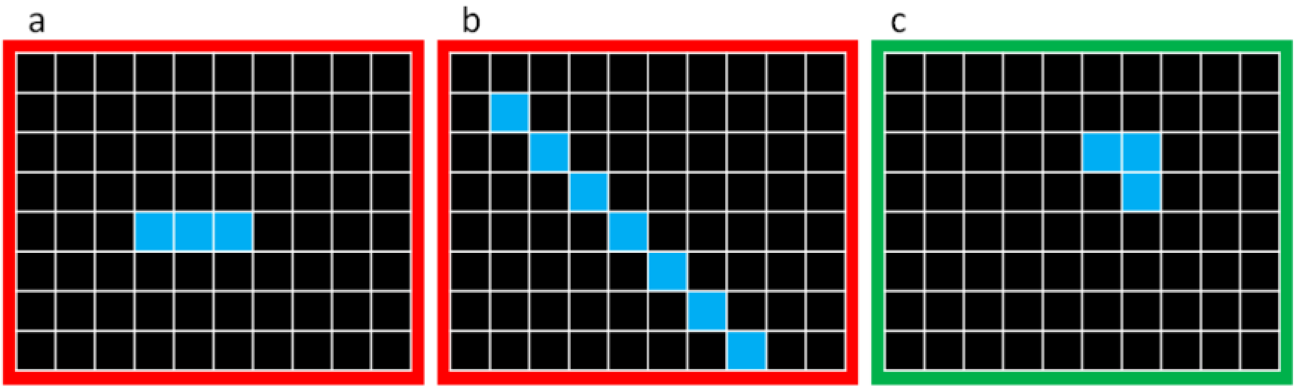

Figure 2: Unacceptable Data Gap for 200% Bathymetric Coverage as Shown in 2(a) and 2(b). Acceptable Data Gap as Shown in 2(c).

Source: AHO HIPP SOR 2023

2.4.3 Positioning Systems

Multiple independent GNSS positioning systems are required to provide real time quality assurance, with primary and secondary positioning solutions to be clearly described in the SMP. Primary and secondary solutions are to be operational, continuously monitored for differences and acquiring data throughout the survey.

Positioning systems shall be capable of meeting the guidelines and horizontal uncertainty detailed in the HI. Examples include: RTK GNSS, post processed carrier phase GNSS.

Details of the method of positioning and how it meets the uncertainty requirements for positioning of soundings and features shall be included in the SMP.

2.4.3.1 Static Position Test

The vessel positioning systems must be verified against a reference position which is more accurately known, or by comparison with a more accurate system at the start of the survey and at regular intervals throughout.

The vessel position data must be derived using the same procedures used to obtain all positions associated with the bathymetric data in the survey (e.g., post-processed kinematic).

For position validation, the 3D position of the primary GNSS antennae, or another appropriate point within the reference frame of the vessel, shall be recorded for at least 30 minutes at 1 minute resolution. The subsequent report shall separately detail the statistical reliability of both the horizontal and vertical position of this point.

2.4.3.2 Dynamic Position Checks

Position validation in the survey area shall include dynamic positional checks over a small feature at least depth position, as surveyed by multiple lines from multiple directions. Where multiple survey platforms are employed, all platforms should survey across one or more common features, validating the position of the feature's least depth.

2.4.4 Vessel Squat and Settlement

For each survey vessel a squat model is to be observed and established via analysis of GNSS height variation (minus the effect of tide) resulting from the vessel operating at various shaft RPM or propeller pitch settings corresponding to likely survey speeds.

2.4.5 Reference Surface

At least one reference surface must be established at a convenient location in the survey area to support calibration and testing of the integrated survey systems. For shallow surveys (<200 m), the reference surface should be created in water depths of not more than 30 m, or at the mean depth expected within the survey area. Additional reference surfaces may be required for large survey areas or if specified in the HI.

Each reference surface must be created by sounding a minimum of four parallel lines, run with at least 50% overlap, ensuring the inner beams overlap providing redundancy and at least 150% coverage. For MBES systems with a swath width two times the water depth this means that the line spacing should be less than the water depth to provide sufficient overlap. At least four parallel lines are to be run perpendicular to the previous lines with the same swath width and overlap. The same speed is to be maintained for all lines and a run-in of at least 800m is required to provide sufficient settling time for the IMU. A digital terrain model is to be created from the cleansed data using an average gridding algorithm, with a cell size no larger than the average footprint of the inner beams.

All survey platforms must run validation lines over this surface prior to, during and at the end of each survey and after any major system changes. The comparison results must be documented in the ROS.

2.4.6 Reduction of Soundings

In reducing soundings, the principle to be observed is that depths are never to be shown greater than they are, relative to sounding datum.

Tidal regime for reduction of soundings may be provided in the HI. Tidal information is to be collected such that analysis confirms that the method of reduction of soundings to the sounding datum is appropriate and valid.

All soundings shall be corrected for vessel draught, squat, settlement, pitch, roll, yaw, and heave as appropriate to the platform.

All soundings shall be reduced to sounding datum and the ellipsoid by applying the relevant tidal corrections. The Survey Instruction shall provide details on the tide model to be used for the reduction of soundings.

2.5 Acoustic Survey Systems

2.5.1 Multibeam Bathymetric Survey Systems

MBES shall be capable of meeting the required guideline of the survey order specified in the Survey Instruction (THU, TVU, feature detection and sounding density).

Proposed MBES settings including proposed swath angles, pulse frequency settings, sounding speed and line overlap shall be detailed in the SMP with justification proving survey order will be achieved. These details and any subsequent changes are to be detailed in the ROS.

For shallow water operations (<200 m) the MBES should have the following characteristics:

- Operating frequency not lower than 150 kHz,
- Roll corrected (mandatory),
- Pitch Correction (desirable),
- Yaw stabilization (desirable),
- Nominal beamwidth not greater than 1.5° (at operating setting).

For surface vessel deep water operations (>200 m) the MBES must have the following characteristics:

- Operating frequency not greater than 100 kHz,
- Roll corrected (mandatory),
- Pitch Correction (mandatory),
- Yaw stabilization (mandatory),
- Nominal beamwidth not greater than 2°.

2.5.1.1 Mobilization - Calibrations and checks

2.5.1.1.1 Sensor Offsets

A dimensional control survey showing all sensor positions shall be conducted for every survey vessel prior to the commencement of surveying operations. This must be revised after any sensor reconfiguration (e.g., change out of MBES sensors, GNSS or Inertial Motion Unit (IMU)).

2.5.1.1.2 Navigation System Heading Alignment

Heading alignment test requires the vessel heading to be determined by an independent solution and compared to the primary heading solution. This should also be conducted over a 30-minute period with at least 1-minute resolution

2.5.1.1.3 Patch Test

A patch test calibration determines corrections to remove errors related to latency and heading between navigation and MBES sensors and errors relating to pitch and roll between attitude and MBES Sensors.

A patch test calibration of the MBES and all associated sensors shall be performed at the start of each survey period and after changing out or reconfiguration of the sensor suite. The patch test methodology shall be detailed in the SMP. Records and results of all calibrations are to be detailed in the ROS.

2.5.1.1.4 Feature Detection Check

For each new mobilization, a feature detection test is to be conducted to prove the MBES system can detect features as required by the specified survey order.

Ideally, the feature used in the check should have known dimensions to accurately verify whether the size of the feature can be detected. Lines shall be planned around the feature so that detection can be proven in all sectors of the swath (nadir and outer beams) at the expected survey line spacing.

Data shall be processed with only accepted soundings used. On each line the number of across track and along track detections shall be noted in the report. The planned method of the check is to be included in the initial SMP and all results included in the ROS.

2.5.1.1.5 Squat validation

Two passes over one line of sounding on the reference surface are to be conducted at normal sounding speed, one line is to be processed with squat correction and the other without squat correction. Each line is to be compared with the reference surface and the results included in the ROS.

2.5.1.1.6 Acoustic Noise Interference

A check shall be conducted to ensure there is no significant interference from vessel systems, hull flow or propeller revolutions on the acoustic return of the MBES. The results and any limitations are to be reported in the ROS.

2.5.1.1.7 Processed Depth Comparison

The processed depth of the MBES is to be verified by at least one of the following methods:

- A fully processed bar check with zero tide applied to the MBES data,
- Comparison with a feature of independently measurable depth such as:
  - a dock sill or lock floor, or
  - man-made feature placed on the sea floor over which depth can be accurately determined by calibrated and validated depth sensor.
- Comparison with recently calibrated Single Beam Echo Sounder (SBES) over flat and featureless seabed.

2.5.1.1.8 Reference Surface Depth Comparison

For each MBES system 3 check lines are to be sounded as follows over the reference surface: two parallel lines (overlap not required) and one line where the vessel maneuvers, as experienced during normal sounding operations, e.g., close to the shoreline.
Each beam depth from the processed check lines is then compared against the reference surface and statistics computed. Statistics are to include beam number, mean, maximum and minimum differences and standard deviation. The results are to be reported in the ROS.

2.5.1.1.9 Seafloor Backscatter Check

Where backscatter is required to be collected, a backscatter check shall be undertaken in the survey area upon arrival at the survey area so that any data acquired will have the correct settings applied during acquisition.

The chosen area should be flat, level, and of a homogeneous seafloor type so processing assumptions, such as projected beam footprint estimates, will result in minimal bias to the results. The area should also be deep enough to be in the far field of the echosounder for a consistent beam pattern. Ideally a depth of 20-30m shall be used for shallow water MBES systems. The backscatter check shall as a minimum comprise of:

- Log three parallel lines (dual head MBES) or two reciprocal lines (single head MBES) over the reference area for each setting mode to be utilized for the survey.
- Record the parameters of these setting modes ROS.
- Monitor the backscatter waterfall/intensity in real time during the logging of the lines for any hardware failure/missing channels.
- Store all logged lines in their native format within the project folder structure.
- Repeat the process (logging reciprocal lines) over the same reference area to check for any walk/degradation of performance of the system.

