Paper for Consideration by S-101PT
Discrepancy Between S-44 and S-100 Maximum Allowable Total Vertical Uncertainty

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Executive Summary:	The purpose of this paper is to inform the IHO working groups and IHO representatives of the differences between the maximum allowable Total Vertical Uncertainty (TVU) thresholds between S-44 and S-57/S-101, its implications and a proposed path forward. The HSWG Chair Team proposes to equate the maximum allowable TVU threshold calculation and rounding between S-44 and S-101 by implementing the S-44 equation to the S-101 standard. Due to the potential impact of CATZOC values requiring re-evaluation, HSWG recommends implementing this change to all products going forward, not to existing charting products. These inconsistencies have caused problems which cannot continue with S-100 implementation. This change is critical because: 1. CATZOC classification may be inconsistent across hydrographic offices depending on the method and inputs used to determine CATZOC; 2. IHO Survey Order classification cannot be used as an input to determine the CATZOC classification with respect to vertical uncertainty due to the different thresholds; 3. Conversely, specifying an IHO Survey Order is insufficient when identifying requirements for a new survey intended to support a CATZOC A1 product. 4. It is problematic to have inconsistent standards for a similar parameter within an international standards organization; 5. The root sum square method is more appropriate mathematically because it is generally the appropriate way to combine independent variables.
Related Documents:	1. IHO S-101 Ed 1.2.0 20231127 Annex A Data Classification and Encoding Guide • 27.73 category of zone of confidence in data (CATZOC) (pages 657-659) • CATZOC Table – Depth Accuracy column along with footnote 3, "Depth accuracy of depicted soundings = a + (b*d)/100" example 2. IHO S-44 Ed 6.1.0 Standards for Hydrographic Surveys • Table 1 Page 18 3. IHO S-68 Ed 1.0.0 [Guidelines and Recommendations for Hydrographic Offices for the Allocation of CATZOC/QOBD Values from Survey Data](#)
Related Projects:	S-100 Implementation

Note: FOR REASONS OF ECONOMY, DELEGATES ARE KINDLY REQUESTED TO BRING THEIR OWN COPIES OF THE DOCUMENTS TO THE MEETING

Introduction / Background

There are differences between the maximum allowable Total Vertical Uncertainty (TVU) thresholds of S-44 Standards for Hydrographic Surveys and S-57/S-101 ENC Product Specification. First, thresholds are calculated from different equations and second the variables are rounded to different precision.

	Equation	Fixed (a) Precision	Variable (b) Precision
S-44	$\sqrt{a^2 + (b \times d)^2}$	0.0 and 0.00	0.000 and 0.0000
S-57/S-101	$a + (b \times d)$	0.0	0.00

Figure 1: Equations for maximum allowable TVU and their associated precision.

The S-44 and S-57 maximum allowable TVU thresholds were developed independently of each other. Over the years this inconsistency was raised but an appropriate solution has not been identified due to; 1) the implementation of S-100 with the initiative to abolish the aggregated data quality attribute (CATZOC) and initiation of independent data quality attributes (e.g., feature detection, seafloor coverage, etc.) and 2) the potential consequences of using one equation over the other for both standards. However, CATZOC has not been removed and it is understood that CATZOC will continue through the dual fuel transition of S-57 to S-101 causing this inconsistency to remain for the next decade.

Analysis/Discussion

The main implication is the inability to determine the CATZOC classification from the Survey Order Classification with respect to vertical uncertainty. We recognize that hydrographic offices may use a one-to-one mapping between Survey Order and CATZOC even though the standards do not align.

