INTERNATIONAL FEDERATION OF SURVEYORS

INTERNATIONAL HYDROGRAPHIC ORGANIZATION

INTERNATIONAL CARTOGRAPHIC ASSOCIATION

STANDARDS OF COMPETENCE FOR CATEGORY "A" HYDROGRAPHIC SURVEYORS

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1. INTRODUCTION

All components of the hydrographic surveying and nautical cartography profession face challenges as to how best to ensure the continuance of high standards and how best to ensure the continuation of best practices based on minimum standards of competence world-wide. In order to achieve these objectives, three international organizations (FIG, IHO and ICA) have developed Standards of competence that institutions or professional bodies may adopt for their educational/training programmes and competency schemes.

Standards indicate the minimum competences necessary for hydrographic surveyors. Standards recognize two levels of competence. Category "A" programmes introduces competences from the underlying principles level. Category "B" programmes introduce the competences from a practical level.

The intention is that a Category "A" individual with appropriate experience, would be a senior professional in their chosen field (government, industry, academia). Category "B" individuals with appropriate experience would be technical professionals leading and delivering products and services to meet specifications and outcomes.

2. DEFINITIONS

2.1 Subjects, topics, and elements

The S5-A standard contains the following list of ***B****asic subjects,* ***F****oundation Science subjects* and ***H****ydrographic Science subjects*:

Topics and Elements:

- Each **Foundation Science, Hydrographic Science** or **Basic** *subject* comprises a list of *topics* which are denoted by Bx.y, Fx.y, or Hx.y;
- Each *topic* contains *elements* which are denoted by Bx.y<c> Fx.y<c> or Hx.y<c>.

For example, the *subject* H1 "Positioning" contains the *topic* H1.1 Vessel and sensor reference frames that has the *element* H1.1a "Common reference frames for sensors".

2.2 <u>Learning outcomes and list of content</u>

It is important to understand that each *element* is associated with:

- one or more intended *learning outcomes*, that a student should be able to achieve on completion of the programme. All *learning outcomes* should be assessed. This may be done through one of, or a combination of, the following: examination, assessed exercise or presentation, laboratory report, or final project work.
- a list of *content*. This list is associated with one or more *learning outcomes* and describes the theoretical knowledge or practical/technical context which the course syllabi should address in order to meet a particular *learning outcome*.

3. Programme preparation and submission

The preparation of a programme submission to the IBSC should be done in accordance with the document entitled GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS. This document is available from the IHO website: www.iho.int → Standards & Publications.

The cross reference table is a mandatory requirement for a programme submission and **MUST** be completed. A template is specified and is available from the IHO website: www.iho.int

LIST OF ACRONYMS AND INITIALISMS USED IN THIS DOCUMENT

1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
A	Advanced (level of knowledge)
ADCP	Acoustic Doppler Current Profiler
AIS	Automatic Identification System
ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
B	Basic (level of knowledge)
CAD	Computer Aided Design
CMFP	Complex Multidisciplinary Field Project
CW	Continuous Wavelength
DOP	Dilution of Precision
ECDIS	Electronic Chart Display and Information System
ECS	Electronic Chart System
ENC	Electronic Navigational Chart
EPIRB	Emergency Position Indicating Radio Beacon
F	Fundamental Sciences Subjects
FIG	International Federation of Surveyors
FOG	Fiber Optic Gyroscope
GEBCO	General Bathymetric Chart of the Oceans
GIS	Geographical Information System
GK	Gauss-Krüger
GLONASS	GLObal NAvigation Satellite System
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRS80	Geodetic Reference System (1980)
H	Hydrographic Sciences Subjects
HAT	Highest Astronomical Tide
I	Intermediate (level of knowledge)
IBSC	International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers
ICA	International Cartographic Association
IHO	International Hydrographic Organization
IMU	Inertial Motion Unit
INS	Inertial Navigation System
LAN	Local Area Network
LAT	Lowest Astronomical Tide
LiDAR	Light Detection And Ranging
MBES	Multi-Beam Echo Sounder
MEMS	Microelectromechanical systems
MSDI	Marine Spatial Data Infrastructure
MSI	Maritime Safety Information
MSL	Mean Sea Level
NAVTEX	Navigational Telex
NMEA	National Marine Electronics Association

NtoM	Notice to Mariners
P	Practicals (fieldwork and/or laboratories)
RAM	Random Access Memory
RINEX	Receiver Independent Exchange Format
RNC	Raster Navigational Chart
ROV	Remotely Operated Underwater Vehicle
S-44	IHO Publication S-44 - *Standards for Hydrographic Surveys*
S-100	IHO Publication S-100 *Universal Hydrographic Data Model*
S-102	IHO Publication S-102 *Bathymetric Surface Product Specification*
SARSAT	Search And Rescue Satellite Aided Tracking
SAS	Synthetic Aperture Sonar
SBES	Single Beam Echo Sounder
SG	Self-guided exercises (or student's personal independent work)
SQL	Structured Query Language
SSDM	Standard Seabed Data Model
T	Theoretical (theory through lectures)
TIN	Triangulated Irregular Network
UNCLOS	United Nations Convention on the Law of the Sea
UPS	Universal Polar Stereographic
USBL	Ultra Short Baseline
UTM	Universal Transverse Mercator
WWNWS	World Wide Navigational Warning Service
XML	Extended Markup Language

S-5A STANDARDS:

INTENDED LEARNING OUTCOMES
AND
ASSOCIATED CONTENT

1. BASIC SUBJECTS

B1: Mathematics, statistics, theory of observations		
Topic/Element	**Content**	**Learning outcomes**
B1.1 Geometry and Linear Algebra		
B1.1a Geometry *(B)*	(i) Conic Sections, geometry of the ellipse and of the ellipsoid. (ii) Parametric equations of curves and surfaces.	Express curves and surfaces in parametric form. Compute lengths and coordinates on an ellipse.
B1.1b Linear Algebra *(I)*	(i) Vector and affine spaces, vector and inner products, norms. (ii) Linear operators, matrix representation, composition, transpose. (iii) Translations, rotations, coordinate transformations, similitudes, orthogonal projection.	Derive and compute 2D and 3D transformations, as typically involved in geodesy, surveying and survey data geo-referencing.
B1.1c Numerical methods for linear systems of equations *(I)*	(i) Systems of linear equations, Gauss elimination. (ii) Matrix decomposition, and factorization. (iii) Condition number of a matrix.	Solve linear equations by numerical methods in a scientific computing environment and analyze error bounds.
B1.2 Differential calculus and differential equations		
B1.2a Differential and integral calculus *(B)*	(i) Real and vector valued functions. (ii) Series, Taylor expansions (iii) Gradient of a real-valued functions. (iv) Jacobian matrix (v) Integrals of real-valued functions. (vi) Numerical integration methods.	Apply differential calculus to real and vector valued functions from a n-dimensional vector space. Calculate integral of classical functions and approximate numerical values.

B1.2b Differential equations *(I)*	(i) Linear ordinary differential equations, general solution with right hand side. (ii) Nonlinear differential equations, and linearization. (iii) Numerical methods for non-linear ordinary differential equations.	Compute explicit solutions for linear ordinary differential equations and apply numerical methods to approximate solutions to non-linear differential equations.
B1.2c Numerical solutions of non-linear equation *(B)*	(i) Iterative methods. (ii) Rounding and numerical errors.	Apply numerical methods to find approximate solutions for non-linear equations.
B1.3 Probability and statistics		
B1.3a Probabilities and Bayesian estimation *(I)*	(i) Probability measures, density functions (ii) Mathematical expectation, variance (iii) Covariance, correlation (iv) Conditional probabilities, Bayes law (v) Minimum mean square estimation (vi) Distributions including normal, chi-squared, t and F	Define probability measures, derive associated formulae and calculate values from data. Select a distribution for a given random variable and apply a Bayesian estimation method.
B1.3b Statistics *(I)*	(i) Random variables, mean, variance, standard deviation (ii) Estimation of mean, variance, covariance (iii) Statistical testing, confidence intervals	Compute confidence intervals and associated statistical measures for random variables using various distributions.
B2: Information and Communication Technology		
Topic/Element	**Content**	**Learning outcomes**
B2.1 Computer systems *(I)*	(i) Central Processing Unit (ii) RAM, data storage devices and standards (iii) Communication board, serial links, communication ports and standards, buffers, Ethernet links, data transmission rates (iv) Communication protocols (v) Clocks, clocks drift, time tagging and synchronization of data (vi) Operating systems (vii) Device drivers	Describe the different components of a real-time data acquisition system, including various modes of communication and time-tagging. Describe the role of a device driver and its relation to data exchange. Create/Configure a data link and evaluate any time delays across the link.

