S-5A

International Federation of Surveyors

International Hydrographic Organization

International Cartographic Association

Standards of Competence for Category "A" Hydrographic Surveyors

Edition 2.0.0 – August 2026

Comments arising from the experience gained in the application of the guidance are welcome. They should be addressed to the Chair of the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers at the below address. This document is published periodically. Please check with IHO for the latest edition, including current amendments.

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1. PREFACE

All components of the hydrographic surveying and nautical cartography professions face challenges as 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. To meet these challenges, three international organizations (FIG, IHO and ICA) have developed Standards of competence which detail the minimum competences considered necessary for the specified category of nautical cartographer or hydrographic surveyor, have been developed by the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC).

The IBSC is composed of members of known competence in the civil, governmental or educational sectors of hydrographic surveying and nautical cartography, selected to provide as wide as possible a spectrum of knowledge and experience in educational practices, hydrography and nautical cartography, from different geographical areas. The members of the IBSC belong to three international organizations: International Federation of Surveyors (FIG), International Hydrographic Organization (IHO), and International Cartographic Association (ICA).

Changes to these standards will be released by the IHO as a New Edition, Revision, or Clarification as per the IHO Resolution 02/2007. The associated version control numbering to identify changes (n) to these S-8 and S-5 Standards is as follows:

- **New Editions** denoted as **n**.0.0
- **Revisions** denoted as n.**n**.0
- **Clarifications** denoted as n.n.**n**

Edition 2 of the S5A Standard involved broad consultation with the international hydrographic community of the expected tasking of a Category A qualified hydrographic surveyor for the next 10 years, and a comprehensive review of the educational and training needs of a student to meet these tasks. As a result, there are significant changes. New concepts and content have been introduced while in some areas the content has remained similar, but the knowledge levels have been changed as deemed appropriate to reflect the changing knowledge needs as technology and methods have evolved and will continue to do so. In other areas, traditional techniques have been reduced from Intermediate to Basic knowledge levels. Some of the historical S5A Nautical Science topics have been removed from the standard. These items are common to many marine operations and other national and IMO recognised maritime safety courses deliver this content to approved standards, whereas the coverage in the S5A standard was not sufficient to be recognised as meeting national or IMO training requirements. Accordingly seagoing hydrographic surveyors would be required to undertake recognised maritime training in addition, leading to unnecessary duplication. Note also that S5A is a minimum standard, and institutions can add additional maritime safety elements to meet their own requirements if they wish.

2. INTRODUCTION

These standards indicate the minimum competences necessary for hydrographic surveyors. Standards recognize two levels of competence. Category "A" programmes introduce 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.

Institutions and professional bodies must align with the Standards when submitting their education/training programmes and competence schemes for IBSC Recognition. In addition, even if they are not applying for Re-recognition, education and training providers should adopt the Standards for planning, scheduling and delivering their programmes.

This document provides the details of the subjects, topics, their levels of knowledge and learning outcomes that are required to meet the Category A Standard in hydrographic surveying. A student that completes a recognized programme should have achieved the required levels of knowledge; however, this alone does not translate directly into a level of competence. Competence is achieved by a combination of knowledge and experience. The IBSC has recognized a number of competency schemes for individuals. These schemes assess both the level of knowledge and the specific experience of an individual in order to certify their competence.

3. DEFINITION

3.1 Subjects, topics, and elements

The S-5A standard contains the following list of ***B**asic subjects, **F**oundation Science subjects* and ***H**ydrographic Science subjects*:

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 “Systems Integration and Positioning” contains the topic H1.1 “Vessel and sensor reference frames” that has the element H1.1a “Common reference frames for sensors”.

Basic subjects are considered mandatory prerequisite learning for the Foundation Science subjects and the Hydrographic Science subjects and support the content and learning outcome of those subjects. Mastery of the Basic subject material is essential for learning to apply those principles to the geodetic, oceanographic, or hydrographic applications but does not presume knowledge of those applications. Basic learning content and outcomes can be presented and achieved concurrently with, or before, Foundation or Hydrographic learning outcomes. The content and learning outcomes of Foundation Science subjects are required but may be addressed and achieved separately from Hydrographic Science subjects.

