Canadian Board of Examiners for Professional Surveyors
Core Syllabus Item
C12: HYDROGRAPHIC SURVEYING
Learning Outcomes

Introduction

The hydrographic surveying mandatory syllabus item C12 criteria covers general aspects of hydrographic surveying which may be required in a typical Canadian land surveying practice. The emphasis is placed on a general understanding of the principles, equipment and processes for hydrographic surveying.

Whilst conducting this work there are a variety of sensors that could be deployed to measure and map the bed, image and find debris. Hence the C12 criterion provides information on single beam echo sounder (SBES), multibeam echo sounder (MBES), and side scan sonar (SSS).

The information provided in the C12 criteria should allow the candidate sufficient knowledge to be able to understand the complexity of a typical hydrographic survey, AND appreciate the candidate's own limitations to execute such surveys.

Should any candidate become involved in these surveys, it is suggested that at least the Transport Canada Marine Emergency Duties A1 or A3, and Small Vessel Operator Proficiency certificates are obtained before any of these surveys is carried out.

If a candidate wishes to pursue advanced hydrographic surveying aspects and techniques, they should consider the elective E2, which requires a fuller and more in depth understanding of the C12 topics.

Programmable calculators may be used in the examinations of this item; however, candidates must show all formulae used, the substitution of values into them, and any intermediate values to 2 more significant figures than warranted for the answer. Otherwise, full marks may not be awarded even though the answer is numerically correct. A collection of formulae are provided with the examination questions.

Recommended Prior Knowledge and Skills
Item C1: Mathematics
Item C2: Least-Squares Estimation and Data Analysis
Item C3: Advanced Surveying
Item C4: Coordinate Systems and Map Projections
Item C5: Geospatial Information Systems
Item C6: Geodetic Positioning (which includes GNSS RTK)
Item C7: Remote Sensing and Photogrammetry
Item C9: Survey Law

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In order to fulfil the requirements of this syllabus item, each candidate should possess, at an introductory level, knowledge of the following topics.

1. Underwater Acoustics

Topic	Outcome
Acoustic Velocity	Describe effects of the physical properties of water on the calculation of the speed of sound in fresh, mixed and sea water. Understand how to calculate sound speed from measurements of temperature, pressure (depth), and salinity (conductivity).
Sound Wave Propagation	Understand how sound wave refract and reflect as they propagate according to Snell's law. Describe Harmonic Mean Sound Speed and how it is used in single beam sounding reduction.
Acoustic System Parameters	Define frequency, wavelength, amplitude, beamwidth, pulse duration (pulse length), pulse repetition rate, detection threshold, bandwidth, resolution, continuous wave pulse, Linear Frequency Modulated (CHIRP) pulse.

2. Single Beam Echo Sounders (SBES)

Topic	Outcome
Transducers	Discriminate between the following types of transducers: narrow beam, wide beam, parametric. Explain methods of mounting transducers: hull, towed, over the side, and boom.
Data Recording	Differentiate between analogue and digital recording systems and media.
Sounder Calibration	Evaluate and select appropriate echo sounder calibration methods and equipment for specific applications.
Sounding Reduction	Explain and apply the reductions to measured depths due to water level variations, draft, dynamic draft (settlement, squat, fuel depletion, and buoyancy changes) and speed of sound in water. Evaluate and apply all appropriate factors affecting depth reductions for specific applications.
Sounding Accuracy (or Error Budget)	Calculate and assess the uncertainty in soundings due to errors in the positioning system, SBES, water level measurement, vessel motion, speed of sound in water, and seabed topography. Evaluate and select appropriate methods for controlling or reducing sounding uncertainty for specific applications.
System Selection	Identify SBES characteristics that affect performance in varying survey applications. Specify appropriate SBES characteristics (e.g. resolution, depth capability, frequency, bandwidth, beamwidth) for specific applications.
Equipment Evaluation	Understand the technical limitations of various SBES systems and understand how to select the appropriate system for a given requirement.

