HYDROGRAPHIC CODE OF PRACTICE FOR PORTS AND HARBOURS IN MALAYSIAN

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Term(s) and Definition(s)

BM	Benchmark
CD	Chart Datum
DGPS	Differential GPS
ENC	Electronic Nautical Chart
FIG	Federation of Surveyors
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision
IHO	International Hydrographic Organization
MBES	Multi Beam Echo Sounder
NHC	National Hydrographic Centre
PDOP	Position Dilution of Precision
RTK	Real Time Kinematic
RMN	Royal Malaysian Navy
SBAS	Satellite Based Augmentation System
SBES	Single Beam Echo Sounder
SV	Sound Velocity
TPE	Total Propagated Error
TPU	Total Propagated Uncertainty
WAAS	Wide Area Augmentation System
WGS84	World Geodetic Datum 1984
ZOC	Zones of Confidence
CATZOC	Category Zones of Confidence

HYDROGRAPHIC CODE OF PRACTICE FOR PORTS AND HARBOURS IN MALAYSIA

INTRODUCTION

1. This document outlines the basic 'good practice' guidelines that should be considered in the planning, execution and management of hydrographic surveys used to support the safe navigation of vessels in Malaysian ports and harbours. These guidelines have been endorsed by the National Hydrographic Centre, Royal Malaysian Navy (RMN) as the 'National Authority' for hydrographic matters in Malaysia.

2. Hydrographic surveys of harbours and ports are undertaken primarily to support the safe navigation of vessels. Port authorities are charged with maintaining and developing their harbours with regard to harbour use, and the size of vessels the harbours accommodate. This duty of maintenance covers several specific requirements, including the execution of hydrographic surveys. To meet increasing demands for volume and efficiency, ships are becoming larger and, with maximum loading, under keel clearances are diminishing. Consequently, there is an increased burden of responsibility on port administrators and surveyors to ensure that hydrographic surveys are undertaken to appropriate standards by appropriately qualified personnel.

SCOPE

3. These guidelines are intended for use in Malaysian ports and harbours where hydrographic surveys are conducted to support, either directly (e.g. to define the least depth in a shipping channel) or indirectly (e.g. post dredge survey) the safe navigation of vessels. They are based upon widely accepted 'good practice' for the planning, execution and management of hydrographic surveys. These guidelines should be used in determining those aspects of a hydrographic nature that should be considered in the development of robust risk assessments relevant to the safe navigation of vessels. This document is primarily intended for those with responsibility for the provision of hydrographic information in Malaysian ports and harbours. Others

include users of the MAL charts series and other nautical products generated from this information that require confidence in the work done through documented processes.

4. These guidelines have been prepared to provide an overview of good practice for port administrators and surveyors striving to develop the capacity to either conduct their own hydrographic surveys, or to contract this work to a third party.

REFERENCE TO HYDROGRAPHIC STANDARDS AND GUIDELINES

5. Standards and guidelines for hydrographic surveys relating to safe navigation generally fall into one of three levels, each with differing content and application.

a. **International Standard**. The highest level for hydrographic surveys, are those adopted by the International Hydrographic Organization (IHO). They form the basis from which IHO member states can produce their own national standards, and are intended to ensure a consistent quality of hydrographic information contained on internationally recognised nautical charts. The set of minimum criteria that must be met to achieve a recognised level of accuracy, or 'Order' of survey, is set out in Special Publication No. 44 Standards for Hydrographic Surveys (S-44 6th Edition), produced by the IHO, and now in its fifth edition. Typically, Exclusive Order, Special Order or Order 1a applies to surveys of ports and harbours. The IHO Manual of Hydrography (M-13) provides more specific details of the application of surveying methodology. Reference should be made to S-44 6th Edition for standards relating to the broader science of hydrography, and particularly for authoritative definitions of common hydrographic terms. S-44 6th Edition, and the Manual of Hydrography, can be downloaded from the IHO website at http://www.iho.int/.

b. **National Standard**. Second level or national standards are produced by IHO member states. They are predominantly based on S-44 6th Edition, and

modified to suit each country's unique requirements. These standards are usually quite detailed and contain considerable prescriptive processes. Similar to S-44 6th Edition, their purpose is to provide minimum standards for the capture of hydrographic survey data to support the production of official nautical charts. For Malaysia, these standards are produced by National Hydrographic Centre as it was laid down in the Guidelines for Hydrographic Survey Specification and RMN General Instructions for Hydrographic Surveyor (RMN GIHS).

c. **Third Parties**. Third level guidelines and standards are often produced by agencies and organizations to describe good practice and procedures for specific hydrographic surveys. The scope of such guidelines is often narrower than national standards, and focuses on key areas of hydrographic surveying that support a particular requirement (e.g. Hydrographic Code of Practice for Ports and Harbours in Malaysia). The United States Army Corp of Engineers, for example, publishes a document pertaining to pre and post dredging surveys.