3.2 Learning outcomes and list of content

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*.

Both areas are equally important in their implementation, and each contributes in different ways to the overall outcome. The relevance of learning outcomes is not prioritized over that of learning content. All learning content is of significant importance for achieving the intended learning outcomes. The achievement of learning outcomes—and thus also of learning content—is also documented using the cross-reference table (Guidelines Chapter 7).

The analysis of learning outcomes is an essential aspect of the educational process. Written and oral examinations can be used to evaluate whether the current learning outcomes have been achieved at the intended and required level.

For the sake of clarity, a level of knowledge associated with each element has been defined. It is indicated in italics in the left column, by a letter (*B*): Basic, (*I*): Intermediate, (*A*): Advanced; see "Guidelines for the Implementation of the Standards of Competence for Hydrographic Surveyors and Nautical Cartographers"). This letter designation is complemented by the verbs included in each learning outcome description which indicate the level of knowledge tested (refer Blooms Taxonomy). In S5A, two or more verbs are included in many learning outcomes to elaborate on the level of knowledge intended. For example, the verb “*explain*” can be considered a “basic”

level verb, and the inclusion of an additional verb such as "*justify*" is intended to describe the complexity of explanation expected in the learning outcome at the intermediate or advanced level.

All learning outcomes must be assessed prior to commencement of the final project. This may be done through one or a combination of: examination, assessed exercise, laboratory report, presentation, or practical exercise.

4. 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
AI	Artificial Intelligence
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
ML	Machine Learning
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)
PMBS	Phase Measurement Bathymetric Sonar
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
SfM	Structure from Motion
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
USV	Uncrewed Surface (or Survey) Vessel
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WWNWS	World Wide Navigational Warning Service
XML	Extended Markup Language

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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 *(I)*	(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 a sphere and on an ellipsoid.
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
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 and *interpret* error bounds in a scientific computing environment.
B1.2 Differential calculus and differential equations		
B1.2a Differential and integral calculus *(I)*	(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 and interpret* 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 and interpret* 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 equations *(I)*	(i) Iterative methods. (ii) Rounding and numerical errors.	*Evaluate* and *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* and select probability measures, *derive* associated formulae and calculate values from data. *Select* and *justify* 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* and interpret 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. *Select*, *configure,* and *evaluate* 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	*Develop* a program or script for data analysis and/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	*Explain* and *interpret* 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 Expert Systems *(B)*	(i) Expert Systems and the concepts of Machine Learning, Artificial Intelligence, Robotics (ii) Widely used AI tools provided by common commercial software (e.g., ChatGPT, Gemini) (iii) 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 summarizing • Data analysis and decision support	*Describe* common types of AI *Use* Generative AI to create or summarize a technical report *Identify* potential uses of AI, describe processes to create AI solutions and tools. *Describe* the use of training data sets and deep neural networks in ML applications. *Describe* key applications of AI in the context of big data. *Explain* the relationship between AI-generated content and the surveyor. Review, *edit* and *confirm* AI generated content

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 characteristics 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 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		
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 Regulatory Regime (B)	(i) International Convention for the Prevention of Collisions at Sea (ii) IMO Rules for Marine Autonomous Surface Ships (iii) National rules for remotely operated or autonomous uncrewed vessels	Summarize the Navigation Rules for stand-on and give-way vessels in meeting, crossing, and overtaking situations *Explain* the requirements and regulatory challenges of operating uncrewed vessels for survey operations
B4.3 GMDSS *(B)*	(i) EPIRBs and SARSAT (ii) Digital selective calling	*Describe* the EPIRB, SARSAT, and DSC components of GMDSS.
B4.4 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.
B4.5 Navigation publications *(B)*	(i) Sailing directions, (ii) Tides and current tables (iii) Notice to Mariners (NtoM)	Use content of nautical publications in a planning context.
B4.6 Basic Offshore Safety Training *(B)*	(i) Basic requirements for working offshore	Recognize the requirement for completion of a Basic Offshore Safety Course
B4.7 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	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.

