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OGC® GeoPackage Encoding Standard – With Corrigendum

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i. Abstract

This OGC® Encoding Standard defines GeoPackages for exchange and GeoPackage SQLite Extensions for direct use of vector geospatial features and / or tile matrix sets of earth images and raster maps at various scales. Direct use means the ability to access and update data in a “native” storage format without intermediate format translations in an environment (e.g. through an API) that guarantees data model and data set integrity and identical access and update results in response to identical requests from different client applications. GeoPackages are interoperable across all enterprise and personal computing environments, and are particularly useful on mobile devices like cell phones and tablets in communications environments with limited connectivity and bandwidth.

ii. Keywords

ogcdoc, geopackage, sqllite, raster, tiles, vector, feature, data, storage, exchange, mobile, smartphone, tablet

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Introduction

Mobile device users who require map/geospatial application services and operate in disconnected or limited network connectivity environments are challenged by limited storage capacity and the lack of open format geospatial data to support these applications. The current situation is that each map/geospatial application requires its own potentially proprietary geospatial data store. These separate application-specific data stores may contain the same geospatial data, wasting the limited storage available, and requiring custom applications for data translation, replication, and synchronization to enable different map/geospatial applications to share the same world view. In addition, many existing geospatial data stores are platform-specific, which means that users with different platforms must translate data to share it.

An open, standards-based, application-independent, platform-independent, portable, interoperable, self-describing, GeoPackage (GPKG) data container, API and manifest are needed to overcome these challenges and to effectively support multiple map/geospatial applications such as fixed product distribution, local data collection, and geospatially enabled analytics. This standard is intended to facilitate widespread adoption and use of GeoPackages by both COTS and open-source software applications on enterprise production platforms as well as mobile hand-held devices[B1][B2], given that mobile hand held devices do not yet have the processing power or battery life to effectively tackle difficult geospatial product production and analysis tasks. An application that accesses a GPKG will make use of the GPKG capabilities it requires; few if any such applications will make use of all GPKG capabilities.

This OGC® Encoding Standard defines GeoPackages for exchange and GeoPackage SQLite Extensions for direct use of vector geospatial features and / or tile matrix sets of earth images and raster maps at various scales. Direct use means the ability to access and update data in a “native” format without intermediate format translations in an environment (e.g. through an API) that guarantees data model and data set integrity and identical access and update results in response to identical requests from different client applications.

A **GeoPackage** is a platform-independent SQLite [5] database file that contains GeoPackage data and metadata tables shown in Figure 1 below, with specified definitions, integrity assertions, format limitations and content constraints. The allowable content of a **GeoPackage** is entirely defined in this specification.

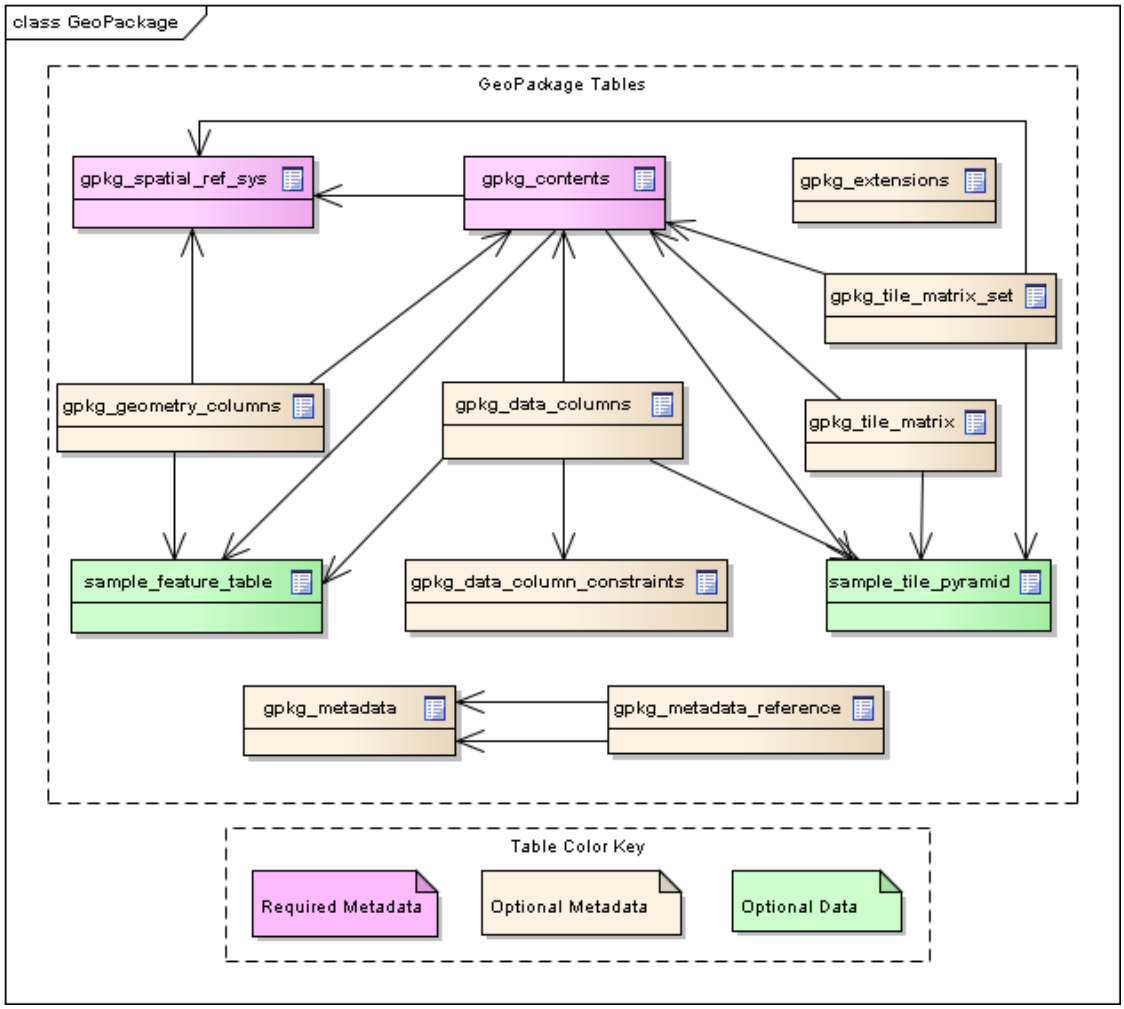
An **Extended GeoPackage** is a **GeoPackage** that contains any additional data elements (tables or columns) or SQL constructs (data types, functions, indexes, constraints or triggers) that are not specified in this encoding standard.

A **GeoPackage** MAY be “empty” (contain user data table(s) for vector features and/or tile matrix pyramids with no row record content)) or contain one or many vector feature type records and /or one or many tile matrix pyramid tile images. GeoPackage metadata CAN describe GeoPackage data contents and identify external data synchronization sources and targets. A GeoPackage MAY contain spatial indexes on feature geometries and SQL triggers to maintain indexes and enforce content constraints.

A **GeoPackage SQLite Configuration** consists of the SQLite 3 software library and a set of compile- and runtime configurations options.

A **GeoPackage SQLite Extension** is a SQLite loadable extension that MAY provide SQL functions [12] to support spatial indexes and SQL triggers linked to a SQLite library with specified configuration requirements to provide SQL API [1][2][3][4] access to a GeoPackage. This standard does not address the issues listed in the Potential Future Work clause in Annex B, which MAY be addressed in a subsequent version of this specification or by other specifications.

Figure 1- GeoPackage Tables Overview[1]



[1] Also see Figure 4 GeoPackage Tables Details in B.13

OGC® GeoPackage Encoding Standard

1. Base

The required capabilities specified in this clause serve as the base for options specified in clause 2 and extensions specified in clause 3. All gpkg_* tables and views and all tiles user data tables specified in this standard SHALL have only the specified columns and table constraints. Any features user data tables MAY have columns in addition to those specified. All specified table and column name values SHALL be lowercase.

1.1. Core

The mandatory core capabilities defined in sub clauses and requirement statements of this clause SHALL be implemented by every **GeoPackage** and **GeoPackage SQLite Configuration**.

1.1.1. SQLite Container

The SQLite software library provides a self-contained, single-file, cross-platform, serverless, transactional, open source RDBMS container. The GeoPackage specification defines a SQL database schema designed for use with the SQLite software library. Using SQLite as the basis for GeoPackage simplifies production, distribution and use of GeoPackages and assists in guaranteeing the integrity of the data they contain.

“Self-contained” means that container software requires very minimal support from external libraries or from the operating system. “Single-file” means that a container not currently opened by any software application consists of a single file in a file system supported by a computing platform operating system. “Cross-platform” means that a container file MAY be created and loaded with data on one computing platform, and used and updated on another, even if they use different operating systems, file systems, and byte order (endian) conventions. “Serverless” means that the RDBMS container is implemented without any intermediary server process, and accessed directly by application software. “Transactional” means that RDBMS transactions guarantee that all changes to data in the container are Atomic, Consistent, Isolated, and Durable (ACID) despite program crashes, operating system crashes, and power failures.

1.1.1.1. Data

1.1.1.1.1. File Format

Req 1: ***A GeoPackage SHALL be a SQLite [5] database file using version 3 of the SQLite file format [6][7]. The first 16 bytes of a GeoPackage SHALL contain "SQLite format 3"[1] in ASCII[B4].[2]***

Req 2: ***A GeoPackage SHALL contain 0x47503130 ("GP10" in ASCII) in the application id field of the SQLite database header to indicate that a GeoPackage version 1.0 file.[3]***

The maximum size of a GeoPackage is about 140TB. In practice a lower size limit MAY be imposed by the filesystem to which the file is written. Many mobile devices require external memory cards to be formatted using the FAT32 file system which imposes a maximum size limit of 4GB.

1.1.1.1.2. File Extension Name

Req 3: ***A GeoPackage SHALL have the file extension ".gpkg".***

It is RECOMMENDED that **Extended GeoPackages** use the file extension ".gpkx", but this is NOT a GeoPackage requirement.

1.1.1.1.3. File Contents

Req 4: ***A GeoPackage SHALL only contain data elements, SQL constructs and GeoPackage extensions with the "gpkg" author name specified in this encoding standard.***

In order to guarantee maximum interoperability between applications, **GeoPackages** SHALL NOT contain data elements (tables or columns), SQL constructs (data types, indexes, constraints or triggers) or extensions that are not specified in this encoding standard. SQLite databases that use constructs from the GeoPackage specification but extend that to contain any of these elements are referred to as **Extended GeoPackages** throughout this specification.

Req 5: ***The columns of tables in a GeoPackage SHALL only be declared using one of the data types specified in Table 1.***

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[1] SQLite version 4 [B25], which will be an alternative to version 3, not a replacement thereof, was not available when this specification was written. . See Future Work clause in Annex B.

[2] SQLite is in the public domain (see http://www.sqlite.org/copyright.html)

[3] With SQLite versions 3.7.17 and later this value MAY be set with the "PRAGMA application_id=1196437808;" SQL statement, where 1196437808 is the 32-bit integer value of 0x47503130. With earlier versions of SQLite the application id can be set by writing the byte sequence 0x47, 0x50, 0x31, 0x30 at offset 68 in the SQLite database file (see http://www.sqlite.org/fileformat2.html#database_header for details).

Table 1 GeoPackage Data Types

Data Type	Size and Description
BOOLEAN	A boolean value representing true or false. Stored as SQLite INTEGER with value 0 for false or 1 for true
TINYINT	8-bit signed two's complement integer. Stored as SQLite INTEGER with values in the range [-128, 127]
SMALLINT	16-bit signed two's complement integer. Stored as SQLite INTEGER with values in the range [-32768, 32767]
MEDIUMINT	32-bit signed two's complement integer. Stored as SQLite INTEGER with values in the range [-2147483648, 2147483647]
INT, INTEGER	64-bit signed two's complement integer. Stored as SQLite INTEGER with values in the range [-9223372036854775808, 9223372036854775807]
FLOAT	32-bit IEEE floating point number Stored as SQLite REAL limited to values that can be represented as a 4-byte IEEE floating point number
DOUBLE, REAL	64-bit IEEE floating point number Stored as SQLite REAL
TEXT{(maxchar_count)}	Variable length string encoded in either UTF-8 or UTF-16, determined by PRAGMA encoding; see http://www.sqlite.org/pragma.html#pragma_encoding The optional maxchar_count defines the maximum number of characters in the string. If not specified, the length is unbounded. The count is provided for informational purposes, and applications MAY choose to truncate longer strings if encountered. When present, it is best practice for applications to adhere to the character count. Stored as SQLite TEXT
BLOB{(max_size)}	Variable length binary data. The optional max_size defines the maximum number of bytes in the blob. If not specified, the length is unbounded. The size is provided for informational purposes. When present, it is best practice for applications adhere to the maximum blob size. Stored as SQLite BLOB
<geometry_type_name>	<geometry type_name> is one of the geometry types listed in Annex E encoded per clause 2.1.3 or a user-defined geometry type encoded per clause 3.1.2 and Annex K. Geometry Types XY, XYZ, XYM and XYZM geometries use the same data type. Stored as SQLite BLOB
DATE	ISO-8601 date string in the form YYYY-MM-DD encoded in either UTF-8 or UTF-16. See TEXT. Stored as SQLite TEXT
DATETIME	ISO-8601 date/time string in the form *YYYY-MM-DD***T***HH:MM:SS.SSS***Z** with **T** separator character and **Z** suffix for coordinated universal time (UTC) encoded in either UTF-8 or UTF-16. See TEXT. Stored as SQLite TEXT

1.1.1.1.4. File Integrity

Req 6: ***The SQLite PRAGMA integrity_check SQL command SHALL return "ok" for a GeoPackage.*** [1]

Req 7: ***The SQLite PRAGMA foreign_key_check SQL with no parameter value SHALL return an empty result set indicating no invalid foreign key values for a GeoPackage.***

1.1.1.2. API

1.1.1.2.1. Structured Query Language (SQL)

Req 8: ***A GeoPackage SQLite Configuration SHALL provide SQL access to GeoPackage contents via SQLite version 3 [6] software APIs.*** [2]

1.1.1.2.2. Geopackage SQLite Configuration

The SQLite [8] library has many compile time and run time options that MAY be used to configure SQLite for different uses. Certain elements of the GeoPackage specification depend on the availability of SQLite functionality at runtime. This clause specifies the set of compile~~ and run~~time options that SHALL or SHALL NOT be used.

Req 9: ***Every GeoPackage SQLite Configuration SHALL have the SQLite library compile ~~and run~~ time options specified in clause 1.1.1.2.2Table 2.***

Table 2 Every GeoPackage SQLite Configuration

Setting	Option	Shall / Not	Discussion
compile	SQLITE_OMIT_*	Not	SHALL NOT include any OMIT options from http://www.sqlite.org/compile.html#omitfeatures
~~run~~	~~PRAGMA foreign_keys~~	~~Not (OFF)~~	~~Foreign key constraints are used to maintain GeoPackage relational integrity.~~

1.1.2. Spatial Reference Systems

1.1.2.1. Data

1.1.2.1.1. Table Definition

Req 10: ***A GeoPackage SHALL include a gpkg_spatial_ref_sys table per clause 1.1.2.1.1,Table 3 and Table 18.***

A table named gpkg_spatial_ref_sys is the first component of the standard SQL schema for simple features described in clause 2.1.1 below. The coordinate reference system definitions it

[1] The SQLite PRAGMA integrity_check SQL command does a full database scan that can take a long time to complete on a large GeoPackage file.

