Correction 1: Applicable to the printed book and digital files downloaded before 23 August 2006

Page 89, sub-paragraph d, 4th line should read "10.23 MHz"; and

Page 89, sub-paragraph d, 3rd bullet, 5th line should read "that is 1 x f0 = 10.23 MHz...."

Correction 2: Applicable to the printed book and all digital files downloaded before 28 May 2008

Table of Contents page vi, Annex A should read "Reference and Coordinate Systems";

Table of Contents page x, 5.7 should read "Charting the Foreshore";

Page 27, Fig 1.6 Bottom right hand box should read "BSB";

Page 154, sub-paragraph 5.1.3, 2nd and 3rd bullets should be moved to the left;

Pages 215, 2nd paragraph, at the end delete the duplicated text "Category B sweeps ..... critical.";

Page 464, 2nd bulleted list, the bullets should read a to h;

Page 509, Contents, Part 2 – Technical, delete bullet "R Underwater Handbook Amendments" and renumber remaining bullets R to V; and

Page 518, List of Co-ordinates and Heights, bottom left hand box insert "]" after 4

Correction 3: Applicable to the printed book and all digital files downloaded before 30 April 2010 Note the first set of corrections reflect the introduction of the 5th Edition of IHO Publication S-44 "Standards for Hydrographic Surveys"

Chapter 1 Pages 8 – 11 Delete Section 2.1 Survey Specifications and replace with the new Section 2.1 attached as Annex A to this document.

Chapter 1 Page 16 Amend footnote 13 to read: "International Hydrographic Organisation, Monaco, IHO Standards for Hydrographic Surveys (S-44), Section 5.2, 5th Edition 2008."

Chapter 2 Page 114 Amend reference to read "S-44 5th Edition 2008

Chapter 2 Page 114 Delete entire reference to "IHO Standards for Hydrographic Survey" Supplement to S-44.

Chapter 2 Page 116 Amend reference to read "S-44 5th Edition 2008

Chapter 2 Page 116 Delete entire reference to "IHO Standards for Hydrographic Survey" Supplement to S-44.

Chapter 3 Page 119 Section 1 Introduction – at end of first paragraph amend to read "S-44 5th Edition"

Chapter 3 Page 119 fifth paragraph amend first sentence to read "The state of the art of the depth measurement equipment was evaluated by the working group on S-44 preparing the 4th Edition in 1998 as follows:

Chapter 4 Page 200 replace Tables 4.1 and 4.2 with the following:

IHO S-44 Order and example areas		Search Requirement
Special Order	Areas where under-keel clearance is critical.	Full sea floor search required.
Order 1a	Areas shallower than 100 metres where under-keel clearance is less critical but features of concern to surface shipping may exist.	Full sea floor search required.
Order 1b	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Full sea floor search not required.
Order 2	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.	Full sea floor search not required.

Table 4.1 "IHO S-44 Search Requirements"

IHO S-44 Order	System Detection Capabilities
Special Order	Cubic features >1.0 m
Order 1a	Cubic features >2.0 m in depths up to 40 m or 10% of depth beyond 40 m
Order 1b	Not applicable.
Order 2	Not applicable.

Table 4.2 IHO S-44 System Detection Capabilities

Chapter 5 Page 275; 2.2.1 a Delete second sentence "The measurement error, including ..... section 4.2)." and replace with: (See IHO S-44 5th Edition 2008 Chapter 3.)

Chapter 6 Page 302 Delete section 2.1.2 and renumber sections 2.1.3 to 2.1.8 as 2.1.2 to 2.1.7

Chapter 6 Page 302 Replace existing 2.1.3 (New 2.1.2) with:

In S-44 Table 1, errors with regard to positions for other important details and coastal features are expected to be below the following limits:

TABLE 6.1 (TABLE 1 IN S-44)			
	SPECIAL ORDER	ORDERS 1a and 1b	ORDER 2
Positioning of fixed aids to navigation and topography significant to navigation. (95% Confidence level)	2 m	2 m	5 m
Positioning of the coastline and topography less significant to navigation. (95% Confidence level)	10 m	20 m	20 m
Mean position of floating aids to navigation. (95% Confidence level)	10 m	10 m	20 m

Chapter 6 Page 302 Existing 2.1.6 (New 2.1.5) lines 3 - 6 Delete “are accurate ..... Orders 1, 2 and 3.”

