Article

'ZOCman Cometh' or 'On the Application of Category of Zone of Confidence in the Australian Hydrographic Service'

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Abstract

In 1997 Zone of Confidence (ZOC) was included in the ENC Product Specification in IHO S-57. ZOC was developed by the IHO Data Quality Working Group as a practical solution for the assessment and display of hydrographic data quality to support safe and efficient navigation. Despite adoption by the IHO, Australia is the only country that employs ZOC in paper charts, and one of the few using ZOC comprehensively in ENC. This paper will:

- provide a brief history of ZOC development - explain the standard - describe AHS implementation - outline issues identified since ZOC were developed.

Résumé

En 1997, le terme Zone de Confiance (ZOC) a été inclus dans la Spécification de produit pour les ENC, dans la S-57 de l'OHI. Les ZOC ont été élaborées par le groupe de travail de l'OHI sur la qualité des données comme solution pratique pour l'évaluation et l'affichage de la qualité des données hydrographiques à l'appui d'une navigation sûre et efficace. En dépit de leur adoption par l'OHI, l'Australie est le seul pays qui utilise les ZOC dans les cartes papier, et l'un des rares qui utilise les ZOC en détail dans les ENC. Cet article:

- fournit une brève histoire du développement des ZOC - explique la norme - décrit la mise en œuvre du SHA - souligne les problèmes identifiés depuis que le développement des ZOC.

Resumen

En 1997, el término "Zona de Confianza" (ZOC) fue incluido en la Especificación de Productos ENC, Publicación S-57 de la OHI. Dicho término (ZOC) fue desarrollado por el Grupo de Trabajo de la OHI sobre Calidad de Datos como solución práctica para la evaluación y la presentación de la calidad de los datos hidrográficos en apoyo de una navegación segura y eficaz. A pesar de su adopción por la OHI, Australia es el único país que emplea ZOCs en las cartas de papel, y uno de los pocos que utiliza las ZOCs ampliamente en las ENCs. Este artículo:

- proporcionará una breve reseña histórica del desarrollo de las ZOCs - explicará la norma - describirá la implementación del SH Australiano - destacará los puntos identificados desde que se desarrollaron las ZOCs.

Introduction

International Hydrographic Organisation (IHO) Publication S-57, *Transfer Standard for Digital Hydrographic Data*, includes the Feature Object Attribute 'CATZOC' - Category of Zone of Confidence in Data (ZOC) - as the method of encoding data quality information. ZOC was developed under the auspices of the IHO Data Quality Working Group (DQWG) set up to *"establish criteria against which the quality of data used in charting could be codified in order that its reliability can be indicated to the user (IHO, 1987)."*

The first paper to address a solution was published by the Australian Hydrographic Office (AHO) in March 1995 and introduced ZOC (AHS, 1995). Proposals had previously undergone critical analysis within the Australian Hydrographic Service (AHS) and Royal Australian Navy (RAN) field survey units, and were tested by Australian user groups and practicing master mariners employed on coastal and international voyages. User comment indicated that ZOC had been well received and was favoured over existing source and reliability diagram methods for describing data confidence.

ZOC criteria was provisionally adopted at the 8th IHO Committee on Hydrographic Requirements for Information Systems (CHRIS) meeting and subsequently published in S-57 as a mandatory attribute of the meta object 'Quality of Data' (M_QUAL), which defines areas within which uniform assessment exists for the quality of bathymetric data (IHO, 1997) (IHO, 1996a).

Chart Reliability Diagram

The original concept of the chart reliability diagram was to indicate the quality of source survey data from which the mariner could consider an appropriate use of the chart in terms of good, fair or poor quality data. The diagram was to be displayed as an inset to provide the mariner with the capacity to assess the danger involved in transiting through different areas on the chart. However, in Australia's view this simple concept was not achieved and there was growing concern over the complexity of the reliability diagram and the increasing difficulty of maintaining it in a form which is simple to understand by the chart user. Reliability diagrams were concluded to be *"complicated for the mariner to use, usually ignored, difficult to construct as a cartographic activity, and prone to error in construction" (Roberts & Lewis, 1992).* Put simply, the mariner could not look at a chart and say that it was safe/unsafe/ risky for them to take their ship through a particular area. Source diagrams can be said to suffer similar shortcomings.

Figure 1, reproduced slightly larger than shown on chart Aus 293, provides an example of the complexity of a reliability diagram. This can be compared with the equivalent ZOC diagram at Figure 2.

