Paper for Consideration by NCWG

ENC-derived Paper Chart Guidelines

Submitted by:	United States
Executive Summary:	This document serves as the minimum guidelines for ENC-derived Paper Charts as defined by the participating IHO Member States in its creation.
Related Documents:	S-4, INT-1, IHO website > Publications > Standards
Related Projects:	The Future of the Paper Nautical Chart (Final Report, 29 August 2020)

Introduction

1. In October 2022, IHO Council 6 Action No. C6/17 "endorsed the offer of the US (supported by AU, DE, DK, KR, and NZ) to document use cases and develop associated guidelines, as well as identify challenges with S-4, to achieve automated production of derived paper charts from ENC [Electronic Navigational Chart] content databases and submit them to the HSSC/NCWG for their consideration."

2. The Proposed guidelines for automated paper chart output from ENC (C6-04.1B) states: "The IMO considers paper nautical charts to be an adequate independent back-up for ECDIS when produced and updated according to the S-4 standard. Recognizing that the information and capabilities of ENC and ECDIS have surpassed that which can be captured on a sheet of paper and that it requires significant effort to automate a paper reproduction following existing cartographic IHO standards of all information available on an ENC, we must consider establishing guidelines for minimum content for those who wish to continue to rely on paper for route planning, training, certification (Licensure, pilot certification) situational awareness, and backup navigation or where hardcopy requirements still exist. Consideration of the changing use cases for paper nautical charts is needed, including the possible adjustments to IMO resolution A.817(19), as amended or resolution MSC.232(82) to allow for the use of a minimal product. Some Hydrographic Offices already are developing solutions that enables mariners to generate paper chart-like products from [up-to-date] ENCs in a national context for specific use cases. In order to ensure maximum uniformity for global shipping, facilitate mariner's training and assist Hydrographic Offices (HOs) with their transition away from current, resource intense, paper chart compilation and maintenance methods, the IHO should play a role in developing guidelines for automated paper chart output."

3. As presented to HSSC14 and HSSC15, the Committee notes in both actions HSSC14/56 HSSC15/48 "that nothing prevents national HOs from developing bespoke solutions for the automated paper chart production from ENC content database meeting their national requirements, HSSC did not support a new task on NCWG however invited the US to keep the NCWG informed."

4. This document serves as the minimum guidelines for ENC-derived Paper Charts as defined by the participating IHO Member States in its creation.

Use Cases

5. There are three overarching use cases for ENC-derived Paper Charts:

5.1 Backup Safety of Navigation (SoN) product for ECDIS-mandated vessels
    5.1.1   Reduced geographic coverage of the chart catalog (i.e. sea buoy to sea buoy): this will provide enough information to get vessels to sea buoys or pick up pilots.
    5.1.2   Reduced number of scales.
    5.1.3   Fixed product extents to support updating and navigational consistency/safety.
    5.1.4   Some divergence from S-4 requirements (e.g., adequate hybrid INT/ECDIS portrayal).
    5.1.5   Update process required for adequate, independent back-up arrangements in place according to SOLAS.
5.2 Primary SoN product for non-ECDIS-mandated vessels
    5.2.1   Supporting all scales and geographic coverage for SoN as determined by appropriate authority.
    5.2.2   Fixed product extents to support updating and navigational consistency/safety.
    5.2.3   Limited divergence from S-4 requirements.
    5.2.4   Regulated updated processes required.
5.3 Non-SoN planning products
    5.3.1   No requirement to meet S-4.
    5.3.2   Must be marked, such as, "Not for Navigation".

Challenges to Meet S-4 and Considerations to Overcome Them

6.   Static Cartographic Representation
    6.1 ENC is a dynamic and queryable product; while it is possible to translate much of its content into rules to represent as S-4 symbols, it is frequently not compiled with intent to be viewed at a single static scale, nor is it always edge-matched between scales or even adjacent cells. When printed, issues like edge-matching, over collection, cluttering, and other cartographic anomalies will be apparent and compete against the readability and usability of ENC-derived paper charts.