PORTS AND HARBOURS ENVIRONMENT

6. Most ports and harbours have dredged channels, berths and anchorages, which suffer from siltation, thereby reducing the depth of water available to shipping. Ports operate with a minimum under keel clearance that must be maintained by a ship transiting a port. Regular surveys are required to monitor the published depth, as charted depth accuracy is a significant component of the calculation of a port's under keel clearance. Minimum under keel clearance can be determined by anticipating the following contributing factors:

a. Squat and settlement (related to speed).

b. Manoeuvring characteristics.

c. Draught as affected by roll, pitch & heave movement.

d. Accuracy of the predicted or measured tide.

e. Accuracy of published depth.

f. Rate of siltation since last survey.

g Sea state (wave height), direction & tidal stream.

7. The hydrographic surveyor contributes to the measurement of factors such as tidal height, accuracy of declared depth, and the required frequency of hydrographic surveys. The surveyor may also contribute expertise necessary for the measurement of a vessel's squat and roll, pitch and heave movement. Various methodologies exist for the collection, processing and presentation of hydrographic survey information. Whilst the presentation of such information is largely determined by the needs of the end user, the fundamentals of hydrographic data collection remain the same, i.e. the accurate measurement of water depth (Z) below a stated datum, and the position of this measured depth (X,Y). Additionally the hydrographic surveyor would be concerned with determining bottom type and as well the positioning of 'intertidal' and shoreline features above a stated datum.

8. The widely accepted method for obtaining depth data has been with a single-beam echo sounder (SBES), with position provided by electronic ranging equipment. Positioning has been made easier with the advent of the Global Positioning System (GPS), particularly in differential (DGPS) and real time kinematic (RTK) modes. The introduction of the multi-beam echo sounder (MBES) has provided the ability to ensonify and measures much greater areas of sea floor to a higher level of detail. As all hydrographic survey data has some degree of uncertainty, it is important to ensure that charted depths are accurate, and that the charted depth tolerance is commensurate with the allowance made for under keel clearance at the port.

9. S-44 6th Edition requires that hydrographic surveyors include with their survey data, a statistical estimate of the probable error. It is important that the estimate of the depth error is based on the survey methodology adopted; the equipment used to perform the survey, and is unambiguously reported for each survey undertaken. Furthermore IHO S-57, the current standard for electronic nautical chart (ENC) data exchange prescribes standards for encoding metadata to identify areas based on specific depth and positional uncertainties called Zones of Confidence (ZOC).

TYPES AND FREQUENCY OF HYDROGRAPHIC SURVEYS

10. The varied and dynamic nature of ports and harbours dictates that the frequency and methodology for hydrographic survey operations should be determined primarily by a risk assessment, rather than by the blanket adoption of a set of rigid criteria. The usefulness and credibility of associated risk assessments largely depend upon the quality of the balanced and quantifiable information on which they are based. Hydrographic factors for consideration in risk assessments should take account of the stability of the seabed and depth of available water in relation to vessel draught, as well as intended development that will affect the navigable depth in a given area.

11. Assessments should be undertaken in a rigorous manner. An important product of the risk assessment is a plan that sets out the requirements for surveys, including the type, extent and frequency. Other considerations include (but are not limited to):

a. Vessel type and operations (i.e. high speed, restricted in ability to manoeuvre etc).

b. Potential environmental impact of a hydrographic-related event.

c. Quality/reliability and/or uncertainty of existing hydrographic information.

d. Complexity of the area to be surveyed.

e. Stability of seabed.

f. Depth and width of navigable water in relation to vessel draught.

g. Regional development.

h. Fairway design.

i. Reports arising from vessel groundings or reported depth discrepancy.

j. Competency of persons responsible for the surveys.

