S-101 PROJECT TEAM

Visualization methodology of Quality of Bathymetric Data

and

S-100 Validation Checks

Presented by Chair of the
Data Quality Working Group

Data Quality

Good data quality does not mean
that the quality of the data has to be good.

It means that the end user is well informed
how good the Quality of the Data is.

IHO Data Quality Working Group [1]

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English	Français
DATA QUALITY WORKING GROUP (DQWG)	***GROUPE DE TRAVAIL SUR LA QUALITE DES DONNEES (DQWG)***
Chair: Mr. Rogier BROEKMAN (Netherlands) **Vice-Chair:** Mr. Sean LEGEER (USA) **Secretary:** Vacant	***Président :*** *M. Rogier BROEKMAN (Pays-Bas)* ***Vice-président :*** *M. Sean LEGEER (Etats-Unis d'Amérique)* ***Secrétaire :*** *Vacant*
Objectives: The primary objective of the DQWG is to develop appropriate methods of classifying and depicting the quality of digital hydrographic information. See **Terms of Reference**, for further details.	***Objectifs :*** *Développer des méthodes appropriées de classement et de description de la qualité des informations hydrographiques numériques.* Voir le **mandat** pour plus de détails.
Meetings: The WG works primarily by correspondence and aims to meet at least once every two years, normally in connection with another convenient IHO forum. See DQWG Work Plan as part of the HSSC Work Plan.	***Réunions:*** *Le GT travaille essentiellement par correspondance et a pour objectif de se réunir au moins une fois tous les deux ans, normalement en liaison avec d'autres réunions appropriées de l'OHI. Voir le programme de travail du DQWG au sein du programme de travail du HSSC.*
Members: The WG comprises representatives of IHO Member States, Expert Contributors and Observers from International Organizations. Expert Contributors principally from industry participate in the WG at the invitation of the Chair. See the list of WG Members.	***Membres:*** *Le GT est composé de représentants des Etats membres de l'OHI, d´intervenants à titre d'experts et d´observateurs d´organisations internationales. La participation des intervenants à titre d'experts, représentant principalement l'industrie, est soumise à l'approbation du président. Voir la liste des membres du GT.*

List of WG Members:

- *Australia*
- Brazil
- Canada
- Denmark
- Finland
- France
- *India*
- Italy
- *Indonesia*
- Japan
- *Mexico*
- Netherlands
- Norway
- *South Africa*
- *Sweden*
- UK
- USA

Expert Contributors:

- *TELEDYNE*
- *IC-ENC*
- INTERTANKO
- PRIMAR
- IHO TSSO
- IHO Secr.

italic = correspondence member

IHO Data Quality Working Group [2]

Next Meeting / *Prochaine réunion*	
15th meeting, Monaco (4-7 February 2020)	Documents

Past Meetings / *Réunions passées*	
14th meeting, Monaco (5-8 February 2019)	Documents
13th meeting (incl. workshop), Monaco (15-19 January 2018)	Documents
12th meeting, The Hague, Netherlands (13-15 June 2017)	Documents
11th meeting, Arlington, Virginia, USA (10-12 May 2016)	Documents
10th meeting, Brest, France (7-9 July 2015)	Documents
9th meeting, Poole, UK (3-7 November 2014)	Documents
8th meeting, Wollongong, Australia (25-27 March 2014)	Documents
7th meeting, Fredericton, New Brunswick, Canada (16-18 July 2013)	Documents
6th meeting, Silver Spring, Maryland, USA (24-26 July 2012)	Documents
5th meeting, Monaco (15-18 November 2011)	Documents
4th meeting, Helsinki, Finland (14-17 June 2011)	Documents
3rd meeting, Rostock, Germany (5 November 2010)	Documents
2nd meeting, Norfolk, Virginia, USA (10 May 2009)	Minutes
1st meeting, Bath, United Kingdom (23 September 2008)	Minutes

DQWG Reference Documents / *Documents de référence du DQWG*	
National Methodologies: from survey data to CATZOC values	Australia , **France** (eng ; fra), Netherlands, Norway, United Kingdom, USA
	Link

What problem needs to be resolved?

1. Paper CHRIS19-01.5B (former HSSC).

- **Enhancing the Presentation of Survey Quality in an ENC** (submitted by UK).
- Executive summary: To consider a recommendation of the UK's Marine Accident Investigation Branch (MAIB) arising from its investigation into the grounding of the jack-up barge Octopus.
- Specifically, to investigate ways of ensuring that ECDIS displays provide a clear warning or indication to the mariner whenever the survey data used to produce the electronic chart in use is of poor quality.
- UK MAIB Report No 18/2007, published 9 August 2007: "Report of the investigation of the grounding of the jack-up barge Octopus towed by the tug Harald, Stronsay Firth, Orkney Islands, 8 September 2006".
- Damage value: approximate UK£1M

What has been done from 2007 to 2019? [1]

2. IHO DQWG was tasked to develop a method to depict Data Quality in ENC

- "The DQWG concluded that to support future expected uses of data quality in S-101, hydrographic offices should populate POSACC, SOUACC and TECSOU in M_QUAL if these values are better than specified by the CATZOC shown for the area. This will allow S-101 to build a different (as yet undecided) composite data quality indicator from S-57 data sets." (HSSC3-05.6A).
- "The University of Southern Mississippi (USM) propose a two stage approach: stage 1 will visualize individual data quality indicators (e.g. color banding based upon horizontal uncertainty). Stage 2 will look at how these individual visualizations can be combined to provide a composite indicator." (HSSC4-05.6A).

What has been done from 2007 to 2019? [2]

2. IHO DQWG was tasked to develop a method to depict Data Quality in ENC

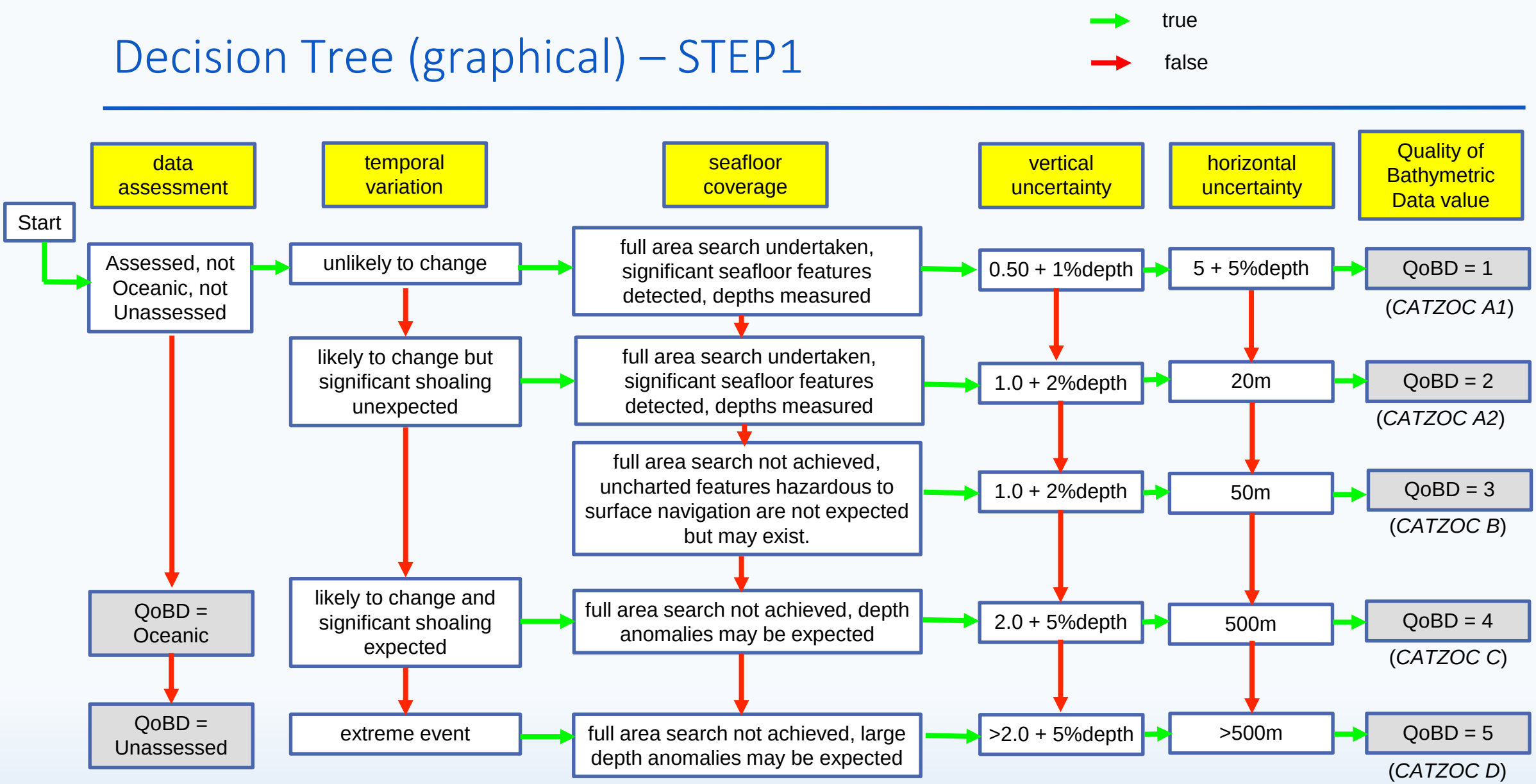
- “Essentially the findings of USM confirmed that the concept of representing data quality by a color wash overlay of red for poor, yellow (amber) for medium and green (or clear) for good is the most intuitive and clearest means of doing so.” (HSSC5-05.6A).
- “One conclusion from this work was that the long held view that the final data quality display should be a red, amber or green color wash overlay was abandoned.” (HSSC6-05.6A rev.1).
- DQWG14-08C: Proposal for a new method to display quality information
- DQWG14: workshop to discuss this paper -> Proposal to HSSC-11 (May 2019)

The solution to the problem

3. Proposal for a conditional visualization methodology of Quality of Bathymetric Data.

1. Decision Tree How to allocate appropriate Quality of Bathymetric Data values.
2. Introduction of the concept of a SAFETY ZONE around the vessel.
3. Get the POSACC and VERACC values of isolated features dangerous to navigation.
4. If not available, make use of the Aggregated value of QoBD and apply this to isolated features dangerous to navigation.
5. Draw circles around isolated features if they are within the SAFETY ZONE.
6. Provide clear visible alarms to the Mariners -> SAFETY ZONE ALERT / GROUNDING RISK.
7. Make use of smart algorithms to show this information when needed.

