S-65

Annex A

High Density (HD) ENC Production and Maintenance Guidance

Edition 1.0.0 – January 2020

IHO

International Hydrographic Organization

Published by the
International Hydrographic Organization
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Document History

Version Number	Date	Author	Purpose
0.0.1	May 2019	ENCWG	Draft document for discussion (S-101PT4)
0.0.2	August 2019	ENCWG	Draft document for WG approval
0.0.3	November 2019	ENCWG	Revised draft document for WG review
0.0.4	January 2020	ENCWG	Final draft for WG approval
1.0.0	January 2020	ENCWG	Publication of Edition 1.0.0

Contents

1 Overview

1.1 Introduction

When Electronic Navigational Charts (ENCs) were first introduced most HOs used their paper chart series as the source for this new vector product. Unfortunately, while enabling the relatively quick creation of ENC data, it has also led to some more unforeseen issues. One of the principle advantages of using ECDIS for navigation is that the system enables the setting of a safety contour, differentiating the safe and unsafe water. This can only accurately be achieved if the data within the ECDIS includes higher density contour intervals than those traditionally shown on the paper chart. Many of our ENCs today only contain the standard series of contour lines mirroring the paper chart as specified in IHO Publication S-4 - *Regulations of the IHO for International (INT) Charts and Chart Specifications of the IHO*, section B-411. This results in some vessels having to navigate in waters indicated on the ECDIS as dangerous, when in reality the vessel is still safe and has not reached the maximum permitted water depth.

There is also an emerging requirement for ENC covering commercial ports to include significantly larger scale and higher bathymetric content levels than included in the corresponding paper chart portfolio. This requirement is driven by:

- The increasing size of vessels in relation to ports, and their channels and confined waters;
- Reduced under-keel depth margins as more vessel sailings are required within each tidal window;
- A fundamental shift in the way these vessels are navigated and a change in user expectations.

The preference is to meet these requirements through official S-57/S-63 ENC rather than unofficial 'closed' proprietary formats. There is a concern that use of a proprietary format creates a situation whereby the ship's Pilot has a considerably different view of the navigation situation compared to the vessel's Master, leading to ineffective Bridge Resource Management, confusion and increased safety risk. In contrast, exclusive use of S-57/S-63 ENC allows for access and use of the same information by all parties.

With advances in the processing of high-resolution bathymetry it is now possible to automatically create sets of supplementary contours that can directly feed into the creation of high density (HD) ENCs. This Annex will provide HOs with survey capture, processing and production guidance to enable the effective creation of HD ENCs.

1.2 References

IHO S-4	Regulations of the IHO for International (INT) Charts and Chart Specifications of the IHO, Edition 4.8.0, October/November 2018
IHO S-44	Standards for Hydrographic Surveys, 5th Edition, February 2008
IHO S-57	Transfer Standard for Digital Hydrographic Data – Appendix B.1 – ENC Product Specification, November 2000.
IHO S-58	ENC Validation Checks, Edition 6.1.0, September 2018

1.3 Definitions

High Density ENC (HD ENC)
An ENC product that includes bathymetry depicted with depth area intervals of 1 metre or closer within the depth range of relevance, focussed on a physically constrained waterway. The additional bathymetric information is incorporated in the base ENC dataset. The product may also include more detailed port infrastructure. Under the current IMO ECDIS Performance Standards, this product is suitable to be displayed and operated on any type-approved ECDIS and consequently it can be used to fulfil the IMO's chart carriage requirements.

2 Bathymetric Surveys for HD ENCs

HD ENCs are considered to be of maximum benefit to the Mariner in areas where there are areas of minimal under-keel clearance and/or vessel manoeuvrability is restricted.

Careful consideration must be given when planning surveys, so that the resulting data can be used to compile areas of HD bathymetry where a requirement is identified. Hydrographic offices should consult with ports, pilots etc. regarding surveys, maintenance, accuracy of infrastructure, target vessel type(s) and any other characteristics of the area of interest that may influence the structure and content of a HD ENC.

