TSMAD18- 17 CA-ECDIS_Bathy

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Executive Summary:	CA proposes new S10X product specification for the use of high definition bathymetry as an auxiliary data layer to be used in conjunction with S.101 ENC data in navigational products
Related Documents:	*"Proposed Specification for Auxiliary Bathymetry Data for use with ENC – S10x"*
Related Projects:	S-101

Introduction / Background

This document describes the proposed use of high definition bathymetry as an auxiliary data layer to be used in conjunction with S.101 ENC data in navigational products. It is based on the emerging standards in the International Organization for Standardisation (ISO) and the International Hydrographic Organization (IHO) S.100 Imagery and Gridded Data and Metadata components and the requirements identified by the user community through the St Lawrence Project of the Canadian Hydrographic Service.

Analysis/Discussion

ISO has developed a suite of geographic information standards that addresses all areas of geographic information. The ISO and IHO standards are based on a "General Feature Model" as defined in the ISO standard 19109 Rules for Application Schema. In accordance with the General Feature Model, all geographic information is feature oriented. Features have properties, associations and constraints. Among the properties of a feature is its location, spatial geometry, and associated attributes. This concept applies equally well to boundary defined features such as those used in "vector" based charts, as to gridded data sets representing bathymetry. In the latter case, the feature is the area of sea bottom for which a depth surface is defined. The location is defined by a spatial referencing system and the geometry by a grid. The attributes consist of a set of depth measurements and associated metadata. The distribution of the attributes across the area covered by the grid is described by a coverage function.

The IHO S-100 Imagery and Gridded Data component describes the concept of coverages and the basic structure for a coverage data set. The concept of coverage geometry is defined in ISO standard 19123 and metadata in ISO standard 19115. The framework for Imagery, Gridded and Coverage data is described in ISO standard 19129. These standards are in place and can be used to produce a product specification. The ISO IGD component of S-100 is closely aligned to the ISO 19129 standard since the original ISO 19129 draft document was based on the IHO S-100 Imagery and Gridded data component of S-100.

The approach of treating all data as feature data allows the easy mixing of different data types. This means that multiple "layers" or "groups" can be defined and co-presented as integrated data. This layering concept is very important for providing additional aids to navigation. The S.101 product specification for the Electronic Nautical Chart describes the essential data required to drive an Electronic Chart Display Information System. An official ECDIS system is considered as a replacement for the official paper chart and so can only display the ENC data

in a prescribed way. However, the user requirements show that the mariner at times wants access to other data that can be displayed together with the ENC data. In particular the user requirement has identified a need for high resolution bathymetry. This is permissible as long as the ECDIS display is available and not corrupted.

In order to be able to mix different types of data together it is necessary to orient this data using a common tiling scheme, spatial referencing system, and other common system wide attributes. Each additional type of data needs to be defined completely in its own product specification. This document introduces the concept of having a standardized set of auxiliary data layers or groups that can be used together, and it describes one particular data type for the representation of high resolution bathymetry. All of the components in the layers will derive from the same S.100 schema so they will closely interwork.

This document is distinct from the proposal for a Bathymetric Attributed Grid that describes a method of exchanging sets of bathymetric data between agencies and for stand-alone use. There is room to align the metadata requirements in the Bathymetric Attributed Grid proposal and this proposal, but the underlying use case for the two approaches is different.

Recommendations

CA Recommends that TSMAD take the proposed specification for auxiliary bathymetry data for use with ENC into consideration as a formal S10X product specification.

Proposed Specification for Auxiliary Bathymetry Data for use with ENC S.10x

Canadian Hydrographic Service
Fisheries and Oceans Canada

31 March 2009
Revised

Introduction

This document describes the proposed use of high definition bathymetry as an auxiliary data layer to be used in conjunction with S.101 ENC data in navigational products. It is based on the emerging standards in the International Organization for Standardisation (ISO) and the International Hydrographic Organization (IHO) S.100 Imagery and Gridded Data and Metadata components and the requirements identified by the user community through the St Lawrence Project of the Canadian Hydrographic Service.

This document also makes use of work on an Elevation Surface Model that has been prepared by the US National Geospatial Intelligence Agency for application in military systems, which was presented to the IHO TSMAD sub-committee on S-100 in November 2006 and has been provided to the international Defence Geospatial Information Working Group (DGIWG) as the basis for future work in that forum.

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The approach of treating all data as feature data allows the easy mixing of different data types. This means that multiple "layers" or "groups" can be defined and co-presented as integrated data. This layering concept is very important for providing additional aids to navigation. The S.101 product specification for the Electronic Nautical Chart describes the essential data required to drive an Electronic Chart Display Information System. An official ECDIS system is considered as a replacement for the official paper chart and so can only display the ENC data in a prescribed way. However, the user requirements show that the mariner at times wants access to other data that can be displayed together with the ENC data. In particular the user requirement has identified a need for high resolution bathymetry. This is permissible as long as the ECDIS display is available and not corrupted.

In order to be able to mix different types of data together it is necessary to orient this data using a common tiling scheme, spatial referencing system, and other common system wide attributes. Each additional type of data needs to be defined completely in its own product specification. This document introduces the concept of having a standardized set of auxiliary data layers or groups that can be used together, and it describes one particular data type for the representation of high resolution bathymetry. All of the components in the layers will derive from the same S.100 schema so they will closely inter-work.

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Proposed Specification for Auxiliary Bathymetry Data for use with ENC - S.10x

Scope

This document specifies a template product specification for geospatial elevation surface data for bathymetry as auxiliary data to S.101 ENC data. The data is described as a grid coverage in accordance with ISO 19123. The metadata is derived from the IHO S-100 metadata component which itself is derived from the ISO 19115 metadata standard.

This document specifies the bathymetry as elevation data content separately from the encoding of the data. It identifies a mapping of the content to several formats commonly used for elevation data.

Conformance

Conformance clauses have not been defined explicitly for this draft product specification document. Data complying with this specification shall comply with the conformance clauses inherited from the referenced ISO and IHO standards. In the future an explicit conformance clause may be developed for this specification when the IHO standards have been revised and a bathymetry section has been added.

Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this profile.

IHO S.100 IHO Geospatial Standard for Hydrographic Data
ISO 19101-2:2008 Geographic Information - Rules for Application Schema
ISO/TS 19103:2005 Geographic information - Conceptual schema language
ISO 19106:2004 Geographic Information - Profiles
ISO 19109:2005 Geographic Information - Rules for Application Schema
ISO 19111:2003 Geographic information - Spatial referencing by coordinates
ISO 19115:2003 Geographic information - Metadata
ISO 19115-2:2009 Geographic information - Metadata: Extensions for imagery and gridded data
ISO 19123:2005 Geographic information - Schema for coverage geometry and functions
ISO 19129:2009 Geographic information - Imagery gridded and coverage data framework
ISO 19131:2007 Geographic information - Data product specifications
ISO/IEC 19501:2005, Information technology — Open Distributed Processing - Unified Modeling Language Version 1.4.2
Note: a summary of UML is given in ISO/TS 19103
US INCITS 1574-D, Information technology - Geographic Information Framework Data Content Standards

Terms, and definitions

Terms and definitions

Terms and definitions have been taken from the normative references cited in clause 3. Only those, which are specific to this profile, have been included and modified where necessary to reflect this profile.

continuous coverage

coverage that returns different values for the same feature attribute at different **direct position**s within a single **geometric object** in its **spatiotemporal domain**
[ISO 19123]

coordinate

one of a sequence of numbers designating the position of a point in N-dimensional space
[ISO 19111]

coordinate reference system

coordinate system which is related to the real world by a datum
[ISO 19111]

coverage

feature that acts as a function to return values from its range for any direct position within its spatial, temporal, or spatiotemporal domain
[ISO 19123]

EXAMPLE Examples include a digital image, polygon overlay, or digital elevation matrix.

NOTE In other words, a coverage is a feature that has multiple values for each attribute type, where each direct position within the geometric representation of the feature has a single value for each attribute type.

coverage geometry

configuration of the domain of a coverage described in terms of coordinates
[ISO 19123]

direct position

position described by a single set of coordinates within a coordinate reference system
[ISO 19107]

domain

well-defined set
[ISO 19103]

NOTE Domains are used to define the domain set and range set of operators and functions.

evaluation

< coverage>
determination of the values of a **coverage** at a **direct position** within the **spatiotemporal domain** of the **coverage**
[ISO 19123]

feature

abstraction of real world phenomena
[ISO 19101]

NOTE A feature may occur as a type or an instance. Feature type or feature instance should be used when only one is meant.

feature attribute

characteristic of a feature
[ISO 19109]

NOTE A feature attribute type has a name, a data type and a domain associated to it. A feature attribute instance has an attribute value taken from the value domain of the feature attribute type.

function

rule that associates each element from a **domain** (source, or domain of the function) to a unique element in another domain (target, co-domain, or **range**)
[ISO 19107]

NOTE The range is defined by another domain.

geometric object

spatial object representing a set of **direct positions**
[ISO 19107]

NOTE A geometric object consists of a **geometric primitive**, a collection of geometric primitives, or a geometric complex treated as a single entity. A geometric object may be the spatial characteristics of an object such as a **feature** or a significant part of a feature

grid

network composed of two or more sets of **curves** in which the members of each set intersect the members of the other sets in a systematic way
[ISO 19123]

NOTE The curves partition a space into grid cells.

grid point

point located at the intersection of two or more curves in a **grid**
[ISO 19123]

range

<coverage>
set of values associated by a **function** with the elements of the **spatiotemporal domain** of a **coverage**
[ISO 19123]

record

finite, named collection of related items (objects or values)
[ISO 19107]

NOTE Logically, a record is a set of pairs <name, item >.

rectified grid

grid for which there is a linear relationship between the grid coordinates and the coordinates of an external coordinate reference system
[ISO 19123]

NOTE If the coordinate reference system is related to the earth by a datum, the grid is a georectified grid.

referenceable grid

grid associated with a transformation that can be used to convert grid coordinate values to values of **coordinates** referenced to an **external coordinate reference system**
[ISO 19123]

spatiotemporal domain

<coverage>
domain composed of **geometric objects** described in terms of spatial and/or temporal **coordinates**
[ISO 19123]

NOTE The spatiotemporal domain of a **continuous coverage** consists of a set of **direct positions** defined in relation to a collection of geometric objects.

surface

connected 2-dimensional **geometric primitive**, representing the continuous image of a region of a plane
[ISO 19107]

NOTE The boundary of a surface is the set of oriented, closed curves that delineate the limits of the surface.

tessellation

partitioning of a space into a set of conterminous **geometric objects** having the same dimension as the space being partitioned
[ISO 19123]

NOTE A tessellation composed of congruent regular polygons or polyhedra is a regular tessellation; One composed of regular, but non-congruent polygons or polyhedra is semi-regular. Otherwise the tessellation is irregular.

height

distance of a point from a chosen reference surface measured upward along a line perpendicular to that surface
[ISO 19111:2006]

NOTE Height is distinguished from elevation in that it is a directional measurement.

depth

distance of a point from a chosen reference surface measured downward along a line perpendicular to that surface

[ISO 19111:2006]

NOTE Height is distinguished from elevation in that it is a directional measurement A depth above the reference surface will have a negative value.

elevation

distance of a point from a chosen reference surface along a line perpendicular to that surface

vector

quantity having direction as well as magnitude
[ISO 19123]

NOTE A directed line segment represents a vector if the length and direction of the line segment are equal to the magnitude and direction of the vector. The term vector data refers to data that represents the spatial configuration of features as a set of directed line segments.

Symbols and abbreviated terms

Abbreviations

This product specification adopts the following convention for presentation purposes:

DGIWG	Defence Geospatial Information Working Group
ECDIS	Electronic Chart Display Information System
ECS	Electronic Chart System
ENC	Electronic Nautical Chart
IHO	International Hydrographic Organization
IMO	Imternational Maratime Organization
SOLAS	Safety Of Life At Sea
TIN	Triangulated Irregular Network
UML	Universal Modelling Language

Notation

In this product specification conceptual schemas are presented in the Unified Modelling Language (UML). An overview of the use of UML in geographic information standards is provided in ISO 19103.

Several model elements used in this schema are defined in ISO standards developed by ISO TC 211, or in IHO S-100. In order to ensure that class names in the model are unique ISO TC/211 has adopted a convention or establishing a prefix to the names of classes that define the TC/211 defined UML package in which the UML class is defined. Since the IHO standards and this product specification make use of classes derived directly from the ISO standards this convention is also followed here. In the IHO standards the class names are identified by the name of the standard, such as "S100" as the prefix. For the classes defined in this document the prefix is "S10x".

Table 1 - Sources of externally defined UML classes

Prefix	Standard	Package
CI	ISO 19115	Citation and Responsible Party
CV	ISO 19123	Coverage Core & Discrete Coverages
DQ	ISO 19115	Data Quality Information
DS	ISO 19115	Metadata Application Information
EX	ISO 19115	Metadata extent information
GF	ISO 19109	General Feature Model
GM	ISO 19107	Geometry Root
IF	ISO 19129	Imagery Gridded and Coverage Data Framework
LI	ISO 19115	Data Quality Information
MD	ISO 19115	Metadata entity set information
MI	ISO 19115-2	Metadata entity set imagery
S100	IHO S.100	IHO Standard for Hydrographic Data
SC	ISO 19111	Spatial Referencing by Coordinates
SC	ISO 19111	Coordinate Reference Systems
SD	ISO 19130	Sensor Model

Auxiliary Data to ENC

The S.100 standard permits the definition of many types of data related to navigation at sea or on inland waters. One type, vector data corresponding to a paper navigational chart, is a special case in that it corresponds to the official paper chart and is required for safe navigation under the IMO SOLAS conventions. This type of data is defined by the product specification S.101.