Decision Tree (graphical) – STEP1



Decision Tree (textual) – STEP 1

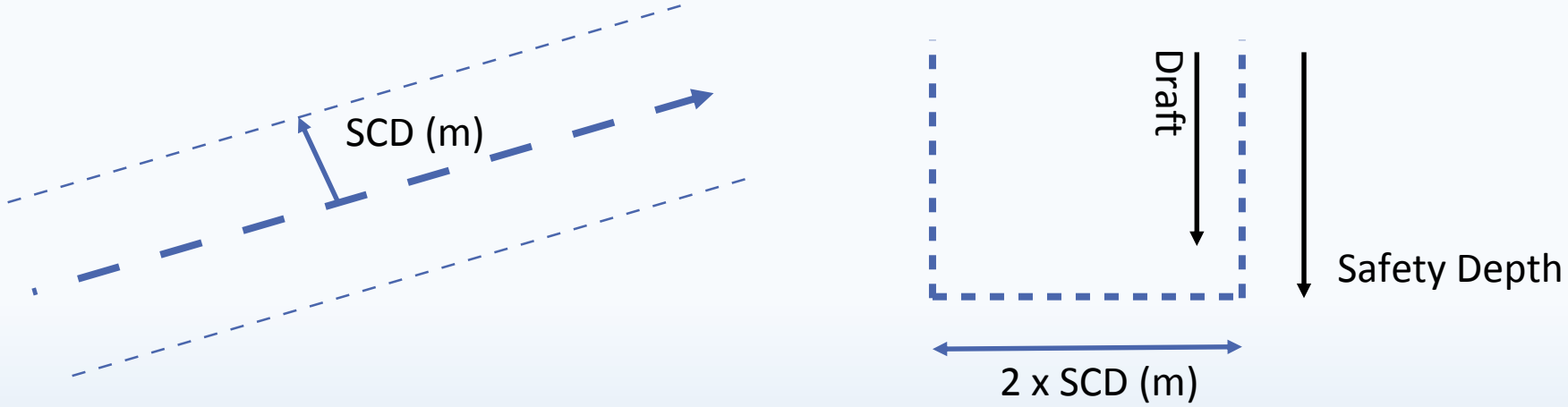
STEP	Question/Result	Answer = YES	Answer = NO
1	Is data assessment = unassessed?	Go to 2	Go to 3
2	QUALITY OF BATHYMETRIC DATA = UNASSESSED		
3	Is data assessment = Oceanic?	Go to 4	Go to 5
4	QUALITY OF BATHYMETRIC DATA = OCEANIC		
5	Is category of temporal variation “Unlikely to change”?	Go to 6	Go to 10
6	full area search undertaken, significant seafloor features detected, depths measured?	Go to 7	Go to 15
7	Is vertical uncertainty < 0.5m + 1% of depth?	Go to 8	Go to 12
8	Is horizontal position uncertainty < 5m + 5% of depth?	Go to 9	Go to 13
9	QUALITY OF BATHYMETRIC DATA = 1 (*CATZOC = A1*)		
10	Is category of temporal variation = likely to change but significant shoaling unexpected?	Go to 11	Go to 19
11	full area search undertaken, significant seafloor features detected, depths measured?	Go to 12	Go to 15
12	Is vertical uncertainty < 1.0m + 2% of depth?	Go to 13	Go to 21
13	Is horizontal position uncertainty < 20m?	Go to 14	Go to 17
14	QUALITY OF BATHYMETRIC DATA = 2 (*CATZOC = A2*)		

Decision Tree (textual) – STEP 1

STEP	Question/Result	Answer = YES	Answer = NO
15	Full area search not achieved, uncharted features hazardous to surface navigation are not expected but may exist?	Go to 16	Go to 20
16	Is vertical uncertainty < 1.0m + 2% of depth?	Go to 17	Go to 21
17	Is horizontal position uncertainty < 50m?	Go to 18	Go to 22
18	QUALITY OF BATHYMETRIC DATA = 3 (*CATZOC = B*)		
19	Is category of temporal variation = likely to change and significant shoaling expected?	Go to 20	Go to 24
20	Full area search not achieved, depth anomalies may be expected?	Go to 21	Go to 25
21	Is vertical uncertainty < 2.0m + 5% of depth?	Go to 22	Go to 26
22	Is horizontal position uncertainty < 500m?	Go to 23	Go to 26
23	QUALITY OF BATHYMETRIC DATA = 4 (*CATZOC = C*)		
24	Is category of temporal variation = extreme event?	Go to 26	Go to 2
25	Full area search not achieved, large depth anomalies may be expected?	Go to 26	Go to 2
26	QUALITY OF BATHYMETRIC DATA = 5 (*CATZOC = D*)		

SAFETY ZONE – STEP 2

- In current ECDIS systems, the Mariner enters a draft value, a Safety Depth and Safe Clear Distance (SCD) from isolated objects hazardous to navigation.
- By doing so, the Mariner creates a SAFETY ZONE around the vessel.



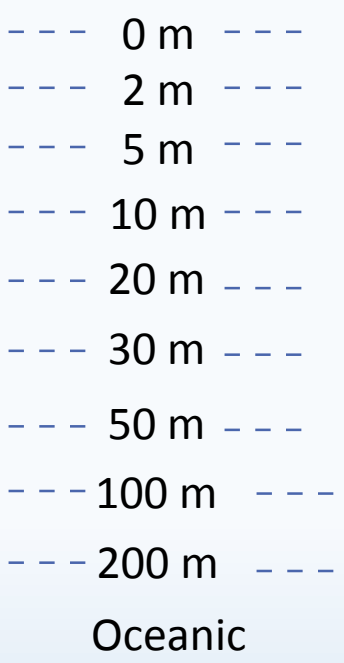
STEP 3: Get POSACC and VERACC values, if present

S-101 Data Classification and Encoding Guide – paragraph 24.5

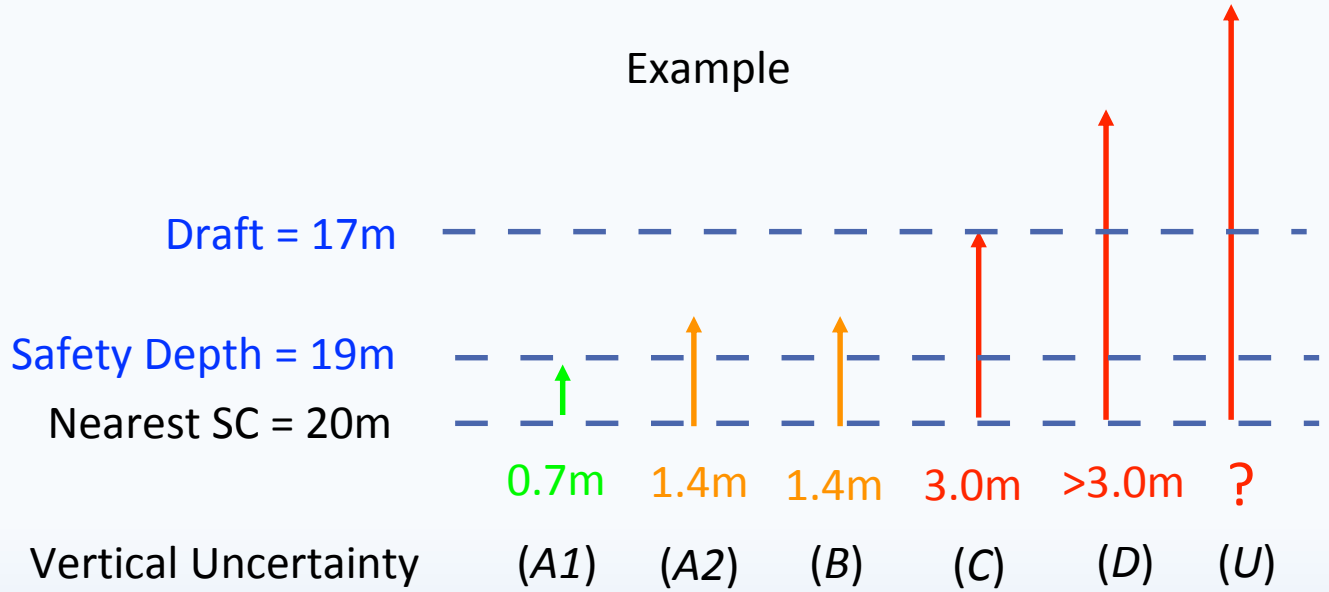
IHO Definition: SPATIAL QUALITY. Definition required				
S-101 Information Type: Spatial Quality				
Primitives: None				
S-101 Attribute	S-57 Acronym	Allowable Encoding Value	Type	Multiplicity
horizontal position uncertainty			C	0,1
uncertainty fixed	(POSACC)		(S) RE	1,1
uncertainty variable factor			(S) RE	0,1
quality of horizontal measurement	(QUAPOS)	1: surveyed 2: unsurveyed 3: inadequately surveyed 4: approximate 5: position doubtful 6: unreliable 9: estimated 10: precisely known 11: calculated	EN	0,1
vertical uncertainty			C	0,1
uncertainty fixed	(VERACC)		(S) RE	1,1
uncertainty variable factor			(S) RE	1,1

STEP 4 – USE CATZOC VERTICAL UNCERTAINTY VALUES

- Smart algorithm, vertical uncertainty of Quality of Bathymetric Data is taken into account for decision support of a safe passage.

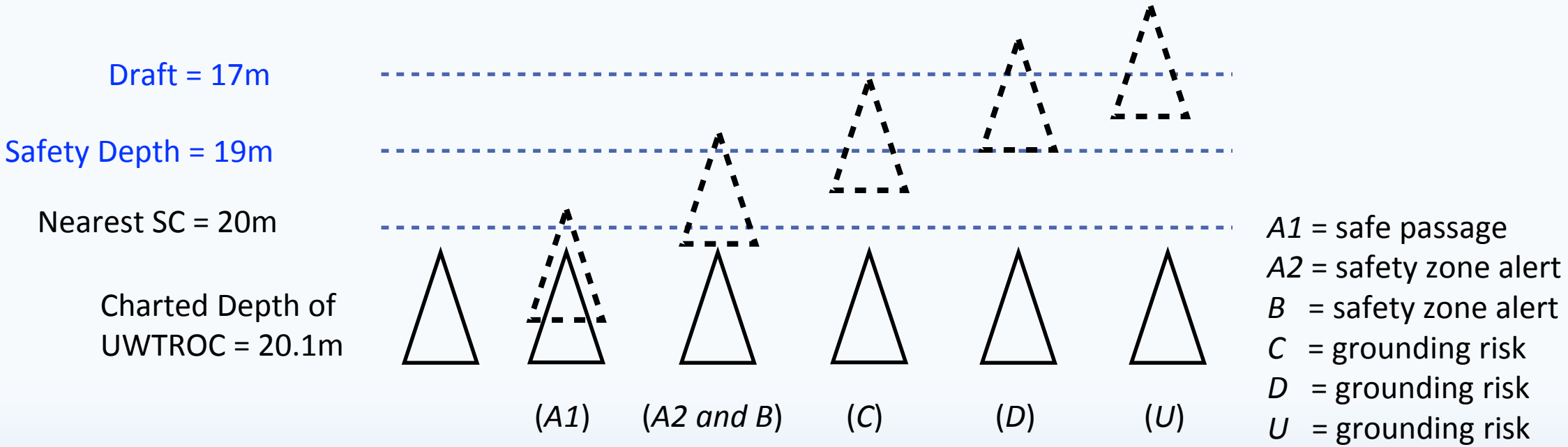


Standard Contour Lines



STEP 4 – USE CATZOC VERTICAL UNCERTAINTY VALUES

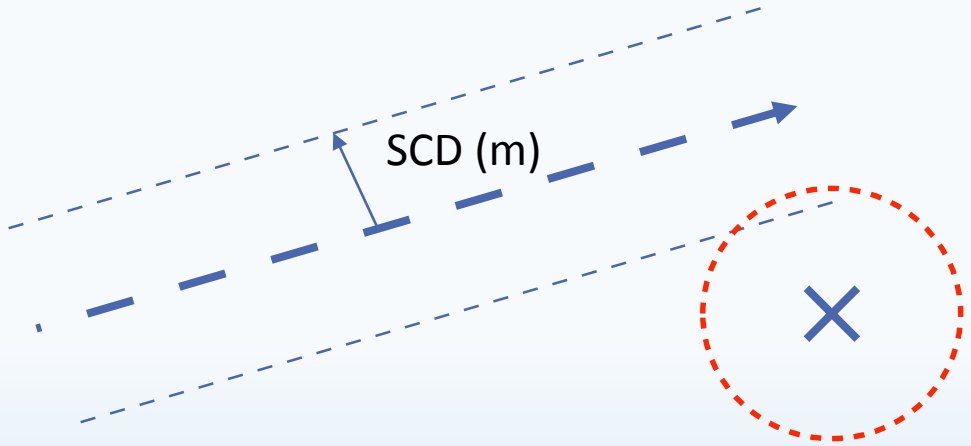
- SAFETY ZONE alarm for UWTROC, WRECKS, OBSTRN, SOUNDG.