B2.2 Office work software suites *(I)*	(i) Word processors (ii) Spreadsheets (iii) Graphics software	Use classical office work software suites.
B2.3 Programming *(I)*	(i) Basic operations of a computer program or script (ii) Algorithms (loops, conditional instructions) (iii) Scientific computation environments (iv) Application to data exchange, file conversion	Write a program or script for data analysisand/or algorithm computation.
B2.4 Web and network services *(I)*	(i) Networks (LANs) (ii) Network and cloud storage (iii) Internet (iv) Networks integrity (v) Communication protocols	Describe the different network options used in remote data exchange and storage applications. Configure a small network and transfer data over that network
B2.5 Databases *(I)*	(i) File types (binary, text, XML) (ii) Relational databases (iii) Geospatial databases (iv) Database management systems and query languages	Describe different types of geospatial data and their representation. Construct a database, populate it and query its content using a database language, such as SQL.
B.2.6 Artificial Intelligence (AI) *(B)*	(i) Widely used AI tools provided by common commercial software (e.g., ChatGPT, Gemini) (ii) AI applications based on Large Language Models (LLMs): • Commercial platforms (e.g., ChatGPT, Gemini) • Open-access tools based on released model weights (e.g., LLaMA 3, Gemma 3) (iii) Generative AI tools for content creation: • Text generation and summarization • Code generation (iv) AI tools for technical and scientific tasks: • Technical report drafting and summarisation • Data analysis and decision support (v) Applications of AI in the context of big data:	Describe common types of AI Use Generative AI to create or summarize a technical report Use Generative AI to create preliminary code Describe the use of training data sets and deep neural networks in ML applications.

	Clustering, classification, (Semantic / instance) segmentation	
B3: Physics		
Topic/Element	**Content**	**Learning outcomes**
B3.1 Kinematics *(B)*	(i) Angular and linear velocities, accelerations (ii) Angular velocities addition rules, accelerations due to rotational motion, Coriolis Law	Explain the principle and the relationship between position, velocity and acceleration for both rotational and linear motion.
B3.2 Gravity *(B)*	(i) The inertial frame (ii) Newton's law, forces, accelerations, energy (iii) Center of gravity, center of instantaneous rotation (iv) Gravitational field (v) Potential fields	Differentiate between inertial and Earth fixed frames. Differentiate center of gravity from center of instantaneous rotation. Develop the mathematical relationship between potential and acceleration in a gravitational field.
B3.3 Magnetism *(B)*	(i) Magnetic characteristic of ferrous bodies (ii) Magnetic field	Describe ferromagnetic properties and resulting magnetic field.

B3.4 Waves *(B)*	(i) Harmonic waves modeling and wave parameters (amplitude, frequency, wavelength, celerity and phase) (ii) Longitudinal and transverse waves (iii) Intensity, Decibel scale (iv) Attenuation (v) Doppler effect (vi) Interferometric principles	Explain harmonics in the context of waves and resulting constructive and destructive interferences patterns from multiple waves and sources. Use the Decibel scale to define intensity and characterize attenuation. Explain the Doppler effect.
B3.5 Electromagnetic waves *(B)*	(i) Electromagnetic waves properties and propagation (ii) Radiation, emission and absorption (iii) Reflection, refraction, diffraction (iv) Optical reflectance	Calculate field of view and resolving power of optics. Describe aberrations in optical systems. Describe the effect of wavelength on the propagation in a medium. Describe the effect of a medium in the propagation of an electromagnetic wave
B3.6 Lasers *(B)*	(i) Principle of lasers (ii) Laser parameters (frequency, wavelength) (iii) Types of lasers (iv) Laser attenuation	Describe the operation, unique properties, and applications of stimulated sources of emission.
B3.7 Transducers and clocks *(B)*	(i) Pressure transducers (ii) Thermal transducers (iii) Types of clocks (iv) Measurement of elapsed time	Describe different types of transducers and their calibration requirements. Describe time measurement devices in relation to their drift coefficient and accuracy.

B4: Nautical Science and Weather

Topic/Element	**Content**	**Learning outcomes**
B4.1 Conventional aids to navigation *(B)*	(i) Types of buoys and beacons (ii) AIS systems	Describe the characteristics and purposes of fixed and floating aids to navigation and the use of automatic identification systems.
B4.2 GMDSS *(B)*	(i) EPIRBs and SARSAT (ii) Digital selective calling (iii)	Describe the EPIRB, SARSAT, and DSC components of GMDSS.

B4.3 Nautical charts and Electronic Navigational Charts *(B)*	(i) Content, datum, projection, scale and types of nautical charts (ii) Chart symbols (iii) Chart graticules (iv) Uncertainty indicators (e.g. source diagram, reliability diagram, zone of confidence, notes) (v) Navigational hazards (vi) ECDIS, ENC, RNC and ECS	Plan and layout a route for an oceanographic mission on a nautical chart or ENC, enter/plot positions, identify navigational hazards and revise navigational plan as required. Describe the content of a nautical chart and explain datum, projection and scale. Describe the uncertainty indicators associated with nautical charts.
B4.4 Navigation publications *(B)*	(i) Sailing directions, (ii) Tides and current tables (iii) Notice to Mariners (NtoM)	Use content of nautical publications in a survey planning context.
B4.5 Basic Offshore Safety Training *(B)*	(i) Basic requirements for working offshore	Recognize the requirement for completion of a Basic Offshore Safety Course
B4.6 Safe working practice *(B)*	(i) Stability, Water-tight doors and hatches (ii) Suspended loads (iii) Enclosed spaces (iv) Working aloft, with equipment over the side, life lines. (v) Securing equipment for sea (vi) Cables and antenna installation (viii) (ix)	For the listed content, describe procedures for maintaining a safe working environment in operations at sea. Design safe cable routes for electronic instruments. Define procedures for securing equipment for heavy weather.
B4.7 Rope and wires *(B)*	(i) Types of wire and rope (ii) Characteristics (stretch, floating, strength) of ropes and wires. (iii) Basic knots	Select appropriate wire or rope for a specific application Select and tie basic knots.
B4.8 Towed and over the side instruments *(I)*	(i) Rosette systems and instruments (ii) ROVs, AUVs, ASVs, towed systems, catenary and layback (iii) A-frames, cable blocks, electro-mechanical wire, wire strength factor for deep casts, slip rings and optical cabling (iv) Moon pools (v) Deployment and recovery of instruments and vehicles (vi) Station keeping and	Specify procedures for deployment and recovery of oceanographic and hydrographic equipment.

	maneuvering with instruments over the side	
B4.9 Small boats *(B)*	(i) Small boat anchoring and mooring (ii) Launch and recovery of small boats	Describe small boats anchoring techniques Describe methods for launching and recovering small boats
B4.10 Instrument moorings *(I)*	(i) Deployment and recovery (ii) Anchors and acoustic releases (iii) Scope, wire, flotation, tension (iv) Weights	Specify types of mooring and procedures for mooring underwater instruments.
B4.11 Weather fundamentals *(B)*	(i) Vertical structure and the variability of the atmosphere (ii) (iii) Atmospheric pressure, pressure systems, fronts, winds (iv) Clouds and precipitations (v) Rain, snow, fog, ice (vi) Sea state scales, weather warning categories, wave height, periods and direction	
B4.12 Wind, waves and seas *(B)*		Explain the relation between atmospheric pressure, temperature and wind. Describe wind circulation around pressure systems
B4.13 Assessing Weather *(B)*	(i) Synoptic charts (ii) Weather forecasts	Interpret a synoptic chart. Identify available sources of weather forecasts for sea areas Assess the impact of forecast weather on hydrographic operations

2. FOUNDATION SCIENCE SUBJECTS

<table>
<tr><th colspan="3">F1: Geodesy, GNSS, and Geomatics</th></tr>
<tr><th>Topic/Element</th><th>Content</th><th>Learning outcomes</th></tr>
<tr><th colspan="3">F1.1 Physical geodesy</th></tr>
<tr><td>F1.1aThe gravity field of the Earth

(I)</td><td rowspan="2">(i) Newton’s law of gravitation
(ii) Centrifugal acceleration
(iii) Gravity (acceleration)
(iv) Gravity potential
(v) Level or equipotential surfaces
(vi) The Geoid
(vii) Normal gravity and ellipsoidal models such as GRS80.
(viii) Gravity anomalies
(ix) Gravity observations</td><td>Describe relationships between the gravity field of the Earth, normal gravity and level surfaces.</td></tr>
<tr><td>F1.1b Gravity observations and their reduction.

(B)</td><td>Explain methods for observing gravity and computation of gravity anomalies</td></tr>
<tr><td>F1.1c Height systems and height determination

(I)</td><td rowspan="2">(i) Dynamic heights
(ii) Orthometric heights
(iii) Normal heights
(iv) Level ellipsoid
(v) Theoretical misclosure of a leveling loop
(vi) Geopotential models
(vii) High resolution global and local geoid grids
(viii) Deflection of the vertical</td><td>Describe different height models and the role of gravity-based heights in modern levelling networks.</td></tr>
<tr><td>F1.1d Geopotential and geoidal Modelling

(I)</td><td>Describe techniques used to model the Earth’s geopotential.