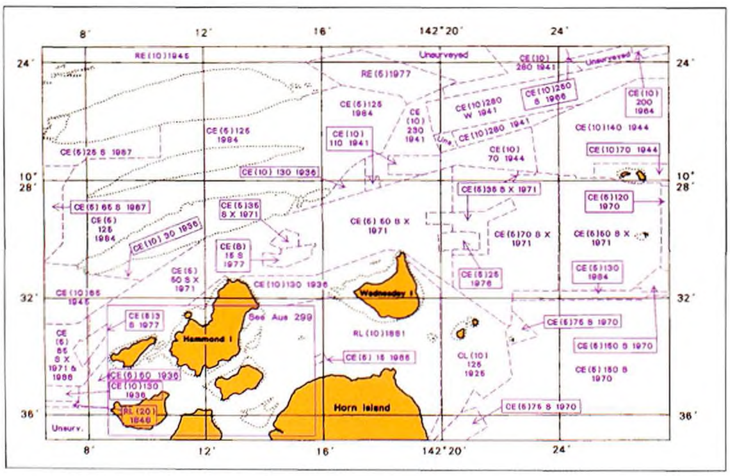

Figure 1: Chart Reliability diagram.

Category of Zone of Confidence

The ZOC concept was developed to provide a simple and logical means of classifying all bathymetric data, and displaying to the mariner the confidence that a national charting authority places in it. Areas are classified according to the level of confidence that can be placed in the underlying bathymetric model using a combination of depth and position accuracy, and thoroughness of seafloor search.

When considering position and depth accuracy for all levels of ZOC assignments it is the absolute accuracy which must be considered, i.e., the relationship to the origin of the coordinate system (WGS84). Although this is less of a problem with surveys conducted in the GPS era, an offshore or remote survey might be accurate relative to local control points, but inaccurate in absolute terms. Similarly, instrumental depth accuracy may be good in terms of specific measurement, but could be compromised by poor tidal models or imprecise tidal datums.

With this concept in mind, six ZOC

were developed - A1, A2, B, C, D and U. ZOC A1, A2 and B, by definition reflect modern and future surveys with, significantly, ZOC A1 and A2 requiring a full area sea floor search. ZOC C and D reflect low accuracy, low density and/or poor quality data whilst ZOC U represents data which is unassessed at the time of publication. ZOC can be depicted on paper charts, as an insert diagram in place of the current reliability diagram, and on electronic displays as overlays. Qualifying ZOC criteria are at Table 1.

Notes to Table 1:

1. Position accuracy criteria at 95% CI (2.45σ) with respect to the given datum. It is the cumulative error and includes survey, transformation and digitising errors etc.
2. Depth accuracy of depicted soundings for (e.g.) ZOC A1 = 0.5m + 1% d at 95% CI (2.00σ) where d = depth in metres at the critical depth. Positional and depth accuracy need not be rigorously computed for ZOC B, C and D but may be estimated based on type of equipment, calibration regime, historical accuracy etc.
3. Significant seafloor features are defined as those rising above depicted depths by more than:

Depth	**Significant Feature**
< 10m	> 0.1 x depth
10-30m	> 1.0m
> 30m	> (0.1 x depth) minus 2m

   The size of significant features is considered to reflect those required to be detected and measured in very shallow water, or that could be expected to be detected by SideScan Sonar (SSS) or MultiBeam EchoSounder (MBES).
4. Typical survey characteristics are indicative and do not imply specific requirements.
5. The data has been assessed, but the assignment of a higher ZOC cannot be justified from the supporting information.
6. Data unassessed at the time of chart publication.

Mariners should have due regard to the limitations of their depth measuring equipment when assessing margins of safety to be applied.

Of particular note is the qualitative summary that is

<table>
<tr><th>ZOC</th><th>Position Accuracy (m) (Note 1)</th><th>Depth Accuracy (m) (Note 2)</th><th>Seafloor Coverage (Note 3)</th></tr>
<tr><td rowspan="2">A1</td><td>± 5.0</td><td>= 0.5 + 1% depth</td><td>full area search undertaken; all significant seafloor features detected have had depths measured.</td></tr>
<tr><td colspan="3">Typical Survey Characteristics (Note 4): controlled, systematic, high accuracy survey on WGS 84; using DGPS or a minimum 3 lines of position with multibeam, channel or mechanical sweep system.</td></tr>
<tr><td rowspan="2">A2</td><td>± 20</td><td>= 1.0 + 2% depth</td><td>full area search undertaken; all significant seafloor features detected have had depths measured.</td></tr>
<tr><td colspan="3">controlled, systematic survey; using modern survey echosounder with sonar or mechanical sweep.</td></tr>
<tr><td rowspan="2">B</td><td>± 50</td><td>= 1.0 + 2% depth</td><td>full area search not achieved; uncharted features, hazardous to navigation, may exist.</td></tr>
<tr><td colspan="3">controlled, systematic survey.</td></tr>
<tr><td rowspan="2">C</td><td>± 500</td><td>= 2.0 + 5% depth</td><td>full area search not achieved; depth anomalies may be expected.</td></tr>
<tr><td colspan="3">low accuracy survey or data collected on an opportunity basis such as soundings on passage.</td></tr>
<tr><td rowspan="2">D</td><td>worse than ZOC C</td><td>worse than ZOC C</td><td>full area search not achieved; large depth anomalies may be expected.</td></tr>
<tr><td colspan="3">poor quality or data that cannot be assessed due to lack of information (Note 5).</td></tr>
<tr><td>U</td><td colspan="3">quality of bathymetric data yet to be assessed (Note 6).</td></tr>
</table>