Many different types of auxiliary data may be defined as an aid to navigation. This additional information may be displayed together with all or some of the vector chart data from an ENC as specified in S.101. An Electronic Chart System (ECS) does not provide legal paper chart equivalency per the SOLAS conventions, but it is very useful to a mariner for planning and obtaining a broader sense of the environment.

Auxiliary data is defined in layers (or groups) each with its own product specification. Extensive interaction with the user community in Canada has identified high definition bathymetry as the most important auxiliary layer; however there are many other potential data types. Each type, of international interest, should be defined in its own product specification standardized through IHO. Additional types may also be defined nationally or in other international arenas. The WMO and Ice services have already defined the required feature types for an Ice chart layer. The military Additional Military Layers, by the NATO GMWG are special layers of data or interest to the military..

The following table identifies several types of data that are being addressed in the Canadian Hydrographic Service St Lawrence project. These are given here as an example of auxiliary layers. It is proposed to only standardize the high definition bathymetry layer at this time. Future S.1xx standards may address other layers.

The data is organized spatially in terms of several different geometries. The type of data of interest to this specification is bathymetry data which is described as a continuous coverage quadrilateral grid. This is highlighted in the table below. Some of the other data types identified in the table may also be handled as a quadrilateral grid, but are not addressed specifically by this document.

Table 2 - Example of Auxiliary Layers of Data

Data Type	Data Organization	Geometry Elements
Electronic Nautical Chart (per IHO **S-57, S-101**)	Vector (per ISO 19107)	Point, Curve, Surface
Water Level	Continuous Coverage (Per ISO 19123)	Quadrilateral Grid (X,Y,T and L)
Tide Gauge & Tide Prediction (SPINE)	Continuous Coverage	Quadrilateral Grid
Bathymetry	Continuous Coverage	Quadrilateral Grid
Real Time Surface Current (CODAR Radar)		Data Type to be determined
Current	Continuous Coverage	Quadrilateral Grid
Ice Chart	Discrete Coverage (scanned raster image of a paper product) (Per ISO 19123) Vector (using ICE Feature Catalogue)	Quadrilateral Grid Point, Curve, Surface
Ice Image	Continuous Coverage (RADARSAT Satellite Image)	Quadrilateral Grid
Ice Route	Vector Data (complementary to ENC)	Point, Curve
Ice Forecast	Continuous Coverage	Quadrilateral Grid
Ship own position	Vector	Point
Other ships positions	Vector	Points
Bottom Normative Bathymetry	Continuous Coverage	Quadrilateral Grid
Bottom material classification	Discrete Coverage (material type)	Quadrilateral Grid
Wind	Continuous Coverage	Quadrilateral Grid
Notice to shipping	Vector	Point data with Text attributes
wave model	Continuous Coverage	Quadrilateral Grid

The reference system must be the same for the data types identified above for the data to be integrated into a compound data set.

The various data types can be organized either as 2 dimensional vector data sets, or as continuous coverages or discrete coverages. Elevation is expressed as an attribute (called 2.5 D because there can only be one elevation value per X, Y location)

Vector data is represented by the geometry element **GM_Object** from the ISO 19107 and can be of type Point, Curve (Line) or Surface (Area). The feature data dictionary used to describe feature types is the IHO feature data dictionary and the complementary ICE feature object data dictionary. Any other features required for other feature types would have to be added to the IHO feature object dictionary or to a special feature dictionary and feature catalogue for that data type.

Coverage data may be either continuous or discrete. Continuous coverages exist for situations where grid values are numerical entities and where interpolation can occur. For example, it is possible to interpolate intermediate water levels between tide gauges according to an interpolation formula. Discrete coverages exist for situations where grid cell values represent discrete quantities such as sand, rock, mud. A scanned paper ice chart is a discrete coverage because the grid cell values correspond to elements from a synthetic image that is discrete. Cells correspond to different types of ice as portrayed on the chart and to the shoreline and other lines from the original chart. In integrating data certain discrete coverage cell types can be retained and others discarded.

Several types of vector data elements (GM_Objects) are used. These are Point, Curve and Surface. Ships own position is the simplest geometry consisting of only a single point with a bearing and size thematic attribute. The S-57 ENC chart data uses Point, Curve and Surface. Topological objects are not used because they would need to be recalculated as part of the data integration if used. They can be calculated when required when the data set is processed in an extended Electronic Chart System (ECS)

Several different types of coverage geometry may be used for different classes of auxiliary data. This specification addresses the Spatially Referenced Quadrilateral Grid for bathymetric data. The Riemann Hyperspatial Grid (Quad Tree) coverage, point set coverage and TIN coverage may be used for other organizations or types of data..

Both the continuous and discrete referenced quadrilateral grid coverages may be used for different types of data. Since the difference between the continuous and discrete referenced quadrilateral grid is only the type of data these two data models are almost identical. The continuous coverage is used to express bathymetric data and the discrete coverage is used to express a tiling system.

The 2D vector data model is identical to the S-57 and S-100 vector model and is not reproduced here. The continuous referenced quadrilateral grid is shown in the following section. This model is adapted from ISO 19101-2 Reference Model for Imagery and 19129 Imagery, Gridded and Coverage Data Framework.

Data Structure for High Resolution Bathymetric Data

Coverage function

Coverage is a subtype of feature in that it represents real world phenomena in terms of a set of attributes. The attribute values may be organized in a grid. These values drive the coverage function. A coverage function allows one to interpolate attribute values across a spatiotemporal domain. A continuous coverage function returns a distinct attribute value for each and every position in the domain. Bathymetry is inherently a continuous coverage since there are real values on the sea floor or river bottom between the data points that make up the grid. The interpolation method to be used is described as part of the metadata associated with a coverage function.

Bathymetric Quad Grid Coverage

The Bathymetric Quad Grid Coverage represents a set of depth values assigned to the points in a 2D grid. The ISO standards permit several organizations of grids with different grid traversal orders, and variable or fixed grid cell sizes. Two grids are of interest to bathymetry, the simple quadrilateral grid with equal cell sizes traversed by a linear sequence rule, and the variable cell size quadrilateral grid traversed by a Morton Order sequence known as the Quad Tree for a two dimensional grid. This specification only makes use of the simple quadrilateral grid with equal cell sizes. Two other coverage types, the Triangular Irregular Network (TIN) and the point set coverage are also of interest to bathymetry but are not addressed in this document.

A quad grid coverage data set for bathymetry consists of a sequence of data values organized as a continuous quadrilateral grid coverage together with metadata. The data model describes the relationship between the various attributes and classes that describe the coverage. Except for the set of data values all of these attributes are just another form of metadata. They are attributes that must be provided along with a data set.

Figure 1 gives a simplified representation of the structure of a data set of bathymetry data containing a set of gridded data elements and a set of metadata. The metadata set includes the metadata elements taken from the S-100 metadata standard as well as the attributes that define

the grid, which are effectively the metadata of the grid. In some encoding schemes the attributes that define a grid are included with the grid, whereas in others, they are carried with the remaining metadata items.

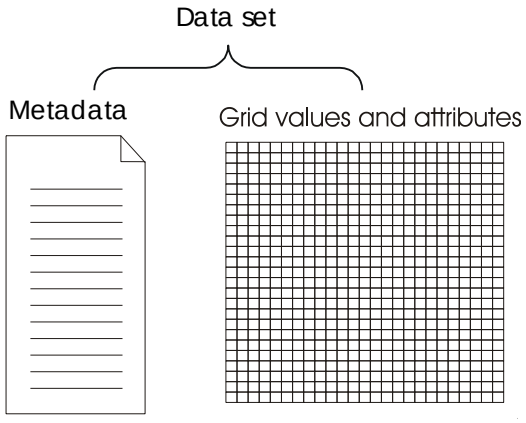

Figure 1 - Metadata and Data

The model in Figure 2 is a more detailed description of the same structure expressed using the UML modelling language and using the modelling elements defined in the ISO geographic information suite of standards and the IHO S-100 standard. It illustrates that a data set of S-100 compliant bathymetric data contains both metadata and a grid values matrix of gridded data.

The model in Figure 2 states that:

> An S-100 data set (**S100_DataSet**) of bathymetric data references an S-100 Image and Gridded Data Collection (**S100_IGCollection**). The relationship allows a 1 to n (**1..***) multiplicity on both ends of the relationship from the data set to the collection. Multiple data sets may reference the same collection and one data set may reference multiple collections. That is to say, that any amount of data may be included in a data set.
>
> An S-100 Image and Gridded Data Collection (**S100_IGCollection**) is a group (collection/layer) of gridded data sets with a common theme as expressed in the metadata. Instances of the collection are described by a set of S100 Collection Metadata (**S100_CollectionMetadata**). This relationship also has multiplicity on both ends of the relationship. That is, multiple sets of metadata may describe the instances of the collection. The relationship shows navigability on both ends indicating that the collection refers to the metadata and the metadata refers back to the instance of the collection which it describes.
>
> The metadata also refers to the coordinate reference system (**SC_CRS**). This information is carried in the metadata but it describes the location of the Quadrilateral Grid Coverage. This is shown by a second relationship from the Grid Coverage element to the coordinate reference system. The details of how a coordinate reference system is expressed are described in the standard ISO 19111.
>
> The Quadrilateral Grid Coverage (**S100_GridCoverage**) is defined as a subtype of the S.100 Imagery and Gridded data types type (**S100_IGDataTypes**) as defined in the standard S.100. The Grid Coverage has two components the Grid Value Matrix and the Grid Value Cell. Both of these objects are also taken from ISO 19123. The Quadrilateral Grid Coverage is a component of the **S100_IGCollection**. That is the metadata and quadrilateral grid coverage make up the collection. The component relationship between **S100_IGCollection** and **S100_GridCoverage** derives from an equivalent relationship in ISO 19101-2 Reference Model - Imagery**.**

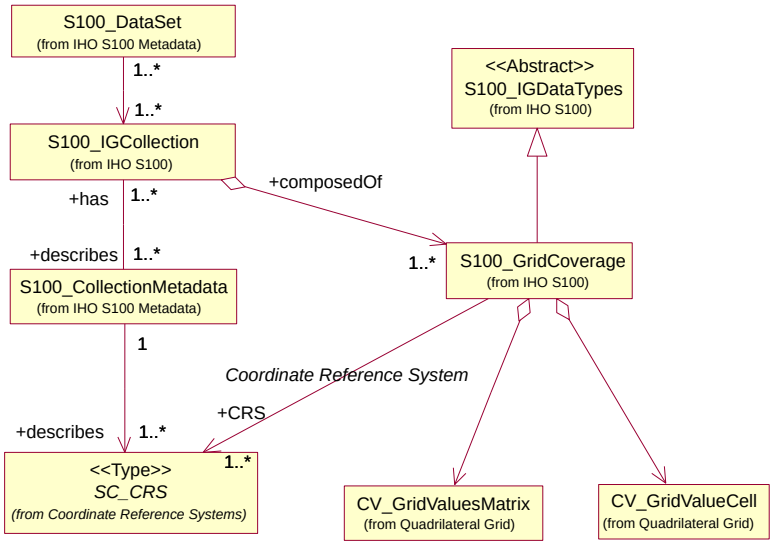

Figure 2- Grid Coverage Data Set with Associated Metadata

A more detailed model is shown in Figure 3 with the attributes that are inherited from the root classes defined in the ISO standards.

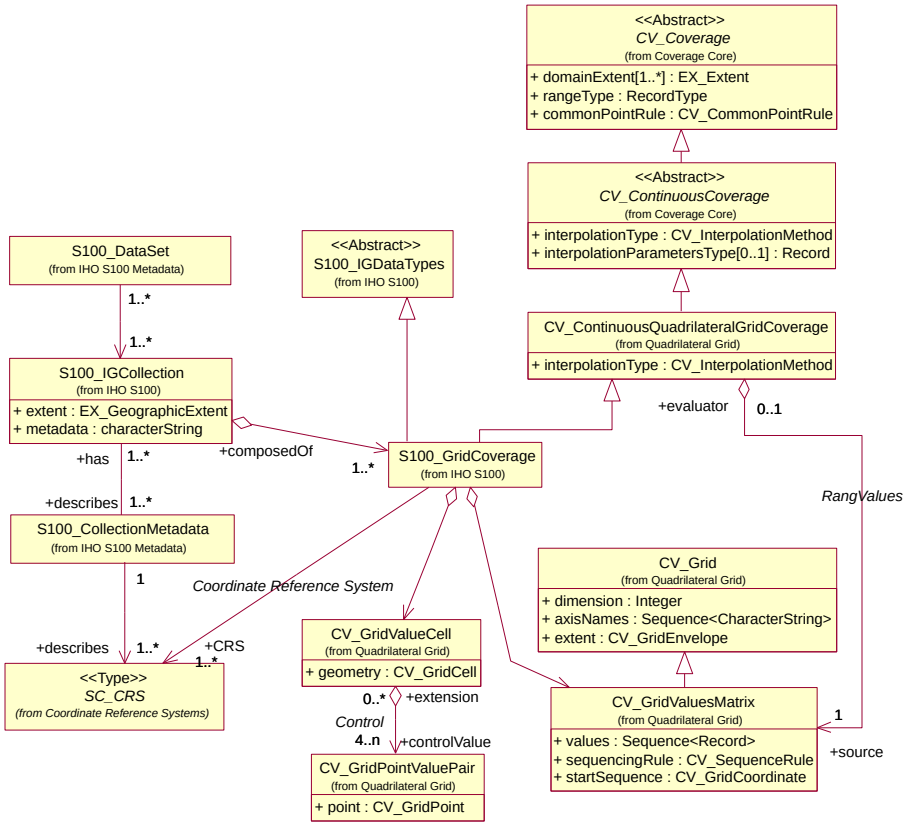

Figure 3- Grid Coverage Data Set with Attributes

This model shows that the data set is composed of instances of a subtype of **CV_ContinuousQuadrilateralGridCoverage**. The grid inherits the attributes: domainExtent,

rangeType, commonPointRule, interpolationType, and interpolationParameter from its supertypes. The CV_GridValuesMatrix and the CV_GridValuesCell are components of the CV_ContinuousQuadrilateralGridCoverage. That is, the coverage is described by a matrix of grid cells. CV_GridCell describes the geometry (size) of a grid cell and the matrix contains a sequence of values.