HYDROGRAPHIC SURVEYOR COMPETENCIES

12. The nature and extent of hydrographic surveys required to support safe navigation in a particular port or harbour, should be determined primarily by a risk assessment. The same risk assessment process should also address the minimum level of competencies required by those charged with the conduct of such work. Guidance on competencies appropriate for particular hydrographic surveys is detailed in ***IHO Publication S-5A Standards of Competence for Category "A" Hydrographic Surveyors*** *and* ***S-5B Standards of Competence for Category "B" Hydrographic Surveyors***, and includes guidance specific to the port and harbour environment. It can be downloaded from the IHO website (http://www.iho.int/.) Formal qualifications supported by practical experience, certification by a recognised professional body, or demonstrable experience, are all valid means of determining an individual's level of hydrographic competency.

13. The hydrographic surveyor should be accredited by the International Hydrographic Organization/International Federation of Surveyors (IHO/FIG) Category A/B course and should produce documented proof of such accreditation. The Surveyor shall be responsible for all survey works carried out and for the submission of plans and reports. The Surveyor shall also ensure that all works are carried out in accordance with IHO Standards for Hydrographic Surveys S-44 6th Edition.

PERMISSION TO CONDUCT SURVEY

14. The surveyor is to be certified by IHO/FIG/ICA Category A or Category B and the activities conducted shall at all-time be informed to Port Authority and National Hydrographic Centre a month before the survey conducted.

ACCESS TO INSPECT SURVEY WORKS

15. The representative of Port Authority or National Hydrographic Centre shall at all reasonable times have access to the development sites and survey facilities. The Contractor shall arrange for check survey or survey inspection at the request of the Port Authority or National Hydrographic Centre. All costs incurred for the above inspection or check surveys carried out by the Port Authority or National Hydrographic Centre shall be borne by the Contractor.

SURVEY LIMITS

16. The survey limits shall extend to at least 100 meters beyond the perimeter of the approved working limit or up to the adjacent sea-wall, wharf, coastline, etc. The survey limits shall be approved by the National Hydrographic Centre and shown in a drawing titled ‘Plan showing Limits of Survey’. All structures, floating or fixed within the

survey limits shall be surveyed and shown on the plan. Any obstructions detected shall be shown clearly on the survey plan. The composition or the nature of the obstructions shall be described in details in the report. Hydrographic survey must cover up to High Water Line or Coastline where applicable.

METHOD OF SURVEY

17. The Contractor shall obtain the procedure and the requirement of survey under S-44 6th Edition. The Contractor shall aware the method of survey at Ports and Harbour are stated in Order 1a and above. Any doubt, National Hydrographic Centre shall be an advisory service to be reached out.

SURVEY EQUIPMENT

18. Equipment to be used during hydrographic survey operations falls within the broad groupings of equipment to measure depth, to establish position, and to measure water level. Generic considerations for the use of such equipment are covered in this section. Advances in survey equipment technology have enabled some processes to be automated, thus significantly reducing the level of user input in normal modes of operation. It is vital, however, that users possess a reasonable understanding of the capabilities and limitations of the equipment used. In particular, it should be understood that manufacturer's specifications rarely guarantee equipment performance, unless the equipment is operated in accordance with strict parameters and under optimum environmental conditions. Regardless of the manufacturer's stated specifications, in accordance with principles of good practice, the surveyor is still required to identify, eliminate or reduce, and quantify remaining sources of error in an appropriate error budget.

19. As Total Propagated Uncertainty (TPU) values are often estimates based on the

claims of manufacturers, these can be difficult to formulate correctly for a dynamic vessel. It is therefore suggested that a priori TPU is used to determine whether the proposed system-package is capable of meeting the required specifications. A more quantifiable measure, however, should be used to derive the post priori precision (e.g. from comparison of the results of tie line/interline and previous data).

DEPTH MEASUREMENT EQUIPMENT

20. Depths are normally measured using both single-beam (SBES) and multi-beam (MBES) echo sounders. MBES shall be the preference for ports and harbours survey. Complete seabed ensonification for the purpose of small target detection can be achieved when these systems are used in conjunction with a towed or fixed side scan sonar system.

a. **MBES**. MBES as a hydrographic survey tool has significant advantages over SBES in its ability to detect small objects and achieve full bottom coverage.

(1) It requires key ancillary equipment such as an appropriate motion and heading sensor, which must be properly integrated for correct operation.