A seabed sample shall be obtained over the backscatter check/reference area to enable the interpretation of backscatter records.

2.5.1.2 Final Integrated Verification

The final procedure before commencing MBES survey operations shall be a verification of the entire integrated hydrographic suite over a known area/feature to determine whether the combined platform solution for horizontal position, depth and feature detection falls within the guidelines of the survey. The method used and statistical results are to be detailed in the ROS.

The preferred method of verification shall include surveying a small, clearly defined feature on the seabed near the nadir beam from multiple directions (as a minimum north/south and east/west). Secondly it should be boxed in, so that it appears in the outer beams of the port side for 2 lines and starboard side for 2 lines.

The subsequent report should separately state the computed statistical reliability of the position and the measured depth of the feature and prove that the combined platform solution falls within the guidelines of the survey.

Where multiple survey platforms are employed, all should use a common feature if practical.

2.5.1.3 MBES Measurements

2.5.1.3.1 Sound Velocity (SV) Measurements

Equipment used to measure SV shall have the following parameters:

- SV accuracy: better than 0.5 ms^{-1},
- Depth: ±0.01 m,
- Time: ±1 min,
- Horizontal Position: ± 200 m.

Sound velocity profiles shall be observed at an interval consistent with the error budget for the survey and the complexity of conditions within the survey area. At a minimum, Sound Velocity Profile (SVPs) shall be measured at:

- 4-hourly intervals for MBES operations,
- 6-hourly intervals for SBES operations, and
- 4-hourly for passage sounding operations.

Shallow water SVP casts should be 80% of the water depth. Where there is significant depth variation across the survey area it will be necessary to conduct additional casts in deeper water to capture the full water column.

Deep water operations will normally require a mix of observation and modelling to determine SVPs. Unless specified in the HI routine casts will be required to be at least 700m with deeper values determined by modelling and validated by a smaller number of full-depth observations based on deep Expendable Bathy Thermograph (XBT) or other sensors as agreed in the approved SMP.

2.5.1.3.2 Feature Detection and Sounding Density

To ensure detection of small wavelength features on the seafloor, a minimum of 9 soundings are required to strike the feature (three across-track and three along-track pings). This will require an equipment capable of meeting the feature detection requirements for the Survey Order stated in the HI and survey techniques to optimize detection.
Sounding density requirements will be relative to the nominated grid resolution of the required final bathymetric surface (see Table 3, paragraph 2.10.1.2), or specified in the HI, which will be based on a resolution of half the required feature detection capability. Density calculations will be based on the single node resolution and not influenced by adjacent nodes.

For 100% bathymetric coverage, 95% of nodes must contain at least 5 accepted soundings with 100% of nodes over the top of all significant features are to contain at least 5 accepted soundings.

For 200% bathymetric coverage 95% of nodes must contain at least 9 accepted soundings with 100% of nodes over the top of all significant features are to contain at least 9 accepted soundings.

A density surface model of the final processed dataset is to be included with the ROS.

2.5.1.3.3 Deep Water Sounding Density

Deep water sounding density may vary considerably depending on the nature of the survey task and the priority of all acoustic sensors to be deployed. Where required, the HI will provide specific guidance for sounding density.

2.5.1.3.4 Daily Verifications

The transducer draught shall be determined daily and all echosounders (SBES and MBES) updated as required. A comparison of the MBES nadir and SBES (if fitted) is to be conducted daily. The Sub-Bottom Profiler (SBP) may also be used for comparison.

2.5.1.3.5 MBES Line Planning

MBES sounding lines are to be planned parallel to depth contours wherever possible. Sounding lines are to be planned such that the TVU of the outer beams are within the guidelines for the survey order and provide sufficient overlap to fulfil the coverage requirements.

2.5.1.3.6 MBES Crosslines

Crosslines are to be planned perpendicular to the typical mainline orientation in each survey area. A minimum of 3 bathymetric crosslines are required for each survey sub-area conducted, with crosslines 5 km apart on an average, at approximately equal spacing.

At least one crossline should be repeated on multiple occasions (at least 3) during the survey to confirm system performance and repeatability. Where multiple survey platforms are employed, all should use a common crossline for this analysis if practical.

A cross line comparison is to be conducted against the mainline soundings with the sounding difference between these two datasets falling within the assessed error budget (at 95% confidence level) of the survey. The crossline comparison report is to be included in the ROS.

Crosslines shall be rendered separate from the mainline data structure. Crosslines shall not be included in the final surface generation.

2.5.1.3.7 MBES Data Cleaning

Only soundings collected from the usable swath can be incorporated into the final processed dataset. Rejected outer beams may be used for reconnaissance to reduce survey risk but are not to be incorporated in the final processed data set.

Data collected during turns can be logged but is not to be incorporated into the final processed dataset unless there is evidence that the soundings remain within the uncertainty requirements of the HI.

All outliers and erroneous data are to be flagged as “rejected” and included in the final processed data set. This data shall not contribute to the final gridded surface.

2.5.1.3.8 Water Column Data (WCD)

WCD is to be logged for wreck investigations and feature examinations to determine the least depth. Additional requirements for WCD over known bathymetric features may be specified in the HI.

WCD is to be analyzed in appropriate software to compare the data captured in real time with other features that may be present in the water column. Important georeferenced soundings from the water column are to be selected for inclusion in the final data submission. All soundings are to be reduced to the sounding datum.

Details of the procedures and software used for processing WCD are to be included in the ROS.

2.5.1.3.9 Backscatter Data

MBES backscatter is to be calibrated prior to survey operations. Backscatter reference lines are to be recorded at the start and end of the survey using the standard MBES settings in use.

Georeferenced backscatter intensity data from MBES shall be continuously logged throughout all areas of the survey. Backscatter data shall be rendered in both proprietary raw and processed formats, and shall include all real-time acquisition parameters required to conduct post processing, such as backscatter intensity, source level, pulse length, etc. Where MBES settings (i.e., gain, pulse length) are manually changed during data collection, the changes are to be recorded and included in the ROS.

Where backscatter mosaics are called for in the HI, they should be generated from processed point data and included in the rendered Generic Sensor Format (GSF) files.

2.5.1.4 Passage Sounding

If passage sounding data is to be collected it shall comply with Passage Sounding Order (Section 2.2.1.6 above) unless otherwise specified in the HI. Passage sounding data must be fully processed and reported on in the ROS.

Unless otherwise instructed in the HI, passage sounding should be rendered as separate project and surfaces to that of the main survey area.

2.5.2 Single Beam Bathymetric System

When SBES surveys are specified in the HI, depth shall be measured using a SBES capable of meeting the required guideline of the survey order (THU, TVU, Feature Detection). The SBES shall be capable of producing digital records that can be processed with appropriate software.

High frequency SBES capable of determining a first bottom return in depths less than 40m with a beam width less than 8° are to be utilized for shallow water surveys. The system is to be capable of continuously tracking the bottom in steeply shelving areas.

SBES may be required to operate simultaneously with MBES to provide a continuous depth confidence check on nadir beams.

2.5.2.1 Calibration and Checks

The SBES is to be calibrated for transmission error, draught offset and sound velocity at the start and end of each surveying period and as required to ensure that the uncertainty requirements for depth and position are met for the duration of the survey.

Heave compensation is to be applied using industry standard equipment.

2.5.2.1.1 Bar check

The shallow bar check should be carried out at the start and finish of SBES operations. Index error and draught setting are to be determined and corrections applied.

Where a SBES has multiple frequencies, each frequency shall be calibrated independently.

The lengths and markings of bar-check lines must be verified at mobilization and demobilization.

Between bar checks the echo sounder draught setting should be adjusted for known changes in the draught of the vessel. These changes can be determined by waterline measurements to a particular offset on the vessel and verified at the bar-check.

For surveys in depths to 20 m the SV may be set by deep bar-check or SV probe.

For surveys in depths greater than 20 m, the SV shall be determined by SV probe.

2.5.2.1.2 Squat

Squat (see 2.4.4) is to be applied to all measured depths where the effect exceeds 0.05m

2.5.2.1.3 Sound Velocity Observations

SVP observations are to be recorded at 6 hourly intervals using equipment specified in (see above under MBES SVP)

2.5.2.1.4 Speed Whilst Sounding

Survey speed shall be determined in relation to the depth of water and pulse repetition rate such that the along track density of valid soundings shall not exceed 5m and be dense enough to detect significant features on the seabed.

2.5.2.1.5 SBES Line Planning

Sounding lines are to be planned perpendicular to the contours or, in areas of sand waves, perpendicular to the crests.

Line spacing is to be determined by the SIC and documented in the SMP. Line spacing will be dependent on the SBES beam width, depth of water and complexity of the survey area detailed in the HI. The minimum coverage requirements in S-44 (6.1.0) are to be achieved.

Where Feature Search is specified for an SBES area, Side Scan Sonar (SSS) to be utilized to meet that requirement. Additional sounding lines are to be obtained along recommended tracks, areas used for anchorages and off headlands where the mariner may pass close to shore.

Where irregularities are found to exist, or where the nature of the seabed or adjacent coastline features may indicate previously undetected dangers, the areas must be more carefully sounded using interlines, and/or crosslines.

Features are to be examined at slow vessel speed to ensure that the least depth is recorded on all features.

2.5.2.1.6 SBES Crosslines

Crosslines are to be run throughout the survey area in a direction perpendicular to the main sounding lines at intervals no greater than 15 times the line interval of the main sounding lines.

Additional crosslines should be run whenever the SIC is not satisfied that the normal sounding has revealed all significant features, as well as in sand wave fields, near headlands, in bays and along channels and recommended routes.

A statistical comparison of raw data between the main survey lines and the crossline is to be undertaken to ensure that the uncertainty requirements of the order of the survey are met. A summary of the statistics and definitive statement about the results are to be included in the ROS.

Whenever crossline comparisons reveal a discrepancy in depth exceeding 2 times the specified TVU, the discrepancy is to be investigated and resolved.

