Information Paper for consideration by TSMAD, DIPWG, CSPCWG, TWLWG

New ways of representing quality of bathymetric data for surface navigation

Submitted by: DQWG

Executive Summary:

The DQWG has developed a hierarchical model for display of quality of bathymetric data in the next generation of ENC. The model uses a three tier system, suitable for demarcation and indication of areas of differing quality on screen via either a range of colours or patterns. Use of Red, Amber and Green is specifically not recommended.

The proposed system allows for a direct translation from S-57 and the existing CATZOC system, but also allows for different individual parameters, such as horizontal or vertical uncertainty, or achievement of full seafloor feature detection, to drive the overall assessment indication. Further, the system allows for vertical 'stacking' of differing levels of uncertainty, such that a vessel of shallow draft may be operating within the depth limit of a swept area, while a vessel in the same area with a draft deeper than the swept depth may encounter information of much lower quality. In addition to dredged and swept areas, this caters for LiDAR reaching an extinction depth, and potential future use of satellite derived bathymetry. Both share, or will share, the ability to produce a layer of known safe water in the upper water column, with depths below being of lower quality or completely unknown.

Significantly, DQWG has noted that there must be a significant cultural shift in the understanding of what constitutes a high quality ENC; it is absolutely essential that a 'high quality ENC' is one that accurately represents the quality of the information currently contained in that ENC in relation to current real-world conditions, rather than one that exclusively contains only very modern data, or worse, one which fails to recognise degradation over time or artificially misrepresents the quality as being better than it actually ever was.

Additional work will be required by DIPWG (or the equivalent WG following HSSC restructure) to finalise presentation. Specific requirements for attributes and enumerates inclusion within S-100 and S-101 will be passed directly to TSMAD (or the equivalent WG following HSSC restructure).

Related Documents: DQWG Work Plan 2013-14, Task E

Related Projects: S-100, S-101

Background

The IHO Data Quality Working Group has been tasked to 'investigate ways of ensuring that ECDIS displays provide a clear warning or indication to the mariner on the quality of the underlying survey data, through appropriate use of the attribute CATZOC and/or improvement of the existing display capabilities (IHO Task 2.5.2 refers)'.

DQWG has conducted a detailed analysis, considering the following:

- Use of objective thresholds between the three tiers, rather than the very subjective assessments apparent in the existing use of CATZOC.
- The usefulness of those layers, particularly in support of surface navigation in constrained waterways.
- Mapping between the five tiers of CATZOC and the directed three tiers of "son of CATZOC".
- Ability to accept a single value of CATZOC within any existing ENC, and populate the component attributes using default values from existing CATZOC
- An ability to eventually accept tide as an input when it becomes available in the future to refine the layer of quality within the water column in which a ship is operating.
- With regard to display, the need to reserve a red / amber / green display to a go or no-go indicator which includes the combination of bathymetry, tide, data quality and dynamic draught. Noting that this type of indicator, using these inputs, is already in use within ports using dynamic under-keel clearance systems, use of the same display mechanisms for a different purpose would create significant confusion.

The three quality tiers – Good, Fair and Low

All tiers are focussed on quality of bathymetric data in relation to surface navigation only. Differing bathymetric data quality assessments can be "stacked" vertically throughout the water column.

Good. An area of **Good** quality is one that can support minimal under-keel / manoeuvring clearances of typically 0.5m metre or less within ports and their approach routes. The primary measures include very good horizontal and vertical uncertainties, as well as full seafloor feature detection (to 95% confidence level) with least depths determined, in an area which is stable and not subject to temporal variation. S-44 Special Order and Order 1a (if the seabed remains unchanged) would typically lie within this quality tier, as would an area of regularly maintained depth or CATZOC A1.

Fair. An area of **Fair** quality has slightly higher levels of horizontal and vertical uncertainty, but meets the same requirements for full feature detection (but a larger size of feature), as well as meeting the same requirement for either seabed stability. However, it also permits an area where the seabed is subject to change through the horizontal movement of sand waves, so long as the least depth in an area remains substantially stable. CATZOC A2 would typically lie within this tier, as would S-44 Order 1b and Order 2 and some areas of CATZOC B, as long as full seafloor feature detection has been achieved in all cases.

