Canadian Board of Examiners for Professional Surveyors
Elective Syllabus Item
E2: ADVANCED HYDROGRAPHIC SURVEYING
Learning Outcomes

Introduction

The advanced hydrographic surveying elective syllabus item E2 criteria covers in depth all aspects of hydrographic and offshore surveying. E2 builds on the CBEPS hydrographic surveying mandatory syllabus item C12. If the candidate has not already passed C12, it is recommended the candidate become fully familiar with and understands the C12 Learning Outcomes, Study Guide and associated questions, and Study Material before proceeding further.

The elective E2 requires a fuller and more in depth understanding of all C12 topics. In addition, E2 covers such topics as follows: contract charting surveys, offshore engineering surveys, and offshore construction support. The charting surveys are usually undertaken under the auspices of the Canadian Hydrographic Service (CHS) or a similar entity, and the offshore surveys are usually undertaken in offshore Canada Lands for various oil and gas companies. The Learning Outcomes of E2 are a combined subset of most of the outcomes defined in the International Hydrographic Organization (IHO) S-5 document “Standards of Competence for Hydrographic Surveyors”, and knowledge in offshore oil and gas surveys. Those topics which are omitted from the S-5 standard are already covered in other CBEPS subjects.

The candidate who successfully passes E2 will be able to further the interest in and activities related to hydrographic surveying within their province or territory.

The elective E2 is a requirement to become a Certified Professional Hydrographer (CPH) if an Association of Canada Lands Surveyors (ACLS) member, or otherwise a Certified Hydrographer (CH), also via the ACLS.

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, along with any oil and gas industry safety requirements. For candidates who chose to become a CPH or CH then these courses in combination with practical hydrographic and/or offshore survey experience should satisfy the IHO S-5 Basic 4: Nautical Science component, which will be assessed by the ACLS.

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
Item C11: Business Practice and the Profession
Item C12: Hydrographic Surveying
Item E1: Spatial Databases and Land Information Systems

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In order to fulfil the requirements of this syllabus item, each candidate should possess **IN DEPTH** knowledge of the following topics.

1. Background and the Natural Environment

Topic	Outcome
Historical Context	Describe the history of hydrography including the development of hydrographic related measurement units, the echo sounder, radio positioning, other physical means of positioning, and aids to navigation. Describe the historic role of offshore surveying related to the international oil and gas industry.
Marine Environment Introduction	Describe oceanic marine geology, seawater properties, and seawater circulation. Describe continental margin geology and seawater circulation and composition. Describe near shore geology and seawater circulation, and river fresh and seawater mixing.

2. Underwater Acoustics

Topic	Outcome
Review	Full review of all associated topics in C12
Acoustic Fundamentals	Distinguish between plane and spherical waves. Distinguish between sound speed and particle velocity. Describe the Active Sonar Equation. Define acoustic units, intensities and sound levels
Acoustic Velocity	Calculate sound speed from measurements of temperature, pressure (depth), and salinity (conductivity).
Sound Wave Propagation	Describe how acoustic waves are generated, define source level. Explain the causes of propagation loss and list the differences in water properties that affect propagation loss.
Ray Tracing	Describe the effects of variation of sound speed in the water column on the path of sound rays through the water. Describe the basic principles of ray path development and analysis. Predict shallow zones and sound channels.
Reflection and Scattering of Acoustic Waves	Describe the characteristics of the seafloor and seafloor targets that affect the reflection of acoustic waves. Define the characteristic impedance of an acoustic medium. Assess the effects of varying seafloor composition, texture, and slope on echo strength.
Acoustic Noise and the Directivity Index	Identify the sources of noise in the environment and describe the effect of noise on echo sounding. Define the directivity index. Calculate the effect on sonar range of a variety of noise conditions and sonar directivity circumstances.

3. Single Beam Echo Sounders (SBES)

Topic	Outcome
Review	Full review of all associated topics in C12
Transducers	List the transducer characteristics that affect beam width. Describe the piezo-electric principle and explain its application to transducers. Describe the arrangement of single element and multi-element array transducers.
Data Recording	Evaluate and select appropriate range, scale, and pulse repetition rate for specific applications.
Equipment Evaluation	Describe and provide an in depth analyse the technical performance of various SBES systems and how to select appropriate system(s) for certain site conditions.