2.5.2.1.7 SBES Processing

All SBES echograms are to be processed using appropriate software to remove outliers and systematic errors. All accepted soundings within the final dataset are to fall within the uncertainty allowances specified in the HI.

Details of SBES processing parameters including the vessel configuration and any automatic cleaning algorithms are to be detailed in the ROS.

2.5.3 Multi-Transducer Vertical Sweep Systems (MTES)

MTES are to be calibrated at the beginning of every survey season as per manufacturers' instructions. The calibration is to cover all aspects of the survey system and to include spatial coordinates (x,y,z) of each transducer, the GNSS antenna and motion sensor. The draught of each transducer is to be calculated. Daily draught and SV corrections are to be applied by determining the daily variation in draught of the vessel and SVP of the water column with the harmonic mean applied to the echo sounder.

A reference surface shall be used to ground truth the system and validate against known results.

Vessel speed is critical to feature detection. Care is to be utilized when using MTES to ensure that coverage requirements are met when operating in very shallow water or rapidly changing topography.

2.5.4 Side Scan Sonar System (SSS)

The requirement to conduct SSS sweeps may be specified in the HI. The type of technology to be employed will be driven by the range, resolution and sounding speed requirements. SSS sweeps will normally be required along leading lines, anchorages, recommended tracks and when SBES is used.

Where SSS sweeps are required, they are to ensure 200% coverage of the seafloor. Survey lines are to be spaced to ensure that the seabed directly under the transducer, and at least 50 m beyond it is ensonified by the adjacent sweeps. Where practical, adjacent lines are to be run in opposite directions. The optimum height at which to keep the tow fish above the seabed is equivalent to 10% of the range scale in use.

When used for feature detection, investigation of underwater obstructions (wreck/shoal), pipeline orientation and hazards, sounding speed shall be chosen such the minimum sized feature shall be ensonified by at least five along-track pings.

SSS is not to be used for determining the least depth of a feature.

2.5.4.1 Calibration and Checks

Prior to commencing SSS operations, and regularly during its execution, confidence checks are to be made using known features of the required dimensions. These confidence checks shall be documented in the ROS.

2.5.4.2 Format and Data Requirements

SSS data shall be rendered in the proprietary format of the system utilized or in XTF format and all real-time acquisition parameters such as: intensity, source level, pulse length, transmit and receiver beam patterns shall be included with the digital logged data.

2.5.4.3 SSS Backscatter

If specified in the HI, SSS shall be processed with altitude and positioning data to create georeferenced seabed texture mosaics. Mosaics are to be delivered in a resolution to match the bathymetric surface in a floating point 32-bit Georeferenced TIFF files (GeoTIFFs) with backscatter values.

2.5.5 Sub Bottom Profiler (SBP)

The requirement to collect SBP data may be specified in the HI. SBP is used for shallow seismic observations of the softer bottom sediments and may be useful for identifying buried infrastructure and profiling sub bottom layers to depths of 200 m at varying resolutions depending on the technology deployed.

The requirements for penetration and resolution detailed in the HI will be the key determinants of the appropriate systems technology.

2.5.5.1 Calibration and Checks

Prior to commencing SBP operations, and regularly during its execution, confidence checks are to be made using known features. These confidence checks shall be documented in the ROS. Calibration and operation shall be undertaken as recommended in Australian Sub-bottom Profiling Guidelines (McNeil, 2023) at the beginning and end of the field survey.

2.5.5.2 Operation and Data Requirements

RAW SBP data should be logged in proprietary native file format and rendered unprocessed. The data should also be provided in SEG-Y data exchange format (Society of Exploration Geophysicists, 2023).

Where specified in the HI, SBP data, combined with MBES backscatter, seabed samples (ground truthing) must be processed and interpreted to produce bottom quality (surficial geology) maps in the coastal zone, and provided in SHP (ESRI Shapefile - geospatial vector data format for geographic information systems) format.

2.6 Optical survey systems

2.6.1 LiDAR Bathymetric Surveys

LiDAR may be used to fulfil survey tasking. When utilizing LiDAR to conduct survey tasking the system shall be capable of meeting the survey order (THU, TVU, Feature Detection and Coverage). Bathymetric LiDAR, topographic LiDAR and aerial imagery collection, processing and derived products are to be in accordance with this guideline or the Guidelines for Remote Sensing for the Kingdom of Saudi Arabia () if not covered by this guideline. Bathymetric LiDAR sensors must be modern in terms of technology and design should be less than 3 years old and shall be capable of:

- Detecting the seafloor to the depths expected in the survey area in the prevailing water conditions.
- Achieving a spot spacing at the water surface of at least 3 x 3 m, or as required to achieve required IHO Order for the sensor in use.
- Modelling the sea surface and correcting seabed returns.
- Recording the reflectivity / intensity from each pulse, normalize returns between lines is desirable.
- Multiple bathymetric LiDAR sensors may be used to provide high-resolution shallow data provided overlap between sensors is achieved.
- Provide concurrent imagery at resolution to match the point spacing or better. Unless otherwise specified imagery should be provided at the highest resolution possible.

Topographic LiDAR sensors (if specified) must be capable of:

- Detecting multiple discrete returns, with a minimum of 4 potential returns for each outbound laser pulse.
- Achieving at least 4 points per meter.
- Recording the intensity of each return.

The Inertial Measurement Unit shall meet or exceed the following performance guidelines:

- Accuracy in roll and pitch (RMS): 0.015 degrees.
- Accuracy in heading (RMS): 0.050 degrees.

2.6.1.1 LiDAR Control Areas

2.6.1.1.1 LiDAR Benchmark Reference Surfaces

A reference surface known as a LiDAR Benchmark shall be surveyed by MBES to IHO Special Order. Benchmark areas should be square shaped with dimensions wider than the planned swath width of LiDAR lines. They should be in areas of smooth seabed with no more than one meter change in depth across the benchmark. Benchmark areas should be chosen strategically during the planning stage depending upon the average survey depth, turbidity conditions and terrain. Ideally, a LiDAR Benchmark area is located on the same line as a Topographic Integration Point

2.6.1.1.2 Topographic Control Points (TCPs)

Topographic Control Points (TCPs) are to be surveyed independently to a higher standard than the required THU of the survey. TCPs must be established to adequately cover the full extent of the survey area and be representative of the project area landscape. A minimum of 20 topographic control points, then 1 per 40 km² where LiDAR coverage exceeds 400 km². The TCP survey design shall be included in the SMP.

2.6.1.1.3 Topographic Integration Points (TIPs)

Topographic Integration Points (TIPs) are flat areas free of any vegetation or other obstructions such as sports fields or open parks, located close to the coastal strip. TIPs are to be surveyed independently of any LiDAR GNSS operations at a grid interval smaller than the largest bathymetric spot spacing used in the survey. TIPs are to be surveyed with topographic and bathymetric LiDAR systems to allow vertical accuracy checks and comparisons to be conducted.

2.6.1.2 Calibration and Checks

2.6.1.2.1 Factory Calibration

Factory calibration of LiDAR sensors is required within 3 months of the commencement of survey. Factory calibration shall address both radiometric and geometric performance and calibration and details furnished in the ROS. The calibration will include:

- LiDAR Radiometric Calibration (sensor response) – The output of the laser must be shown to meet guidelines for pulse energy, pulse width, rise time, frequency, and divergence for the model of LiDAR being tested.
- Range Calibration – Determine rangefinder calibrations including first/last range offsets, temperature dependence, and frequency offset of rangefinder electronics, range dependence on return signal strength. Provide updated calibration values.
- Scanner Calibration – Verify that scanner passes accuracy and repeatability criteria. Provide updated scanner calibration values for scanner offset and scale.
- Position Orientation System (POS) - Laser Alignment – Check alignment of output beam and POS. Also, provide updated POS misalignment angles.

2.6.1.2.2 Sensor Offsets

The LiDAR sensor-to-GPS-antenna offset vector components ("lever arm") shall be determined with an absolute accuracy of 0.01 m or better for each component. Measurements shall be referenced to the antenna phase center. The offset vector components shall be re-determined each time the sensor or aircraft GPS antenna is moved.

2.6.1.2.3 Field Calibration

Field calibration check of LiDAR to confirm both depth and horizontal position performance is to be performed on each bathymetric survey flight by collecting data over a local LiDAR benchmark site and a TCP or TIP. The statistical comparisons of position and depth and topographic height are to be calculated and included in the ROS.

2.6.1.3 LiDAR Cross Lines

Cross lines are to be flown to ensure tidal and datum consistency over the entire survey area. Cross lines are to be planned, avoiding areas of reef. Optimum cross line statistics are obtained when cross lines are flown over areas of flat sea floor and varying depth.

2.6.1.4 LiDAR Coverage

Adjacent survey lines shall be flown to achieve a 20% overlap and a water surface laser spot spacing of 3 m or less.

2.6.1.5 LiDAR Intensity

Where LiDAR intensity is required for the survey, the following shall be provided:

- Intensity of seafloor reflectance values for each discrete return.
- A description of the adjustments that have been applied to intensity information shall be provided, e.g., intensity correction, intensity normalization.

2.6.1.6 Aerial Imagery

Where aerial imagery is required to be collected concurrently with LiDAR depth and topographic height measurements, the following shall apply:

- Index files in SHP format shall be provided that show the extents of each image/tile.
- The spectral range of the imagery shall be rendered with the maximum number of bands supported by the photographic equipment.
- Contrast, brightness and color of each image shall be adjusted to minimize the color variation between photos and photo runs. Color balance across the whole mosaic shall be optimized to allow quality color discrimination whilst still providing the best possible tonal match across the image.
- The imagery shall be provided at source resolution in Enhanced Compression Wavelet (image format) (ECW) or GeoTIFF format.

2.6.2 Satellite Derived Bathymetry

2.6.2.1 Passive Satellite Derived Bathymetry (SDB) – Reflectance

The proven technique of passive SDB using remotely sensed reflectance is not able to meet the accuracy standards specified in S-44 (6.1.0) (International Hydrographic Organization, IHO, 2022) within the depths of water where it is capable of returning credible results, and therefore it is not being considered as a viable hydrographic survey method for safety of navigation surveys in KSA. The TVU of passive SDB is not likely to be better than 10% of depth, its depth capability is limited to about 25m in clear water and less than 5m in turbid water.

