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Critical issues relating to the integration of land and marine geospatial information

Status Report on Hydrography and Mapping of the World's Seas, Oceans and Coastal Waters

Background Document Prepared by
the International Hydrographic Organization (IHO)

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[1] The designations used and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. The term "country" as used in this publication also refers, as appropriate, to territories and areas.

UN-GGIM3

Critical Issues relating to the Integration of Land and Marine Geospatial Information

<u>Study on the Status of Mapping in the World</u>

STATUS REPORT ON HYDROGRAPHY AND MAPPING OF THE WORLD'S SEAS, OCEANS AND COASTAL WATERS

1. This report by the International Hydrographic Organization (IHO) provides a summary of the status of hydrography and charting of the world's seas, oceans and coastal waters. Standardization issues are not discussed here as they are reviewed in a separate report prepared by ISO/TC211 in cooperation with the Open Geospatial Consortium (OGC) and the IHO.

Introduction

2. The International Hydrographic Organization (IHO) is an intergovernmental consultative and technical organization. 81 States are currently member of the Organization, with 8 more States in the process of acceding to membership. Each Member State is normally represented by its national Hydrographer.

3. The IHO coordinates on a worldwide basis the setting of standards for hydrographic data and the provision of hydrographic services in support of safety of navigation and the protection and sustainable use of the marine environment.

4. The IHO maintains IHO Publication C-55 - *Status of Surveying and Nautical Charting Worldwide* - that is available from the IHO website: *www.iho.int*. Much of the information contained in this report is drawn from this publication.

Importance of Hydrography

5. No human activity can take place in, on or under the sea in a safe, sustainable and cost effective way without hydrographic information.

6. Hydrography is increasingly being recognised as a fundamental pre-requisite to the development of successful and environmentally sustainable human activities in the seas and oceans. It is the fundamental enabler for a sustainable, cost-effective, and environmentally sensitive development of *The Blue Economy*. Unfortunately, there is little or no hydrographic data for many parts of the world.

7. Hydrographic information is required in support of all maritime and related activities, including but not limited to:

- Aquaculture
- Biomedicine
- Boats and Shipbuilding
- Cables and pipelines
- Coastal Zone management
- Defence and Security
- Desalination and water treatment
- Marine recreation
- Ocean energy and minerals
- Ocean science and observation
- Port operations
- Robotics and submarines
- Shoreline development
- Telecommunications
- Tourism
- Transportation
- Very large floating platforms
- Weather and climate science

8. The advent of deeper draught shipping and greater use of the sea has increased the urgency of national programmes to review and upgrade charts. The advent of larger vessels and the increasing tendency of cruise liners to seek new routes, anchorages, and port calls, have highlighted the need for more rigorous surveys of areas that were originally explored only in the nineteenth century. This is a major challenge in the Caribbean, Indian Ocean, Pacific and Polar regions.

9. Many States rely on sea routes and ports where the seabed is unstable. Routine re-survey programmes are essential in such areas. Examples include many of the navigation routes and ports in the southern part of the North Sea.

10. Besides the requirements associated with the safety of navigation, the ever-growing pressure on the coastal zones and the mitigation of climate change and natural hazards entail informed decision making which relies also on the availability of accurate and high resolution hydrographic data.

Government Obligations

11. It was not until the revision of the International Convention for the Safety of Life at Sea (SOLAS) which came into force in 2002 that an explicit obligation was put on the Contracting Governments to provide and maintain hydrographic services and products, in particular by ensuring

"... that hydrographic surveying is carried out, as far as possible, adequate to the requirements of safe navigation".

12. This requirement was emphasized the following year by the General Assembly of the United Nations which included in its annual Resolution on Oceans and Law of the Sea a broader invitation to the IHO and International Maritime Organization (IMO) to continue their efforts

"to increase the coverage of hydrographic information on a global basis, especially in areas of international navigation and ports and where there are vulnerable or protected marine areas".

A Nautical Chart is Not Just a Map of the Seafloor

13. A nautical chart or a map of the ocean depicts an area that cannot be observed with the naked eye. All the information about the seafloor, including the features and the hazards that lie upon it, must be determined using remote observation techniques. In addition, changes may occur that will not be detected until a new survey is conducted or a user of the chart discovers its inaccuracy - the hard way!