Chapter 6 Page 384 Amend first reference to read: IHO (2008). / “IHO Standards for Hydrographic Surveys. S-44 5th. Ed ” / IHB, Monaco. There will be French and Spanish versions available.

Chapter 7 Page 414 Section 2.9 first paragraph amend reference to read S-44 4.2

Chapter 7 Page 455 Bullet a iii at end amend to read “standards listed in S-44 5th Edition 2008.”

Chapter 7 Page 478 Amend reference to read “S-44 5th Edition 2008

Chapter 7 Page 478 Delete entire reference to “IHO Standards for Hydrographic Survey” Supplement to S-44.

Chapter 7 Page 480 Amend reference to read “S-44 5th Edition 2008

Chapter 7 Page 480 Delete entire reference to “IHO Standards for Hydrographic Survey” Supplement to S-44.

Title pages and footer of all pages change M-13 to read C-13

Title Pages After “May 2005” Insert new line (Corrections to April 2010)

Table of Contents page viii 3.2 Title should read Non-Photogrammetric Remote Sensing Imagery

Page 347 3.2 Title should read Non-Photogrammetric Remote Sensing Imagery

Page 34 Figure 2.1 Amend label “Zenit” to read “Zenith”

Page 3 Delete all of 2nd paragraph “To adequately address …… defence and exploitation.” This text is repeated immediately below.

Page 25 2.9.1.2 1st paragraph last line. Insert “The” before “computer” and at end of line replace “six” with “five”.

Page 34 bottom of page insert new paragraph 3 in 2.1.1 “Figure 2.1 shows the general relationship between geoid, ellipsoid and the physical shape of the earth. Figure 2.2 shows the structure and parameters of the ellipsoid.”

Page 35 2.1.2 third paragraph delete “15 km” and insert “8km”.

Page 36 Section 2.2 just above Figure 2.3 delete “horizontal and vertical: a. Local Ellipsoid; b. Local Geoid.” And insert: “horizontal (local ellipsoid) and the vertical (local geoid / mean sea level). Figure 2.3 attempts to show this relationship.”

Page 37 Bottom of page add new sentence: “See Figure 2.4 for a graphical depiction of the relationship between 2 ellipsoids.”

Page 46 2.5.3.1 first paragraph fourth line delete “only for parallels and meridians,” and insert “and”

Page 74 4.2.3 first paragraph replace with “This correction must be introduced to take into account the bending which the light ray experiences when passing through layers of the atmosphere of different density. Such bending always tends downwards.”

Page 76 4.2.5 b 2nd line replace “i.e. m.A” with “i.e. $m\alpha$”

Page 88 6.1.1 a first line amend to read “… is formed by a minimum of 24 satellites, although there are often more, in near…”

Page 88 6.1.1 a second bullet point amend to read “(10^{-12} to 10^{-14} sec)”

Page 91 6.1.3 top of page point c amend to read “10^{-8} to 10^{-6} of the base line”

Page 92 6.1.3 h First word delete “Voluntary” insert “Induced”

Page 95 6.1.6 replace 1st paragraph with: “In this technique the satellite clock errors and the errors associated with the ionospheric and tropospheric refraction are eliminated. The correction of range of phase can be transmitted in real time by the reference station receiver to the rover station receiver through the RTCM protocol or through proper format of the receiver manufactures. DGPS with measurement of phase is used for kinematic applications of precision in real time: such techniques are termed RTK (Real Time Kinematic). The aim is for the time of latency to be removed or in practice much reduced (a few milliseconds).”

Page 129 2.3.2 second paragraph amend first line to read “According to Snell’s Law and considering two media …”

Page 165 Figure 3.33 The text was missing in the top 4 boxes in the pdf files prior to April 2010.

Page 124 2.1.2 top of page delete “The power, Π, of the acoustic pulse is equal to Intensity x Area” text repeated from earlier page.