Passive SDB may be useful for initial reconnaissance of un-surveyed coastal areas and for coastline determination, thus it may be permitted to support a hydrographic survey project.

Where SDB is proposed to be used the SIC shall demonstrate how it will be utilized and provide a full assessment of methods to be used, the uncertainties associated with the technique, and how it will add value to the final product.

Australian collaborative seabed mapping program () has developed detailed guidelines for SDB (). A guideline for SDB from Land Information New Zealand (LINZ) Hyspec 2.0 () is included at 3.5.

2.7 Other Hydrographic Observations

2.7.1 Wreck and Seabed Feature Investigations

2.7.1.1 Significant Features

Identification, investigation, determination of least depth, and reporting of significant features is a fundamental part of a hydrographic survey and of ensuring the safety of navigation within the survey area.

A significant feature may be any item on the seafloor that is distinctly different from the surrounding area. It is defined in S-44 (6.1.0) (International Hydrographic Organization, IHO, 2022) as a feature "that poses a potential danger to navigation or object one would expect to see depicted on a nautical chart or product". However, S-57

(International Hydrographic Organization, IHO, 2000) Edition 3.1 Supplement 3 defines Significant Features as listed in the below Table 2 which aligns generally with the feature detection standards of S-44 (6.1.0).

Table 2: Significant Features (S-57 Ed 3.1 Supp 3) (International Hydrographic Organization, IHO, 2000).

Depth (m)	Is a Significant Feature if the variation in depth is greater than…
<40m	2.0m
>40m	10% of depth

This definition of significant features shall be used unless otherwise specified in the HI.

The SIC is to ensure that all wrecks, obstructions, shoals, and other seabed features are detected and measured to ensure the survey achieves the desired feature detection required by the survey standard and HI.

2.7.1.2 Investigations

Significant features are to be investigated and WCD logged and analyzed to ensure that the least depth is determined, and such sounding shall be designated in the final bathymetric surface.

2.7.1.2.1 Wrecks

All wrecks located during the survey shall be investigated to determine the position, orientation, dimensions, height above seabed and least depth, together with an opinion on its nature of material (steel/ wood/concrete, etc.) and attributes as per S-101 (Annex A in International Hydrographic Organization, IHO, 2023). A full description of each wreck investigation and its findings are to be reported in the ROS.

Investigation lines are to be run using survey parameters to maximize sounding density with WCD logged to enable post–processing of the water column to provide least depth if the real-time swath bathymetry did not digitize this feature.

Survey lines are to be conducted as follows:

- One line centered over the major axis of the wreck with two parallel lines either side ensuring no data gaps exist between these lines.
- At least one line perpendicular to the major axis of the wreck and subsequent lines on either side of this line ensuring the whole wreck is fully ensonified from this direction.

For all isolated wrecks in less than or equal to 50 m water depth or in shipping lanes, in areas of high traffic density, or in areas where minimal under-keel clearance is regularly experienced, a sonar sweep by SSS is to be undertaken on a larger scale of at least 1:5,000 to delineate the wreck clearly.

Further investigative observations such as: the use of magnetometer, drop camera or remotely operated underwater vehicle may be called for in the HI.

Newly discovered wrecks, and any changes in the charted depths and other vital navigational information for existing wrecks, are to be reported by Notice to Mariners (Form H102) to Mawani (Saudi Ports Authority) and the GEOSA, Hydrography Department on occurrence.

2.7.1.2.2 Obstructions

All obstructions, including abandoned well heads, pipelines and other man-made objects shall be investigated using survey parameters to maximize sounding density and with WCD logged to determine least depth.

For all isolated obstructions in less than, or equal to, 50 m water depth or in shipping lanes, in areas of high traffic density, or in areas where minimal under-keel clearance is regularly experienced, a sonar sweep by SSS is to be undertaken on a larger scale of at least 1:5000.

Existing oil/gas/water pipeline infrastructure, telecom cables, etc. in the area do not need continuous SSS sweep. However, alignment and least depth are to be determined.

Reporting requirements for obstructions are the same as for wrecks.

2.7.1.3 Disproving Searches / Elimination of Doubtful Data

The field checking of published navigational charts is an important part of the modern hydrographic survey.

Doubtful data includes features thought to be unlikely from a study of the general seabed topography, or those whose position is not known with sufficient accuracy. These will be charted as Position Approximate (PA), Position Doubtful (PD), Existence Doubtful (ED), Sounding Doubtful (SD), Reported danger or soundings (Rep) or noted as Discolored Water. Many charted features shown as 'doubtful' data have been sourced from old navigation charts and the source and reliability are unknown.

Care shall be taken to fully disprove any shoals and features (including PA, ED) which are present on published charts, but not found in the collected survey data. Where the doubtful data position falls outside coverage of a routine full seafloor search hydrographic survey, the search radius should be at least 3 times the estimated uncertainty of the reported hazard. Unless otherwise specified in the HI, high resolution MBES and/or SSS sweeps in two directions at right-angles should be conducted over the position, extending the search area as required to confidently disprove the reported feature.

The SIC shall provide a definitive statement as to whether they exist or not, or whether further investigation is required. If further investigation is still required, the SIC shall provide an explanation why this is the case and what course of action they believe should be undertaken to remove the data from the chart.

2.7.1.4 Shoal Summary and Uncharted Feature Reporting

Newly discovered significant features together with suspected wrecks located during the survey shall be reported by Notice to Mariners (Form H102) to Mawani (Saudi Ports Authority) and GEOSA, Hydrography Department without delay (with respect to position, extent, and least depth).

A shoal summary, listing and allocating a unique identifier to each significant feature (shoals / wrecks), as well as disproved shoals / wrecks, shall be provided in the ROS. The shoal summary shall record the position and least depth, together with charting recommendations relating to the feature and the reference of its H102 report. Each feature in the shoal summary shall be reviewed to ensure that survey coverage is adequate to confirm least depth with confidence, and that least depth is represented in the final bathymetric surfaces.

2.7.2 Nature of the Seabed

Unless otherwise specified in the HI the nature of the seabed shall be determined down to the depth of 100 m (e.g., to inform anchoring, trawling etc.) by sampling (where permitted), drop camera or AUV images and interpretation of backscatter from other sensors such as side scan sonar and/or sub-bottom profiler. Ground truthing will be used to determine inference techniques using physical sampling or photographic means.

SSS and SBP data, combined with MBES backscatter and bottom samples (ground truthing), shall be processed & interpreted to produce surficial geology maps in the coastal zone. Bottom Quality maps, classified and attributed in accordance with S-57/S-101 Object SBDARE shall be produced from this process.

2.7.2.1 Seabed Sampling

2.7.2.1.1 General Requirements

Seabed samples are required to ground truth significant changes in seabed textural areas (as determined by acoustic inference from MBES/SSS) and over significant bathymetric features. Seabed sampling to describe the nature of the seabed shall be obtained:

- In all charted and likely anchorages,

- On all banks, navigationally significant shoals, and seamounts, particularly where these are likely to be unstable, and in the channels between them,
- As required to assist in the interpretation of side-scan sonar records or MBES seafloor backscatter records with at least one sample being taken in each major textural area identified.

2.7.2.1.2 Methods

Samples shall be obtained by diver, grab, dredge or drop camera with the vessel stationary in the water. In sensitive marine areas seabed type may be determined with seabed photographs by means of a drop camera or equivalent subsea camera system.

2.7.2.1.3 Reporting

All samples taken shall be recorded, photographed with scale and reported in the ROS. The position, heading and COG (Course Over Ground) of the vessel when the sample is taken shall be recorded along with the time of sample and nature of sample. The method of sampling used shall be described and any problems with the equipment or the recovery of seabed samples should be explained. Where the HI calls for retention of seabed samples, approximately 200 grams of each seabed sample is to be retained, stored in plastic screw top containers and refrigerated until forwarded.

Sample types are to be classified in accordance with the types shown in INT1 Section J, Nature of the Seabed (United Kingdom Hydrographic Office, UKHO, 2020).

Additional seabed sampling requirements may be included in the HI.

2.8 Oceanography and Meteorological Observations

Six hourly weather observations are to be made at the World Meteorological Organization (WMO) standard observation times of 00Z, 06Z, 12Z, 18Z, and on occurrence of severe weather.

A digital copy of all observations shall be included in the ROS. Where weather impacts on the conduct of survey operations, it is to be explained in the ROS.

Codes for weather reports are contained in WMO-No 306 (World Meteorological Organization, WMO, 2019).

The following parameters are to be recorded / observed:

- Latitude,
- Longitude,
- Quadrant of the globe,
- Time,
- Air pressure,
- Cloud cover,
- Temperature (dew point, dry bulb, sea surface temperature),
- Wind direction and speed,
- Precipitation since 0001z,
- Current weather,
- Previous weather,
- Wind wave period and height,
- Swell wave period, height, and direction,
- Visibility (horizontal).

In addition to barometric pressure recording for tide gauges, sound velocity for sonar operations and turbidity measurements to support LiDAR operations, the HI may include requirements of additional meteorological and oceanographic observations.

2.8.1 Spatial and Temporal Metadata

All oceanographic and meteorological data must be tagged with the position (latitude and longitude) on WGS 84 and a Date-time. Date-time should always be in UTC and where possible be coded in an ISO8601 format like YYYY-MM-DD hh:mm:ss. Computer clocks on all instruments used should set to UTC time and the time checked prior to observations.

2.8.2 Data Format Requirements

All data should be submitted in either ASCII text format or a recognized readable format such as the netCDF (Network Common Data Form (scientific data format)) format, Excel .xlsx format or ASCII CSV format. Data submitted in the netCDF format should follow the CF metadata standards (see http://cfconventions.org).