STEP 5 – DRAW CIRCLES OF HORIZONTAL UNCERTAINTY

- SAFETY ZONE ALARM for Horizontal Safe Distance. (STEP 5)
- Combine Vertical and Horizontal Quality of Bathymetric Data (STEP 6)
- Use vessel Course over Ground and Speed over Ground to trigger alerts

(e.g. 15 minutes warning prior to event – STEP 7)



Safety Contour = 20m

Position uncertainty

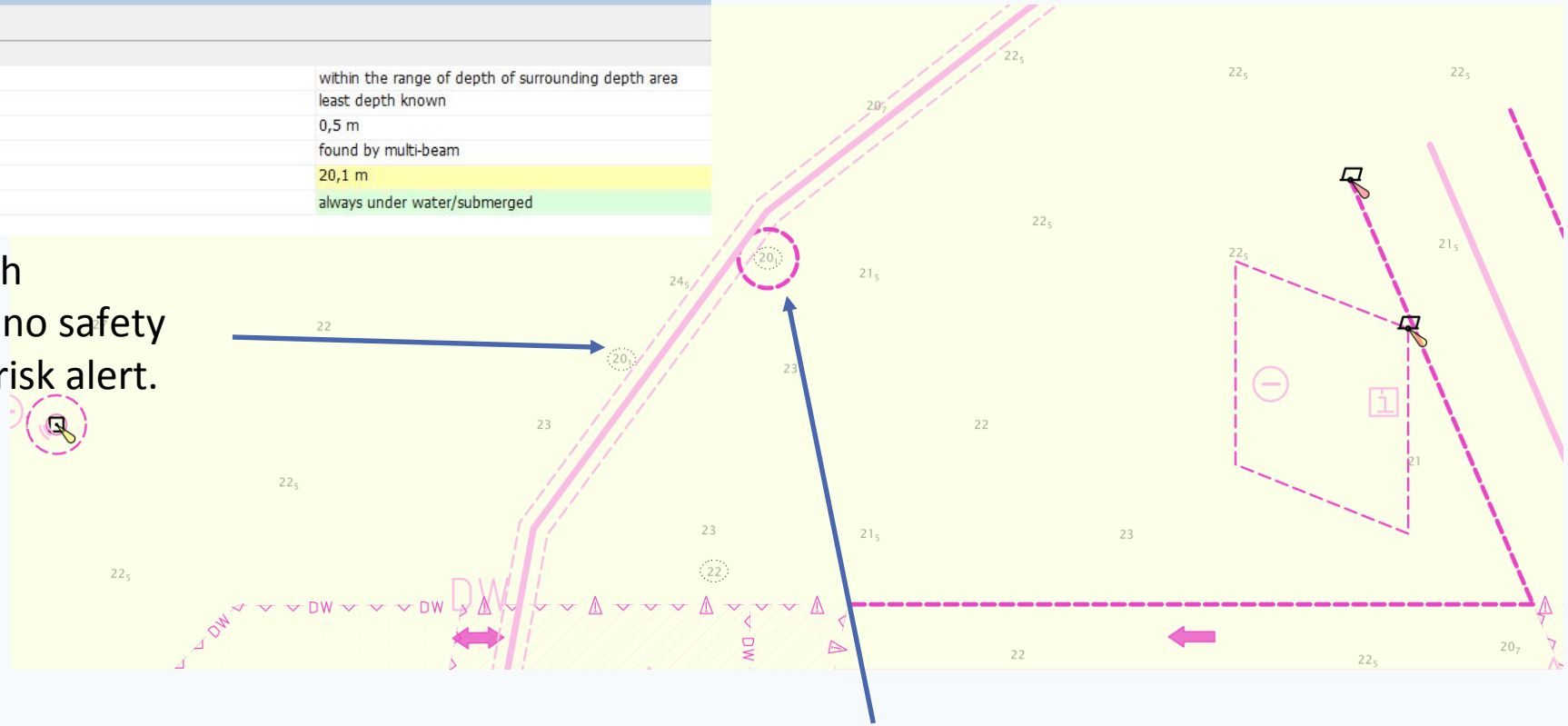
(*A1*) = 6m (vary with depth)
(*A2*) = 20m (fixed value)
(*B*) = 50m (fixed value)
(*C*) = 500m (fixed value)
(*D*) > 500m (more than)
(*U*) = ? (unknown)

GROUNDING RISK ALERT

Attributes - WRECKS

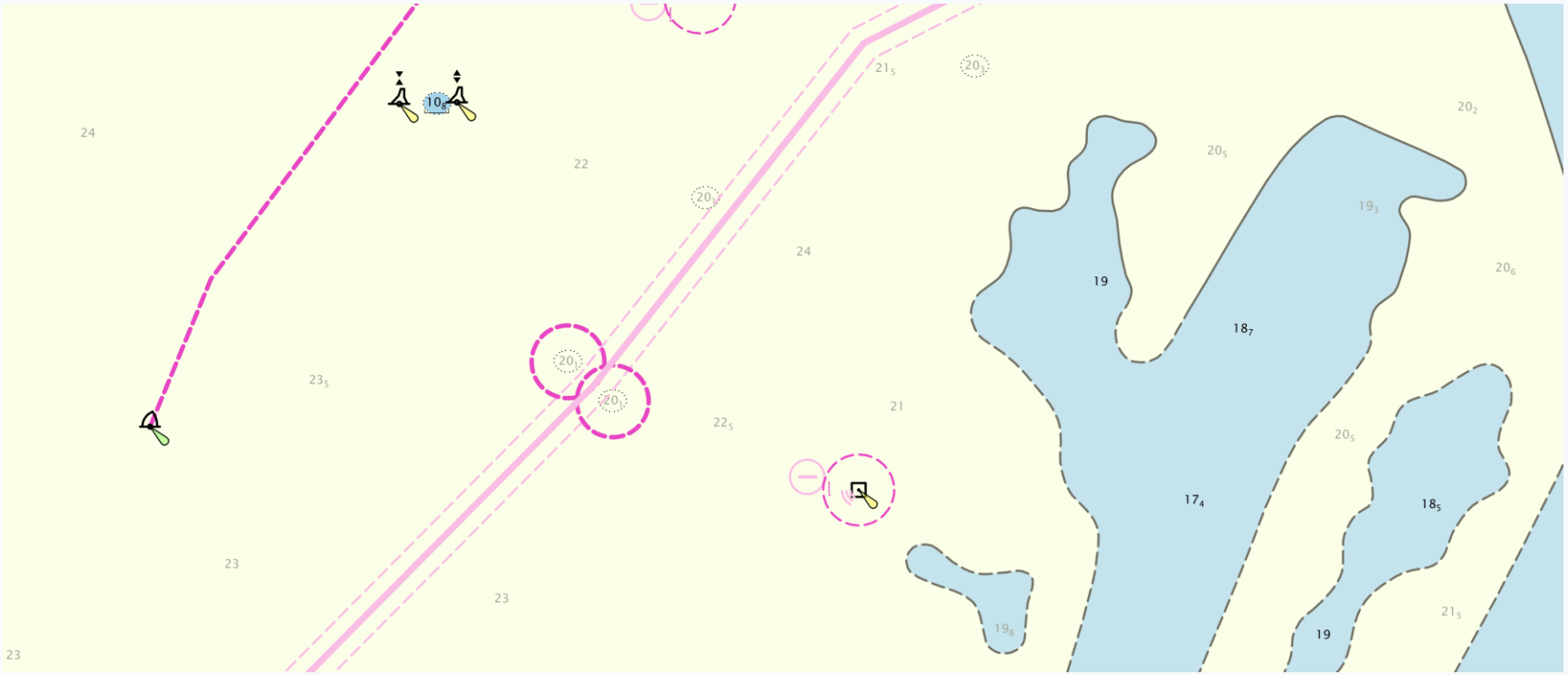
Attributes	
Exposition of sounding	within the range of depth of surrounding depth area
Quality of sounding measurement	least depth known
Sounding accuracy	0,5 m
Technique of sounding measurement	found by multi-beam
Value of sounding	20,1 m
Water level effect	always under water/submerged

Isolated danger with POSACC/VERACC – no safety zone or grounding risk alert.



Isolated danger with minimum depicted depth of 20.1m, no individual quality values. In area of CATZOC = C, least possible depth = 17.1m. System will issue a grounding risk alert.

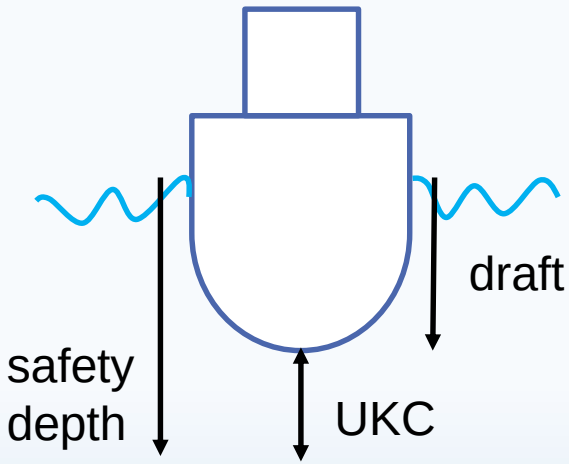
BLOCKED PASSAGE D/T POOR QUALITY

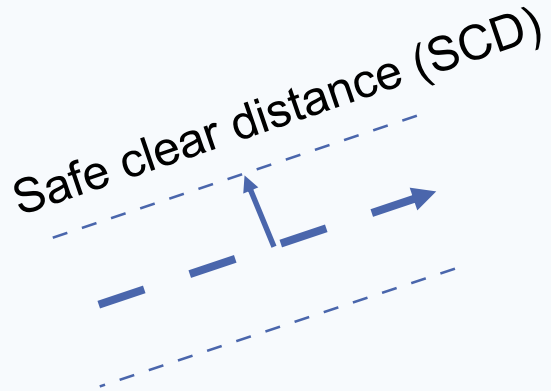


Transit in-between two isolated dangers in CATZOC C area is not advised. DEPCNTs are approximate, drawn as dashed lines.