[2] New applications should use the latest available SQLite version software [8]

contains are referenced by the GeoPackage gpkg_contents and gpkg_geometry_columns tables to relate the vector and tile data in user tables to locations on the earth.

The gpkg_spatial_ref_sys table includes ~~at a minimum~~ the columns specified in SQL/MM (ISO 13249-3) [12] and shown in Table 3 below containing data that defines spatial reference systems. Views of this table MAY be used to provide compatibility with the SQL/MM [12] (Table 19) and OGC Simple Features SQL [9] (Table 20) specifications.

Table 3 Spatial Ref Sys Table Definition

Column Name	Column Type	Column Description	Null	Key
srs_name	TEXT	Human readable name of this SRS	no	
srs_id	INTEGER	Unique identifier for each Spatial Reference System within a GeoPackage	no	PK
organization	TEXT	Case-insensitive name of the defining organization e.g. EPSG or epsg	no	
organization_coordsys_id	INTEGER	Numeric ID of the Spatial Reference System assigned by the organization	no	
definition	TEXT	Well-known Text [32] Representation of the Spatial Reference System	no	
description	TEXT	Human readable description of this SRS	yes	

See Annex C Table Definition SQL (Normative) C.1 gpkg_spatial_ref_sys.

1.1.2.1.2. Table Data Values

Definition column WKT values in the gpkg_spatial_ref_sys table SHALL define the Spatial Reference Systems used by feature geometries and tile images, unless these SRS are unknown and therefore undefined as specified in Req 11. Values SHALL be constructed per the EBNF syntax in [32] clause 7. Values SHALL include optional <authority> EBNF entities. Values for SRS other than WGS-84 SHOULD include optional <to wgs84> EBNF entities. Values MAY omit optional <to wgs84> and <twin axes> EBNF entities. EBNF name and number values MAY be obtained from any specified <authority>, e.g. [13][14]. For example, see the return value in A.1.1.2.1.2 Test Method step (3) used to test the definition for WGS-84 per Req 11:

Req 11: ***The gpkg_spatial_ref_sys table in a GeoPackage SHALL contain a record for organization EPSG or epsg [B3] and organization_coordsys_id 4326 [13][14] for WGS-84 [15], a record with an srs_id of -1, an organization of "NONE", an organization_coordsys_id of -1, and definition "undefined" for undefined Cartesian coordinate reference systems, and a record with an srs_id of 0, an organization of "NONE", an organization_coordsys_id of 0, and definition "undefined" for undefined geographic coordinate reference systems.***

Req 12: ***The gpkg_spatial_ref_sys table in a GeoPackage SHALL contain records to define all spatial reference systems used by features and tiles in a GeoPackage.***

1.1.3. Contents

1.1.3.1. Data

1.1.3.1.1. Table Definition

Req 13: ***A GeoPackage SHALL include a gpkg_contents table per clause 1.1.3.1.1, Table 4 and Table 21.***

The purpose of the gpkg_contents table is to provide identifying and descriptive information that an application can display to a user in a menu of geospatial data that is available for access and/or update.

Table 4 Contents Table or View Definition

Column Name	Type	Description	Null	Default	Key
table_name	TEXT	The name of the tiles, or feature table	no		PK
data_type	TEXT	Type of data stored in the table:. “features” per clause 2.1.2.1.1, “tiles” per clause 2.2.2.1.1, or an implementer-defined value for other data tables in an Extended GeoPackage.	no		
identifier	TEXT	A human-readable identifier (e.g. short name) for the table_name content	yes		
description	TEXT	A human-readable description for the table_name content	yes	“”’’	
last_change	DATETIME	timestamp value in ISO 8601format as defined by the strftime function '%Y-%m-%dT%H:%M:%fZ' format string applied to the current time	no	strftime('%Y-%m-%dT%H:%M:%fZ','now')	
min_x	DOUBLE	Bounding box minimum easting or longitude for all content in table_name	yes		
min_y	DOUBLE	Bounding box minimum northing or latitude for all content in table_name	yes		
max_x	DOUBLE	Bounding box maximum easting or longitude for all content in table_name	yes		
max_y	DOUBLE	Bounding box maximum northing or latitude for all content in table_name	yes		
srs_id	INTEGER	Spatial Reference System ID: gpkg_spatial_ref_sys.srs_id; when data_type is features,	yes		FK

		SHALL also match gpkg_geometry_columns.srs_id; When data_type is tiles, SHALL also match gpkg_tile_matrix_set.srs.id			

The gpkg_contents table is intended to provide a list of all geospatial contents in a GeoPackage. The data_type specifies the type of content. The bounding box (min_x, min_y, max_x, max_y) provides an informative bounding box (not necessarily minimum bounding box) of the content. If the srs_id column value references a geographic coordinate reference system (CRS), then the min/max x/y values are in decimal degrees; otherwise, the srs_id references a projected CRS and the min/max x/y values are in the units specified by that CRS.

See Annex C Table Definition SQL (Normative) C.2 gpkg_contents.

1.1.3.1.2. Table Data Values

Req 14: ***The table_name column value in a gpkg_contents table row SHALL contain the name of a SQLite table or view.***

Req 15: ***Values of the gpkg_contents table last_change column SHALL be in ISO 8601 [29] format containing a complete date plus UTC hours, minutes, seconds and a decimal fraction of a second, with a 'Z' ('zulu') suffix indicating UTC.***[1]

Req 16: ***Values of the gpkg_contents table srs_id column SHALL reference values in the gpkg_spatial_ref_sys table srs_id column.***

2. Options

The optional capabilities specified in this clause depend on the required capabilities specified in clause 1 Base above. Each subclause of this clause defines an indivisible module of functionality that can be used in GeoPackages. These modules are referred to as options. GeoPackages MAY use one or more options defined in this section. GeoPackages MAY omit the tables for options that are not used. As a minimum, a GeoPackage SHALL contain one user data table as defined by the Features or Tiles options in clauses 2.1.6.1.1 and 2.2.8.1.1 respectively.

Req 17: ***A GeoPackage SHALL contain features per clause 2.1 and/or tiles per clause 2.2 and row(s) in the gpkg_contents table with lowercase data_type column values of "features" and/or "tiles" describing the user data tables.***

[1] The following statement selects an ISO 8601timestamp value using the SQLite strftime function:
`SELECT (strftime('%Y-%m-%dT%H:%M:%fZ','now')).`

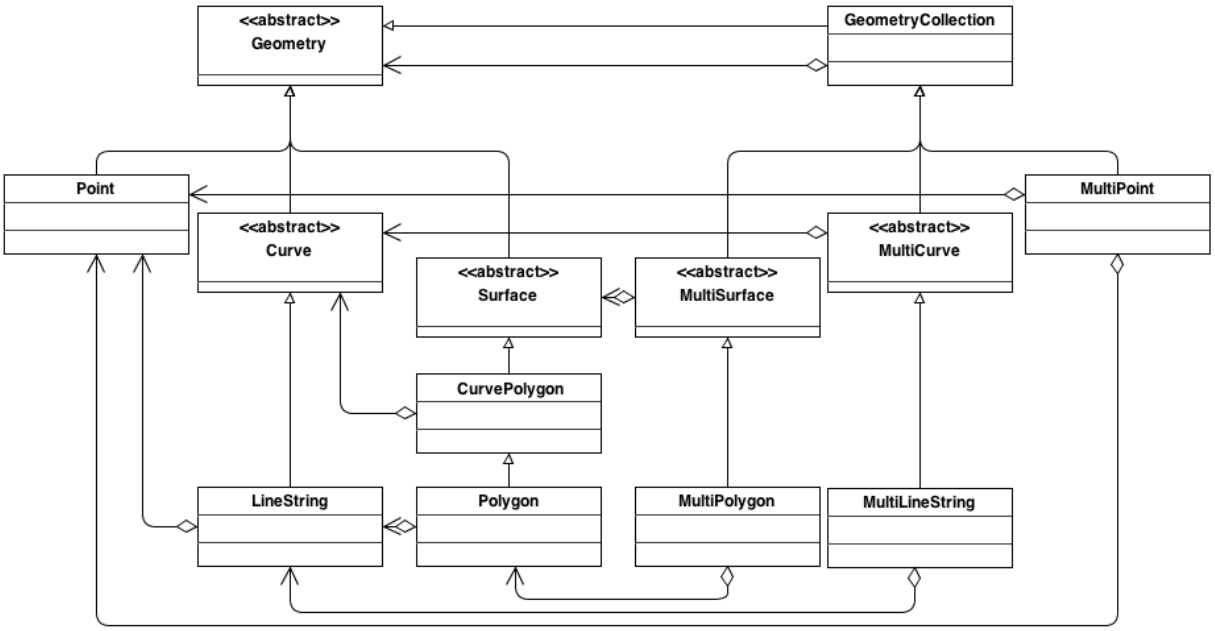
2.1. Features

2.1.1. Simple Features SQL Introduction

Vector feature data represents geolocated entities including conceptual ones such as districts, real world objects such as roads and rivers, and observations thereof. International specifications [9][10][11][12] have standardized practices for the storage, access and use of vector geospatial features and geometries via SQL in relational databases. The first component of the SQL schema for vector features in a GeoPackage is the gpkg_spatial_ref_sys table defined in clause 1.1.2 above. Other components are defined below.

In a GeoPackage, "simple" features are geolocated using a linear geometry subset of the SQL/MM (ISO 13249-3) [12] geometry model shown in figure 2 below.

Figure 2 – Core Geometry Model



The instantiable (not abstract) geometry types defined in this Standard are restricted to 0, 1 and 2-dimensional geometric objects that exist in 2, 3 or 4-dimensional coordinate space (R2, R3 or R4). Geometry values in R2 have points with coordinate values for x and y. Geometry values in R3 have points with coordinate values for x, y and z or for x, y and m. Geometry values in R4 have points with coordinate values for x, y, z and m. The interpretation of the coordinates is subject to the coordinate reference systems associated to the point. All coordinates within a geometry object should be in the same coordinate reference systems.

Geometries MAY include z coordinate values. The z coordinate value traditionally represents the third dimension (i.e. 3D). In a Geographic Information System (GIS) this may be height above or below sea level. For example: A map might have a point identifying the position of a

mountain peak by its location on the earth, with the x and y coordinate values, and the height of the mountain, with the z coordinate value.

Geometries MAY include m coordinate values. The m coordinate value allows the application environment to associate some measure with the point values. For example: A stream network may be modeled as multilinestring value with the m coordinate values measuring the distance from the mouth of stream.

All geometry types described in this standard are defined so that instances of Geometry are topologically closed, i.e. all represented geometries include their boundary as point sets. This does not affect their representation, and open version of the same classes MAY be used in other circumstances, such as topological representations.

A brief description of each geometry type is provided below. A more detailed description can be found in ISO 13249-3[12].

- Geometry: the root of the geometry type hierarchy.
- Point: a single location in space. Each point has an X and Y coordinate. A point MAY optionally also have a Z and/or an M value.
- Curve: the base type for all 1-dimensional geometry types. A 1-dimensional geometry is a geometry that has a length, but no area. A curve is considered simple if it does not intersect itself (except at the start and end point). A curve is considered closed its start and end point are coincident. A simple, closed curve is called a ring.
- LineString: A Curve that connects two or more points in space.
- Surface: the base type for all 2-dimensional geometry types. A 2-dimensional geometry is a geometry that has an area.
- CurvePolygon: A planar surface defined by an exterior ring and zero or more interior ring. Each ring is defined by a Curve instance.
- Polygon: A restricted form of CurvePolygon where each ring is defined as a simple, closed LineString.
- GeometryCollection: A collection of zero or more Geometry instances. [1]
- MultiSurface: A restricted form of GeometryCollection where each Geometry in the collection must be of type Surface.
- MultiPolygon: A restricted form of MultiSurface where each Surface in the collection must be of type Polygon.
- MultiCurve: A restricted form of GeometryCollection where each Geometry in the collection must be of type Curve.
- MultiLineString : A restricted form of MultiCurve where each Curve in the collection must be of type LineString.

[1] GeometryCollection is a generic term for the ST_GeomCollection type defined in [12], which uses it for the definition of Well Known Text (WKT) and Well Known Binary (WKB) encodings. The SQL type name GEOMCOLLECTION defined in [10] and used in Clause 1.1.2.1.1 and Annex E below refers to the SQL BLOB encoding of a GeometryCollection.

- MultiPoint: A restricted form of GeometryCollection where each Geometry in the collection must be of type Point.

2.1.2. Contents

2.1.2.1. Data

2.1.2.1.1. Contents Table – Features Row

Req 18: ***The gpkg_contents table SHALL contain a row with a lowercase data_type column value of "features" for each vector features user data table or view.***

2.1.3. Geometry Encoding

2.1.3.1. Data

2.1.3.1.1. BLOB Format

Req 19: ***A GeoPackage SHALL store feature table geometries with or without optional elevation (Z) and/or measure (M) values in SQL BLOBs using the StandardGeoPackageBinary format specified in Table 5 and clause 2.1.3.1.1.***

Table 5 GeoPackage SQL Geometry Binary Format

```
GeoPackageBinaryHeader {
  byte[2] magic = 0x4750; // 'GP'
  byte version;           // 8-bit unsigned integer, 0 = version 1
  byte flags;             // see flags layout below
  int32 srs_id;
  double[] envelope;      // see flags envelope contents indicator code below
}
```

bit layout of flags byte:

bit	7	6	5	4	3	2	1	0
use	R	R	X	Y	E	E	E	B

flag bits use:

R: reserved for future use; set to 0

X: GeoPackageBinary type
0: StandardGeoPackageBinary. See below.
1: ExtendedGeoPackageBinary See clause 3.1.2, Annex K.

Y: empty geometry flag
0: non-empty geometry
1: empty geometry

E: envelope contents indicator code (3-bit unsigned integer)

code value	**description**	**envelope length (bytes)**
0	no envelope (space saving slower indexing option)	0
1	envelope is [minx, maxx, miny, maxy]	32
2	envelope is [minx, maxx, miny, maxy, minz, maxz]	48

3	envelope is [minx, maxx, miny, maxy, minm, maxm]	48
4	envelope is [minx, maxx, miny, maxy, minz, maxz, minm, maxm]	64
5-7	invalid	unknown

```
  B: byte order for header values (1-bit Boolean)
     0 = Big Endian    (most significant byte first)
     1 = Little Endian (least significant byte first)

StandardGeoPackageBinary {
  GeoPackageBinaryHeader header; // The X bit in the header flags field
                                 //   must be set to 0.
  WKBGeometry geometry;          // per ISO 13249-3[12] clause 5.1.46 OGC
06-103r4[9][1][2][3]
}
```

Well-Known Binary as defined in ~~ISO 13249-3 [12]~~ OGC 06-103r4 [9] does not provide a standardized encoding for an empty point set (i.e., 'Point Empty' in Well-Known Text). In GeoPackages these points SHALL be encoded as a Point where each coordinate value is set to an IEEE-754 quiet NaN value. GeoPackages SHALL use big endian 0x7ff8000000000000 or little endian 0x000000000000f87f as the binary encoding of the NaN values.

When the WKBGeometry in a GeoPackageBinary is empty, either the envelope contents indicator code SHALL be 0 indicating no envelope, or the envelope SHALL have its values set to NaN as defined for an empty point.