Hydrographic surveys to be used in the compilation of HD bathymetric areas will in the majority of cases need to meet IHO S-44 Special Order survey requirements:

Table 2.1 – S-44 Special Order survey requirements

Maximum allowable Total Horizontal Uncertainty (95% confidence):	+/- 2 m
Maximum allowable Total Vertical Uncertainty (TVU) (95% confidence)*: a = +/- 0.25m b = 0.0075	Examples: TVU for 10m depths = +/- 0.26m TVU for 20m depths = +/- 0.29m
Feature Detection:	Full seafloor search (able to detect features greater than 1 cubic metre in size)

* Recognizing that there are both depth independent and depth dependent error sources that affect the measurements of depths, the formula below is used to compute an acceptance interval for vertical measurement uncertainties. The interval of the *total vertical uncertainties* of depth measurements calculated with a 95 % confidence level must comply with this acceptance interval.

The parameters “a” and “b”, together with the depth “d”, have to be introduced into the formula below in order to calculate the acceptance interval $A_{TVU}(d)$:

$$A_{TVU}(d) = \left[-\sqrt{a^2 + (b \times d)^2}\,;\; +\sqrt{a^2 + (b \times d)^2}\right]$$

Where:

a	represents that portion of the uncertainty that does not vary with depth
b	is a coefficient which represents that portion of the uncertainty that varies with depth. It is given in percent format and must be divided by 100 when used in the equation above (i.e. for 0.75% of depth, use b = 0.0075)
d	is the depth
b x d	represents that portion of the uncertainty that varies with depth[1]

The bathymetry supplied must be referenced to:

- WGS84. This is what ships, pilots, and ENC use. Transformation to other reference systems, and back again, increases the Total Horizontal Uncertainty.
- A specified port tidal datum (such as “zero of the port tide gauge”, “x.xx metres below [named] benchmark” or similar). Where multiple tidal stations or nodes have been used, each should be listed to ensure accuracy is maintained through to the ENC. Simply stating “LAT” (Lowest Astronomical Tide) does not necessarily provide sufficient detail to replicate the tidal reference plane. LAT within ports is frequently insufficiently defined for levels of accuracy to be maintained through to the HD ENC.

In cartographic terms, HD bathymetric data should only be depicted in areas categorized as CATZOC A1 or A2.

[1] IHO Publication S-44 – *IHO Standards for Hydrographic Surveys* – Draft [h] Edition 6.0.0 (January 2020), clause 3.2.3

The exception to the above is where the bottom quality is mud/silt and the water column is holding significant amounts of sediment. Given these environmental conditions multibeam as a survey technique is not suited when acquiring depth information. In this situation other survey techniques may be used.

It is recommended that charting authorities consider the following criteria when developing HD ENCs:

a. Ability for larger vessels to access the port.

b. Improvement to routes to avoid areas of environmental risk.

c. Improvement to routes to improve traffic flow.

d. Is it practical to maintain the cells once produced?

3 HD ENC Cell Creation

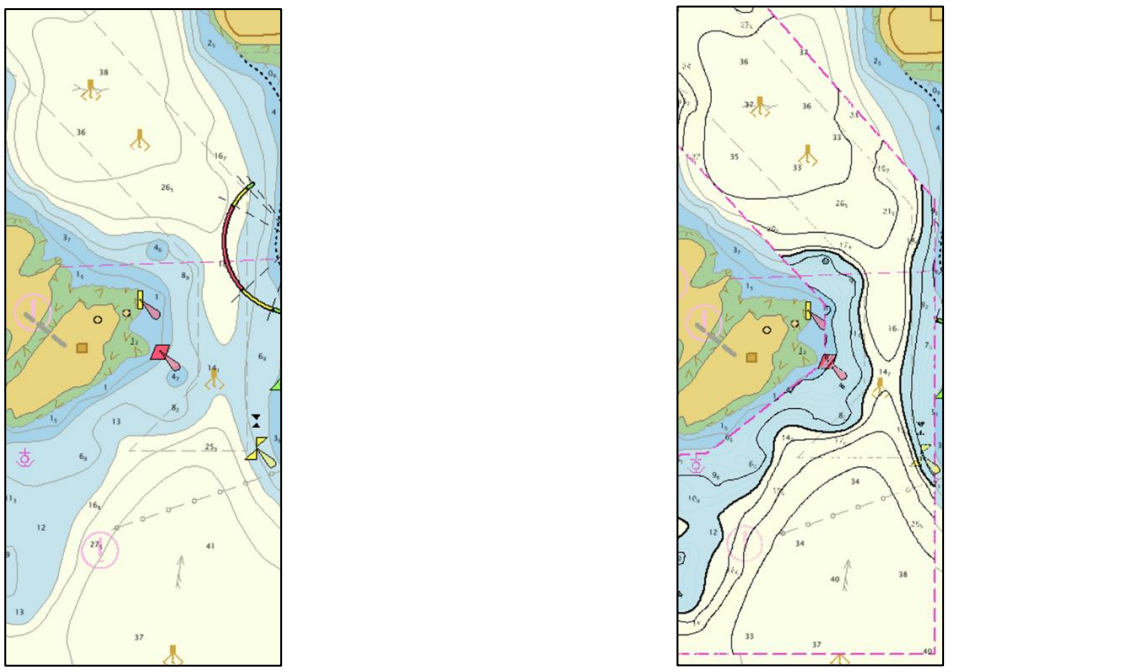
There are two options for creating HD ENCs:

