



## DGIWG 116-3-1

### Elevation Surface Model (ESM) Encoding rules - Part 1: Core

<b>Document type:</b>	Standard
<b>Document date:</b>	2 October 2020
<b>Edition number:</b>	1.1.1
<b>Responsible Party:</b>	Defence Geospatial Information Working Group
<b>Supersedes:</b>	This document supersedes DGIWG 116-3-1 Ed. 1.1.0, Elevation Surface Model (ESM) Encoding rules – Part 1: Core, 18 May 2017.
<b>Audience:</b>	This document is approved for public release and is available on the DGIWG website, <a href="http://www.dgiwg.org/">http://www.dgiwg.org/</a>
<b>Abstract:</b>	This document defines the Encoding Rules on the basis of the ESM UML model and metadata, (DGIWG 116-1) and ESM GML application schema (DGIWG 116-2)
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## i. Submitting organizations

Nation	Parent organization
France (Lead Nation)	Institut Géographique National (IGN)
Czech Republic	Military Geographic and Hydrometeorologic Office (MGHM)
Denmark	Danish Geospatial Agency (SDFE)
Sweden	Military Geographic Service
Turkey	General Command of Mapping
United States	National Geospatial-Intelligence Agency (NGA)

## ii. Revision history

Date	Release	Primary clauses modified	Description
12/09/2013	0.1	All	Initial version submitted
25/04/2014	0.2	All	2 <sup>nd</sup> version submitted (after comments on initial version)
19/05/2014	0.3		Final adjustments after comments in Prague TP (D32, T05)
26/06/2014	1.0 (draft r1)		Final draft after D32 telecon (June 2014)
2/10/2014	1.0		Standard for publication (after resolution of comments)
19/08/2015	1.1(draft)		Inclusion of GMLJP2 encoding
11/12/2015	1.1 (draft 2)		Final resolution of comments after DGIWG TP Antalya (Oct. 2015)
19/04/2016	1.1 (draft3)		Addition of NSIF/NITF Encoding rules (Annex D)
18/10/2016	1.1		Restriction to ESM Encoding rules - Part 1: Core (multi-part document) Review in DGIWG TP Oct. 2016
18/05/2017			Resolution of comments from DEU, FRA and SWE, as approved in DGIWG TP May 2017
02/10/2020	1.1.1		Update of normative references (Section 3) and throughout the document + addition of GMLCOV abbreviated term in 4.2

## iii. Future work

Incorporation of the TIN encoding into the ESM Encoding rules once it has been included into the ESM GML Application Schema.

## Introduction

The Elevation Surface Model Standardized Profile (DGIWG 116-1) provides the conceptual schema for describing and manipulating the information content required for the exchange of surface elevation information for a variety of surfaces such as bare earth, vegetation canopy, or bathymetric depth, under different data models, such as coverages (Rectified Grids, Point Coverages or TIN Coverages) or Point Sets, together with the associated metadata.

This document defines the Core of the ESM GML Encodings Rules that apply for the encoding of ESM data, addressing elevation data file, associated metadata and (optionally) ESM GML instance. It contains the relevant conformance clauses and conformance classes associated to the various use cases. It is to be associated to another document specifying the encoding rules for the implementation standardized encoding, that is GeoTIFF (cf. Part 2 document), GMLJP2 (cf. Part 3 document) and NSIF/NITF (cf. Part 4 document).

**Limitation:** As the GML coverage application schema, in its present version, does not handle the TIN coverage model, the TIN component is currently excluded from this ESM Encoding Rules.

The ESM Encodings Rules comply with:

- GMLCOV (for its Coverage components only), for its ESM GML Coverage instance (if any), in order to facilitate ESM data access via WCS service.
- GML (and more particularly DGIWG GML profile L1.3D.0d for its PointSet components only), in order to facilitate ESM data access via WFS service.
- DMF for ESM metadata, in order to be consistent with other DGIWG standards for topographic and imagery metadata.