2.1.4. SQL Geometry Types

2.1.4.1. Data

2.1.4.1.1. Core Types

Req 20: ***A GeoPackage SHALL store feature table geometries with the basic simple feature geometry types (Geometry, Point, LineString, Polygon, MultiPoint, MultiLineString, MultiPolygon, GeomCollection) in Annex E Table 42 in the GeoPackageBinary geometry encoding format.***

[1] OGC WKB simple feature geometry types specified in ~~[13]~~[9] are a subset of the ISO WKB geometry types specified in ~~[16]~~[12]

[2] WKB geometry types are are restricted to 0, 1 and 2-dimensional geometric objects that exist in 2, 3 or 4-dimensional coordinate space; they are not geographic or geodesic geometry types.

[3] The axis order in WKB is always (x,y[,z][,m]) where x is easting or longitude, y is northing or latitude, z is optional elevation and m is optional measure.

2.1.5. Geometry Columns

2.1.5.1. Data

2.1.5.1.1. Table Definition

Req 21: ***A GeoPackage with a gpkg_contents table row with a "features" data_type SHALL contain a gpkg_geometry_columns table or updateable view per clause 2.1.5.1.1, Table 6 and Table 22.***

The second component of the SQL schema for vector features in a GeoPackage is a gpkg_geometry_columns table that identifies the geometry columns and geometry types in tables that contain user data representing features.

Table 6 Geometry Columns Table or View Definition

Column Name	Type	Description	Key
table_name	TEXT	Name of the table containing the geometry column	PK, FK
column_name	TEXT	Name of a column in the feature table that is a Geometry Column	PK
geometry_type_name	TEXT	Name from Table 42 or Table 43 in Annex E	
srs_id	INTEGER	Spatial Reference System ID: gpkg_spatial_ref_sys.srs_id	FK
z	TINYINT	0: z values prohibited 1: z values mandatory 2: z values optional	
m	TINYINT	0: m values prohibited 1: m values mandatory 2: m values optional	

The FK on gpkg_geometry_columns.srs_id references the PK on gpkg_spatial_ref_sys.srs_id to ensure that geometry columns are only defined in feature tables for defined spatial reference systems.

Views of this table or view MAY be used to provide compatibility with the SQL/MM [12] (Table 23) and OGC Simple Features SQL [9][10][11] (Table 24) specifications.

See Annex C Table Definition SQL (Normative) C.3 gpkg_geometry_columns.

2.1.5.1.2. Table Data Values

Req 22: ***The gpkg_geometry_columns table or updateable view SHALL contain one row record for the geometry column in each vector feature user data table (clause 2.1.6) in a GeoPackage.***

Req 23: ***Values of the gpkg_geometry_columns table_name column SHALL reference values in the gpkg_contents table_name column for rows with a data_type of "features".***

Req 24: ***The column_name column value in a gpkg_geometry_columns row SHALL be the name of a column in the table or view specified by the table_name column value for that row.***

Req 25: ***The geometry_type_name value in a gpkg_geometry_columns row SHALL be one of the uppercase geometry type names specified in Annex E.***

Req 26: ***The srs_id value in a gpkg_geometry_columns table row SHALL be an srs_id column value from the gpkg_spatial_ref_sys table.***

Req 27: ***The z value in a gpkg_geometry_columns table row SHALL be one of 0, 1, or 2.***

Req 28: ***The m value in a gpkg_geometry_columns table row SHALL be one of 0, 1, or 2.***

2.1.6. Vector Feature User Data Tables

2.1.6.1. Data

2.1.6.1.1. Table Definition

The third component of the SQL schema for vector features in a GeoPackage described in clause 2.1.1 above are tables that contain user data representing features. Feature attributes are columns in a feature table, including geometries. Features are rows in a feature table.[1]

Req 29: ***A GeoPackage MAY contain tables or updateable views containing vector features. Every such feature table or view in a GeoPackage SHALL have a column with column type INTEGER and 'PRIMARY KEY AUTOINCREMENT' column constraints per Table 7 and Table 25.***

The integer primary key of a feature table allows features to be linked to row level metadata records in the gpkg_metadata table by rowid [B5] values in the gpkg_metadata_reference table as described in clause 2.4.3 below.

Req 30: ***A feature table SHALL have only one geometry column.***

Feature data models [B23] from non-GeoPackage implementations that have multiple geometry columns per feature table MAY be transformed into GeoPackage implementations with a separate feature table for each geometry type whose rows have matching integer primary key values that allow them to be joined in a view with the same column definitions as the non-GeoPackage feature data model with multiple geometry columns.

Req 30b: The declared SQL type of the geometry column in a vector feature user data table SHALL be the uppercase geometry type name from Annex E specified by the geometry_type_name column for that column_name and table_name in the gpkg_geometry_columns table.

Table 7: EXAMPLE: Sample Feature Table or View Definition

Column Name	Type	Description	Null	Key
id	INTEGER	Autoincrement primary key	no	PK
geometry	GEOMETRY	GeoPackage Geometry	yes	
text_attribute	TEXT	Text attribute of feature	yes	
real_attribute	REAL	Real attribute of feature	yes	
boolean_attribute	BOOLEAN	Boolean attribute of feature	yes	
raster_or_ photo	BLOB	Photograph of the area	yes	

See Annex C Table Definition SQL (Normative) C.4 sample_feature_table

[1] A GeoPackage is not required to contain any feature data tables. Feature data tables in a GeoPackage MAY be empty

2.1.6.1.2. Table Data Values

A feature geometry is stored in a geometry column specified by the lowercase geometry_column value for the feature table in the gpkg_geometry_columns table defined in clause 2.1.5 above.

The geometry type of a feature geometry column specified in the gpkg_geometry_columns table geometry_type_name column is an uppercase name from Table 42 or Table 43 in Annex E.

Req 31: ***Feature table geometry columns SHALL contain geometries of the type or assignable for the type specified for the column by the gpkg_geometry_columns geometry_type_name uppercase column value[1].***

Geometry subtypes are assignable as defined in Annex E, and shown in part in Figure 2 – Core Geometry Model. For example, if the geometry_type_name value in the gpkg_geometry_columns table is for a geometry type like POINT that has no subtypes, then the feature table geometry column MAY only contain geometries of that type. If the geometry type_name value in the gpkg_geometry_columns table is for a geometry type like GEOMCOLLECTION that has subtypes, then the feature table geometry column MAY only contain geometries of that type or any of its direct or indirect subtypes. If the geometry type_name is GEOMETRY (the root of the geometry type hierarchy) then the feature table geometry column MAY contain geometries of any geometry type.

The presence or absence of optional elevation (Z) and/or measure (M) values in a geometry does not change its type or assignability. The unit of measure for optional elevation(Z) values is determined by the CRS of the geometry; it is as-defined by a 3D CRS, and undefined for a 2D CRS. The unit of measure for optional measure (M) values is determined by the CRS of the geometry.

The spatial reference system type of a feature geometry column specified by a gpkg_geometry_columns table srs_id column value is a code from the gpkg_spatial_ref_sys table srs_id column.

Req 32: ***Feature table geometry columns SHALL contain geometries with the srs_id specified for the column by the gpkg_geometry_columns table srs_id column value.***

2.2. Tiles

2.2.1. Tile Matrix Introduction

There are a wide variety of commercial and open source conventions for storing, indexing, accessing and describing tiles in tile pyramids. Unfortunately, no applicable existing consensus, national or international specifications have standardized practices in this domain. In addition, various image file formats have different representational capabilities, and include different self-descriptive metadata.

[1] GeoPackage applications MAY use SQL triggers or tests in application code to meet Req 32:.

The tile store data / metadata model and conventions described below support direct use of tiles in a GeoPackage in two ways. First, they specify how existing applications MAY create SQL Views of the data /metadata model on top of existing application tables that that follow different interface conventions. Second, they include and expose enough metadata information at both the dataset and record levels to allow applications that use GeoPackage data to discover its characteristics without having to parse all of the stored images. Applications that store GeoPackage tile data, which are presumed to have this information available, SHALL store sufficient metadata to enable its intended use.

The GeoPackage tile store data model MAY be implemented directly as SQL tables in a SQLite database for maximum performance, or as SQL views on top of tables in an existing SQLite tile store for maximum adaptability and loose coupling to enable widespread implementation.

A GeoPackage CAN store multiple raster and tile pyramid data sets in different tables or views in the same container. [1] "Tile pyramid" refers to the concept of pyramid structure of tiles of different spatial extent and resolution at different zoom levels, and the tile data itself. "Tile matrix" refers to rows and columns of tiles that all have the same spatial extent and resolution at a particular zoom level. "Tile matrix set" refers to the definition of a tile pyramid's tiling structure.

The tables or views that implement the GeoPackage tile store data / metadata model are described and discussed individually in the following subsections.

2.2.2. Contents

2.2.2.1. Data

2.2.2.1.1. Contents Table – Tiles Row

Req 33: ***The gpkg_contents table SHALL contain a row with a lowercase data_type column value of "tiles" for each tile pyramid user data table or view.***

2.2.3. Zoom Levels

In a GeoPackage, zoom levels are integers in sequence from 0 to n that identify tile matrix layers in a tile matrix set that contain tiles of decreasing spatial extent and finer spatial resolution. Adjacent zoom levels immediately precede or follow each other and differ by a value of 1. Pixel sizes are real numbers in the terrain units of the spatial reference system of a tile image specifying the dimensions of the real world area represented by one pixel. Pixel sizes MAY vary by a constant factor or by different factors or intervals between some or all adjacent zoom levels in a tile matrix set. In the commonly used "zoom times two" convention, pixel sizes vary by a factor of 2 between all adjacent zoom levels, as shown in the example in Annex F. Other "zoom other intervals" conventions use different factors or irregular intervals with pixel sizes chosen for intuitive cartographic representation of raster data, or to coincide

[1] Images of multiple MIME types MAY be stored in given table. For example, in a tiles table, image/png format tiles COULD be used for transparency where there is no data on the tile edges, and image/jpeg format tiles COULD be used for storage efficiency where there is image data for all pixels. Images of multiple bit depths of the same MIME type MAY also be stored in a given table, for example image/png tiles in both 8 and 24 bit depths.

with the original pixel size of commonly used global image products. See WMTS [16] Annex E for additional examples of both conventions.

2.2.3.1. Data

2.2.3.1.1. Zoom Times Two

Req 34: ***In a GeoPackage that contains a tile pyramid user data table that contains tile data, by default[1], zoom level pixel sizes for that table SHALL vary by a factor of 2 between adjacent zoom levels in the tile matrix table.***

2.2.4. Tile Encoding PNG

2.2.4.1. Data

2.2.4.1.1. MIME Type PNG

Req 35: ***In a GeoPackage that contains a tile pyramid user data table that contains tile data that is not MIME type image/jpeg [17][18][19], by default SHALL store that tile data in MIME type image/png [20][21].[2]***

2.2.5. Tile Encoding JPEG

2.2.5.1. Data

2.2.5.1.1. MIME Type JPEG

Req 36: ***In a GeoPackage that contains a tile pyramid user data table that contains tile data that is not MIME type image/png [20][21], by default SHALL store that tile data in MIME type image/jpeg[17][18][19], [3]***

2.2.6. Tile Matrix Set

2.2.6.1. Data

2.2.6.1.1. Table Definition

Req 37: ***A GeoPackage that contains a tile pyramid user data table SHALL contain a gpkg_tile_matrix_set table or view per clause 2.2.6.1.1, Table 8 and Table 26.***

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[1] See clause 3.2.1.1.1 for use of other zoom levels as a registered extensions.

[2] See Clause 3.2.2 regarding use of the WebP alternative tile MIME type as a registered extension.

[3] See Clause 3.2.2 regarding use of the WebP alternative tile MIME type as a registered extension.

Table 8 Tile Matrix Set Table or View Definition

Column Name	Column Type	Column Description	Null	Key
table_name	TEXT	Tile Pyramid User Data Table Name	no	PK, FK
srs_id	INTEGER	Spatial Reference System ID: gpkg_spatial_ref_sys.srs_id	no	FK
min_x	DOUBLE	Bounding box minimum easting or longitude for all content in table_name	no	
min_y	DOUBLE	Bounding box minimum northing or latitude for all content in table_name	no	
max_x	DOUBLE	Bounding box maximum easting or longitude for all content in table_name	no	
max_y	DOUBLE	Bounding box maximum northing or latitude for all content in table_name	no	

The gpkg_tile_matrix_set table or updateable view defines the minimum bounding box (min_x, min_y, max_x, max_y) and spatial reference system (srs_id) for all content in a tile pyramid user data table.

See Annex C Table Definition SQL (Normative) C.5 gpkg_tile_matrix_set

2.2.6.1.2. Table Data Values

The minimum bounding box defined in the gpkg_tile_matrix_set table or view for a tile pyramid user data table SHALL be exact so that the bounding box coordinates for individual tiles in a tile pyramid MAY be calculated based on the column values for the user data table in the gpkg_tile_matrix table or view. For example, because GeoPackages use the upper left tile origin convention defined in clause 2.2.7.1.2 below, the gpkg_tile_matrix_set (min_x, max_y) ordinate is the upper-left corner of tile (0,0) for all zoom levels in a table_name tile pyramid user data table.

Req 38: ***Values of the gpkg_tile_matrix_set.table_name column SHALL reference values in the gpkg_contents table_name column for rows with a data_type of "tiles".***

Req 39: ***The gpkg_tile_matrix_set table or view SHALL contain one row record for each tile pyramid user data table.***

Req 40: ***Values of the gpkg_tile_matrix_set.srs_id column SHALL reference values in the gpkg_spatial_ref_sys table srs_id column.***

2.2.7. Tile Matrix

2.2.7.1. Data

2.2.7.1.1. Table Definition

Req 41: ***A GeoPackage that contains a tile pyramid user data table SHALL contain a gpkg_tile_matrix table or view per clause 2.2.7.1.1, Table 9 and Table 27.***

Table 9 Tile Matrix Table or View Definition

Column Name	Column Type	Column Description	Null	Key
table_name	TEXT	Tile Pyramid User Data Table Name	no	PK, FK
zoom_level	INTEGER	0 <= zoom_level <= max_level for table_name	no	PK
matrix_width	INTEGER	Number of columns (>= 1) in tile matrix at this zoom level	no	
matrix_height	INTEGER	Number of rows (>= 1) in tile matrix at this zoom level	no	
tile_width	INTEGER	Tile width in pixels (>= 1)for this zoom level	no	
tile_height	INTEGER	Tile height in pixels (>= 1) for this zoom level	no	
pixel_x_size	DOUBLE	In t_table_name srs_id units or default meters for srs_id 0 (>0)	no	
pixel_y_size	DOUBLE	In t_table_name srs_id units or default meters for srs_id 0 (>0)	no	

The gpkg_tile_matrix table or updateable view documents the structure of the tile matrix at each zoom level in each tiles table. It allows GeoPackages to contain rectangular as well as square tiles (e.g. for better representation of polar regions). It allows tile pyramids with zoom levels that differ in resolution by factors of 2, irregular intervals, or regular intervals other than factors of 2.

See Annex C Table Definition SQL (Normative) C.6 gpkg_tile_matrix

2.2.7.1.2. Table Data Values

Req 42: ***Values of the gpkg_tile_matrix table_name column SHALL reference values in the gpkg_contents table_name column for rows with a data_type of "tiles".***

Req 43: ***The gpkg_tile_matrix table or view SHALL contain one row record for each zoom level that contains one or more tiles in each tile pyramid user data table or view.***

The gpkg_tile_matrix table or view MAY contain row records for zoom levels in a tile pyramid user data table that do not contain tiles.

GeoPackages follow the most frequently used conventions of a tile origin at the upper left and a zoom-out-level of 0 for the smallest map scale "whole world" zoom level view[1], as specified by WMTS [16]. The tile coordinate (0,0) always refers to the tile in the upper left corner of the tile matrix at any zoom level, regardless of the actual availability of that tile.