- Incorporating HD ENC information in existing published ENC cells.
- Creation of dedicated new HD ENC datasets.

In order for RENCs or other service providers to identify a HD ENC for catalogue service purposes, the text string "HD ENC" should be included in the “Comment” [COMT] subfield of the “Data Set Identification” [DSID] field of the ENC Data Set General Information record.

3.1 Existing cells

HD bathymetric data can be included in any navigational purpose so long as the product is the largest scale ENC available in the area. The area of the data coverage of the ENC cell to be covered by HD ENC information should, for reasons of economy and maintenance, be restricted to the area of interest for the target vessel classes for the HD ENC information; with the remainder of the area of data coverage containing the more “traditional” level of bathymetric detail. In general, the area of interest for HD ENC data coverage will include (but is not restricted to) shipping channels (including dredged areas), anchorages, emergency escape channels, waiting areas, vessel manoeuvring areas (for example turning basins) and berths. In most cases these areas will require a larger compilation scale (using the S-57 meta object M_CSCL) to support the extra detail provided and the way the end user will use the ENC.



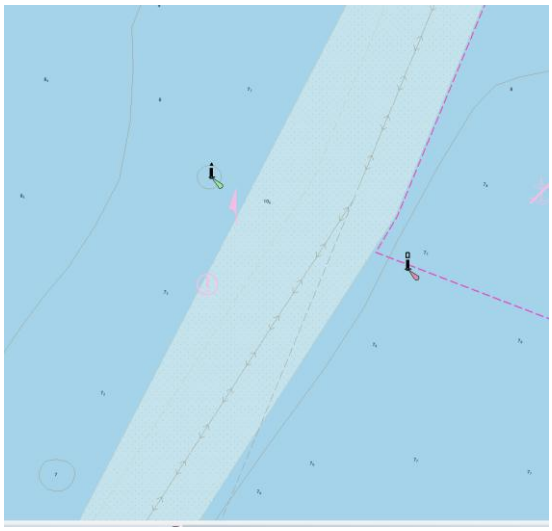
Standard ENC **ENC containing HD bathymetric data**

Figure 3.1 – Standard ENC and ENC containing HD information – comparison

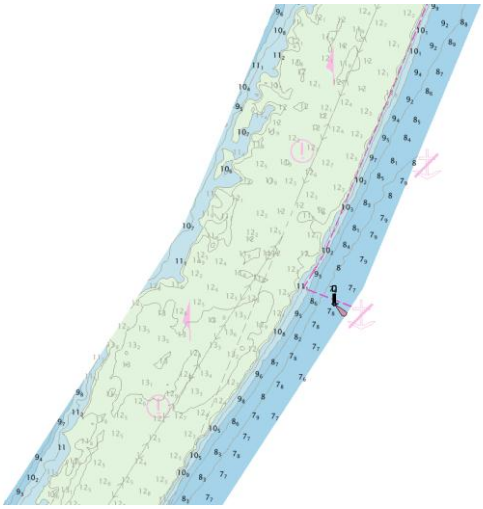
The images above show the impact on the available safe water when additional contours are included.

3.2 New cells

New ENC cells containing only HD ENC data must be the largest Navigational Purpose ENC data covering the area. Where ENC data already exists at the Harbour (Navigational Purpose 5) band, the Navigational Purpose band 6 (Berthing) may be used. It is expected that the majority of HD bathymetric data will be included in new cells created in the Berthing Navigational Purpose. This approach is preferred as it simplifies the updating process.