(2) The ability to measure sound velocity (SV) profiles through the water column (in some cases continuously) is required to correct for the refraction of beams, particularly where shallow water systems employ wide swath widths. MBES with flat transducer arrays also require an accurate instantaneous measurement of the sound velocity at the transducer face to enable correct beam steering to occur. Users should be aware of the expected performance of the system and employ robust methodology to prove this before accepting the system as operational.

(3) Careful calibration of MBES is required at regular intervals thereafter. Good practice calls for the use of a reference surface, an area of seafloor where repeatable measurements can be compared. Inherent with the increased detail and coverage achieved with MBES is the ability to clearly see errors associated with incorrect lever arm and sensor offsets, time delays, sound velocity and excessive vessel motion. The ability to 'average' or 'smooth' out such errors in subsequent processing is potentially misleading and should be avoided unless the magnitude of the change from the raw to the smoothed record is clearly stated. Such errors should be included in the calculation of the overall accuracy value accompanying the data.

b. **SBES**. SBES must be calibrated by a bar check to correct for errors in the speed of sound in the water column, and to set the correct transducer draught. The latter is to ensure that the instrument records the depth below the sea surface and not below the transducer. Where no sound velocity profile data is available, a bar check should be conducted at least daily, and on any change of survey area during the day, to ensure consistent data quality. Likewise a bar check must be conducted when any SBES components are modified or replaced on the vessel.

POSITIONING SYSTEM EQUIPMENT

21. Differential GPS is widely used to fix vessel position during hydrographic surveys. The source of the differential corrections should be proven by comparison with a known survey control point, particularly if a local base station is established. GPS receivers should be configured to output positions in the desired datum (normally WGS84) with associated quality tags. The quality of the position fixes should be monitored during sounding operations through examination of the GPS parameters in

use (number of tracked satellites, dilution of precision (HDOP and PDOP), etc), and real-time comparison with a second positioning system is recommended.

22. Post-processed differential is an alternative to RTK in instances where a high accuracy positioning solution is required. Real time kinematic GPS offers increased precision of the horizontal position, provided that the footprint of the echo sounder in use is of a comparable dimension. Users of the sounding data need to be aware that the horizontal accuracy quoted for an RTK GPS survey (or any other positioning system) may be affected by the beam width of the echo sounder. If the beam width is large, an increase in depth will increase the footprint on the seabed and degrade the actual positioning of the soundings. This is, potentially, more of a problem with SBES as MBES beam width is usually much smaller. Additionally the accuracy of position of the soundings will be improved with the use of motion sensor equipment.

23. The DGPS or any electronic positioning system used shall provide horizontal positioning accuracy of +/- 0.5 meter or better.

MOTION SENSOR EQUIPMENT

24. The demand for greater transparency in the derived accuracy of soundings taken in swell conditions has seen the use of motion sensor equipment become standard in an increasing number of port and harbour surveys. The accelerometer is the standard type of motion sensor equipment, and different units range in their complexity, and in the precision they are capable of achieving. The correct installation and definition within the vessel reference frame is vital, and consideration should be given to obtaining assistance from the manufacturer if the user is unfamiliar with the equipment.

25. Kinematic GPS is becoming increasingly popular as an alternative method of correcting vessel motion, either in conjunction with, or in lieu of, accelerometer-

based motion sensors. While providing a low cost alternative for measuring roll, pitch and heading, the update rate of the GPS (typically 10Hz) limits its ability to serve as an accurate heave measurement sensor. Thus, users of both types of motion sensors should take all practical steps to check their correct operation, preferably by some means of ground-truthing.

TIDE GAUGE EQUIPMENT

26. Sea level (tide) measurements of height and time are required to reduce collected soundings to Chart Datum, and they are subsequently used (as a continuous record over long periods) to define tidal reference levels (e.g. MHWS). Tidal observations are normally obtained via automatic recording gauges, which are permanently installed in many ports. Other methods used to obtain tidal information include: manual tide pole (or staff) readings, referenced to a recognised datum (normally Chart Datum); and RTK GPS with centimetre precision in the vertical (Z) dimension. This latter method provides a total height measurement, including tide height, but the geoidal separation must be accurately known, and the base station- rover range limitations clearly understood.

27. If Kinematic GPS is used in this manner, it is considered good practice to regularly correlate the results against tidal observations obtained by traditional (e.g. tide gauge) methods. Regardless of the type and method used, the equipment must be capable of measuring the tide to the required accuracy. If the method of tidal reduction requires interpolation between individual observations, the interval between observations must be such as to provide an adequate representation of the tide curve. If automatic tide gauges are used, these must be regularly calibrated against a tide pole to ensure their accuracy. The accuracy of the tide readings used to reduce soundings impacts directly on the overall accuracy of the survey.