Req 44: ***The zoom_level column value in a gpkg_tile_matrix table row SHALL not be negative.***

Req 45: ***The matrix_width column value in a gpkg_tile_matrix table row SHALL be greater than 0.***

Req 46: ***The matrix_height column value in a gpkg_tile_matrix table row SHALL be greater than 0.***

Req 47: ***The tile_width column value in a gpkg_tile_matrix table row SHALL be greater than 0.***

Req 48: ***The tile_height column value in a gpkg_tile_matrix table row SHALL be greater than 0.***

Req 49: ***The pixel_x_size column value in a gpkg_tile_matrix table row SHALL be greater than 0.***

Req 50: ***The pixel_y_size column value in a gpkg_tile_matrix table row SHALL be greater than 0.***

Req 51: ***The pixel_x_size and pixel_y_size column values for zoom_level column values in a gpkg_tile_matrix table sorted in ascending order SHALL be sorted in descending order.***

Tiles MAY or MAY NOT be provided for level 0 or any other particular zoom level.[2] This means that a tile matrix set can be sparse, i.e. not contain a tile for any particular position at a certain tile zoom level.[3] This does not affect the informative spatial extent stated by the min/max x/y columns values in the gpkg_contents record for the same table_name, the exact spatial extent stated by the min/max x/y columns values in the gpkg_tile_matrix_set record for the same table name, or the tile matrix width and height at that level.[4]

[1] GeoPackage applications MAY query the gpkg_tile_matrix table or the tile pyramid user data table to determine the minimum and maximum zoom levels for a given tile pyramid table.

[2] GeoPackage applications MAY query a tile pyramid user data table to determine which tiles are available at each zoom level.

[3] GeoPackage applications that insert, update, or delete tile pyramid user data table tiles row records are responsible for maintaining the corresponding descriptive contents of the gpkg_tile_matrix table.

[4] The gpkg_tile_matrix_set table contains coordinates that define a bounding box as the exact stated spatial extent for all tiles in a tile (matrix set) table. If the geographic extent of the image data contained in tiles at a particular zoom level is within but not equal to this bounding box, then the non-image area of matrix edge tiles must be padded with no-data values, preferably transparent ones.

2.2.8. Tile Pyramid User Data Tables

2.2.8.1. Data

2.2.8.1.1. Table Definition

Req 52: ***Each tile matrix set in a GeoPackage SHALL be stored in a different tile pyramid user data table or updateable view with a unique name that SHALL have a column named "id" with column type INTEGER and 'PRIMARY KEY AUTOINCREMENT' column constraints per clause 2.2.8.1.1, Table 10 and Table 29~~Table 30~~.***

Table 10 Tile Pyramid User Data Table or View Definition

Column Name	Column Type	Column Description	Null	Default	Key
id	INTEGER	Autoincrement primary key	no		PK
zoom_level	INTEGER	min(zoom_level) <= zoom_level <= max(zoom_level) for t_table_name	no	0	UK
tile_column	INTEGER	0 to gpkg_tile_matrix matrix_width – 1	no	0	UK
tile_row	INTEGER	0 to gpkg_tile_matrix matrix_height - 1	no	0	UK
tile_data	BLOB	Of an image MIME type specified in clauses 2.2.4, 2.2.5, 3.2.2	no		

See Annex C Table Definition SQL (Normative) **C.7** sample_tile_pyramid

2.2.8.1.2. Table Data Values

Each tile pyramid user data table or view[1] MAY contain tile matrices at zero or more zoom levels of different spatial resolution (map scale).

Req 53: ***For each distinct table_name from the gpkg_tile_matrix (tm) table, the tile pyramid (tp) user data table zoom_level column value in a GeoPackage SHALL be in the range min(tm.zoom_level) <= tp.zoom_level <= max(tm.zoom_level).***

Req 54: ***For each distinct table_name from the gpkg_tile_matrix(tm) table, the tile pyramid (tp) user data table tile_column column value in a GeoPackage SHALL be in the range 0 <= tp.tile_column <= tm.matrix_width – 1 where the tm and tp zoom_level column values are equal.***

Req 55: ***For each distinct table_name from the gpkg_tile_matrix(tm) table, the tile pyramid (tp) user data table tile_row column value in a GeoPackage SHALL be in the range 0 <= tp.tile_row <= tm.matrix_height – 1 where the tm and tp zoom_level column values are equal.***

[1] A GeoPackage is not required to contain any tile pyramid user data tables. Tile pyramid user data tables in a GeoPackage MAY be empty.

All tiles at a particular zoom level have the same pixel_x_size and pixel_y_size values specified in the gpkg_tile_matrix row record for that tiles table and zoom level.[1]

2.3. Schema

2.3.1. Schema Introduction

The schema option provides a means to describe the columns of tables in a GeoPackage with more detail than can be captured by the SQL table definition directly. The information provided by this option can be used by applications to, for instance, present data contained in a GeoPackage in a more user-friendly fashion or implement data validation logic.

2.3.2. Data Columns

2.3.2.1. Data

2.3.2.1.1. Table Definition

Req 56: ***A GeoPackage MAY contain a table or updateable view named gpkg_data_columns. If present it SHALL be defined per clause 2.3.2.1.1, Table 11 and Table 31.***

Table 11 Data Columns Table or View Definition

Column Name	Column Type	Column Description	Null	Key
table_name	TEXT	Name of the tiles or feature table	no	PK
column_name	TEXT	Name of the table column	no	PK
name	TEXT	A human-readable identifier (e.g. short name) for the column_name content	yes	
title	TEXT	A human-readable formal title for the column_name content	yes	
description	TEXT	A human-readable description for the table_name content	yes	
mime_type	TEXT	MIME [21] type of column_name if BLOB type, or NULL for other types	yes	
constraint_name	TEXT	Case sensitive column value constraint name specified by reference to gpkg_data_column_constraints.constraint name	yes	

GeoPackage applications MAY[2] use the gpkg_data_columns table to store minimal application schema identifying, descriptive and MIME [21] type[1] information about columns

[1] The zoom_level / tile_column / tile_row unique key is automatically indexed, and allows tiles to be selected and accessed by "z, x, y", a common convention used by some implementations. This table / view definition MAY also allow tiles to be selected based on a spatially indexed bounding box in a separate metadata table.

[2] A GeoPackage is not required to contain a gpkg_data_columns table. The gpkg_data_columns table in a GeoPackage MAY be empty.

in user vector feature and tile matrix data tables that supplements the data available from the SQLite sqlite_master table and pragma table_info(table_name) SQL function. The gpkg_data_columns data CAN be used to provide more specific column data types and value ranges and application specific structural and semantic information to enable more informative user menu displays and more effective user decisions on the suitability of GeoPackage contents for specific purposes.

See Annex Annex C Table Definition SQL (Normative) C.8 gpkg_data_columns

2.3.2.1.2. Table Data Values

Req 57: ***Values of the gpkg_data_columns table table_name column value SHALL reference values in the gpkg_contents table_name column.***

Req 58: ***The column_name column value in a gpkg_data_columns table row SHALL contain the name of a column in the SQLite table or view identified by the table_name column value.***

Req 59: ***The constraint_name column value in a gpkg_data_columns table MAY be NULL. If it is not NULL, it SHALL contain a case sensitive constraint_name column value from the gpkg_data_column_constraints table.***

2.3.3. Data Column Constraints

2.3.3.1. Data

2.3.3.1.1. Table Definition

Req 60: ***A GeoPackage MAY contain a table or updateable view named gpkg_data_column_constraints. If present it SHALL be defined per clause 2.3.3.1.1, Table 12 and Table 32.***

The gpkg_data_column_constraints table contains data to specify restrictions on basic data type column values. The constraint_name column is referenced by constraint_name column in the gpkg_data_columns table defined in clause 2.3.2.1.1.

[1] GeoPackages MAY contain MIME types other than the raster image types specified in clauses 2.2.4, 2.2.5, and 3.2.2 as feature attributes, but they are not required to do so

Table 12 Data Column Constraints Table or View Definition [1]

Column Name	Column Type	Column Description	Null	Key
constraint_name	TEXT	Case sensitive name of constraint	no	Unique
constraint_type	TEXT	Lowercase type name of constraint: 'range' | 'enum' | 'glob'	no	Unique
value	TEXT	Specified case sensitive value for ‘enum’ or ‘glob’ or NULL for ‘range’ constraint_type	yes	Unique
min	NUMERIC	Minimum value for ‘range’ or NULL for ‘enum’ or ‘glob’ constraint_type	yes	
minIsInclusive	BOOLEAN	0 (false) if min value is exclusive, or 1 (true) if min value is inclusive	yes	
max	NUMERIC	Maximum value for ‘range’ or NULL for ‘enum’ or ‘glob’ constraint_type	yes	
maxIsInclusive	BOOLEAN	0 (false) if max value is exclusive, or 1 (true) if max value is inclusive	yes	
description	TEXT	For ranges and globs, describes the constraint; for enums, describes the enum value.	yes	

See Annex C Table Definition SQL (Normative) C.9 gpkg_data_column_constraints.

2.3.3.1.2. Table Data Values

The lowercase gpkg_data_column_constraints constraint_type column value specifies the type of constraint: "range", "enum", or "glob" (text pattern match). The case sensitive value column contains an enumerated legal value for constraint_type "enum", a pattern match string for constraint_type "glob", or NULL for constraint_type "range". The set of value column values in rows of constraint_type "enum" with the same constraint_name contains all possible enumerated values for the constraint name. The min and max column values specify the minim and maximum valid values for constraint_type "range", or are NULL for constraint_type "enum" or "glob". The minIsInclusive and maxIsInclusive column values contain 1 if the min and max values are inclusive, 0 if they are exclusive, or are NULL for constraint_type "enum" or "glob". These restrictions MAY be enforced by SQL triggers or by code in applications that update GeoPackage data values.

[1] The min and max columns are defined as NUMERIC to be able to contain range values for any numeric data column defined with a data type from Table 1. These are the only exceptions to the data type rule stated in Req 5.

Table 13 Sample Data Column Constraints

constraint_name	constraint_type	value	min	minIsInclusive	max	maxIsInclusive
sampleRange	range	NULL	1	true	10	true
sampleEnum	enum	1	NULL	NULL	NULL	NULL
sampleEnum	enum	3	NULL	NULL	NULL	NULL
sampleEnum	enum	5	NULL	NULL	NULL	NULL
sampleEnum	enum	7	NULL	NULL	NULL	NULL
sampleEnum	enum	9	NULL	NULL	NULL	NULL
sampleGlob	glob	[1-2][0-9][0-9][0-9]	NULL	NULL	NULL	NULL

Req 61: ***The gpkg_data_column_constraints table MAY be empty. If it contains data, the lowercase constraint_type column values SHALL be one of "range", "enum", or "glob".***

Req 62: ***gpkg_data_column_constraint constraint_name values for rows with constraint_type values of 'range' and 'glob' SHALL be unique.***

Req 63: ***The gpkg_data_column_constraints table MAY be empty. If it contains rows with constraint_type column values of "range", the value column values for those rows SHALL be NULL.***

Req 64: ***The gpkg_data_column_constraints table MAY be empty. If it contains rows with constraint_type column values of "range", the min column values for those rows SHALL be NOT NULL and less than the max column value which shall be NOT NULL.***

Req 65: ***The gpkg_data_column_constraints table MAY be empty. If it contains rows with constraint_type column values of "range", the minIsInclusive and maxIsInclusive column values for those rows SHALL be 0 or 1.***

Req 66: ***The gpkg_data_column_constraints table MAY be empty. If it contains rows with constraint_type column values of "enum" or "glob", the min, max, minIsInclusive and maxIsInclusive column values for those rows SHALL be NULL.***

Req 67: ***The gpkg_data_column_constraints table MAY be empty. If it contains rows with constraint_type column values of "enum" or "glob", the value column SHALL NOT be NULL.***

2.4. Metadata

2.4.1. Introduction

Two tables in a GeoPackage provide a means of storing metadata in MIME [21] encodings that are defined in accordance with any authoritative metadata specifications, and relating it to the features, rasters, and tiles data in a GeoPackage. These tables are intended to provide the support necessary to implement the hierarchical metadata model defined in ISO 19115 [28], Annex B B.5.25 MD_ScopeCode, so that as GeoPackage data is captured and updated, the most local and specific detailed metadata changes associated with the new or modified data MAY be captured separately, and referenced to existing global and general metadata.

The gpkg_metadata table that contains metadata is described in clause 2.4.2, and the gpkg_metadata_reference table that relates gpkg_metadata to GeoPackage data is described in clause 2.4.3. There is no GeoPackage requirement that such metadata be provided or that defined metadata be structured in a hierarchical fashion[1] with more than one level, only that if it is, these tables SHALL be used. Such metadata[2] and data that relates it to GeoPackage contents SHALL NOT be stored in other tables.

2.4.2. Metadata Table

2.4.2.1. Data

2.4.2.1.1. Table Definition

Req 68: ***A GeoPackage MAY contain a table named gpkg_metadata. If present it SHALL be defined per clause2.4.2.1.1, Table 14 and Table 33.***

The first component of GeoPackage metadata is the gpkg_metadata table that MAY contain metadata in MIME [21] encodings structured in accordance with any authoritative metadata specification, such as ISO 19115 [28], ISO 19115-2 [B6], ISO 19139 [B7], Dublin Core [B8], CSDGM [B10], DDMS [B12], NMF/NMIS [B13], etc. The GeoPackage interpretation of what constitutes “metadata” is a broad one that includes UML models [B14] encoded in XMI [B15], GML Application Schemas [30], ISO 19110 feature catalogues [B18], OWL [B20] and SKOS taxonomies [B21], etc.

[1]: Informative examples of hierarchical metadata are provided in Annex G.

[2] An informative example of raster image metadata is provided in Annex H

Table 14 Metadata Table Definition

Column Name	Column Type	Column Description	Null	Default	Key
id	INTEGER	Metadata primary key	no		PK
md_scope	TEXT	Case sensitive name of the data scope to which this metadata applies; see table 14 below	no	'dataset'	
md_standard_uri	TEXT	URI [23] reference to the metadata structure definition authority [1]	no		
mime_type	TEXT	MIME [21] encoding of metadata	no	text/xml [24]	
metadata	TEXT	metadata	no	''	

The md_standard_uri data value provides an identifier for the metadata structure (schema) specified by its definition authority. The structure (schema) information could be in whatever encoding is used by the definition authority, e.g. UML [B14], or IDEF1x [B16], or XML/Schema [25][26][27], or RDF/S [B19].

See Annex C Table Definition SQL (Normative) C.10 gpkg_metadata.

2.4.2.1.2. Table Data Values

The md_scope column in the gpkg_metadata table is the name of the applicable scope for the contents of the metadata column for a given row. The list of valid scope names and their definitions is provided in Table 15 below. The initial contents of this table were obtained from the ISO 19115 [40], Annex B B.5.25 MD_ScopeCode code list, which was extended[2] for use in the GeoPackage specification by addition of entries with "NA" as the scope code column in Table 14.

[1] For example, for ISO 19139 metadata the URI value should be the metadata schema namespace http://www.isotc211.org/2005/gmd.

[2] The scope codes in Table 15 include a very wide set of descriptive information types as "metadata" to describe data.