Low. An area of **Low** quality is one where full seafloor feature detection has not been achieved, irrespective of the horizontal or vertical accuracies achieved. All assessed areas of bathymetry not meeting the requirements of **Good** or **Fair** are considered **Low**. However, this should not be assumed that this tier is unsuitable for navigation, merely that is cannot be specifically guaranteed as being suitable. The depth of water, draft of vessel or height of tide may be factors which determine whether the risk of entering such an area is acceptable.

Unassessed. A fourth tier remains within the proposed system, primarily to cater for mapping from S-57 and CATZOC. This is "**Unassessed**", which remains in widespread use, even though the usefulness of this existing CATZOC category for mariners is limited. This fourth tier does not specifically require a fourth tier for depiction.

There may be more appropriate terms to describe the three tiers of quality of bathymetric data. The terms Good, Fair and Low are used in this paper but may be revised based upon feedback to ensure the terms are easily understood.

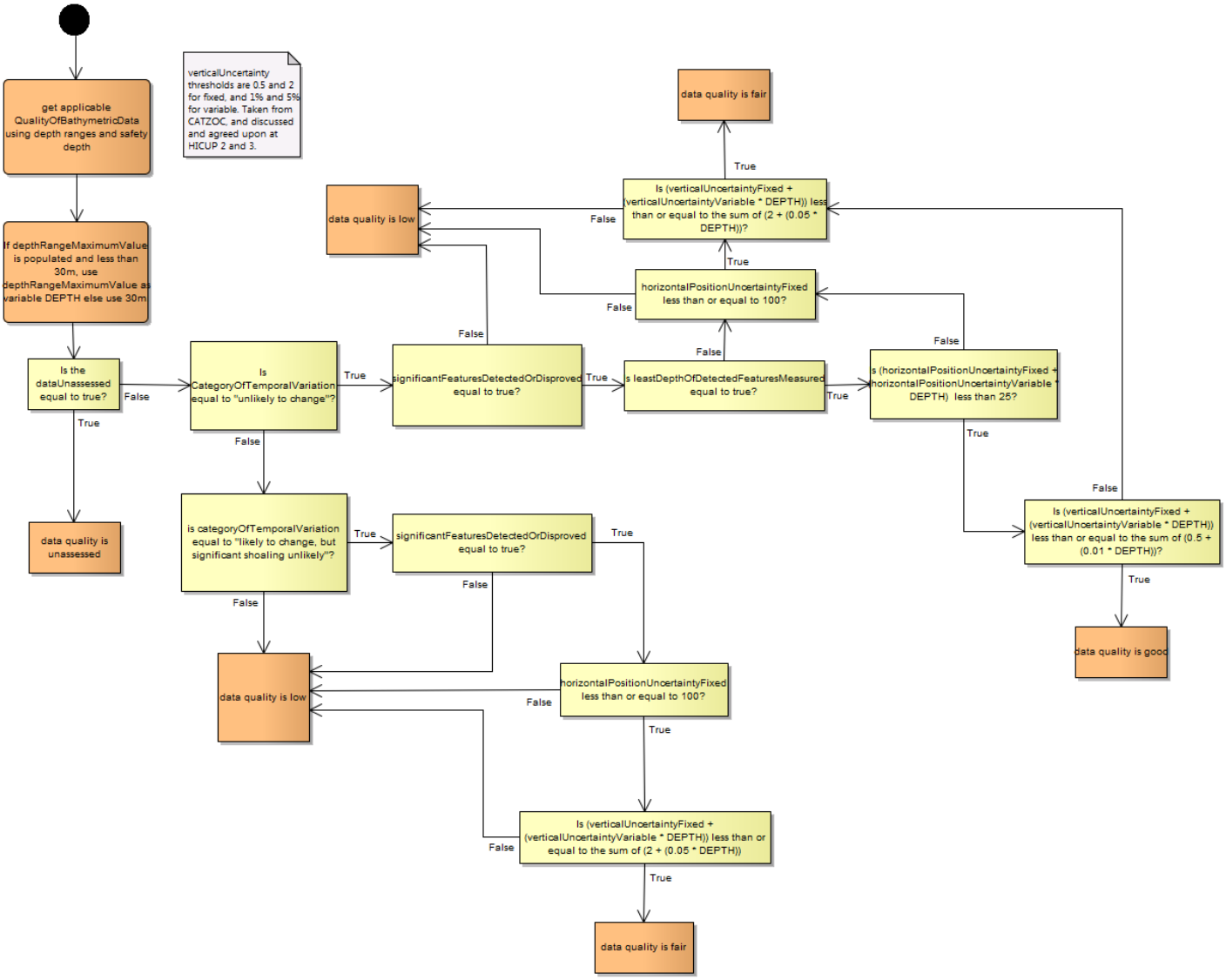


Figure 1 – Logic Tree

Attribute Thresholds for Good, Fair and Low

	Good	**Fair**	**Low**
Is there a Depth Range defined?	*Differing tiers of quality of bathymetric data can be "stacked" within the water column. If the Depth Range Maximum Value is populated and less than 30, use DRMV. If greater, use 30 metres. This is used when combining fixed and variable uncertainties to derive a total combined uncertainty which is applicable to surface navigation.*		
Is the data Unassessed?	*The data remains categorised as Unassessed if it is Unassessed in S-57 CATZOC.*		
Is the data subject to temporal variation?	*No.*	*Yes, but there is only horizontal migration within the defined area.*	*Yes, there may also be vertical change within the defined area.*
Have all (95%) significant seafloor features been detected or disproved?	*Yes, within the defined area and depth range.*	*Yes, within the defined area and depth range.*	*No.*
Have least depths over all significant seafloor features been measured within the required horizontal and vertical uncertainty ranges?	*Yes, within the defined area and depth range.* *Hor: < / = 25* *Ver < / = (0.5+(0.01xD))*	*Yes, within the defined area and depth range.* *Hor: < / = 100* *Ver < / = (2+(0.05xD))*	*No.*
Are areas within the quality tier that have different component attributes identifiable?	*No.*	*Yes.*	*Yes.*

Layering of quality tiers within the water column