TIDAL OBSERVATION

28. In addition to the use of tide readings to reduce sounding data, a continuous record of tidal data (at least one lunar cycle of measurement) is important for the maintenance of accurate predictions for the ports recommended that an unbroken record of tidal readings is maintained and archived (accompanied by relevant calibration records) for this purpose.

EQUIPMENTS OFFSET

29. The position of the various sensors on the survey vessel should be carefully measured in relation to a common reference point, and correctly applied within the survey acquisition or post processing software. This information must be included in the survey documentation. Furthermore, it should be noted that not all equipment and software engineers adhere to the same conventions when applying the axes and arithmetic signs used to describe a vessel's (Cartesian) reference coordinate system.

EQUIPMENTS CALIBRATION

30. Preparation for the survey involves the planning of hydrographic observations and ancillary activity necessary to support the collection of data, the most important of which is calibration of the surveying equipment. Equipment calibrations need to be conducted at regular intervals and documented in order to support the quality estimate given to the final survey dataset. Maintaining a data-pack for key equipment, and/or including the relevant information in a final report accompanying each survey, is recommended.

a. **MBES Calibration**. Initial calibration of MBES equipment is a complex

task. It is strongly advised that assistance is sought from the manufacturer, and, if necessary, a hydrographic surveyor with MBES experience. Individual MBES error tolerances are much smaller than for SBES. The results will only be as good as the accuracy of the sensors installed in the system, and the quality of each sensor with respect to the manufacturer's quoted accuracy. Check calibrations or rigorous confidence checks are required at regular intervals, starting at daily intervals for newly installed systems, and after significant component upgrade/change to key sensors. Once repetitive results for calibration values are obtained, checks should be carried out weekly and monthly. It is recommended that each organization performing surveys with MBES setup their own regular calibration and inspection/maintenance regime, and employ a reference surface for ongoing system calibrations. The surveyor needs to become intimately familiar with all the aspects of the system to be able to locate and understand small variations in data quality. As a minimum, full calibrations should quantify the system error sources.

b. **SBES Calibration**. SBES should be calibrated by bar checks to correct for index error, set the correct draught setting and ensure that the instrument records the depth below the sea surface and not below the transducer. A bar check should be conducted at least daily and on any change of survey area during the day to ensure consistency of data quality.

c. **Tide Gauge Calibration**. It is good practice to confirm automatic gauge readings with the level of the tide observed on a co-located tide pole or tape, referenced to Chart Datum, at least weekly, if not daily, during survey operations. These comparisons provide a valuable record of the gauge performance and should be retained (e.g. in the equipment data-pack). Where a permanently recording automatic tide gauge is installed, a full calibration of this system should be conducted at least annually, or when necessary after maintenance etc. This procedure involves manual observation of the pole readings over a full tidal cycle (preferably 25 hours although 12.5 hours may be sufficient) in order to correlate

gauge readings with the theoretically 'correct' pole readings. Regardless of the type of automatic gauge equipment being used to observe tidal data, confirmation of the tide pole zero against the Standard Port Reference Benchmark should be carried out by levelling at least annually, or whenever the pole is moved. Results should be fully documented, and retained with the tidal archive and/or equipment data-pack. Likewise, the benchmarks that reference the vertical datum should be checked regularly for movement by a closed levelling loop.

MISCELLANEOUS CHECKS AND CALIBRATIONS

31. Regular confidence checks of the vessel positioning system should be conducted at least weekly, preferably daily, during the course of a survey. A static check of the vessel's derived position against a mark ashore (e.g. a pin on a wharf) established to a higher order of accuracy than that required for the vessel is recommended. In both MBES and SBES systems, position system latency (time delays) should also be determined and applied in the survey acquisition or post processing software. Guidance on determining the latency correction can be obtained from the equipment manufacturer.

31. If possible, a dynamic check against a distinctive bottom target for which a known position has been derived, should be undertaken, as this serves to reveal any latency or vessel layback errors not otherwise detectable with a static check. Bottom targets should be located in shallow (i.e. less than 10 m) water to ensure the echo sounder footprint and subsequent resolution of the target is comparable with the positioning system in use. Calibration of ancillary equipment, such as SV probes, should be carried out by the equipment manufacturer or agent in accordance with the manufacturer's guidelines and copies of subsequent certificates should be retained in the equipment data-pack.