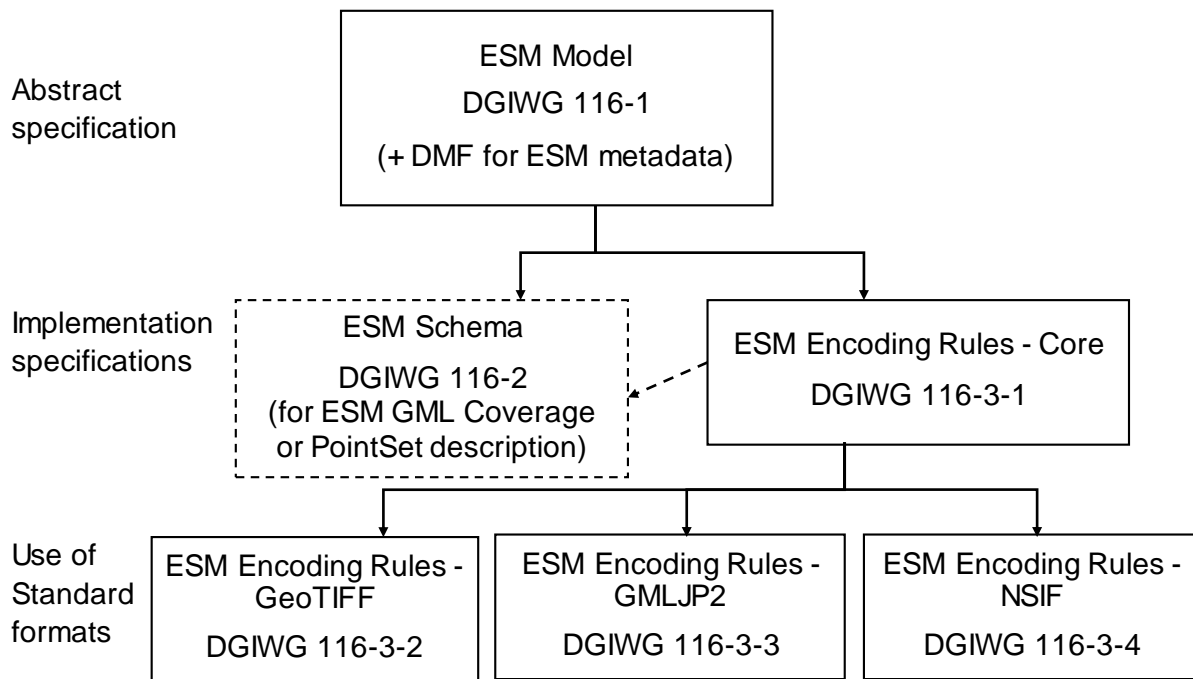
# 1 Scope

This document defines the Elevation Surface Model (ESM) GML Encoding Rules that apply for ESM data based on DGIWG ESM standard (DGIWG 116-1), including their associated ESM GML coverage or point set documents (as specified in DGIWG 116-2) and ESM DMF/XML metadata.

As stated in DGIWG 116-1, ESM model includes Gridded and Point coverage model, as well as TIN coverage (not retained in the present version of ESM encoding rules), and Point set model. It should be noticed that it does not include Elevation Contour Lines, which are usually part of a dedicated theme / layer of topographic data.

These encoding rules and this document are to be associated to another document specifying the encoding rules for the implementation standardized encoding, that is GeoTIFF (cf. Part 2 document), GMLJP2 (cf. Part 3 document) and NSIF/NITF (cf. Part 4 document).

The following figure illustrates the use of the various ESM specifications.



Note: The ESM GML Coverage or Point Set description is optional.

## 2 Conformance

Conformance to ESM Encoding Rules apply to, as detailed in Annex A - ESM Encoding Rules:

- General encoding rules for ESM collection or single ESM dataset
- ESM metadata, applicable to the dataset or collection of datasets, or TilingScheme resources. The TilingScheme description is associated to ESM Collection metadata, in case a tiling scheme applies to the collection.
- ESM Coverage schema based on GMLCOV for RectifiedGridCoverage or MultiPointCoverage with 2 options for the conformance class:
  - in case of a message-based encoding for a web service, with the GMLCOV *gml-coverage* and *multipart* conformance classes incorporating the supported format. This is the multipart data delivery conformance test for ESM Coverage data.
  - in other cases (e.g. a physical media based encoding), with the *gml-coverage* and the *gml* conformance classes, with the exception of Clause A.1.1.17 - GML special format for the GML encoding of the RectifiedGridCoverage. In this case, the ESM GML Coverage document and the ESM data (corresponding to the rangeSet of GMLCOV), encoded in a dedicated format, are 2 distinct files. This is the multiframe data encoding conformance test for ESM Coverage data.
- ESM PointSet schema based on GML profile L1.3D.0d for PointSet
- Any encoding of ESM Coverage Elevation data, in one of the format supported in the additional parts 2 to 4, with conformance rules specified in corresponding parts, in either a separate file, or as part of the multipart message.

Any ESM data claiming conformance to the DGIWG ESM Encoding Rules shall pass the applicable test specified in Annex A - ESM Encoding Rules.

Any software implementation claiming conformance to the DGIWG ESM Encoding Rules shall document its ability to import and/or export ESM compliant data.

### 3 Normative References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of these profiles.

1. DGIWG 116-1: Elevation Surface Model, Edition 1.1, 17 September 2020 [ESM]
2. DGIWG 114: DGIWG Metadata Foundation, 2.0.0, 12 July 2017 [DMF]
3. DGIWG 116-2: DGIWG ESM GML Application Schema, Edition 1.0.2, 2 October 2020 [ESM\_GML\_AS]
4. DGIWG 116-3-2: DGIWG ESM Encoding Rules – GeoTIFF, Edition 1.1.1, 2 October 2020 [ESM\_ER GeoTIFF]
5. DGIWG 116-3-3: DGIWG ESM Encoding Rules – GMLJP2, Edition 1.1.1, 2 October 2020 [ESM\_ER GMLJP2]
6. DGIWG 116-3-4: DGIWG ESM Encoding Rules – NSIF, Edition 1.1.1, 2 October 2020 [ESM\_ER NSIF]
7. ISO 639-2:1998 Codes for the representation of names and languages
8. ISO 19136-1:2020— Geographic information – Geography Markup Language (GML) – Part 1: Fundamentals
9. ISO 19136-2:2015— Geographic information – Geography Markup Language (GML) – Part 2: Extended schemas and encoding rules
10. ISO 19139:2007 Geographic information – Metadata – XML schema implementation
11. ISO/TS 19139-1:2019 Geographic information — XML schema implementation — Part 1: Encoding rules
12. OGC® GML Application Schema – Coverages, Version: 1.0.1, 11 May 2012 (OGC 09-146r2)

## 4 Terms and definitions, and abbreviated terms

### 4.1 Terms and definitions

Generally, the terms and definitions of the base standard ISO 19106, ISO 19107, ISO 19123, ISO 19136-1 and ISO 19136-2 as well as DGIWG 116-1 (ESM) apply to this profile. Some abbreviated terms are repeated in this document, for the sake of readability.