Classic Navigational Purpose 5 ENC view



HD ENC view

Figure 3.2 – Standard ENC and new HD ENC cell – comparison

4 Cell Size

An ENC dataset containing HD bathymetric data should contain no more than 5 Megabytes of data. Appropriate scheming of the area of interest, for instance consideration of multiple cells in lieu of a single large sized cell, should be considered; particularly if it is considered important that the 5 Megabyte data limit is to be retained.

5 Quality of Bathymetric Data

To ensure the mariner has access to all the metadata related to the bathymetric survey the meta object M_QUAL must be used, in accordance with S-57 Appendix B.1, Annex A – *Use of the Object Catalogue for ENC*. However for HD bathymetric data the use of the attribute value CATZOC = *6* (Unassessed) is prohibited.

It is strongly recommended that the attributes POSACC, SOUACC, SUREND and TECSOU are used on the M_QUAL where possible to relay important information about the quantitative accuracy of the source surveys and the survey technique of sounding measurement, taking into account the guidance on the use of these attributes as included in S-57 Appendix B.1, Annex A, clause 2.2.3.1.

The quality of source surveys used to compile HD bathymetric data should be the equivalent to ENC data CATZOC values A1 or A2 (see clause 2).

5.1 HD ENC validation checks

ENC cells containing HD bathymetric data must conform to S-58 – *ENC Validation Checks*, noting however the allowance to exceed to 5 Megabyte data content limit (see clause 4 above).

6 Automatic Generation of Depth Contours and Sounding Selection

Hydrographic Offices are free to determine density of contours. It is recommended that a contour interval of 1m is used as this represents the most useful contour interval for the end user, although there has been HD bathymetry data produced with a 0.1m contour interval.

For use in ECDIS HD bathymetric data does not need to extend in the whole 0m – 50m depth range; the most useful depth range for surface navigation is between 5m to 30m. Hydrographic offices should consider factors such as the nature of the topography, area to be covered and classes of vessels for which the data is intended when determining the depth range within which to compile HD bathymetry.

For reasons of economy, it is considered that the cartographic quality of contours auto-generated and smoothed by modern production software tools is sufficient for use of HD bathymetry in ECDIS. Cartographic intervention should only be applied when matching the “standard” depth contours to adjoining data and in the depiction of isolated shoals and deeps (see clause 8).

The use of denser sounding patterns (50-100m ground spacing) may be beneficial to support the navigation of large vessels that may still require higher accuracy than the recommended 1m contour interval. In these cases, an evenly spaced sounding pattern (production software automated sounding suppression/selection (shoal biased) routine) is preferred. With modern production software, such an automated process is very quick and reliable taking into account the additional contours to be supported, noting that with such higher density data there is no expectation that the mariner may sail ‘from sounding to sounding’ as is common practice when navigating on traditional charts. It is important to remember that soundings are not part of the S-52 ‘Standard’ display and they can be turned off at any moment.

Note: When dredged areas (S-57 object class DRGARE) exist within the area of HD bathymetry the use of ‘supplementary’ contours matching the design depth of the dredged area is highly recommended (for example 7.6m). HOs may decide to replace dredged areas with full bathymetry, in which case the limit of the dredged area and the dredged depth should be indicated using a fairway (S-57 object class FAIRWY).

7 Application of SCAMIN

7.1 SCAMIN on contours

SCAMIN must be applied to the “standard” contours (0, 2, 5, 10, …) such that they match the SCAMIN values of the corresponding contours outside and adjoining the area of HD bathymetry. This ensures that the “standard” depth contours will appear and disappear at the same time irrespective of whether they sit within or outside the HD bathymetry area.

To avoid excess clutter within the ECDIS it is recommended that SCAMIN is applied to the intermediate (non-standard) contours within the HD bathymetry area so they are either not visible or only visible at the compilation scale of the HD bathymetry. The decision depends on the sea bottom topography and on how close together the contours are at compilation scale. Related S-58 checks (1553) can be ignored where the decision is to apply SCAMIN such that the intermediate contours disappear from ECDIS display at the compilation scale.

7.2 SCAMIN on soundings

Soundings must have SCAMIN applied in accordance with the general accepted practice for the Hydrographic Office.