Discuss the application and limitations of geopotential models and their verification in height determination.</td></tr>
<tr><th colspan="3">F1.2 Coordinate Systems</th></tr>
<tr><td>F1.2a Coordinate Systems for Positioning

(I)</td><td rowspan="2">(i) Traditional geodetic datums
(ii) Terrestrial reference systems and reference frames.
(iii) Modern geodetic datums based on terrestrial reference frames.
(iv) Datum transformation techniques including similarity transformations and grid based approaches.</td><td>Explain principles of astronomic and geocentric datums together with their practical realizations.</td></tr>
<tr><td>F1.2b Datum transformation techniques

(A)</td><td>Compare datum transformation methods and transform coordinates between datums and between reference frames.

Estimate transformation parameters from observations.</td></tr>
<tr><td>F1.2c Geodetic computations on the ellipsoid

(I)</td><td>(i) Grid computations and spherical trigonometry.
(ii) Forward and inverse computations for geodesic and normal section curves on the ellipsoid.</td><td>Assess the various solutions available for forward and inverse computations on the ellipsoid.

Compare grid and spherical methods with ellipsoidal computations.</td></tr>
<tr><td>F1.2d Three-Dimensional Geodetic Modeling</td><td>(i) Local and global Cartesian coordinate frames. Reference to physical plumb line and ellipsoidal normal. Geoid</td><td>Explain the mathematical model of 3D geodesy, integrating satellite and terrestrial observations.</td></tr>
</table>

(A)	heights and deflections of the vertical. (ii) 3D observation equations and 3D adjustment. Laplace equation.	Evaluate a typical hybrid network, using commercial software. Describe application of 3D Geodesy to hydrographic survey control and 3D positioning of survey vessels.
F1.3 Traditional methods and techniques		
F1.3a Trigonometric surveys *(I)*	(i) Principles of distance measurement and angle measurement (ii) Plane surveys vs. geodetic surveys (iii) Forward and inverse calculations (iv) Instrument calibration requirements and documentation (v) Theodolite (in legacy context) (vi) Total Station (vii) Instrument tests (viii) Control station recovery (ix) Logistical aspects of providing control	Describe the concepts in triangulation, trilateration, and traverse
F1.3b Survey control (I)		Recover survey marks and associated documentation with an appreciation for the datum and accuracy associated with the historical survey.
F1.3c Local surveys *(I)*		Field test and use total station for distance and angle measurement in vessel offset surveys.
F1.3d Historical surveys *(B)*		Identify the methods used in survey control for historical hydrographic surveys
F1.4 GNSS		
F1.4a GNSS Signals *(I, B)*	(i) GNSS Systems, such as GPS, GLONASS, Galileo, Beidou, etc. (ii) Signal structure. (iii) Frequencies, time keeping and logistical segments: Ground, Space, User. (iv) Broadcast almanac ephemerides and precise orbit information. (v) Ionospheric and tropospheric effects. (vi) Earth rotation information.	Describe the structure of signals broadcast by GNSS and explain the impact of the atmosphere on these signals. *(I)* Describe the characteristics of different components of GNSS and detailed sources of information relating to the orbital and timing parameters. *(B)*

F1.4b GNSS observables *(A)*	(i) Code phase and carrier phase observables, mixed observables. (ii) Differencing using carrier phase including single, fixed and float double, and triple differences. (iii) Corrections for earth rotation, ionosphere, and troposphere.	Write observation equations for different GNSS observables and develop mathematical and stochastic models for the solutions that include earth rotation and ionospheric elements.
F1.4c Relative and absolute techniques *(A)*	(i) Differential and Wide area augmentation services. (ii) Real time kinematic and post-processed kinematic techniques. (iii) Precise Point Positioning techniques and services. (iv) System selection in alignment with survey requirements.	Evaluate and select appropriate system for applications by aligning survey requirements with capabilities and limitations of GNSS techniques
3F1.4d Installation and operation *(A)*	(i) Antenna installation to consider coverage, stability and multipath environment. (ii) Levels of redundancy in systems and communications (iii) Data exchange formats and protocols such as RINEX and NMEA	Specify, supervise, and test the installation of GNSS hardware and software for both inshore and offshore operations.
F1.4e Quality control *(A)*	(i) Sources of error including multipath, atmospheric effects, base station network, sensor offsets, etc. (ii) Measures and monitoring of precision (DOP variations) and reliability (statistical testing). (iii) Integrity monitoring of base station data. (iv) Verification checks between systems or against known points.	Develop a quality control plan for GNSS operations including risk management associated with GNSS components and services. Assess the performance of GNSS positioning against the defined quality control criteria.
F1.5 Leveling		
F1.5a Leveling instruments *(I)*	(i) Leveling instruments (ii) Total stations (iii) Calibration requirements and documentation	Explain the principles of operation of instruments used in determination of height differences.
F1.5b Height reduction *(A)*	(i) Effects of curvature and refraction (ii) Reduction of levels and correction to the relevant height datum	Reduce elevation measurements and use adjustment procedures.
F1.6 Map Projections		

F1.6a Map Projections (*A*)	(i) Equidistant, equal area, azimuthal and conformal projections. (ii) Properties and applications of cylindrical, conical and stereographic projections. (iii) Grids, graticules, and associated coordinates. (iv) Convergence, scale factors and arc to chord corrections. (v) Worldwide cartographic (vi) systems including UTM, GK and UPS.	Classify the properties of projections. Use parameters associated with map projections to compute distortion and apply corrections between geodetic and grid coordinates. Use geometrical properties of map projections to contrast and compare the Use of different projections for different applications

F1.7 Trigonometry and least-squares		
F1.7a Trigonometry *(B)*	(i) Plane trigonometry (ii) Sphere, great circle, rhumb lines, spherical triangles and spherical excess	Apply plane and spherical trigonometry to surveying problems.
F1.7b Theory of observations *(I)*	(i) Measurements and observation equations (ii) Biases in observations (iii) Notion of uncertainty related to observations (iv) Accuracy, precision, reliability, repeatability (v) Linearized observation equations and variance propagation law (vi) Propagation of uncertainty in observations through multiple measurements (vii) Jacobian matrix (viii) Relative and absolute confidence ellipse (ix) BIPM Guide to the Estimation of Uncertainty (x) 1-dimensional and 2-dimensional uncertainty	Differentiate between accuracy, precision, reliability and repeatability of measurements. Relate these notions to statistical information. Account for measurement biases in uncertainty calculations Apply the variance propagation law to a simple observation equation, and derive an estimate uncertainty as a function of observations covariances. Apply propagation of uncertainty using the Jacobian Matrix Estimate uncertainty in situations where the number of observations is small Test two populations of measurements to determine if they are statistically the same or different
F1.7c Least squares *(A)*	(i) Least squares principle (ii) Covariance of observation (iii) Weighted least squares (iv) Orthogonal least square (v) Total Least Square (vi) Problems with explicit solutions (vii) Condition equations (viii) Covariance of estimated parameters (ix) Unit variance factor estimates (x) Internal and external reliability	Solve geodetic problems by least squares estimation. Determine quality measures for least square solution to geodetic problems, to include reliability and confidence levels.

F2: Oceanography		
Topic/Element	**Content**	**Learning outcomes**
F2.1 Physical Oceanography and measurements		
F2.1a Water masses and circulation *(I)*	(i) Global ocean circulation (ii) Mechanisms of regional circulation. (iii) Global and local water masses and their physical properties. (iv) World oceanographic databases (v) Seasonal and daily variability of temperature and salinity profiles. (vi) Types of estuaries and their associated salinity profiles.	Use the knowledge of spatial and temporal variability of water masses to plan oceanographic observations. Establish a water column sampling regime for operational use that accounts for spatial and temporal variability of the water column.
F2.1b Physical properties of sea water *(A)*	(i) Sound Velocity Profilers, Conductivity, Temperature, Depth sensors, Expendable probes. (ii) Units used in measuring and describing physical properties of sea water, normal ranges and relationships including: salinity, conductivity, temperature, pressure, density. (iii) Thermodynamic Equation of State of Seawater (iv) Density-compensated conversion from hydrostatic pressure to depth (v) Sound speed equations (vi) Oceanographic sampling. (vii) Oceanographic sensors: • Current meters • ADCP • Turbidity sensors (viii) Instrument calibration	Specify oceanographic sensors to measure physical properties of sea water. Apply appropriate equations to estimate density and speed of sound. Create a sound speed profile.
F2.1c Oceanographic measurements *(I)*		Specify equipment and procedures for oceanographic measurement to characterize the local environment Configure and use oceanographic sensors and sampling equipment.
F2.1d Waves *(B)*	(i) Wave measurement by radar and buoys (ii) Wave parameters and elements involved in the wave growth process including fetch and bathymetry (iii) Tsunamis (iv) Rossby waves (v) Breaking waves, long-shore drift and rip current processes. (vi) Beach profiles	Outline wave generation and propagation processes. Describe the principles of wave measurement systems. Describe how beach survey monitoring strategies are related to wave regimes.