The quality of bathymetric data is not always the same throughout the full height of the water column. Examples include a declared maximum safe depth derived from bar sweeping or similar, LiDAR which has reached an identifiable extinction depth and confirmed no hazards exist within that layer, or satellite derived bathymetry once more consistent confidence in the possible results has evolved. Consequently, it must be possible to "stack" differing tiers of quality within the full height of the water column. Notably, an area of **Fair** or **Low** quality data can be overlaid by one or more layers of higher quality data within the water column.

Compatibility with S-57 and CATZOC

Most nations are limited in their capacity to radically alter the manner in which hydrographic surveys are categorised with regard to data quality, while some have yet to apply meaningful Zones Of Confidence (ZOC / CATZOC) to their ENC. The preferred option is to present information which already exists, or to which producer nations are already working, in a more intuitive manner, rather than developing an entirely new data quality system. It is considered absolutely critical that any new scheme does not force new requirements upon chart producers, even though it offers the opportunity to do so.

Combining fixed and variable uncertainties

The existing Zones Of Confidence system uses the combination of both a fixed uncertainty and a depth related variable uncertainty. This does not translate well to either a systematic decision path, and is very poorly understood by mariners. To address this systematic risk, as well as ensure relevance to surface shipping, a default depth of 30m has been included for areas where the depth of water would otherwise allow a very large variable component.

Depiction

While a three tier system can be made to work, it must be accompanied by a fourth data quality category of "**Unassessed**" if compatibility with S-57 CATZOC is to be retained. However, there is nothing preventing an **Unassessed** area being shown with the same symbology as an area considered **Low**.

In using a three tier depiction system, the use of Red, Amber and Green is strongly not recommended. Red and green are immediately understood to be "go" or "no-go". However, the quality of bathymetric data does not define such a decision – the decision is much more complex and can only be made by the master of the vessel taking into account a much broader range of considerations, or using a system performing the same function.