B4.8 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.
B4.9 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 maneuvering with instruments over the side	*Select*, *justify* and employ procedures for deployment and recovery of oceanographic and hydrographic equipment.
B4.10 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
B4.11 Instrument moorings *(I)*	(i) Deployment and recovery (ii) Anchors and acoustic releases (iii) Scope, wire, flotation, tension (iv) Weights	*Select* and *justify* types of mooring and procedures for mooring underwater instruments.

B5: Meteorology

Topic/Element	**Content**	**Learning outcomes**
B5.1 Weather fundamentals *(B)*	(i) Vertical structure and the variability of the atmosphere (ii) Temperature, humidity, dew point, frost point (iii) Atmospheric pressure, pressure systems, fronts, winds (iv) Clouds (v) Precipitation—rain, snow, sleet, freezing rain (vi) Visibility, advection fog and	*Define* physical meteorological parameters Operate instruments and sensors used to register temperature, pressure, direction and speed of wind. Record these parameters according to internationally accepted standards

B5.2 Wind, waves and seas *(B)*	radiation fog (vii) Icing conditions (viii) Sea state scales, weather warning categories (ix) Wind waves, wave height, periods and direction (x) Instruments and sensors used to measure temperature, pressure, wind speed and direction	*Explain* the relation between atmospheric pressure, temperature, and wind. *Describe* wind circulation around pressure systems *Explain* the effects of wind, waves, and current on sea surface and their impact on survey operations
B5.3 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

F1: Geodesy, GNSS, and Geomatics		
Topic/Element	**Content**	**Learning outcomes**
F1.1 Physical geodesy		
F1.1aThe gravity field of the Earth *(I)*	(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	*Explain* relationships between the gravity field of the Earth, normal gravity, and level surfaces.
F1.1b Gravity observations and their reduction. *(B)*		*Explain* methods for observing gravity and computation of gravity anomalies
F1.1c Height systems and height determination *(I)*	(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	*Explain* and *assess* different height models and the role of gravity-based heights in modern levelling networks.
F1.1d Geopotential and geoidal Modelling *(I)*		*Explain* techniques used to model the Earth's geopotential. *Evaluate* and discuss the application and limitations of geopotential models and their verification in height determination.
F1.2 Coordinate Systems		
F1.2a Coordinate Systems for Positioning *(I)*	(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	*Explain* principles of astronomic and geocentric datums together with their practical realizations.

F1.2b Datum transformation techniques *(A)*	transformations and grid-based approaches.	*Compare* datum transformation methods and transform coordinates between datums and between reference frames and *assess* suitability, impact, or compliance for geospatial applications *Estimate*, *assess*, and *apply* transformation parameters from observations.
F1.2c Geodetic computations on the ellipsoid *(I)*	(i) Grid computations and spherical trigonometry. (ii) Forward and inverse computations for geodesic and normal section curves on the ellipsoid.	*Assess* and determine the various solutions available for forward and inverse computations on the ellipsoid. *Compare* grid and spherical methods with ellipsoidal computations.
F1.2d Three-Dimensional Geodetic Modeling *(A)*	Local and global Cartesian coordinate frames. Reference to physical plumb line and ellipsoidal normal. Geoid heights and deflections of the vertical. (i) (ii) 3D observation equations and 3D adjustment. Laplace equation.	*Explain* and *assess* the mathematical model of 3D geodesy, integrating satellite and terrestrial observations. *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	*Explain* 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 *Assess* the suitability and compliance for hydrographic and topographic applications.
F1.3c Local surveys *(I)*		Field test, *assess* results, and *use* a 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 topographic 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, GNSS time, 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.	*Develop* and *justify* 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 *Establish* terrestrial control using GNSS in accordance with published quality control procedures.
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 static and dynamic survey operations, and *assess* suitability for application.
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* and *justify* a quality control plan for GNSS operations, including risk management associated with GNSS components and services. *Determine* and *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. *Select* and set up level and level staff to measure difference in elevation in compliance with second-order standards
F1.5b Height reduction *(A)*	(i) Effects of curvature and refraction (ii) Reduction of levels and correction to the relevant height datum	Reduce and assess 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 and suitability for specific applications *Select* and use parameters associated with map projections to compute distortion and *apply* corrections between geodetic and grid coordinates and *assess* suitability, impact, or compliance for hydrographic applications. 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 *((I)*	(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 concepts to statistical information. Account for measurement biases in uncertainty calculations and *assess* the impact of those biases. *Apply* the variance propagation law to a simple observation equation and *derive* an estimate of uncertainty as a function of observations covariances. *Apply* and *evaluate* propagation of uncertainty using the Jacobian Matrix *Estimate* and *evaluate* 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* and *justify* quality measures for least square solution to geodetic problems, including 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 *select* sensors and *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, and 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) Other cceanographic sensors: • Current meters • ADCP • Turbidity sensors (viii) Instrument calibration	*Specify* and *justify* oceanographic sensors to measure physical properties of sea water. *Evaluate* and *apply* appropriate equations to estimate density and speed of sound. *Create* and *evaluate* a sound speed profile.
F2.1c Oceanographic measurements *(I)*		*Specify* and *justify* equipment and procedures for oceanographic measurement to characterize the local environment *Configure and use* oceanographic sensors and sampling equipment, and *assess* suitability, impact, or compliance for specific applications.