Where raw data comes from an instrument in a proprietary binary format it must be converted to a readable ASCII format prior to submission.

2.8.3 Instrument Configuration

Oceanographic instruments shall be configured such that all sensed data parameters are recorded.

2.8.4 Expendable Bathy Thermograph (XBT)

In addition to XBT casts to support deep water MBES the HI will detail the need to determine the temperature profile of the water column by XBT throughout the survey area and whilst on passage to the survey area.

2.8.5 CTD Probes

A Conductivity / Temperature / Depth (CTD) probe provides a vertical profile of salinity, temperature and depth which allows SVP to be calculated more accurately than some sound velocity probes. CTD technology is normally used for ships' hull sea surface temperature and salinity measurement and are fitted to Moving Vessel Profiler (MVP) and oceanographic instruments such as Argo Floats and Ocean Gliders.

2.8.6 Sound Velocity Probes

Accuracy of sound velocity probes vary depending on the technology they employ. Time of flight probes are recommended as they are the most accurate, ±0.035 ms-1. CTD measurements generally provide SVP accuracy of ±0.25 ms-1, and 'sing around' sound velocity probes provide an accuracy of ±0.3 ms-1. The accuracy of XBT probes depends on how closely the climatological salinity matches the actual salinity.

2.8.7 Sea Surface Temperature and Salinity

As a minimum, sea surface temperature and salinity is to be measured concurrent with 6-hourly weather observations and other at-rest survey operations such as when Secchi disc observations and seabed samples are undertaken.

2.8.8 Secchi Disk – Water Clarity

Water clarity and color observations via Secchi disk or by optical instruments shall be conducted as detailed in the HI.

The Secchi disk provides a simple integrated measure of visibility through the water column. Secchi disk observations are best taken at planned location(s)/times in the survey area to indicate the variation over time or tidal cycles rather than random observations.

Optical measurements provide a more detailed vertical profile of visibility (turbidity) and will indicate the presence of more/less turbid layers such as plankton.

2.8.9 Bioluminescence

Bioluminescence observations shall be conducted at night as detailed in the Survey Instruction. The absence of bioluminescence is of equal importance to its presence and if no bioluminescence was observed the words 'Nil Bioluminescence' should be recorded.

2.8.10 Magnetometer Observations

The magnetometer is a valuable tool for searching for wrecks, particularly those which may be buried or distributed in a debris field and for determining their construction materials.

The HI may detail requirements for investigation of other magnetic anomalies. This is most likely where isogonic lines run closely together, and a series of observations through the area will be of high value.

2.9 Miscellaneous Observations

Miscellaneous observations are a general requirement of hydrographic surveys to augment the primary measurements taken during the survey and provide essential information to be included in the navigational products to support safe navigation. The HI may provide specific requirements for such observations.

2.9.1 Aids to Navigation

Where required by the HI, aids to navigation are to be checked and their position fixed in accordance with the accuracies of the survey order as specified in table 2, Section 7.4, S-44 (6.1.0) (International Hydrographic Organization, IHO, 2022), their positions and characteristics are to be reported in a tabular format in the ROS.

Aids to navigation that are found to be significantly displaced from the charted position, or characteristics differ from those charted, are to be considered a danger to navigation, and are to be reported immediately by Notice to Mariners (Form H102) to Mawani (Saudi Ports Authority) with a copy to GEOSA, Hydrography Department.

2.9.1.1 Floating Navigation Marks

Floating navigational aids such as light floats, buoys and lightships are to be fixed in both their flood and ebb position, to determine their range of movement with the mean position as detailed in the ROS. If the range is significant to surface navigation, noting the likely use of a digital chart, this variation is to be shown on the digital products. The mooring positions may also be used to determine the mean position of the aid.

2.9.1.2 Characteristics

The characteristics of aids to navigation are to be checked in the field against the details on both the official navigation chart / Electronic Navigational Chart (ENC) and the relevant Admiralty List of Lights publication. Light arcs, flashing characteristics and colors are to be checked for all lit marks.

2.9.2 Coastline Delineation – Natural Coastlines

The coastline is defined as the line of sea level at MHWS or MHHW.

When the survey extends to the coast and the coastline is required to be delineated in the field it shall be delineated by the best method available to meet the positional uncertainty requirements of the survey order IAW table 2, Section 7.4 of S-44 (6.1.0) (International Hydrographic Organization, IHO, 2022).

Outside of ports, harbors and marinas (see next paragraph) the delineation shall include the position and description of any piers, jetties, groynes, sewer outfalls and other features within the intertidal zone. A report of the methods and findings shall be included in the ROS and accompanied by Point, Line, Area (PLA) data.

2.9.3 Harbor Features

Unless required in the HI, detailed field surveys of ports, harbors and constructed marinas are not normally required as this information can be obtained from as-built surveys and port authority spatial information systems.

In all cases a comparison of the current chart information with the existing infrastructure shall be made and differences shall be identified, resolved by reference to the latest satellite imagery, and reported in the ROS, accompanied by corrected PLA data.

2.9.4 Conspicuous Objects and Landmarks

A comparison of the current status with charted conspicuous objects and landmarks shall be made and differences identified and resolved.

Objects that no longer exist, or are no longer conspicuous, shall be reported in the ROS.

The positions of all new objects which may be of use to the mariner from the conventional navigation point of view, are to be fixed to the positional uncertainty requirements of the survey order and documented in the ROS, accompanied by PLA data with attributes as per S-57/S-101.

2.9.5 Delineation of the Drying Line

When the survey area extends to the shore, and the HI requires the drying line to be delineated, this shall include the drying line of the mainland, all islands, and drying features (especially rocks), and shall be determined to the positional uncertainty requirements of the survey order.

The best way to fix the drying line is by reduced soundings, however, even when this is not possible, due to minimal tidal ranges, it is important that the whole foreshore is sighted at least once during low water to detect features and dangers that may be a risk to surface navigation. Other techniques such as GNSS, LiDAR scanning, bathymetric lidar, aerial photography and SDB may be utilized to determine the drying line. The method of determining the drying line is to be described in the ROS.

2.9.6 Tidal Stream Observations

Requirement for tidal stream observations will be included in the HI.

Observations of the direction and rate are normally recorded, wherever they are, of navigational significance such as at entrances to harbors, channels, within anchorages and adjacent to wharfs when the tidal stream is greater than 0.5 ms^{-1}.

Observations shall be processed using harmonic analysis methods and results are to be related to the closest standard port and shall clearly state the recommended text and numerical values, for insertion in the "tidal diamond" table, to be included on the chart.

When tidal streams are required and unless otherwise specified in the HI:

- An Acoustic Doppler Current Profiler (ADCP) shall be used with the priority to determine the tidal stream in the ‘surface’ layer of the water column which is top 25 m depth band below MSL.
- Each station shall be observed for a period of at least 35 days.
- The speed and direction of the tidal stream shall be determined to ±0.1 knots and ±5° respectively.
- In depths <130 m the surface layer, a full water column tidal stream shall be recorded at a resolution appropriate to the survey order and depth of water.

2.9.7 Elevations

The position and height of significant above water features that should appear on a navigational chart are to be determined to the vertical and horizontal uncertainty requirements of the survey order.

2.9.8 Overhead Clearances

Clearances from bridges, overhead cables and other above water obstructions are to be determined to the vertical and horizontal uncertainty requirements of the survey order and documented in the ROS accompanied by PLA data with attributes as per S-57/S-101.

2.9.9 Cables and Pipelines

Any offshore cables, pipelines, abandoned well heads, seabed obstructions, etc. falling outside of Saudi Aramco Restricted Oilfields are to be accurately delineated and included in PLA data with attributes as per S-57/S-101.

2.9.10 Fresh water springs

The positions of any freshwater springs are to be determined during normal surveying operations. These are to be reported in the ROS and rendered in the S-57 dataset. If required by the HI, a CTD profiler should be lowered over the freshwater spring to measure the seawater salinity profile and quantify the extent of freshwater dilution.

2.9.11 Sailing Directions and Nautical Publications

The relevant Admiralty Sailing Directions, Admiralty List of Lights and Admiralty List of Radio Signals volumes shall be checked in the field and appropriate amendments detailed in a marked up copy of the original text and submitted with the ROS. Particular attention shall be paid to any recommended approach routes, shipping channels and anchorages within or adjacent to the survey area.

Where specified by the HI, additional PLA files, attributed as per S-57/S-101, may be required to describe new ports, harbors, infrastructure developments, anchorages, fishing areas and restricted areas.

2.9.12 Photographic views

All photographic views shall be in color digital format of at least 20 Mega-pixel resolution, labelled with time, position and view direction and stored in JPEG or TIFF format.

Photographic views to support sailing directions should be taken as described in Admiralty Mariner's Handbook NP100 (United Kingdom Hydrographic Office, UKHO, 2023). The same techniques should be applied to the additional images taken to assist the cartographer in interpretation of significant features in the survey area.

2.9.13 Channels and recommended tracks

Unless otherwise specified in the HI:

- All channels shall be swept by SSS and sounded to IHO Special Order to the channel width.
- All leading lines and recommended tracks shall be swept by SSS and sounded to IHO Order 1a to 1 nm on either side of the centerline such that all significant features are identified, and least depths found.
- Two Way Routes, and traffic separation zones are to be sounded by MBES to their charted width, plus an additional 500 m buffer on either side.

2.9.14 Geographic undersea feature and place names

In general, names and spelling shall be accepted from the latest authoritative charts and maps of the area. Newly identified undersea features may be provisionally named in the survey. Every effort should be made to find out the locally used name and its spelling from local sources.

For above water place names, the correct names in English and Arabic are normally required to be ascertained by close liaison with the local municipality or civic authorities and duly certified by them. The source of where the name was obtained from shall be included in the ROS.

2.9.15 Other Observations / Outstanding Work

At the completion of a hydrographic survey the SIC shall report any other observations or information that impacts the completeness of the current survey or may necessitate future work. Such observations could include part of offshore facility construction or demolitions work in progress, inaccessible areas or gaps in survey coverage, incomplete investigations or anything observed in or adjoining the survey area that may need to be resolved. This report is to be included in the ROS and accompanied by any PLA data in CARIS .HOB format.