Visualization *methodology* of Quality of Bathymetric Data

- Method to depict the quality of the bathymetry and isolated features hazardous to the safety of navigation. (wrecks, rocks, obstructions)
- Also supportive for decision making and autonomous shipping.
- Visual warning on front bridge (SAFETY ZONE ALERT or GROUNDING RISK).





20m

Nearest safety contour

Safety zone = UKC+SCD

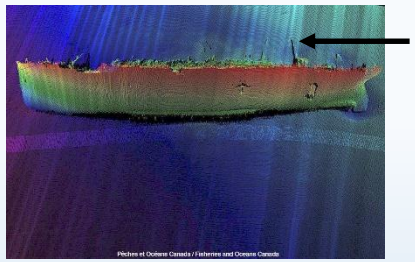
Navigable depth (95% confidence)

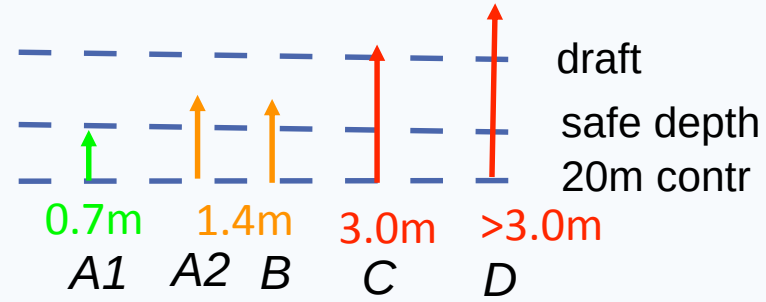
D < 17.1

C = 17.1

A2, B = 18.7

A1 = 19.4





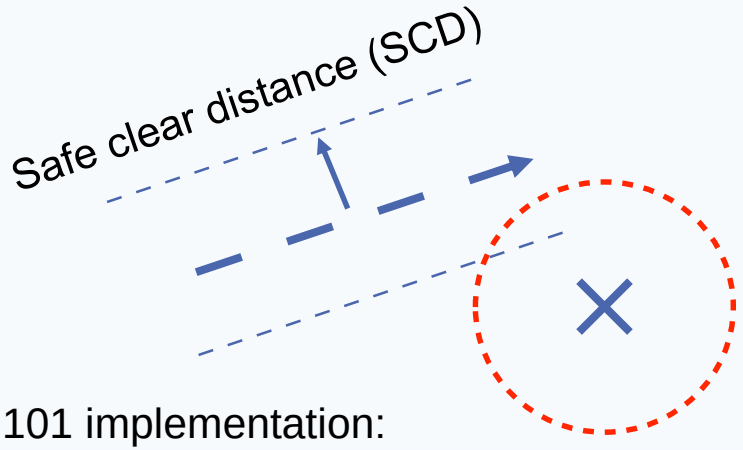
CATZOC value

Charted depth = 20.1 m

Visualization *methodology* of Quality of Bathymetric Data

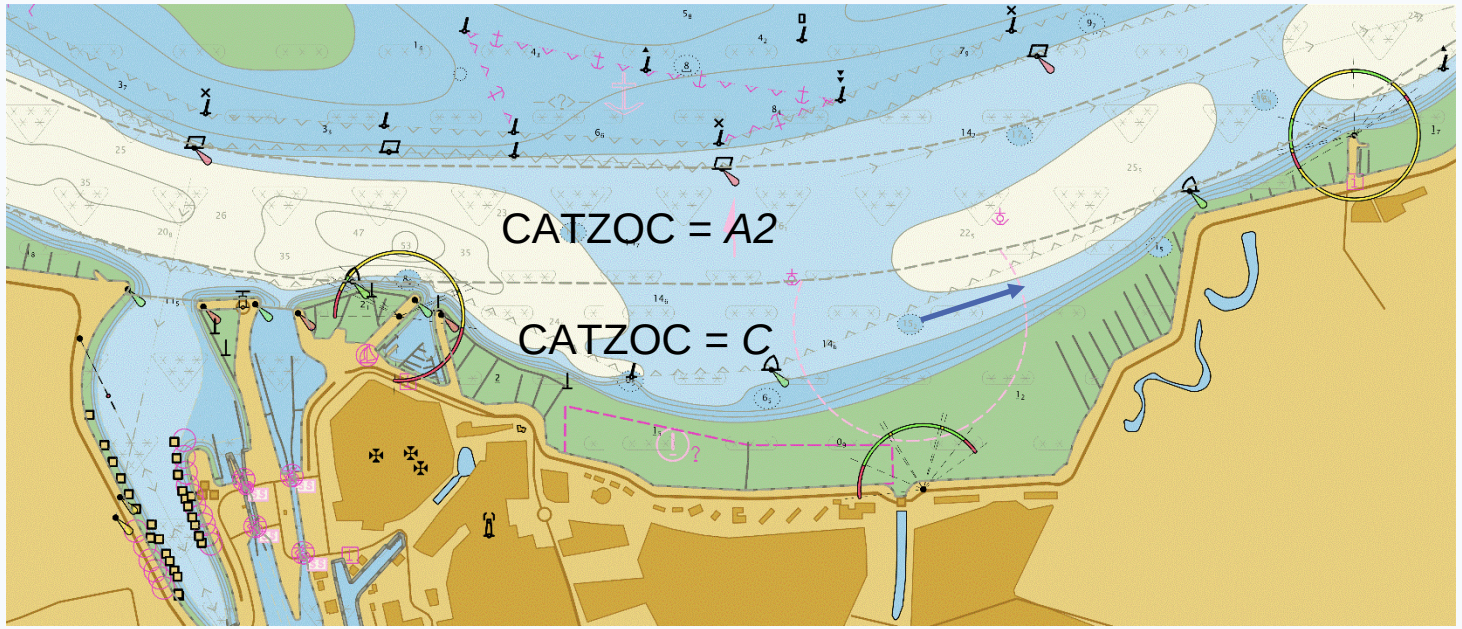
Position uncertainty

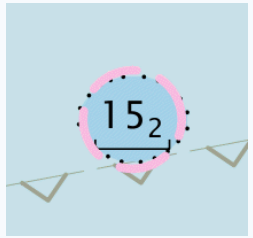
(*A1*) = 6m (@20m)
(*A2*) = 20m (fixed value)
(*B*) = 50m (fixed value)
(*C*) = 500m (fixed value)
(*D*) > 500m (more than)
(*U*) = ? (unknown)



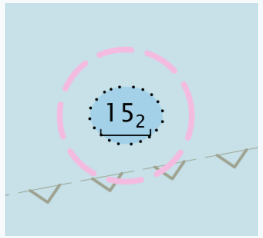
S-101 implementation:

IF VERACC and/or POSACC of a wreck is available it will be used, ELSE the QoBD value will be used and depicted as PRECNT area





50m circle
1:22000



50m circle
1:10000

A circle is drawn around the wreck, the positional uncertainty of CATZOC *C* is applied. The fairway has CATZOC *A2*, the circle stops at the edge of the fairway.
If the navigable depth > Mariners safety depth, no circle is drawn. Vessel can sail over the isolated feature.

Recommendations for S-101PT

- Screen wide symbology (*CATZOC*) is needed for spatial awareness.
- Avoid screen clutter.
- Should be an area centered symbol, not staggered. Maximum size = 5 mm.
- Boundaries of Quality of Bathymetric Data should be visualized.
- Introduce a check route functionality.
- Use QoBD values to validate the SAFETY ZONE under/around the vessel.
- Create clear warning signals (show details/accept) for SAFETY ZONE alerts in planning and monitoring mode.

Recommendations for HOs

- Provide meaningful values to Quality of Bathymetric Data (S-101)

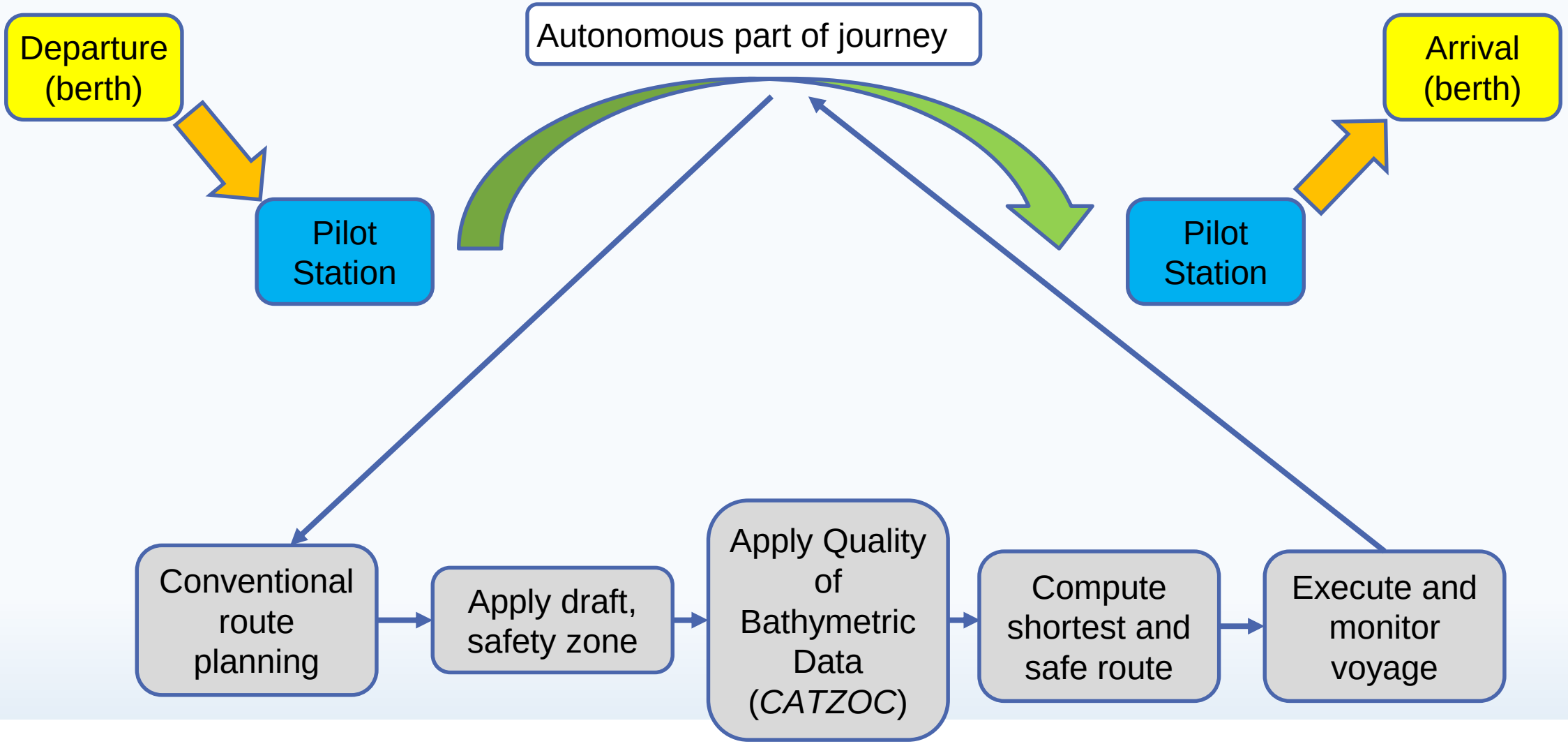
  (1, 2, 3, 4, 5 or Oceanic. Unassessed should not be used)
- Provide horizontal/vertical uncertainty for isolated features