7.   Labeling Features
    7.1 Adhering to the S-4 standard in the development of ENC-derived paper charts introduces a host of complexities when needing to label geographic places, features, hazards, and other essential locations. Traditionally, skilled cartographers assigned labels to features, carefully considering their size and placement to optimize readability and visual clarity. Each label was crafted to ensure that mariners could quickly and accurately identify crucial geographic elements and other prominent features.
    7.2 Digital production methods, now routinely rely on automated labeling systems. These automated systems built into the GIS software generate labels based on data extracted from the ENC, making it more efficient to produce charts on a larger scale. However, this automation introduces its set of challenges, including overprinting errors and difficulties in distinguishing labels from one another.
    7.3 One of the primary challenges of labeling stems from the uniformity of font and font size when the labels are generated and placed. This one-size-fits-all approach can lead to instances where labels intended to emphasize key features appear identical in size to those describing less critical elements. Consequently, mariners may struggle to differentiate vital information amidst the background noise of labels, potentially endangering safe navigation.
    7.4 One solution would be the ability to edit the font style, size and color so that different features would be labeled in a way that distinguished them from others. Also a label

ranking system could be implemented that determines what features should be labeled and which ones can be truncated or removed.

7.5 Furthermore, another crucial issue pertains to the accurate association of labels with their corresponding features. Traditionally, cartographers could intuitively place labels, ensuring that each name or descriptor aligned precisely with its designated feature. In contrast, automated systems must rely on algorithms and data matching. Sometimes it is unclear which feature a label is referring to, which can cause confusion and pose a significant risk to navigation, especially in intricate or densely populated maritime regions.

7.6 Lastly, automatically generated and placed labels can be hidden by or themselves block critical features from the view of the mariner. This overprinting would cause confusion and may take time to decipher what is being shown. Labeling with accepted abbreviations/abridgements can alleviate some of these clutter issues.

8. Notes and Cautions

8.1 The transition from traditional paper nautical charts to ENC-derived paper charts has introduced a new set of challenges when dealing with the placement of notes and cautions. Cartographers in the past carefully positioned these textual warnings in close proximity to the feature or condition being referenced in the note, while also avoiding obscuring important areas or essential navigational features. With the advent of automated chart production driven by algorithms, the ability to ensure the appropriate placement of notes and cautions has become a complex issue.

8.2 The reliance on algorithms to place notes and cautions on ENC-derived paper charts raises the risk of these important warnings obstructing critical information. Unlike human cartographers, algorithms may lack the nuanced understanding of what constitutes a strategically sound placement for these notes. Automated systems may have difficulty finding appropriate open space for notes, such as land areas and non-navigable waters, and inadvertently cover crucial navigational details or areas that must remain visible for safe marine navigation.

8.2.1 There is a possible solution where the initial chart has the notes and cautions manually placed by the cartographer and then their placement would be remembered and saved for future editions of the chart. This would prevent the placement of notes and cautions on navigable or important areas of the chart to the mariner.

8.3 Furthermore, the challenge extends to ensuring the comprehensive coverage of all necessary notes and cautions for a specific charted area. In the past, cartographers could exercise their judgment and expertise to select and place relevant warnings based on their knowledge of local conditions and hazards or by utilizing the various sources used to create their chart. However, relying solely on algorithms might lead to omissions, as automated systems may struggle to identify and include all pertinent information, especially when dealing with complex and dynamic maritime environments.

8.4 There is also difficulty to know which notes that exist in an ENC cell should appear on the ENC-derived chart. There may be some notes that refer to a part of the ENC cell that is not on the subsequent ENC-derived chart. It would then be beneficial to have all notes be geo-referenced so that only the ones that fall within a chart's boundaries show up. These notes will not only be applicable to specific polygons where the danger or other phenomena occurs but also be linked to individual features. Additionally, the use of "See Note B" style of labels should not be used because of the increasing difficultly to accurately automate being shown on a chart.

9. Updating and Correcting Charts

9.1 The application of traditional Notice to Mariners (NtMs) poses a significant challenge in the context of ENC-derived paper charts. Traditionally, NtMs were manually applied to nautical charts by mariners, who received textual descriptions of required changes along with the corresponding chart locations. This hands-on approach allowed mariners to carefully update their charts with precision, ensuring that the latest navigational information was readily available. However, as chart production has shifted towards automation driven by ENC data, the need for a faster and more efficient method of applying NtMs has become increasingly apparent.