Red areas are already in use within dynamic under-keel clearance systems, with red used to depict a definitive area in which (or when) a ship simply cannot go in relation to vessel draft, depth of water, height of tide, sea-state and the pitch, heave, speed and squat / settlement characteristics of individual vessels. The quality of bathymetric data is simply one component of this complex dynamic calculation, and is not a definitive statement of where or when a ship can go. If red is to be used for an area within an ENC display, the nearest equivalent would simply be to change the area defined by the safety depth contour to red rather than continuing to use blue in accordance with current generation ENC.

An area- based colour coding or pattern is recommended. A repeating pattern of isolated symbols, such as currently used to depict CATZOC, is not recommended. It is visually confusing and difficult to comprehend (irrespective of whether it is understood). When used for small areas, the symbols can also be cut off and actually result in an apparently different assessment.

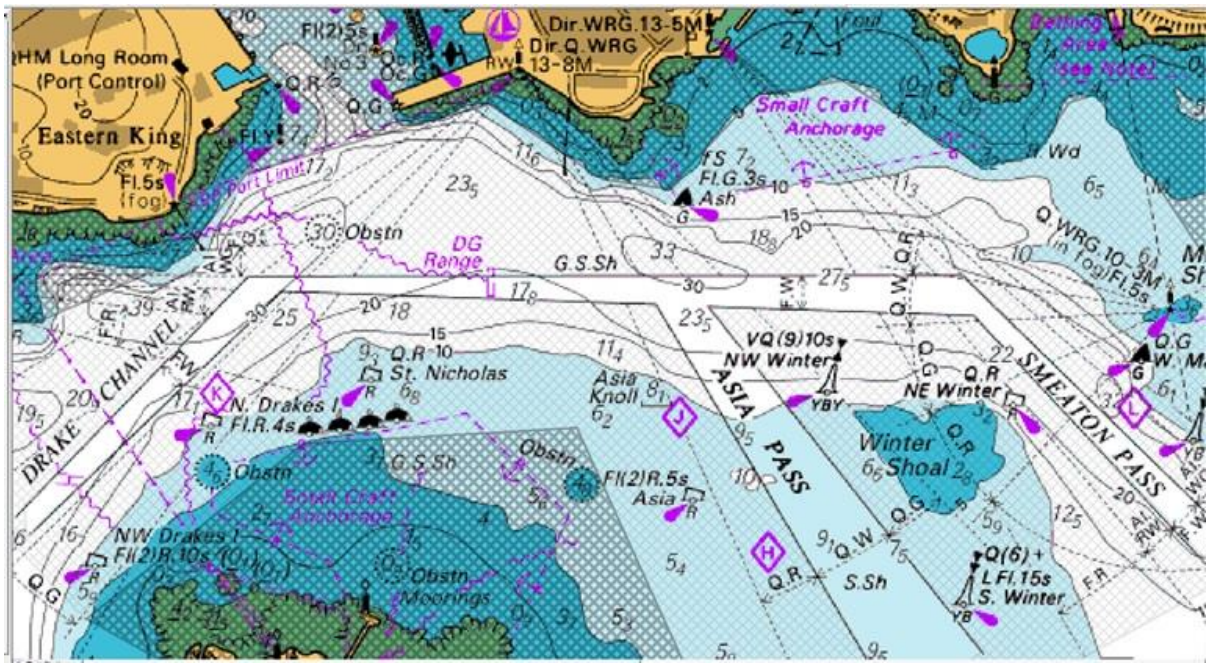


Figure 2 – A possible depiction method for three tiers of quality of bathymetric data

How deep should data quality indicators for surface navigation extend?

While the "son of CATZOC" system is intended to support surface navigation only, features hazardous to surface navigation can lie in areas of apparently very deep water. This is particularly prevalent in remote areas of the Arctic, Antarctic and Pacific Oceans. The existing standards of coverage in most oceanic areas is likely to result in most ocean areas being shown as Low quality. The proposed system permits a hydrographic office to place an upper layer of Fair or Good quality over the Low (deeper) layer in the water column if they believe that this is appropriate. However, this facility should clearly be used with caution.