Table 1: ZOC table (from IHO S-57, Ed. 3.1).

associated with each ZOC. These simple to understand descriptions, coupled with a straightforward descending scale of reliability can be readily appreciated by mariners and requires little or no technical appreciation of how the underlying chart information was collected or displayed on the chart.

Figure 2, comprises the ZOC diagram of the same area as that at Figure 1, and displays well the clarity with which data quality can be depicted using ZOC.

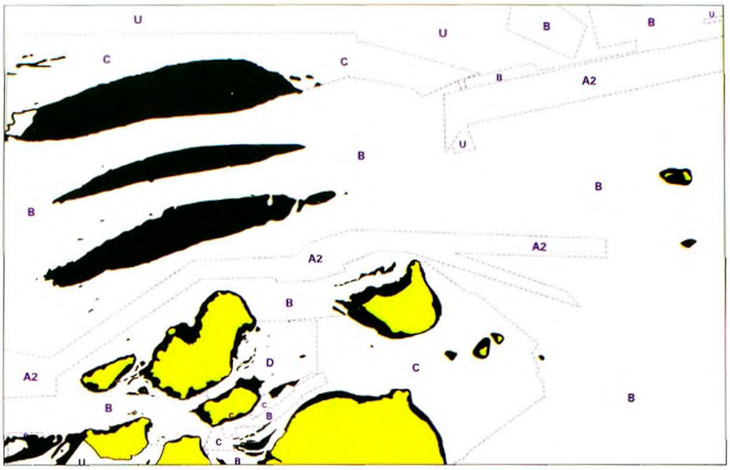

Figure 2: ZOC diagram.

Assigning ZOC to a Survey or Portion of a Survey

The following section describes the guidance employed by the AHS (AHS, 2004) for assigning ZOC. It may help serve as a basis for other agencies to follow.

ZOC A1

As ZOC A1 (and A2) are intended to provide the mariner with an assurance that uncharted hazards do not exist in an area, these assignments cannot be made without due consideration of the circumstances of the survey. In cases of doubt, a conservative assignment must be made. Due to the intensity of data gathering and the considerable time required to meet this standard, it can be expected that data with a ZOC A1 rating will most likely be restricted to areas with minimum underkeel clearances, berthing areas, critical channels, harbours and approaches, navigation channels and recommended tracks. ZOC A1 can only be assigned if all of the following conditions have been met:

- the survey has been conducted using multibeam echosounder, channel or mechanical sweep system
- the 95% CI (2.00σ) depth accuracy is equal to or better than 0.5m + 1% depth
- the 95% CI (2.45σ) positional accuracy is equal to or better than 5m.

Confirmation of the appropriate sensor or sweep system must be available from the fair sheet or in the survey metadata. Unless there is positive confirmation of this fact, only ZOC B (or worse) can be assigned. The credentials of the surveyor or data provider need also to be considered. For example, some research cruises operate MBES, but there is little thought given to the processing and accuracy of the data. Professional surveys normally include depth and positional accuracy values on the fair sheet and in the Report of Survey. Where this is not the case, some assumptions may need to be made, but this could only elevate the data to ZOC B.

Whether a survey meets the depth accuracy requirement will depend very much on the tidal model, the sea state, and the quality of the ship's motion sensor. Surveys conducted in relatively small, and protected areas by recognised organisations will usually meet the requirement. Also, a survey properly controlled by DGPS or a more sophisticated system should meet the ZOC A1 positional accuracy requirement.

ZOC A2

Although position and depth accuracies are not as high as ZOC A1, seafloor coverage is such that the mariner can place a high level of confidence in the quality of data. ZOC A2 can only be assigned if all of the following conditions have been met:

- the survey has been able to guarantee that all significant shoals have been found
- the 95% CI (2.00σ) depth accuracy is equal to or better than 1.0m + 2% depth
- the 95% CI (2.45σ) positional accuracy is equal to or better than 20m.