### 4.2 Abbreviated terms

ASCII	American Standard Code for Information Interchange
CRS	Coordinate Reference System
DMF	DGIWG Metadata Foundation
DTED	Digital Terrain Elevation Data (US MIL and NATO standard)
EPSG	European Petroleum Survey Group (now OGP, International Association of Oil & Gas Producers)
ESM	Elevation Surface Model
GeoTIFF	Geographic TIFF
GML	Geography Markup Language
GMLCOV	GML Coverage schema (associated to OGC 09-146r2)
GMLJP2	GML (embedded) in JPEG2000
ISO	International Organization for Standardization
NSIF	NATO Secondary Imagery Format (STANAG 4545) – equivalent to NITF2.1 (US National Imagery Transmission Format)
OGC	Open Geospatial Consortium
TIFF	Tagged Image File Format
XML	eXtensible Markup Language



## 5 Applicability and use

This ESM Encoding Rules is applicable to any ESM data, claiming compliance to ESM. The following GML instances are optional. A web coverage service must provide this information, but these GML instances are optional (except for the GML PointSet document) depending on implementation choice:

- A single ESM GML Coverage document, together with its associated metadata, including or associated to the corresponding ESM Coverage Data (rangeSet of GMLCOV) encoded in one standardized format addressed in Annexes B to E. Depending on the use case, this ESM Coverage data is either a separate file or included in a multipart message.
- A single ESM GML PointSet document, together with its associated metadata and including the PointSet Data.
- A collection of ESM Coverage or collection of ESM PointSet document, together with its associated metadata which, if tiling is used, this metadata is required to include the TilingScheme resource description, and associated TilingScheme geometry, according to the RectifiedGrid or MultiSurface Coverage model.

These documents provide the full set of encoding requirements on ESM model information encoded in GML instances (based on ESM GML schema), ESM metadata encoded in XML (based on DMF schema), associated to any ESM data (in any available “legacy” format – such as GeoTIFF, JPEG2000 or NSIF/NITF).

As a result, such ESM encoded data can be produced, discovered (via a catalog web service) and delivered to the users via Web Coverage Service (for the Coverage compliant data) or Web Feature Service (for the PointSet compliant data), in addition to the basic transmittal on a physical media.

This ESM Encoding Rules is intended to result in a higher degree of interoperability between elevation (including bathymetric) data based on GML and GML Coverage application schemas, the DGIWG Metadata Foundation (DMF), and other DGIWG imagery or topographic data standards.

## 6 ESM Encoding Rules

### 6.1 Introduction

This section contains information and requirements that is applicable to both producers and users of ESM data. An ESM data may be a single dataset or a collection of datasets.

These requirements apply to:

- the ESM collection GML instance (optional), and its associated ESM Collection metadata set (based on the DS\_Aggregate element of 19139) in accordance with DMF for collection resource, with RSTYPE set to 'series'.
- the ESM dataset GML instance (optional in the coverage case), based either on the GMLCOV or the PointSet model, and its associated ESM dataset metadata set (based on DS\_Dataset element of 19139) in accordance with DMF for dataset resource, with RSTYPE set to 'dataset'. In the case of the PointSet model, this document includes the GML Point set data.

Note: Depending on implementation choice, ESM collection and datasets in the collection may be organized according to 2 schemes:

- separate files under a collection directory structure: ESM dataset GML instances for all the coverages in a collection in separate files / subdirectories under the ESM collection directory; in this case, either the GML collection document or the metadata associated to the collection / series must refer to the ESM datasets resources;
  - one single integrated GML instance describing collection and all dataset components of the collection.
- the ESM data file (in the coverage case), in a standardized encoding format, which is in a separate file, or may be part of a multipart message as a response to a delivery request.

The specific information and requirements on the encoding of the ESM data file in standardized formats are addressed by the parts 2 to 4 of the suite of DGIWG 116-3-x standards for the supported encoding formats.

Note: The metadata resource and the elevation data file are usually both constrained by specific requirements in terms of metadata or information on the data. Consequently, some information items are redundant in the two components of an "ESM dataset". In order to avoid redundant information, the ESM GML instance information is specified with the minimum level of information required by the GMLCOV or PointSet model. However, the constraints of ESM GML model will provide some information (e.g. CRS, UoM) three times, as explained further in this document.

The metadata property of the feature or coverage specified in the ESM GML instance (if any) should reference the metadata set resource.

The applicable use cases that this ESM encoding rules is intended to support are presented in [ESM] and [ESM\_GML\_AS] documents in their Use cases section.

## 6.2 General ESM encoding rules for ESM collection or single ESM dataset

An ESM dataset contains the ESM data file encoded in a standardized format and the associated ESM metadata set; it may also contain the associated ESM GML instance, conformant to its applicable ESM schema (ESMCoverage or ESMPointSet). This application schema facilitates web service capability, on the basis of GML (for PointSet) and GML coverage schemas.

An ESM collection contains the packaging ESM Collection GML instance, associated ESM Collection metadata set and ESM datasets.

A transmittal may contain an ESM dataset or an ESM collection and associated metadata.

Access to metadata may be provided by a dedicated web service. In a WCS2.0 context, a message in reply to a describeCoverage will provide the ESM metadata associated to the coverage.

This encoding rules document places no requirement on the implementer to give precedence to the data file, or the metadata resource or the GML coverage document as an entry point into the associated set of artifacts.

**Requirement 1:** An ESM dataset (or collection of datasets) shall contain the following components:

- An ESM GML instance (optional), for the ESM collection corresponding to an ESM Transmittal / exchange, and its associated ESM collection metadata.

For each Coverage or PointSet dataset in the ESM collection

- an ESM GML instance (optional in the coverage case), according to ESM Coverage schema and ESM\_COV conformance class (for a Coverage dataset), or to ESM PointSet schema and ESM\_PTS conformance class (for a PointSet dataset)
- its associated ESM metadata set based on DMF-all schema and the ESM metadata rules.
- (for coverage elevation data) the Elevation data in a standardized encoding format as specified in one of the Parts 2 to 4 of the suite of DGIWG 116-3-x standards.

**Requirement 2:** An ESM collection instance shall be based on ESM GML Application Schema:

- for a collection of Coverage data, according to ESM coverage schema and ESM\_COV conformance class ;
- for a collection of PointSet data, according to ESM PointSet schema and ESM\_PTS conformance class.

**Requirement 3:** The ESM datasets resources shall be referred to by either the GML collection document (if any) or the metadata associated to the collection / series (or both mechanisms).