  (UWTROC, WRECKS, OBSTRN, SOUNDG) hazardous to navigation:

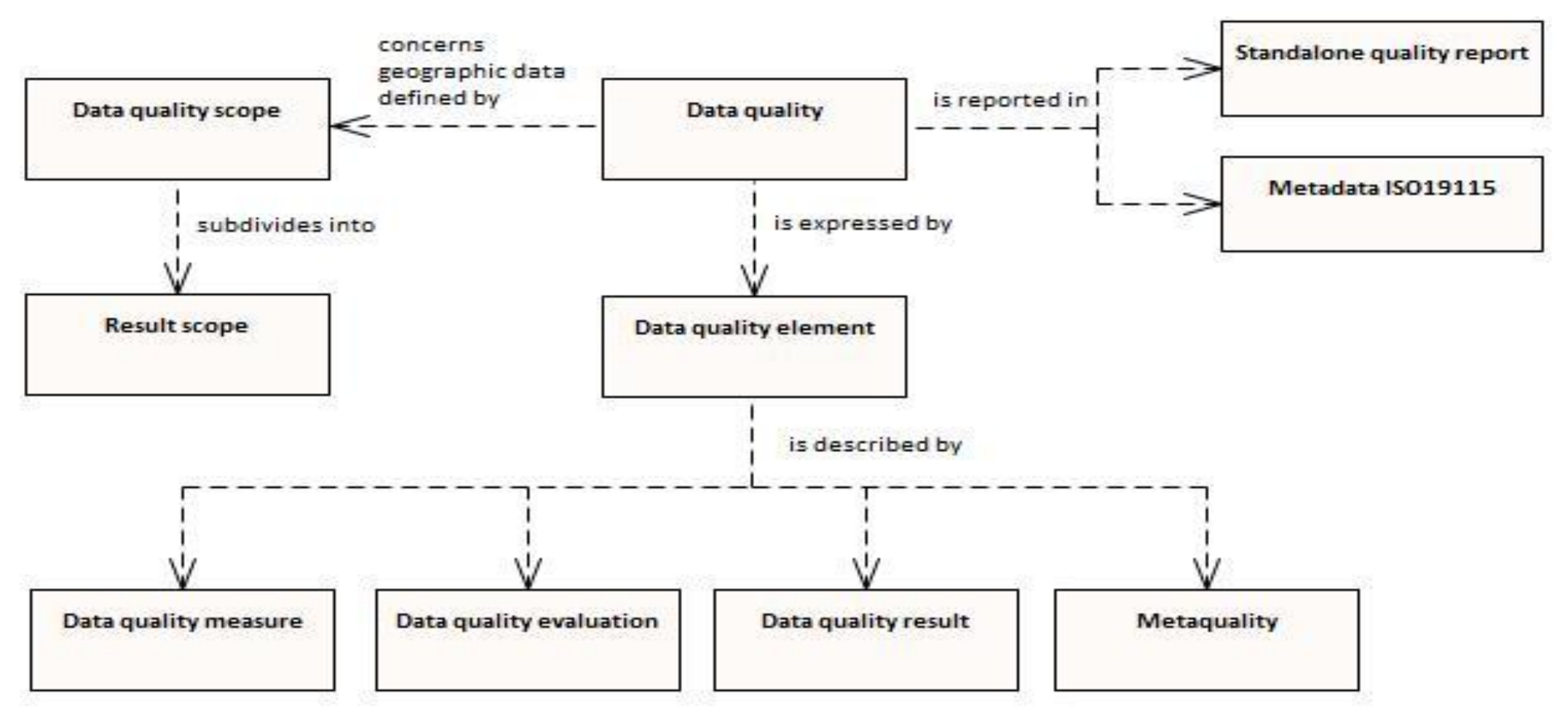
- if the horizontal/vertical uncertainty of the individual features is different from the surrounding Quality of Bathymetric Data (*CATZOC*),
- mainly in areas < 30m depth,
- in/close to major shipping routes.

- Assign DEPCNTs with *QUAPOS*=3 (inadequately surveyed) or *QUAPOS*=4 (approximate) in areas with *CATZOC=D (all depths)* or *C (<30m depth*).
- Be aware of vertical uncertainty when generating High-Density ENCs in areas of Quality of Bathymetric Data = 4 or 5 (*CATZOC = C or D*).
- Be aware of the use of S-102 as a decision aid, combined with S-101.

Decision making and autonomous shipping



The concept of Data Quality -> Validation

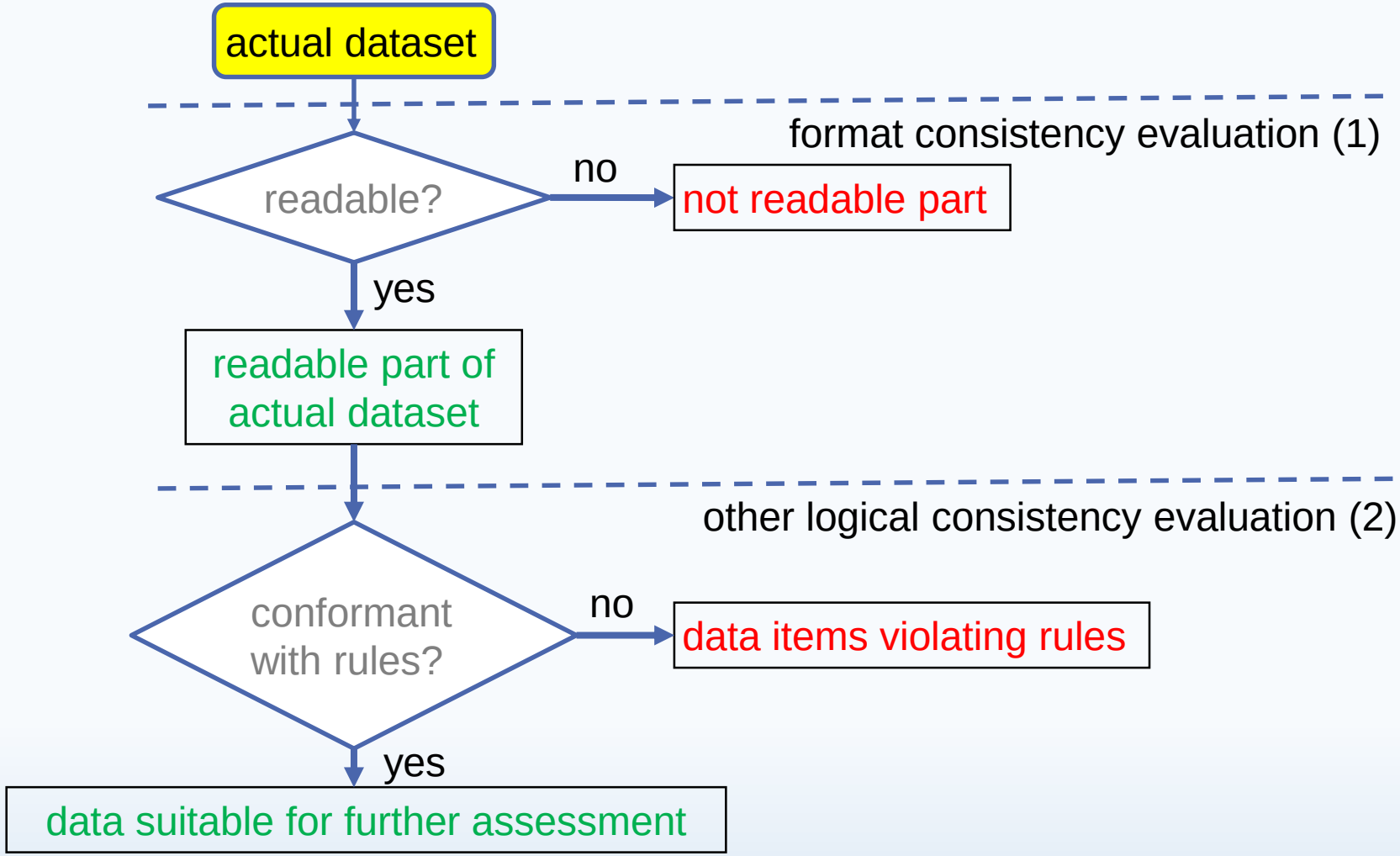


courtesy of ISO

S-1xx Validation Checks

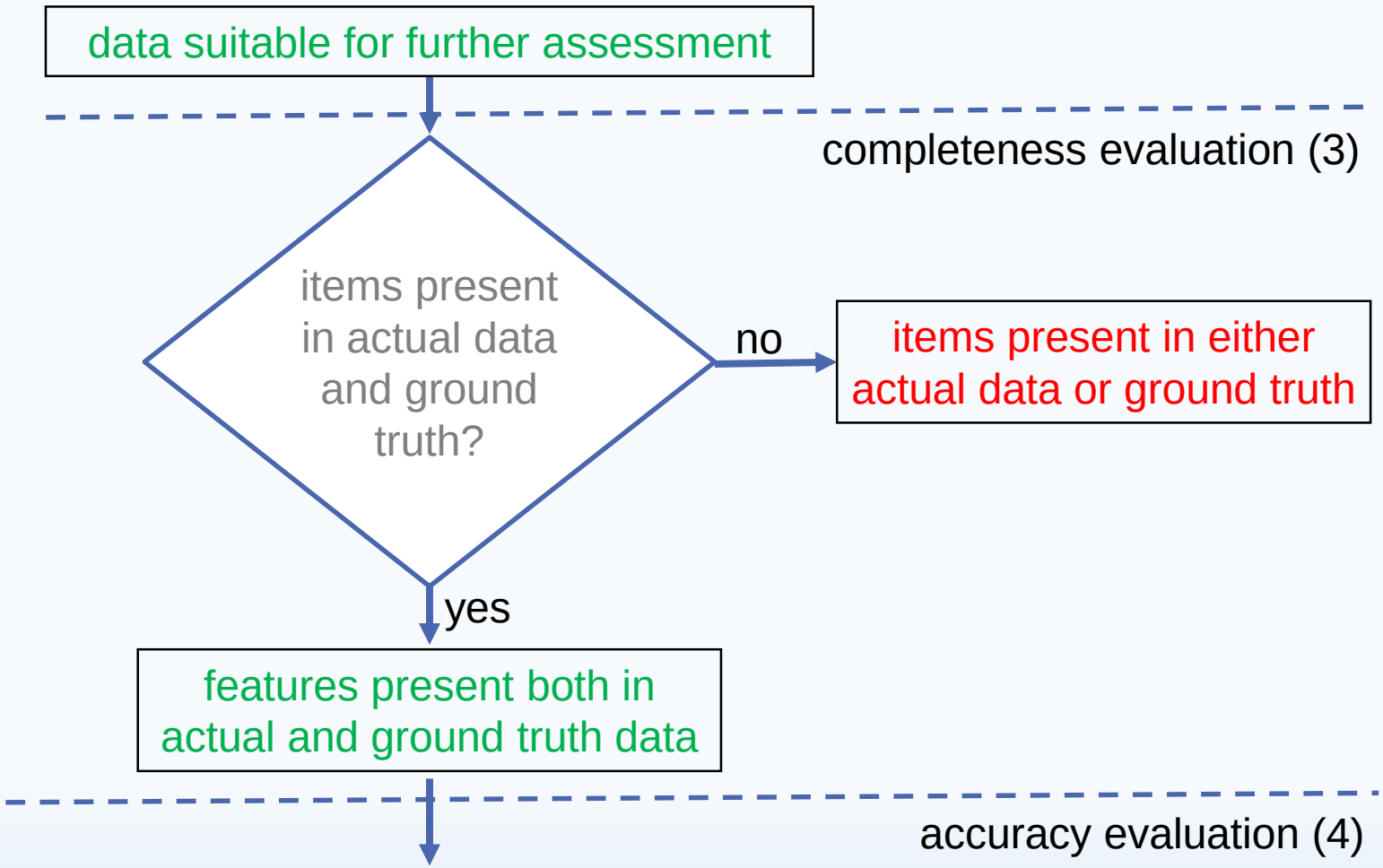
- List of recommendations of Validation Checks
- Follows the ISO 19157 Guideline
- Will lead to a Minimum Standard for Data Validation
- To be incorporated into S-97 part C (Data Quality)
- Validation needs to be operational for acceptance of S-101 Ed 3.0.0