2.10 Processing of Bathymetric Data

2.10.1 General Principles

All bathymetric data is to be corrected for SV and observed tides reduced to LAT and the ellipsoid.

Non swath systems (i.e., SBES, satellite derived bathymetry) are to be processed using appropriate software packages. The software, processing methodology and processing quality control procedures shall be documented in the ROS.

LiDAR is to be cleaned, corrected, and processed at the final grid resolution using a software package that provides statistical information for each grid node. Coverage and standard deviation are to be assessed to ensure compliance with specified survey order.

High resolution swath data, such as MBES, is to be processed using a software package that uses CUBE, a statistical method based on the uncertainty of the sounding and how closely it agrees with adjacent soundings, so as to create a gridded final bathymetric surface. Blunders, gross errors and systematic errors must be removed before CUBE processing. Altitude and swath data is to be cleaned and the outer beams may need to be flagged to remove from the final surfaces. Only soundings that fall within the uncertainty requirements of the survey can contribute to the final gridded surface.

For CUBE processing, a TPU must be calculated for every depth and these values must be reflected in the full density data. The magnitude of any tidal uncertainty variation within the survey area should be represented in the TPU values.

2.10.1.1 LiDAR Bathymetric Surface Resolution

The final gridded bathymetric surface for LiDAR shall be at a resolution 3 m x 3 m cells with a target of 2 soundings per cell. Topographic LiDAR shall be gridded at 1 m x 1 m cells with 4 spots per cell.

2.10.1.2 MBES Bathymetric Surface Resolution

The resolution of the final gridded bathymetric surface shall be dependent on the required survey order, feature detection criteria and the depth of water. If not specified in the HI, the grid resolution shall be such that all significant features for that order of survey are retained and apparent. This means the grid resolution/bin size should be half the distance of feature detection criteria for the depth range.

Table 3 below shows the recommended grid resolution for MBES to achieve the object detection requirements for each survey order:

Table 3: Recommended MBES Grid Resolution.

Depth (m)	Order			
	IHO Exclusive	**IHO Special**	**IHO 1a**	**Passage Sounding**
0-20	0.25	0.5	1.0	2.0
19-40	0.25	0.5	1.0	2.0
39-60	N/A	0.5	2.0	2.0
59-100	N/A	N/A	4.0	5.0
More than 100	N/A	N/A	10.0	10.0

2.10.2 Bathymetric Data and Attributes

Raw data files for all sensors are to be recorded in proprietary sensor specific file formats. Options to record data relative to the ellipsoid and relative to the water line are to be enabled so that the data may be processed relative to the ellipsoid or LAT.

The full density processed bathymetric point data should be provided in the relevant software package project structure and format, including the project files.

The final bathymetric information from a LiDAR survey should be a processed gridded dataset in S-102 Bathymetric Attributed Grid (BAG) (International Hydrographic Organization, IHO, 2022) format including uncertainty and coverage information. With the current generation of LiDAR systems, CUBE is not to be used due to inadequate density of data (unless multiple passes are collected).

The final bathymetric information from a MBES survey should be a collection of CUBE statistical surfaces delivered in S-102 BAG format. The S-102 BAG files must contain designated soundings and fully populated metadata, in particular specifying the horizontal and vertical datum and Separation Model (SEP) used.

Bathymetry from other non-swath sources shall be submitted in a format readily understood and compatible with CARIS HIPS (CARIS HIPS and SIPS a bathymetric data cleaning and validation tool). These soundings should be delivered corrected for all offsets, sound velocity etc. and shall at a minimum contain the following attributes:

- Position,
- Depth (2POD of a meter),
- Date and Time,
- Tide Applied,
- 95% statistical THU,
- 95% statistical TVU.

2.10.3 CUBE Guidelines

2.10.3.1 Capture Radius

When creating the CUBE surface, to capture all soundings that should apply to each grid node at the 95% Confidence Interval (CI) (2 standard deviations). A fixed capture radius of 0.707 x bin size shall be used. The resulting values for Order 1a are in the Table 4 below.

Table 4: Cube Capture Radius Order 1a.

Bin Resolution (m)	Capture Radius (m) at 95% CI
0.5	0.356
1.0	0.707
2.0	1.414
4.0	2.828
10.0	7.070

A value of 0.35 m should be used for IHO Special Order and 0.20m for IHO Exclusive Order.

2.10.3.2 Capture Distance

Capture distance should not be used and thus it should be set at 0.8% to avoid impacting sounding capture radius.

2.10.3.3 Outliers

The incorporation of noisy data or outliers into the final gridded solution may result in a surface that is shoaler or deeper than the sea floor. All data is to be carefully cleaned to reject all ‘gross’ noise (such as noise at the transducer face) before CUBE is applied.

2.10.3.4 Surface Editing

Where the CUBE surface does not represent the "true" seafloor in an area (with either the wrong hypothesis selected by the CUBE disambiguation engine, or there is no suitable hypothesis at the required depth), then the SIC shall correct the surface using one of the following techniques:

- Rejecting soundings as necessary and re-CUBE the area to force the CUBE disambiguation to select the most correct hypothesis. The 'user nominate' hypothesis function in CARIS should not be used as any edits made using this method will be lost if the data is re-CUBE-d.
- Selecting Designated Sounding(s).

2.10.3.5 Designated Soundings (or Golden Soundings)

All shoal peaks, wrecks, obstructions and all hazards to navigation must be reviewed to ensure complete coverage and that least depth and valid position appear in the final bathymetric surface. The least depths must be designated in the sounding files and included in the final S-102 BAG surfaces. All shoals in navigationally significant areas must be designated. For areas other than navigationally significant areas, when it appears that the gridding selection does not adequately represent the shoal peak, additional soundings shall be designated if the difference between the gridded surface and reliable shoalest sounding is greater than:

- One-half of the allowable TVU in waters 0-20 m.
- The allowable TVU in waters 20+ m.

When the distance between two soundings that would warrant individual designation are plottable at less than 2 mm at the scale of the survey (i.e., 10 m for 1: 5,000 scale) then only the shoalest of the soundings shall be designated.

2.10.3.6 Finalized CUBE Surface

Upon completion of all editing the CUBE surface is to be finalized. Care must be taken to ensure that all edits, designated soundings, and selected hypothesis are correctly applied.

The standard deviation and the uncertainty of each node must be less than the depth accuracy allowance for the survey order. The only exception will be on steep slopes. The uncertainty value in the finalized surface shall be the greater of either the Uncertainty (TVU) or the Standard Deviation (Scaled to 95%). The finalized CUBE surface(s) shall be clearly named (by survey area / sub-area etc.) and referenced in the ROS.

2.10.3.7 Final Bathymetric Surface

The final S-102 BAG files must contain designated soundings and fully populated metadata, specifying the horizontal and vertical datum and SEP model used. As a minimum this will require:

- A surface referenced to the ellipsoid, and
- A surface referenced to LAT.

Multi-resolution grid surfaces are not acceptable. Each survey area / sub-area requiring a separate grid resolution is to be rendered as a separate final bathymetric surface in BAG format with all associated metadata.

2.10.4 Processing Quality Control

A robust and documented method of quality control is to be adhered to during data processing.

2.10.4.1 Reporting of Bathymetric Processing

The following information describing processing of bathymetric data is to be included in the ROS:

- Detailed description of all CUBE parameters that were used to create the surface(s).

- A section explaining the calculation of the THU/TVU and TPU values for all soundings and CUBE nodes, (including breakdown of errors and the vessel model used), and an explanation of how these values accurately represent the data.
- The SIC shall demonstrate that the uncertainty and standard deviation at each surface node are internally consistent and validated with empirical quality indicators, such as crossline comparison.
- Any areas of unusually high uncertainty should be explained.
- Any spatial or temporal variation in THU should be explained including area boundaries and the typical values for the different areas.
- A description of the method for determining least depth that is found on a feature, and method of any shoal and wreck investigations undertaken (see paragraph 2.7.1).

2.10.4.2 QAX Quality Assurance Tool

QAX is an open-source software tool jointly developed by collaboration between AusSeabed, National Oceanographic and Atmospheric Administration (NOAA) Office of Coast Survey, and the University of New Hampshire's Center for Coastal and Ocean Mapping which facilitates quality assurance of MBES data.

The latest version of QAX (currently 3.0.14) is available on the AusSeabed GitHub (https://github.com/ausseabed/qax)

QAX provides an efficient workflow for checking multibeam echosounder data. The tool standardizes QA outputs and assists the surveyor to perform a robust QA of data.

Three plug-in tools are available through the QAX user interface:

- MATE – performing checks on raw data, and logs results to a QAJSON file.
- MBESGC – performing grid checks against IHO or other survey orders.
- FinderGC – performing grid checks to identify holidays and erroneous data.

Use of this tool is recommended for all MBES data collection activities in KSA as it facilitates the robust QA of survey outputs and provides standard QA outputs.

MBESGS grid checks should be conducted on all surfaces.

2.10.5 Processing, Storage and Security of Data

All data is to be processed and stored either on the survey vessel, or at an approved premises in Saudi Arabia or as otherwise specified in the HI.

The SIC must ensure that there are positive measures in force to ensure the safe custody of all original and processed survey data (including field records), and that there is a place of safety that the data can be taken to should the compartments on board or on-shore processing offices be threatened by fire, flood or other damage. There is to be a pro-active cyber security policy to safeguard data from cyber theft or manipulation. Further data security requirements may be detailed in the HI.

2.11 Data Formats and Deliverables

2.11.1 Data Formats

The formats listed in Table 5 below outline the recommended standards for exchanging hydrographic data types, unless otherwise specified in the HI.

Table 5: Recommended Data Formats.