4. Multibeam Echo Sounder (MBES)

Topic	Outcome
Review	Full review of all associated topics in C12
Multibeam Transducers	Explain the basic principles of MBES shading and focussing, using flat or curved transducers.
Coverage and Accuracy (or Error Budget)	Estimate depth coverage and uncertainty, taking all factors into account.
Object Detection	Predict the nominal sounding density on the seafloor using available information for depth, vessel speed, beam dimensions, and total swath angle. 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.
Backscatter	Describe the generation of backscatter data and the various modes of backscatter recording (e.g., beam average, side scan time series, beam time series). Explain the concept of angle dependence and describe the signal processing steps required to obtain corrected backscatter data for seafloor characterization.
Equipment Evaluation	Describe and provide an in depth analyse the technical performance of various MBES systems and how to select appropriate system(s) for certain site conditions.

5. Phase Differencing Bathymetry (Interferometry)

Topic	Outcome
Phase Differencing Systems	Explain the principles and geometry of interferometry and phase differencing bathymetric sonars and the arrangement of transducer arrays.
Deployment and Mounting	Describe the options for deployment and mounting of phase differencing systems.
Equipment Evaluation	Assess the relative merits of multibeam and phase differencing systems for specific mapping applications in water depths from very shallow to full ocean depths.

6. Side Scan Sonar (SSS)

Topic	Outcome
Review	Full review of all associated topics in C12
SSS vs MBES	Explain the differences between side scan sonar and similar data provided by MBES, interferometric multibeam or bathymetric side scan systems.
Equipment Evaluation	Describe and provide an in depth analyse the technical performance of various SSS systems and how to select appropriate system(s) for certain site conditions.

7. Sub Bottom Profiler (SBP)

Topic	Outcome
Sub Bottom Profiler Systems	Explain the effect on sub bottom profiler performance of frequency, resolution, gain, towing speed, and deployment (pole mount and shallow tow). Evaluate and select appropriate sub bottom profiler frequency, features and deployment, for specific applications.
Sub Bottom Profiler Data Interpretation	Describe the different types of sub bottom profilers and their application. Explain sub bottom profiler signatures of such items as typical river bed strata, debris, wrecks, pipelines, and gas.
System Selection	Identify sub bottom profiler characteristics that affect performance in varying survey applications. Specify appropriate sub bottom profiler characteristics (e.g. resolution, frequency, bandwidth, and beamwidth) for specific applications.
Equipment Evaluation	Describe and provide an in depth analyse the technical performance of various SBP systems and how to select appropriate system(s) for certain site conditions.

8. Marine Magnetometer

Topic	Outcome
Marine Magnetometer Systems	Explain the effect on marine magnetometer performance of frequency, resolution, gain, towing speed, and deployment (towed or held by diver). Evaluate and select appropriate marine magnetometer frequency, features and deployment, for specific applications.
Marine Magnetometer Data Interpretation	Describe the different types of marine magnetometers and their application. Explain marine magnetometer signatures of such items as debris, wrecks, and pipelines.
System Selection	Identify marine magnetometer characteristics that affect performance in varying survey applications. Specify appropriate sub bottom profiler characteristics (e.g. resolution and frequency) for specific applications.
Equipment Evaluation	Describe and provide an in depth analyse the technical performance of various marine magnetometers and how to select appropriate system(s) for certain site conditions.

9. Tide and Non-Tidal Water Levels

Topic	Outcome
Review	Full review of all associated topics in C12
Tidal Fundamentals	Describe the static and dynamic tidal theories. Explain the concept of amphidromic points and co-tidal charts.

Topic	Outcome
Tidal Analysis and Prediction	Determine a preliminary sounding datum from observed water levels.

10. Surface Positioning

Topic	Outcome
Surface Positioning	Describe total station, GNSS RTK and inertial navigation systems positioning for small survey launches and explain the issues and benefits of each. Describe GNSS systems for vessel positioning. Describe INS systems used for hydrographic and offshore surveys.

11. Acoustic Positioning

Topic	Outcome
Acoustic Devices	Describe the purpose and operation of acoustic devices such as: transponders, pingers, acoustic release (tripping) devices, speed of sound in water meters and acoustic Doppler current profilers. Select appropriate acoustic devices for particular applications.
Acoustic Positioning Systems	Describe the principles of long, short and super short baseline acoustic positioning system modes. Describe signal structure, sources of error, and expected uncertainties for each mode.
Deployment and Calibration	Describe the deployment and calibration methods for each mode.
Error Sources and Accuracy	Predict and evaluate sources of error and expected uncertainties for each system and appropriate application for positioning diver(s), a towed body(ies), autonomous underwater vehicles (AUV), and remotely operated vehicles (ROV).

12. Hydrometric Surveys (Streams and Rivers)

Topic	Outcome
Hydrometric Surveys	Discuss the requirements for and observations required including water level recording, and stream or river velocity and area of flow to compute discharge. Describe the various aspects of hydrometric surveys including stream reconnaissance, site selection, station design and construction, instrumentation, gauge height measurement, discharge calculation, stage-discharge rating and discharge compilation.
Water Sampling	Discuss the requirements for and the equipment and methods used to collect stream or river water samples.