## 6.3 ESM Coverage GML instance

### 6.3.1 ESM GML coverage instance

**Requirement 4:** The GML instance for ESM Coverage shall be based on ESM Coverage Application Schema, according to the ESM\_COV conformance class, either for ESM\_GridCoverage or ESM\_PointCoverage.

**Requirement 5:** The coverage domain information in the GML instance for ESM Coverage shall be consistent with the corresponding information specified by the internal encoding format for the ESM data. In case of discrepancy, the internal encoding format information shall prevail.

### 6.3.2 Modes for encoding / packaging ESM coverage data

For coverages, different encodings may be used for the domain and the range of the coverage. Two modes are allowed for packaging the domain and range encoding when producing or delivering coverage data on a physical media, or delivering it through a download service, as discussed below:

#### **Mode 1: Multipart representation: for download service delivery**

For performance reasons, binary file formats are usually preferred to text-based formats such as XML for storing large amounts of coverage data. However, they cannot directly constitute an alternative to pure GML, since their own data structure might often not support all the ISO 19123 elements used to describe coverages in the conceptual model.

The OGC standard GML Application Schema for coverages [OGC 09-146r2] offers a format encoding which combines these two approaches. The first part consists of a GML document representing all coverage components except the range set, which is contained in the second part in some other encoding format such as 'well known' binary formats' (for example TIFF or GeoTIFF, according to the dedicated GMLCOV encoding extension). Some information in the second part may be redundant with the GML content of the first part. In this case, consistency must be ensured through a mapping of the additional encoding format structure to GML

The advantage of this multipart representation is that coverage constituents are not handled individually (as in Mode 2 below)

**Requirement 6:** Coverage data encoded as multipart document shall comply with the *multipart* representation conformance class defined in GML Application Schema for Coverages [OGC 09 146r2]. This mode shall be used when delivering coverage data through a web coverage service.

Note: The GML Application Schema for Coverages establishes a one-to-one relationship between coverages and multipart document instances.

#### **Mode 2: Reference to an external file: for encoding on a physical media**

The range set can be encoded as an external binary file and referenced within the XML structure using the `gml:File` element. This has the benefit of efficiently storing the range set

data within an external file that is of a well-known format type, for example TIFF / GeoTIFF. This method of encoding is of most use for the storage of large files.

**Requirement 7:** The reference to an external binary file using the gml:File element shall be used when encoding or delivering coverage data via a physical media, according to the GML special format requirement class specified by GMLCOV.

#### 6.4 ESM PointSet GML instance

**Requirement 8:** The GML instance for ESM PointSet shall be based on ESM GML PointSet Application Schema, for the ESM\_PTS conformance class.

This ESM GML PointSet instance shall include the ESM PointSet data, according to the DGIWG GML profile L1.3D.0d.

#### 6.5 ESM metadata encoding

ESM metadata are associated with each ESM data resource (collection, dataset). An ESM metadata set is a XML resource conformant to DMF schema, and following the rules specified in [ESM] for ESM metadata and hereafter.

**Requirement 9:** An ESM metadata set shall be associated with each ESM data resource (ESM collection, ESM dataset,), based on the relevant metadata elements as specified in ESM metadata (ESM) and [DMF], with the RSTYPE element as follows:

- for collection RSTYPE = series
- for dataset : RSTYPE = dataset.

**Requirement 10:** The association between the ESM metadata resource and the ESM data file should be bi-directional:

- the ESM metadata resource shall provide the reference to the ESM data file, according to the ESM metadata dictionary (Dataset identifier, DMF – RSID element)
- the data file should (if format allows this) provide a link to the ESM metadata resource. The location of the link will be defined in the relevant encoding annex.

**Requirement 11:** Each ESM metadata set associated to each ESM resource shall conform to the DMF/Data+ conformance class applicable to metadata set, on the basis of the DMF-All schema and to the ESM metadata test suite specified in [ESM].

**Requirement 12:** In case of ESM collection with external tiling, the ESM TilingScheme shall be documented as metadata elements (Collection Tiling scheme and Tile Identifier) of the ESM collection metadata on the basis of DMF and to the ESM metadata test suite specified in [ESM] (TilingScheme test case).

**Requirement 13:** ESM metadata shall be consistent with the corresponding information specified by the ESM GML instance (if any) and the internal encoding format. In case of discrepancy, the internal encoding format information shall prevail.

## 6.6 General rules for ESM data encodings

### 6.6.1 CRS

**Horizontal datum:** This document recommends the use of World Geodetic System 1984 (WGS84) as the horizontal datum for Elevation data in Defense Elevation data.

**Vertical datum:** This document recommends the use of any of the following vertical datums (Vertical CRS) for elevation data<sup>1</sup>:

- WGS84 ellipsoid (EPSG code 4979)
- the geoids defined by the following WGS 84 Earth Gravity Field Models (EGM):
- EGM96 (EPSG code 5773), used by DTED data,
- EGM08 (EPSG code 3855), the emergent updated geoid included in EPSG registry,
- EGM84 (EPSG code 5798), in order to support legacy systems that may not be able to accommodate the increased level of detail of EGM96
- a global Sounding Datum or Hydrographic Datum, based on a selected tide level related to Mean Sea Level (MSL): MSL height (EPSG code 5714) and MSL depth (EPSG code 5715),
- or any other user-defined vertical datum; for specific local vertical reference systems.

**Requirement 14:** The identification of the Horizontal and Vertical CRS shall be based on EPSG code (as in EPSG active registry), or the reference of the sounding datum for the Vertical CRS in the DGIWG Geodetic Codes and Parameters registry ([http://www.dgiwg.org/DGIWG\\_Geodetic\\_Codes](http://www.dgiwg.org/DGIWG_Geodetic_Codes)) for the other hydrographic datum, or by description of user-defined vertical CRS.

**Coordinate systems:** This document limits expression of coordinate references to longitude and latitude (geographic coordinate system) or the UTM Grid System Easting and Northing (projected / cartographic coordinate system).