The attribute ***domainExtent*** describes the spatial extent of the domain coverage. The data type EX_Extent is defined in ISO 19115 as part of the metadata.

The attribute ***rangeType*** describes the range of the ElevationCoverage. It uses the data type RecordType specified in ISO/TS 19103. An instance of RecordType is a list of name:data type pairs each of which describes an attribute type included in the range of the coverage. The name field is used to identify the type of the surface that each value describes. For bathymetry the range type might be "bathymetry:Real" for depth measurements, however, other range types might be used for other types of gridded data.

The attribute ***commonPointRule*** identifies a method for resolving potential conflicts between attribute values resulting from evaluation of a coverage at a direct position when that position falls on the boundary between two value objects, such the edge of two grid cells. A code list **CV_CommonPointRule** is specified in ISO 19123. For elevation coverages appropriate values of the CV_CommonPoint Rule include 'average', 'high', and 'low'. For bathymetry the appropriate value would be "low", meaning the lesser depth value, to ensure that depths are given at their shallowest value to promote safety of navigation. In the case of an elevation model for air charts the value might be "high" to ensure that vertical air obstructions are emphasised.

The class S100_GridCoverage also inherits a relationship to the coordinate reference system **SC_CRS**. The coordinate reference system is defined in ISO 19111.

The attribute ***interpolationType*** describes the interpolation method recommended for evaluation of the ElevationGridCoverage. For bathymetry data the value is either 'bilinear' or 'bicubic'.

> **Bilinear interpolation** is used to interpolate feature attribute values at direct positions within a quadrilateral grid using the function:
>
> $v = a_0 + a_1x + a_2y + a_3xy$
>
> **Bicubic interpolation** is also used to compute feature attribute values at direct positions within a quadrilateral grid. Bicubic interpolation uses the function:
>
> $v = a_0 + a_1x + a_2y + a_3x^2 + a_4xy + a_5y^2 + a_6x^2y + a_7xy^2 + a_8x^2y^2 + a_9x^3 + a_{10}y^3 + a_{11}x^3y + a_{12}xy^3 + a_{13}x^3y^2 + a_{14}x^2y^3 + a_{15}x^3y^3$
>
> ISO 19123 references sources for algorithms for implementing bilinear and bicubic interpolation.

Quadrilateral grid bathymetry coverage is a type of **CV_ContinuousQuadrilateralGridCoverage** as defined in ISO 19123. The only thing that distinguishes a bathymetry grid coverage from any other grid coverage is that the attributes in the sequence of records in the Grid Values Matrix represent bathymetry depth values. Depth is a measurement from the water surface toward the centre of the earth. Depth values are positive numbers representing this concept. Depths are the opposite of elevation values that are measured in the direction away from the centre of the earth.

The object **CV_GridValueCell** has the attribute ***geometry*** which defines the geometry of the grid cell. Four grid points maybe used to control the shape of a cell.

The object **CV_GridValuesMatrix** contains the actual matrix of grid values. The attribute *values* is a sequence of value records. Each **Record** may contain one or more values at a particular grid cell. For a single valued coverage such a bathymetry, the records consist of a single value per cell. The attribute ***sequenceRule*** indicates the order of the attribute values in the sequence. The simplest rule is linear (Row, Column), but more complex rules may be used. For example a Quad Tree Variable cell size grid is traversed in Morton order. The attribute ***startSequence*** gives the position of the first cell in the sequence.

Attributes are also inherited from the supertype class **CV_Grid**. The attribute dimension describes the dimension of the grid, which for bathymetry is 2 dimensions. The attribute ***axisNames*** defines the names of the axis, which are here Latitude and Longitude. The attribute ***extent*** describes an envelope encompassing the matrix of grid values.

S10x_Bathymetry Grid Model

In order to implement the model described in Figure 3 a specific implementation class is defined for a bathymetry grid. The class S10x_BathymetryGrid shown in Figure 4 is a realisation of the class **CV_GridMatrix**. Two types of grids are possible, rectified grids and referencable grids. Rectified grids have a direct linear relationship to a coordinate reference system, whereas a referencable grid requires the use of a transform to convert grid coordinate values to values that can be referenced to a coordinate reference system. Since a bathymetry grid is also a rectified grid it also realizes the class **CV_RectifiedGrid** and inherits the two attributes ***origin*** and ***offsetVectors***.

Figure 4 illustrates the S10x_BathymetryGrid class showing its attributes, as derived from CV_RectifiedGrid and CV_GridValuesMatrix. The actual sequence of values has been extracted into a separate component S10x_BathymetryValues. The values are each represented by a Record. A Record is a data type, defined in ISO 19103, that consists of a set of individual data values for the grid cell. Only one value, the depth is mandatory. Other values may be included in the record such as a reliability or quality indicator number.

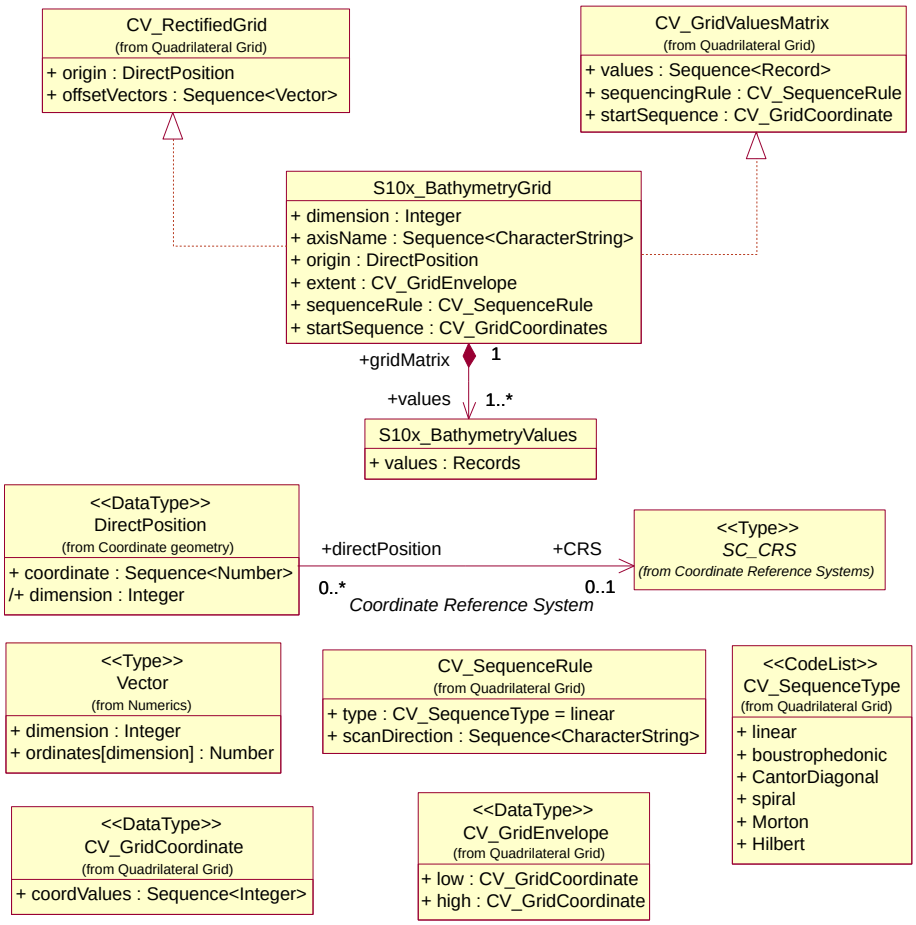

Figure 4 - S10x Bathymetry Grid with associated Attributes

The class **S10x_BathymetryGrid** is a realization of CV_RectifiedGrid and **CV_GridValuesMatrix** from ISO 19123. The attributes inherit from the classes in ISO 19123.

The attribute ***dimension*** specifies the dimension of the elevation grid. Bathymetry grids are restricted to two dimensions so the value of this attribute shall be "2".

The attribute ***axisNames*** specifies the names of the grid axes.

The attribute ***origin*** specifies the coordinates of the grid origin with respect to an external coordinate system. The data type DirectPosition, specified in ISO 19107, has an association through the role name *coordinateReferenceSyetem* to the class SC_CRS specified in ISO 19111 which specifies the external coordinate reference system. This information is described in the metadata.

The attribute ***offsetVectors*** specifies the spacing between grid points and the orientation of the grid axis with respect to the external coordinate reference system identified through the attribute *origin*. It uses the data type Vector specified in ISO/TS 19103. For simple grids with equal cell sizes the offset vector establishes the cell size. For variable cell size grids (Quad Tree grids) the offset vector establishes the minimum cell size. The actual cell size is included as an attribute in the data record that describes the level of aggregation of the quad structure. The attribute ***offsetVectors***

implements the geometry of a **CV_GridValueCell** for a simple quadrilateral grid with equal cell sizes.

The attribute ***extent*** specifies the area of the grid for which elevation data are provided. It uses the type **CV_GridEnvelope** specified in 19123 to provide both the **CV_GridCoordinates** of the corner of the area having the lowest grid coordinate values and the **CV_GridCopordinates** of the corner of the area having the highest grid coordinate values. **CV_GridCoordinate** is specified in 19123.

The attribute ***extent*** effectively defines a bounding rectangle describing where data is provided. For simple grids with equal cell sizes, if data is not available for the whole area within this rectangle, then padding with null values shall be used to represent areas where no data is available.

The attribute ***sequencingRule*** specifies the method to be used to assign values from the sequence of elevation values to the grid coordinates. It uses the data type **CV_SequenceRule** specified in ISO 19123. Only the values "linear" (for a regular cell size grid) shall be used. The sequence rule for a regular cell size grid is simple. When the cells are all of the same size the cell index can be derived from the position of the Record within the sequence of Records.

The attribute ***startSequence*** identifies a value of **CV_GridCoordinate** to specify the grid coordinates of the grid point to which the first in the sequence of elevation values is to be assigned. The choice of a valid point for the start sequence is determined by the sequencing rule.

The class **S10x_BathymetricValues** is a separate component describing the set of data values that apply to the grid matrix. The attribute ***values*** shall be a sequence of **Records** each containing one or more depth values to be assigned to a single grid point. The Record shall conform to the **RecordType** specified by the ***rangeType*** attribute of the **S10x_QuadGridCoverage** with which the **S10x_BathymetryGrid** is associated.

For simple grids with equal cell sizes the **sequenceRule** attribute of an **S10x_BathymetryGrid** equals "linear" and the offset vector establishes the cell size. The attribute ***extent*** specifies the area of the grid for which elevation data is provided.

Tiling

A tile is a set of data that is edge-matched with other data within a tiling scheme. This allows for the handling of data of different densities or data over an extended or irregularly shaped area. A common tiling scheme is a prerequisite for establishing a set of common auxiliary layers that may be applied to hydrographic data. The tiling scheme must match the tiling scheme that the ENC data is delivered in, or the ENC data must be cut to fit a new tiling scheme as the base data for the set of auxiliary layers. This clause on tiling schemes is general to all of the product specifications that build auxiliary layers.

A tile naming convention is required to uniquely identify the tiles. This is a common issue to the cell (tile) naming issues in ENC.

Tiles must fit together. Some producers of ENC data provide additional data beyond a tile to ensure an overlap and identify the actual valid area using the MCOVR attribute. This approach is acceptable for ENC data as long as the data identified by MCOVR fits together in the tiling coverage.

A tiling scheme is effectively a second higher level of grid. That is, a tiling scheme behaves as a discrete grid coverage where the grid elements are themselves grid coverages.

The simplest approach to handling higher density data is to build a tiling mechanism that supports both higher and low-density tiles. This means that higher density data could be mixed with low-

density conventional data. That is, certain areas may be surveyed in high density and this data may be combined with the low-density data in a single coverage. This is simple since cells at the boundary of tiles may be coincident with cells of different resolution. One must consider the cells as data samples at a varying-sampling rate. There will be a need to conflate the surfaces using rules based on accuracy of the surfaces. Variable density tiling is illustrated in Figure 5.