Translating Zones Of Confidence to a three colour data quality indicator system

The existing full ZOC Table is attached as Table 1. In charting use, as well as in application, it can become ambiguous as it is invariably shown or used in abridged form and without the accompanying notes shown in Table 2. The absence of Table 2 leads mariners to question "How big is a significant seafloor feature?" The answer is most important, as for ZOC A1 and A2, it is larger than the uncertainty associated with measured depths, though these at least have a specific requirement for all seafloor features to be detected. ZOC B and lower do not have this specific requirement. In shallow water the risk of an undetected feature can significantly outweigh the quality of those depths which have been collected (rather than those which have not). Even in very deep water, the risk of encountering an undetected seamount remains significant in many oceanic areas. However, many assessors make a subjective assessment that, on balance, the water depth in an area is sufficient to mitigate risk. This is a highly subjective assessment.

Noting that a move from a five tier to three tier system must result in broader groupings, and that the rational approach is to be as objective as possible, the threshold requirement for

feature detection will result in very large areas being indicated as Low quality. However, it remains possible for an assessor to create a higher quality layer in the upper water column if they have sufficient evidence that safe navigation can be guaranteed in a defined area. In particular, the feature detection requirements remain an intrinsic part of the proposed system.

Further actions

Successful development of '*ways of ensuring that ECDIS displays provide a clear warning or indication to the mariner on the quality of the underlying survey data, through appropriate use of the attribute CATZOC and/or improvement of the existing display capabilities (IHO Task 2.5.2)*' will require the coordinated contribution of several working groups and cannot be achieved in isolation.

TSMAD will be invited to note the parameters and values required to drive a revised system for a quality of bathymetric data. These will be provided directly.

DIPWG is invited to note that requirements will soon be passed to that WG to develop a display regime for area-based colour bands providing three risk tiers which would be displayed as 'temporary overlays' which can be switched on or off as necessary by the ECDIS operator.

DIPWG will be further invited to:

- Note that colour- coding of individual soundings does not meet depiction requirements in areas of sparse data;

- Note the visual confusion which is already associated with S-57 CATZOC, suggesting that an area based pattern would be more effective than a repeating pattern of separate symbols;

- Note the requirement for internal limits within areas of **Fair** and **Low**;

- Note the requirement for areas of **Unassessed** data to use the same symbology as for **Low**.

CSPCWG will be invited to note the proposed scheme and comment upon any aspect, as well as consider any desirable parallels with paper charts (but also noting that paper charts and ENC already differ significantly with regard to quality indicators and paper charts and may have difficulty representing "stacked" bathymetric data quality layers).

TWLWG will be invited to note the desirability of applying predicted or real-time tides to the overall ECDIS / ENC display.

ZOC	Position Accuracy	Depth Accuracy		Seafloor Coverage	Typical Survey Characteristics
A1	± 5 m + 5% depth	=0.50 + 1% depth		Full area search undertaken. Significant seafloor features[1] detected and depths measured.	Controlled, systematic survey[2] high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 0.6 ± 0.8 ± 1.5 ± 10.5		
A2	± 20 m	= 1.00 + 2% depth		Full area search undertaken. Significant seafloor features[1] detected and depths measured.	Controlled, systematic survey[2] achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder[3] and a sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 1.2 ± 1.6 ± 3.0 ± 21.0		
B	± 50 m	= 1.00 + 2% depth		Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey[2] achieving similar depth but lesser position accuracies than ZOCA2, using a modern survey echosounder[3], but no sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 1.2 ± 1.6 ± 3.0 ± 21.0		
C	± 500 m	= 2.00 + 5% depth		Full area search not achieved, depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 2.5 ± 3.5 ± 7.0 ± 52.0		
D	worse than ZOC C	Worse Than ZOC C		Full area search not achieved, large depth anomalies may be expected.	Poor quality data or data that cannot be quality assessed due to lack of information.
U	Unassessed - The quality of the bathymetric data has yet to be assessed				