14. Much of the information shown on charts in use today has been obtained using old technology and techniques. Many of the world's charts still rely on information obtained up to two centuries ago when the methods of obtaining both position and depth were extremely limited. In the absence of any other data, many of today's charts contain significant amounts of information derived from non-systematic observations. These range from single observations of dangers reported by mariners to information derived from casual observations obtained as part of scientific expeditions. Hydrographic authorities and nautical cartographers must use judgement to determine if and how to show this non-validated information on a chart. As a result, most nautical charts are a data-mosaic of information derived from many sources with various and often wide-ranging differences in quality of position, depth and reliability. The IHO has developed principles and established standards for determining the reliability of all the information shown on a chart and ways of qualifying and portraying that information.

Existing Survey Technologies

15. Modern high-resolution hydrographic data is obtained using echo sounders mounted in boats and ships and from laser depth-sounders mounted in aircraft. The use of ship borne multibeam echosounders or aircraft-mounted laser depth sounders (LiDAR) yields data that will meet the recognised international standards required for safe and effective nautical charts. Broad indications of large subsea features, such as seamounts can be inferred from satellite radar altimetry and from

satellite-based gravity measurements, but these are of almost no value for nautical charting purposes and have only limited value for ocean mapping. The existence and extent of shallow water areas can also be observed from satellite and aerial photography, but not if the water is turbid.

16. Surveying using ships, boats and aircraft is expensive and sometimes problematic. This is because of hostile and unpredictable sea conditions and the logistic support required to operate boats, ships and aircraft.

Global Status of Hydrography and Charting

17. A large percentage of the world's seas and oceans are still unsurveyed. This is a fact of which the general population is generally unaware and which is either not acknowledged or else given a very low priority by many governments. Where nautical charts and ocean maps do exist, they have limited utility because of the lack of reliable and detailed underlying information. Currently, there are higher resolution maps of the Moon and Mars than most of the world's sea and ocean areas. The grounding of vessels operating outside previously navigated routes is not uncommon.

18. There is no indication of any significant improvement in the level of hydrographic surveying being conducted around the world. At the XVIIIth International Hydrographic Conference held in April 2012, the Member States of the IHO acknowledged that in the last three decades the numbers of surveying vessels operated by Member States has declined by 34% for offshore vessels and 35% for coastal vessels. Furthermore, it seems unlikely that this reduction in numbers has been matched by a corresponding increase in capacity through the use of more efficient technology, such as LiDAR or multibeam sonar sensors or through governments opting to use commercial surveying contractors.

19. Some national hydrographic authorities represented in the IHO report that government-sponsored surveying activity is decreasing because of financial pressures and competing priorities in home waters. The immediate effect is to concentrate priorities on home waters. This means that even less progress than hitherto will be achieved in developing States with little or no indigenous surveying and charting capability of their own. These are usually the States where the situation regarding hydrography and charting is at its poorest.

20. An examination of IHO Publication C-55 - "*Status of hydrographic surveying and nautical charting*" shows that progress in the amount of sea area surveyed in most coastal States is slow or non-existent.

<u>The very significant lack of hydrographic data and reliable, high resolution maps and charts for many parts of the world's coastal waters, and most of the world's seas and oceans should be a cause of particular concern to the UN-GGIM.</u>

Status of Hydrographic Survey Coverage

21. A formal process for monitoring the status and progress of hydrographic surveying was initiated by the IHO at the end of the 1960's in partnership with the United Nations. Progress was slow due to limited responses from coastal States. The first edition of IHO publication S-55 (now C-55) was published in 1991. The second Edition was published in 1998 and from 2004 the 3rd Edition has been updated on a continuous basis as new or revised statistics are obtained.

22. Data is now available for 90% of the 234 geographic entries listed in C-55. The most significant gaps in the statistics are in the Mediterranean and Black Seas.

23. The C-55 information is based on national assessments. Survey coverage is quantified as a percentage of the extent of <u>navigable waters</u> out to the limits of the Exclusive Economic Zone (EEZ). Percentages are provided for two depth bands; either side the 200m depth contour. Percentages are then provided for each of the two depth bands as follows:

- percentage that is adequately surveyed
- percentage that requires re-survey at larger scale or to modern standards

- percentage that has never been systematically surveyed

24. Determining what is *adequately surveyed* is not fixed and is also subjective. Surveys and the resultant charts that may have been considered adequate only a decade ago, may have to be repeated to obtain a higher degree of accuracy and greater thoroughness. This can be because of such things as larger ships navigating in the area, economic demands for reduced under-keel clearances in shipping lanes and choke points, moving sandbanks, growing coral or natural events such as tsunami and cyclones. Such changes in what is classified as *adequate* can apply to any State; ranging from the sparsely surveyed waters of developing nations to the coastal waters of major industrial States. In particular, the advent of accurate satellite-based navigation has exposed navigators and others to increased risks from poorly positioned historical data being included in existing charts.