F3: Geology and geophysics		
Topic/Element	**Content**	**Learning outcomes**
F3.1 Geology		
F3.1a Earth structure *(B)*	(i) Plate tectonics and other Earth processes (ii) Earthquakes zones (iii) Types of continental margins (iv) Ocean basins, trenches, ridges and other ocean floor features (v) Different types of rocks in the marine environment (vi) Subsidence and uplift (vii) Glaciation, isostasy, and sea levels	Describe the structure of the Earth and explain the relationship between Earth processes and bathymetric /topographic features of the Earth.
F3.1b Geomorphology *(A)*	(i) Types of coasts (ii) Seafloor features and bed forms (iii) Erosion, transport and deposition (iv) Estuaries and inlets (v) Seafloor temporal and spatial variability (vi) Sediment sampling	Interpret geomorphological information and relate expected seafloor features to bathymetric and sub bottom mapping strategies and the likelihood and timescale of change over time. Explain how currents impact sediment transport and seafloor features such as bars, sand waves and sand ripples
F3.1c Substrates *(I)*	(i) Sediment types (ii) Outcropping rocks (iii) Submerged aquatic vegetation (iv) Corals	Predict seafloor type and characteristics based on knowledge and observations of local geological information.

F3.2 Geophysics		
F3.2a Gravity fields and gravity surveys *(B)*	(i) Gravity meters (ii) Relative and absolute gravity measurements (iii) Bathymetric corrections for gravity measurements (iv) Local gravity anomalies and gravity surveys (v) Influence of gravity on sea surface topography and correlation with seafloor features	Explain the principle of operation of gravity meters and the need for corrections. Discuss the objectives of gravity surveys in relation to seabed features. Explain the relationship of gravity surveys to water level models
F3.2b Magnetic fields and magnetometer surveys *(B)*	(i) Magnetic fields of the Earth (ii) Magnetic anomalies in relation to rock types and tectonic history (iii) Temporal variations (iv) Magnetic Earth models and databases (v) Magnetometers and Gradiometers (vi) Regional Magnetometer surveys (vii) Local high resolution	Describe the Earth magnetic field, its spatial and temporal variability. Explain the difference between global/regional scale magnetic surveys and high-resolution magnetometer/gradiometer surveys

	magnetometer surveys for debris and unexploded ordinance	
F3.2c Seismic surveys *(I)*	(i) Continuous seismic reflection profiling (ii) Seismic refraction surveys (iii) Typical sound sources, receiversreceivers, and recorders. (iv) High resolution seismic systems (v) Frequency and wavelength in relation to resolution and penetration (vi) Equipment configuration for hull mounted and towed systems (vii) Applications such as pipeline or hazard detection, seabed sediment identification for mapping, shallow sedimentary channels. (viii) Principles of seismic stratigraphy	Evaluate coverage, seabed penetration, and resolution of systems and correlate equipment with geophysical applications. Distinguish between noise, outliers, and real seafloor features and sub-seafloor geometry

3. HYDROGRAPHIC SCIENCE SUBJECTS

H1: System Integration and Positioning		
Topic/Element	**Content**	**Learning outcomes**
H1.1 Vessel and sensor reference frames		
H1.1a Common reference frames for sensors *(A)*	(i) Identification of a common reference point and reference frame for the vessel (ii) Centre of rotation for the vessel (iii) Centers of measurement for sensors (iv) Sensor offset and alignment measurements.	Specify a suitable vessel reference frame for sensor offsets and configure software to use values accordingly. Reconcile the application of offsets between various hardware and software components of the survey system. Plan and supervise a vessel sensor offset survey.
H1.1b Integration of reference frames *(A)*	(i) Sensor body reference frames. (ii) Transformations between reference frames associated with sensor bodies, the vessel and local geodetic frame.	Define and apply appropriate transformations between the different frames in the navigation solution. Identify bathymetric artifacts resulting from errors in reference frame integration

H1.2 Timing and Latency		
H1.2a Time References *(A)*	(i) GPS time (ii) System and sensor time (iii) Time synchronization	Configure position, attitude, and sounding systems for consistent time reference
Hi.2b Time Latency	(iv) Relative time delays of system instruments (v) Transmit/Receive timing	Assess and account for time reference throughout the system ping cycle
H1.3 Inertial navigation and attitude systems		
H1.3a Accelerometers and gyroscopes, inclinometers, and compass *(A)*	(i) Accelerometers technology (pendulums, vibrating elements) (ii) Gyroscopes (FOG, Ring laser, Sagnac effect) (iii) MEMS (iv) Inclinometers (v) Flux gate compass	Describe accelerometer technologies, and differentiate between inclinometers, compass and gyroscopes. Describe error sources associated with these devices.

H1.3b Strapdown inertial measurement units *(A)*	(i) Technologies available for IMU measurements through gyroscopes and accelerometers (ii) Sources of error in inertial sensors: bias, scale factor, drift, and, noise. (iii) The inertial navigation equation and error equations. (iv) Static alignment of the IMU. (v) Heave estimation from gyros and accelerometers. (vi) Induced heave.	Describe the technologies used in inertial measurements and quantify associated navigation errors. Select and justify an optimum location for an IMU based on vessel design and configuration. Undertake static alignment of an IMU. Identify bathymetric artifacts resulting from IMU integration and performance Develop strategies for mitigating induced heave and select filter parameters for heave estimation.
H1.3c Kalman filtering *(I)*	(i) Bayesian estimation (ii) State representation of a dynamic observation equation, observability (iii) Continuous, Semi-discrete and discrete Kalman filtering (iv) Extended Kalman filter for non-linear systems (v) Optimal smoothing	Apply Kalman filtering methods to a dynamic observation process. Define the parameters of a Kalman Filter in relation to sensors performances and dynamic model uncertainty. Differentiate between stationary and non-stationary observation processes
H1.3d Aided inertial navigation	(i) INS and GNSS loosely and tightly coupled solutions. (ii) Velocity and ranging aided INS navigation.	Describe the role of aiding sensors to reduce INS navigation drift. Identify and explain survey situations where aided inertial navigation is essential for meeting survey specifications.
(I)	(iii) Dynamic and aided alignment of INS by Kalman filtering. (iv) INS solutions from IMU and other sensors by Kalman filtering and smoothing.	Apply appropriate settings to filtering and smoothing for aided navigation solutions. Assess the uncertainty of a GNSS + IMU combination from the component uncertainty sources
H1.4 Integration of sound path and travel time		
H1.4a. *(A)*	(v) Location and orientation of transducer at transmit and receiver (vi) Sounds speed variability in the water column. • Temperature/salinity fronts • Internal waves	Explain how changes in the transducer's location and orientation during the ping cycle affect sounding depth and position determination Distinguish sound path artifacts from integration artifacts.

H1.5 Subsea positioning		
H1.5a. Subsea positioning applications *(I)*	(i) Towed vehicles (ii) Autonomous vehicles (iii) ROVs (iv) Surface vessel dynamic positioning (v) Engineering and installation (vi) Metrology	Identify appropriate subsea positioning solutions for different applications, considering potential sources of error.
H1.5b Subsea positioning principles *(A)*	(i) Long base line (ii) Short baseline (iii) Ultra-short baseline (iv) Doppler velocity log (v) Transponders (vi) Acoustic modems (vii) Subsea INS (viii) Optical scanners (ix) Underwater LiDAR (x) Simultaneous Localization and Mapping (SLAM) (xi) Water column structure (xii) Acoustic ray multipath (xiii) Time synchronization (xiv)Depth determinations from pressure sensor (xv) Altitude above the seabed	Describe the signal structure and observables of mobile and fixed acoustic positioning devices. Relate observables and platform orientation to relative positions through observation equations.
H1.5cSubsea positioning systems *(A)*		Explain how acoustic positioning observables, orientation and surface positioning data are used to achieve subsea rover spatial referencing. Describe how (SLAM) techniques are applied to subsea positioning. Specify the deployment and calibration methods for fixed and mobile acoustic positioning systems.
H1.5d Subsea Metrology		Explain the purpose of subsea metrology. Describe metrology methods using acoustic, optical, LiDAR, and inertial, including their strengths and limitations.
H1.5d Subsea positioning error analysis *(I)*		Compute the total propagated uncertainty in subsea positioning, accounting for GNSS, time, sound speed and pressure sensors, water density, doppler velocity log, acoustic positioning system, and other observable errors.
H1.6 Sounding density and guidance control		