Towed SSS will guarantee that all significant shoals have been found provided that the line spacing is consistent with effective sonar range. Details of SSS use will be found on the fair sheet, in the metadata or in the Report of Survey. It should never be assumed that towed SSS has been used, confirmation is always required.

Surveys conducted with the assistance of Forward Looking Sonar (FLS) cannot be assigned ZOC A2 unless a permanent sonar record can be provided and reviewed. MBES surveys which fail to meet ZOC A1 because of depth and/or positional accuracy can be assigned ZOC A2 provided that they meet the relevant accuracy requirements.

Airborne Lidar Bathymetry (ALB) surveys conducted using RAN and Tenix Laser Airborne Depth Sounder (LADS) systems can detect all significant shoals provided full ensonification has been met (i.e., all of the sea floor has been covered by the laser beam) and the sea floor itself has been detected by the system. Full ensonification is dependent on water depth and beam geometry as follows:

- RAN LADS achieves full ensonification in depths of:
  - 15m or greater using full scan (depth is that measured at time of survey, i.e., not corrected for tide)
  - 8m or greater using half scan.
- Tenix LADS achieves full ensonification in depths of:
  - 8m or greater using 5 x 5m scan
  - 5m or greater using 3 x 3m scan
  - 3m or greater using 2 x 2m scan.

In most cases, LADS should meet the ZOC A2 positional accuracy requirement.

Use of DGPS, P-code GPS and microwave systems such as Trisponder, Miniranger or Microfix should meet the ZOC A2 positional accuracy requirement.

Most surveys which have been systematically reduced to Lowest Astronomical Tide (LAT) should meet the ZOC A2 depth accuracy requirement. In depths less than 50m, 'systematically reduced' implies that large survey areas will be reduced by multiple tidal stations.

ZOC B

Whilst a significant proportion of surveys conducted since 2001 could meet ZOC A1 or A2, the majority of surveys conducted prior to this time will only meet ZOC B. ZOC B has the same depth accuracy as that required for ZOC A2 and applies to modern surveys which have not met a full seafloor search and feature detection. The prudent mariner would desire more underkeel clearance within this area than in ZOC A1 or A2. This ZOC category will predominate on the majority of charts, and should be adequate for most navigation. The most difficult question for the ZOC assessor is: "can this survey be confidently used by the mariner, and hence can I assign ZOC B?" ZOC B should only be assigned if all of the following conditions have been met:

- the survey must be sufficient to justify the claim that *'uncharted features hazardous to surface navigation are not expected but may exist'*
- the 95% CI (2.00σ) depth accuracy is equal to or better than 1.0m + 2% depth
- the 95% CI (2.45σ) positional accuracy is equal to or better than 50m.

These justification requirements can take several forms. The most common of these is based on survey density. For instance, if the density of sounding lines has met a published standard, then the assignment of ZOC B can be justified. To this end, a depth related table (Table 2) has been devised by the AHS to determine whether ZOC B should be assigned.

Surveys which fail to meet this standard could still be assigned ZOC B provided there are other factors which add confidence to the survey. Examples include:

- the ship is known to have operated a FLS which would have effectively compensated for the broader than normal line spacing
- the area has been proven safe by long-term use by vessels whose draft is comparable to the draft of modern vessels using the area
- the appearance of the survey and/or the reputation of the surveyor are such that undetected hazards are unlikely.

However, these criteria maybe difficult to assess. For example, surveys might just fail the ZOC B criteria, but otherwise give the appearance of being adequate and thorough. Conversely, a survey which meets these requirements may be downgraded to a lower ZOC category if there are indications of a less than thorough survey, e.g., significant deviation from planned lines.

It is difficult to assign a ZOC B to a leadline survey, particularly in depths of greater than 50m. If a leadline survey appears adequate in all other respects for ZOC B, then it may be considered, but only if the sea floor shows clear evidence of being uniform.

Most modern surveys which have been systematically reduced to LAT will meet the ZOC B depth accuracy requirement.

In determining whether the ZOC B horizontal accuracy requirement has been met, it is necessary to consider the nature of the survey area, and whether dangers to surface navigation or significant underwater features have been detected. For

Depth (m)	Maximum Line Spacing (m)	Amplifying Comments
0-10	75	port approaches, harbours
	125	general coastal
10-20	200	
20-30	300	
30-50	400	
50-100	600	
100-200	800	
> 200	5 x water depth	

Table 2: ZOC B maximum line spacing (AHS criteria).

example, a survey conducted using C/A GPS prior to 2001 cannot meet the ZOC B horizontal accuracy requirement, although this has little practical significance if the surveyed sea floor is featureless. However where dangers do exist, these criteria must be rigidly imposed. In the event of a grounding, the position of the offending shoal feature will undoubtedly be checked using modern methods. If this check proves that the difference between the actual and charted positions exceeded the maximum value, the hydrographic office may be open to criticism, even though this fact may have been unrelated to the incident.