F2.1d Waves *(I)*	(i) Wave measurement by radar and buoys (ii) Wave parameters and elements involved in the wave speed of propagation and growth process including fetch and bathymetry (iii) Tsunamis (iv) Rossby waves (v) Kelvin waves, internal waves (vi) Breaking waves, long-shore drift and rip current processes. (vii) Beach profiles	*Outline* wave generation and propagation processes. *Explain* and interpret 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* and *evaluate* 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* and *identify* 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 mapping the seabed *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 magnetometer surveys for debris and unexploded ordinance	*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
F3.2c Seismic surveys *(I)*	(i) Continuous seismic reflection profiling (ii) Seismic refraction surveys (iii) Typical sound sources, receivers, 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) Center 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 and *justify* the application of offsets between various hardware and software components of the survey system. *Design*, *plan* and execute a vessel sensor offset survey and determine offset values.

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 frames.	*Define*, *justify*, and *apply* appropriate transformations between the different frames in the navigation solution. *Identify* and *assess* bathymetric artifacts resulting from errors in reference frame integration
H1.2 Timing and Latency		
H1.2a Time References *(A)*	(i) System time and relation to GPS, UTC, and Unix times (ii) Time synchronization	*Configure* position, attitude, and sounding systems for consistent time reference
H1.2b Time Latency *(I)*	(i) Relative time delays of system instruments (ii) 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	*Explain* 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 and *evaluate* 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. *Compare* and *assess* results *Define* and test 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)*	(i) INS and GNSS loosely and tightly coupled solutions. (ii) Velocity and ranging aided INS navigation. (iii) Dynamic and aided alignment of INS by Kalman filtering. (iv) INS solutions from IMU and other sensors by Kalman filtering and smoothing.	*Explain* 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. *Evaluate* and *apply* appropriate settings for filtering and smoothing for aided navigation solutions. *Determine* and *assess* the uncertainty of a GNSS + IMU combination from the component uncertainty sources
H1.4 Integration of sound path and travel time		
H1.4a. Sound Path *(A)*	(i) Location and orientation of transducer at transmit and receive (ii) Sound speed variability in the water column. • Temperature/salinity fronts • Kelvin waves and internal waves	*Explain* and *assess* 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* and *assess* 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	Explain and *differentiate* 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)*	(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	*Explain* and *assess* how acoustic positioning observables, orientation and surface positioning data are used to achieve subsea robotic platform spatial referencing. *Describe* how SLAM techniques are applied to subsea positioning. *Specify* and *justify* the deployment and calibration methods for fixed and mobile acoustic positioning systems.