H1.6a Track guidance *(I)*	(i) Track guidance and route following information systems. (ii) Tolerances for track guidance in compliance with survey specifications and positioning system precision. (iii) Impact of MBES sounding mode on beam footprint distribution and orientation (iv) Maintaining uniform sounding density in swath systems. (v) The impact of the environment on the line keeping and data density (vi) Special track control requirements for uncrewed vessels including collision and obstacle avoidance	Specify the methods to be used in maintaining a survey vessel or remote survey system on a planned survey line or route and meeting sounding density specifications. Explain the impact on sounding distribution and density and how to compensate and mitigate for the effects of strong currents across a survey area/in a river estuary. Explain the impact of beam shading and beam sectors on sounding distribution Describe and implement survey strategies for uncrewed vessels that maximize productivity and minimize risk

H2: Underwater Acoustic Sensors		
Topic/Element	**Content**	**Learning outcomes**
H2.1 Underwater acoustics		
H2.1a Transducers and generation of acoustic waves *(I)*	(i) Piezoelectric principles (ii) Transducer arrays design, beamforming, side lobes. (iii) Plane and spherical waves in terms of wavelength, amplitude, and frequency. (iv) Absorption, spherical spreading (v) Frequency, attenuation relationship to range (vi) Acoustic units, intensities and sound levels (vii) Signal to noise ratio (viii) Active Sonar Equation including sound source, causes of propagation loss in relation to water properties together with characteristics of the sea floor and targets, acoustic noise level and directivity (ix) Continuous Wavelength (CW), Chirp transmission (x) System parameters including bandwidth, transducer quality factor, pulse length, pulse repetition rate, gain, detection threshold. (xi) Range resolution and spatial	Analyze the effect of transducer design on beam characteristics and performance. Describe the design and use of multi-frequency, wide-bandwidth and parametric transducers. Explain how side lobe suppression is achieved in transducer arrays and the impact of suppression on sounding data. Differentiate between chirp and CW transmission, and characterize their relative performance. Explain the relationship between bandwidth and range resolution Determine source level from typically available sonar specifications.
H2.1b Propagation of acoustic waves *(A)*		Explain how properties of the acoustic medium and source frequency affect the propagation of acoustic waves. Calculate propagation loss in practical situations, using water property observations and available tables. Use this calculation to determine the effective depth range of the echo sounder

H2.1c Acoustic noise *(I)*	resolution. (xii) Dynamic range, clipping and saturation (xiii) Sound speed profile and gradient (xiv) Ray-tracing theory (xv) Sound channel (xvi) Non horizontal sound speed layers	Identify the sources of noise and describe the effect of noise on echo sounding. Define the directivity index. Calculate the effect on sonar range of a variety of noise conditions and sonar directivity circumstances.
H2.1d Reflection, scattering, and system performance. *(I)*		Define the characteristic impedance of an acoustic medium. Assess the effects of varying seafloor composition, texture, grazing angle, and slope on echo strength.
H2.1e Refraction and ray-tracing. *(A)*		Use the sound speed profile to compute the path of sound ray through the water column.
H2.2 Single beam systems		
H2.2a Single beam echo sounders principles *(I)*	(i) Single beam, split beam and dual beam/dual frequency concepts (ii) Beam footprint (iii) Specification of a single beam echo sounder. (iv) Bottom detection principles (matched filtering, thresholding) and range resolution. (v) Full echo envelope returns and bottom characterization	Explain the principles of operation of a single beam sounder detailing how acoustic parameters influence sounder returns.
H2.2b Single beam returns interpretation *(A)*		Interpret single beam returns including analysis of full echo envelopes and features of the seabed and water column. Specify a survey system to perform a single beam survey in accordance with application requirements.
H2.2c Single beam survey system *(A)*	(i) Components of a single beam echo sounder system to include positioning system, motion sensor, acquisition system, source of reference level (i.e. tide gauge, GNSS) (ii) Acoustic parameters of single beam echo-sounders	Select appropriate range, scale, frequency, and pulse for specific applications in relation to spatial resolution, bottom penetration, depth of water, and water column analysis.
H2.3 Side Scan Sonar systems		
H2.3a Side-scan sonar systems *(A)*	(i) Principles, components and geometry of side scan sonar systems (ii) Range, beam angle (iii) Resolution in relation to beam width, sampling rate, angle of incidence, and pulse length.	Evaluate, select and configure side-scan sonar in alignment with survey operational needs.

<table>
<tr><td></td><td>(iv) Beam focusing
(v) Multibeam side scan systems</td><td></td></tr>
<tr><td>H2.3b Synthetic Aperture Sonar

(I)</td><td>(i) Principles of synthetic aperture imaging</td><td>Discuss and compare the use of SAS with that of more conventional sonar imaging systems.</td></tr>
<tr><td></td><td>(ii)</td><td></td></tr>
<tr><td colspan="3">**H2.4 Swath echo sounder systems**</td></tr>
<tr><td>H2.4a Multibeam echosounder (MBES)

(A, I)</td><td rowspan="2">(i) Principles and geometry of multi-beam sonar systems
(ii) Combination of transducer elements into transmit and receive arrays.
(iii) Beam stabilization and beam steering
(iv) Amplitude and phase bottom detection
(v) Variations in beam spacing and footprint size
(vi) Backscatter recording modes (e.g., beam average, side scan time series, beam time series)
(vii) Backscatter and seabed classification
(viii) Water column data
(ix) Power, gain, pulse length
(x) Multiple signal returns,
(xi) aliasing of multiple signals in the water</td><td>Explain the basic principles of multi-beam sonar transmit and receive beam forming and beam steering. *(I)*

Explain the effect of aperture size and element spacing on array performance. *(I)*

Analyze the techniques of amplitude and phase methods of bottom detection and relate them to depth uncertainty. *(A)*</td></tr>
<tr><td>H2.4b Multibeam system parameters

(A)</td><td>Tune acoustic parameters on-line for depth *and* backscatter.

Determine the beam footprint size and sounding spacing across the swath and assess the limitations and likelihood of detecting objects on the seafloor under varying surveying conditions.

Explain the use of water column returns and differentiate from bottom detection.</td></tr>
</table>

H2.4c Multibeam systems *(A)*	(i) positioning system, telemetry, motion and attitude sensors, (ii) acquisition system, (iii) source of reference level (i.e. tide gauge, GNSS), (iv) Sound Speed measurements	Specify survey system to perform an MBES survey in accordance with application requirements.
	(i)	

H2.4d Phase Measurement Bathymetric Side Scan Sonar (PMBS) *(A)*	(i) Principles and geometry of phase measurement sonar systems (ii) Angle of arrival determination methods (iii) Sounding determination principles (iv) Mounting methods and towing (v) Transducers arrangement (i) Sounding filtering and binning techniques	Analyze the principles and geometry of phase measurement bathymetric sonars and the arrangement of transducer arrays. Compare MBES's averaging inherent in the amplitude and phase detection methods, vs the un-binned or binned sounding estimation methods in PMBS Explain the need for filtering phase measurement data for depth, object detection, and backscatter. Explain the effect of aperture size and transducer geometry on array performance. Assess the relative merits of MBES and PMBS for specific mapping applications in water depths from very shallow to full ocean depths.
H2.5 Backscatter		
H2.5a Backscatter from phase measurement bathymetric sonars and multi-beam echo sounders *(A)*	(ii) Relationship between backscatter content and characteristics of the seabed, water column properties and acoustic signal parameters (iii) Generation of backscatter information within acoustic systems (iv) Principle of backscatter compensation for absorption, incidence angle, gain and power (v) Mosaicking	Specify and configure multibeam and phase measurement bathymetric systems for backscatter acquisition under varying environmental conditions and for specific application. Monitor and assess quality on-line and apply appropriate compensation. Apply backscatter principles to produce a compensated backscatter mosaic. Create a backscatter mosaic from MBES data Set operational parameters to minimize the variations in mosaic intensity that occur as a result of different track headings and sonar frequencies and systems

H3: LiDAR and Remote Sensing		
Topic/Element	**Content**	**Learning outcomes**
H3.1 LiDAR		
H3.1a Airborne LiDAR systems *(A)*	(i) Wavelength, water penetration, ground detection, and laser safety. (ii) Scanning frequency and pattern in relation to power, coverage and spatial density. (iii) Influence of sea surface	Determine the applicability of topographic and bathymetric LiDAR to specific mapping applications. Specify the appropriate LiDAR technology for given applications and identify supporting survey operations required to conduct the survey and process data.