Table 15 Metadata Scopes

Name (md_scope)	Scope Code	Definition
undefined	NA	Metadata information scope is undefined
fieldSession	012	Information applies to the field session
collectionSession	004	Information applies to the collection session
series	006	Information applies to the (dataset) series[1]
dataset	005	Information applies to the (geographic feature) dataset
featureType	010	Information applies to a feature type (class)
feature	009	Information applies to a feature (instance)
attributeType	002	Information applies to the attribute class
attribute	001	Information applies to the characteristic of a feature (instance)
tile	016	Information applies to a tile, a spatial subset of geographic data
model	015	Information applies to a copy or imitation of an existing or hypothetical object
catalog	NA	Metadata applies to a feature catalog[2]
schema	NA	Metadata applies to an application schema[3]
taxonomy	NA	Metadata applies to a taxonomy or knowledge system[4]
software	013	Information applies to a computer program or routine
service	014	Information applies to a capability which a service provider entity makes available to a service user entity through a set of interfaces that define a behaviour, such as a use case
collectionHardware	003	Information applies to the collection hardware class
nonGeographicDataset	007	Information applies to non-geographic data
dimensionGroup	008	Information applies to a dimension group

Req 69: ***Each md_scope column value in a gpkg_metadata table SHALL be one of the case-sensitive name column values from Table 15 in clause 2.4.2.1.2.***

2.4.3. Metadata Reference Table

2.4.3.1. Data

2.4.3.1.1. Table Definition

Req 70: ***A GeoPackage that contains a gpkg_metadata table SHALL contain a gpkg_metadata_reference table per clause 2.4.3.1.1, Table 16 and Table 34.***

[1] ISO 19139 format metadata [B32] is recommended for general-purpose description of geospatial data at the series and dataset metadata scopes.

[2] The "catalog" md_scope MAY be used for Feature Catalog [B40] information stored as XML metadata that is linked to features stored in a GeoPackage.

[3] The "schema" md_scope MAY be used for Application Schema [B37][B38][B39][B44] information stored as XML metadata that is linked to features stored in a GeoPackage.

[4] The "taxonomy" md_scope MAY be used for taxonomy or knowledge system [B41][B42] "linked data" information stored as XML metadata that is linked to features stored in a GeoPackage.

The second component of GeoPackage metadata is the gpkg_metadata_reference table that links metadata in the gpkg_metadata table to data in the feature, and tiles tables defined in clauses 2.1.6 and 2.2.8. The gpkg_metadata_reference table is not required to contain any rows.

Table 16 Metadata Reference Table Definition

Column Name	Col Type	Column Description	Null	Default	Key
reference_scope	TEXT	Lowercase metadata reference scope; one of ‘geopackage’, ‘table’,‘column’, ’row’, ’row/col’	no		
table_name	TEXT	Name of the table to which this metadata reference applies, or NULL for reference_scope of ‘geopackage’.	yes		
column_name	TEXT	Name of the column to which this metadata reference applies; NULL for reference_scope of ‘geopackage’,‘table’ or ‘row’, or the name of a column in the table_name table for reference_scope of ‘column’ or ‘row/col’	yes		
row_id_value1	INTEGER	NULL for reference_scope of ‘geopackage’, ‘table’ or ‘column’, or the rowed of a row record in the table_name table for reference_scope of ‘row’ or ‘row/col’	yes		
timestamp	DATETIME	timestamp value in ISO 8601format as defined by the strftime function '%Y-%m-%dT%H:%M:%fZ' format string applied to the current time	no	strftime('%Y-%m-%dT%H:%M:%fZ',’now’)	
md_file_id	INTEGER	gpkg_metadata table id column value for the metadata to which this gpkg_metadata_reference applies	no		FK
md_parent_id	INTEGER	gpkg_metadata table id column value for the	yes		FK

[1] In SQLite, the rowid value is always equal to the value of a single-column primary key on an integer column [B30] and is not changed by a database reorganization performed by the VACUUM SQL command.

		hierarchical parent gpkg_metadata for the gpkg_metadata to which this gpkg_metadata_reference applies, or NULL if md_file_id forms the root of a metadata hierarchy			

Every row in gpkg_metadata_reference that has null value as md_parent_id forms the root of a metadata hierarchy[1].

See Annex C Table Definition SQL (Normative)C.11 gpkg_metadata_reference.

2.4.3.1.2. Table Data Values

Req 71: ***Every gpkg_metadata_reference table reference scope column value SHALL be one of 'geopackage', 'table','column', 'row', 'row/col' in lowercase.***

Req 72: ***Every gpkg_metadata_reference table row with a reference_scope column value of 'geopackage' SHALL have a table_name column value that is NULL. Every other gpkg_metadata_reference table row SHALL have a table_name column value that references a value in the gpkg_contents table_name column.***

Req 73: ***Every gpkg_metadata_reference table row with a reference_scope column value of 'geopackage','table' or 'row' SHALL have a column_name column value that is NULL. Every other gpkg_metadata_reference table row SHALL have a column_name column value that contains the name of a column in the SQLite table or view identified by the table_name column value.***

Req 74: ***Every gpkg_metadata_reference table row with a reference_scope column value of 'geopackage', 'table' or 'column' SHALL have a row_id_value column value that is NULL. Every other gpkg_metadata_reference table row SHALL have a row_id_value column value that contains the ROWID of a row in the SQLite table or view identified by the table_name column value.***

Req 75: ***Every gpkg_metadata_reference table row timestamp column value SHALL be in ISO 8601 [29] format containing a complete date plus UTC hours, minutes, seconds and a decimal fraction of a second, with a 'Z' ('zulu') suffix indicating UTC.[2]***

Req 76: ***Every gpkg_metadata_reference table row md_file_id column value SHALL be an id column value from the gpkg_metadata table.***

---

[1] Such a metadata hierarchy MAY have only one level of defined metadata.

[2] The following statement selects an ISO 8601timestamp value using the SQLite strftime function:

```
SELECT (strftime('%Y-%m-%dT%H:%M:%fZ','now')).
```

Req 77: ***Every gpkg_metadata_reference table row md_parent_id column value that is NOT NULL SHALL be an id column value from the gpkg_metadata table that is not equal to the md_file_id column value for that row.***

2.5. Extension Mechanism

2.5.1. Introduction

A GeoPackage extension is a set of one or more requirements clauses that are documented by filling out the GeoPackage Extension Template in Annex I. A GeoPackage Extension either profiles / extends existing requirements clauses in the geopackage specification or adds new requirements clauses. Existing requirement clause extension examples include additional geometry types, additional SQL geometry functions, and additional tile image formats. New requirement clause extension examples include spatial indexes, triggers, additional tables, other BLOB column encodings, and other SQL functions.

GeoPackage extensions are identified by a name of the form <author>_<extension name> where <author> indicates the person or organization that developed and maintains the extension. The author value "gpkg" is reserved for GeoPackage extensions that are developed and maintained by OGC and used in Geopackages. Implementers use their own author names to register other extensions[1] used in Extended GeoPackages.

2.5.2. Extensions

2.5.2.1. Data

2.5.2.1.1. Table Definition

Req 78: ***A GeoPackage MAY contain a table or updateable view named gpkg_extensions. If present this table SHALL be defined per clause2.5.2.1.1, Table 17 and Table 36***

The gpkg_extensions table or updateable view in a GeoPackage is used to indicate that a particular extension applies to a GeoPackage, a table in a GeoPackage or a column of a table in a GeoPackage. An application that accesses a GeoPackage can query the gpkg_extensions table instead of the contents of all the user data tables to determine if it has the required capabilities to read or write to tables with extensions, and to "fail fast" and return an error message if it does not.

Table 17 GeoPackage Extensions Table or View Definition

Column Name	Col Type	Column Description	Null	Key
table_name	TEXT	Name of the table that requires the extension. When NULL, the extension is required for the entire GeoPackage. SHALL NOT be NULL when the column_name is not NULL.	yes	Unique

[1] See Req 82:.

column_name	TEXT	Name of the column that requires the extension. When NULL, the extension is required for the entire table.	yes	Unique
extension_name	TEXT	The case sensitive name of the extension that is required, in the form <author>_<extension name>.	no	Unique
definition	TEXT	Definition of the extension in the form specified by the template in Annex I or reference thereto.	no	
scope	TEXT	Indicates scope of extension effects on readers / writers: "read-write" or "write-only" in lowercase.	no	

See Annex C Table Definition SQL (Normative) C.12 gpkg_extensions.

2.5.2.1.2. Table Data Values

Req 79: ***Every extension of a GeoPackage SHALL be registered in a corresponding row in the gpkg_extensions table. The absence of a gpkg_extensions table or the absence of rows in gpkg_extnsions table SHALL both indicate the absence of extensions to a GeoPackage.***

Req 80: ***Values of the gpkg_extensions table_name column SHALL reference values in the gpkg_contents table_name column or be NULL. They SHALL NOT be NULL for rows where the column_name value is not NULL.***

Req 81: ***The column_name column value in a gpkg_extensions row SHALL be the name of a column in the table specified by the table_name column value for that row, or be NULL.***

Req 82: ***Each extension_name column value in a gpkg_extensions row SHALL be a unique case sensitive value of the form <author>_<extension name> where <author> indicates the person or organization that developed and maintains the extension. The valid character set for <author> SHALL be [a-zA-Z0-9]. The valid character set for <extension name> SHALL be [a-zA-Z0-9_]. An extension_name for the "gpkg" author name SHALL be one of those defined in this encoding standard or in an OGC Best Practices Document that extends it.***

Complete examples of how to fill out the GeoPackage Extension Template in Annex I are provided by Annex L through Annex P. The definition column value in a gpkg_extensions row for those extensions SHALL contain the Annex name as a reference.

Partial examples of how to fill out the GeoPackage Extension Template in Annex I are provided by the templates in Annex J and Annex K. Extension definitions created using those templates and other extension definitions created using Annex I MAY be provided in the definition column, preferably as ASCII text, or as a reference such as a URI [23] or email address whereby the definition may be obtained.

Req 83: ***The definition column value in a gpkg_extensions row SHALL contain or reference the text that results from documenting an extension by filling out the GeoPackage Extension Template in Annex I.***

Some extensions do not impose any additional requirements on software that accesses a GeoPackage in a read-only fashion. An example of this is an extension that defines an SQL trigger that uses a non-standard SQL function defined in a GeoPackage SQLite Extension. Triggers are only invoked when data is written to the GeoPackage, so usage of this type of extension can be safely ignored for read-only access. This is indicated by a gpkg_extensions.scope column value of "write_only".

Req 84: ***The scope column value in a gpkg_extensions row SHALL be lowercase "read-write" for an extension that affects both readers and writers, or "write-only" for an extension that affects only writers.***

3. Registered Extensions

This clause specifies requirements for GeoPackage extensions. Definitions of those extensions in the form specified by the template in Annex I are provided in Annexes J through P.

3.1. Features

The extensions defined in the following sub clauses MAY be implemented in a GeoPackage that implements features per clause 2.1.

3.1.1. GeoPackage Geometry Types Extension

3.1.1.1. Data

This extension of clause 2.1.4 partially described in Annex J defines additional GeoPackage geometry types.

3.1.1.1.1. Extension Types

Req 85: ***A GeoPackage MAY store feature table geometries with the extended non-linear geometry types (CircularString, CompoundCurve, CurvePolygon, MultiCurve, MultiSurface, Curve, Surface) in Annex E. If it does so, they SHALL be encoded in the GeoPackageBinary geometry format.***

3.1.1.1.2. Extensions Types - Extensions Name

Req 86: ***An extension name to specify a feature geometry extension type SHALL be defined for the "gpkg" author name using the "gpkg_geom_<gname>" template where <gname> is the uppercase name of the extension geometry type from Annex E used in a GeoPackage.***

3.1.1.1.3. Extensions Types - Extensions Row

Req 87: ***A GeoPackage that contains a gpkg_geometry_columns table or updateable view with row records that specify extension geometry_type_name column values SHALL contain a gpkg_extensions table that contains row records with table_name and column_name values from the gpkg_geometry_columns row records that identify extension***

type uses, and extension_name column values for each of those geometry types constructed per clause 3.1.1.1.2.

3.1.2. User-Defined Geometry Types Extension

3.1.2.1. Data

This extension of clauses 2.1.3, 2.1.4, 2.1.5 and 3.1.1 partially described in Annex K enables encoding of additional user-defined geometry types in ExtendedGeoPackageBinary format in an Extended GeoPackage.

3.1.2.1.1. Extensions Encoding

Req 88: ***The ExtendedGeoPackageBinary format defined in Annex K SHALL be used to encode geometry types other than those specified in clauses 2.1.4 and 3.1.1 and listed in Annex E.***

3.1.2.1.2. Extensions Encoding - Extensions Name

Req 89: ***An extension name to specify a feature geometry extension type encoded in the ExtendedGeoPackageBinary format SHALL be defined for an author name that is NOT "gpkg" using the "<author_name>_geom_<gname> template where <gname> is the uppercase name of an extension geometry type NOT listed in Annex E used in a GeoPackage.***

3.1.2.1.3. Extensions Encoding- Extensions Row

Req 90: ***An Extended GeoPackage that contains a gpkg_geometry_columns table or updateable view with row records that specify extension geometry_type_name column values other than those specified in clauses 2.1.4 and 3.1.1 and listed in Annex E SHALL contain a gpkg_extensions table that contains row records with table_name and column_name values from the gpkg_geometry_columns row records that identify extension type uses, and extension_name column values for each of those geometry type constructed per clause 3.1.2.1.2.***

3.1.2.1.4. Geometry Columns Geometry Type Name

Req 91: ***The geometry_type_name value in a gpkg_geometry_columns row SHALL be the Req 89: extension name in uppercase.***

3.1.3. Rtree Spatial Indexes

3.1.3.1. Data

This extension described in Annex L adds a new capability for spatially indexing columns with geometries encoded per clause 2.1.3 and 3.1.2.

3.1.3.1.1. Spatial Indexes Implementation

Spatial indexes provide a significant performance advantage for searches with basic envelope spatial criteria that return subsets of the rows in a feature table with a non-trivial number (thousands or more) of rows.[1]

Req 92: ***A GeoPackage SHALL implement spatial indexes on feature table geometry columns as specified in clause 3.1.3.1.1 using the SQLite Virtual Table RTrees and triggers specified in Annex L.***

3.1.3.1.2. Spatial Indexes - Extensions Name

Req 93: ***The "gpkg_rtree_index" extension name SHALL be used as a gpkg_extensions table extension name column value to specify implementation of spatial indexes on a geometry column.***

3.1.3.1.3. Spatial Indexes - Extensions Row

Req 94: ***A GeoPackage that implements spatial indexes SHALL have a gpkg_extensions table that contains a row for each spatially indexed column with extension_name "gpkg_rtree_index", the table_name of the table with a spatially indexed column, and the column_name of the spatially indexed column.***

3.1.4. Geometry Type Triggers

3.1.4.1. Data

This extension described in Annex M adds a new geometry type triggers capability for columns with geometries encoded per clause 2.1.3 and 3.1.2.

3.1.4.1.1. Geometry Type Triggers – Implementation

Req 95: ***A GeoPackage SHALL include the SQL insert and update triggers specified in Annex M on every geometry column to enforce the geometry type values specified for those columns in the gpkg_geometry_columns table.***

3.1.4.1.2. Geometry Type Triggers – Extensions Name

Req 96: ***The "gpkg_geometry_type_trigger" extension name SHALL be used as a gpkg_extensions table extension name column value to specify implementation of geometry type triggers.***

3.1.4.1.3. Geometry Type Triggers – Extensions Row

Req 97: ***A GeoPackage that implements geometry type triggers on geometry columns SHALL contain a gpkg_extensions table that contains a row for each such geometry***

[1] If an application process will make many updates, it is often faster to drop the indexes, do the updates, and then recreate the indexes.

column with extension_name "gpkg_geometry_type_trigger", table_name of the feature table with a geometry column, and column_name of the geometry column.