Table 1 – Zones Of Confidence Full Table

Notes:	
1.	Significant seafloor features are defined as those rising above depicted depths by more than: Depth — Significant Feature less than 40 m — 2 m greater than 40 m — 10% depth A full seafloor search indicates that a systematic survey was conducted using detection systems, depth measurement systems, procedures, and trained personnel designed to detect and measure depths on significant seafloor features. Significant features are included on the chart as scale allows. It is impossible to guarantee that no significant feature could remain undetected, and significant features may have become present in the area since the time of the survey.
2.	Controlled, systematic surveys (ZOC A1, A2 and B) - surveys comprising planned survey lines, on a geodetic datum that can be transformed to WGS 84.
3.	Modern survey echo sounder - a high precision single beam depth measuring equipment, generally including all survey echo sounders designed post 1970.

Table 2 – Zones Of Confidence Notes

Annex A Conversion of M_QUAL to QualityOfBathymetricData

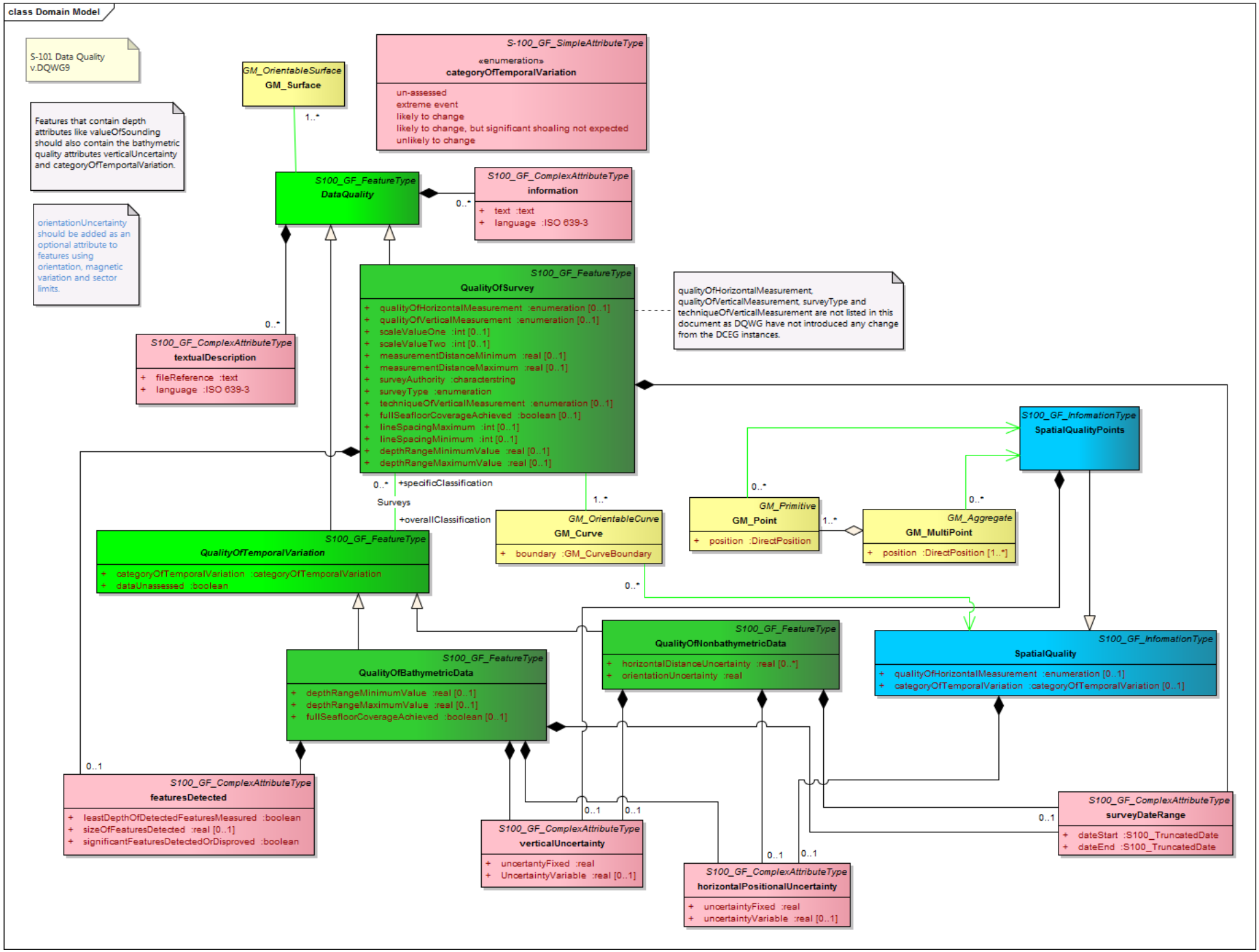
M_QUAL (S-57)		QualityOfBathymetricData (S-101)		Category of zone of confidence in data					
CATQUA									
CATZOC	ZOC			A1	A2	B	C	D	U
	Position Accuracy	horizontalPositionalUncertainty	UncertaintyFixed	5	20	50	500	empty	No value
			UncertaintyVariable	0.05					
	Depth Accuracy	verticalUncertainty	UncertaintyFixed	0.5	1	1	2	empty	No value
			UncertaintyVariable	0.01	0.02	0.02	0.05	empty	
	Typical Survey Characteristics	techniqueOfVerticalMeasurement							
		featuresDetected	significantFeaturesDetected	yes	yes	no	no	no	No value
			sizeOfFeaturesDetected	2	2	empty	empty	empty	No value
			leastDepthOfDetectedFeaturesMeasured	yes	yes	no	no	no	No value
	Seafloor Coverage	fullSeafloorCoverageAchieved		yes	yes	no	no	no	No value
		dataUnassessed		false	false	false	false	false	true
DRVAL1		depthRangeMinimumValue							
DRVAL2		depthRangeMaximumValue							
POSACC		horizontalPositionalUncertainty	UncertaintyFixed *any value goes here if different than values set by CATZOC conversion.						
			UncertaintyVariable * values set by CATZOC conversion.						
SOUACC		verticalUncertainty	UncertaintyFixed *any value goes here if different than values set by CATZOC conversion.						