9.2 Automated ENC-derived charts, while efficient in many respects, may struggle to incorporate NtMs seamlessly. The process of manually interpreting textual NtM descriptions and then implementing the required changes algorithmically presents substantial technical and logistical challenges. It requires complex data processing and validation to ensure that updates are accurate and applied to the correct charted locations, a task that was previously handled with human expertise.

9.3 One solution to expedite the application of NtMs to ENC-derived paper nautical charts involves the development of automated algorithms capable of interpreting NtM data and accurately updating charts. This approach aims to harness artificial intelligence and machine learning to decipher NtM textual descriptions and transform them into actionable changes on the charts. This automation not only accelerates the update process but also reduces the potential for human error, ensuring that NtMs are consistently and accurately applied.

9.4 Another solution involves a comparison tool that looks at two versions of an ENC cell to determine what has changed between them. It then feeds these changes into an algorithm to determine which changes need to be highlighted on the ENC-derived paper chart. This requires some human training of the data in order to teach the machine what are critical changes versus changes that are not critical for SoN. Users could then note where the changes are and apply them to their ENC-derived chart if they do not have access to a plotter or have printing capacity.

9.5 The easiest solution is for the chart producer to regularly refresh the digital catalog of fixed product extent ENC-derived paper charts (aligned with the updating of source ENC) and place the requirement of printing on the user as the user needs it. Known as a Print-on-Demand (POD) model, this type of approach removes any manual correcting by the user and will always give the latest view of charted information for any use case.

Guidelines

10. Scale
    10.1   Scale Considerations for Use Cases 5.1 and 5.2
        10.1.1 In general, the ENC-derived paper chart should exactly match the compilation scale of the ENC cell(s) from which it is derived. This ensures that the largest scale values of SCAMIN, for the ENC cells used, are respected in the derived paper chart. This can be accomplished by ensuring that scale of the paper chart is within the same usage band of the parent ENC data. The use of M_CSCL is also an option to decide the scale of the ENC-derived paper chart where the area shown on the chart is at a different scale than the sourced ENC cell.
        10.1.2 As long as the producer of the ENC-derived paper chart is fully aware of the SCAMIN steps of the ENC cells used, the producer may be able to scale the ENC-derived paper chart within tolerances of SCAMIN step values closest to

the compilation scale of the chart, and with respect to the nearest smaller and larger scale ENCs with overlapping coverage.

10.1.3 If rescaling the derived paper chart respective to the ENC, in most cases it is more reliable to scale the derived paper chart slightly larger than the ENC cell used than to go smaller in scale. This is because the ENC should show all features at scales larger than the base SCAMIN value, but may progressively display fewer features at scales smaller the compilation scale of the ENC.

10.1.4 The producer of the ENC-derived paper chart can choose to turn off the effects of SCAMIN rescale charts as needed, but still considering the intended navigational purpose of the chart and staying close to the original compilation scale.

10.1.5 Within an end-user-facing self-service application, users should either be restricted to ENCs matching their desired scale of the derived paper chart, or alerted to the scale of the data within their desired extent is of a certain scale band/navigational purpose.

10.1.6 There is a wide range of scales within the ENC usage bands, but as long as source ENC data was appropriate for the derived paper chart, and the chart is intended to be safe for navigation, only the resulting chart's scale should be considered when meeting carriage requirements.

10.1.7 It is recommended that the ENC-derived paper chart display the scale of the source ENC data especially if rescaling occurred or to communicate to the user that all areas of the chart might not be sourced from the same scale ENC.

10.1.8 ENC-derived paper charts should retain marginalia devices to verify correct vertical and horizontal alignment and scale once printed.

10.2 Scale Considerations for Use Case 5.3

10.2.1 If the chart generated without the use case 5.1 and 5.2 scale considerations and is not intended to be used for navigation, the chart will be marked in a conspicuous area, "Not for Navigation. This chart was created with data compiled at a scale not appropriate for the chart scale."