Page 175 5.2.1.8 Last sentence before Equation 3.60 amend to read “Therefore, sound velocity is represented as follows:”

Page 177 First line after Equation 3.71 amend to read “where σ_g^2 corresponds …”

Page 178 First line after Figure 3.41 Amend to read “The time delay to steer the beam by an angle β, is obtained by:”

Page 178 Last line Amend to read “σ_{C0}^2”

Page 180 5.2.1.8.4 After equation 3.84 amend to read “$\sigma^2_{z\ detection}$”

Page 186 6.4 First paragraph last sentence amend to read “Nonetheless, these systems are still valid and remain in use today.”

Page 187 6.4.1.1 third paragraph amend to read “A sounding pole is a pole graduated with marks which is also used for determining the depth of water when sounding manually. It is generally used in depths of less than 4 metres.”

Page 204 2.3.3.1 last sentence amend to read "It must be stressed that this equation can form only the starting point for a consideration of SSS performance because it is not possible to know all the equation terms."

Page 208 2.3.4.14 third sentence amend to read "For example with a 100kHz sonar, a maximum range of 270 m is about all that can be expected for even large wrecks, with small contacts (1-2 m) unlikely to be detected beyond about 120-150 m."

Page 239 3.3.5.1 second sentence amend to read "Together with the acoustic impedance there are other features of the seafloor which will affect the shape and the characteristics of the return."

Page 272 Figure 5.10 Amend heading to read "Semidiurnal".

Page 294 3.2 in the second line of the paragraph above Figure 5.18 amend to read "…when the moon or sun is aligned…"

Page 315 2.2.3 second equation below Figure 6.6 amend to read " $B_{12} = B_{P1} + \alpha_1 \pm 180°$"

Page 327 first sentence after Figure 6.16 amend "Fig. 16" to read "Fig. 6.16"

Page 327 third equation from bottom in first square root amend "a" to read "a^2"

Page 332 in first sentence below 2nd equation delete "y" so as to read " i_1, s_2 and α_1"

Page 455 b iii amend to read "the survey vessel must be equipped with a GPS Rover Receiver capable of performing OTF GPS carrier phase corrections;"

Correction 4: Applicable to the printed book and all digital files downloaded before December 21st 2010

Page 157 at the end of the second sentence after Figure 3.26 to delete "and position".

Page 157 Equation (3.46) read "cos" and not "sec" and "dx_{Roll}" not "dz_{Roll}".

Page 168 Last sentence of the paragraph below Figure 3.35 replace "specula" with "specular".

Page 169 after B) Fast Fourier Transform (FFT)…… renumber the paragraphs 5.2.1.1 to 5.2.1.4 as 5.2.1.2 to 5.2.1.5

Page 169 Paragraph B) First sentence 4.1 should be replaced by 4.2

Page 170 Renumber paragraph 5.2.1.5 as 5.2.1.6

Page 171 b) the last sentence under the equation (3.56) should be deleted and replaced by "where Δx is the apparent offset of a depth on the same survey line run in reciprocal directions".

Page 172 Figure 3.37 a) blue arrow in the wrong direction, correct direction is pointing down.

Page 175 Equation (3.59) Misprint, should read "sin" and not "sen".

Page 175 Equation (3.60) Misprint, should be c_i and not c^i

Page 178 Equation (3.76) amend σ^2_{c0} to read σc^2_0

Page 179 Paragraph 5.2.1.8.3 Second paragraph starting with "The total depth variance……." : reference to 5.1.4.4 is incorrect it should be 5.1.4.5

Page 182 Equation (3.85) Misprint "sin" not "sen"

Page 183 6.1.2 the last sentence of the first paragraph should read "2 to 7 times" instead of "3 times"

Page 185 6.3.2 Second paragraph "seawater is be pulled" amend to read " "seawater is pulled"

Page 195 Chapter 3 – Annex A second paragraph under equation (A.4) $(x,y,z)_V$ should be replaced by $(x',y',z')_N$

Page 197 Equation (A.5) should be replaced by the following:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_L = Rxy \cdot R_3(-\alpha) \cdot R_2(-\theta_T) \cdot R_1(-\theta_R) \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix}_N = T(\alpha, \theta_T, \theta_R) \begin{bmatrix} 0 \\ R\sin(\theta) \\ R\cos(\theta) \end{bmatrix}_N \qquad \textbf{(A. 1)}$$

Page 197 In the two equations below equation (A.5) replace θ_P with θ_T.