**Requirement 15:** CRS information shall be documented consistently in the following two (or three) locations:

- the ESM GML instance, if any,
  - either based on GMLCOV model for the coverage case; the encoding of Horizontal shall be based on a CRS on the basis of OGC-11.135r1 - Name Type Specification for CRSs. The Vertical CRS shall be documented in the SWE common Data Record of the RangeType.
  - or based on DGIWG GML L1.3D.0d profile for the PointSet case with a compound CRS Horizontal+Vertical on the basis of OGC-11.135r1.

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<sup>1</sup> Future evolutions of the gravity model (EGM) should be added to this list as necessary.

- the ESM metadata: DMF/RSRSYS element.
- the CRS information as in the internal encoding format, for example dedicated tags in GeoTIFF.

NB: In some encoding formats, an ASCII identification of the CRS, may be provided in addition to the EPSG (or DGIWG) registry code.

### 6.6.2 Units of Measure

This document recommends the use of the following units of measures:

- decimal degrees for longitude and latitude (geographic coordinate system)
- meters for UTM Grid System Easting and Northing (projected/ cartographic coordinate system)
- meters for elevation values (or submetric units for high resolution elevation when encoded by signed integers).

**Requirement 16:** Horizontal and vertical units of measure information shall be both documented in:

- the ESM Coverage GML instance (if any) or ESM PointSet instance, respectively based on GMLCOV or DGIWG GML L1.3D.0d profile
- the units of measure information as in the internal encoding format, for example dedicated tags in GeoTIFF, or in the GML coverage document in GMLJP2.

**Note:** [ESM] states that the unit of measure is associated to the CRS (as in EPSG registry) and therefore need not to be documented in metadata. This statement is valid as long as the metric unit is used in the encoding of the elevation data.

### 6.6.3 Security Classification

ESM metadata set should be used to associate security markers and dissemination controls for content of ESM data. However, in the case of classified ESM data, inclusion of the security constraint information within the encoding format structure is also required so that the data file will always include security marking information.

**Requirement 17:** When the data is classified, the security marking shall be present in both the encoding format and in the XML metadata (DMF/Resource Security Constraint).

When the data is not classified, the security system (DMF/Resource Security System) determines whether the dataset must be marked 'unclassified'. When required, this marking must appear in both the encoding format and the additional XML metadata.

### 6.6.4 Intellectual property rights information encoding

ESM metadata set should be used to declare Intellectual property rights information on ESM data. However, when the data is subject to Intellectual property rights restriction, this restriction must also be reflected within the encoding format structure.

**Requirement 18** When the use of data is restricted by Intellectual property rights, the Intellectual property rights information must be present in both the encoding format and in the additional XML metadata (DMF/Resource Legal Constraint).

### 6.6.5 Void Areas

Identification of void or missing data areas is a requirement that only applies to grids (cf. [ESM] § 7.4.5). The gridded data formats that are used to carry elevation data generally have some provision to declare a value for void areas, by use of a designated “out-of-range” value, typically the most negative value available for the data type selected (or the non-number value designated for the selected data type) to represent the elevation values. Since the ESM supports bathymetric surfaces, due care must be taken when using a negative “out-of-range” value to avoid confusion with actual data values.

**Requirement 19:** For gridded elevation data, void area value shall be both documented in:

- the NULL value definition of the encoding format for void areas
- in the ESM Coverage instance (if any), in the quantity element of the rangeType (cf. ESM Grid coverages requirements in [ESM\_GML\_AS]).
- in the ESM metadata, by using the Content Information of the Coverage Metadata element : GRCINF.specialCell.

**Note 1:** For elevation data, NULL values are represented by a designated “out-of-range” value, typically an arbitrary negative value (or the non-number value designated for the selected data type).

#### Recommendations:

- for SINT16 values, -32767 (Hex. 0x8001)
- for SINT32 values, -32767 (Hex. 0xFFFF8001)
- for float32, NaN (Hex. 0xFFFFFFFF)

**Note 2:** Some encoding formats may also use transparency mask or alpha channel for coding void areas.

NB: Suspect areas have associated elevation values that are obviously outside of the logical range for the surface described. Suspect areas can be adequately addressed using the data quality section of the metadata and are not addressed by the encoding rules.

### 6.6.6 ESM data quality

**Requirement 20:** ESM dataset quality metadata (according to ESM specification for Metadata) shall include at least;

- Absolute horizontal and vertical accuracy reports
- A report of ‘completeness’ (percentage of the direct positions within the dataset extents where the range values are not void or suspect values).



### 6.6.7 ESM data encoding

ESM elevation data (Point Sets or optionally for Coverages) are encoded in GML and included in the ESM GML instance.

For the coverage data that are encoded in formats other than GML, encoding rules to map the ESM GML AS to the format data structure are required. They are provided in the parts 2 to 4 of the suite of DGIWG 116-3-x standards.

**Requirement 21:** The encoding of coverage components in one of the supported file formats (GeoTIFF, GMLJP2 or NSIF/NITF) shall conform to the requirements and mapping rules specified in the appendix of the corresponding part of this standard (respectively 2 for GeoTIFF, 3 for GMLJP2 and 4 for NSIF/NITF).

**Requirement 22:** Depending on encoding format, elevation values in an ESM coverage data shall be represented by:

- signed integer, encoded on 2 bytes (signed short) or 4 bytes (signed long)
- floating point values: single precision (4-byte) IEEE formats

High resolution Elevation data are usually stored as 4 bytes signed integers or single precision point values.

However, the floating-point option is not ideally suited to elevation data, which are usually produced either as integer or decimal values (with one or two significant decimal digits) in case of high resolution elevation with values expressed in meters. Consequently, the use of a floating-point mode may result in variations of the mantissa (due to processing) which are not significant of any terrain elevation variations. Users should be aware that the number of significant digits in the provided elevation values must be in accordance with the quality information provided by metadata.

Note: Therefore, the use of floating-point mode is not recommended for elevation data values at levels 0-3<sup>2</sup>.