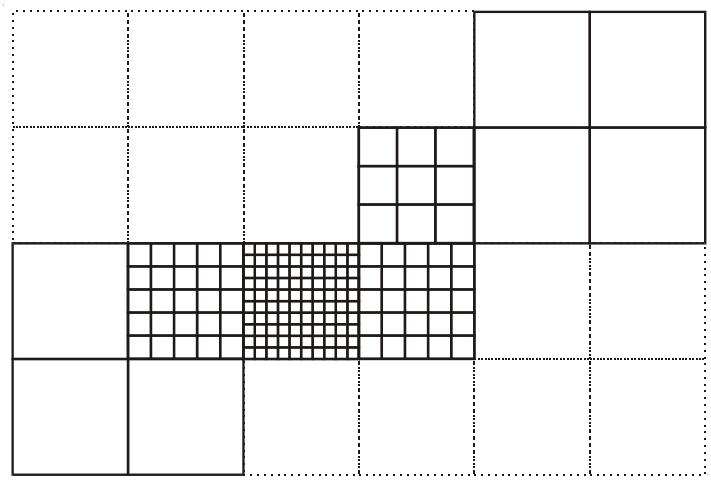

Figure 5 - Tiling Density

A Quadrillateral Grid tiling schemet

This section shows an example of a discrete quadrilateral grid used as a tiling scheme. This example is taken from the CHS St Lawrence Project.

Tiling Grid Type - For the St. Lawrence Test Project the type of tiling scheme will be a simple quadrilateral grid with equal cell sizes traversed by a linear sequence grid rule. A particular data set may include a few (2 to 4) tiles. The approach of using groups of tiles to form products provides the flexibility required to shape the coverage of the product to the shape of the water mass territory

Tiling Orientation - The orientation of the grid will fit the orientation of the meridians and the parallels (north-south and east-west).

As the tiling grid is based on latitude and longitudes, the origin of the grid is the intersection of the equator and the zero degree meridian. The positive direction of the horizontal axe is towards east and its limits are 0 to 180 degrees. The positive direction of the vertical axe is towards north and its limits are 0 to 90 degrees.

Resolutions

The tiling scheme used in the St Lawrence system is a three level system. The following types of tiles are defined:.

Harbour entry = 0.02 X 0.02 degrees and is identified as level 1

Coastal = 0.1 X 0.1 degrees and is identified as level 2

Overview = 1 X 1 degrees and is identified as level 3

Tiles origin are based on a round number in latitude and longitude (ex: 48.0 N 72.0W). This is a self defining tiling scheme has the coverage built up you can define new cells using a round number origin and the 3 predefined tiling resolution.

The grid associated with the tiles respect the following rule for grid node spacing.

Tile resolution / 1000 = grid node spacing

Harbour entry = 0.02 / 1000 = 0.00002 degrees

Coastal = 0.1 / 1000 = 0.0001degrees

Overview = 1 / 1000 = 0.001 degrees

File naming is based on the South - West corner of the tile with the resolution level where 1 = Harbour entry, 2 = Coastal and 3 = Overview . File name convention is :

5 digits for latitude 6 digits for longitude 1 digit for resolution.TIF

ex: 4802N07202W3.TIF

Figure 6 and 7 illustrates the general tiling scheme for the St Lawrence river area. These figures are just an approximation shown to illustrate how tiling will work, and does not illustrate the correct placement or size of tiles.

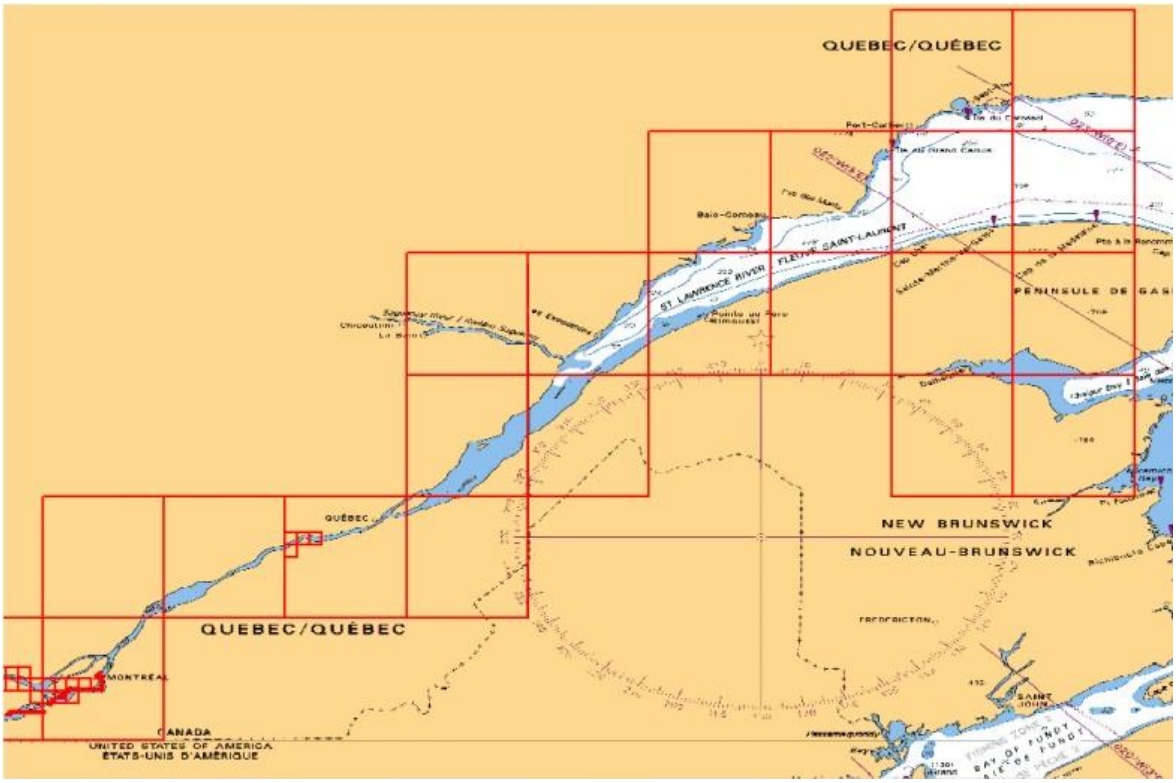

Figure 6 - St Lawrence Tiling Example

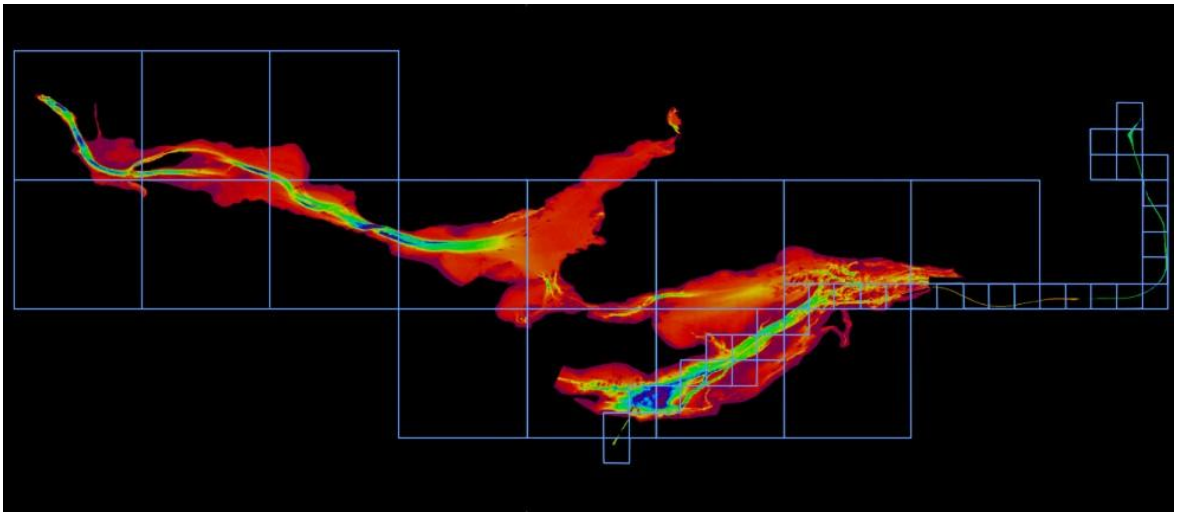

Figure 7 - St Lawrence Tiling Example

Tiling Model

There are two elements to the tiling model, the description of the tiling scheme and the identification of each individual tile. Figure 8 shows that a tiling scheme is associated with a set of data forming a **S100_IGCollection**. The identification of an individual tile is associated with the metadata for a particular instance of the collection.

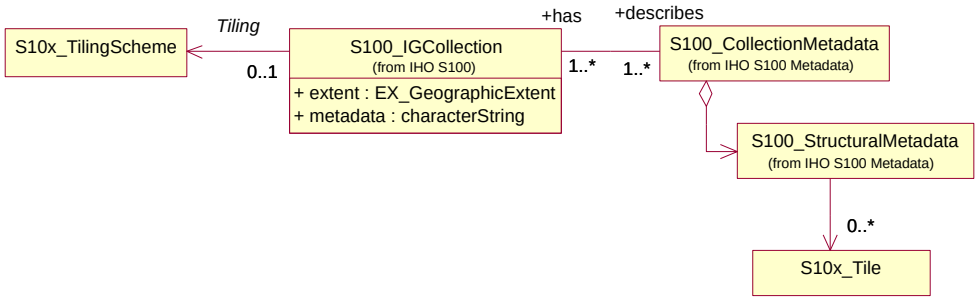

Figure 8 - Tiling Model

An individual tile may be identified either by a tile ID or by the tile boundary. The tile boundary is described by the geometry type **GM_CurveBoundary**. This is illustrated in Figure 9.

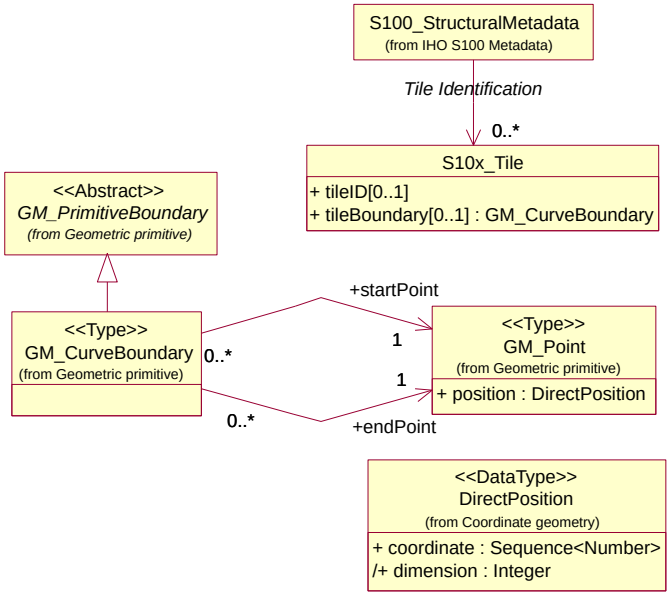

Figure 9 - Tile Reference

The description of the tiling scheme requires the description of a complete discrete coverage that has as its elements the tiles. The S10x_TilingScheme is a realization of the CV_GridValuesMatrix and the CV_DiscreteSurfaceCoverage. This is illustrated in Figure 10. The description of the tiling scheme includes similar attributes to those used to describe the gridded data forming the bathymetric data within each tile. The difference is that the attributes apply to the larger tile grid and not to the individual bathymetric grid data points.

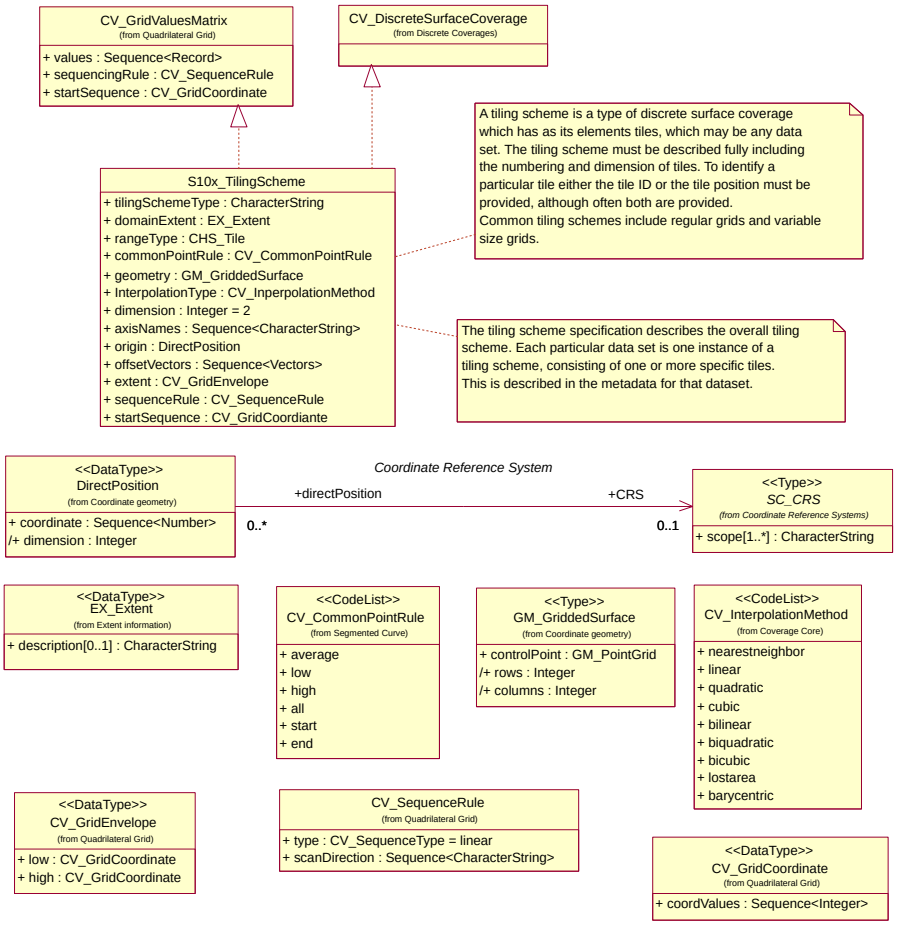

Figure 10 - Tiling Scheme

Coordinate Reference System

Types of referencing

Position relative to the earth is described in terms of a coordinate reference system. Three-dimensional geospatial data positions are usually referenced to a compound coordinate reference system (ISO 19111) consisting of a 2-dimensional horizontal reference system and a one-dimensional vertical reference system.