Data Type	Format
Aerial imagery	ECW or GeoTIFF (with Lempel–Ziv–Welch lossless data compression algorithm (LZW) compression)
Aerial Imagery Index	ESRI SHP
Ancillary information	Excel .XLS/.XLSX/.CSV or CARIS .HOB with S-57 / S-101 attribution
Bathymetry - Final Bathymetry Surfaces (MBES) – (Resolutions per Table 3 paragraph 2.10.1.1)	Caris Spatial Archive (high volume storage framework) (CSAR) and BAG (appropriately attributed)
Bathymetry – Full Density MBES	CARIS HIPS & SIPS project, Qimera/ Fledermaus Geocoder Toolbox (FMGT) project and GSF
Bathymetry LIDAR - Raw	LAS (File format for exchange of 3-dimensional point cloud data) 1.4 + waveforms in proprietary format
Bathymetry – Final Bathymetry Surfaces (LIDAR)	CSAR and BAG (appropriately attributed)
Bathymetry - SBES	CSAR and BAG (appropriately attributed)
SVP/CTD Profiles/SST (Sea Surface Temperature)	ASCII CSV, including date/time/lat/long or netCDF
LIDAR Flight Tracks	ESRI SHP
GNSS	RINEX
Marine Laser Scanner Point Data	LAS
Photographs	JPEG or TIFF resolution >=300dpi
Point Line Area	ESRI SHP or Caris .HOB attributed per S-57/S-101
Raw files – all sensors	Proprietary sensor format
Seafloor reflectance (unprocessed)	XTF
Seafloor reflectance (processed)	GeoTIFF (LZW compression is preferred) with backscatter values – Mosaiced to match resolution of final bathymetric surface
Tidal streams	RAW in Proprietary sensor format, processed data ASCII CSV
Sea level data	RAW data in proprietary sensor format Processed data ASCII CSV
Seabed Bottom Quality Map	SHP or CARIS .HOB attributed per S-57/S-101
Water Column Data	Proprietary or ASCII CSV (XYZ)
Wrecks and Obstructions	Tabulated text description – Excel, attributed data CARIS .HOB or SHP, Images and WCD

2.11.2 Deliverables

Standard deliverables are identified in Sections 2.1 to 2.10 of this Guideline. Additional requirements will be provided in the HI.

3. Supplementary Informative Elements

3.1 Vessel Requirements

All survey vessels, launches and Uncrewed Survey Vessels (USV) employed in the survey work shall be seaworthy, compliant with IMO requirements and subject to inspection & approval by GEOSA Executive Directorate of Permits, Control and Compliance (LD@geosa.gov.sa) prior to deployment to survey area. Aramco Marine Department, Surveys within the Saudi Aramco restricted areas may only be initiated by Saudi Aramco and coordinated through the Ministry of Energy.

All aircraft and Uncrewed Aerial Vehicles (UAV) are to be airworthy, compliant with International Civil Aviation Organization (ICAO) requirements and subject to inspection & approval by KSA's General Authority for Civil Aviation

Hydrographic survey platforms must maintain a safety management system, good ships husbandry and where appropriate they are to include good habitability conditions for crew and visiting personnel. All crew are to be appropriately qualified for their employment.

All personnel joining a vessel shall undertake a safety induction within 24 hours. The induction shall, at a minimum, cover vessel layout, escape routes, location of emergency equipment, alarms and emergency actions. All vessels must keep clear of the 500-meter safety zone around fixed oil or gas production platforms and mobile drilling rigs, under tow.

Charted offshore field development area limits are not to be encroached upon without prior permission from Saudi Aramco Field Supervisor and/or competent authorities.

3.2 Safety and Compliance

A safety management plan, incorporating standard risk assessment procedures, shall be maintained for all operations in Saudi Arabian waters. An emergency response plan, tailored to the specific risks of the HI, is to be maintained and should address all relevant aspects such as response to first aid incidents, diving and other medical emergencies, vessel emergencies including fire, collision, and grounding.

Equipment and survey personnel employed in the survey shall be always the responsibility of the survey operator. Any loss, injury or damage suffered or caused by them shall be at the risk of the survey operator.

Any loss, injury or damage to personnel, equipment or the environment must be reported to the appropriate KSA authority as required by local regulations and the national legislation of the flag state of the vessel.

3.3 Reporting / Report of Survey

3.3.1 Routine and Operational Reporting

The conduct of a hydrographic survey is often challenging, complex, of an extended duration and generates massive quantities of raw and processed data. To minimize risk, facilitate good data management, archiving and processing, and enable milestone payments, a variety of interim reports and deliverables may be required at various points in the survey.

The HI will provide details of required milestone, interim and routine reports which may include but not be limited to the following:

3.3.1.1 Survey Management Plan (SMP)

This report entails the plan for conducting the survey including tide stations, vessels and equipment, personnel a-priori TPU estimates, system settings, schedule etc. Updates to the plan shall be submitted as and when changes become necessary.

3.3.1.2 Pre-Acquisition Report

This report details the establishment of horizontal and vertical datum, tide gauge calibration and connection to geoid, vessel and equipment sensor alignment and calibrations, interference and backscatter trials and confidence checks, reference surface checks, etc. This report may require approval from the tasking authority prior to commencement of survey data collection.

3.3.1.3 Milestone/Progress Report

This report will state whether survey coverage has been achieved, while describing weather and traffic impacts, survey miles and areas completed.

3.3.1.4 Quality Assurance Report

This report details a-posteriori TPU achieved, cross line comparison results, reference surface checks, SSS confidence checks, and how the survey meets the required guidelines.

3.3.1.5 Final Field Report

This report details the completion of survey operation, including areas surveyed and results achieved, data recovered from tide gauges, completeness of the survey and feature detection as well as plans for demobilization.

3.3.1.6 Demobilization Report

This report will detail the recovery of all infrastructure and the movement of all data to the shore processing facility.

3.3.2 Report of Survey (ROS)

All hydrographic surveys must be accompanied by a comprehensive ROS which provides a full description of all aspects of survey operations. It must give a clear and comprehensive account of how the survey was carried out, the results achieved, the difficulties encountered and other shortcomings. And a comprehensive listing of all records and metadata.

Guidance on the format and content of the ROS is contained in the IHO Manual of Hydrography (/2011). The example layout of annexes and content in Appendix 5 of the IHO Manual of Hydrography should be followed unless otherwise specified in this guideline or the HI.

The ROS is the key document where the SIC shall certify the standards and guideline that have been met and the quality of the results achieved. It must include a comprehensive quality assurance report with documentation and quality records to demonstrate how the survey met the guidelines in all aspects, particularly vertical and horizontal uncertainty and bathymetric coverage and feature detection.

It shall include: overall quality plan, mobilization, sensor alignment and calibration reports, reference surface comparisons, operational parameters of all systems, monitoring controls, results of wreck and feature examinations, quality assurance and verification procedures, data processing procedures, records of all settings, offsets and corrections applied for DP, all system log files, all metadata (especially reference datums & epochs), variances from guidelines, as well as how the above mentioned were addressed.

The ROS should be in two or three parts:

- Part 1 (Descriptive)
- Part 2 (Technical Annexes)
- Part 3 (Oceanographic and Science Annexes) (only necessary if these observations are specified in the Survey Instruction)

Emphasis within Part 1 should be placed on the analysis of achieved accuracies and whether the guidelines called for in this survey guideline and IHO Publication S-44 (6.1.0) standards have been met.

Part 2 contains the necessary technical discussion to support opinions expressed in Part 1.

Part 3 is a standalone section that will only be required where substantial additional scientific observations are to be made. It should contain enough information for the recipient to effectively use the data collected for oceanographic and scientific purposes.

Guidance on the format and content of the ROS is contained in the IHO Manual of Hydrography (/2011). The example layout of annexes and content in Appendix 5 of the IHO Manual of Hydrography should be followed unless otherwise specified in this guideline or the HI.

Additional detail on the content of individual annexes is contained in section 13.4 of Hydrographic Industry Partnership Program (HIPP) Statement of Requirement (SOR) 2023.2 (Australian Hydrographic Office, 2023)

3.4 Related Standards

In addition to the standards, guidelines and guidelines directly referenced in this guideline, the following standards are also relevant to Hydrographic Surveys in KSA.

- Standards for Hydrographic Surveys V2.0 (2005), Saudi Ports Authority (SPA).
- Hydrographic MBES Survey Standards (2005). Saudi Ports Authority (SPA).
- The General Authority for Survey and Geospatial Information (GEOSA) Hydrographic Data Management (HDM) File Naming Convention (Version 1, revision2).
- Guidelines for Geodesy for the Kingdom of Saudi Arabia, 2024.
- Guidelines for Remote Sensing Analysis Ready Data for the Kingdom of Saudi Arabia, 2025.

3.5 Satellite Derived Bathymetry Guideline

(Edited reproduction with permission of Toitū Te Whenua Land Information New Zealand Hydrographic Authority – Source: LINZ HYSPEC (Land Information New Zealand, LINZ, 2020) 2.0 – Annex B)

3.5.1 Imagery

- Avoid capture during periods of heavy smoke haze.
- Calm seas and clear water.
- Avoid capture during periods of high turbidity.
- Recording geometries should avoid sun-glint and sun-glitter effects on the water surface.
- Avoid capture during periods of high cloud/fog cover, more than 10% cloud cover over the marine area of interest is unacceptable. The marine area of interest extending from the high waterline to the SDB extinction depth (15-20m contour).
- Avoid capture during times of flooding. Capture should be done at times of base flow in areas with floodplains and wetlands.
- There is no tidal restriction on data acquisition. Consideration shall be given to the state of the tide and its effect on turbidity.
- Strong wave activities with whitecaps shall be avoided.

3.5.2 Orthorectification

Basic level satellite imagery is usually referred to the WGS 84 ellipsoid. Unless fully orthorectified, imagery acquired off-nadir will demonstrate increasing horizontal positional errors with increasing elevation – and in offshore areas with increasing depth – away from the reference surface. To mitigate this error, imagery should be appropriately geo-processed to refer to a geoid equipotential surface before deriving bathymetry. Higher levels of imagery such as Level OR2A of image processing may remove the need to correct for this.