DATA ACQUISITION SYSTEM

32. The Hydrographic Data Acquisition System (HDAS) shall comprise hardware and software configured to control, manage, acquire and store digital data in survey format from the positioning system and Single-beam and Multi-beam echo sounder systems. The system shall include helmsman display facilities indicating vessel steering in a pre-planned survey line, with digital displays showing information on position, depth, Course over Ground (COG), heading, Speed over Ground (SOG), line and fix number, and distance from start and end lines.

33. The online Quality Control (QC) for positioning and depth shall be monitored to ensure positional accuracy standard. Daily QC reports shall be included as an annex to the Report of Survey (ROS).

34. The automated logging system for HDAS shall be set at the following intervals:

a.	Navigation Cycle Time	:	2 sec or better.
b.	Depth Cycle Time	:	2 sec or better.
c.	Position Logging Interval	:	2 sec or better

DATA COLLECTION

35. Methods employed by surveyors to collect hydrographic data do not greatly vary – all involve the collection of data required to meet the overall objective as well as the collection of additional data that is used for validation purposes throughout the survey. Some hydrographic standards prescribe rigid procedures and criteria to achieve this but these may not be appropriate in the port and harbour environment

where repeat surveys are regularly undertaken and such rigid requirements can be considerably relaxed.

36. The shallow water MBES at a frequency of about 200 to 400 kHz shall be utilised for the sounding operation. The methodology for MBES survey encompasses the following:

a. Depths shall be recorded in metres and tenths of metres.

b. The total sounding uncertainty for swath widths of at least three times the average water depth shall be in compliance, at the 95% confidence level, with the allowable Total Vertical Uncertainty (TVU) of $\pm \sqrt{[0.25 + (0.0075 \times d)^2]}$ where d = depth.

c. Sounding track lines shall be generally parallel to the general configuration of the depth contour lines.

d. The total uncertainties in the position of soundings and all other significant features shall not exceed ±2 metres at 95% confidence level.

e. All Multi-beam data shall be corrected for settlement and squat, heave, pitch, roll and the heading of the vessel.

f. The velocity of sound through water shall be determined at least daily during Multi-beam sonar operations. The velocity profile shall be determined to a minimum of 95% of anticipated water depth. Velocity corrections shall be based on the data obtained from profile and not on an averaged sound velocity reading for the water column.

g. The survey lines shall be run to achieve 100% seabed coverage, ie with 50% overlap on each side. The line spacing shall not exceed 3 times the

water depth.

h. Cross lines shall be run at angles of 45 to 90 degrees to the main scheme lines. At least 5 cross lines shall be run in the Survey Area.

i. All drying lines and drying features shall be delineated accurately and measured from LAT.

j. Accuracy tests shall be conducted on the MBES and DGPS sensors. Prior to commencing Multi-beam operation, a system accuracy test (patch test) shall be conducted to quantify the accuracy, precision and alignment of the MBES. The patch test shall include determination of roll, pitch, heading and time latency. Depth accuracy testing shall also include testing of MBES against SBES system. Details of the test shall be included in an annex to the ROS.

k. Accuracy check for DGPS system shall be conducted using at least two different reference stations. Positional differences should be less than ±2 metres. Details of the test shall be included in an annex to the ROS.

37. The high frequencies SBES providing a depth accuracy of +/- 0.1 metre shall be used for the sounding. The methodology for SBES survey encompasses the following:

a. The echo sounder shall be calibrated daily either by bar-check or sound velocity probe up to the maximum depth of the Survey Area, before and after sounding.

b. Actual tidal observation curves will be smoothed and used for reduction of soundings. Depths will be inked in metres and decimetres.

c. Horizontal Accuracy shall not exceed ±2 metres.

d. Sounding lines shall be run at spacing of 5 mm on paper throughout the entire survey limits and at closer intervals where seabed is irregular and high spots are detected. Cross-lines shall be run at intervals of not more than 10 times the line interval of the sounding lines.

e. All drying lines and drying features shall be delineated accurately and measured from LAT.

DATA PROCESSING

38. The processing of hydrographic data involves the removal of invalid data and the selection of a ‘cleaned ‘data set for further processing or for the generation of required products (e.g. sounding sheets) for subsequent analysis. It is also the stage where tidal data is normally applied or where tidal level data collected in real time and applied during data acquisition is validated. It is recommended that data processing be conducted using a dedicated hydrographic processing package that preserves data integrity through audit functions and is capable of shoal bias thinning.