ISO 19157 Ordering in data quality evaluation [1]



courtesy of ISO

ISO 19157 Ordering in data quality evaluation [2]



courtesy of ISO

Logical consistency - definition

- Logical Consistency is defined as the degree of adherence to logical rules of data structure, attribution, and relationships (data structure can be conceptual, logical or physical). If these logical rules are documented elsewhere (for example in a data product specification) then the source should be referenced (for example in the data quality evaluation).

Format consistency evaluation (1)

- format consistency – degree to which data is stored in accordance with the physical structure of the dataset
- Format consistency is described in S-100 part 10 – Encoding formats
- S-100 does not mandate particular encoding formats so it is left to developers of product specifications to decide on suitable encoding standards and to document their chosen format. The issue of encoding information is complicated by the range of encoding standards that are available, which include but are not limited to: ISO/IEC8211, GML, XML, GeoTiff, HDF-5, JPEG2000.

Other logical consistency evaluation (2)

- conceptual consistency – adherence to rules of the conceptual schema
- domain consistency – adherence of values to the value domains
- topological consistency – correctness of the explicitly encoded topological characteristics of a dataset

Conceptual consistency (2a)

- S-100 part 1, conceptual schema language. It provides description of:

- classes
- attributes
- basic data types
- primitive types
- complex types
- predefined derived types
- enumerated types
- codelist types
- relationships and associations
- composition and aggregation
- stereotypes
- optional, conditional, and mandatory attributes and associations
- naming and name spaces
- notes
- packages

Domain consistency (2b)

This is described in S-100 Part 5 – Feature Catalogue.

This Part provides a standard framework for organizing and reporting the classification of real world phenomena in a set of geographic data. It defines the methodology for classification of the feature types and specifies how they are organized in a feature catalogue and presented to the users of a set of geographic data. This methodology is applicable to creating catalogues of feature types in previously uncatalogued domains and to revising existing feature catalogues to comply with standard practice. It applies to the cataloguing of feature types that are represented in digital form. Its principles can be extended to the cataloguing of other forms of geographic data.

Topological consistency (2c)

- This is described in S-100 Part 7 – Spatial Schema. It supports 0, 1, 2, and 2.5 dimensional spatial schemas and two levels of complexity – geometric primitives and geometric complexes.
- S-101 Validation Checks.xlsx lists a number of Topological checks.
- Inherited from S-58 Validation checks that apply to S-57 Topological Validation.
- Based on ISO 19125-1:2004 Geometry

Definitions for ISO 19125-1:2004 geometry [1]

- *Polygon* - A Polygon has a geometric dimension of 2. It consists of a boundary and its interior, not just a boundary on its own. It is a simple planar surface defined by 1 exterior boundary and 0 or more interior boundaries. The geometry used by an S-57 Area feature is equivalent to a Polygon.
- *Polygon boundary* - A Polygon boundary has a geometric dimension of 1 and is equivalent to the outer and inner rings used by an S-57 Area feature
- *Line String* - A LineString is a Curve with linear interpolation between Points. A LineString has a geometric dimension of 1. It is composed of one or more segments – each segment is defined by a pair of points. The geometry used by an S-57 Line feature is equivalent to a LineString

Definitions for ISO 19125-1:2004 geometry [2]

- *Line* - An ISO 19125-1:2004 line is a LineString with exactly 2 points. Note that the geometry used by an S-57 Line feature is equivalent to a LineString, not a line in ISO 19125-1:2004 terms. In this document the term Line refers to an S-57 Line feature or a LineString which can have more than two points.
- *Point* - Points have a geometric dimension of 0. The geometry used by an S-57 Point feature is equivalent to an ISO 19125-1:2004 point.
- *Reciprocal* – inversely related or opposite.

ISO 19125-1:2004	S-101
Polygon	Area feature geometry OR Area
Polygon boundary	Outer and inner rings
LineString	Line feature geometry OR Line
Point	Point feature geometry OR Point

Geometric operator relationships

- In ISO 19125-1:2004 the dimensionally extended nine-intersection model (DE-9IM) defines 5 mutually exclusive geometric relationships between two objects (Polygons, LineStrings, and/or Points). One and only one relationship will be true for any two given objects:

1. WITHIN
2. CROSSES
3. TOUCHES
4. DISJOINT
5. OVERLAPS

Other operators to help define the relationship

1. CONTAINS

- the reciprocal of WITHIN
- within is the primary operator; however, if **a** is not within **b** then **a** may contain **b** so CONTAINS may be the unique relationship between the objects.

2. EQUAL

- a special case of WITHIN / CONTAINS.

3. INTERSECTS

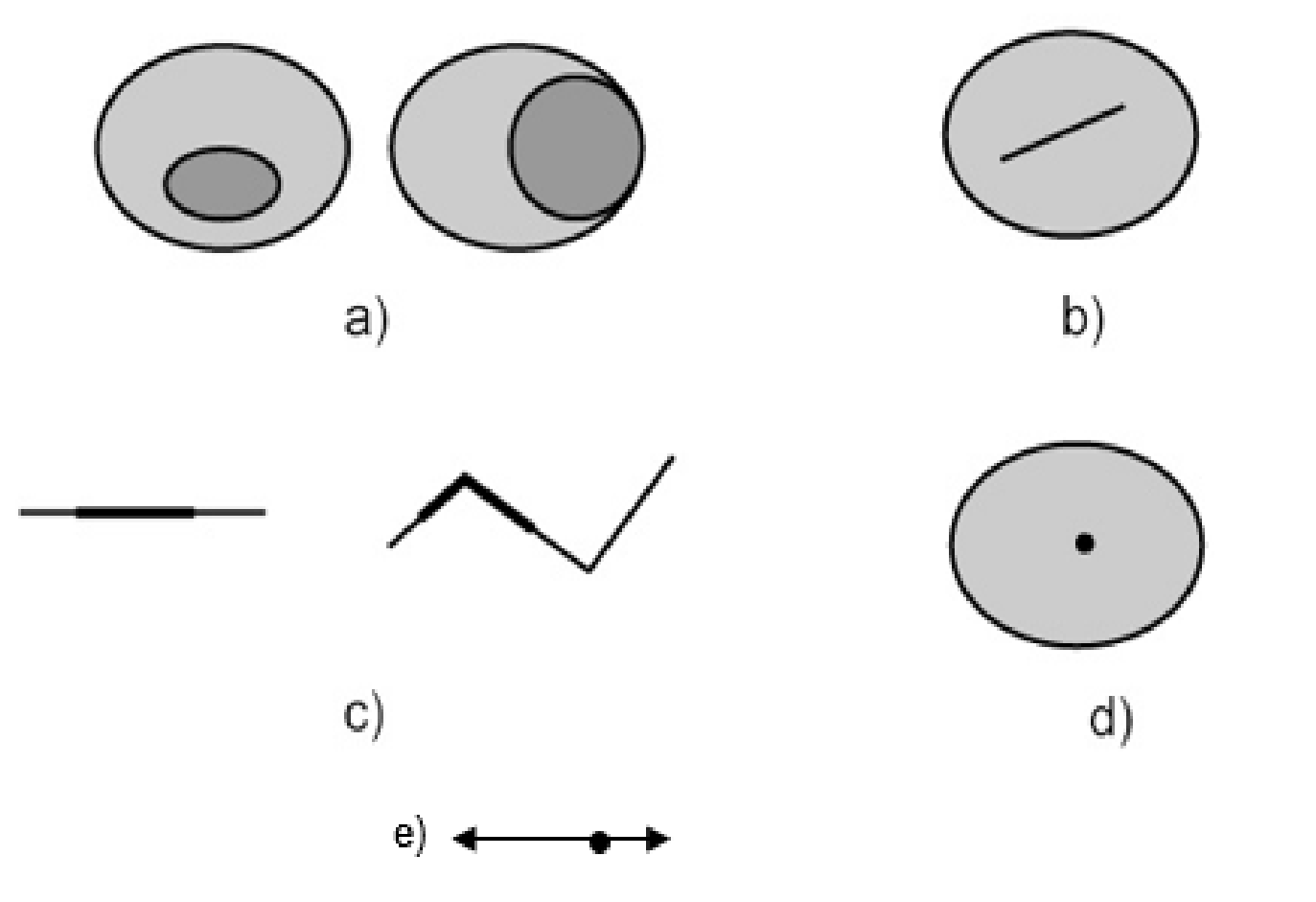
- reciprocal of DISJOINT
- have at least one point in common