H3.1b Airborne LiDAR data products *(I, A)*	roughness, water column turbidity on the beam pattern and penetration. (iv) Seabed optical characteristics and bottom detection. (v) Influence of seabed on reflectance (vi) Relationship between full waveform signature and seabed characteristics. (vii) Secchi disc and Secchi depth (viii) Impact of structure and canopy on topographic LiDAR (ix) Optical characteristics of coastal terrain. (x) Influence of geometry and waveform on feature detection. (xi) Integration of components including time stamping, attitude compensation, sensor offsets, and networking. (xii) Sources and levels of uncertainty associated with LiDAR data and products. (xiii) Combined bathymetric and topographic LiDAR systems (xiv) Vessel-based LiDAR (xv) LiDAR Simultaneous Localization and Mapping (SLAM)	Identify potential sources of error in combined topographic and bathymetric LiDAR data and apply corrective processing techniques as appropriate. *(I)* Evaluate results (x,y,z) of specific bathymetric LiDAR surveys for compliance with hydrographic requirements. *(I)* Explain how to incorporate information from full waveform analysis in the production of LiDAR mapping products. *(A)*
H3.1c Terrestrial and vessel-based scanning LiDAR *(B)*		Determine situations where terrestrial and vessel-based LiDAR data can be used to complement other coastal and offshore spatial data. Explain the methods and need for calibration and validation of vessel-based LiDAR and describe how data from such a system will be integrated with other data streams.
H3.2 Remote Sensing		
H3.2a Remotely sensed bathymetry *(I)*	(i) Multispectral imagery and water penetration in relation to wavelength (ii) Optical properties of sea water. (iii) Model based and empirical inversion methods for determining bathymetry. (iv) Atmospheric corrections. (v) Spatial resolution and accuracy in position and depth. (vi) Reflectance properties of the sea floor.	Explain and compare the methods that enable depth to be determined from wavelength together with optical properties of both the water and the seabed.
H3.2b Satellite altimetry *(B)*	(i) Missions and sensors (ii) Products	Describe the principles and limitations of satellite altimetry products including sea-surface topography and derived bathymetry
H3.2c Satellite-based LiDAR	(i) IceSat2 depth measuring principles (ii) IceSat2 point clouds (iii) IceSat2 track orientation and spacing	Describe how IceSat2 bathymetry can supplement other sources of bathymetry

H3.2d Optical methods of shoreline delineation *(I)*	(i) Color imagery and multispectral imagery. (ii) Reflectance of multispectral imagery in relation to wavelength and terrain characteristics. (iii) Use of imagery in shoreline mapping and identification of other topographic features. (iv) Aerial drone-based shoreline mapping with and without ground control (v) 3D Structure from Motion (SfM) (vi) Visual Simultaneous Localization and Mapping (SLAM) (vii) Uncertainty associated with map features derived from imagery. (viii) Geometrical properties of satellite images and aerial photographs	Describe geometrical properties of images and principles of orthorectification. Explain how imagery can be used in planning survey operations and in supporting hydrographic products. Compare image-based methods with those of LiDAR for shoreline delineation Identify sources of error in optical remote sensing techniques Assess uncertainty for optical remote sensing surveys Produce geo-referenced three-dimensional (3D) point louds, and digital elevation models (DEMs) from SfM imagery using available commercial or custom software.
H4: Survey Applications and Operations		
Topic/Element	**Content**	**Learning outcomes**
H4.1 Hydrographic survey projects		
H4.1a Hydrographic survey requirements *(A)*	(i) IHO S-44 and other survey quality standards. (ii) Relation between underkeel clearance and survey requirements (iii) Procedures required to conduct hydrographic surveys of specific types, for example: • Nautical charting survey • Boundary delimitation survey • Ports, harbors, and waterways surveys. • Engineering works and dredging surveys • Coastal engineering surveys • Inland surveys • Benthic habitat mapping • Erosion and land-sea interface monitoring • Oceanographic surveys • Deep sea and ROVs /AUVs surveys • Seismic, gravity and geomagnetic surveys • Pipeline route, pipeline	Establish procedures required to achieve quality standards in hydrographic surveys. Set requirements for non-standard surveys using the S-44 matrix approach. Specify the type of survey system and equipment needs together with associated parameters and procedures for various components of the overall survey operation. Evaluate the impact of local physical and environmental factors on survey results.

	installation, inspection and cable laying surveys • Wreck and debris surveys.	
H4.1b Hydrographic survey project management	(i) Hydrographic instructions and tenders. (ii) Estimating and drafting survey work plans and schedules	Prepare hydrographic specifications, instructions, and tenders associated with survey objectives.

(A)	(iii) Risk assessment in survey operations associated with the proposed work plan. (iv) Assessment and reporting of work progress against the work plan (v) Environmental impact of survey activities (vi) Emergency Response Situations and Plan	Estimate the resources, scheduling and timing associated with hydrographic projects and prepare project plans including health and safety requirements, environmental issues and emergency response. Define, assign, and distribute the roles and responsibilities of individuals within a survey team. Prepare progress reports and submit interim project deliverables.
H4.2 Hydrographic survey operations		
H4.2a Survey planning *(A)*	(i) Components of survey planning including sensor selection, platform characteristics and dynamics, remote installations, data from satellites and telemetry links. (ii) Planning of survey operations considering general depth, bottom character, water column variability, weather, currents, tides, coastal features and vessel/flight safety. (iii) Logistical considerations for survey operations (iv) Use of uncrewed vessels including USVs, AUVs, and ROVs (v) Maintaining safe working conditions.	Plan survey lines and schedule to accommodate environmental and topographic conditions for the vessel or aircraft and for towed, remote and autonomous vehicles. Evaluate the suitability of uncrewed survey vessels for specific survey situations Develop a mission profile for uncrewed survey vessels or platforms.

H4.2b Single Beam operations *(A)*	(i) Transducer mounting (ii) Calibration techniques and requirements (iii) Line spacing, orientation and line planning (iv) Causes and effects of motion artefacts and water properties artefact on data (v) Bottom detection in fluid mud (vi) Integration with ancillary systems (vii) Compensation for vessel motion, attitude, dynamic draft (viii) Feature development (ix) Data logging parameters	Specify survey procedures and quality assurance practices to perform a single beam survey in accordance with application requirements. Select appropriate range, scale, frequency and pulse repetition rate for specific application in relation to spatial resolution, bottom penetration, depth of water, and water column analysis.
H4.2c Multi beam and phase-measusring bathymeteic system operations *(A)*	(i) Selection of platform and deployment (hull mount, pole mount, AUV, USV, ROV) (ii) Swath coverage and resolution (iii) Object detection (iv) Sound speed profile (v) Survey speed in relation to system parameters (vi) Causes and effects of motion artefacts and water property artefacts on data (vii) Swath planning (viii) Calibration methods and procedures (ix) On-line monitoring of data being acquired (x) Uncertainty models	Specify survey procedures and quality assurance practices to perform a multi-beam or phase-meaurement bathymetric system survey in accordance with application requirements. Identify deficiencies in multibeam echo sounder or phase measuring sonar data Relate deficiencies encountered to system or operational factors Devise mitigation measures for identified deficiencies

H4.2d Magnetometer surveys *(I)*	(i) Operating principles and sensitivity characteristics of magnetometers and gradiometers (ii) Deployment of magnetometers and gradiometers and planning of magnetic surveys (iii) Objectives of magnetic surveys in the detection of objects such as pipelines, cables, ordnance, debris, and wrecks. (iv) Display and interpretation of magnetometer and gradiometer data.	Describe the capabilities and limitations of magnetometers and gradiometers in conducting object detection surveys.
H4.2e Airborne LiDAR surveys *(I)*	(i) Calibration techniques and requirements (ii) Flight line spacing, ground speed, orientation and aircraft turning characteristics (iii) Environmental factors affecting data coverage (i.e., sunlight, clouds, rain, smoke, sea conditions, etc.)	Specify survey procedures and quality assurance practices to perform a LiDAR survey in accordance with application requirements. Specify LiDAR coverage and data density requirements for a survey. Assess LiDAR survey data (xyz point cloud and resultant depth grid) for adequacy and quality of overlap with adjacent acoustic survey data. Consider operational and environmental conditions in planning LiDAR surveys.
H4.2f Side scan sonar operations *(A)*	(i) Selection of platform and deployment (tow, hull mount, AUV) (ii) Elevation above the seafloor. (iii) Swath coverage (iv) Survey speed in relation to sonar system parameters (v) Towfish positioning (vi) Target aspect (vii) Effects of motion and water properties on images (viii) Layback calculations	Design and conduct a side scan sonar survey as part of an integrated data acquisition system in compliance with survey objectives. Explain and identify the effects of stratification of the water column and develop mitigating strategies for surveying in a variety of environmental conditions. Specify and configure side scan sonar imagery acquisition under varying environmental conditions and for specific applications.