H1.5d Subsea Metrology *(B)*		*Explain* the purpose of subsea metrology. *Describe* and *assess* metrology methods using acoustic, optical, LASER, and inertial, including their strengths and limitations.
H1.5e Subsea positioning error analysis *(I)*		*Compute* and *interpret* 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* and *justify* the methods to be used in maintaining a survey sensor, vessel or remote survey system on a planned survey line or route and meeting survey requirements and specifications. *Explain* and *assess* the impact on sounding distribution and density and how to compensate and mitigate the effects of strong currents across a survey area/in a river estuary. *Explain*, *assess*, 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	*Analyze* the effect of transducer design on beam characteristics and performance. *Explain* 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

	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 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	*Determine* source level from typically available sonar specifications.
H2.1b Propagation of acoustic waves *(A)*		*Explain* and *assess* how properties of the acoustic medium and source frequency affect the propagation of acoustic waves. *Calculate* and *interpret* 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 for various frequencies
H2.1c Acoustic noise *(I)*		*Identify* the sources of noise and describe the effect of noise on echo sounding. *Calculate* the effect on sonar range of a variety of noise conditions and sonar directivity circumstances. *Define* the directivity index.
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)*		*Select* and use the appropriate 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* and *assess* single beam returns including analysis of full echo envelopes and features of the seabed and water column.

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	*Specify* and *justify* a survey system to perform a single beam survey in accordance with application requirements. *Evaluate*, *select* and *justify* 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. (iv) Beam focusing (v) Multibeam side scan systems	*Evaluate*, *select* and *configure* side-scan sonar in alignment with survey operational needs.
H2.3b Synthetic Aperture Sonar *(I)*	(i) Principles of synthetic aperture imaging	*Describe* and *evaluate* the use of SAS and *compare* with the use of more conventional sonar imaging systems.
H2.4 Swath echo sounder systems		
H2.4a Multibeam echosounder (MBES) *(A, I)*	(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 (xii) Beam sectors (xiii) Beam shading	*Explain* the basic principles of multi-beam sonar transmit and receive beam forming and beam steering. *(I)* *Explain* and *assess* the effect of aperture size and element spacing on array performance. *(I)* *Analyze* and *assess* the techniques of amplitude and phase methods of bottom detection and relate them to depth uncertainty. *(A)*
H2.4b Multibeam system parameters *(A)*		Tune acoustic parameters on-line for depth and backscatter and *assess* suitability, impact, or compliance for hydrographic applications *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* and *assess* the use of water column returns and *differentiate* from bottom detection. *Explain* and *assess* the impact of beam shading and beam sectors on sounding distribution

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* and *justify* survey system to perform an MBES survey in accordance with application requirements.
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*, *interpret*, and *assess* the principles and geometry of phase measurement bathymetric sonars and the arrangement of transducer arrays. *Compare* MBES's averaging inherent in amplitude and phase detection methods, vs the un-binned or binned sounding estimation methods in PMBS *Explain* and *assess* the need for filtering phase measurement data for depth, object detection, and backscatter. *Compare* and *differentiate* 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 (v) gain and power (vi) Backscatter mosaics	*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 and *evaluate* a compensated backscatter mosaic. Overlay a backscatter mosaic on bathymetry and *interpret* combined product set. D*efine* operational parameters to minimize the variations in mosaic intensity that occur as a result of different track headings and sonar frequencies and systems and *assess* suitability, impact, or compliance for hydrographic applications

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 roughness, water column turbidity on the beam pattern and penetration.	*Determine* and *justify* 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)*	(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* and *assess* 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 and *interpret* information from full waveform analysis in the production and application of LiDAR mapping products. *(A)*
H3.1c Terrestrial and vessel-based scanning LiDAR *(B)*		*Determine* and *justify* 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 and satellite derived bathymetry *(I)*	(i) Multispectral imagery and water penetration in relation to wavelength (ii) Satellite Derived Bathymetry (SDB) (iii) Optical properties of sea water. (iv) Model based and empirical inversion methods for determining bathymetry. (v) Atmospheric corrections. (vi) Spatial resolution and accuracy in position and depth. (vii) Reflectance properties of the sea floor.	*Explain*, *assess*, 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 inferred Bathymetry
H3.2c Satellite-based LiDAR *(B)*	(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	*Explain* and *interpret* geometrical properties of images and principles of orthorectification. *Explain* and *assess* 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* and *assess* sources of error in optical remote sensing techniques *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 under keel 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	*Establish* procedures required to achieve quality standards in hydrographic surveys. *Set* requirements for non-standard surveys using the S-44 matrix approach and *assess* suitability for hydrographic applications *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.