3.5.3 Positioning

The horizontal accuracy of all depths and positions shall be 5 m circular error at the 90% confidence level without ground control. If ground control is used, then the allowable horizontal error is 2 m or one pixel width.

Horizontal ground control is required during processing to improve the positional accuracy. If MBES and LIDAR data is available, then this should be used to improve and assess the accuracy of the imagery and calculated bathymetry.

Positions of depth points are to be horizontally corrected to account for view-angle geometry and refraction effects.

3.5.4 Bathymetry

3.5.4.1 Extinction Depth

The SIC shall carefully select an extinction depth. This is the depth where bathymetry can no longer be derived (optically deep) or where the uncertainty in the derived bathymetry becomes too unreliable. The extinction depth will depend on the quality of the input imagery. An explanation of the selected extinction depth shall be included in the ROS.

3.5.4.2 Depth Determination

SDB depths are a measure of observed path length from surface to seabed, as such off-nadir satellite imagery will be subject to errors combining diagonal view angle and refraction through the water surface. Both factors will need to be accounted for to derive the correct depth. The SIC shall describe how this correction was made in the ROS.

3.5.4.3 Ground Truthing

Where possible SDB shall be assisted by ground truthing. Existing bathymetric datasets shall be used in the processing and quality control of SDB data where they are available. The underlying uncertainty in the "ground truth" datasets shall be considered when these datasets are used.

3.5.4.4 Uncertainty Assessment

The SIC shall provide an assessment of the horizontal and vertical accuracy of the derived depths. A full explanation of how these derived accuracies is to be included in the ROS.

Vertical uncertainty values are to be provided for each depth measurement. The SIC shall outline the approach taken to calculate uncertainty values in the ROS.

3.5.4.5 Depth Density

The density of the depth data shall be the same resolution as the input image (accounting for minor differences due to refraction and diagonal view angle).

3.5.4.6 Coverage

Full seabed coverage should be achieved from the low waterline to the extinction depth (i.e. the optically shallow area). This may be limited in areas of cloud cover or vessels/obstructions where there are expected to be gaps in the data.

3.5.4.7 Depth Data cleaning

All systematic errors and obvious outliers shall be removed from the delivered dataset. This includes:

- Areas where false depths are automatically derived from clouds/vessels in the image.
- False depths over dry land.
- False depths in deep water beyond the extinction depth.
- Areas of localised turbidity.

Depths shall not be interpolated to fill holes in the dataset.

3.5.5 Data Processing

Data processing of SDB shall include but not be limited to the following steps:

- Data import & conversion, quality inspection, radiometric calibration.
- Land-Water masking.
- Aerosol retrieval, atmospheric & water surface correction.
- Correction for adjacency effect.
- Optical properties analysis.
- Retrieval of water constituent concentrations.
- Coupled retrieval of in water optical properties (IOPs), atmosphere and depth.
- Analysis of main sea bottom albedo types.
- Creation of vertical and horizontal uncertainty information. Apply the client-provided and/or available in-situ data for validation purposes.
- Adjustment of water depth to the required vertical datum.

Full details of the processing involved in each step shall be included in the ROS. The SIC shall provide any intermediary datasets from each stage of the process if required.

3.5.6 Accuracy Requirements

SDB vertical uncertainty will likely exceed all of the survey orders contained in section 2., therefore, where SDB is permitted to be used for hydrographic surveys, the accuracy requirements outlined below are to be achieved unless otherwise specified in the HI:

3.5.6.1 Vertical Uncertainty

- <= ±0.5 m ± 10% depth 90% confidence interval where ground truth measurements are provided.
- <= ±1 m ± 15% depth. 90% confidence interval where no ground truth calibration exists.

3.5.6.2 Horizontal Uncertainty (90% CI)

- <= +/- 2 m or within one pixel value. In case of ground control points.
- +/- 5 m (in case of no ground control points).

3.5.7 Tides

All depths are to be reduced to sounding datum. The SIC shall outline the method used for tide reduction and outline the uncertainty involved in the reduction. All methods are to be outlined in the ROS.

3.5.8 SDB Deliverables

3.5.8.1 Satellite Data

All original satellite data is to be rendered in the deliverables; this includes:

- Raw images.
- Satellite orientation.
- Rational Polynomial Coefficients (RPC) files.
- Ephemeris data.
- All imagery is to be provided in georeferenced GeoTIFFs. The imagery must be accompanied by an index shapefile showing the extents of each image.

3.5.8.2 Bathymetric Point Cloud Data

Two sets of derived bathymetry products are to be delivered; these include:

- One set to represent the vertical water depth at time of image acquisition.
- One set depicting depths reduced to chart datum using tide data or separation model.

Bathymetric point clouds are to be cleaned, un-gridded and provided in ASCII XYZ format.. In conjunction to the bathymetric information, the associated uncertainty of each derived point is to be provided as an extra attribute for each depth. This is also to be included in an ASCII XYZ format.

3.5.8.3 Gridded Bathymetry

32bit floating point GeoTIFF or BAG. Grid resolution is dependent on the resolution of the imagery. There is no requirement to return uncertainty for the gridded dataset.

3.6 Symbols, Acronyms and Abbreviations

Symbols, Acronyms and Abbreviations	Definition
ADCP	Acoustic Doppler Current Profiler
AHO	Australian Hydrographic Office
ASCII	American Standard Code for Information Interchange
AusSeabed	Australian collaborative seabed mapping program
AUV	Autonomous Underwater Vehicle
BAG	Bathymetric Attributed Grid
CD	Chart Datum
CF	Climate and Forecast
CI	Confidence Interval
COG	Course Over Ground
CORS	Continually Operating Reference Station
CSAR	Caris Spatial Archive (high volume storage framework)
CSV	Comma Separated Values file format
CTD	Conductivity / Temperature / Depth
CUBE	Combined Uncertainty and Bathymetry Estimator
ECW	Enhanced Compression Wavelet (image format)
ED	Existence Doubtful
EGM08	Earth Gravitational Model 2008
ENC	Electronic Navigational Chart
EPSG	European Petroleum Survey Group
ESRI	Environmental Systems Research Institute Inc.
FIG	Federation International Geographic
FinderGC	QAX plug in performing grid checks to find gaps and erroneous data
FMGT	Fledermaus Geocoder Toolbox
GEOSA	General Authority for Surveying and Geospatial Information
GeoTiFF	Georeferenced TIFF file format
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference System 1980
GSF	Generic Sensor Format
HAT	Highest Astronomical Tide

HDM	Hydrographic Data Management
HI	Hydrographic Survey Project Instruction
HIPP	(AHO) Hydrographic Industry Partnership Program
HIPS/SIPS	CARIS HIPS and SIPS a bathymetric data cleaning and validation tool
HOB	CARIS .HOB Hydrographic Object Binary data format file
IAW	In Accordance With
ICA	International Cartographic Association
ICAO	International Civil Aviation Organization
IHO	International Hydrographic Organization
IMU	Inertial Motion Reference Unit
INT1	INT1 Symbols, Abbreviations and Terms used on Charts (IHO Publication)
IOPs	Inherent Optical Properties
ITRF	International Terrestrial Reference Frame
JPEG	Joint Photographic Experts Group file format
KSA	Kingdom of Saudi Arabia
LAS	File format for exchange of 3-dimensional point cloud data
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LINZ	Land Information New Zealand
LZW	Lempel–Ziv–Welch lossless data compression algorithm
MATE	QAX plug in that performs checks on raw MBES data
MBES	Multibeam Echo Sounder
MBESGC	QAX plug in that performs grid checks against survey orders
MHWS	Mean High Water Springs
MHHW	Mean Higher High Water
MLWS	Mean Low Water Springs
MSL	Mean Sea Level
MTES	Multi-Transducer Vertical Sweep System
MVP	Moving Vessel Profiler
netCDF	Network Common Data Form (scientific data format)
NGN	National Gravity Network

NOAA	National Oceanographic and Atmospheric Administration - USA
OR2A	View-Ready (2A) Imagery
PA	Position Approximate
PD	Position Doubtful
PLA	Point, Line, Area
POD	Points of Decimals
POS	Position Orientation System
PPP	Precise Point Positioning
QA	Quality Assurance
QAX	Quality Assurance Tool (open-source software)
Rep	Reported (danger or soundings)
RINEX	Receiver Independent Exchange (for GNSS data)
RMS	Root Mean Square
ROS	Report of Survey
RPM	Revolutions Per Minute
RTK	Real Time Kinematic
SANSRS	Saudi Arabia National Spatial Reference System
SBDARE	Seabed Area (S-101 Object Class with multiple attributes)
SBES	Single Beam Echo Sounder
SBP	Sub-Bottom Profiler
SD	Sounding Datum
SD	Sounding of Doubtful Depth
SDB	Satellite Derived Bathymetry
SEP	Separation Model
SHP	ESRI Shapefile - geospatial vector data format for geographic information systems
SI	International System of Units, internationally known by the abbreviation SI (from French Système international d'unités)
SIC	Surveyor in Charge
SMP	Survey Management Plan
SOR	Statement Of Requirement

SPA	Saudi Ports Authority
SPC	Survey Party Chief
SSS	Side Scan Sonar
SST	Sea Surface Temperature
SU	Survey Uncertainty
SV	Sound Velocity
SVP	Sound Velocity Profile
TCP	Topographic Control Point
THU	Total Horizontal Uncertainty
TIFF	Tagged Image File Format (Images)
TIP	Topographic Integration Point
TPU	Total Propagated Uncertainty
TVU	Total Vertical Uncertainty
UAV	Uncrewed Aerial Vehicle
USV	Uncrewed Surface Vessel
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WCD	Water Column Data
WGS 84	World Geodetic System 1984
WMO	World Meteorological Organization
XBT	Expendable Bathy Thermograph
XTF	eXtended Triton Format (open source format for SSS, Multibeam Echo Sounder (MBES) &navigation system data)
XYZ	ASCII gridded data format

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