3.1.5. SRS_ID Triggers

3.1.5.1. Data

This extension described in Annex N adds a new srs_id triggers capability for columns with geometries encoded per clause 2.1.3 and 3.1.2.

3.1.5.1.1. SRS_ID Triggers – Implementation

Req 98: ***A GeoPackage SHALL include the SQL insert and update triggers specified in Annex Non every geometry column to enforce the srs_id values specified for those columns in the gpkg_geometry_columns table.***

3.1.5.1.2. SRS_ID Triggers – Extensions Name

Req 99: ***The "gpkg_srs_id_trigger" extension name SHALL be used as a gpkg_extensions table extension name column value to specify implementation of SRS_ID triggers specified in Annex N.***

3.1.5.1.3. SRS_ID Triggers – Extensions Row

Req 100: ***A GeoPackage that implements srs_id triggers on feature table geometry columns SHALL contain a gpkg_extensions table that contains a row for each geometry column with extension_name "gpkg_srs_id_trigger", table_name of the feature table with a geometry column, and column_name of the geometry column.***

3.2. Tiles

The extensions defined in the following sub clauses MAY be implemented in a GeoPackage that implements tiles per clause 2.2.

3.2.1. Zoom Levels

3.2.1.1. Data

This extension of clause 2.2.3 described in Annex O allows zoom level intervals other than a factor of two.

3.2.1.1.1. Zoom Other Intervals – Extensions Name

Tile pyramid user data tables MAY have pixel sizes that vary by irregular intervals or by regular intervals other than a factor of two (the default) between adjacent zoom levels.

Req 101: ***The "gpkg_zoom_other" extension name SHALL be used as a gpkg_extensions table extension name column value to specify implementation of other zoom intervals on a tile pyramid user data table as specified in Annex O.***

3.2.1.1.2. Zoom Other Intervals – Extensions Row

Req 102: ***A GeoPackage that implements other zoom intervals SHALL have a gpkg_extensions table that contains a row for each tile pyramid user data table with other zoom intervals with extension_name "gpkg_zoom_other", the table_name of the table with other zoom intervals, and the "tile_data" column_name.***

3.2.2. Tile Encoding WEBP

3.2.2.1. Data

This extension of clauses 2.2.4 and 2.2.5 described in Annex P allows encoding of tile images in WebP format.

3.2.2.2. WEBP MIME Type

A GeoPackage that contains a tile pyramid user data table that contains tile data MAY store tile_data in MIME type image/x-webp[22].

3.2.2.2.1. WEBP -- Extensions Name

Req 103: ***The "gpkg_webp" extension name SHALL be used as a gpkg_extensions table extension name column value to specify storage of tile pyramid images in WEBP format as specified in Annex P.***

3.2.2.2.2. WEBP -- Extensions Row

Req 104: ***A GeoPackage that contains tile pyramid user data tables with tile_data columns that contain images in WEBP format SHALL contain a gpkg_extensions table that contains row records with table_name values for each such table, "tile_data" column_name values and extension_name column values of "gpkg_webp".***

4. Security Considerations

Security considerations for implementations utilizing GeoPackages are in the domain of the implementing application, deployment platform, operating system and networking environment. The GeoPackage specification does not place any constraints on application, platform, operating system level or network security

Annex A Conformance / Abstract Test Suite (Normative)

A.1 Base

A.1.1 Core

A.1.1.1 SQLite Container

A.1.1.1.1 Data

A.1.1.1.1.1 File Format

Test Case ID: /base/core/container/data/file_format
Test Purpose: Verify that the Geopackage is an SQLite version_3 database
Test Method: Pass if the first 16 bytes of the file contain “SQLite format 3” in ASCII.
Reference: Clause 1.1.1.1.1 Req 1:
Test Type: Basic

Test Case ID: /base/core/container/data/file_format/application_id
Test Purpose: Verify that the SQLite database header application id field indicates GeoPackage version 1.**0**
Test Method: Pass if the application id field of the SQLite database header contains “GP10” in ASCII.
Reference: Clause 1.1.1.1.1 Req 2:
Test Type: Basic

A.1.1.1.1.2 File Extension Name

Test Case ID: /base/core/container/data/file_extension_name
Test Purpose: Verify that the geopackage extension is ".gpkg"
Test Method: Pass if the geopackage file extension is ".gpkg"
Reference: Clause 1.1.1.1.2 Req 3:
Test Type: Basic

A.1.1.1.1.3 File Contents

Test Case ID: /base/core/container/data/file_contents
Test Purpose: Verify that the Geopackage only contains specified contents
Test Method:

1) For each gpkg_* table_name
   a) PRAGMA table_info(table_name)
   b) Continue if returns an empty result set
   c) Fail if column definitions returned by PRAGMA table_info do not match column definitions for the table in Annex C.
2) Do test /opt/features/vector_features/data/feature_table_integer_primary_key
3) Do test /opt/features/vector/features/data/feature_table_one_geometry_column
4) Do test /opt/tiles/contents/data/tiles_row
5) SELECT extension_name FROM gpkg_contents
6) For each row from #4
   a) Fail if the substring before the first “_” is not “gpkg”

7) Pass if no fails

Reference: Clause 1.1.1.1.3 Req 4:
Test Type: Basic

Test Case ID: /base/core/container/data/table_data_types
Test Purpose: Verify that the data types of GeoPackage columns include only the types specified by Clause 1.1.1.1.3 Table 1
Test Method:

1) SELECT table_name FROM gpkg_contents WHERE data_type = 'features'
2) Not testable if returns empty set
3) For each row table name from step 1
   a) PRAGMA table_info(table_name)
   b) Fail if returns empty set
   c) For each row type column value
      i. Fail if value is not one of the data type names specified by Clause 1.1.1.1.3 Table 1
4) Pass if no fails

Reference: Clause 1.1.1.1.3 Table 1 Req 5:
Test Type: Basic

A.1.1.1.1.4 Integrity Check

Test Case ID: /base/core/container/data/file_integrity
Test Purpose: Verify that the geopackage passes the SQLite integrity check.
Test Method: Pass if PRAGMA integrity_check returns "ok"
Reference: Clause 1.1.1.1.4 Req 6:
Test Type: Capability

Test Case ID: /base/core/container/data/foreign_key_integrity
Test Purpose: Verify that the geopackage passes the SQLite foreign_key_check.
Test Method: Pass if PRAGMA foreign_key_check() with no parameter value returns an empty result set
Reference: Clause 1.1.1.1.4 Req 7:
Test Type: Capability

A.1.1.1.2 API

A.1.1.1.2.1 Structured Query Language

Test Case ID: /base/core/container/api/sql
Test Purpose: Test that the GeoPackage SQLite Extension provides the SQLite SQL API interface.
Test Method:

1) sqlite3_exec('SELECT * FROM sqlite_master;)

2) Fail if returns an SQL error.
3) Pass otherwise

Reference: Clause 1.1.1.2.1 Req 8:
Test Type: Capability

A.1.1.1.2.2 Every GPKG SQLite Configuration

Test Case ID: /base/core/container/api/every_gpkg_sqlite_config
Test Purpose: Verify that a GeoPackage SQLite Extension has the Every GeoPackage SQLite Configuration compile and run time options.
Test Method:

1) For each "SQLITE_OMIT_*" <option> listed at http://www.sqlite.org/compile.html#omitfeatures
   a) SELECT sqlite_compileoption_used**(**'SQLITE_OMIT_<option>'**)**
   b) Fail if returns 1
2) PRAGMA foreign_keys
3) Fail if returns 0
4) Pass otherwise

Reference: Clause 1.1.1.2.2 Req 9:
Test Type: Basic

A.1.1.2 Spatial Reference Systems

A.1.1.2.1 Data

A.1.1.2.1.1 Table Definition

Test Case ID: /base/core/gpkg_spatial_ref_sys/data/table_def
Test Purpose: Verify that the gpkg_spatial_ref_sys table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_spatial_ref_sys'
2) Fail if returns an empty result set
3) Pass if column names and column definitions in the returned CREATE TABLE statement in the sql column value, including data type, nullability, and primary key constraints match all of those in the contents of C.1Table 18. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.
4) Fail otherwise.

Reference: Clause 1.1.2.1.1 Req 10:
Test Type: Basic

A.1.1.2.1.2 Table Data Values

Test Case ID: /base/core/gpkg_spatial_ref_sys/data_values_default
Test Purpose: Verify that the gpkg_spatial_ref_sys table contains the required default contents.
Test Method:

1) SELECT srs_id, organization, organization_coordsys_id, definition FROM gpkg_spatial_ref_sys WHERE srs_id = -1 returns -1 “NONE” -1 “Undefined”, AND
2) SELECT srs_id, organization, organization_coordsys_id, definition FROM gpkg_spatial_ref_sys WHERE srs_id = 0 returns 0 “NONE” 0 “Undefined”, AND
3) SELECT definition FROM gpkg_spatial_ref_sys WHERE organization IN (“epsg”,”EPSG”) AND organization_coordsys_id 4326 returns GEOGCS ["WGS 84",
   DATUM ["World Geodetic System 1984",
   SPHEROID["WGS 84", 6378137, 298.257223563 ,
   AUTHORITY["EPSG","7030"]],
   AUTHORITY["EPSG","6326"]],
   PRIMEM["Greenwich", 0 , AUTHORITY["EPSG","8901"]],
   UNIT["degree", 0.017453292519943278, AUTHORITY["EPSG","9102"]],
   AUTHORITY["EPSG","4326"] (rounding the UNIT conversion factors to 16 decimal places, and ignoring any optional EBNF components <twin axes> and <to wgs84> and whitespace differences in the returned text)
4) Pass if tests 1-3 are met
5) Fail otherwise

Reference: Clause 1.1.2.1.2 Req 11:
Test Type: Capability

Test Case ID: /base/core/gpkg_spatial_ref_sys/data_values_required
Test Purpose: Verify that the gpkg_spatial_ref_sys table contains rows to define all srs_id values used by features and tiles in a GeoPackage.
Test Method:

1) SELECT DISTINCT gc.srs_id AS gc_srid, srs.srs_name, srs.srs_id, srs.organization, srs.organization_coordsys_id, srs.definition FROM gpkg_contents AS gc LEFT OUTER JOIN gpkg_spatial_ref_sys AS srs ON srs.srs_id = gc.srs_id
2) Pass if no returned srs values are NULL.
3) Fail otherwise

Reference: Clause Clause 1.1.2.1.2 Req 12:
Test Type: Capability

A.1.1.3 Contents

A.1.1.3.1 Data

A.1.1.3.1.1 Table Definition

Test Case ID: /base/core/contents/data/table_def
Test Purpose: Verify that the gpkg_contents table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_contents'
2) Fail if returns an empty result set.
3) Pass if the column names and column definitions in the returned CREATE TABLE statement, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents of C.2 Table 21. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.
4) Fail Otherwise

Reference: Clause 1.1.3.1.1 Req 13:
Test Type: Basic

A.1.1.3.1.2 Table Data Values

Test Case ID: /base/core/contents/data/data_values_table_name
Test Purpose: Verify that the table_name column values in the gpkg_contents table are valid.
Test Method:

1) SELECT DISTINCT gc.table_name AS gc_table, sm.tbl_name
   FROM gpkg_contents AS ge LEFT OUTER JOIN sqlite_master AS sm ON gc.table_name = sm.tbl_name
2) Not testable if returns an empty result set.
3) Fail if any gpkg_contents.table_name value is NULL
4) Pass otherwise.

Reference: Clause 1.1.3.1.2 Req 14:
Test Type: Capability

Test Case ID: /base/core/contents/data/data_values_last_change
Test Purpose: Verify that the gpkg_contents table last_change column values are in ISO 8601 [29]format containing a complete date plus UTC hours, minutes, seconds and a decimal fraction of a second, with a ‘Z’ (‘zulu’) suffix indicating UTC.
Test Method:

1) SELECT last_change from gpkg_contents.
2) Not testable if returns an empty result set.
3) For each row from step 1
   a. Fail if format of returned value does not match yyyy-mm-ddThh:mm:ss.hhhZ
   b. Log pass otherwise
4) Pass if logged pass and no fails.

Reference: Clause 1.1.3.1.2 Req 15:
Test Type: Capability

Test Case ID: /base/core/contents/data/data_values_srs_id
Test Purpose: Verify that the gpkg_contents table srs_id column values reference gpkg_spatial_ref_sys srs_id column values.
Test Method:

1) PRAGMA foreign_key_check('gpkg_contents')
2) Fail if does not return an empty result set

Reference: Clause 1.1.3.1.2 Req 16:
Test Type: Capability

A.2 Options

Test Case ID: /opt/valid_geopackage
Test Purpose: Verify that a GeoPackage contains a features or tiles table and gpkg_contents table row describing it.
Test Method:

1) Execute test /opt/features/contents/data/features_row
2) Pass if test passed
3) Execute test /opt/tiles/contents/data/tiles_row
4) Pass if test passed
5) Fail otherwise

Reference: Clause 2 Req 17:
Test Type: Capability

A.2.1 Features

A.2.1.1 Simple Features SQL Introduction

A.2.1.2 Contents

A.2.1.2.1 Data

A.2.1.2.1.1 Contents Table Feature Row

Test Case ID: /opt/features/contents/data/features_row
Test Purpose: Verify that the gpkg_contents table_name value table exists, and is apparently a feature table for every row with a data_type column value of "features"
Test Method:

1) Execute test /opt/features/vector_features/data/feature_table_integer_primary_key

Reference: Clause 2.1.2.1.1 Req 18:
Test Type: Capability

A.2.1.3 Geometry Encoding

A.2.1.3.1 Data

A.2.1.3.1.1 BLOB Format

Test Case ID: /opt/features/geometry_encoding/data/blob
Test Purpose: Verify that geometries stored in feature table geometry columns are encoded in the StandardGeoPackageBinary format.
Test Method:

1) SELECT table_name AS tn, column_name AS cn FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type = 'features')
2) Not testable if returns an empty result set
3) For each row from step 1
   a. SELECT cn FROM tn
   b. Not testable if none found
   c. For each cn value from step a
      i. Fail if the first two bytes of each gc are not "GP"
      ii. Fail if gc.version_number is not 0
      iii. Fail if gc.flags.GeopackageBinary type != 0
      iv. Fail if ST_IsEmpty(cn value) = 1 and gc.flags.envelope != 0 and envelope values are not NaN
4) Pass if no fails

Reference: Clause 2.1.3.1.1 Req 19:
Test Type: Capability

A.2.1.4 SQL Geometry Types

A.2.1.4.1 Data

A.2.1.4.1.1 Core Types

Test Case ID: /opt/features/geometry_encoding/data/core_types_existing_sparse_data
Test Purpose: Verify that existing basic simple feature geometries are stored in valid GeoPackageBinary format encodings.
Test Method:

1) SELECT table_name FROM gpkg_geometry_columns
2) Not testable if returns an empty result set
3) SELECT table_name AS tn, column_name AS cn FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type = 'features'),
4) Fail if returns an empty result set
5) For each row from step 3
   a. SELECT cn FROM tn;
   b. For each row from step a, if bytes 2-5 of cn.wkb as uint32 in endianness of gc.wkb byte 1of cn from #1 are a geometry type value from Annex E Table 42, then
      i. Log cn.header values, wkb endianness and geometry type
      ii. If cn.wkb is not correctly encoded per ISO 13249-3 clause 5.1.46 then log fail

iii. If cn.flags.E is 1 - 4 and some cn.wkbx is outside of cn.envelope.minx,maxx then log fail
iv. If cn.flags.E is 1 - 4 and some gc.wkby is outside of cn.envelope.miny,maxy then log fail
v. If cn.flags.E is 2,4 and some gc.wkb.z is outside of cnenvelope.minz,maxz then log fail
vi. If cn.flags.E is 3,4 and some gc.wkb.m is outside of cn.envelope.minm,maxm then log fail
vii. If cn.flags.E is 5-7 then log fail
viii. Otherwise log pass

6) Pass if log contanins pass and no fails

Reference: Clause 2.1.4.1.1 Req 20:
Test Type: Capability

Test Case ID: /opt/features/geometry_encoding/data/core_types_all_types_test_data
Test Purpose: Verify that all basic simple feature geometry types and options are stored in valid GeoPackageBinary format encodings.
Test Method:

1) Open GeoPackage that has feature geometry values of geometry type inAnnex E, for an assortment of srs_ids, for an assortment of coordinate values, without and with z and / or m values, in both big and little endian encodings:
2) /opt/features/geometry_encoding/data/core_types_existing_sparse_data
3) Pass if log contains pass record for big and little endian GP headers containing big and little endian WKBs for 0-1 envelope contents indicator codes for every geometry type value from Annex E Table 42 without and with z and/or m values.
4) Fail otherwise

Reference: Clause 2.1.4.1.1 Req 20:
Test Type: Capability

A.2.1.5 Geometry Columns

A.2.1.5.1 Data

A.2.1.5.1.1 Table Definition

Test Case ID: /opt/features/geometry_columns/data/table_def
Test Purpose: Verify that the gpkg_geometry_columns table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_geometry_columns'
2) Fail if returns an empty result set.
3) Pass if the column names and column definitions in the returned Create TABLE statement in the sql column value, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents of

C.4Table 21. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.