The following items summarise the conditions required to meet the ZOC B horizontal positioning requirement.

- With the exception of C/A code GPS prior to 2001, all surveys controlled by electronic position fixing (EPF) systems where the control points (if applicable) are accurate in absolute terms, should meet the ZOC B requirement.
- Horizontal sextant angle surveys can meet the ZOC B horizontal accuracy requirement provided that the absolute position of the control points are known to a high degree, the survey geometry is good, and the area is not too distant from the control points (i.e., does not exceed 10NM/18km).
- Surveys controlled by floating beacons cannot be assigned ZOC B.
- The requirement for absolute accuracy also means that the ZOC value may eventually depend on work conducted since the survey was completed. A controlled survey conducted relative to an offshore island or other remote area may have subsequently been found to have poor absolute positional accuracy. However, it may be possible to overcome these errors if the correct positions of the control points are obtained subsequently.

Many surveys could become a jigsaw puzzle of ZOC A2 and ZOC B areas. To make these ZOC polygons manageable, any ZOC A2 area which will be less than 2mm square at the largest planned chart scale, can be generalised into a ZOC B area. However, it is never appropriate to generalise a ZOC B area into a larger ZOC A2 area.

ZOC C

ZOC C can be assigned to any survey, including passage sounding, which meets the depth accuracy of 2m + 5% depth, the positional accuracy of 500m, and where the chart will at least contain indicative soundings rather than significant areas of 'white space'. ZOC C is intended to indicate that the mariner should navigate with special care and due regard to the depth of water in which they are navigating, and allow greater safety margins in relation to the charted information.

In practical terms, these conditions will be met by almost any survey which has involved a conscious effort to control position and to correct for tide or deep water effects. The horizontal accuracy, however, must be more carefully considered where surveys indicate dangers to navigation or major features. The positional accuracy of older offshore surveys, or passage sounding, may be quite poor, but this will be of little significance in deep water greater than 500m.

ZOC D

Surveys which fail to meet any of the higher level classifications are assigned ZOC D, which warns the mariner that this is very poor or very sparse data. There are no depth or positional accuracy requirements. The only consideration is when the data is so sparse that a particular area should be classified as 'unsurveyed'. A few isolated soundings, or a single line of soundings, will not generally constitute a surveyed area. However, as soon as the soundings point to an overall description of an area, even if very sparse, ZOC D is justifiable.

ZOC U

ZOC U means the quality of the bathymetric data or area is 'unassessed', it does NOT mean it is 'unsurveyed'.

Assigning ZOC Values to a Single Line of Soundings

Even though a single line of soundings should not change the 'unsurveyed' status or ZOC assignment for a particular area, it is an AHS requirement that single lines of sounding be assigned a ZOC value. The value assigned will be based on the characteristics of the survey, including full feature detection, depth and positional accuracy. For example, a single line of soundings gathered in 2003 using a modern echo sounder, some systematic form of tidal reduction, and C/A code GPS would be assigned ZOC B.

For ZOC A1 and A2, the width of the ZOC polygon must be no greater than the MBES swath width or the effective range of SSS. Where depth varies, the only generalisation permitted is one which shows an area equal to or less than that which was ensonified.

For other ZOC levels, the polygon width will generally be four times the water depth. For rapidly changing depths an 'average picture' generalisation is permitted.

Assigning *'Maintained Depth See Chart'* to a Portion of a Paper Chart

The AHS uses an additional classification on paper charts *'Maintained Depth See Chart'* (MDSC). The MDSC area in the body of a paper chart is defined by a closed polygon. This polygon can be transferred directly to the ZOC diagram. There is no MDSC equivalent in either ENCs or the ZOC database and such areas are coded as ZOC A1 in these products/database.

It must be stressed that the area must be maintained, not simply dredged at some particular time. The ZOC for a dredged area is dependent on dredging date, with a recent date justifying ZOC A2, and an old date implying ZOC B. In this case the ZOC assessor's application of 'recent' and 'old' will depend upon sea floor stability.

Assigning ZOC Values – Summary

As a result of experience gained so far, the AHS has reached the following conclusions regarding the assignment of ZOC to earlier surveys (Whitmore, 1997).