		UncertaintyVariable * values set by CATZOC conversion.						
SUREND	surveyDateRange > DateEnd							
SURSTA	surveyDateRange > DateStart							
TECSOU								
VERDAT								
INFORM NINFOM	Information *if INFORM and NINFOM is present in M_QUAL, two instances of information are needed.							
TXTDSC NTXTDS	textualDescription *if TXTDSC and NTXTDS is present in M_QUAL, two instances of textualDescription are needed.							
RECDAT								
RECIND								
SORDAT								
SORIND								
	categoryOfTemporalVariation *default value is not likely to change, but users of a convertor should be made aware that this value is inappropriate for areas of mobile seabed.		Not likely to change	Not likely to change	Not likely to change	Not likely to change	Not likely to change	Not likely to change

Annex B Conversion of M_SREL to QualityOfSurvey

M_SREL	QualityOfSurvey		
QUAPOS	qualityOfHorizontalMeasurement		
QUASOU	qualityOfVerticalMeasurement		
SCVAL1	scaleValue1		
SCVAL2	scaleValue2		
	measurementDistanceMinimum		
	measurementDistanceMaximum		
SURATH	surveyAuthority		
SURTYP	surveyType		
TECSOU	techniqueOfVerticalMeasurement		
	fullSeafloorCoverageAchieved		
SDISMX	lineSpacingMaximum		
SDISMN	lineSpacingMininum		
	featuresDetected	significantFeaturesDetected	
		sizeOfFeaturesDetected	
		leastDepthOfDetectedFeaturesMeasured	
	depthRangeMinimumValue		
	depthRangeMaximumValue		
SURSTA	surveyDateRange	dateStart	
SUREND		dateEnd	
INFORM	information		
NINFOM	information		
TXTDSC	textualDescription		
NTXTDS	textualDescription		
RECDAT			
RECIND			
SORDAT			
SORIND			

Annex C
S101 Data Model



Annex D Example of Overlapping QualityOfBathymetricData objects