39. Modern packages offer almost complete flexibility and the potential to ‘manipulate’ or overly ‘smooth’ data - this practice is potentially misleading and should be avoided unless the magnitude of the change in the raw to the smoothed record is clearly stated. This is especially relevant where sounding sheets are produced from ‘gridded’ data. Surveyors should refer to the manufacturers’ instructions accompanying survey processing packages and develop a series of standard operating procedures for the processing of data, mindful of the above considerations.

40. The Hydrographic Data Processing System (HDPS) software shall include facilities for editing and reducing depth, smoothing and filtering, sound velocity corrections, common format conversion, QC analysis for depth and positioning and be able to generate the final survey product presentations i.e. fair sheet with hydrographic

symbology in accordance with IHO standards. The software shall also be able to handle and manage huge amount of raw and processed digital bathymetric data systematically. The workflow of the 'Data Processing model' utilised by the software shall be included in the ROS.

41. The HDPS shall be able to perform area based and line by line editing with automatic and/or manual removal of outliers. The survey data shall be able to be displayed in plan, spread sheet, profile and 3-dimensional digital terrain model views. All methods used for data editing shall be recorded and included in the ROS. The system shall be able to perform QC for the depths between main lines and cross lines/check lines. The depth and positional data QC test result shall be included as an annex to the ROS to define the reliability of the Survey. The system shall be able to generate colour-coded soundings, contours, and smooth sheet plotting capabilities.

DATA ANALYSIS

42. Data collected during survey operations should be monitored closely to ensure the required standard and the desired extent of coverage is being met; however, it is not possible to fully assess the overall quality until all data can be viewed together or in suitably sized blocks. Cross-line comparisons and various other consistency checks are undertaken at this time. Areas requiring re-running, either because of gaps in coverage or due to suspect data, are identified at this stage.

43. Perhaps the most crucial aspect of data analysis is the assessment of the accuracy achieved. Soundings on a chart, sounding sheet, or other plots used as decision aids in navigation (including post dredge surveys), are meaningless without associated information on their quality. The accuracy of soundings cannot simply be estimated without proper justification. In determining depth accuracy, all sources of individual errors need to be quantified and incorporated into a statistical model to derive the 'Total Propagated Uncertainty' (TPU). Individual error values should be

derived from the various calibrations conducted at the preparation phase and throughout the survey, and be appropriately documented

DATA PRESENTATION

44. Hydrographic data can be presented in a number of formats and styles, depending on its intended purpose. The underlying principle in compiling records of any survey is that they must be entirely intelligible to any person having a sound knowledge of the type of survey concerned, but not necessarily involved in the survey. A large proportion of hydrographic surveys in ports and harbours will be repeat surveys for a specific purpose, and for specific end users, where extensive reports and deliverables are not usually required. Nevertheless, a minimum level of information should accompany sounding data, not only to provide the necessary confidence that the data is fit for its intended purpose, but also to allow for its use by end users with differing requirements. This information shall be maintained by the surveyor for inspection at any time by the National Hydrographic Centre. The following records must be duly certified copies and submitted to the National Hydrographic Centre.

a. General information about the survey (date, area, equipment used, name of survey platform).

b. The name of surveyor/agency who conducted the work.

c. The geodetic reference system used, including horizontal and vertical datum.

d. Calibration procedures and results.

e. Tidal datum and reduction details.

f. An assessment of horizontal and vertical positioning accuracies (Survey Order or CATZOC).

g. White watch book (daily record).

h. Tidal data.

i. Track and sounding plot.

45. Most of the above information can easily be incorporated on the sounding sheets using a simple template. Metadata that is impractical to show on sheet templates, e.g. calibration procedures and results, should be documented and stored in a manner that allows it to be subsequently recovered if necessary, to confirm data quality. This requirement could be achieved through the use of a separate report.

HORIZONTAL DATUM

46. The Survey shall be carried out in World Geodetic System 1984 (WGS84) Datum and shall be plotted on the Universal Transverse Mercator (UTM). Horizontal control and positioning is generally measured using precise GPS-DGPS, RTK, P- Code or PPS, or Wide Area DGPS derived from a Satellite-Based Augmentation System (SBAS). The Surveyor shall be responsible for the accuracy of all control stations used for the survey irrespective of whether the station co-ordinates are provided by the JUPEM. All new control stations are to be connected to JUPEM station. Before the commencement of any survey, the Surveyor shall submit to the National Hydrographic Centre a plan at the survey scale showing all the control stations to be used for the surveys and a list of their respective co-ordinates and station descriptions.