- Few surveys undertaken prior to the 1980's can be assigned higher than ZOC B.
- The status of historical surveys means that areas assessed as ZOC B will feature larger than any other on the Continental Shelf.
- A searchlight FLS does not meet the requirements of ZOC A1/A2.
- Prior to the advent of DGPS or P-code GPS, it is difficult to guarantee positional accuracy better than ZOC B. Under optimal conditions of signal strength, geometry and fix redundancy, a microwave system such as Miniranger may meet ZOC A2.
- Provided there has not been a blunder, most EPF systems have the potential to meet ZOC B.
- With the exception of GPS positioning, it is necessary to consider the accuracy of the horizontal control and its contribution to absolute positional accuracy.
- No survey controlled by floating beacons can be better than ZOC B.
- It is very difficult to assign ZOC B to a leadline survey in water deeper than 50m.
- A thorough tidal infrastructure is necessary to meet ZOC B. This is particularly the case for older surveys when only single station reductions could be computed and little predicted tidal data was available.
- For older surveys, the appearance of a Fair Sheet and the information provided in the memoir will often be a guide to the thoroughness of the survey, and whether ZOC B can be assigned.

Particular care must be taken when ZOC B is being considered for surveys which depict dangers to surface navigation. The assignment of ZOC B implies that any danger is charted to an accuracy of at least 50m. In the event of a grounding such an indication will be closely examined, and may reflect poorly on the hydrographic office involved even though it may have in no way caused the grounding.

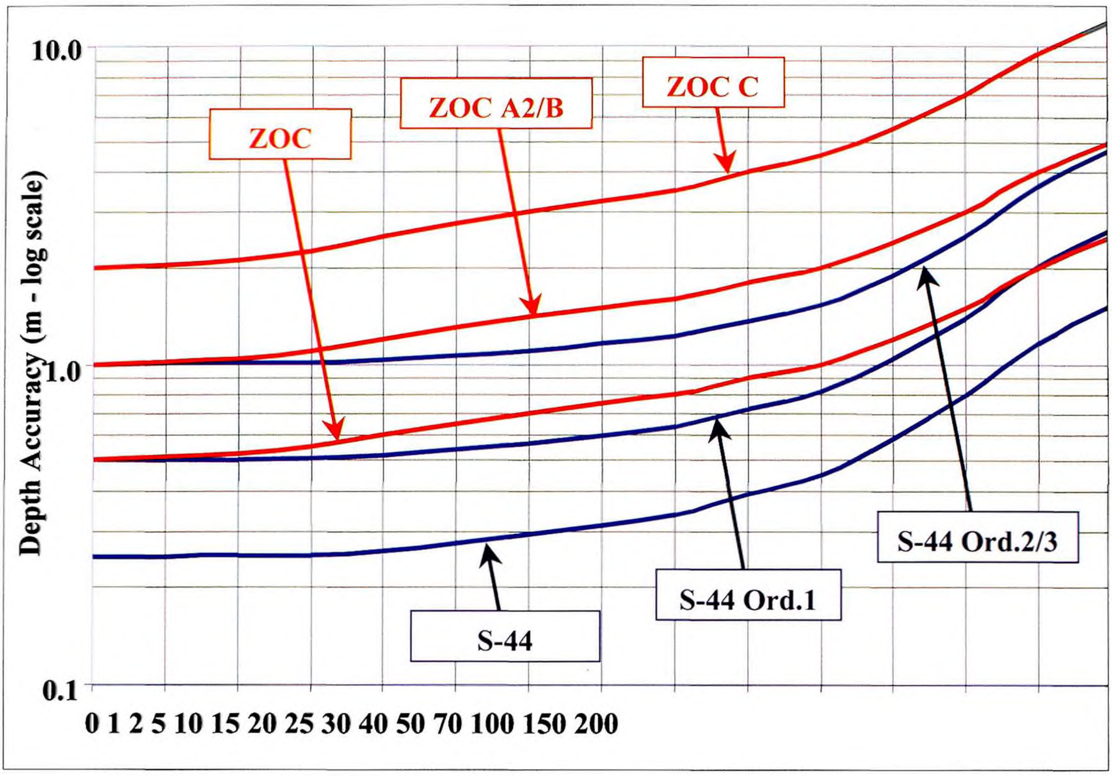

Figure 3: IHO S-44 order and ZOC depth accuracy criteria.

Creating the ZOC Mosaic for a Chart or ENC

The mosaic-like ZOC diagram, appearing on a chart or stored in the hydrographic database, is generally the combination of all the 'best value' ZOC assignments for the area concerned. For example, if the same area is covered by two separate surveys, one ZOC B and the other ZOC C, then the mosaic will depict ZOC B for that area. However, there are several exceptions to this rule.