This is illustrated in the graph below which demonstrates the comparison of maximum TVU for S-44 Orders 1a & 1b compared to CATZOC A1. For depths <145 meters, the S-44 equation and rounding rules create a lower threshold (blue line) and for depths > 145 meters the S-57/S-101 equation creates a lower threshold (orange line). Following the math in the current standards, an IHO Order 1a or 1b survey in 200 meters of water with a TVU of 2.55m cannot be classified as a CATZOC A1.
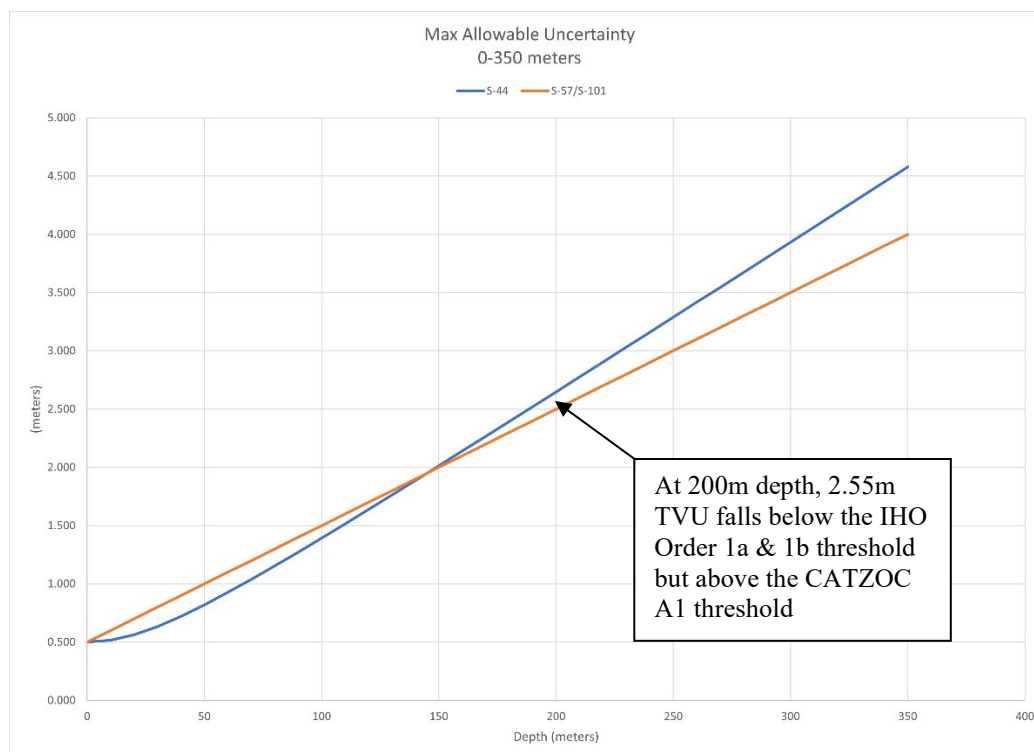

Figure 2: Maximum TVU for S-44 Orders 1a & 1b compared to CATZOC A1

We understand that the vertical uncertainty of a hydrographic survey is not the only component of a CATZOC classification of a resultant product. We also understand that the difference between these two definitions is relatively small. However, edge cases that preclude automated handling of data in accordance with expected behaviors is generally problematic.

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Using the same example as above with Order 1a & 1b compared to CATZOC A1, the areas are highlighted in yellow in the figure below which have been labeled as "Region A" and "Region B". Either of these scenarios should have thrown a red flag as they would be out of the ordinary.