Correction 5: Applicable to the printed book and all digital files downloaded before 4 February 2011

Page 55 - Chapter Section 3.3 Mixed Method

Delete all section 3.3 From "The combination of …" to "…multiplied by 100" and replace with:

3.3 Mixed Method

When combining observations made by different systems it is necessary to make allowance for both differences in accuracy and the measurement units; for instance angles may be measured in seconds of arc to ±4" and a distance in metres to ± 0·15m. This is done by weighting each observation in proportion to its assessed quality and is achieved by scaling each observation equation by 1/Standard Error (1/σ) where σ is expressed in the same unit of measure as the observation.

Standard Errors of equipments should be defined by the authorities using them. They will normally result from a combination of experience and equipment manufacturer's guidance. A theodolite which can be read to 1" might be expected to have a σ of ±4" and a mid range Electronic Distance Measurement (EDM) a σ of (±0·05m ±5ppm). For EDM there are two elements; a fixed error, in this example 0·05m, and a variable error 5ppm i.e. 5 parts per million of the distance measured. These two elements have to be combined to give a Root Mean Square (RMS) error for the actual distance measured.

For example for a distance of 10km we would have

$$\sigma = \sqrt{(0.05)^2 + \left(10{,}000 \times 5 \times 10^{-6}\right)^2}\, m \qquad (2.16)$$

An advantage of scaling observation equations by 1/σ is that the resulting equations become dimensionless. A distance equation in metres is multiplied by 1/σ also in metres and therefore all units are removed thereby allowing different types of observation to be combined.

In Least Squares Adjustment, the mathematical process for solving a set of simultaneous equations where there are more observations than unknowns, using matrix algebra this weighting is achieved using a "Weight Matrix" of the form (for 3 observations a, b and c):

$$W = \begin{bmatrix} \frac{1}{\sigma_a^2} & 0 & 0 \\ 0 & \frac{1}{\sigma_b^2} & 0 \\ 0 & 0 & \frac{1}{\sigma_c^2} \end{bmatrix} \qquad (2.17)$$

It should be noted that the Weight Matrix, as shown above, contains 1/variance i.e. ($1/\sigma^2$) for each observation, rather than (1/σ). Whilst this might appear to be at odds with the text above, this is a function of matrix algebra and the actual result within the matrix equation is indeed to scale each observation by (1/σ).

It is common to find that EDM distances are given more weight than angles but the degree is very much a function of the particular equipments used and the distance measured.

2.1 Survey Specifications

Requirements for hydrographic surveys arise as the result of policy decisions, product user reports or requests, national defence needs, and other demands. The inception of a specific hydrographic survey project follows an evaluation of all known requirements and the establishment of priorities. Among the many objective and subjective factors that influence the establishment of priorities are national and agency goal, quantitative and qualitative measures of shipping and boating, the adequacy of existing surveys, and the rate of change of the submarine topography in the area5. To accommodate in a systematic manner different accuracy requirements for areas to be surveyed, four orders of survey are defined by IHO in publication S-44 5th Edition 2008. These are described in subsequent paragraphs. Table 1 summarizes the overall requirements but should be read in conjunction with the complete standard.6

2.1.1 Special Order This is the most rigorous of the orders and its use is intended only for those areas where under-keel clearance is critical. Because under-keel clearance is critical a full sea floor search is required and the size of the features to be detected by this search is deliberately kept small. Since under-keel clearance is critical it is considered unlikely that Special Order surveys will be conducted in waters deeper than 40 metres. Examples of areas that may warrant Special Order surveys are: berthing areas, harbours and critical areas of shipping channels.

2.1.2 Order 1a This order is intended for those areas where the sea is sufficiently shallow to allow natural or man-made features on the seabed to be a concern to the type of surface shipping expected to transit the area but where the under-keel clearance is less critical than for Special Order above. Because man-made or natural features may exist that are of concern to surface shipping, a full sea floor search is required, however the size of the feature to be detected is larger than for Special Order. Under-keel clearance becomes less critical as depth increases so the size of the feature to be detected by the full sea floor search is increased in areas where the water depth is greater than 40 metres. Order 1a surveys may be limited to water shallower than 100 metres.