11. Print Media Requirements

11.1 Printing requirements apply to ENC-derived paper charts intended for Use Cases 5.1 and 5.2.

11.2 The ENC-derived paper charts should be printed on paper or other media that is suitable for nautical chart printing. Similar to existing paper chart requirements, these requirements include; being relatively stable (i.e., not susceptible to excessive stretching or shrinking), printed with ink that does not smear/rub off and is water resistant, and should be easily annotatable with the marking and erasing of penciled plot lines and notes.

11.3 Ink colors can be easily mapped from the S-52 Day color scheme to those already used by nautical paper charts. The chart provider (i.e., hydrographic authority) should already understand the color space rendering and adequacy of colors used for legacy print products and their readability in red light, and apply those same colors to ENC-derived paper charts. Charts should at least use four colors: black, magenta or purple, buff (YELLOW on Euroscala spec) or gray, and blue or cyan.

12. Chart Elements

12.1 Graticule

12.1.1 Graticules will show at least two lines of latitude and two lines of longitude with correct labels in degrees, minutes, seconds (D.M.S) or degrees and decimal minutes.

12.1.2 For Use Cases 5.1 and 5.2, Graticules should still conform to INT 2 Borders, Graduation, Grids and Linear Scales.

    12.2   Compass Roses

12.2.1 All compass roses fit completely within the neatline, are appropriately spaced, and do not obstruct important information.

12.2.2 Compass roses show single degree marks for 360 degrees, for both true north and magnetic north.

12.2.3 The magnetic declination and annual change are shown for the location of each compass rose.

13. Chart Marginalia

    13.1   Necessary Marginalia for Use Cases 5.1 and 5.2

13.1.1 A title and number appropriate to describe and locate the area covered by the chart.

13.1.2 The hydrographic authority providing the ENC-derived chart, and their contact information.

13.1.3 The scale of the chart.

13.1.4 The datum of the chart.

13.1.5 The IALA buoyage region of the chart.

13.1.6 Any pertinent information relating to the updating of the chart.

13.1.7 A caveat/warning to explain the chart was ENC-derived, that cartographic anomalies exist, and generation methods of which the user should be made aware. Because there will be limited or no human interaction with the automated ENC-derived charts before publishing, the caveat should remind the mariner of the need to use all available resources to ensure safety of navigation (example below).

<div style="color:purple">

AUTOMATION CAVEAT

This chart has been automatically rendered from Electronic Navigational Charts (ENCs) that are produced by the [hydrographic authority] and/or received from [hydrographic authority's] trusted-partners. While significant technological development efforts have been made in this automation process, cartographic anomalies could nonetheless exist. Mariners using this chart must understand this is a static reproduction of the ENC and has not been individually quality checked or adjusted for optimal navigation usage in the area covered by this chart. Navigational users are reminded of the affirmative duty of the prudent mariner to "use all available means to assure safe navigation of their vessels" and to not rely solely on any single aid to navigation.

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    13.2   Chart Generation Date

13.2.1 Regardless of the use case, the date when the paper chart is generated shall be clearly shown on the chart.

14. Notes and Cautions

    14.1   All notes that are appropriate for the area covered by the paper chart are displayed in the margin of the chart or on the separate A4 or other standard Letter size paper standards.

    14.2   As mentioned in Section 8, greater standardization of notes and cautions organization in ENC is needed to improve simple solutions for direct extraction and application to ENC-derived paper chart. Whereas legacy paper charts clearly display references to complex notes and cautions and can

associate them with the appropriate feature on the chart, ENC-derived paper charts are inherently limited by the lack of standardization in handling this information. While the INFORM attribute may contain much of this information, other attributes and files may also contain this information, which can differ between hydrographic authorities. This information is usually related to anchorages, restricted areas, etc., which are portrayed in ECDIS with symbols, such as:

14.3   In lack of solutions to easily/uniformly extract and apply this information without a standardized, cross-referencing system between features and notes, it is at least recommended to retain the ECDIS symbology for references to regulations, information, restrictions and cautions so that users are aware of the existence of additional information pertaining to charted features available in the ENC from which the chart is derived. An effort should be made to develop a solution on how to extract and display this information instead of just the symbology.