- Region A (<145 meters): A survey could not be classified as Order 1a or 1b but can be classified as supporting a CATZOC A1 product.
- Region B (>145 meters): A survey can be classified as Order 1a or 1b but cannot be classified as supporting a CATZOC A1 product.
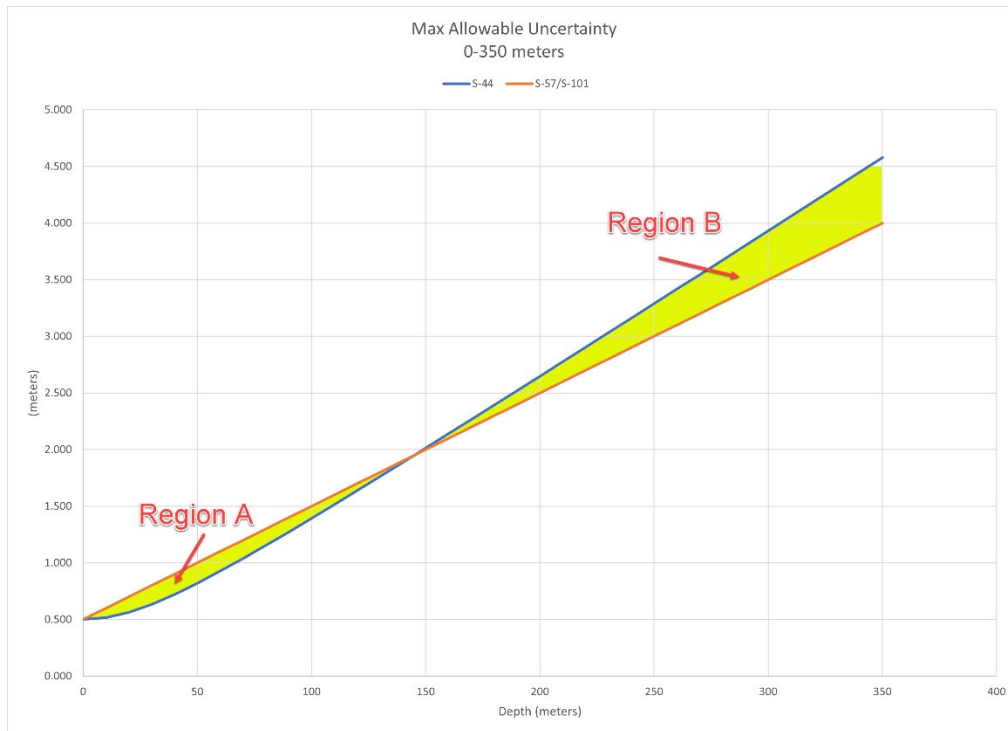
This inconsistency is further illustrated in the new S-68 "Guidelines and Recommendations for Hydrographic Offices for the Allocation of CATZOC/QOBD Values from Survey Data". The Data Quality Working Group (DQWG) took this complex issue and demonstrated the inconsistency in the depth accuracy table on page 7 (note the split cells with red and green). This table clearly shows there is a misalignment between the standards and IHO Survey Order cannot be used to predetermine the CATZOC classification with respect to vertical uncertainty of the product in all depths. More frustratingly, this also shows that if a hydrographic office is specifying for a survey intended to support a CATZOC A1 product, it will need to include additional vertical uncertainty standards on top of IHO Order 1a or 1b to meet the charting standard.

7.5   Check 5: Depth accuracy

Table 7-5 – Valid CATZOC Capabilities for the Survey Orders based on depth accuracy

Vertical Accuracy	Survey Order tolerance	$\sqrt{(0.15^2 + (0.0075 \cdot d)^2)}$	$\sqrt{(0.25^2 + (0.0075 \cdot d)^2)}$	$\sqrt{(0.5^2 + (0.013 \cdot d)^2)}$		$\sqrt{(0.5^2 + (0.013 \cdot d)^2)}$		$\sqrt{(1.0^2 + (0.023 \cdot d)^2)}$
ZOC tolerance	Survey Zoc/QoBD	Exclusive	Special	1a		1b		2
0.5m+0.01*d	A1/1			d≤145 m	d≥145 m	d≤145 m	d≥145 m	
1.0m+0.02*d	A2/2							
1.0m+0.02*d	B/3							
2.0m+0.05*d	C/4							
>2.0m+0.05*d	D/5							
N/A	U/6							
N/A	-/Oceanic							

d=depth

Figure 3: Extract of Depth Accuracy table from IHO S-68 document.

Alternatives for Equating TVU Thresholds:

There are three alternatives for addressing this issue:

Option 1:

Change the S-57/S-100 equation and rounding precision to the S-44 equation and rounding precision.

	Equation	Fixed (a) Precision	Variable (b) Precision
S-44	$\sqrt{a^2 + (b \times d)^2}$	0.0 and 0.00	0.000 and 0.0000
S-57/S-101	$\sqrt{a^2 + (b \times d)^2}$	0.0 and 0.00	0.000 and 0.0000

    A. Tighter S-57/S-101 accuracy threshold in shallower waters (i.e., < 145 meters) resulting in surveys with smaller vertical uncertainty to be classified as CATZOC A1, which better supports safety of navigation.