13. Other Techniques

Topic	Outcome
Laser Bathymetry	Explain the principles, capabilities and limitations of shipborne and submersible laser bathymetry. Select survey areas suitable for laser bathymetry.
LiDAR Bathymetry	Explain the principles, capabilities, and limitations of bathymetric LiDAR. Describe the environmental and operational environments in which bathymetric LiDAR surveys are complementary to echo sounder surveys.
Remote Sensing Bathymetry	Describe other airborne and satellite remote sensing techniques that can be used for bathymetry. Explain the limitations and advantages of remote sensing.

Mechanical Techniques	Describe wire and bar sweeps.
Other Data Capture	Describe other data capture techniques including underwater laser scanning and synthetic aperture sonar.

14. Meteorology

Topic	Outcome
The Atmosphere	Describe the vertical structure of the atmosphere.
Meteorological Elements	Define the following parameters, explain how they are measured / classified and describe their effect on hydrographic operations: temperature, humidity, dew-point, frost-point, atmospheric pressure, clouds and precipitation, rain, snow, visibility, advection fog and radiation fog.
Winds	Explain the relation between atmospheric pressure and winds, the origin of geostrophic winds and Buys Ballot's law. Describe wind circulation around pressure systems and the effect of friction.
Climatology	Describe the general circulation of the atmosphere and the global distribution of pressure systems, air and sea surface temperatures, winds and precipitation over the oceans, local circulation and land and sea breezes.
Weather Systems	Describe the elements of a weather system and their evolution (e.g. air masses, extra-tropical cyclones, anticyclones and associated weather; fronts, clouds and weather at different stages of fronts; intertropical convergence zone, tropical revolving storms and associated weather).

15. Oceanography

Topic	Outcome
Physical Properties of Sea Water	Explain the effects of solar radiation. Describe the optical properties of sea water. Explain temperature and salinity (T/S) distribution and variation. Prepare T/S diagrams.
Marine Circulation Dynamics	Define types of circulation (e.g. geostrophic, wind-driven, Ekman spiral, slope currents, coastal and thermohaline). Explain the effect of friction.
General Circulation of the Oceans	Define the general characteristics of climatic mean ocean currents. Explain the western intensification of ocean currents and the vertical circulation, along with their driving mechanisms.
Wind Waves and Swell	Define wave parameters. Explain the elements involved in the wave growth process including typical fetches. Explain the relationship between winds, waves, swell, sea state (Beaufort scale), and icing conditions.
Wave Propagation	Define, giving practical examples: refraction, diffraction and reflection. Explain breaking waves, and long-shore and rip current processes.
Oceanographic Measurements	Describe oceanographic sampling, and methods for measuring common oceanographic parameters.
Oceanographic Instruments	Describe principles of oceanographic sensors including temperature / salinity (T/S) probes, current meters, wave sensors and acoustic Doppler current profiler. Select equipment for specific applications.

16. Marine Geology and Geophysics

Topic	Outcome
Marine Geology	Describe various river and sea bed grabs, corers and samplers including cone penetration test (CPT) and their uses. Describe various types of dredging equipment.
Seismic Profiling	Define the objective of continuous reflection / refraction seismic profiling, and the equipment needed to conduct it.
Geotechnical Sampling	Define the objective of geotechnical sampling. Describe geotechnical sampling equipment. Explain how samples are obtained, stored, and analysed.
Deposition and Erosion	Identify types of seabed material. Describe the processes of sediment transport and deposition, as well as the normal fluvial process and formation of bars and other focal points of deposition. Describe the methods of spoil dispersal and selection of spoil grounds.
Environmental Impact	Outline the basic concepts of environmental impact studies. List applications (e.g. to water quality, sedimentation, coastal development, shipping, living and non-living resource development, etc.).

17. Data Management

Topic	Outcome
Real-Time Data Acquisition and Control	Collect hydrographic data manually and automatically. Describe and operate integrated navigation systems and data logging systems. Explain the significance and effect of the use of various data logging rates. Describe the process of on-line data sampling, validation and selection techniques. Explain the effects of using various gating and filtering parameters.
Analogue Data Capture	Explain the manual input of alphanumeric data, raster scanning processes and vector digitisation. Describe digitising systems and scanners. Describe digital data formats. Carry out digital data transfer.
Approximation and Estimation	Apply approximation and estimation procedures to survey measurements. Evaluate and select the best filtering and / or cleaning procedure, for specific applications.
Spatial Data Processing and Analysis	Describe the properties of spatial databases and Database Management Systems (DBMS). Explain the concepts of raster and vector data. Explain the concepts of Geographical Information Systems (GIS) and Spatial data Infrastructures (SDI). Recognize algorithms used for spatial data selection, filtering, smoothing, approximation, estimation, correlation and analysis. Describe Digital Elevation Models (DEMs).
Visualisation and Presentation	Explain and perform manual and automatic plotting and contouring of hydrographic data. Describe the use of vector and raster digitising and plotting systems. Describe the hydrographic applications of 3D modelling and visualisation.
Chart and Marine Cartography	Describe the chart compilation and composition process and flow line including chart compilation, adding coastal topography, Canadian and international hydrographic publications and correction of charts.