- A particular area may be covered by a number of independent ZOC C surveys. Provided there is sufficient overall coverage, and the positional accuracy of any features meets the ZOC B requirement, the overall mosaic value could be ZOC B.
- A particular ZOC polygon may be insignificant at chart scale. The polygon appearing on a chart may be expanded so that it can be read at ZOC diagram scale (1mm on paper). However, such expansion cannot take place for ZOC A1 and A2 areas. If these cannot be sensibly depicted on the chart they should be omitted.
- In compiling a chart it will usually be decided that areas which contain only a single line of soundings remain classified as 'unsurveyed'. The resultant ZOC diagram on the chart will be consistent with this decision, however the database mosaic will contain the soundings' ZOC assignment.

ZOC Attributes

ZOC criteria have been selected to minimise the need for future change. This has been done by reflecting the major epochs of bathymetric data collection technology, both historically and into the foreseeable future. ZOC categories are intended to reflect a charting standard rather than a hydrographic survey standard. Depth and position accuracies specified for each ZOC category refer to the errors of the final depicted soundings or bathymetry, and include not only hydrographic survey measurement errors but also other errors introduced in the chart production process. In this respect, they differ from the measurement standards set out in S-44 that reflect instrumental or procedural accuracy of the measurement process rather than the absolute accuracy or fidelity of the resultant hydrographic survey.

During the work of the DQWG, it was generally agreed that the number of ZOC categories be limited to six. The addition of further categories for use in areas of, for example, minimum underkeel clearance (equivalent to the highest S-44 Order) was avoided because it would only complicate matters from the mariner's point of view. This does not mean that additional qualifiers cannot be included. In S-57, data can be further qualified by the M_QUAL sub-attributes POSACC and SOUACC, used to indicate that a higher position or depth accuracy has been met than is defined in the ZOC Table. For example, a survey where full seafloor coverage was not achieved could not be classified higher that ZOC B; however, if the position accuracy was, for example, ±15m, the sub-attribute POSACC can be used to indicate this.

Other M_QUAL sub-attributes qualifiers include:

- DRVAL1. Swept areas where the clearance depth is accurately known but the actual seabed depth is not accurately known may be accorded a 'higher' ZOC (i.e., A1 or A2) providing positional and depth accuracies of the swept depth meets the criteria in the Table. In this instance Depth Range Value 1 (DRVAL1) may be used to specify the swept depth. The position accuracy criteria apply to the boundaries of swept areas
- SURSTA and SUREND may be used to indicate the start and end dates of the survey
- TECSOU may be used to indicate the technique employed for sounding measurement, such as:
  - found by: ALB, diver, echosounder, electromagnetic sensor, leadline, levelling, MBES, photogrammetry, satellite imagery, SSS, or wire drag
  - swept by: SSS or vertical acoustic system
  - computer-generated
- VERDAT may be used to indicate the vertical datum.

Who 'ZOCs it to 'em'?

AHS staff assign ZOC to all newly received surveys, whether they be conducted by the AHS, are supplied under contract to the AHS, or are received from external sources. ZOC assignments are currently maintained in a database, called 'ZOCMAN'. However, in the future, ZOC will be stored as CARIS layers in the new AHS Digital Hydrographic Database which became operational in 2004.

Issues

Alignment of S-44 Orders and ZOC

A recurring theme expressed by some IHO Member States is a desire for alignment between S-44 Orders and ZOC. As mentioned earlier, ZOC and S44 are related but purposely independent of each other. S-44 Orders are intended to specify minimum standards to which hydrographic surveys should be undertaken. They are a guide to the hydrographic authority ordering the survey and to those responsible for conducting it. To avoid possible litigation, S-44 Orders may only reflect standards that are generally considered achievable at the time of publication and will undoubtedly be amended in future editions as technology and the standards to which the hydrographer can undertake a survey improve. In other words, criteria that define S-44 Orders are not permanent.

<table>
<tr><th>ZOC</th><th>Requirement</th><th>Depth / Significant Feature</th></tr>
<tr><td>A1</td><td rowspan="2">full area search undertaken; all significant seafloor features detected have had depths measured.</td><td rowspan="2">< 10m = > 0.1 x d
10-30m = > 1m
> 30m = > (0.1 x d) - 2m</td></tr>
<tr><td>A2</td></tr>
<tr><td>B</td><td rowspan="3">full area search not achieved.</td><td rowspan="3">not applicable</td></tr>
<tr><td>C</td></tr>
<tr><td>D</td></tr>
<tr><th>S-44 Order</th><th>Requirement</th><th>System Detection Capability</th></tr>
<tr><td>Special</td><td>compulsory.</td><td>cubic features >1m</td></tr>
<tr><td>Order 1</td><td>required in selected areas.</td><td rowspan="2">< 40m = cubic features > 2m
> 40m = 0.1 x d</td></tr>
<tr><td>Order 2</td><td>may be required in selected areas.</td></tr>
<tr><td>Order 3</td><td>not applicable.</td><td>not applicable.</td></tr>
</table>

Table 3: IHO S-44 and ZOC area search and feature detection requirements.