Horizontal reference systems

Horizontal positions of elevation points shall be directly referenced to the World Geodetic System 1984 (WGS84). This shall be done by the inclusion of the Geodetic Codes for WGS84 datum, and ellipsoid in the metadata.

Vertical reference systems

A vertical reference system consists of a surface identified as a datum from which heights are measured and an axis normal to the surface through the point for which the height is stated. The

WGS 84 ellipsoid, which is the fundamental datum used by the Global Positioning System, is commonly used as the vertical reference surface for elevation measurements on land. Reference to a constant gravity surface is useful in terrestrial applications. Since water depths vary with the tides, bathymetric data is normally referenced to a datum defined in terms of tide state. Bathymetric data in a river or lake is often referred to a special river or lake datum, such as the Great Lakes Datum.

In order for the auxillary data described in this product specification to be able to be used with the base vector data (derived from or from) ENC, the vertical datum must be the same as described for the ENC data. The vertical datum shall be referenced in the metadata.

The use of a sounding datum based on sea level as opposed to an ellipsoid (or geoid) height is the major difference between hydrographic data and land elevation data. The measurement of depth from sea level is important for navigation, and since the level of the sea varies with the tides and other conditions the lowest level is normally used to provide a safety margin. Because the land elevation is measured to a different reference the coastline as determined from the land and from the sea is seldom coincident. Data over the land and over the sea can be used together as long as the user is aware that they are normally measured against different references.

Bathymetry Data Set Structure

Data Set Components

A bathymetry data set consist of an imagery/gridded data collection composed of coverages. Metadata is associated at several levels. Metadata maybe associated with the data set as a whole, or with the coverage. Metadata may also be associated with particular data elements where needed as part of the data value record. More detailed metadata at a lower level overrides general metadata for an entire coverage or collection. Metadata may also be associated with particular tiles.

Metadata is organized into modules. The Discovery Metadata Module relates to the data set as a whole whereas other metadata applies to the imagery/gridded data collection (**S100_IGCollection**). The Collection Metadata Module refers to the Discovery Metadata Module, the Structure Metadata Module, the Acquisition Metadata Module and the Quality Metadata module as sub-components. That is, some elements from the Discovery Metadata Module may also be repeated or overwritten at the collection level.

The overall structure of a bathymetry data set is illustrated in Figure 11 below.

In a data exchange format there are four classes that need to be implemented for each tile in a collection. These are:

S10x_TilingScheme
S10x_BathymetryGrid
S10x_BathymetryValues, and
S100_CollectionMetadata

The S100_Collection Metadata, of course includes the elements used from the four metadata modules, discovery, structural (and tile ID), acquisition and quality metadata.

For the entire data set the S100_DiscoveryMetadata class must be implemented.

In any particular transmittal (data exchange) a whole or part of a data set, or several data sets may be communicated. This is identified in the S100_Transmittal.

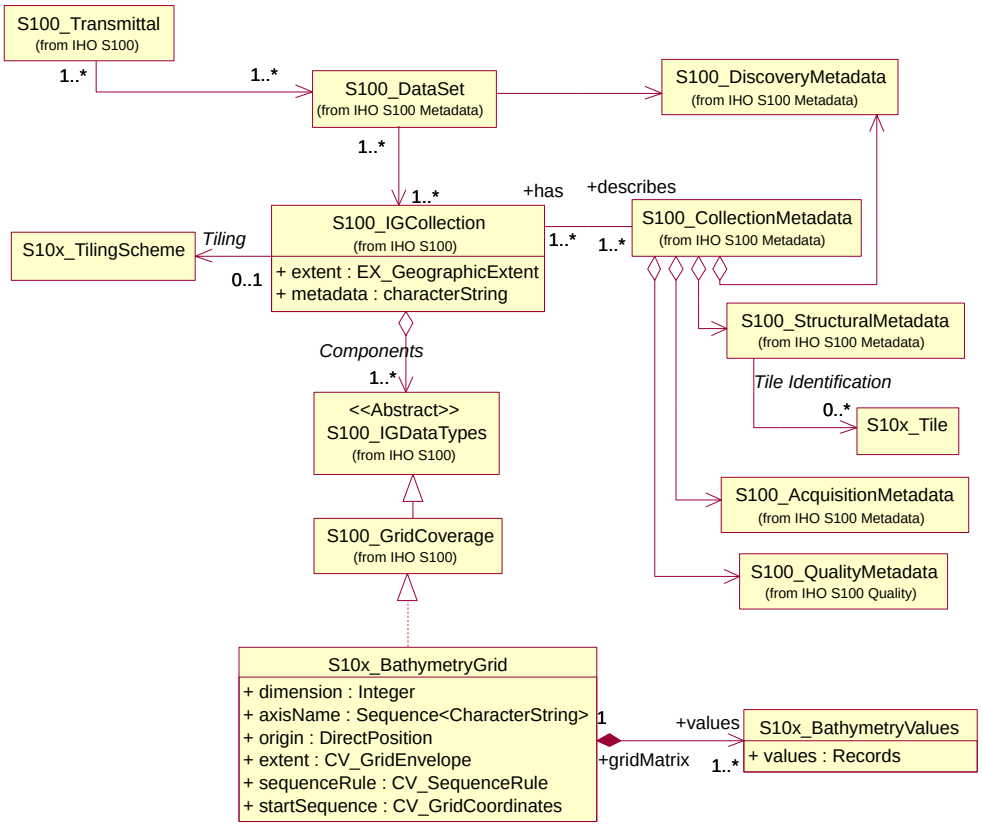

Figure 11- Data Set Structure

Data Set Class

A data set is an identifiable collection of data that can be represented in an exchange format or stored on a storage media. A data set can represent all or a part of a logical bathymetry collection and may include one or many tiles of data. The content of a data set is defined by the Product Specification (per ISO 19131) for that particular type of data and is normally suited to the use of that data. A product specification for a particular data type needs indicate the organization of that data product. For example, a simple gridded bathymetry product may have only one elevation grid coverage, and a tiling scheme that indicates that every data set contains one tile. More complex products may include several colocated coverages and more complex tiling schemes such as a quad tree based variable size tiling scheme, where one data set may, at times contain more than one tile. The data set is the logical entity that can be identified by the associated discovery metadata, not the physical entity of exchange.

S100_Discovery Metadata Module

Associated with a data set is a set of discovery metadata that describes the data set so that it can be accessed. It consists of the "core" metadata defined in ISO 19115.

S100_Transmittal

A transmittal is the encoded exchange format used to carry all, part of, or several data sets. It represents the physical entity of exchange. The transmittal is dependent upon the encoding format and the exchange media. A transmittal on a physical media such as a DVD may carry a number of data sets, whereas a transmittal over a low bandwidth telecommunications line may carry only a

small part of a data set. Any metadata carried with a transmittal is integral to the transmittal and may be changed by the exchange mechanism to other exchange metadata as required for the routing and delivery of the transmittal. A common exchange mechanism would be to carry a whole data set on one physical media such as a CD-ROM. Transmittal metadata is not shown because any transmittal metadata, exclusive of the information in the Discovery Metadata Module, it is dependent upon the mechanism used for exchange, and may differ from one exchange media or encoding format to another. An example of transmittal Metadata would be counts of the number of data bytes in a unit of exchange.

S100_IGCollection

An S100_IGCollection represents a collection of bathymetry data. A collection may include multiple different data types over a particular area, or multiple coverages of data of the same coverage type, but representing different surfaces. For example a collection may consist of a grid coverage and a point set over the same area, where the grid coverage represents an elevation surface and the point set a number of soundings.

S100_Collection Metadata Module

Associated with an S100_IGCollection is a set of collection metadata that describes the data product as represented in the collection. It consists of a number of sub-components that include the Discovery Metadata Module as well as the Structure Metadata Module, the Acquisition Metadata Module and the Quality Metadata Module. Metadata from the Discovery Metadata Module may be applied to an elevation collection so that the entire collection may be discovered. The other metadata modules are descriptive metadata defined in ISO 19115.

Metadata

Metadata Context

The metadata associated with bathymetry data is a profile of the S-100 metadata specification, which itself is taken from the ISO 19115 Metadata specification and the ISO 19115-2 Imagery Metadata specification. The quality metadata elements make use of the metadata classes defined in ISO 19115 with the attributes described in ISO 19138 Data Quality Measures. The acquisition metadata makes use of metadata classes defined in ISO 19115 Metadata together with attributes defined in ISO 19130 Sensor Data Models. Since ISO 19130 is still in development, and is being expanded to cover sonar and other methods of acquisition of direct interest to hydrography, there may be some future enhancements to this area of metadata.

The ISO standard on profiling 19106 defines two classes of profile. A class 1 profile is a pure subset of a base standard, whereas a class 2 profile allows for the extension of the metadata classes within the context defined in the base standard. It is permitted in a class 1 profile to make character strings into code lists, and to introduce other constraints. A class 2 profile can add new metadata and other classes of information. The intent is to promote interoperability. A system that implements a base standard should be able to recognize and process all of the data fields in a profile. If a profile is of class 1 and consists only of constraints, or codification of lists, then a system built to the base standard can process all of the metadata fields at least to the level specified in the base standard. If a data set makes use of a profile of class 2 then a system built to a base standard can recognize and process all of the data fields defined in the base standard and gracefully ignore any extensions. That is, any extensions must provide supplementary information in a form that can be recognized by a system implementing the base standard and ignored without invalidating the context of the other information.

The IHO S-100 metadata standard is a class 1 profile of ISO 19115 Metadata. It also adds some metadata elements from ISO 19115-2. As such any system compliant with the ISO 19115 standard can recognize and process any data defined using the IHO S-100 standard. For example the ISO standard may contain a character string data field to express the source of a data set, where IHO includes a code list of the IHO member states as sources of hydrographic data.

A product specification for bathymetric data may be a class 2 profile of the ISO standards because it would incorporate data fields for other facets of the information not necessarily addressed in the collection of ISO standards profiled in the product specification. An application such as data discovery that only makes use of a subset of the ISO metadata would operate on the product because it would be a compliant class 1 profile within that context, however other applications that made use of the entire set of information within the product may be specific applications such as navigation.

Metadata is broken down into several modules. This specification makes use of the same breakdown as is used in the NGA Elevation Model specification. This not only provides compatibility with land based elevation model metadata but is also a very logical way to organize the metadata. Metadata may be applied at several levels within the structure of a data set. It is usually information from one or several modules that apply at each level. For example, only discovery metadata applies at the data set level, whereas all types of metadata apply at the collection level. Only specific metadata elements are extracted at the individual grid cell level and at that level are included as attributes in the data record. Metadata is hierarchical, so that any metadata element at a higher level applies unless superseded by more detailed metadata at a lower level. That is, metadata elements only need to be described at the highest level since metadata at a lower level overrides metadata inherited from a higher level. Typically it is the acquisition and quality metadata modules that are applied at the lower levels.

The metadata modules are illustrated in Figure 12.

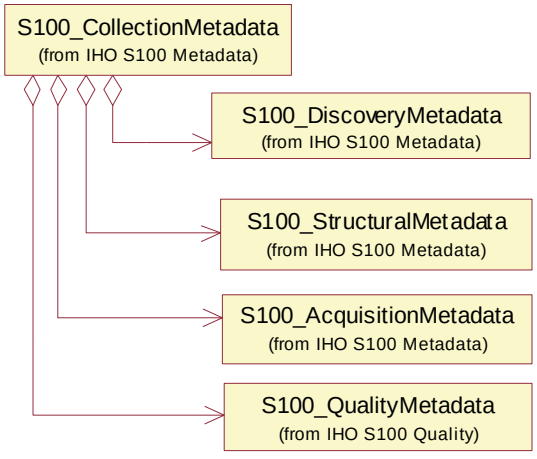

Figure 12- Metadata Modules

The S100_DiscoveryMetadata applies to the whole data set. This is shown by the reference from the S100_DataSet to the S100_DiscoveryMetadata module as shown in Figure 11. ISO 19115 indicates that certain of the metadata fields in the discovery metadata module are mandatory at the data set level. Only a very few metadata fields are actually mandatory, but many more are conditional. That is, if a product specification indicates that some class of metadata is required in that product specification, then other metadata associated with and conditional on that metadata element becomes mandatory.