4) Fail otherwise.

Reference: Clause 2.1.5.1.1 Req 21:
Test Type: Basic

A.2.1.5.1.2 Table Data Values

Test Case ID: /opt/features/geometry_columns/data/data_values_geometry_columns
Test Purpose: Verify that gpkg_geometry_columns contains one row record for each geometry column in each vector feature user data table.
Test Method:

1) SELECT table_name FROM gpkg_contents WHERE data_type = 'features'
2) Not testable if returns an empty result set
3) SELECT table_name FROM gpkg_contents WHERE data_type = 'features' AND table_name NOT IN (SELECT table_name FROM gpkg_geometry_columns)
4) Fail if result set is not empty

Reference: Clause 2.1.5.1.2 Req 22:
Test Type: Capability

Test Case ID: /opt/features/geometry_columns/data/data_values_table_name
Test Purpose: Verify that the table_name column values in the gpkg_geometry_columns table are valid.
Test Method:

1) PRAGMA foreign_key_check('geometry_columns')
2) Fail if returns any rows with a fourth column foreign key index value of 1 (gpkg_contents)

Reference: Clause 2.1.5.1.2 Req 23:
Test Type: Capability

Test Case ID: /opt/features/geometry_columns/data/data_values_column_name
Test Purpose: Verify that the column_name column values in the gpkg_geometry_columns table are valid.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns
2) Not testable if returns an empty result set
3) For each row from step 1
   a. PRAGMA table_info(table_name)
   b. Fail if gpkg_geometry_columns.column_name value does not equal a name column value returned by PRAGMA table_info.
4) Pass if no fails.

Reference: Clause 2.1.5.1.2 Req 24:

Test Type: Capability

Test Case ID: /opt/features/geometry_columns/data/data_values_geometry_type_name
Test Purpose: Verify that the geometry_type_name column values in the gpkg_geometry_columns table are valid.
Test Method:

1) SELECT DISTINCT geometry_type_name from gpkg_geometry_columns
2) Not testable if returns an empty result set
3) For each row from step 1
   a. Fail if a returned geometry_type_name value is not in Table 42 or Table 43 in Annex E
4) Pass if no fails.

Reference: Clause 2.1.5.1.2 Req 25:
Test Type: Capability

Test Case ID: /opt/features/geometry_columns/data/data_values_srs_id
Test Purpose: Verify that the gpkg_geometry_columns table srs_id column values are valid.
Test Method:

1) PRAGMA foreign_key_check('gpkg_geometry_columns')
2) Fail if returns any rows with a fourth column foreign key index value of 0

Reference: Clause 2.1.5.1.2 Req 26:
Test Type: Capability

Test Case ID: /opt/features/geometry_columns/data/data_values_z
Test Purpose: Verify that the gpkg_geometry_columns table z column values are valid.
Test Method:

1) SELECT z FROM gpkg_geometry_columns
2) Not testable if returns an empty result set
3) SELECT z FROM gpkg_geometry_columns WHERE z NOT IN (0,1,2)
4) Fail if does not return an empty result set
5) Pass otherwise.

Reference: Clause 2.1.5.1.2 Req 27:
Test Type: Capability

Test Case ID: /opt/features/geometry_columns/data/data_values_m
Test Purpose: Verify that the gpkg_geometry_columns table m column values are valid.
Test Method:

1) SELECT m FROM gpkg_geometry_columns

2) Not testable if returns an empty result set
3) SELECT m FROM gpkg_geometry_columns WHERE m NOT IN (0,1,2)
4) Fail if does not return an empty result set
5) Pass otherwise.

Reference: Clause 2.1.5.1.2 Req 28:
Test Type: Capability

A.2.1.6 Vector Features User Data Tables

A.2.1.6.1 Data

A.2.1.6.1.1 Table Definition

Test Case ID: /opt/features/vector_features/data/feature_table_integer_primary_key
Test Purpose: Verify that every vector features user data table has an integer primary key.
Test Method:

1) SELECT table_name FROM gpkg_contents WERE data_type = 'features'
2) Not testable if returns an empty result set
3) For each row from step 1
    a. PRAGMA table_info(table_name)
    b. Fail if returns an empty result set
    c. Fail if result set does not contain one row where the pk column value is 1 and the not null column value is 1 and the type column value is "INTEGER"
4) Pass if no fails.

Reference: Clause 2.1.6.1.1 Req 29:
Test Type: Basic

Test Case ID: /opt/features/vector_features/data/feature_table_one_geometry_column
Test Purpose: Verify that every vector features user data table has one geometry column.

Test Method:

1) SELECT table_name FROM gpkg_contents WERE data_type = 'features'
2) Not testable if returns an empty result set
3) For each row table name from step 1
    a. SELECT column_name from gpkg_geometry_columns where table_name = row table name
    b. Fail if returns more than one column name
4) Pass if no fails

Reference: Clause 2.1.6.1.1 Req 30:
Test Type: Capability

Test Case ID: /opt/features/vector_features/data/feature_table_geometry_column_type

Test Purpose: Verify that the declared SQL type of a feature table geometry column is the uppercase geometry type name from Annex E specified by the geometry_type_name column for that column_name and table_name in the gpkg_geometry_columns table.

Test Method:

1. SELECT table_name, column_name, geometry_type_name table_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type = 'features')
2. For each row selected in (1):
    a. Fail if selected geometry_type_name value is not a value from the NAME column in Annex E Table 42 or Table 43.
    b. SELECT sql FROM sqlite_master WHERE type = 'table' AND name = '{selected table_name}'
    c. Pass if declared type of column_name selected in (1) is the geometry_type_name selected in (1)
    d. Fail otherwise

Reference: Clause 2.1.6.1.1 Req 30:
Test Type: Capability

A.2.1.6.1.2 Table Data Values

Test Case ID: /opt/features/vector_features/data/data_values_geometry_type
Test Purpose: Verify that the geometry type of feature geometries are of the type or are assignable for the geometry type specified by the gpkg_geometry columns table geometry_type_name column value.
Test Method:

1) SELECT table_name AS tn, column_name AS cn, geometry_type_name AS gt_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type = 'features')
2) Not testable if returns an empty result set
3) For each row from step 1
    a. SELECT DISTINCT ST_GeometryType(cn) FROM tn
    b. For each row actual_type_name from step a
        i. SELECT GPKG_IsAssignable(geometry_type_name, actual_type_name)
        ii. Fail if any returned 0
4) Pass if no fails

Reference: Clause 2.1.6.1.2 Req 31:
Test Type: Capability

Test Case ID: /opt/features/vector_features/data/data_value_geometry_srs_id
Test Purpose: Verify the the srs_id of feature geometries are the srs_id specified for the gpkg_geometry_columns table srs_id column value.
Test Method:

1) SELECT table_name AS tn, column_name AS cn, srs_id AS gc_srs_id FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents where data_type = ‘features’)
2) Not testable if returns an empty result set
3) For each row from step 1
   a. SELECT DISTINCT st_srid(cn) FROM tn
   b. For each row from step a
      i. Fail if returnvalue not equal to gc_srs_id
4) Pass if no fails

Reference: Clause 2.1.6.1.2 Req 32:
Test Type: Capability

A.2.2 Tiles

A.2.2.1 Contents

A.2.2.1.1 Data

A.2.2.1.1.1 Contents Table –Tiles Row

Test Case ID: /opt/tiles/contents/data/tiles_row
Test Purpose: Verify that the gpkg_contents table_name value table exists and is apparently a tiles table for every row with a data_type column value of “tiles”.
Test Method:

1) SELECT table_name FROM gpkg_contents WHERE data_type = “tiles”
2) Not testable if returns empty result set
3) For each row from step 1
   a) PRAGMA table_info(table_name)
   b) Fail if returns an empty result set
   c) Fail if result set does not contain one row where the pk column value is 1 and the not null column value is 1 and the type column value is “INTEGER”and the name column value is “id”
   d) Fail if result set does not contain four other rows where the name column values are “zoom_level”,”tile_column”,”tile_row”, and “tile_data”.
4) Pass if no fails.

Reference: Clause 2.2.2.1.1 Req 33:
Test Type: Capability

A.2.2.2 Zoom Levels

A.2.2.2.1 Data

A.2.2.2.1.1 Zoom Times Two

Test Case ID: /opt/tiles/zoom_levels/data/zoom_times_two
Test Purpose: Verify that by default zoom level pixel sizes for tile matrix user data tables vary by factors of 2 between adjacent zoom levels in the tile matrix metadata table.
Test Method:

1) SELECT CASE
   WHEN (SELECT tbl_name FROM sqlite_master WHERE tbl_name = 'gpkg_extensions') = 'gpkg_extensions' THEN
   (SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles' AND table_name NOT IN
   (SELECT table_name from gpkg_extensions WHERE extension_name = 'gpkg_zoom_other'))
   ELSE (SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles')
   END;
2) Not testable if returns empty result set
3) For each row table_name from step 1
   a. SELECT zoom_level, pixel_x_size, pixel_y_size FROM gpkg_tile_matrix WHERE table_name = selected table name ORDER BY zoom_level ASC
   b. Not testable if returns empty result set, or only one row
   c. Not testable if there are not two rows with adjacent zoom levels
   d. Fail if any pair of rows for adjacent zoom levels have pixel_x_size or pixel_y_size values that differ by other than factors of two
4) Pass if no fails

Reference: Clause 2.2.3.1.1 Req 34:
Test Type: Capability

A.2.2.3 Tile Encoding PNG

A.2.2.3.1 Data

A.2.2.3.1.1 MIME Type PNG

Test Case ID: /opt/tiles/tiles_encoding/data/mime_type_png
Test Purpose: Verify that a tile matrix user data table that contains tile data that is not MIME type image/jpeg by default contains tile data in MIME type image/png.
Test Method:

1) SELECT CASE
   WHEN (SELECT tbl_name FROM sqlite_master WHERE tbl_name = 'gpkg_extensions') = 'gpkg_extensions' THEN
   (SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles' AND table_name NOT IN
   (SELECT table_name from gpkg_extensions WHERE extension_name = ‘gpkg_webp’))
   ELSE (SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles')
   END;
2) Not testable if returns empty result set
3) For each row tbl_name from step 1
   a. SELECT tile_data FROM tbl_name
   b. For each row tile_data from step a
      i. Pass if tile data in MIME type image/png
4) Fail if no passes

Reference: Clause 2.2.4.1.1 Req 35:
Test Type: Capability

A.2.2.4 Tile Encoding JPEG

A.2.2.4.1 Data

A.2.2.4.1.1 MIME Type JPEG

Test Case ID: /opt/tiles/tiles_encoding/data/mime_type_jpeg
Test Purpose: Verify that a tile matrix user data table that contains tile data that is not MIME type image/png by default contains tile data in MIME type image/jpeg.
Test Method:

1) SELECT CASE
   WHEN (SELECT tbl_name FROM sqlite_master WHERE tbl_name = 'gpkg_extensions') = 'gpkg_extensions' THEN
   (SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles' AND table_name NOT IN
   (SELECT table_name from gpkg_extensions WHERE extension_name= ‘gpkg_webp’))
   ELSE (SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles')
   END;
2) Not testable if returns empty result set
3) For each row tbl_name from step 1
   a. SELECT tile_data FROM tbl_name
   b. For each row tile_data from step a
      i. Pass if tile data in MIME type image/jpeg
4) Fail if no passes

Reference: Clause 2.2.5.1.1 Req 36:
Test Type: Capability

A.2.2.5 Tile Matrix Set

A.2.2.5.1 Data

A.2.2.5.1.1 Table Definition

Test Case ID: /opt/tiles/gpkg_tile_matrix_set /data/table_def
Test Purpose: Verify that the gpkg_tile_matrix_set table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_tile_matrix_set'
2) Fail if returns an empty result set.
3) Pass if the column names and column definitions in the returned CREATE TABLE statement in the sql column value,, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents of

C.5Annex C Table 26. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.

4) Fail otherwise.

Reference: Clause 2.2.6.1.1 Req 37:
Test Type: Capability

A.2.2.5.1.2 Table Data Values

Test Case ID: /opt/tiles/gpkg_tile_matrix_set/data/data_values_table_name
Test Purpose: Verify that values of the gpkg_tile_matrix_set table_name column reference values in the gpkg_contents table_name column for rows with a data type of "tiles".
Test Method:

1) SELECT table_name FROM gpkg_tile_matrix_set
2) Not testable if returns an empty result set
3) SELECT table_name FROM gpkg_tile_matrix_set tms WHERE table_name NOT IN (SELECT table_name FROM gpkg_contents gc WHERE tms.table_name = gc.table_name AND gc.data_type != 'tiles')
4) Fail if result set contains any rows
5) Pass otherwise

Reference: Clause 2.2.6.1.2 Req 38:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix_set/data/data_values_row_record
Test Purpose: Verify that the gpkg_tile_matrix_set table contains a row record for each tile pyramid user data table .
Test Method:

1) SELECT table_name AS <user_data_tiles_table> from gpkg_contents where data_type = 'tiles'
2) Not testable if returns an empty result set
3) For each row from step 1
   a. SELECT sql FROM sqlite_master WHERE type='table' AND tbl_name = '<user_data_tiles_table>'
   b. Fail if returns an empty result set
4) Pass if no fails

Reference: Clause 2.2.6.1.2 Req 39:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix_set/data/data_values_srs_id
Test Purpose: Verify that the gpkg_tile_matrix_set table srs_id column values reference gpkg_spatial_ref_sys srs_id column values.
Test Method:

1) PRAGMA foreign_key_check('gpkg_geometry_columns')

2) Fail if returns any rows with a fourth column foreign key index value of 1 (gpkg_spatial_ref_sys)

Reference: Clause 2.2.6.1.2 Req 40:
Test Type: Capability

A.2.2.6 Tile Matrix

A.2.2.6.1 Data

A.2.2.6.1.1 Table Definition

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/table_def
Test Purpose: Verify that the gpkg_tile_matrix table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_tile_matrix'
2) Fail if returns an empty result set.
3) Pass if the column names and column definitions in the returned CREATE TABLE statement in the sql column value,~~,~~ including data type, nullability, default values~~, and~~ primary~~,~~ and foreign ~~and unique~~ key constraints match all of those in the contents of Annex C Table 23. ~~Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.~~
4) Fail otherwise.