8 Managing Shoals and Deeps

The automated contouring process may generate contours that are too small to easily be displayed at HD ENC compilation scale. It is recommended that no isolated shoal or deep area should be smaller than 2.75mm across any dimension at the compilation scale of the HD ENC. Appropriate automated contour generation algorithms so as to avoid the creation of small shoals should be investigated.

Small isolated deeps may be filtered out of the HD ENC data.

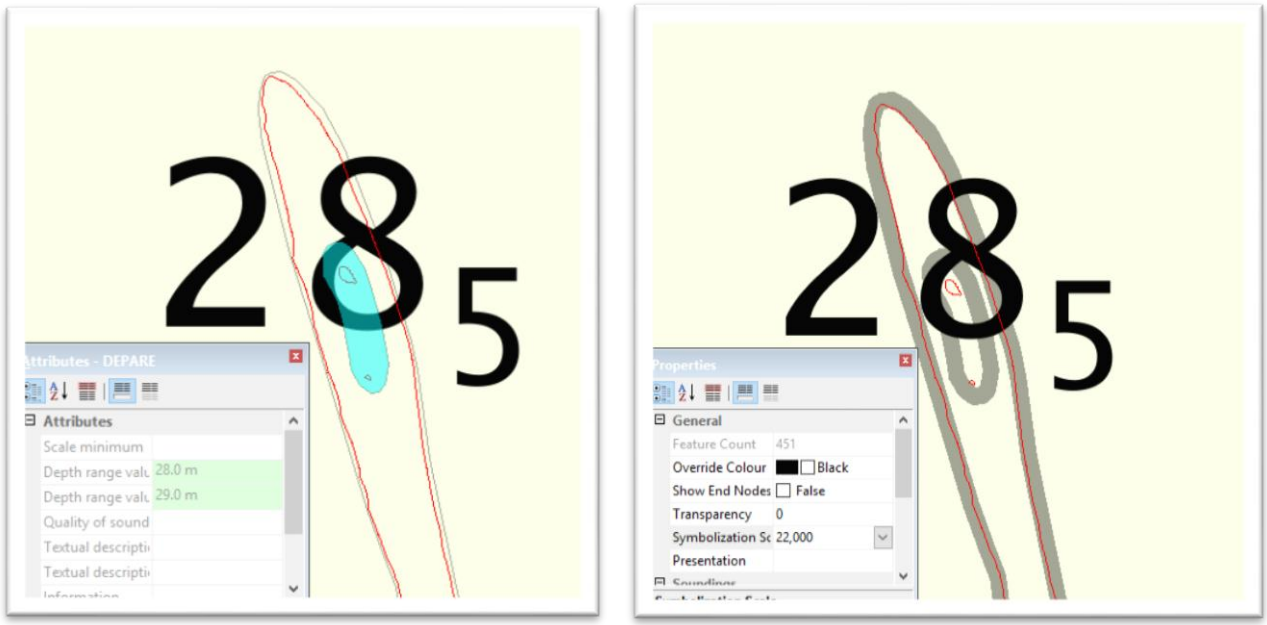


Figure 8.1 – Generalisation and enlarging of contours – example

9 Testing

Prior to publication, it is strongly recommended that HD ENC datasets be supplied to harbour/port authorities and pilots for testing and feedback. If possible, consideration should also be given to supplying HD ENC datasets to local ship simulator training facilities for evaluation, testing and feedback.

10 Maintenance of HD ENC Data

HD ENCs should be maintained at a minimum as is done for the regular ENC maintenance regime, however where there is a requirement to release the data more regularly this would be possible with the agreement of the RENCs.

For post-dredging surveys the Hydrographic Office should consider processing the data and releasing an updated HD ENC dataset within 2 weeks of data receipt.

In all cases where the continued reliability of a HD ENC may be questioned (for example changed circumstances in ability to resurvey in areas of changeable seabed or in dredged areas; consequences of natural disaster), a course of action should be determined in full consultation with the key stakeholders. This may include, for HD ENC datasets having full HD bathymetry coverage, a decision to cancel the cell pending resolution of the issue. Such action should commence as soon as it is considered that the CATZOC for the HD bathymetry within the dataset has degraded beyond the recommended CATZOC A1 or A2 level.