25. **Depths less than 200m**. An analysis of the entries available in C-55 shows that for waters less than 200m deep, 36% of entries report that 10% or less has been surveyed. Only 14% of entries report adequate survey coverage for 90% or more of the water area. 17% of entries report that no surveys have been conducted at all.

Depths 0- 200m	0-10% surveyed	11-49% surveyed	50-89% surveyed	90% or more surveyed
	36%	31%	19%	14%

26. **Depths greater than 200m**. For waters greater than 200m deep, 59% of entries report that 10% or less has been surveyed. Only 11% of entries report adequate survey coverage for 90% or more of the water area. 35% of entries report that no surveys have been conducted at all.

Depths greater than 200m	0-10% surveyed	11-49% surveyed	50-89% surveyed	90% or more surveyed
	59%	23%	7%	11%

27. C-55, in its current form, exhibits several shortcomings. C-55 does not provide any spatial information on the location and geographical extents of the various levels of survey coverage. Moreover, as mentioned earlier, the term “adequate” is interpreted differently by different reporting States. A process has been initiated by the IHO to address those shortcomings through moving from a reports database to a GIS environment.

28. Another limitation of C-55 is that some entries relate only to so-called “navigable waters”. Therefore the percentages reported do not always reflect the surveying work required in currently impassable waters where additional data might find new routes as well as further supporting the protection of the marine environment, including marine disaster prevention and response, and developing the blue economy.

29. As an example, 100% survey coverage reported for the coastal area around New Caledonia in the Pacific still leaves many areas that are only partially surveyed or not surveyed at all!

Metrication and Chart Modernisation

30. The IHO standards encompassed metrication and a satellite-based geodetic reference frame in the early 70’s. However, there are still a large number of charts in use that are based on various local datums and in many cases the depths are shown in fathoms or feet rather than in metres. Metrication programmes are underway for many of these charts, but are often hampered by the lack of significant modern surveys and a reluctance to convert old charts to look like apparently modern charts but with little or no additional data or improvement in accuracy. Some charts have been withdrawn because of lack of data to enable their conversion.

31. Although coverage of both paper and electronic charts has increased in recent years, in many cases there has not been any associated improvement in the source data from which they are derived.

The increase in deeper draught shipping has also exposed the inadequacy of navigational products in many areas, for example, in the States of the West Pacific and Oceania.

32. The widespread use of satellite position fixing lends great urgency to efforts to identify datum transfers and to re-publish charts on satellite-based datums. This is particularly important in the Caribbean, Africa, the Pacific Ocean and the Polar regions.

Status of Ocean Mapping

33. The principal programme for the collation and production of coherent global mapping coverage of the oceans, as opposed to the coastal areas, is through the IHO-IOC GEBCO Project. The General Bathymetric Chart of the Ocean (GEBCO) was founded by HSH Prince Albert I of Monaco at the turn of the 20th century. The IHO has directly overseen the GEBCO Project since 1929 and was joined by the Intergovernmental Oceanographic Commission of UNESCO (IOC) in 1973 as a cooperating partner. However, the Ocean Mapping component of the IOC programme was cancelled in 2005 due to budget cuts.

34. The GEBCO Project relies on the voluntary efforts of an international community of collaborating scientists and hydrographers, who, with the support of their parent organizations, forward data for inclusion in a progressive series of maps of the oceans. These were originally a series of paper maps in five successive editions at 1:10 million scale (1:6 million for the two polar areas). The 5th edition was completed and published in 1982. A digital version of that edition was published in 1994 as the IHO-IOC GEBCO Digital Atlas (GDA) which initially contained only a set of digital bathymetric contours and coastlines. The shallowest contours show a depth of 100m or 200m.

35. IHO-IOC GEBCO released its first global bathymetric grid in 2003. The grid interval was one arc-minute and the values were based mainly on the bathymetric contours contained within the GDA. In January 2009, the Project released a refined grid at 30 arc-second intervals which was generated by combining quality-controlled ship depth soundings with interpolation between sounding points guided by satellite-derived gravity data. This is still a development product, which undergoes periodic update. In uncharted areas, the method produces only low resolution estimated bathymetry and erroneous grid artefacts are induced by the lack of source sounding data in several areas. Better resolution and higher accuracy is required to assist studies such as ocean circulation modelling.