The same mechanism of binding the metadata to the data set or collection is used in this bathymetry specification as is used in the NGA Elevation Model standard. The metadata modules are linked to the data set or data collection by reference. The attribute " + metadata" contains a character string that may contain a file name for an associated file of metadata or any URL at which the metadata may be located. This approach decouples the metadata from the data allowing different encoding techniques or storage techniques to be used to carry the metadata and the coverage data values. For example, the metadata may be carried in an XML file compliant with ISO 19139 or in a NetCDF4/HDF5 format.

Metadata Overview

The metadata packages defined in the metadata component of the S-100 standard are illustrated in Figure 13. This is a "shopping list" of metadata elements and attributes. A particular product specification selects from this list of elements. What the ISO and the S-100 standard does, by providing a list of elements from which to choose, is to ensure that there is a common understanding associated with a particular metadata element when it is provided. Since few metadata elements are mandatory, this is all that is done. It provides a level of interoperability, but it does not provide commonality. To have a common data specification for a particular type of data it is necessary to define a product specification for that data. The product specification provides the commonality.

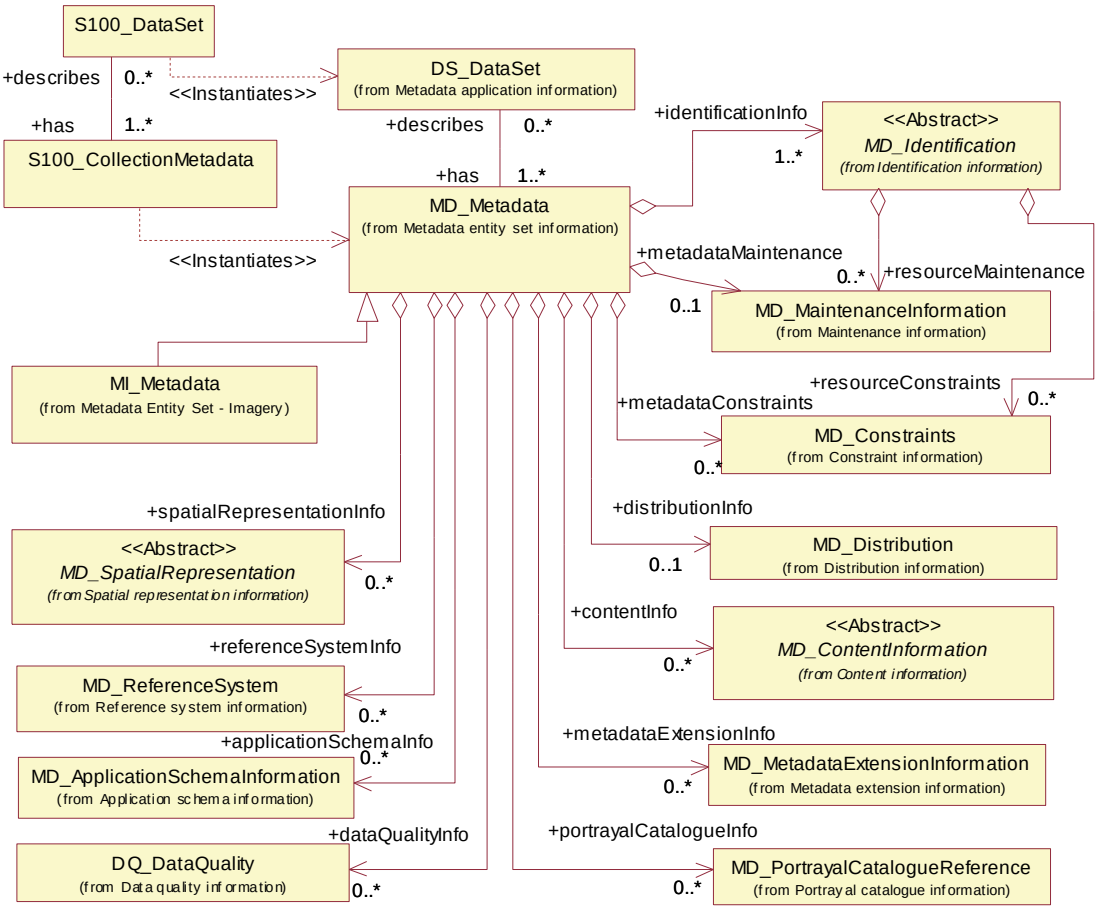

Figure 13- Metadata Overview

The S-100 metadata derives from both the ISO 19115 Metadata standard and the 19115-2 Imagery metadata standard. The MD classes are defined in 19115 and the MI classes in 19115-2. The DQ

classes in 19115 are empty classes whose attributes are provided by ISO 19138 Data Quality Measures.

Discovery Metadata Module

The Discovery Metadata applies to both the data set and a data collection. Elements from the Discovery Metadata Module are derived from the core metadata identified in ISO 19115 plus additional information related to metadata constraints, identification information, descriptive keywords, graphic overview, aggregation information, resource format, resource specific usage and reference system information. This is illustrated in Figure 14.

The description of each metadata field is given in the data dictionary in Appendix A.

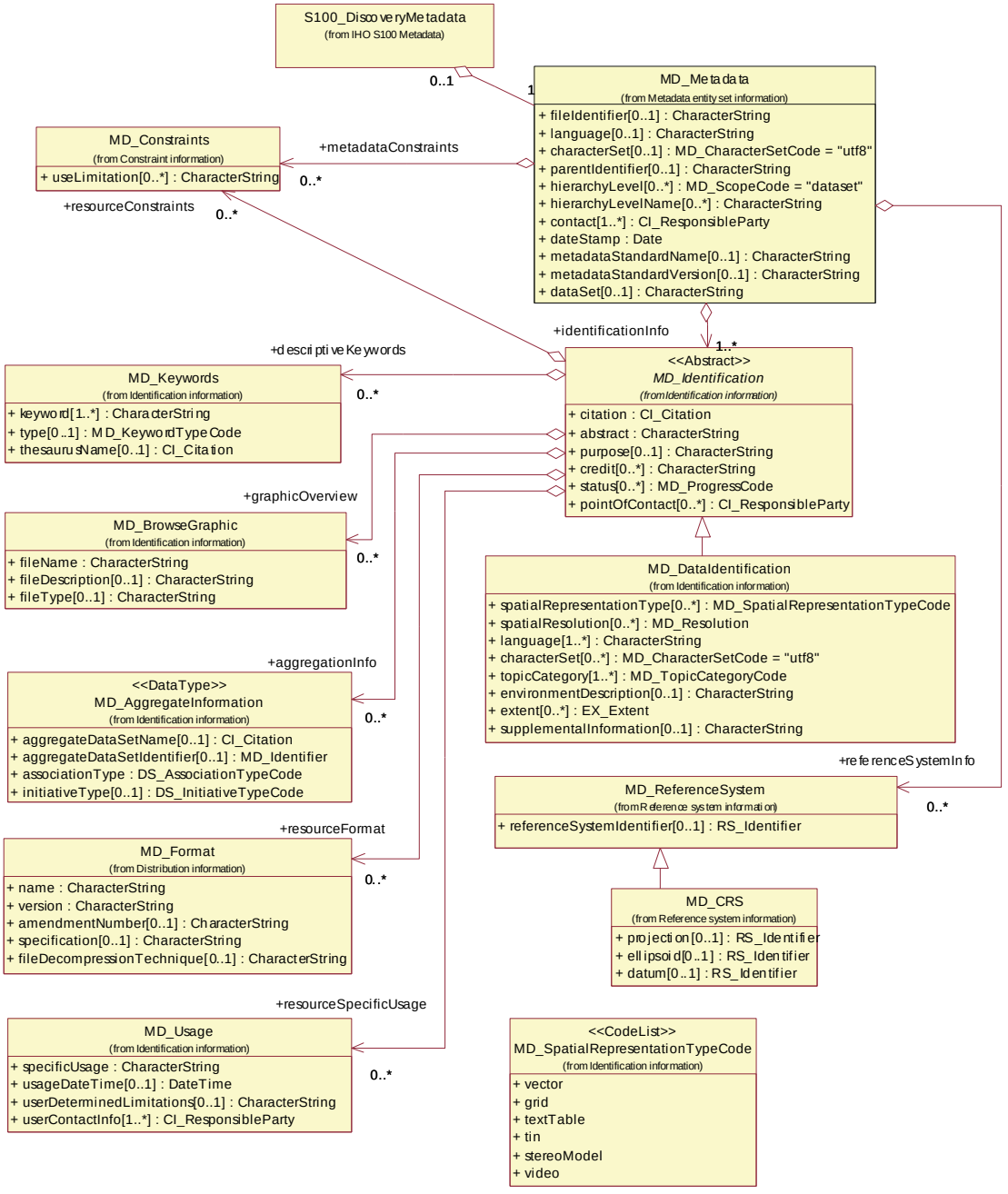

Figure 14- Discovery Metadata Module

The **MD_Metadata** class is the root class for ISO TC211 metadata. It describes the basic characteristics of a data set. Only the ***contact*** and ***dateStamp*** are mandatory attributes. **MD_Identification** is a mandatory component. Within the **MD_Identification** component class only the ***citation*** and ***abstract*** attributes are mandatory. This means that it is possible to have as little as four attributes of mandatory metadata. A product specification for bathymetry will establish which metadata elements are required for that product.

The **MD_Identification** contains information to uniquely identify the data. Identification information includes information about the citation for the resource, an abstract, the purpose, credit, the status

and points of contact. The MD_Identification entity is mandatory. It contains mandatory, conditional, and optional elements. The **MD_DataIdentification** contains information.

The **MD_Constraints** information concerning the restrictions placed on data such as legal constraints or security constraints. Legal constraints are important for navigational data.

The **MD_Keywords** contains keywords describing the data set.

The **MD_BrowseGraphic** contains an overview like a thumbnail image of the area over which the data is held. The browse graphic may be held as an external file referenced by name.

The **MD_AggregationInformation** contains information.

The **MD_Format** contains information about the format of the data. This is encapsulation and encoding information carried as metadata, and this metadata element can be changed to represent other formats if the data is transformed from one format to another. Only information at the level of the name and version of the format is carried. Details of the format, such as byte counts, and other low level details are carried as part of the encoding of the data..

The **MD_Usage** contains information related to the aggregation of data within a dataset..

The **MD_ReferenceSystem** contains a description of the spatial and temporal reference system(s) used in a dataset. The reference system may be specified using an identifier through the attribute ***referenceSystemIdentifier*** or through a MD_CRS, which describes projection, ellipsoid and datum parameters. A postal code is an example of an identifier. If coordinate refereence system is used it may be taken from a register of geodetic codes and parameters as described in ISO 19127 or a sub-register for S-100 or it may be described explicitly by its geodetic parameters. Reference system information are derived from ISO 19108 Temporal Schema, ISO 19111 Spatial Referencing by Coordinates and ISO 19112 Spatial Referencing by Geographic Identifiers.

Structure Metadata Module

Structure Metadata provides information describing the content of the data and the distribution information. This is also selected directly from ISO 19115. In addition information about the instance of a tile is provided as attributes in a related class **S10x_Tile**. Providing this tiling information as an attribute of a related class means that there is no requirement to actually extend the ISO metadata standard. The advantage of not extending the ISO standard is that software designed to recognize and process the ISO metadata will work directly on the S-100 metadata. This is the same approach used in the NGA Elevation Model specification to implement tiling.

Figure 15 illustrates the structural metadata including the tile reference.

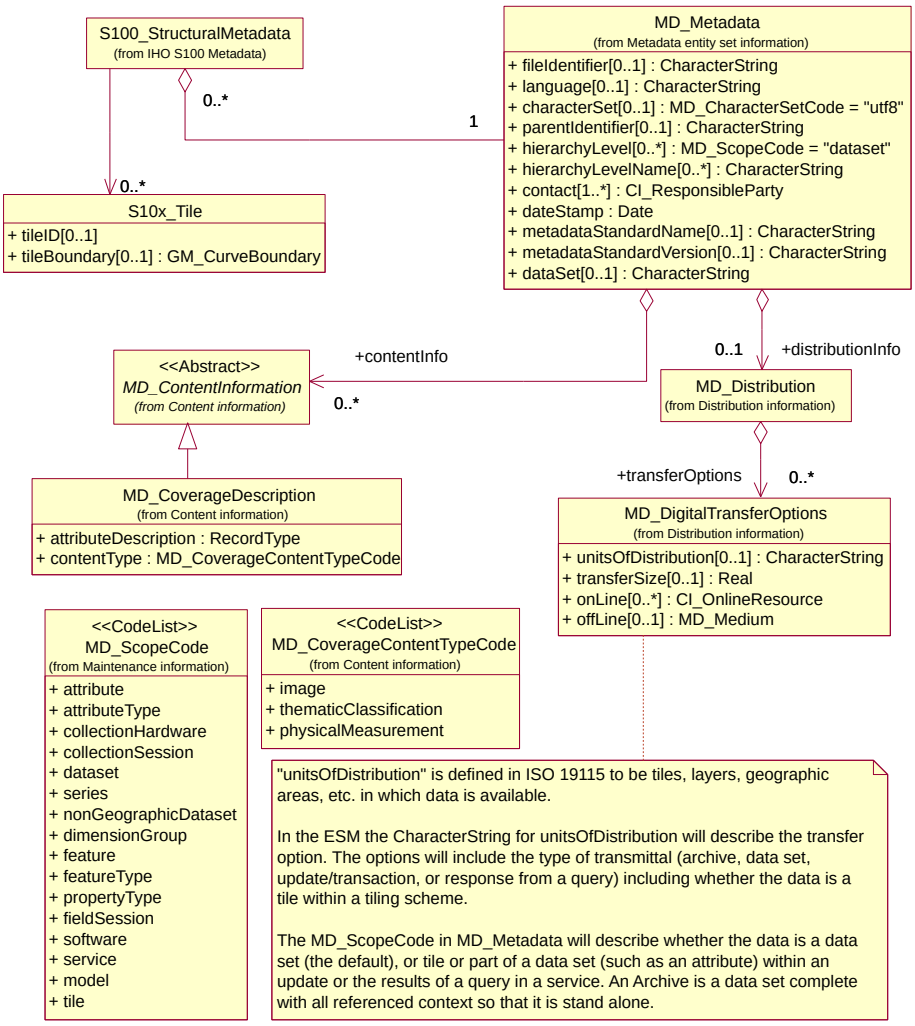

Figure 15 - S-100 Structure Metadata Module

-AcquisitionMetadataModule

Acquisition Metadata provides information related to the sensor or other source of the bathymetry data. This module primarily makes use of the classes defined in ISO 19115-2 Imagery Metadata. Note that the ISO 19130 Sensor Data Model standard on which some of the metadata elements are based are not finalised in ISO.