VERTICAL DATUM

47. At a particular harbour and port, the level of the water is expressed as a height above a local datum, which is also the datum used for the depths of the sea on nautical charts (Chart Datum). This datum is defined with reference to permanent benchmarks ashore and the adopted zero of the tide gauge. The datum adopted should, according to IHO standards, approximate Lowest Astronomical Tide (LAT), which is the lowest level the tide can be predicted to occur under normal meteorological conditions.

48. The Sounding Datum to be used for the reduction of soundings and shall be determined using the National Hydrographic Centre or JUPEM bench mark. The Sounding Datum used shall be stated clearly in all survey plans and records. Tidal readings for the reduction of soundings shall be taken from the Port Authority automatic tide gauge nearest to the survey area or by establishment of tide pole for every 10 minutes manual taken reading and shall be recorded.

REPORT OF SURVEY (ROS)

49. The Surveyor shall submit a comprehensive survey to the National Hydrographic Centre and Port Authority giving details on Outline of Operation, Field Operation, Data Processing, Finding, Fair Sheet, List of Accompanying Documents, and any other relevant information of each survey carried out by the Surveyor. The ROS shall be prepared in English.

SIDE SCAN SONAR

50. A side scan sonar survey covering the limits of the hydrographic survey shall be

carried out by the Contractor in the presence of the Port Authority or his representative. The cost for the side scan sonar survey shall be borne by the Surveyor. The survey lines shall be run at 100 m intervals with dual coverage and shall carry out in a manner to provide the scanned corridor of not less than 100% overlap. The survey shall be carried out using sonar range scale of 100 meters or lesser. All obstructions, debris or other features lying on or protruding from the seabed located by the sonar survey shall be investigated, and identified by divers or by some other means acceptable to the Port Authority representative. The positions of all these features shall be plotted on 1:1000 scale survey plans. All debris or obstructions found shall be removed immediately by the Contractor at his own cost.

CURRENT MEASUREMENT

51. The current measurement shall use the Acoustic Doppler Current Profiler (ADCP) and the ADCP provided shall be seabed mounted and upward looking. The ADCP shall be capable to automatically measure vertical profiles of horizontal water currents. It shall be self-contained to be mounted in a sinker on the seabed. Should the ADCP be buoy mounted, the Surveyor should seek prior approval from the Port Masters Dept for the buoy's location. Upon approval, the buoy's markings and light shall be specified by the Safety Navigational Units, Marine Department. The ADCP shall automatically record the average value over 10-minute intervals. Each data recording shall be the average of all valid data over the 10 minute intervals. The ADCP shall be able self-check the data and reject erroneous data before recording.

52. The output of the recording data for speed shall be in centimetre / second and direction in degrees relative to True North. The Surveyor shall propose to the National Hydrographic Centre, the ADCP's mooring design and location. Should the ADCPs be deployed in shipping channels, the moorings must be dimensionally low profiled to reduce the likelihood of collision with passing vessels. The proposed sinkers for mounting the ADCPs must be resistant to corrosion. The Surveyor must ensure that

the deployed ADCP's tilt angle shall not exceed 5 degrees from the upright direction.

DATA FORMATS

53. In addition to paper plots and reports, digital data is an output from most modern surveys. This primarily comprises point information for each sounding, but can also include coastline, sound velocity, tide etc. Standard formats for the archival and distribution of this data is encouraged. All hydrographic survey packages are capable of outputting sounding data in any gridded surface (*.csar, *.bag, *.ascii, *.grd and etc) which can bring all along appropriate data (as latitude, longitude and depth; or easting, northing and depth). The archival of line information (e.g. coastline) or certain point information in Drawing Exchange Format (DXF) is accepted practice; however, this format should not be used for sounding data, as the subscript decimal place used in standard hydrographic sounding presentation is not fully supported.

54. A set of all bathymetric survey data stored in portable hard disk together with an index chart let showing the surveyed areas covered by each data file and the co-ordinates for those points defining the surveyed areas. The data file shall be structured in accordance with format approved by the National Hydrographic Centre.