36. The IHO continues to compile and manage a global bathymetric dataset. The IHO Data Centre for Digital Bathymetry (DCDB) was established in 1990. Oceanic soundings acquired by hydrographic, oceanographic and other vessels during surveys or while on passage are forwarded to the DCDB, checked and then added to the existing data set. Most recently, IHO Member States have been contributing shallow water soundings derived from chart products such as Electronic Navigational Charts (ENC). All of these data have in turn, contributed to the production of more comprehensive bathymetric maps and grids of the oceans. In addition, the IHO together with IOC, coordinates regional ocean mapping projects such as the International Bathymetric Charting (IBC) programme. The IBC programme is compiling several series of 1:1 million bathymetric maps or databases, covering eight regions (Mediterranean and Black Seas (IBCM), the Western Indian Ocean (IBCWIO), the Caribbean Sea and Gulf of Mexico (IBCCA), the South East Pacific (IBCSEP), the Western Pacific (IBCWP), the Central Eastern Atlantic (IBCEA), the Arctic Ocean (IBCAO) and the Southern Ocean (IBCSO).

37. Despite the efforts of IHO and IOC, the amount of bathymetric data available to produce detailed maps of the oceans is still relatively small. With less that 10 percent of the world's oceans surveyed to modern standards, it is important that information about the availability of bathymetric resources is made available for both nautical charting and bathymetric mapping purposes. Satellite altimeter measurements of the marine gravity field can detect sea-mounts taller than about 2km and studies to date have produced seamount catalogues holding almost 15,000 seamounts. According to an article published in Oceanography, Volume 23, Number 1 (Sandwell and Wessel), more than 90% of all seamounts greater than 1km in height (estimated to be more that 100,000) are unobserved by

either ship soundings or satellite gravity. The reasons for this is that ship time is very expensive, and satellite-derived gravity is only able to reliably measure seamounts that are more than 2km high, although smaller seamounts can sometimes be detected (Wessel, 2001).

38. Two examples of navigationally significant seamounts are Vema Seamount (with a charted depth of 11 metres) - discovered about 1,000 km west-north-west of Cape Town and Walters Shoal Seamount (with a charted depth of 15 metres) - discovered about 400 nautical miles south of Madagascar).

39. As part of the GEBCO project, its Sub-Committee on Undersea Feature Names (SCUFN) selects those names of undersea features in the world ocean appropriate for use on GEBCO graphical and digital products, on the IHO small-scale International chart series, and on the regional IBC series. SCUFN maintains close liaison with the UN Group of Experts on Geographical Names (UNGEGN). All names selected by SCUFN are contained in an international and worldwide IHO-IOC GEBCO Gazetteer of Undersea Feature Names.

Integrated Coastal Zone Mapping

40. Integrated mapping of the coastal zone is a primary requirement for the sustainable development and stewardship of the coast. Due to the fact that land mapping and nautical charting have developed separately to address different categories of users, uniting geospatial information collected on both sides of the coastline is not a straight forward operation. Several historical hurdles such as the use of different horizontal and vertical datums and projections are now overcome with the implementation of the International Terrestrial Reference System. A number of projects initiated in different countries (i.e.: Litto3D in France, ICZM Project in India[2], ICZMap in the UK, etc.) demonstrates that the administrative and technical issues can be resolved in implementing land/sea integrated geospatial data infrastructures. The major challenge lies in the lower data resolution (or even lack of data) on the sea side, as discussed in the previous sections.

Progress and Priorities

41. In a number of regions a systematic approach is being taken to identify and prioritise hydrographic requirements. However, in significant areas of the Caribbean, the coastal waters of Western and Eastern Africa, the Indian Ocean and adjacent seas, and the Western and South West Pacific Ocean, there has been little change, and it is here that the IHO is concentrating its capacity building efforts.

42. Detailed indexes of requirements and priorities are maintained by some Regional Hydrographic Commissions such as the index maintained by Spain for the Mediterranean and Black Seas Region. A sophisticated information system has been developed by the Baltic Sea Hydrographic Commission to manage the re-survey plans of the Baltic Sea. For oceanic areas, coverage information can be accessed through the database maintained by the IHO Data Centre for Digital Bathymetry (DCDB).

43. The IHO Strategic Plan identifies as one of its Strategic Directions:

"Facilitate global coverage and use of official hydrographic data, products and services"

This implies, as a foundation layer, providing "adequate" global survey coverage.