The Acquisition Metadata Module provides information on acquisition requirements, acquisition plans, acquisition operations and objectives, and information about the instrument and its platform used to acquire the data.

There is a tremendous amount of information that can be provided about particular sensors. A product specification needs to choose carefully the metadata elements relevant to that type of data.

Figure 16 presents the acquisition metadata classes.

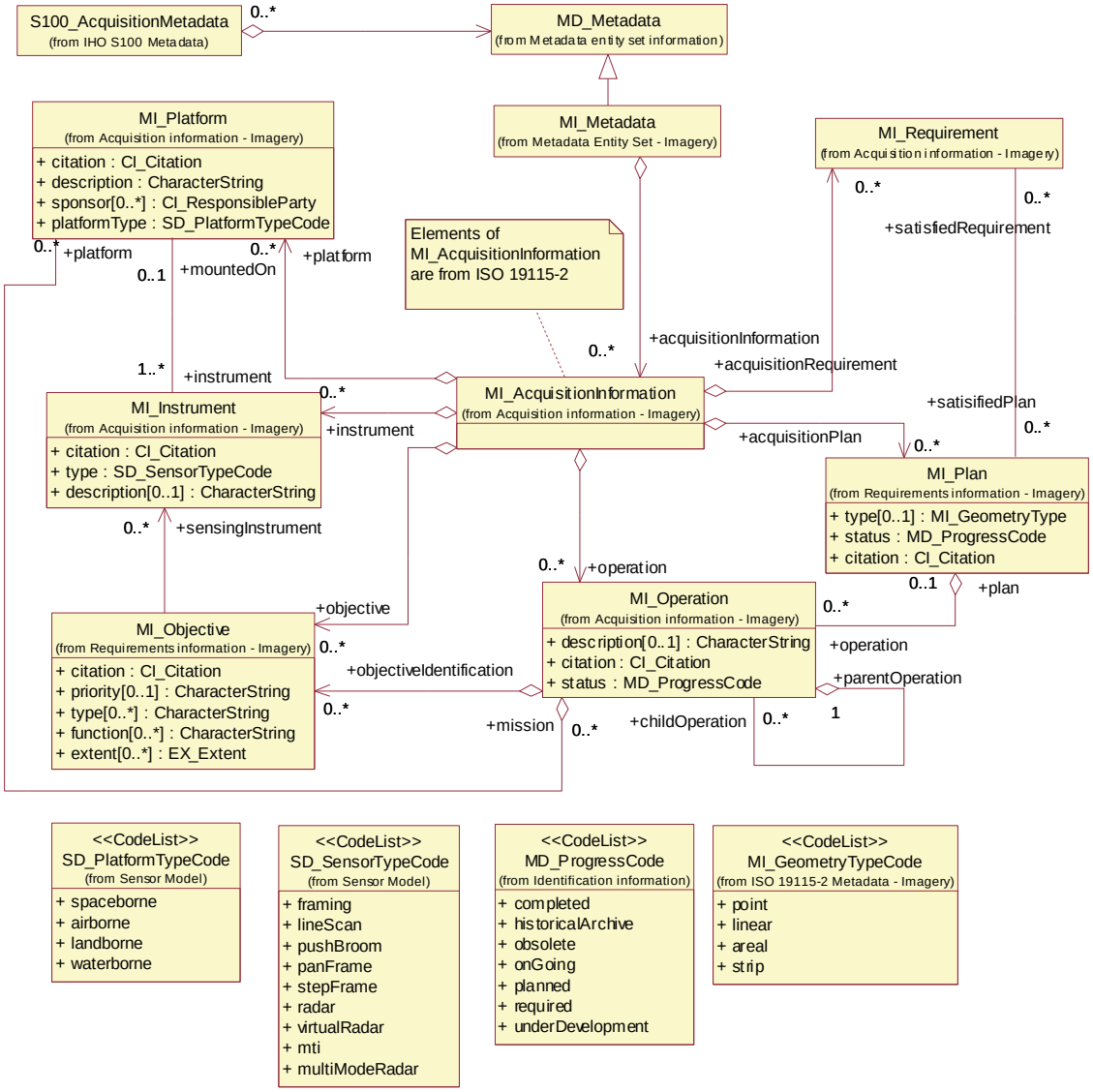

Figure 16 - Acquisition Metadata Module

-QualityMetadataModule

The Quality Metadata Module provides information about the quality of a data set, data collection or specific groups or individual data values. Quality metadata provides information about lineage, source, processing steps and source steps and quality measures. The Quality Metadata Module is a direct subset of the quality metadata provided in ISO 19115. The attributes for quality have been provided by ISO 19138.

Figure 17 provides an overview of the ISO quality metadata. Since there are too many attributes the detailed attributes are not shown here. These are given in the S-100 Quality metadata component.

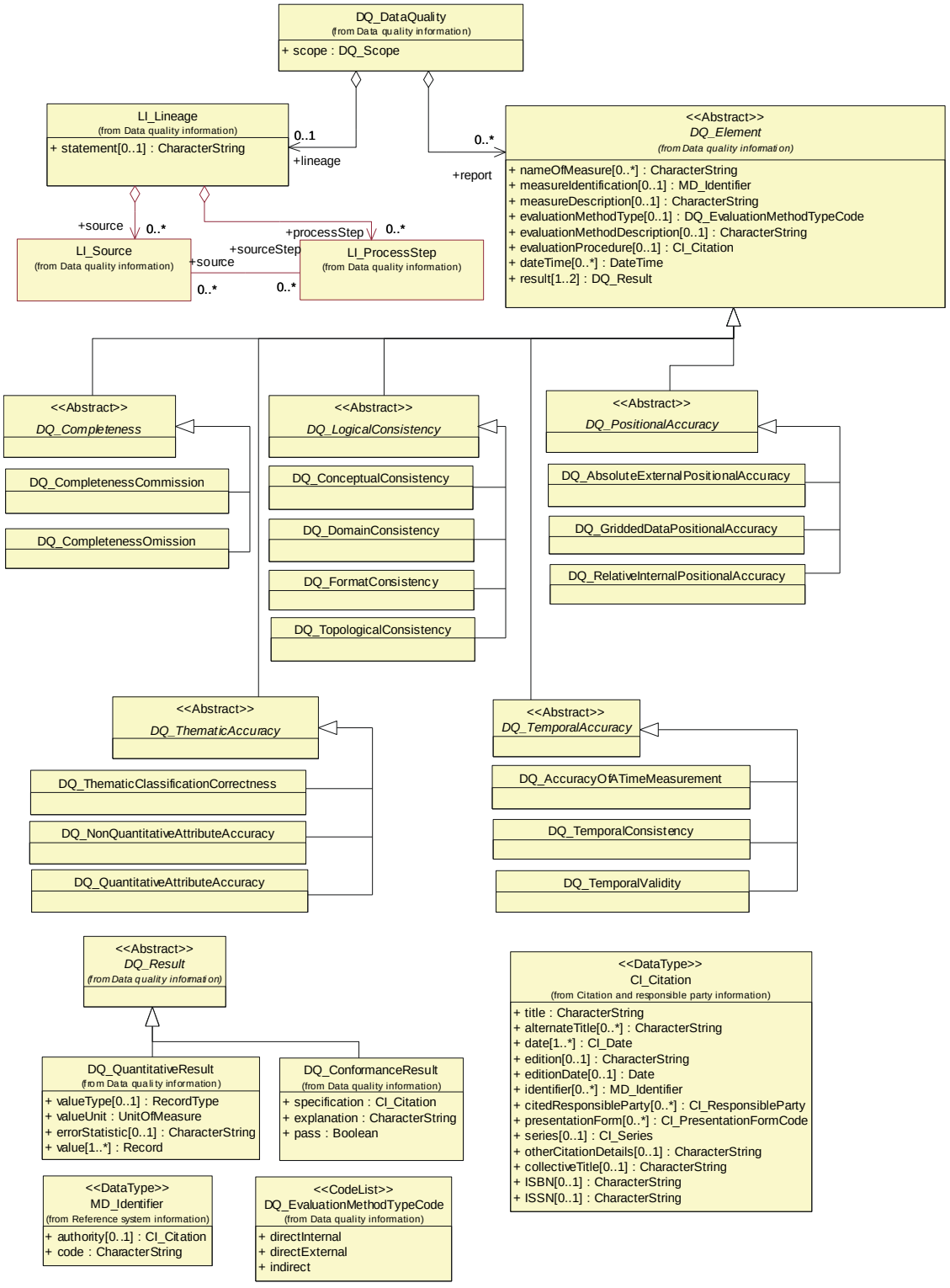

Figure 17 - Quality Metadata Overview

The S100-Quality Measure class structure is derived from ISO 19115 Geographic Information Metadata. The attributes described in the S-100 Quality classes each correspond to independent

quality measures. A full description of these measures are contained in ISO 19138 geographic Information Data Quality Measures.

All of the S100_Quality Measures are intentionally optional so that different measures may be used for different types of data. Where multiple attributes describe the same measure in different ways, either only one measure should be used or the measures must be described in a consistent manner.

All quality measures are described in a register of quality measures as defined in ISO 19138 Annex B, The quality measures selected here are logical extracts from such a register for the purpose of S-100. Additional quality measures may be defined and included in the register as needed,

For bathymetry data the quality measure may be carried as a value associated with each value in the grid value matrix by defining an additional value entity within the value record. (See Fig 4 - S10x_BathemetryValues).

Encoding

Encoding Principals

All data must be encapsulated (delimited) and encoded in order to be exchanged. Encoding is the responsibility of the encoding format. Several encoding formats are available for Bathymetry data.

The basic encoding principle used in the ISO suite of standards is the separation of the "carrier" from the "content". The ISO standards define data in terms of an encoding neutral UML model. Elements from this model are then used to create and Application Schema as part of a product specification. The application schema may be encoded using various different encoding formats.

The only difference between the information carried using different encoding formats is information related to the mechanisms used in that particular encoding technique. If some technique requires delimiters and another requires byte-counts then the encoding format is responsible for any encoding level attributes that identify encoding elements.

Different encoding techniques have different levels of efficiency and others introduce limitations so that certain types of data can not be handled, or if it is handled it is handled in an inefficient manner. By describing the content in an abstract manner and separating the carrier from the content, these limitations are isolated from the data itself.

The following sub-sections identify some of the types of encoding that may be used.

XML plus JPEG Encoding

GML + ISO 19139 + JPEG 2000 (GML JP2)

Bathymetric data is primarily a set of depth values together with a associated metadata. The data volume of the metadata is small compared to the data volume of the depth values. XML is an easily parsable format for delimiting and identifying structured information. However it introduces significant overhead and is not efficient at handling large arrays of numerical data. Therefore the approach to using XML encoding is to combine it with another encoding for the array of data values.

An XML schema, or Data Type Declaration (DTD), is used in XML to establish the syntactic structure of the format and to identify the semantic meaning of the XML tags. The XML schema for

the metadata has already been developed in ISO 19139 and all that is necessary is to select the appropriate portions of that schema to represent the metadata elements used for bathymetry.

JPEG:2000 (ISO 15444) provides a capability to efficiently carry an array of data elements in a lossless manner. The Geography Markup Language GML (ISO 19136) has registered a code in the JPEG header that allows a link to be established to a GML (XML) file.

Note that GML JP2 is an imbedded encoding. That is, the XML data stream is embedded within the JPEG data file. This has the advantage of strongly binding the ISO 19139 metadata to the JPEG data file. The disadvantage is that the file is hard to edit and the normally human readable XML data is not directly available. JPEG can be used the other way around where an application schema is developed in XML which contains a HREF reference to a separate JPEG file. In this configuration the XML can be easily edited and examined, but there is a chance that the two files (the XML/GML and the JPEG) may be separated.