14.4   Where appropriate, ENC-derived charts should include a note indicating what the intended usage of the chart is for example: "This Chart is Suitable for Emergency ECDIS/ECS Only and Should Not Be Used as a Primary Navigation Tool."

15. Charted Information

    15.1   Aids to Navigation

        15.1.1 The characteristics (color and shape) of aids to navigation, and associated light characteristics (flash rate, color, etc.), as well as the name and number of each aid are clearly displayed nearby the aid without overprinting that would obscure other text, soundings, obstructions, or other important navigation features.

    15.2   Depths and Units

        15.2.1 Regardless of use case, chart providers must be able to correctly convert from ENC's native meters to any other distance units they wish to provide. Regardless of units used for depths, the units for depths displayed on the chart must be clearly noted in the marginalia of the chart such as: DEPTHS IN METERS or DEPTHS IN FATHOMS

        15.2.2 If a single unit is displayed for depths and heights of all features appearing within the neatline of the chart, it is recommended to display text such as UNITS IN METERS within the marginalia.

    15.3   Blue Tint

        15.3.1 Charts must use a blue tint to emphasize shallow water.

        15.3.2 Charts may also utilize a second lighter shade of blue to indicate deeper water but this area must be immediately next to the darker shade of blue area.

        15.3.3 Due to the automated nature of ENC-derived charts, it is preferable to keep the depths at which the blue tints are used to remain consistent dependent on the scale of the chart.

        15.3.4 Charts may also use the darker blue tint for lakes and other bodies of water not navigable to vessels.

        15.3.5 Blue tint must also be used or danger areas, wrecks and other obstructions.

    15.4   Symbology

        15.4.1 In order to maintain symbology consistency on ENC-derived paper nautical charts, it is recommended that hydrographic offices adhere to existing S-4 standards as much as possible (See Use Cases 5.1 and 5.2). Following IHO S-4 standards preserves symbology continuity from traditional hardcopy

nautical charts to ENC-derived charts, promoting safe and reliable navigation while upholding the highest cartographic standards. There may be instances where standard ECDIS S-52 symbols may serve in place of S-4 symbols; their usage should be limited and should be documented in the provider's Chart No. 1, which should also be referenced on the ENC-Derived Paper Chart.

15.4.2 As automated solutions are developed, there may be cases where a particular paper-chart portrayal is difficult or impossible to automate. There may be an acceptable alternative that may result in the symbology of traditional paper charts being changed to maintain uniformity.

15.5 Heights

15.5.1 Heights of bridge clearances, lights, drying heights, and other objects for which heights are labeled shall be shown in meters when the user selects metric units and shall be shown in feet when the user selects units of fathoms or feet.

15.6 Labelling of Characteristics

15.6.1 Where there exist navigation aids, waterways, land areas, elevation points, topological features or other features of importance, they should be labelled with all pertinent information required for navigation like traditional nautical charts.

15.6.2 These labels should be placed in a way so that it is clear which feature they are describing.

15.6.3 The use of SCAMIN values may be useful to distinguish which features need to be better emphasized in order to more clearly indicate to a user the importance of text.

16. Updating

16.1 For Use Cases 5.1 and 5.2, there must be some means to alert users to critical changes in the charted area that should be updated on the paper chart. Two approaches for this could exist:

16.1.1 Critical updates via symbolic or textual instructions on how to update managed by Notice to Mariners.

16.1.2 New edition paper chart files must be released by the chart provider if critical changes exist, within a regular update cycle established by the chart provider, to allow printing of the latest view of ENC in paper form. This would then require users to regularly check for any updates to their charts or new editions.

16.2 Means to Provide Critical Updates to ENC-derived Paper Charts

16.2.1 Once an ENC-derived chart is created, there must be a means or outlet for users to be made aware of critical corrections that exist within the charted area. Expiration dates for these charts is insufficient, since a new danger to navigation could manifest itself even as the new chart is being output and printed. However, an expiration date could be used as long as it is within the time of updates being applied to the underlying ENC and it is explicitly stated on the chart that the latest copy must be obtained and printed at the obligation of the user.