4. COVERS and is COVERED_BY

- reciprocal operators
- extends CONTAINS and WITHIN respectively

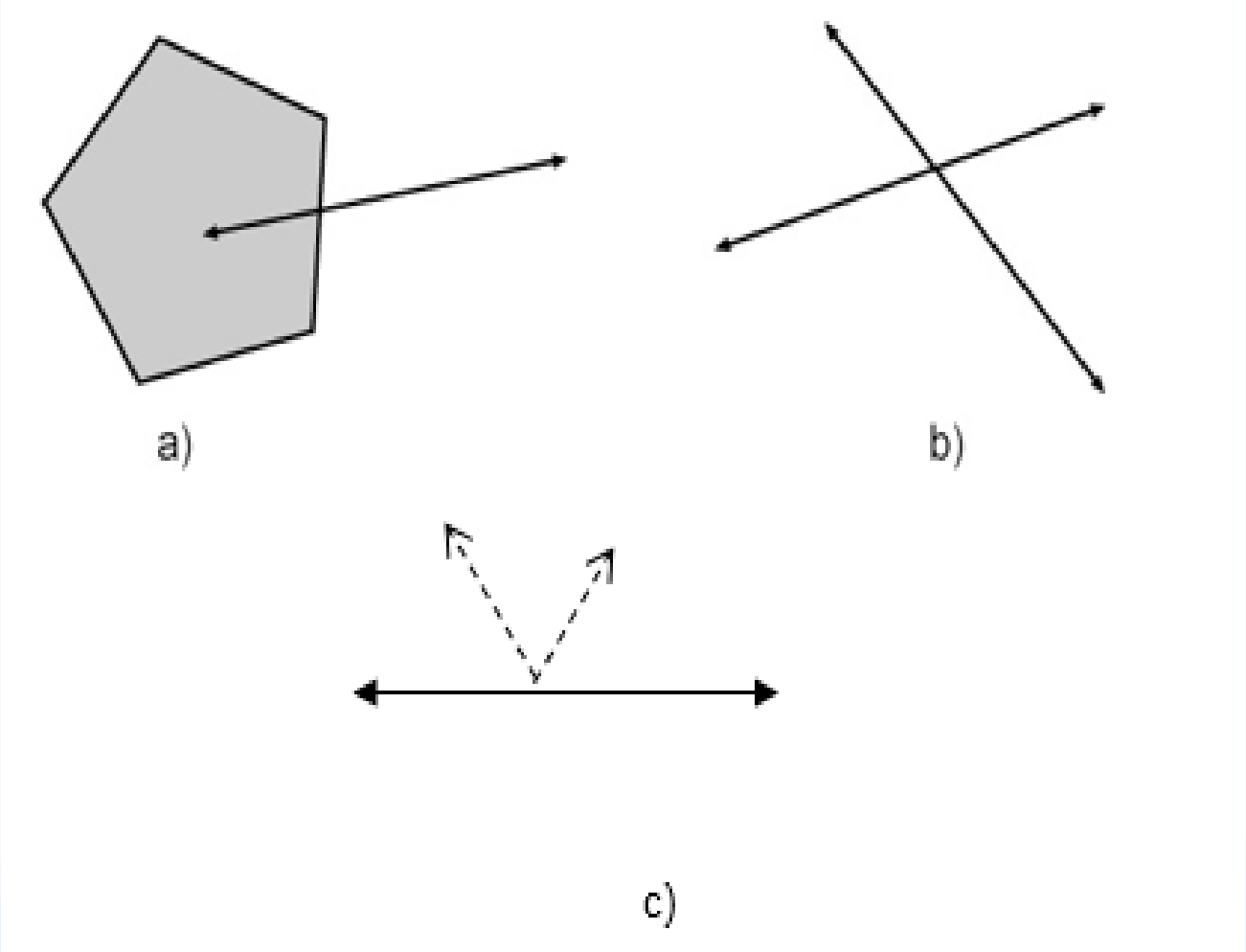
5. COINCIDENT

Example - WITHIN



a) Polygon / Polygon
b) Polygon / LineString
c) LineString / LineString
d) Polygon / Point
e) LineString / Point

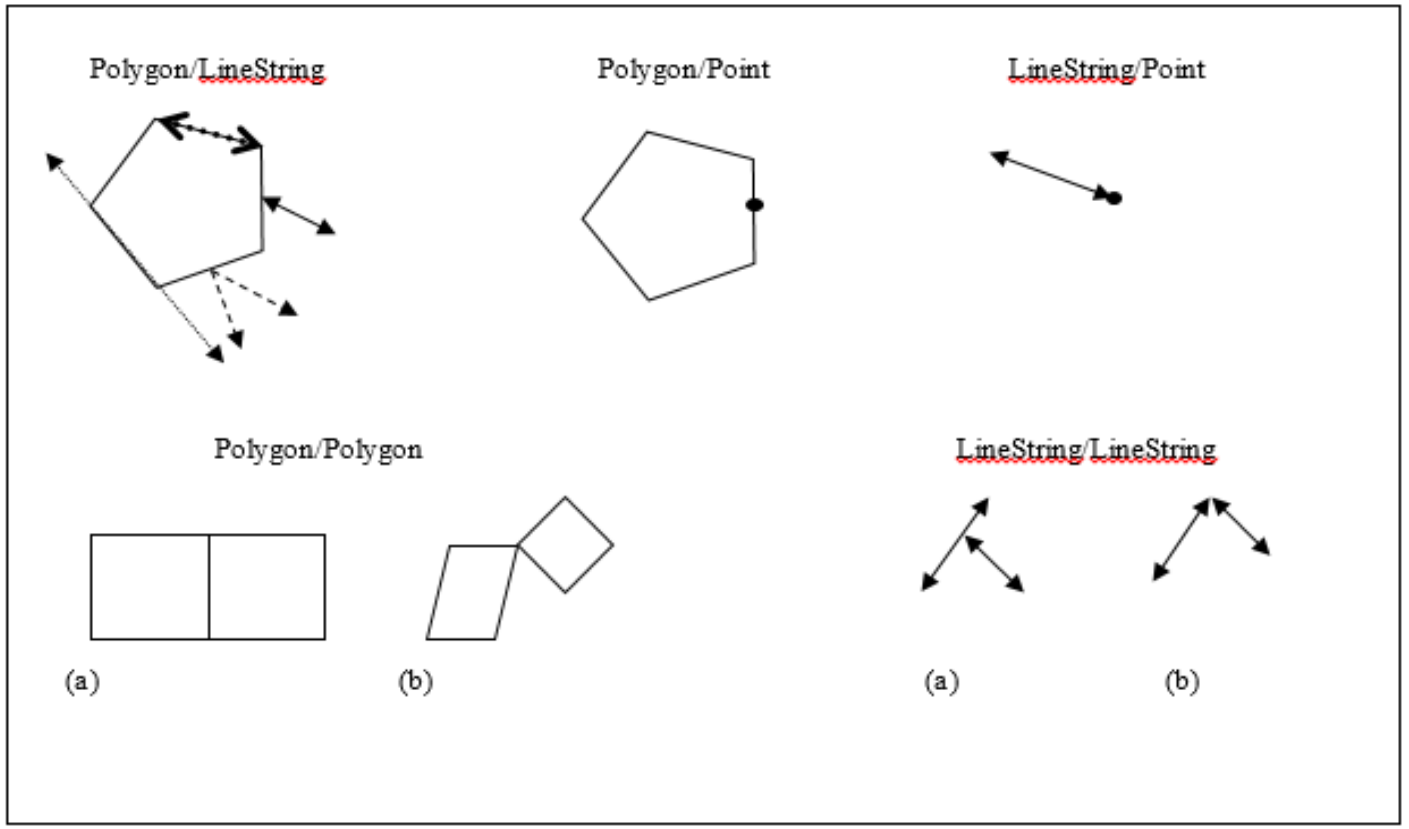
Example - CROSSES



Note that example c) shows one solid line and one dashed line – their interiors intersect.

If any Line were split into two separate Line features at the intersection point then the relationship would be TOUCHES because a boundary would be involved.

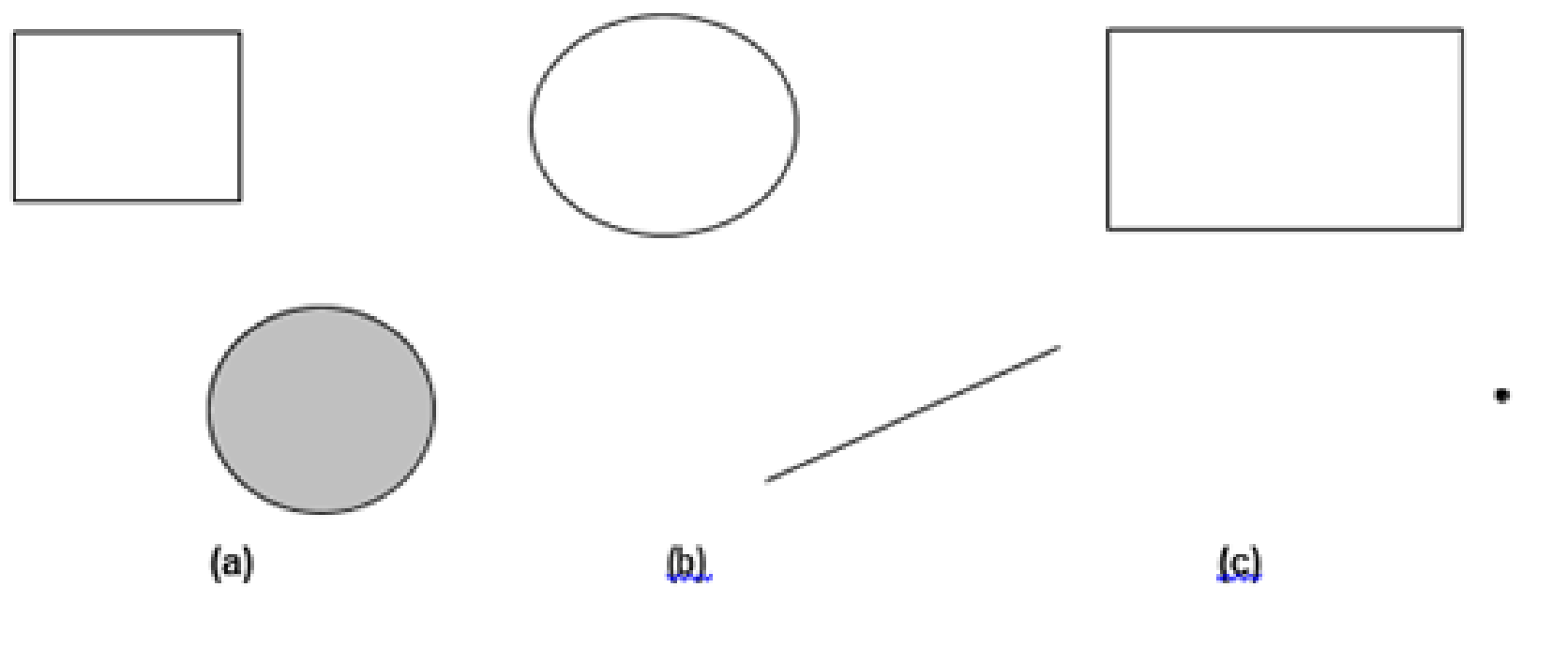
Example - TOUCHES



Note the Polygon touches Polygon example (a) is also a case where the Polygon boundaries are COINCIDENT.