### 6.6.8 ESM data compression

**Requirement 23:** In case of compression of ESM data, lossless compression methods shall be used.

For example, JPEG2000 lossless provides a minimum compression ratio of 2 to 2.5.

### 6.6.9 ESM TilingScheme

ESM allows for value records within an elevation collection or a fundamental dataset to be organized into tiles, as stated in § 10.3 of [ESM]. The three primary motivations for organizing value records into a tiling scheme are:

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<sup>2</sup> As indicated in Table 4 of [ESM]; Level 3 has a resolution between 10 and 5 meters

- 1) The nature and description of the value records within the collection is different, thus requiring different metadata descriptions;
- 2) The sampling density varies within the coverage of the gridded dataset;
- 3) The physical size of the value data is so large that it warrants subdivision for ease of data management.

**Note:** The data encoding formats usually support an internal tiling structure that facilitates indexed addressing to internal tiles data, within the same data file, thus optimizing data access. The term 'ESM\_TilingScheme' does not refer to this internal tiling associated to an encoding format. It refers to what may also be called 'external tiling', with the tiles being composed of separate data files.

As stated in [ESM], the Tiling Scheme normally consists of a simple rectangular grid with tiles of equal density. A grid coverage may also be defined with tiles of variable density (quad tree). A more complex tiling scheme may also be defined as a discrete polygon coverage. An example polygon tiling scheme is a data collection consisting of elevation cut along political boundaries. A tiling scheme may be defined for an elevation collection of any type. For gridded data, the tiling scheme is usually a second grid that is superimposed on the first (simple) grid.

The data encoding formats do not contain a place to address the ESM TilingScheme, consequently it is addressed by the following requirement; the ESM TilingScheme is not addressed by the additional parts 2 to 4 of the suite of DGIWG 116-3-x standards.

**Requirement 24:** The ESM TilingScheme shall be documented in the dedicated ESM metadata elements associated to the ESM Collection resource (according to requirement 12) for the purpose of exchange, data discovery and handling.

The usual Tiling Scheme options are:

- *Simple Grid Tiling:* one ESM data file per ESM-defined tile
- *Quadtree Tiling:* one ESM data file is used to contain the value records for each quadtree tile

In both cases, each ESM Tile data should correspond to a single ESM data file in its encoding format: the entire data file constitutes the ESM Tile.

A more complex tiling scheme may be defined as a set of polygons, as presented in § 10.3 in [ESM]. This method may be useful when it is necessary to separate areas within the dataset according to unique surface types (e.g. land vs. water, or political boundaries). Each polygon shall be assigned an identifier unique within the dataset. The polygon boundaries shall be defined in the metadata as ordered lists of vertices. While the simple grid and quadtree tiling approaches are rectangular in nature and use numeric indices to identify each tile, polygonal tiling defines tiles using a set of geographic points. Except for the specific case where the polygonal vertices are selected to be coincidental with the rectangular data file, the ESM polygonal tiling has no direct relationship with the data files. When polygonal tiling is used to associate different metadata attributes to elevation values, the position of the elevation value must be evaluated to determine which polygon-defined tile it is associated with.

## **Annex A**

### **ESM Encoding Rules Abstract test suites** (normative)

This Annex provides abstract test suites for ESM Encoding Rules build upon the DGIWG 116-1 [ESM] specification, ESM GML application schema and encoded in conformance with the rules specified in this document.

#### **A.1 ESM Coverage GML instance conformance test**

##### **A.1.1 Abstract test for ESM Coverage GML instance (collection or dataset) as valid ESM Coverage GML implementation for the relevant resource (ESM data Coverage structure + schema validation test)**

Purpose: Verify that the ESM Coverage GML instance (if present) is a valid implementation of ESM GML schema for the corresponding resource (ESM Coverage Collection, ESM Coverage).

Method: Inspect ESM data + Validation against ESM schema according to the required conformance class (ESM\_COV).

Reference: [ESM\_GML\_AS]: Annex B Abstract test suites for ESM Coverage GML data + this document, requirements 1, 2, 4.

##### **A.1.2 Abstract test for ESM Coverage GML instance consistency with ESM Coverage data file**

Purpose: Verify that ESM Coverage GML instance (if present) satisfy requirement 5 in section 6.3 of this document.

Method: Inspection of ESM Coverage GML instance and ESM Coverage data file.

Reference: This document, requirement 5 + Mapping tables for the relevant format in parts 2 to 4 of the suite of DGIWG 116-3-x standards.

##### **A.1.3 Abstract test for ESM Coverage type**

Purpose: An ESM coverage instance shall be of type gmlcov:RectifiedGridCoverage or gmlcov:MultiPointCoverage, or a subtype thereof.

Method: If the coverage instance under test is encoded in a multipart message check that its first part consists of a GML instance of type gmlcov:RectifiedGridCoverage or gmlcov:MultiPointCoverage, or a subtype thereof.

Reference: This document, requirement 4 (6.3.1) and [OGC 09-146r2] multipart or gml conformance classes.

#### **A.1.4 Abstract test for ESM Coverage GML instance (multipart for delivery)**

Purpose: Verify that ESM Coverage GML instance encoded as multipart message satisfy requirement 6 in section 6.3 of this document (multipart conformance class of GMLCOV).

Method: Inspect whether ESM coverage GML instance is encoded as a multipart message

Reference: This document, requirement 6 + [OGC 09-146r2] multipart conformance class.

#### **A.1.5 Abstract test for ESM Coverage GML instance (external ESM data file encoding)**

Purpose: Verify that ESM Coverage GML instance encoded with an ESM external data file satisfy requirement 7 in section 6.3 of this document (gml conformance class of GMLCOV, except for the rangeSet).

Method: Inspect whether ESM coverage GML instance is valid with gml/special-format implementation of GMLCOV

Reference: This document, requirement 7 + GML requirements class, gml/special-format (requirement 17 in [OGC 09-146r2]).