3. Multibeam Echo Sounder (MBES)

Topic	Outcome
Multibeam Transducers	Explain the basic principles of MBES transmit and receive beam forming and steering using flat or curved transducers. Describe the difference between beam forming and phase differencing multibeam systems. Understand the importance of sound velocity in determining sounding direction.
Coverage and Accuracy (or Error Budget)	Explain the dependence of depth coverage and uncertainty on bandwidth, beamwidth, swath width, beam elevation angle, grazing and incident angles, depth, pulse repetition rate, speed of sound in water uncertainty, vessel attitude and motion (speed, heave, roll, pitch, heading and yaw).
MBES Calibration	Explain the effects on depth and position uncertainty of errors in sensor locations, system latency and alignments within the vessel reference frame. Explain how to establish the vessel reference frame and sensor offsets and alignments. Define the “patch test”. Select test area and lines to be run for “patch test”. Calibrate the misalignments between transducer and motion sensor.
Importance of Time	Describe the importance of time synchronization in multibeam systems and surveys. Discuss how time can be managed.
Importance of Motion	Understand the effect of vessel motion on multibeam systems and how that motion can be measured.
MBES Data Management	Describe issues affecting acquisition, processing, storage and retrieval of multibeam data. Explain methods for managing data quality. Specify and design a multibeam data management strategy for specific applications.
Equipment Evaluation	Understand the technical limitations of various MBES systems and understand how to select the appropriate system for a given requirement.

4. Side Scan Sonar (SSS)

Topic	Outcome
Side Scan Sonar Systems	Describe the principles, geometry, and deployment of side scan sonar systems. Explain the effect on side scan sonar performance (range, resolution and target detection) of frequency, beam angle, range scale, gain, towing speed, and deployment (deep tow, shallow tow and pole mount). Evaluate and select appropriate side scan sonar frequency, features and deployment, for specific applications.
Side Scan Sonar Data Interpretation	Determine height and size of obstructions from sonar records. Describe sources of side scan image distortion. Explain sonar signatures of such items as debris, wrecks, pipelines, gas, fish and divers.
System Selection	Identify side scan sonar characteristics that affect performance in varying survey applications. Specify appropriate side scan sonar characteristics (e.g. resolution, frequency, bandwidth, and beamwidth) for specific applications.
SSS vs MBES	Explain the differences between side scan sonar and similar data provided by MBES.
Equipment Evaluation	Understand the technical limitations of various SSS systems and understand how to select the appropriate system for a given requirement.

5. Tide and Non-Tidal Water Levels

Topic	Outcome
Tidal Fundamentals	Describe tide generating forces. Describe the major harmonic constituents. Identify and recognise the different types of tide. Define different tidal levels. Classify tidal regimes.
Tidal Measurements	Explain the principles of various types of water level gauges and poles. Describe characteristics of river, coastal and offshore water level gauges. Evaluate and select appropriate instruments and sites for water level monitoring.
Tidal Streams and Currents	Describe the relation between streams and tides. Describe methods for measuring tidal streams and currents, including log ship, pole, current meters and ADCP (Acoustic Doppler Profilers).
Tidal Information	Predict water levels for main and secondary ports, using tide tables. Calculate water level at a particular time, and/or calculate the time at which a specific height will occur.
Non-Tidal Water Level Variations	Describe the temporal and spatial effects on water level caused by: atmospheric pressure, wind, seiches, and precipitation. Identify water level variations occurring in rivers and lakes, and due to dam operations. Evaluate and select appropriate locations for water level gauges in rivers, lakes, and near dams, for specific applications.

6. Vertical Positioning

Topic	Outcome
Previous Datums	Describe the means of relating historical vertical datums, how these came about and their relationship with currently accepted Canadian reference frames. Describe practical methods to confirm these relationships in theory and on site.
Vertical Datum Fundamentals	Explain and describe the characteristics of height systems (e.g. dynamic, orthometric and normal heights). Differentiate between gravity related and ellipsoidal heights.
Datums	Describe the role of, and methods of establishing, the various vertical datums used in hydrographic operations (e.g. Chart, Sounding, MSL, LAT, LW, and HW datums). Select, establish, interpolate and transfer datums in coastal waters, estuaries, rivers, and lakes for soundings and elevations.
Elevation Measurements and Computations	Describe methods for determining differences in elevation (e.g. by spirit level, vertical angle by theodolite, GNSS RTK and GNSS). Correct for effects of curvature and refraction, where appropriate. Compare and evaluate the observing methods and procedures for the determination of elevation. Select an appropriate system for specific applications.
Heave	Describe the principles and limitations of heave compensation systems. Describe the role of filtering in making heave measurements. Evaluate and select appropriate heave compensation systems for specific applications.
Orientation	Describe the operation of heading sensors (e.g. flux-gate and other magnetic, fibre-optic and gyro compasses). Explain the principles of inertial roll and pitch sensors. Describe the principles and limitations of GNSS attitude sensors. Evaluate and select appropriate heading, roll and pitch sensors, for specific applications. Describe field alignment checking procedures.