2.1.3 Order 1b This order is intended for areas shallower than 100 metres where a general depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area. A full sea floor search is not required which means some features may be missed although the maximum permissible line spacing will limit the size of the features that are likely to remain undetected. This order of survey is only recommended where under-keel clearance is not considered to be an issue. An example would be an area where the seabed characteristics are such that the likelihood of there being a man-made or natural feature on the sea floor that will endanger the type of surface vessel expected to navigate the area is low.

2.1.4 Order 2 This is the least stringent order and is intended for those areas where the depth of water is such that a general depiction of the seabed is considered adequate. A full sea floor search is not required. It is recommended that Order 2 surveys are limited to areas deeper than 100 metres as once the water depth exceeds 100 metres the existence of man-made or natural features that are large enough to impact on surface navigation and yet still remain undetected by an Order 2 survey is considered to be unlikely.

[5] NOAA Hydrographic manual Part-1, Edition July 4, 1976, P-2-1, www.thsoa.org/pdf/hm1976/part1ch123.pdf

[6] International Hydrographic Organisation, Monaco, IHO Standards for Hydrographic Surveys (S-44), 5th Edition 2008.

TABLE 1

Minimum Standards for Hydrographic Surveys
(*To be read in conjunction with the full text set out in IHO S-44 5th Edition 2008*.)

Reference	Order	Special	1a	1b	2
Chapter 1	Description of areas.	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but features of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Chapter 2	Maximum allowable THU 95% Confidence level	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
Para 3.2 and note 1	Maximum allowable TVU 95% Confidence level	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
Glossary and note 2	Full Sea floor Search	Required	Required	Not required	Not required
Para 2.1 Para 3.4 Para 3.5 and note 3	Feature Detection	Cubic features > 1 metre	Cubic features > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
Para 3.6 and note 4	Recommended maximum Line Spacing	Not defined as full sea floor search is required	Not defined as full sea floor search is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
Chapter 2 and note 5	Positioning of fixed aids to navigation and topography significant to navigation. (95% Confidence level)	2 metres	2 metres	2 metres	5 metres
Chapter 2 and note 5	Positioning of the Coastline and topography less significant to navigation (95% Confidence level)	10 metres	20 metres	20 metres	20 metres
Chapter 2 and note 5	Mean position of floating aids to navigation (95% Confidence level)	10 metres	10 metres	10 metres	20 metres

See notes on next page. (Full text of S-44 5th Edition available free of charge from www.iho.int)

Notes:

1: Recognising that there are both constant and depth dependent uncertainties that affect the uncertainty of the depths, the formula below is to be used to compute, at the 95% confidence level, the maximum allowable TVU. The parameters "a" and "b" for each Order, as given in the Table, together with the depth "d" have to be introduced into the formula in order to calculate the maximum allowable TVU for a specific depth:

$$\pm \sqrt{a^2 + (b \times d)^2}$$

Where:

a	represents that portion of the uncertainty that does not vary with depth
b	is a coefficient which represents that portion of the uncertainty that varies with depth
d	is the depth
b x d	represents that portion of the uncertainty that varies with depth

2: For safety of navigation purposes, the use of an accurately specified mechanical sweep to guarantee a minimum safe clearance depth throughout an area may be considered sufficient for Special Order and Order 1a surveys.

3: A cubic feature means a regular cube each side of which has the same length. It should be noted that the IHO Special Order and Order 1a feature detection requirements of 1 metre and 2 metre cubes respectively, are minimum requirements. In certain circumstances it may be deemed necessary by the hydrographic offices / organizations to detect smaller features to minimise the risk of undetected hazards to surface navigation. For Order 1a the relaxing of feature detection criteria at 40 metres reflects the maximum expected draught of vessels.

4: The line spacing can be expanded if procedures for ensuring an adequate sounding density are used.
"Maximum Line Spacing" is to be interpreted as the:
- Spacing of sounding lines for single beam echo sounders, or the
- Distance between the useable outer limits of swaths for swath systems.

5: These only apply where such measurements are required for the survey.