    B. The root sum square method is more appropriate mathematically because it is generally the appropriate way to combine independent variables.

Option 2:

Change the S-44 equation and rounding precision to the S-57/S-100 equation and rounding precision.

	Equation	Fixed (a) Precision	Variable (b) Precision
S-44	$a + (b \times d)$	0.0	0.00
S-57/S-101	$a + (b \times d)$	0.0	0.00

    A. For S-44, this is a more relaxed threshold in shallower waters (i.e., < 145 meters) resulting in surveys with higher vertical uncertainty to be classified as Order 1, which increases risk for safety of navigation in shallower waters.

    B. A simplified method to calculate the uncertainty threshold and in most cases this approach would not follow the same calculation method (i.e., root sum squared) as standard error model calculations.

    C. This would diverge from the way uncertainty is typically calculated in sciences, mathematics, and statistics where measurements and their uncertainties are aggregated.

Option 3:

Make no change and continue with different equations and rounding rules between S-44 and S-57/S-101 standards.

    A. Under this scenario, hydrographic offices should recognize that an exact one-to-one mapping between IHO Survey Order and CATZOC is impossible. This implies either:
        a. a re-thresholding of vertical uncertainly in the survey acceptance and product application phases of the chart compilation process, or
        b. changing the vertical uncertainty standards of hydrographic survey specifications away from S-44, or
        c. accepting potential mis-classification of CATZOC for some surveys.

Conclusions

As noted above, these discrepancies across standards have potentially already caused inconsistencies across hydrographic offices of the classification of hydrographic data on the nautical chart (CATZOC and QoBD).

The following implications must be taken into consideration:

1) Hydrographic offices that use S-44 Orders to determine CATZOC should recognize the risk that surveys > 145 meters (Region B above) may have been mis-classified as supporting CATZOC A1 products if the actual TVU is greater than the S-57/S-100 TVU threshold even though it was an Order 1a or 1b survey.

2) Hydrographic offices that use the S-57/S-101 TVU threshold equation and do not consider survey Order to determine CATZOC should recognize the risk that some surveys <145 meters (Region A above) may support a CATZOC A1 product but not meet survey Order 1a or 1b with respect to vertical uncertainty.

If no change is made there will be the continued:
- inability to realize CATZOC and/or QoBD classifications with regards to vertical uncertainty from S-44 Survey Orders.

- lack of standardization and discrepancies of standards within the IHO, leading to potential reputational impact.
- Potentially incorrect CATZOC and/or QoBD classifications.

Recommendations

There is a strong consensus within HSWG to recommend Option 1 above. Therefore, the HSWG Chair Team recommends standardizing the maximum allowable TVU threshold calculation and rounding between S-44 and S-101 by implementing the S-44 equation to the S-101 standard. Due to the potential impact of CATZOC values requiring re-evaluation, HSWG recommends implementing this change as soon as possible to all products going forward, not to existing charting products.

Justification and Impacts

This change is important because:

1. IHO Survey Order classification cannot be used as an input to determine the CATZOC classification with respect to vertical uncertainty due to the different thresholds;
2. It is problematic to have inconsistent requirements within an international standards organization
3. The root sum square method is more appropriate mathematically because it is generally the appropriate way to combine independent variables.
4. CATZOC classification may be inconsistent across hydrographic offices depending on the method and inputs used to determine CATZOC.

Due to the recommendation applying only to forward procedures, not backward, the impacts would be limited to changes in future production, not to existing charting products. Some of the impacts would include updates to S-101 Annex A Data Classification and Encoding, updates to hydrographic office data quality evaluation procedures for nautical products and updates to commercial and custom software code.

Action Required of S-101

The S-101 is invited to:

a. endorse the HSWG's recommendation and work with appropriate IHO working groups (HSWG, DQWG) on a strategic implementation plan

b. agree with the HSWG's recommendation, but make modifications to their recommendation

c. note the HSWG's recommendation but make no changes to standards or procedures. Discuss any potential next steps with HSWG Chair Team.