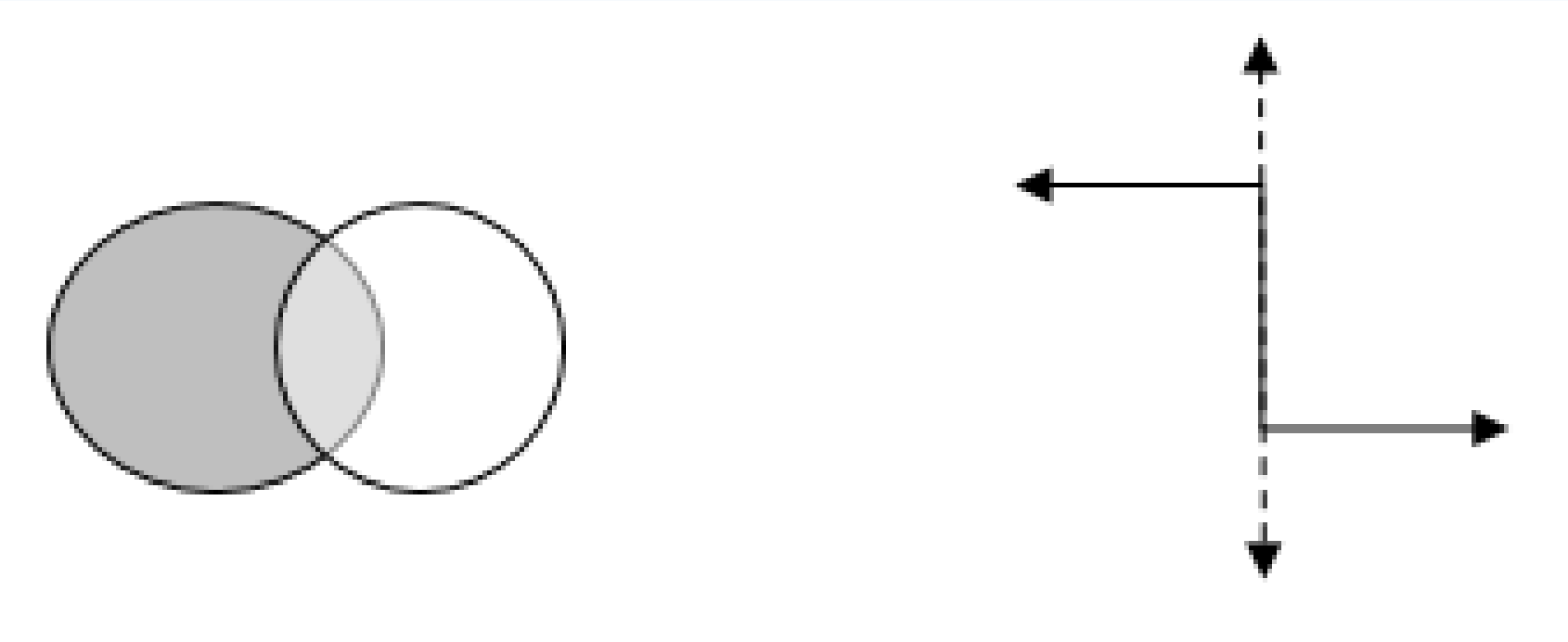
In the Polygon/LineString example two of the LineStrings that share a linear portion of the Polygon boundary are also COINCIDENT with the Polygon boundary

Example - DISJOINT



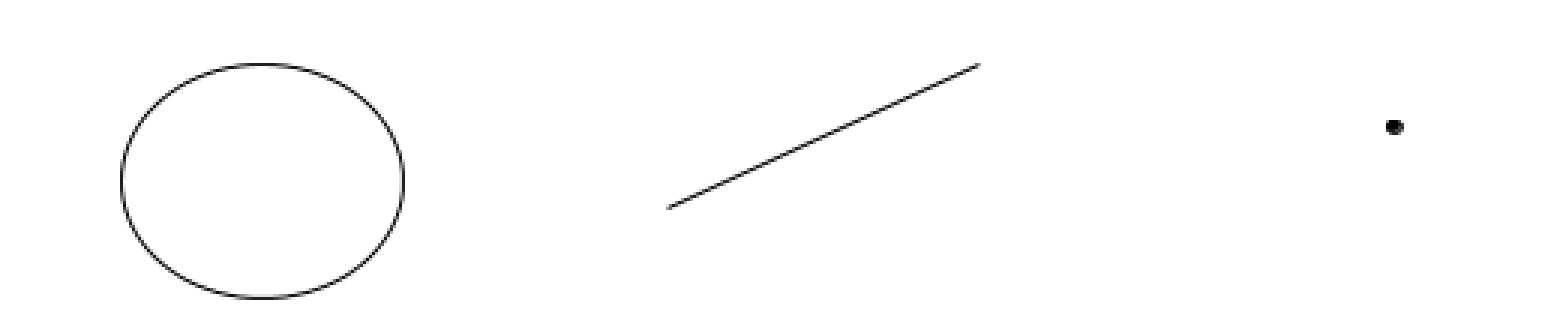
This translates to: Geometric object **a** is disjoint from Geometric Object **b** if the intersection of **a** and **b** is the empty set.

Example - OVERLAPS



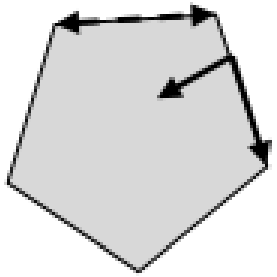
Note: Lines that OVERLAP are also COINCIDENT

Example - EQUALS

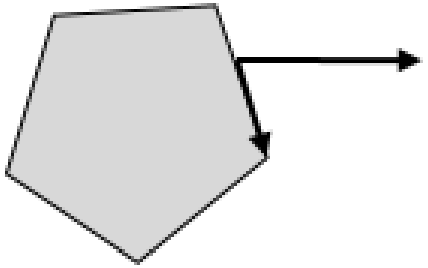


Geometric object **a** is spatially equal to geometric object **b**.

Example – COVERS and IS COVERED BY



LineStrings COVERED_BY Polygon



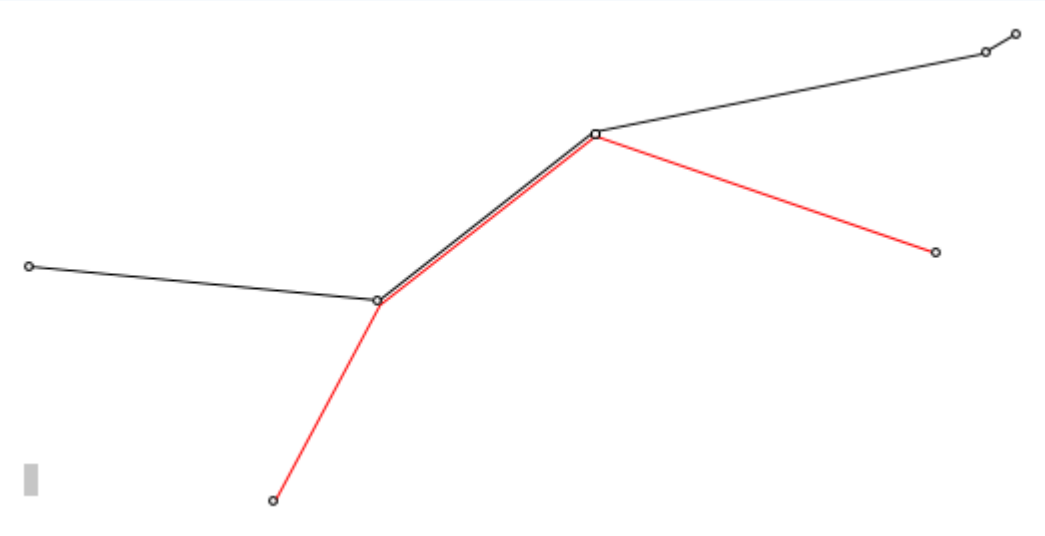
LineString NOT COVERED_BY Polygon but TOUCHES

Given two geometric objects, **a** and **b**,
if **a** is COVERED_BY **b**
then **b** must cover **a**

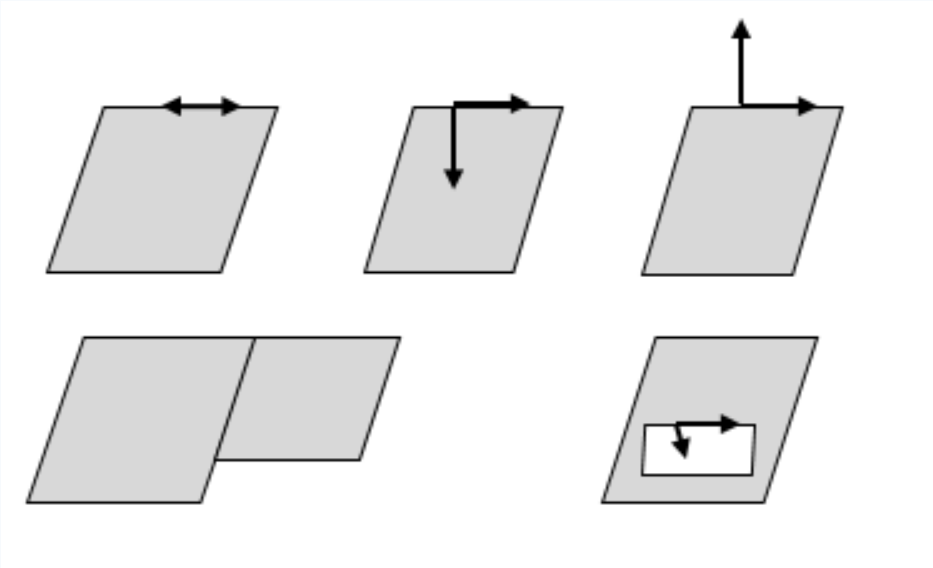
No point of geometry **a** is outside geometry **b**.

Note that the figure above on the left is an example of Lines that are COVERED_BY a polygon. The figure on the right is NOT an example of a Line that is covered by a Polygon – it is an example of a Line that TOUCHES a Polygon. In both cases the Lines are COINCIDENT with the Polygon boundary.

Example - COINCIDENT



Example of two coincident lines.



Above are examples of objects COINCIDENT with the boundary of a Polygon. LineStrings following a portion of a Polygon boundary or Polygons sharing a boundaryportion.
Note that by definition a Line can be COINCIDENT with an interior boundary of a Polygon.

Completeness evaluation (3)

- Completeness is defined as the presence and absence of features, their attributes, and relationships. It consists of two data quality elements:

- commission, excess data present in a dataset;
- omission, data absent from a dataset.

Accuracy evaluation (4)

- Positional accuracy is defined as the accuracy of the position of features within a spatial reference system. It consists of three data quality elements:

- absolute or external accuracy: closeness of reported coordinate values to values accepted or as being true;
- relative or internal accuracy: closeness of the relative positions of features in a dataset to their respective relative positions accepted as or being true;
- gridded data positional accuracy: closeness of gridded data spatial position values to values accepted as or being true.

S-101 Validation Checks (S-101PT4-3.5)

- Total of 420 record (different validation checks)

1. format consistency check: 3 records
2. conceptual consistency checks: 103 records
3. domain consistency checks: 1 record
4. topological consistency checks: 75 records
5. completeness checks: 8 records
6. accuracy evaluation: 2 records

Action required of S-101PT

- Note this report
- Raise own HO awareness about:
  - Existence of the Decision Tree to allocate QoBD value
  - Existence of the methodology of visualization of the QoBD
- Note the recommendations for HOs regarding QoBD
- Provide test data for this methodology
- Note the recommendations from ISO ordering Validation Checks
- Consider if all appropriate logical consistency checks are present
- Take any action as deemed appropriate