NetCDF Encoding

NetCDF (Network Common Data Form) is a machine-independent binary data format commonly used in the scientific data community especially for climatology applications such as weather forecasting and in some imagery applications. Because it is a binary format it is an efficient formt..

NetCDF includes a data header which describes structure of the file together with data arrays and other information elements. In this way it is similar in structure to ISO 8211. There are some limitations built into the structure to make it simpler.

The new version of NetCDF (version 4) has been implemented on top of the HDF5 data format. The Hierarchical Data Format (HDF) is a multi-object file format for scientific data. It includes several data types, such as, multidimensional arrays, raster images, and tables. New data types can be easily added. The latest version of HDF (version 5) is a significant improvement over previous versions and its object-oriented structure is very flexible.

NITIF Encoding

National Imagery Transmission Format standard (NITF) is a widely implemented exchange format based on the ISO Basic Imagery Interchange Format BIFF (ISO 12087-5). NITIF is widely used in the defence community. NITF data contains information about the image, the image itself, and optional overlay graphics. An image may have sub-images, as well as other information related to the image such as overlaying text or graphics. Spatial Data Extensions extend NITF functionality in a compatible manner.

Recently NITIF has incorporated the JPEG-2000 (ISO 15444-1 standard. An NITIF encoding is likely to be one of the encodings of the military Elevation Surface Model standard.

GeoTIFF Encoding

GeoTIFF is an extension of the popular Tagged Image File Format to carry some geospatial metadata together with the image. The elevation values can be carried as an array much like an image. The GeoTIFF specification indicates that it will in the future be extended to carry additional information to support elevation data. The additional metadata identified in this standard can be carried as an optional associated XML file. The advantage of GeoTIFF encoding is that TIFF decoders are very widespread, and therefore bathymetry data expressed in GeoTIFF could easily be viewed, although the other metadata is discarded. This might serve a part of the market for bathymetry data.

Annex A
Metadata Data Dictionary

(normative)

A 1 Metadata Repertoire

The subsections of this annex present the metadata elements applicable to bathymetry applications for each metadata module in the form of a data dictionary.

A 2 Discovery Metadata

Name	Domain	Data Type	Max. Occ
Metadata Identification Module			
MD_Metadata.fileIdentifier	Free Text	Character String	1
MD_Metadata.language	ISO 639-2, other parts may be used	Character String	1
MD_Metadata.characterSet	MD_CharacterSetCode	Class	1
MD_Metadata.contact > CI_ResponsibleParty	CI_ResponsibleParty <<Data Type>>.	Class	1
MD_Metadata.dateStamp	Date	Class	1
MD_Metadata.metadataStandardName	Free Text	Character String	1
MD_Metadata.securityClassification	Security classification of the metadata	M	1
MD_Metadata.metadataStandardVersion	Free Text	Character String	1
MD_Metadata.metadataURL	Free Text	Character String	1
Resource Identification Module	This module describes the resource.		
MD_Metadata > MD_Identification > MD_DataIdentification.citation > CI_Citation.title (Character String)	Free Text	Character String	1
MD_Metadata > MD_Identification > MD_DataIdentification.spatialRepresentationType (spatialRepresentationTypeCode:	SpatialRepresentationTypeCode <<Code List>>	Class	1
MD_Metadata > MD_Identification > MD_AggregationInformation.aggregatedDatasetIdentifier	MD_Identifier	Class	1
MD_Metadata > MD_Identification > MD_DataIdentification.citation > CI_Citation.date (1..*): CI_Date <DataType> CI_Date Date: date DateTypeCode: Publication	CI_DateTypeCode:	Class	1

MD_Metadata > MD_Identification > MD_DataIdentification.pointOfContact > CI_ResponsibleParty	CI_ResponsibleParty: identification of, and means of communication with, organizations associated with the dataset	Class		1
MD_Metadata > MD_Constraints > MD_SecurityConstraints.classification	MD_ClassificationCode <<Codelist>>	Class	1	
MD_Metadata > MD_Identification > MD_DataIdentification.language (CharacterString)	ISO 639-2 other parts may be used	Character String	1..n	
MD_Metadata > MD_Constraints > MD_Legal Constraints.copyright	MD_ContrictionsCode <<Codelist>>	Class	N	
MD_Metadata > MD_Identification > MD_DataIdentification.topicCategory	TopicCategoryCode	Class		1
MD_Metadata > MD_Identification > MD_DataIdentification.abstract	Free Text	Character String		1
MD_Metadata > MD_Identification > MD_Usage.specificUsage	Free Text	Character String		1
MD_Metadata > MD_Identification.citation > CI_Citation.edition	Free Text	Character String		1
MD_Metadata > MD_Identification.citation > CI_Citation.presentationForm >	CI_PresentationFormCode <<Codelist>>	Class	1…n	
MD_Metadata > MD_Identification.extent > EX_Extent > EX_VerticalExtent.minimumValue and maximumValue	Real	Real	1	
MD_Metadata > MD_DataIdentification.extent > EX_Extent >EX_GeographicExtent > EX_GeographicBoundingBox	Angle			
		Class		
southBoundLatitude	Angle	Class		1
westBoundLongitude	Angle	Class		1
northBoundLatitude	Angle	Class		1
eastBoundLongitude	Angle	Class		1
MD_Metadata > MD_DataIdentification.extent > EX_Extent >EX_GeographicExtent > EX_BoundingPolygon	GM_Object	Class	1..n	
MD_Metadata > MD_Distribution > MD_Format				
name	Free Text	Character String		1
version	Free Text	Character String		1
specification	Free Text	Character String		1
fileDecompressionTechnique	Free Text	Character String		1
Reference System Identification Module				
MD_Metadata > MD_ReferenceSystem > HorizontalReferenceSystem	RS_Identifier	Class		1
MD_Metadata > MD_ReferenceSystem > VerticalReferenceSystem	RS_Identifier	Class		1

A 3 Structure Metadata

Name	Domain	Obligation	Max. Occ

Metadata Identification Module

MD_Metadata.fileIdentifier	Free Text	M	1
MD_Metadata.language	ISO 639-2, other parts may be used	M	1
MD_Metadata.characterSet	MD_CharacterSetCode	M	1
MD_Metadata.contact > CI_ResponsibleParty	CI_ResponsibleParty <<Data Type>>.	M	1
MD_Metadata.dateStamp	Date	M	1
MD_Metadata.metadataStandardName	Free Text	M	1
MD_Metadata.securityClassification	Security classification of the metadata	M	1
MD_Metadata.metadataStandardVersion	Free Text	M	1
MD_Metadata.metadataURL	Free Text	M	1

Content Information

MD_Metadata > MD_ContentInformation >MD_Feature CatalogueDescription.featureCatalogueCitation > CI_Citation	Complete bibliographic reference to one or more external feature catalogues	M	n
MD_Metadata > MD_ContentInformation >MD_Feature CatalogueDescription.featureCatalogueCitation > CI_Citation.date > CI_Date	Reference date and event used to describe it	M	1
MD_Metadata > MD_ContentInformation> MD_FeatureCatalogueDescription.includeWithDataset	Feature Catalogue included with dataset		
MD_Metadata > MD_Distribution > MD_DigitalTransferOptions	technical means and media by which a resource is obtained from the distributor		
MD_Metadata > MD_Distribution > MD_DigitalTransferOptions.unitsOfDistribution	tiles, layers, geographic areas, etc., in which data is available	O	1
MD_Metadata > MD_Distribution > MD_DigitalTransferOptions.transferSize	estimated size of a unit in the specified transfer format, expressed in megabytes. The transfer size is > 0.0	O	1
MD_Metadata > MD_Distribution > MD_DigitalTransferOptions.online	information about online sources from which the resource can be obtained	O	n
MD_Metadata > MD_Distribution > MD_DigitalTransferOptions.offline	information about offline media on which the resource can be obtained	O	1
MD_CoverageDescription	information about the content of a grid data cell		
MD_CoverageDescription.attributeDescription	description of the attribute described by the measurement value	M	1

MD_CoverageDescription.contentType	type of information represented by the cell value	M	1

A 4 Acquisition Metadata

Name	Domain	Data Type	Max. Occ
Instrument Identification Module			
MI_Instrument	Lines following	Aggregated Class	Use max occ from referencing object.
MI_Instrument.citation	<<Data Type>> CI_Citation	Class	1
MI_Instrument.type	<<CodeList>> MI_SensorTypeCode	Class	1
MI_Instrument.description	Free Text	Character String	1

Name	Domain	Data Type	Max. Occ
Platform Identification Module			
MI_Platform	Lines following	Aggregated Class	Use max occ from referencing object.
MI_Platform.citation	<<Data Type >> CI_Citation	Class	1
MI_Platform.identifier	<<Data Type>> MD_Identifier	Class	1
MI_Platform.description	Free Text	Character String	1

Name	Domain	Data Type	Max. Occ
Objective Identification Module			
MI_Objective	Lines following	Aggregated Class	Use max occ from referencing object.
MI_Objective.identifier	<<Data Type >> MD_Identifier	Class	1
MI_Objective.extent	<<Data Type>> EX_Extent	Class	n
MI_Objective.type	<<CodeList>> MI_ObjectiveTypeCode	Class	n

Name	Domain	Data Type	Max. Occ
Requirements Identification Module			
MI_Requirements	Lines following	Aggregated Class	Use max occ from referencing object.
MI_Requirement.citation	<<Data Type>> CI_Citation	Class	1
MI_Requirement.identifier	<<Data Type >> MD_Identifier	Class	1

Name	Domain	Data Type	Max. Occ
Plan Identification Module			
MI_Plan	Lines following	Aggregated Class	Use max occ from referencing object.
MI_Plan.type	<<CodeList>> MI_GeometryTypeCode	Class	1
MI_Plan.status	<<CodeList>> MD_ProgressCode	Class	1
MI_Plan.citation	<<DataType>> CI_Citation	Class	1

Name	Domain	Data Type	Max. Occ
Operation Identification Module			
MI_Operation	Lines following	Aggregated Class	Use max occ from referencing object.
MI_Operation.description	Free Text	Character String	1
MI_Operation.citation	<<DataType>> CI_Citation	Class	1
MI_Operation.status	<<CodeList>> MD_ProgressCode	Class	1

A 5 Quality Metadata

Name	Domain	Obligation	Max. Occ

Metadata Identification Module

MD_Metadata.fileIdentifier	Free Text	M	1	
MD_Metadata.language	ISO 639-2, other parts may be used	M		1
MD_Metadata.characterSet	MD_CharacterSetCode	M		1
MD_Metadata.contact > CI_ResponsibleParty	CI_ResponsibleParty <<Data Type>>.	M		1
MD_Metadata.dateStamp	Date	M		1
MD_Metadata.metadataStandardName	Free Text	M		1
MD_Metadata.securityClassification	Security classification of the metadata	M	1	
MD_Metadata.metadataStandardVersion	Free Text	M		1
MD_Metadata.metadataURL	Free Text	M	1	

Data Quality			
MD_Metadata > DQ_DataQuality > DQ_Element	aspect of quantitative quality information		
MD_Metadata > DQ_DataQuality > DQ_Element.nameOfMeasure	name of the test applied to the data	O	n
MD_Metadata > DQ_DataQuality > DQ_Element.measureIdentification	code identifying a registered standard procedure	O	1
MD_Metadata > DQ_DataQuality > DQ_Element.measureDescription	description of the measure	O	1
MD_Metadata > DQ_DataQuality > DQ_Element.evaluationType	type of method used to evaluate quality of the data	O	1
MD_Metadata > DQ_DataQuality > DQ_Element.evaluationDescription	description of the evaluation method	O	1
MD_Metadata > DQ_DataQuality > DQ_Element.evaluationProcedure	reference to the procedure information	O	1
MD_Metadata > DQ_DataQuality > DQ_Element.dateTime	date or range of dates on which a data quality measure was applied	O	1
MD_Metadata > DQ_DataQuality > DQ_Element.result	value (or set of values) obtained from applying a data quality measure or the outcome of evaluating the obtained value (or set of values) against a specified acceptable conformance quality level	O	1

Resource Lineage Module

MD_Metadata > DQ_DataQuality > LI_Lineage.statement	Free Text	M		1
MD_Metadata > DQ_DataQuality > LI_Lineage > LI_Source.sourceCitation	CI_Citation <<DataType>>	M		1..n

MD_Metadata > DQ_DataQuality > LI_Lineage > LI_Source.scaleDenominator >	MD_RepresentativeFraction <<DataType>>	M	1..n
MD_Metadata > DQ_DataQuality > LI_Lineage > LI_Source.description	Free Text	M	1
MD_Metadata > DQ_DataQuality > LI_Lineage > LI_ProcessStep	information about an event or transformation in the life of a dataset including the process used to maintain the dataset		
MD_Metadata > DQ_DataQuality > LI_Lineage > LI_ProcessStep.description	description of the event, including related parameters or tolerances	M	1
MD_Metadata > DQ_DataQuality > LI_Lineage > LI_ProcessStep.rationale	requirement or purpose for the process step	O	1
MD_Metadata > DQ_DataQuality > LI_Lineage > LI_ProcessStep.dateTime	date and time or range of date and time on or over which the process step occurred	O	1
MD_Metadata > DQ_DataQuality > LI_Lineage > LI_ProcessStep.processor	identification of, and means of communication with, person(s) and organization(s) associated with the process step	O	1