H4.2g Uncrewed survey vessel (USV) operations (A)	(i) Levels of autonomy (ii) Remote vessel system monitoring and control (iii) Remote situational awareness (iv) Obstacle and collision avoidance (v) Remote survey system monitoring and control (vi) Real-time and near-real-time transfer of data (vii) Remote operating centers	Set up and configure a remote operating station on a mother vessel or in a shore-based remote operating center Evaluate remotely delivered real-time USV system data for safe and effective operation Evaluate remotely delivered USV survey data for coverage and quality.
H4.3 Seabed characterization		
H4.3a Classification from acoustic data *(I)*	(i) SBES full echo envelope (ii) Sub-bottom profiler full echo-envelope (iii) Side scan sonar images and mosaics (iv) Synthetic aperture sonars images (v) Side scan sonar and swath echo sounders backscatter information (vi) Ground-truthing	Explain the concept of incidence angle dependence and describe the signal processing steps required to obtain corrected backscatter data for seafloor characterization. Segment side scan sonar and swath sonar backscatter mosaics to guide ground truth observations Explain the techniques available and their limitations for observing, interpreting and classifying differences in seabed characteristics from acoustic sensors.
H4.3b Classification from optical data *(B)*	(i) Hyperspectral and multispectral sensors images (ii) Underwater cameras (iii) LiDAR (iv) Ground-truthing	Explain the techniques available and their limitations for observing and interpreting differences in seabed and inter-tidal zone characteristics from optical sensors.
H4.3c Seabed sampling *(I)*	(i) Grabs (ii) Corers (iii) Use in ground-truthing	Plan a sampling campaign to classify the seabed as part of a survey. Use remotely sensed information to select sampling sites.
H4.3d Seabed characterization *(I)*	(i) Classification standards (ii) Classification methods	Consider the combination of remotely sensed information with seabed samples in a seafloor characterization survey. Apply classification standards to seabed characterization results.

H5: Water Levels and Flow		
Topic/Element	**Content**	**Learning outcomes**
H5.1 Principles of Water Levels		
H5.1a Tide theory *(I)*	(i) Tide generating forces, equilibrium and real tides. (ii) Tide constituents and different types of tide. (iii) Amphidromic points and co-tidal and co-range lines. (iv) Geomorphological and basin influences on tidal characteristics	Characterize features of the tide in terms of tide raising forces and local hydrographic features.
H5.1b Non-tidal water level variations *(I)*	(i) Changes in water level caused by atmospheric pressure, wind, seiches, ocean temperature and precipitation. (ii) Water level variations occurring in inland waters. (iii) Water level variations in estuaries, wetlands and rivers	Evaluate the effect of non-tidal influences on water levels in the conduct of a hydrographic survey.
H5.2 Water level measurements		
H5.2a Water level gauges *(A)*	(i) Principles of operation of various types of water level gauges including pressure (vented and unvented), GNSS buoys, float, radar, acoustic sensors and tide poles. (ii) Installing gauges, establishment and levelling of associated survey marks (iii) Determination of tide correctors from water level observations (iv) Networks of water level gauges (v) Use of satellite altimetry in determining water levels (vi) Uncertainties associated with water level measurement devices (vii) Uncertainties associated with duration of observations. (viii) Uncertainties associated with spatial separation of water level measurements.	Select appropriate type of water level gauge technology according to survey project operations. Install, level to a vertical reference, and calibrate a water level gauge. Evaluate sources of water level measurement errors and apply appropriate corrections.
H5.2b Water level measurement *(A)*		Evaluate and select appropriate sites for water level monitoring. Select water level gauge parameters for logging data, data communication, data download and for network operation with appropriate quality control measures.
H5.2c Uncertainty in water level *(I)*		Assess and quantify the contribution of water level observations to uncertainties in survey measurements. Assess the uncertainty in water level observations due to duration of observations and distance from water level gauge.

H5.3 Tide modelling		
H5.3a Harmonic analysis *(I)*	(i) Harmonic constituents from astronomical periods (ii) Harmonic coefficients and residuals. (iii) Water level time series observations (iv) Fourier series and Fourier analysis (v) Tide tables and tide prediction	Compute standard harmonic constituents from astronomical periods. Derive harmonic coefficients and residuals from time series observations using Fourier analysis. Describe the computation of tide tables from harmonic coefficients. Compare the tidal characteristics and residuals of two tide stations using harmonic analysis.
H5.3b Ocean water level *(I)*	(i) Earth tide (ii) Harmonic astronomic component (iii) Oceanographic components (iv) Meteorological components (v) Satellite altimetry	Describe ocean water level models and observation methods.
H5.4 Ellipsoid separation models and vertical datums		
H5.4a Separation models *(I)*	(i) Single-point and regional models (ii) Principle of Separation surface construction (iii) Ellipsoid to Chart Datum separation models (iv) Tidally defined vertical datums components, including LAT, HAT, MSL MTL, MLLW, etc… (v) Chart Datum and sounding datum (vi) Geoid as a reference surface (vii) Datums in oceans coastal waters, estuaries, rivers and lakes (viii) Interpolation of datums between water level stations (ix) Reduction of survey data to a datum	Explain the relationship between geoid, ellipsoid, and chart datum. Apply relevant offsets to convert between datums
H5.4b Vertical Datums *(A)*		Select, establish, interpolate and transfer a vertical datum in various environments.
H5.4c Sounding reduction *(A)*		Reduce ellipsoidal referenced survey data to a water level datum using an appropriate separation model with an appreciation for associated uncertainty. Apply tide correctors to reduce survey soundings to a chart datum.
H5.5 Currents		
H5.5a Tidally induced and non-tidal currents *(I)*	(i) The relationship between currents and tides (ii) Rectilinear and rotary tidal currents (iii) Non-tidal currents (iv) current meters,	Explain the forces behind tidally induced currents and describe temporal variations. Differentiate between tidal and non-tidal current.

Topic/Element	Content	Learning outcomes
H5.5b Current measurement, portrayal and surveys *(I)*	(v) acoustic current profilers (vi) Surface current radar observation (vii) Static and mobile current measurements (viii) Current surveys (ix) Portraying current data	Select, techniques and instruments for current measurement in varying physical environments and for varying requirements.. Plan current surveys. Use appropriate methods for processing and displaying current data.
H6: Hydrographic Data Acquisition and Processing		
Topic/Element	**Content**	**Learning outcomes**
H6.1 Real-time data acquisition and control		
H6.1a Hydrographic Data acquisition *(A)*	(i) Integration of data from various sensors in accordance with survey specifications to include equipment such as: • Echo-sounder (SBES, MBES) • Terrestrial and airborne LiDAR • Sound speed profiler, surface sound speed probe • Side-scan sonar • Surface positioning system • IMU / INS • Subsea positioning system (USBL) • ROVs and AUVs (ii) Data acquisition system and software (iii) Time-tagging (iv) Data visualization (v) Data quality control methods (vi) Types and sources of errors (vii) System errors identification methods	Define, configure, and validate a complex survey suite for different types of surveys in accordance with technical specification. Specify and configure communication interfaces between survey devices and system components.
H6.1b Real-time data monitoring *(A)*		Evaluate performance of an integrated survey system against survey specifications using quality control methods and address deficiencies using troubleshooting methods. Identify type and sources of system errors and undertake system analysis.
H6.1c Survey data storage and transfer *(A)*	(i) Content of files in different formats used to record data in survey planning, data acquisition and products. (ii) Multiple data types (iii) Storage requirements (iv) Proprietary vs. standard data format (v) Metadata (vi) Organization of survey databases.	Export survey data to databases and analysis tools taking account of different data formats. Employ data storage strategies to facilitate survey data flow. Populate and maintain metadata associated with different data types and products.

H6.2 Bathymetric data processing		
H6,2a Data Processing environments	(i) Near-real-time data processing (ii) Remote data processing (iii) Single and multi-vessel project-based data processing (iv) Cloud computing applications for data processing	Develop data processing strategies and workflows for onsite, remote, and cloud computing environments.
H6.2a Single beam data *(A)*	(v) Single beam echo sounders data processing workflows (vi) Data cleaning techniques (manual and automated) (vii) Incorporation of sound speed profiles (viii) Identification of outliers (ix) Identification and classification of systematic errors (x) Total propagated uncertainty - horizontal (xi) Total propagated uncertainty - vertical (xii) Comparing crossing data between survey lines (xiii) Comparing overlapping data between platforms (xiv) Assessing coverage in relation with contour lines and features (xv)	Specify processing workflow for single beam data. Identify and remove outliers and validate data cleaning and other decisions made in processing single beam data. Interpret and resolve systematic errors detected during data processing Perform time series and spatial analysis of data from multiple sensors to detect artefacts and other errors that may exist in a survey dataset. Specify additional coverage and associated survey parameters to resolve shortcomings in survey data.