	• 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 installation, inspection and cable laying surveys • Wreck and debris surveys.	
H4.1b Hydrographic survey project management *(A)*	(i) Hydrographic instructions and tenders. (ii) Estimating and drafting survey work plans and schedules (iii) Risk assessment and management 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	*Prepare* and *justify* hydrographic specifications, instructions, and tenders associated with survey objectives. *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 and *assess* impact for hydrographic applications *Prepare* and *justify* progress reports and submit interim project deliverables. *Identify* risks and *derive* priority tasks for a survey project and assign roles. *Review* and *evaluate* a report of survey operations.
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.	*Design*, *plan* and *justify* 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* and *justify* a mission profile for uncrewed survey vessels or platforms.

H4.2b Survey data transfer *(I)*	(i) Data telemetry links including radio, satellite, cellular, WIFI, Bluetooth, and underwater communications. (ii) Compatibility between equipment and communications devices. (iii) Latency, bandwidth, and redundancy considerations in hydrographic data transfer. (iv) Cybersecurity and (v) encryption protocols for secure data transmission.	*Describe* data telemetry and transmission links used in hydrographic surveying, including latency, bandwidth, redundancy, and cybersecurity and encryption considerations. *Operate* a remote real-time data telemetry link between a survey infrastructure component and a survey system.
H4.2c 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* and *justify* survey procedures and quality assurance practices to perform a single beam survey in accordance with application requirements. *Evaluate*, *select*, and *explain* 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.
H4.2d Multi beam and phase-measuring bathymetric 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* and *justify* survey procedures and quality assurance practices to perform a multi-beam or phase-measurement bathymetric system survey in accordance with application requirements. *Identify* and *assess* deficiencies in multibeam echo sounder or phase measuring sonar data and relate deficiencies encountered to system or operational factors *Devise* mitigation measures for identified deficiencies

H4.2e 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.	*Explain* and *differentiate* the capabilities and limitations of magnetometers and gradiometers in conducting object detection surveys.
H4.2f 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* and *justify* survey procedures and quality assurance practices to perform a LiDAR survey in accordance with application requirements. *Specify* and *justify* LiDAR line spacing and orientation to achieve appropriate coverage and data density for a survey. *Assess* LiDAR survey data (xyz point cloud and resultant depth grid) and determine adequacy and quality of overlap with adjacent acoustic survey data. Consider operational and environmental conditions in planning LiDAR surveys and *assess* suitability or compliance for hydrographic applications
H4.2g 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*, *identify* and *assess* the effects of stratification of the water column and *develop* mitigating strategies for surveying in a variety of environmental conditions. *Specify*, *justify*, and *configure* side scan sonar imagery acquisition under varying environmental conditions and for specific applications.

H4.2h 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	*Design*, set up *configure* and *validate* 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 and *justify* results to guide ground truth observations *Explain* and *assess* 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* and *assess* 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	*Design* and *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 and methods (ii) Characterization methods (iii) Expert systems for classification and characterization	Consider and *select* the combination of remotely sensed information with seabed samples in a seafloor characterization survey. *Discuss* the employment of Expert Systems in seafloor classification and characterization *Evaluate* and *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.	*Evaluate*, s*elect* and *justify* appropriate type of water level gauge technology according to survey project operations. *Install*, level to a vertical reference, and calibrate a water level gauge and *evaluate* for compliance with survey requirements *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. *Evaluate*, *select*, and *justify* 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. *Determine* and *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* and *interpret* standard harmonic constituents from astronomical periods. *Derive* harmonic coefficients and residuals from time series observations using Fourier analysis. *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	*Explain* and *interpret* 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. *Evaluate*, *apply* and *justify* relevant offsets to convert between datums
H5.4b Vertical Datums *(A)*		*Select*, establish, interpolate and transfer a vertical datum in various environments and *assess* compliance for hydrographic applications.
H5.4c Sounding reduction *(A)*		Reduce ellipsoidal referenced survey data to a water level datum using an appropriate separation model and *assess* the 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.