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7. Understanding of Principles and Technology

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Topic	Outcome
Instrumentation	Compare specifications of bathymetric systems SBES, MBES, SSS and other techniques. Explain the importance of the correct installation and determination of the attitude and position of each sensor.
Operations	Describe the roles of the following survey parameters: scale, positional accuracy, survey speed, line orientation, interlines, cross lines, fix interval, data coverage. Explain methods for quality control of survey data, and the quality assurance of surveys. Describe cost estimating, and project scheduling. Create specifications for specific surveys, including appropriate requirements for scale, positional accuracy, survey speed, line orientation, interlines, cross lines, fix interval, and data coverage. Explain the methods to be used for quality control of survey data, and the quality assurance of surveys.
Survey Data Processing	Describe the requirements for processing of hydrographic survey data. Explain the use of Geographical Information Systems (GIS) within the marine environment. Explain the electronic charting concept as a special form of GIS. Describe the hydrographic applications of 3D modelling and visualisation.

8. Hydrographic Surveys

Topic	Outcome
Surveys in Support of River Crossings and Engineering	Describe and distinguish between surveys for river crossings and bridge works.
Surveys in Support of Port Management and Coastal Engineering	Describe and distinguish between surveys for dredging, environmental monitoring and hydraulics, including surveys at a large scale. Describe the methods and instruments used (e.g. geotechnical, magnetic, diving, and under water cameras).
Nautical Charting	Describe the purposes of nautical charting surveys for rivers, lakes and the near shore to ensure safety of navigation. Define the components of a nautical charting survey (general depths, wrecks and obstructions, shorelines, navigation aids, etc.). Describe the IHO S44 specifications for hydrographic surveys.

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Essential Reference Material:
The associated C12 Study Material contains all of the essential material and associated essential references.

Source	Organization	Web Address
CHS	Canadian Hydrographic Service, Standards for Hydrographic Surveys, 2013	http://www.charts.gc.ca/data-gestion/standards-normes/2-eng.html?wbdisable=true
CHS	Canadian Hydrographic Service, Management Guidelines for Hydrographic Surveys, 2013	http://www.charts.gc.ca/data-gestion/guidelines-directrices/7-eng.html
IHO	S-44 Standards for Hydrographic Surveying, 5th Edition, published February 2008	http://www.iho.int/iho_pubs/standard/S-44_5E.pdf
IHO	C-13 Manual on Hydrography, 1st Edition published May 2005 with corrections to February 2011	https://www.iho.int/iho_pubs/CB/C13_Index.htm
CHS	Canadian Tidal Manual by W.D. Forrester	http://www.psmsl.org/train_and_info/training/reading/canadian_manual.php

Secondary Reference Material:
In addition to the essential reference material, there are many commercial and government sources available online which the candidate can access for further information. Some of the governmental organizations which provide publicly available information are listed in alphabetical order below.

Source	Organization	Web Address
IHO	International Hydrographic Organization, Standards and Publications, Downloads	http://www.iho.int/iho_pubs/IHO_Download.htm
UNB	University of New Brunswick, Ocean Mapping and Research	http://www.omg.unb.ca/GGE/JHC_courses.html
NOAA	United States National Oceanic and Atmospheric Administration	http://tidesandcurrents.noaa.gov/pub.html
NOAA	NOS Hydrographic Survey Specifications and Deliverables published April 2016	https://nauticalcharts.noaa.gov/publications/docs/standards-and-requirements/specs/hssd-2016.pdf
NOAA	NOS Hydrographic Survey Specifications and Deliverables published April 2017	https://nauticalcharts.noaa.gov/publications/docs/standards-and-requirements/specs/hssd-2017.pdf
IHO	S-32 Hydrographic Dictionary, 5th Edition published 1994	https://www.iho.int/iho_pubs/standard/S-32/S-32-eng.pdf