### **A.2 ESM PointSet GML instance conformance test**

#### **A.2.1 Abstract test for ESM PointSet GML instance (collection or dataset) as valid ESM PointSet GML implementation for the relevant resource (ESM data PointSet structure + schema validation test)**

Purpose: Verify that the ESM PointSet GML instance is a valid implementation of ESM GML schema for the corresponding resource (ESM PointSet Collection, ESM PointSet).

Method: Inspect ESM data + Validation against ESM schema according to the required conformance class (ESM\_PTS).

Reference: [ESM\_GML\_AS]: Annex B Abstract test suites for ESM Coverage GML data + this document, requirements 1, 2, 8.

### **A.3 ESM metadata encoding conformance test**

The ESM metadata set associated to each ESM resource (collection, dataset) must follow:

- DMF-All schema specified in DMF, for the Data+ conformance class.
- ESM metadata requirements
- The ESM metadata encoding rules specified in 6.5.

#### **A.3.1 Abstract test for ESM metadata set as valid DMF Metadata set for the relevant resource (schema validation test + ESM metadata test)**

Purpose: Verify that the ESM metadata set is a valid metadata set implementation of DMF (based on DMF/Data+) for the corresponding resource.

Method: Validation against DMF-All schema + Inspection of ESM metadata set (for Collection/Series or Dataset metadata).

Reference: DGIWG DMF: Annex A.4 Test module on candidate metadata set + this document, requirements 9, 11, 12.

### **A.3.2 Abstract test for association between ESM metadata and ESM data**

Purpose: Verify that the association between ESM metadata and ESM data is well defined

Method: Inspect the implementation.

Reference: This document, requirement 10.

### **A.3.3 Abstract test for ESM metadata set as valid ESM metadata set implementation**

Purpose: Verify that the ESM metadata is a valid ESM metadata set

Method: Inspect the implementation.

Reference: [ESM]: Annex A.2 Metadata Test Suite and A.3 User-defined Extension Metadata Test Suite (if applicable) and A.4.1 Metadata Profiles Test Case (if applicable) + this document, requirements 11 and 12.

### **A.3.4 Abstract test for ESM metadata set as consistent with ESM data file**

Purpose: Verify that ESM Metadata set is consistent with ESM GML instance and ESM data file.

Method: Inspect the the implementation.

Reference: This document, requirement 13 + Mapping table for the relevant format in parts 2 to 4 of the suite of DGIWG 116-3-x standards.

### **A.3.5 Abstract test for TilingScheme documentation in ESM collection metadata set (if applicable)**

Purpose: Verify that the TilingScheme metadata is addressed in ESM collection metadataset if the ESM data is tiled

Method: Inspect the implementation of the ESM collection metadata set.

Reference: this document, requirements 12 and 24.

## **A.4 Conformity with general rules for ESM encodings**

### **A.4.1 Test for the CRS in ESM GML instance, ESM metadata set and ESM data file**

Purpose: Verify that the CRS identification is based on EPSG or DGIWG registry and consistent in its 3 locations in ESM data resources (GML instance (if present), metadata set, external data file)

Method: Inspect the CRS information content in these 2 (or 3) locations.

Reference: This document, requirement 14 and 15.

#### **A.4.2 Test for the Unit of Measure in ESM GML instance and ESM data file**

Test Purpose: Verify that the Unit of Measure identification is identified and consistent in its 2 locations in ESM data resources (GML instance, external data file)

Test Method: Inspect the Unit of Measure information content in these 2 locations.

Reference: This document, requirement 16.

#### **A.4.3 Tests for the Security classification and IPR in ESM metadata set and ESM data file**

Test Purpose: Verify that the Security classification and IPR is identified and consistent in its 2 locations in ESM data resources (ESM metadata set, external data file)

Test Method: Inspect the Security classification and IPR information content in these 2 locations.

Reference: This document, requirement 17 and 18.

#### **A.4.4 Tests for the void area encoding in ESM metadata set and ESM data file**

Test Purpose: Verify that the void area encoding is identified and consistent in its 2 locations in ESM data resources (ESM metadata set, external data file)

Test Method: Inspect the Security classification and IPR information content in these 2 locations.

Reference: This document, requirement 19.

#### **A.4.5 Tests for the quality information in ESM metadata set**

Test Purpose: Verify that the quality information is provided correctly in ESM metadata set

Test Method: Inspect the quality information (Absolute horizontal and vertical accuracy reports + report of completeness).

Reference: This document, requirement 20 + ESM Metadata Test suite.

### **A.5 ESM Coverage data encoding format conformance**

#### **A.5.1 Tests for ESM Coverage data encoding (special format case)**

Test Purpose: Verify that ESM Coverage data file is encoded with one of the 'well known' binary formats, such as GeoTIFF, GMLJP2, NSIF, following the rules for ESM encodings.

Test Method: Inspect the ESM Coverage data file.

Reference: This document, requirement 21 + conformance part in parts 2 to 4 of the suite of DGIWG 116-3-x standards.

**A.5.2 Tests for ESM elevation values encoding (special format case)**

Test Purpose: Verify that ESM elevation values are encoded correctly (depending on encoding format capabilities)

Test Method: Inspect the ESM Coverage data file.

Reference: This document, requirement 22

**A.5.3 Tests for ESM elevation data compression (special format case, in case of compressed data)**

Test Purpose: Verify that ESM elevation values are compressed in a lossless mode (depending on encoding format capabilities)

Test Method: Inspect the ESM Coverage data file.