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. *Design* and *plan* current surveys. *Select* and use appropriate methods for processing and displaying current data and *assess* suitability and compliance for hydrographic Applications.
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*, *justify*, 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) Cloud and local data storage solutions (v) Proprietary vs. standard data format (vi) Metadata (vii) Organization of survey databases.	*Export* survey data to databases and analysis tools taking account of different data formats. *Employ* and *justify* 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 *(A)*	(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* and *justify* data processing strategies and workflows for onsite, remote, and cloud computing environments.
H6.2b Single beam data *(A)*	(i) Single beam echo sounders data processing workflows (ii) Data cleaning techniques (manual and automated) (iii) Incorporation of sound speed profiles (iv) Identification of outliers (v) Identification and classification of systematic errors (vi) Total propagated uncertainty - horizontal (vii) Total propagated uncertainty - vertical (viii) Comparing crossing data between survey lines (ix) Comparing overlapping data between platforms (x) Assessing coverage in relation with depth, contour lines and features	*Specify* and *justify* 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* and evaluate time series and spatial analysis of data from multiple sensors to detect artefacts and other errors that may exist in a survey dataset. *Specify* and *justify* additional coverage and associated survey parameters to resolve shortcomings in survey data.
H6.2c 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 and *validate* 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* the output of AI-based data processing applications for inclusion (or not) in final products and data sets *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 and *assess* seafloor digital elevation models *Assess* processed data for coverage and quality and *specify* remedial surveys.

H6.2d 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) Machine learning for target detection	*Identify*, distinguish, and *assess* 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 and *justify* mosaic creation parameters *Interpret* side scan sonar imagery to *assess* differences in seafloor composition and topography. *Assess* the output of automated target detection from Expert Systems
H6.2e 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. *Determine* and evaluate procedures used to assess processed spatial data against quality standards, and accept or reject data.
H6.2f 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* and *justify* an appropriate interpolation method and *compute* a surface from sparse survey measurements. *(I)* *Evaluate*, *select*, and *justify* appropriate spatial data processing methods to create digital terrain models or gridded surfaces and contouring. *(A)*
H6.2g 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	*Evaluate* and *apply* estimation procedures to survey measurements to represent data according to survey product requirements. *(I)* *Evaluate*, *select* and *justify* 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 (iv) Cloud-based storage and cloud computing	*Explain* and *assess* 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. *Assess* the implications of cloud-based solutions on management of hydrographic data
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* and *assess* the data types that might be used to represent features from the marine environment considering the attributes that might be associated with such features. *Create* a GIS project using marine spatial data. *Perform* and *assess* spatial processing on marine data sets including datum and projection Transformations *Select* and 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 methods 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).	*Explain* and *interpret* hydrographic deliverables and produce paper products as well as digital products in accordance with specifications and standards. *Prepare* and justify a report on a hydrographic survey.
H8: Legal Aspects		
Topic/Element	**Content**	**Learning outcomes**
H8.1 Professional Responsibility		
H8.1a Responsibilities of the hydrographic surveyor *(I)*	(i) Nautical charts. (ii) Notice to mariners. (iii) Survey notes and reports. (iv) Survey contracts and tenders (v) Fundamentals of professional liability relating to surveying (vi) Professional ethics relating to commercial and government projects (vii) Legal issues and liability associated with hydrographic equipment and products.	*Describe* the legal status of official nautical charts and publications, including ENCs, *Develop* the technical content of a request for tender *Analyze* the risk and *develop* the technical content of an invitation or request for tender *Identify* and *assess* sources of ethical guidance and discuss ethical considerations when dealing in a professional capacity with clients and contracts. *Discuss* the potential liability of the hydrographic surveyor in common hydrographic endeavors.

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* and *explain* 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. *Design*, *plan*, *justify* 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) Avoiding marine pollution (iv) Respect for cultural traditions in relation to use of the environment (v) Marine protected areas (vi) Submerged cultural resources such as historic and military wrecks and submerged archaeological features	*Specify* and *justify* 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. *Interpret* and *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 seafloor 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 types 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.