44. Recognizing that much remains to be done, the IHO Member States at their XVIIIth International Hydrographic Conference which met in 2012 decided:

> " *…. to progress whatever actions are required to improve the collection, quality and availability of hydrographic data worldwide, monitor and rectify possible deficiencies and shortcomings, cooperate with other international organizations and stakeholders as necessary, and to keep Member States informed on progress on this issue. Member States are strongly*

[2] Project assisted by the World Bank.

encouraged to address these deficiencies related to maritime safety worldwide, both within the IMO framework and through national channels.

Alternative Technologies

45. As a general principle, obtaining high resolution, high fidelity depth measurements is limited by the physical properties of the sea and seawater. For centuries the only method of measuring depth was by lead and line. In the last 75 years or so, echo sounders and sonar using pulses of sound and more recently lasers mounted in aircraft (LiDAR), have been used. The levels of sophistication and accuracy of these sensors has progressively increased. However, ships are slow and expensive to operate and airborne lasers can generally only measure depths in relatively clear water down to a maximum of about 70 metres.

<u>Satellite Derived Bathymetry</u>

46. In clear water, it is possible to determine depth and other useful parameters in the water column down to about 20 metres by analysing imagery from multi-spectral satellite sensors. France has been using this technique to improve nautical charts of remote areas for many years. The IHO is encouraging further development of the technique which does not require significant ground infrastructure and is much less expensive than traditional surveying.

47. This technique has some limitations for chart production as it does not yet meet the IHO Standards for operational use, but it is very useful where it is the sole source of information and for reconnaissance survey. The latest technological developments indicate the potential for this tool to meet some of the Standards in the near future.

<u>Hydrographic Data Collection Using Ships of Opportunity</u>

48. Most recently, demonstration programmes have been mounted that enable ships to collect hydrographic data automatically during their voyages. Data is then transmitted digitally to a collection centre and forwarded to the relevant national hydrographic office for review and then used to improve existing charts.

49. This is being described as “crowd-sourced bathymetry” and so far, has taken place predominantly around the Antarctic Peninsula where an increasing number of commercial vessels including cruise ships are operating using charts that have significant limitations in their reliability. It is possible that this automatic collection of hydrographic data could be extended to collect other environmental data at the same time. Issues of funding for the equipment required to be fitted to ships, data validation and reliability are still to be addressed.

50. There are other commercial initiatives, particularly in the fishing sector, that are engaged in similar “crowd-sourced” data gathering activities. Unfortunately, not all of the relevant data is being made available to improve nautical charts.

<u>Limitations</u>

51. Crowd-sourced bathymetry and satellite derived bathymetry cannot replace systematic, fully regulated hydrographic surveys, but these methods can provide rapid improvements to existing charts and help to identify and prioritise those areas that require more comprehensive surveys. For many areas of the world, such techniques may be the only way to obtain at least a first coverage of indicative hydrographic information.

Options for Improvement

52. Options for improvement need to be considered at the national, regional and international levels.

<u>National level</u>

53. The 159 Contracting Governments to the SOLAS Convention have accepted responsibility under Regulation 9 of Chapter V of that Convention for the collection of hydrographic data and in particular to ensure that hydrographic surveying is carried out, as far as possible, adequate to the requirements of safe navigation. However, relatively few coastal States have satisfactory arrangements in place to ensure that surveys are carried out. This is particularly the case for those States that are not Members of the IHO. Even then, up to half of the IHO Member States can be considered as lacking significant levels of capacity that would enable them to properly fulfil their obligations and minimise their exposure to risk and missed opportunities. All coastal States should be invited to commit to setting targets to enable them to fulfil their international hydrographic obligations within the framework of their national spatial data infrastructures.

54. Coastal States should also ensure that systematic procedures are in place for the transmission of relevant survey data collected by third parties in waters under their national jurisdiction to the concerned mapping or charting authority. Diplomatic clearances for surveying and scientific ships or contracting documents with private companies should include such requirements. These measures will greatly assist in the updating and improvement of nautical charts and publications and mapping of the oceans and seas more generally.

Regional level

55. Capacity building is most efficiently addressed at the regional level, especially in regions where a lack of capacity prevails. Regional cooperation organizations should be invited to engage with the relevant Regional Hydrographic Commissions to assess, develop, fund, and implement capacity building plans in partnership with donor nations and agencies and with industry.

International level

56. The rapid development of stop-gap technologies and measures such as satellite derived bathymetry and crowd-sourcing, the facilitation of access to data collected by scientific cruises and the consideration of projects aimed at improving ocean mapping with focused priorities should be considered at the international level. These could all provide significant contributions to the marine component of the Global Mapping initiative.