Reference: This document, requirement 23

## Annex B

### Table of ESM Encoding Rules tests and requirements (informative)

This table summarizes the tests and associated requirements to be fulfilled by any ESM data compliant with ESM ER - Part 1 (this document)

ID	Title	Reference of Requirements	Requirements
	<b>Coverage (optional)</b>		
1	A.1.1 Abstract test for ESM Coverage GML instance (collection or dataset) as valid ESM Coverage GML implementation for the relevant resource (ESM data Coverage structure + schema validation test) <b>(optional)</b>	requirements 1, 2, 4.	ESM Coverage GML instance (if present) is a valid implementation of ESM GML schema for the corresponding resource (ESM Coverage Collection, ESM Coverage).
2	A.1.2 Abstract test for ESM Coverage GML instance consistency with ESM Coverage data file <b>(optional)</b>	requirement 5	The coverage domain information in the GML instance for ESM Coverage shall be consistent with the corresponding information specified by the internal encoding format for the ESM data. In case of discrepancy, the internal encoding format information shall prevail.
3	A.1.3 Abstract test for ESM Coverage type <b>(optional)</b>	Reference: [OGC 09-146r2] multipart or gml conformance classes.	An ESM coverage instance shall be of type gmlcov:RectifiedGridCoverage or gmlcov:MultiPointCoverage, or a subtype thereof.
4	A.1.4 Abstract test for ESM Coverage GML instance (multipart for delivery) <b>(optional)</b>	requirement 6 + [OGC 09-146r2] multipart conformance class	ESM Coverage GML instance encoded as multipart message satisfy requirement 6 in section 6.3 of this document (multipart conformance class of GMLCOV).
5	A.1.5 Abstract test for ESM Coverage GML instance (external ESM data file encoding) <b>(optional)</b>	requirement 7 + GML requirements class, gml/special-format (requirement 17 in [OGC 09-146r2]).	Verify that ESM Coverage GML instance encoded with an ESM external data file satisfy requirement 7 in section 6.3 of this document (gml conformance class of GMLCOV, except



ID	Title	Reference of Requirements	Requirements
			for the rangeSet).
	<b>Point Set (if relevant)</b>		
6	A.2.1 Abstract test for ESM PointSet GML instance (collection or dataset) as valid ESM PointSet GML implementation for the relevant resource (ESM data PointSet structure + schema validation test) - <b>for Point sets</b>	requirements 1, 2, 8.	ESM PointSet GML instance is a valid implementation of ESM GML schema for the corresponding resource (ESM PointSet Collection, ESM PointSet).
	<b>Metadata</b>		
7	A.3.1 Abstract test for ESM metadata set as valid DMF Metadata set for the relevant resource (schema validation test + ESM metadata test)	DGIWG DMF: Annex A.4 Test module on candidate metadata set + ESM ER requirements 9, 11, 12.	ESM metadata set is a valid metadata set implementation of DMF (based on DMF/Data+) for the corresponding resource
8	A.3.2 Abstract test for association between ESM metadata and ESM data	requirement 10.	the association between ESM metadata and ESM data shall be well defined
9	A.3.3 Abstract test for ESM metadata set as valid ESM metadata set implementation	DGIWG ESM: Annex A.2 Metadata Test Suite and A.3 User-defined Extension Metadata Test Suite (if applicable) and A.4.1 Metadata Profiles Test Case (if applicable) + DGED, requirements 11 and 12	ESM metadata is a valid ESM metadata set
10	A.3.4 Abstract test for ESM metadata set as consistent with ESM data file	requirement 13 + Mapping table for the relevant format (in Parts 2 to 4)	ESM Metadata set is consistent with ESM GML instance and ESM data file.

ID	Title	Reference of Requirements	Requirements
11	A.3.5 Abstract test for TilingScheme documentation in ESM collection metadata set (if applicable)	requirements 12 and 24.	TilingScheme metadata is addressed in ESM collection metadataset if the ESM data is tiled
<b>General Rules</b>			
12	A.4.1 Test for the CRS in ESM GML instance, ESM metadata set and ESM data file	requirement 14 and 15.	CRS identification is based on EPSG or DGIWG registry and consistent in its 3 locations in ESM data resources (GML instance (if present), metadata set, external data file)
13	A.4.2 Test for the Unit of Measure in ESM GML instance and ESM data file	requirement 16.	the Unit of Measure identification is identified and consistent in its 2 locations in ESM data resources (GML instance, external data file)
14	A.4.3 Tests for the Security classification and IPR in ESM metadata set and ESM data file	requirement 17 and 18.	the Security classification and IPR is identified and consistent in its 2 locations in ESM data resources (ESM metadata set, external data file)
15	A.4.4 Tests for the void area encoding in ESM metadata set and ESM data file	requirement 19.	the void area encoding is identified and consistent in its 2 locations in ESM data resources (ESM metadata set, external data file)
16	A.4.5 Tests for the quality information in ESM metadata set	requirement 20 + ESM Metadata Test suite	the quality information is provided correctly in ESM metadata set
<b>ESM Coverage data encoding format conformance</b>			
17	A.5.1 Tests for ESM Coverage data encoding (special format case)	requirement 21 + conformance part in the corresponding Part 2 to 4	ESM Coverage data file is encoded with one of the ‘well known’ binary formats, such as GeoTIFF, GMLJP2, NSIF, following the rules for ESM encodings.

ID	Title	Reference of Requirements	Requirements
	<b>ESM Encoding Rules conformance</b>		
18	A.5.2 Tests for ESM elevation values encoding	requirement 22	ESM elevation values are encoded correctly (depending on encoding format capabilities)
19	A.5.3 Tests for ESM elevation data compression (special format case, in case of compressed data)	requirement 23	ESM elevation values are compressed in a lossless mode (depending on encoding format capabilities)

## **Bibliography**

1. D2.8.II.1 Data Specification on Elevation – Technical Guidelines, 2013-12-10 (INSPIRE document D2.8.II.1\_v3.0)
2. D2.8.II.1 Data Specification on Orthoimagery – Technical Guidelines, 2013-12-10 (INSPIRE document D2.8.II.3\_v3.0)
3. Note: This last document includes Encoding rules for JPEG 2000 file formats in its section E.3 (that are not referenced in Elevation data specification).