16.2.2 Although many critical changes related to Aids to Navigators could be tracked independently from the chart through a Light List, this is not a very effective way to identify changes within a specific chart footprint, nor does the light list cover dangers to navigation, such as shoals, rocks, wrecks, and other obstructions.

Point Corrections
+ ADD
◆ CHANGE
✕ DELETE

Area Corrections
ADD
CHANGE
DELETE
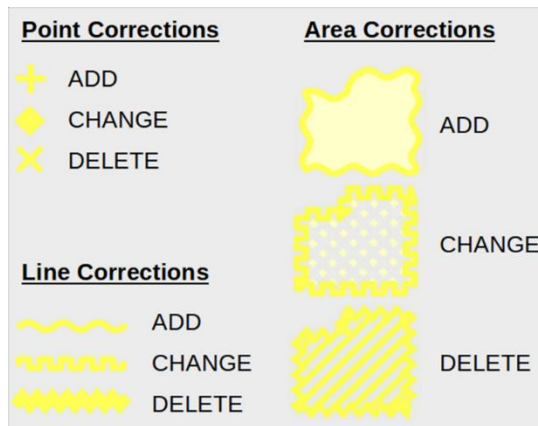
Line Corrections
~~~ ADD
~~~ CHANGE
~~~ DELETE

16.2.3 It is unreasonable for a chart provider to continually print new updated versions for each regular update. Instead, a repository of digital versions of Corrected charts for each ENC-derived chart should be created. Users will then navigate to that repository and find the latest Corrected version of the chart. That Corrected chart will tell users where to apply critical corrections, either graphically (see example correction symbology below) and/or textually.

16.2.4 It is recommended that the chart provider establish a score threshold of critical changes (e.g. weighted by complexity and amount) to not overburden users with corrections. Once the threshold of critical changes has been reached, a new edition of a printed ENC-derived chart should be generated.

16.2.5 Another option would be a system where based on the maximum bounding box of the area to be updated the software generates either a NtM Block or a new edition (based on the number of corrections). The output file would be made available to chart agents via a portal for their printing/distribution and notification to customers. A new edition would simultaneously be updated in the Hydrograph Office's Web Portal for users' awareness of the latest new edition available.

17. Optional Information and Enhancements
    17.1   Transportation Networks (preferred, but not required)
        17.1.1 ENC-derived charts should show roads that are visible from offshore.
    17.2   Topographic Contours (preferred, but not required)
        17.2.1 ENC-derived charts should show topographic contours in areas with significant relief, especially in remote areas that have few other landmarks.
    17.3   User Applied Notes and Marks (enhancement)
        17.3.1 If accessing ENC-derived charts through a self-service application, a helpful tool would allow users to add their own notes and marks, as long as the chart provider allows, in such a way, that notes and marks will not obscure charted information in order to meet carriage requirements
    17.4   Alternative Overlays (enhancement)
        17.4.1 If accessing ENC-derived charts through a self-service application, a helpful tool would allow users to apply and adjust the transparency of spatial overlays, such as, basemaps, imagery, webservices, GIS layers, etc.; however, such an ENC-derived paper chart with alternative information would typically not be able to satisfy carriage requirements in Use Cases 5.1 and 5.2 since their representations/symbology is not controlled in anyway by the chart provider. If the transparency of the overlay was limited to a certain percentage and a caveat was provided indicating the source of the data, then there is a possibility it could meet some carriage requirements in certain circumstances. Any provider-approved overlay (provided by and symbolically curated by the chart provider with the intent to be displayed in a way that

does not impede the readability of charted information) could be deemed acceptable in still meeting carriage requirements when displayed.

Conclusions and recommendations

18. The NCWG should consider this paper and any necessary changes to its content.

Justification and Impacts

19. As more hydrographic offices move towards using ENC data to create paper nautical charts, there exists a need for a standard to be set regarding what should be included and shown on these charts. This will allow for increased ease of use for the mariner, as well as a standard set within the international hydrographic community.

Action Required

20. The NCWG is invited to:

   - Discuss this paper and its recommendations
   - Address any comments regarding ENC derived paper nautical charts
   - Consider adopting these guidelines as a working group document
   - Submit this paper to HSSC for its consideration