Electronic Charts	Describe Electronic Navigational Charts (ENC), and Electronic Chart Display and Information Systems (ECDIS) (concepts, components, impact on hydrography).

18. Hydrographic and Offshore Surveys

Topic	Outcome
Review	Full review of all associated topics in C12
Flood Plain Mapping	Explain the forecasting of floods and low waters in rivers draining a large basin. Describe methods of mapping flood plains. Explain how surveying is done under flood conditions.
Nautical Charting	Describe and analyse the IHO S-44 specifications with respect to offshore industrial surveys.
Drilling Support	Describe the purpose and conduct of drilling support surveys including drilling rig positioning, drilling rig anchor placement in congested areas, drilling rig leg sea bed inspections and the role of ROVs in such work. Define terms used to describe offshore hydrocarbon structures and drill rig equipment.
Marine Seismic	Explain the principles and conduct of marine seismic surveys including towed streamer and gravity, transition zone and shallow marine, ocean bottom cable, ocean bottom node, and marine controlled source electromagnetic (CSEM) surveys and the role of ROVs in such work.
Site, Hazard and Environmental Surveys	Explain the principles and conduct of site, hazard and environmental surveys including prior to shallow water seismic surveys, engineering surveys prior to platform installation, pipeline route selection, surveys prior to offshore drilling, submarine cable route selection and lay, baseline and monitor environmental surveys. Describe the role of MBES, SSS, SBP, marine magnetometer and of ROVs in such work.
Pipeline Lay and Rectification Work	Explain the principles and conduct of pipeline lay including pre-lay, lay, as-built, trenching and ploughing surveys; and any rectification work required such as dead man anchor deployment(s), pipeline defences and pipeline crossing(s), and the role of ROVs in such work. Describe general pipeline inspection procedures e.g. leak detection, damage, scouring.
Structure Emplacement	Explain the principles and conduct of construction support surveys including platform installation, platform as-built, platform dimensional control surveys, and the role of ROVs in such work. Explain the use of drilling templates.
Platform Decommissioning	Describe gravity-based, pile-driven, guyed, floating, and tension-leg platforms. Explain the principles and conduct of platform decommissioning surveys including hazard survey, decommissioning and platform removal, debris clearance and sea bed rectification, and the role of ROVs in such work.

19. Hydrographic Survey Legal Aspects

Topic	Outcome
Product Liability	Describe the liabilities associated with nautical charting and the above offshore surveys and how these risks are mitigated.
Rivers and Lakes	Describe provincial and federal legislation related to surveys over rivers and lakes.

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Topic	Outcome
Law of the Sea Development	Describe the historical development of the Law of the Sea. Explain its influence on hydrographic surveying, marine scientific investigations, and environmental impact.
Near Shore and Offshore	Describe the United Nations Convention of the Law of the Sea (UNCLOS), Canada's Oceans Act, and Canada's offshore boundary regime. Describe federal, provincial and territorial laws and regulations related to coastal and ocean management.
Marine Law	Describe applicable maritime law to Canada's rivers, lakes, near shore and offshore. Describe the basic process of marine accident investigations and court cases, in relation to hydrographic issues.
Marine Cadastre	Describe the concepts and practicalities of a marine cadastre.

With respect to reference material for Section 19 the candidate may have already taken C9: Survey Law, and the following reference material should have already been obtained.

From the CBEPS web site extracts from the new Survey Law in Canada text at https://www.cbeps-cceag.ca/guides-for-sale
Water Boundary Issues – Maritime Boundary Delimitation by David Gray (2011)
Water Boundary Issues – Eastern Canada by Izaak De Rijcke (2012)
Water Boundary Issues – Prairie Provinces by Ken Allred (2014)

In addition, the candidate may already have the text available from the Association of Canada Lands Surveyors by Bruce Calderbank et al., *Canada's Offshore: Jurisdiction, Rights and Management* published in 2006. Copies can be purchased from www.acls-aatc.ca or via www.trafford.com using ISBN 9781412078160.

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Essential Reference Material:
The associated E2 Study Material contains all of the essential material and associated essential references. In addition, there are many commercial and government sources available online which the candidate can access for further information.

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