The same may not be said for ZOC. Hydrographic authorities will assign a ZOC in relation to its utility for charting purposes following assessment of a completed survey which may be divided into several zones depending on its meeting the various criteria. ZOC must also be assigned to historical surveys which the authority will assess during chart compilation. Obviously, once such a historical survey has been assessed and a ZOC assigned, any subsequent change of criteria would render existing ZOC boundaries incorrect and require reassessment of source data. This is both impractical and of questionable value. Instead, ZOC is intended as a fixed standard to be applied to charted data. Figure 3 provides a comparison between S-44 Orders and ZOC depth accuracy criteria. Table 3 shows the different area search and feature detection requirements of S-44 and ZOC.

Temporal Changes to ZOC Assessments

The issue of the effects of time on published ZOC was not considered by the DQWG for inclusion in Edition 3.0 of IHO S-57. This is relevant for ZOC that cover areas of mobile sea floor. In an ENC it is possible for the mariner to query a ZOC to determine when the survey was undertaken along with other information (provided the hydrographic office has populated these attributes). However, some have expressed concern that a ZOC diagram on a paper chart does not provide for the date of an underlying survey to be depicted, and is thus a limitation.

Addressing this issue must be carefully considered so it does not negate the simplicity of the ZOC diagram. The inclusion of dates in a ZOC diagram could further complicate the presentation since multiple surveys making up a single ZOC can be grouped by survey dates, rather than dividing each ZOC area up into individually dated surveys. Providing dates could be significant in navigable waters with minimum underkeel clearances for deep draft vessels. However, the date of a survey in depths greater than 100m would be of little use. Furthermore, the qualifying depth accuracy for most ZOC provides some scope to accommodate relatively large changes in depths over the years. For example, even in ZOC A2, the depth accuracy of soundings is only required to 1m + 2% depth.

The inclusion of a survey date may not actually provide the mariner with any useful information. For instance, how is the mariner to know how much the depth has changed in an area over a given period of time? An alternative might be to provide an indication of maximum expected variability, e.g., 'A2 (1.0m)', meaning the survey meets ZOC A2 but depths may vary over time by up to 1m. The better solution, albeit, an expensive and demanding one, is to ensure the conduct of regular surveys in critical areas from which constantly up-to-date ENC and charts will be produced thereby enabling the ZOC attributes to be contemporary. This in fact already occurs, in areas such as the English Channel, the commercial ports of Europe and the USA.

Legal Liability

Several hydrographic offices' have expressed concern over potential liability for presenting the mariner with ZOC information, rather than leaving the mariner to determine the likely risks from the information supplied in source or reliability diagrams. The AHS takes the view that "hydrographic offices owe a duty of care to mariners in the provision of information" (IHO, 1996b). The AHS' legal advice suggests that a hydrographic office should take all reasonable steps to clearly and simply indicate the limitations of the chart data being presented. There is a requirement to sufficiently communicate the information to avoid liability for negligent misstatement (AGS, 2003). This is achieved with ZOC. To the contrary, reliance on source or reliability diagrams which may depend upon judgement and expertise not readily available to the user, may in fact increase rather than minimise exposure to legal liability in the case of an incident caused by inappropriate assumptions being made of the chart data by a user. Furthermore, on ENC for which no ZOC values are provided, the mariner is actually left with less information about the quality and utility of the chart data than on a paper chart. This too may attract an increased exposure to liability.

Future Uses for ZOC Data

In addition to providing mariners with useful information, ZOC values and attributes can also provide a wider audience with a mechanism for obtaining a measure of data quality and the means by which the data was obtained. Whilst ZOC data included in ENC are currently area-based, individual soundings could be accorded ZOC attributes that would be available for use in other Geographic Information Systems. The use of ZOC is also useful as a means of supplying metadata for legacy data, which otherwise does not exist. Once legacy data has been assigned a ZOC, it is obviously possible to refer to the ZOC criteria to deduce the range of depth and positional accuracies in which it lies.

Conclusion

The AHS has employed ZOC as the method of encoding data quality information since its inclusion in IHO S-57 in 1996. ZOC data is routinely included in new editions of Australian charts and ENC as replacement for reliability diagrams. In providing an easily understandable standard that can be applied to data from any epoch the IHO has overcome the problems of technology creep and increasingly complex reliability diagrams. Use of ZOC is accepted by mariners using Australian chart products. As such, the AHS considers the IHO's aim of displaying 'hydrographic data quality to support safe and efficient navigation' to the mariner is being met.

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