H6.2b Multi-beam data *(A)*	(i) Data cleaning techniques (manual,automated, and AI) (ii) Identification of outliers (iii) Identification and classification of systematic errors (iv) Total propagated uncertainty - horizontal (v) Total propagated uncertainty - vertical (vi) Comparing crossing and adjacent data between survey lines (vii) Comparing overlapping data between platforms (viii) Data file formats	Merge Smooth Best Estimated Trajectory (SBET) files to bring bathymetry data to common vertical reference. Identify and remove outliers and validate data cleaning and other decisions made in processing multi-beam data. Assess and validate the output of AI-based data processing applications Interpret and resolve systematic errors detected during data processing Perform time series and spatial analysis of data from multiple sensors to detect artefacts and other errors that may exist in a survey dataset. Create seafloor digital elevation models Assess processed data for coverage and quality, and specify remedial surveys.
H6.2c Side-scan sonar data processing and interpretation *(A)*	(i) Water column (ii) Shadows (iii) Intensity (iv) Resolution (v) Positioning of targets (vi) Sources of distortion and artefacts from water column properties, motion (vii) Determination of height, size and position of seafloor features (viii) Sonar signature of wrecks, pipelines, gas, fish and fresh water, etc. (ix) (x) Machine learning for target detection	Identify and distinguish water column artifacts in side scan images Interpret side scan sonar imagery through assessment of individual and overlapping swaths to identify potential sonar targets for further investigation. Create side scan sonar mosaics from side scan sonar data Interpret side scan sonar imagery to assess differences in seafloor composition and topography. Assess the output of automated target detection from AI applications

H6.2d Spatial data quality control *(A)*	(i) A posteriori and a priori total propagated uncertainty (horizontal and vertical) (ii) Primary and secondary survey sensors used for quality control (iii) Relative and absolute uncertainties	Differentiate between relative and absolute uncertainties. Estimate and compare uncertainties through the use of different spatial and temporal datasets. Define procedures used to assess and accept or reject data.

H6.2e Spatial data interpolation *(I, A)*	(i) 1D polynomial interpolation (ii) Interpolating splines, B-Splines, multi-dimensional splines (iii) Spatial interpolation by inverse distance and Kriging (iv) Grids and TIN construction from spatial data (v) Contouring techniques	Choose an appropriate interpolation method and compute a surface from sparse survey measurements. *(I)* Select appropriate spatial data processing methods to create digital terrain models or gridded surfaces and contouring. *(A)*
H6.2f Spatial data representation *(I, A)*	(i) Point Clouds (ii) Surface models (iii) Raster and vector data (iv) Spatial resolution (v) Data resolution (vi) Horizontal scale and vertical exaggeration (vii) Volume computations (viii) Profiles	Apply estimation procedures to survey measurements to represent data according to survey product requirements. *(I)* Select optimal parameters for data representation. *(A)*
H7: Management of Hydrographic Data		
Topic/Element	**Content**	**Learning outcomes**
H7.1 Data organization and presentation		
H7.1a Databases *(I)*	(i) Relational databases (ii) Spatial databases (iii) Databases to hold different types of feature and geographical information	Explain the concepts of relational and spatial databases. Conceptualize, develop, and populate a spatial database to represent hydrographic survey elements and define relationships between those elements.
H7.1b Marine GIS basics *(I)*	(i) Features and feature types of point, line and polygon with marine examples. (ii) Data layers (iii) Marine and coastal databases (iv) Datums and projections (v) Vertical datums (vi) Conversion between reference frames (vii) Survey metadata (viii) Loading database maps and images	Identify the data types that might be used to represent features from the marine environment considering the attribute that might be associated with such features. Create a GIS project using marine spatial data. Perform spatial processing on marine data sets including datum and projection Transformations Use a GIS to calculate characteristics such as slope and rugosity from surfaces
H7.2 Marine data sources and dissemination		
H7.2a MSDI *(B)*	(i) Basic concept of MSDI (ii) Importance and role of data standards (iii) The value and benefit of good metadata (iv) Data exchange and sharing	Describe the role of hydrographic data in Marine Spatial Data Infrastructures.

H7.2b Open access marine data *(B)*	(i) Open access databases including GEBCO, EMODNET, NCEI, GMRT, DCDB, etc. (ii) Marine data portals (iii) Data reliability from web sources (iv) Crowd-sourced data	Distinguish between types and sources of data as a measure of reliability and utility.
H7.3 Spatial data integration and deliverables		
H7.3a Spatial data integration *(I)*	(i) Tools and method for integration and comparison of hybrid data sets (ii) Co-registration of hybrid data sets	Integrate data from multiple sources and sensor types in the conduct of a multi-sensor survey.
H7.3b Spatial data visualization *(A)*	(i) Use of color schemes (ii) Shading and illumination (iii) Vertical exaggeration (iv) Standards	Evaluate and select the best visualization method to highlight features of interest and quality-control a hydrographic data set.
H7.3c Deliverables *(A)*	(i) Products provided directly from source data such as sounding data files, high resolution digital bathymetric models and metadata. (ii) Feature databases such as wrecks, rocks and obstructions (iii) Data required for sailing directions, light lists, radio aids to navigation, port guides and notices to mariners. (iv) Digital and paper products derived from source data for various survey types and usage such as GIS and CAD files and/or geo-referenced images. (v) Reports on quality control, procedures, results and conclusions detailing processes adopted within survey operations and data processing. (vi) Standards including: • IHO S-100, and product standards such as S-102. • Standard Seabed Data Model (SSDM).	Describe hydrographic deliverables and produce paper products as well as digital products in accordance with specifications and standards. Prepare a report on a hydrographic survey.
H8: Legal Aspects		
Topic/Element	**Content**	**Learning outcomes**
H8.1 Professional Responsibility		
H8.1a Responsibilities of the	(i) Nautical charts. (ii) Notice to mariners. (iii) Survey notes and reports.	

hydrographic surveyor *(B, I)*	(iv) Fundamentals of professional liability relating to surveying (v) Professional ethics relating to commercial and government projects (vi) Legal issues and liability associated with hydrographic equipment and products.	Identify the sources of ethical guidance and discuss ethical considerations when dealing in a professional capacity with client and contracts. *(I)* Discuss the potential liability of the hydrographic surveyor in common hydrographic endeavors. *(I)*
H8.2 UNCLOS & Maritime zones		
H8.2a Delimitations *(B)*	(i) Historical development of 1982 UNCLOS. (ii) Base points. (iii) Low tide elevations. (iv) Baselines: normal (including bay closing lines); straight and archipelagic. (v) Internal waters. (vi) Territorial seas. (vii) Contiguous zones. (viii) Exclusive Economic Zone (ix) Extended Continental Shelf. (x) High seas.	Define the types of baselines under UNCLOS and how the territorial sea limit and other limits are projected from them, including the use of low tide elevations. Plan and specify hydrographic surveys to be utilized in the delimitation of baselines and maritime boundaries. Describe the legal operational constraints that apply within maritime zones.
H8.3 Environmental and Cultural Considerations		
E8.3a Impact of surveys *(I)*	(i) Vessel speed restrictions, Source power levels, and permanent and temporary threshold shifts (hearing) and harassment levels for marine mammals. (ii) Limitation of use of physical techniques such as bottom sampling and moorings in environmentally sensitive areas. (iii) Respect for cultural traditions in relation to use of the environment (iv) Marine protected areas (v) Submerged cultural resources such as historic and military wrecks and submerged archaeological features	Specify appropriate procedures and limitations for use of surveying equipment in compliance with environmental laws and marine protected area regulations. Estimate sound pressure levels of echo sounders vs range to assess the potential impact on sea life. Apply national and international guidelines on survey and publication of survey results relative to wrecks and submerged cultural features.

CMFP: COMPLEX MULTIDISCIPLINARY FIELD PROJECT

Programmes must include a supervised and evaluated Complex Multidisciplinary Field Project with a minimum aggregate period of **at least four weeks**; see "GUIDELINES FOR THE IMPLEMENTATION OF THE STANDARDS OF COMPETENCE FOR HYDROGRAPHIC SURVEYORS AND NAUTICAL CARTOGRAPHERS".

The Complex Multidisciplinary Field Project for Category "A" level shall comprise a comprehensive field survey incorporating different aspects of hydrography in a complex environment with varying sea-floor and oceanographic conditions.

Students should undertake:

- Survey specification and planning;
- Hydrographic and oceanographic measurements using a comprehensive suite of instruments;
- Data processing, quality control and quality assurance;
- Preparation of different type of product deliverables and reports.

Note: The Complex Multidisciplinary Field Project does not include the practical exercises that form a part of the course modules syllabi and are designed to complement the theory component.