Reference: Clause 2.2.7.1.1 Req 41:
Test Type: Basic

A.2.2.6.1.2 Table Data Values

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_table_name
Test Purpose: Verify that values of the gpkg_tile_matrix table_name column reference values in the gpkg_contents table_name column for rows with a data type of “tiles”.
Test Method:

1) SELECT table_name FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT table_name FROM gpkg_tile_matrix tmm WHERE table_name NOT IN (SELECT table_name FROM gpkg_contents gc WHERE tmm.table_name = gc.table_name AND gc.data_type != ‘tiles’)
4) Fail if result set contains any rows
5) Pass otherwise

Reference: Clause 2.2.7.1.2 Req 42:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_zoom_level_rows
Test Purpose: Verify that the gpkg_tile_matrix table contains a row record for each zoom level that contains one or more tiles in each tile pyramid user data table.

Test Method:

1) SELECT table_name AS <user_data_tiles_table> from gpkg_contents where data_type = ‘tiles’
2) Not testable if returns an empty result set
3) For each row from step 1
   a. SELECT DISTINCT gtmm.zoom_level AS gtmm_zoom, udt.zoom_level AS udtt_zoom FROM gpkg_tile_matrix AS gtmm
      LEFT OUTER JOIN <user_data_tiles_table> AS udtt ON udtt.zoom_level = gtmm.zoom_level AND gtmm.t_table_name = '<user_data_tiles_table>'
   b. Fail if any gtmm_zoom column value in the result set is NULL
4) Pass if no fails

Reference: Clause 2.2.7.1.2 Req 43:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_zoom_level
Test Purpose: Verify that zoom level column values in the gpkg_tile_matrix table are not negative.
Test Method:

1) SELECT zoom_level FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT min(zoom_level) FROM gpkg_tile_matrix_metadata.
4) Fail if less than 0.
5) Pass otherwise.

Reference: Clause 2.2.7.1.2 Req 44:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_matrix_width
Test Purpose: Verify that the matrix_width values in the gpkg_tile_matrix table are valid.
Test Method:

1) SELECT matrix_width FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT min(matrix_width) FROM gpkg_tile_matrix.
4) Fail if less than 1.
5) Pass otherwise.

Reference: Clause 2.2.7.1.2 Req 45:
Test Type: Capabilty

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_matrix_height
Test Purpose: Verify that the matrix_height values in the gpkg_tile_matrix table are valid.
Test Method:

1) SELECT matrix_height FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT min(matrix_height) FROM gpkg_tile_matrix.
4) Fail if less than 1.
5) Pass otherwise.

Reference: Clause 2.2.7.1.2 Req 46:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_tile_width
Test Purpose: Verify that the tile_width values in the gpkg_tile_matrix table are valid.
Test Method:

1) SELECT tile_width FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT min(tile_width) FROM gpkg_tile_matrix.
4) Fail if less than 1.
5) Pass otherwise.

Reference: Clause 2.2.7.1.2 Req 47:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_tile_height
Test Purpose: Verify that the tile_height values in the gpkg_tile_matrix table are valid.
Test Method:

1) SELECT tile_height FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT min(tile_height) FROM gpkg_tile_matrix.
4) Fail if less than 1.
5) Pass otherwise.

Reference: Clause 2.2.7.1.2 Req 48:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_pixel_x_size
Test Purpose: Verify that the pixel_x_size values in the gpkg_tile_matrix table are valid.
Test Method:

1) SELECT pixel_x_size FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT min(pixel_x_size) FROM gpkg_tile_matrix.
4) Fail if less than 0.
5) Pass otherwise.

Reference: Clause 2.2.7.1.2 Req 49:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_pixel_y_size
Test Purpose: Verify that the pixel_y_size values in the gpkg_tile_matrix table are valid.
Test Method:

1) SELECT pixel_y_size FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) SELECT min(pixel_y_size) FROM gpkg_tile_matrix.
4) Fail if less than 0.
5) Pass otherwise.

Reference: Clause 2.2.7.1.2 Req 50:
Test Type: Capability

Test Case ID: /opt/tiles/gpkg_tile_matrix/data/data_values_pixel_size_sort
Test Purpose: Verify that the pixel_x_size and pixel_y_size column values for zoom level column values in a gpkg_tile_matrix table sorted in ascending order are sorted in descending order, showing that lower zoom levels are zoomed "out".
Test Method:

1) SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles'
2) Not testable if returns empty result set
3) For each row table_name from step 1
   a. SELECT zoom_level, pixel_x_size, pixel_y_size from gpkg_tile_matrix WHERE table_name = row table name ORDER BY zoom_level ASC
   b. Not testable if returns empty result set
   c. Fail if pixel_x_sizes are not sorted in descending order
   d. Fail if pixel_y_sizes are not sorted in descending order
4) Pass if testable and no fails

Reference: Clause 2.2.7.1.2 Req 51:
Test Type: Capability

A.2.2.7 Tile Pyramid User Data

A.2.2.7.1 Data

A.2.2.7.1.1 Table Definition

Test Case ID: /opt/tiles/tile_pyramid/data/table_def
Test Purpose: Verify that multiple tile pyramids are stored in different tiles tables with unique names containing the required columns.
Test Method:

1) SELECT COUNT(table_name) FROM gpkg_contents WERE data_type = "tiles"
2) ~~Fail if less than 2~~Not testable if less than 1
3) SELECT table_name FROM gpkg_contents WHERE data_type = "tiles"
4) For each row from step 3

a. PRAGMA table_info(table_name)
b. Fail if returns an empty result set
c. Fail if result set does not contain one row where the pk column value is 1 and the not null column value is 1 and the type column value is “INTEGER”and the name column value is “id”
d. Fail if result set does not contain four other rows where the name column values are “zoom_level”,”tile_column”,”tile_row”, and “tile_data”.

5) Pass if no fails

Reference: Clause 2.2.8.1.1 Req 52:
Test Type: Basic

A.2.2.7.1.2 Table Data Values

Test Case ID: /opt/tiles/tile_pyramid/data/data_values_zoom_levels
Test Purpose: Verify that the zoom level column values in each tile pyramid user data table are within the range of zoom levels defined by rows in the gpkg_tile_matrix table.
Test Method:

1) SELECT DISTINCT table_name AS <user_data_tiles_table> FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) For each row <user_data_tiles_table> from step 1
    a. SELECT zoom_level FROM <user_data_tiles_table>
    b. If result set not empty
        i. SELECT MIN(gtmm.zoom_level) AS min_gtmm_zoom, MAX(gtmm.zoom_level) AS max_gtmm_zoom FROM gpkg_tile_matrix WHERE table_name = <user_data_tiles_table>
        ii. SELECT id FROM <user_data_tiles_table> WHERE zoom_level < min_gtmm_zoom
        iii. Fail if result set not empty
        iv. SELECT id FROM <user_data_tiles_table> WHERE zoom_level > max_gtmm_zoom
        v. Fail if result set not empty
        vi. Log pass otherwise
4) Pass if logged pas and no fails

Reference: Clause 2.2.8.1.2 Req 53:
Test Type: Capability

Test Case ID: /opt/tiles/tile_pyramid/data/data_values_tile_column
Test Purpose: Verify that the tile_column column values for each zoom level value in each tile pyramid user data table are within the range of columns defined by rows in the gpkg_tile_matrix table.
Test Method:

1) SELECT DISTINCT table_name AS <user_data_tiles_table> FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) For each row <user_data_tiles_table> from step 1
    a. SELECT DISTINCT gtmm.zoom_level AS gtmm_zoom, gtmm.matrix_width AS gtmm_width, udt.zoom_level AS udt_zoom, udt.tile_column AS udt_column FROM gpkg_tile_matrix AS gtmm LEFT OUTER JOIN <user_data_tiles_table> AS udt ON udt.zoom_level = gtmm.zoom_level AND gtmm.t_table_name = '<user_data_tiles_table>' AND (udt_column < 0 OR udt_column > (gtmm_width - 1))
    b. Fail if any udt_column value in the result set is not NULL
    c. Log pass otherwise
4) Pass if logged pass and no fails

Reference: Clause 2.2.8.1.2 Req 54:
Test Type: Capability

Test Case ID: /opt/tiles/tile_pyramid/data/data_values_tile_row
Test Purpose: Verify that the tile_row column values for each zoom level value in each tile pyramid user data table are within the range of rows defined by rows in the gpkg_tile_matrix table.
Test Method:

1) SELECT DISTINCT table_name AS <user_data_tiles_table> FROM gpkg_tile_matrix
2) Not testable if returns an empty result set
3) For each row <user_data_tiles_table> from step 1
    a. SELECT DISTINCT gtmm.zoom_level AS gtmm_zoom, gtmm.matrix_height AS gtmm_height, udt.zoom_level AS udt_zoom, udt.tile_row AS udt_row FROM gpkg_tile_matrix AS gtmm LEFT OUTER JOIN <user_data_tiles_table> AS udt ON udt.zoom_level = gtmm.zoom_level AND gtmm.t_table_name = ‘<user_data_tiles_table> ' AND (udt_row < 0 OR udt_row > (gtmm_height - 1))
    b. Fail if any udt_row value in the result set is not NULL
    c. Log pass otherwise
4) Pass if logged pass and no fails

Reference: Clause 2.2.8.1.2 Req 55:
Test Type: Capability

A.2.3 Schema

A.2.3.1 Data Columns

A.2.3.1.1 Data

A.2.3.1.1.1 Table Definition

Test Case ID: /opt/schema/data_columns/data/table_def

Test Purpose: Verify that the gpkg_data_columns table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_data_columns'
2) Fail if returns an empty result set
3) Pass if column names and column definitions in the returned CREATE TABLE statement in the sql column value, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents of C.8 Table 31. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.
4) Fail otherwise.

Reference: Clause 2.3.2.1.1 Req 56:
Test Type: Basic

A.2.3.1.1.2 Data Values

Test Case ID: /opt/schema/data_columns/data/data_values_column_name
Test Purpose: Verify that for each gpkg_data_columns row, the column_name value is the name of a column in the table_name table.
Test Method:

1) SELECT table_name, column_name FROM gpkg_data_columns
2) Not testable if returns an empty result set
3) For each row from step 1
   a. PRAGMA table_info(table_name)
   b. Fail if gpkg_data_columns.column_name value does not equal a name column value returned by PRAGMA table_info.
4) Pass if no fails.

Reference: Clause 2.3.2.1.2 Req 58:
Test Type: Capability

Test Case ID: /opt/schema/data_columns/data/data_values_constraint_name
Test Purpose: Verify that for each gpkg_data_columns row, the constraint_name value is either NULL or a constraint_name column value from the gpkg_data_column_constraints table.
Test Method:

1) SELECT constraint_name AS cn FROM gpkg_data_columns
2) Not testable if returns an empty result set
3) For each NOT NULL cn value from step 1
   a. SELECT constraint_name FROM gpkg_data_column_constraints WHERE constraint_name = cn
   b. Fail if returns an empty result set
4) Pass if no fails

Reference: Clause 2.3.2.1.2 Req 59:
Test Type: Capability

Test Case ID: /opt/schema/data_columns/data/data_values_constraint_type
Test Purpose: Verify that for each gpkg_data_columns row, if the constraint_name value is NOT NULL then the constraint_type column value contains a constraint_type column value from the gpkg_data_column_constraints table for a row with a matching constraint_name value.
Test Method:

1) SELECT constraint_name AS cn, constraint_type AS ct FROM gpkg_data_columns
2) Not testable if returns an empty result set
3) For each NOT NULL cn value from step 1
    a. Fail if ct is NULL
    b. If ct NOT NULL, SELECT constraint_type FROM gpkg_data_column_constraints WHERE constraint_name = cn AND constraint_type = ct
    c. Fail if returns an empty result set
4) Pass if no fails

Reference: Clause 2.3.2.1.2 Req 59:
Test Type: Capability

A.2.3.2 Data Column Constraints

A.2.3.2.1 Data

A.2.3.2.1.1 Table Definition

Test Case ID: /opt/schema/data_column_constraints/data/table_def
Test Purpose: Verify that the gpkg_data_column_constraints table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_data_column_constraints'
2) Fail if returns an empty result set
3) Pass if column names and column definitions in the returned CREATE TABLE statement in the sql column value, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents of Annex C Table 32. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.
4) Fail otherwise.

Reference: Clause 2.3.3.1.1 Req 60:
Test Type: Basic

A.2.3.2.1.2 Data Values

Test Case ID: /opt/schema/data_column_constraints/data/data_values_constraint_type

Test Purpose: Verify that the gpkg_data_column_constraints constraint_type column values are one of "range", "enum", or "glob".
Test Method:

1) SELECT constraint_type AS ct FROM gpkg_data column_constraints
2) Not testable if returns an empty result set
3) For each ct value returned by step 1
   a. Fail if ct NOT IN ("range", "enum", "glob").
4) Pass if no fails.

Reference: Clause 2.3.3.1.2 Req 61:
Test Type: Capability

Test Case ID:
/opt/schema/data_column_constraints/data/data_values_constraint_names_unique
Test Purpose: Verify that the gpkg_data_column_constraints constraint_name column values for constraint_type values of "range", or "glob" are unique.
Test Method:

1) For each SELECT DISTINCT constraint_name AS cn FROM gpkg_data_column_constraints WHERE constraint_type IN (‘range’, ‘glob’)
   a. SELECT count(*) FROM gpkg_data column_constraints WHERE constraint_name = cn
   b. Fail if count > 1
2) Pass if no fails.

Reference: Clause 2.3.3.1.2 Req 62:
Test Type: Capability

Test Case ID: /opt/schema/data_column_constraints/data/data_values_value_for_range
Test Purpose: Verify that the gpkg_data_column_constraints value column values are NULL for rows with a constraint_type value of "range".
Test Method:

1) SELECT constraint_type AS ct, value AS v FROM gpkg_data column_constraints WHERE constraint_type = ‘range’
2) Not testable if returns an empty result set
3) For each v value returned by step 1
   a. Fail if v IS NOT NULL
4) Pass if no fails.

Reference: Clause 2.3.3.1.2 Req 63:
Test Type: Capability

Test Case ID: /opt/schema/data_column_constraints/data/data_values_min_max_for_range
Test Purpose: Verify that the gpkg_data_column_constraints min column values are NOT NULL and less than the max column values for rows with a constraint_type value of "range".
Test Method:

1) SELECT min, max FROM gpkg_data column_constraints WHERE constraint_type = ‘range’
2) Not testable if returns an empty result set
3) For each set of min and max values returned by step 1
   a. Fail if min IS NULL
   b. Fail if max IS NULL
   c. Fail if min >= max
4) Pass if no fails.

Reference: Clause 2.3.3.1.2 Req 64:
Test Type: Capability

Test Case ID: /opt/schema/data_column_constraints/data/data_values_inclusive_for_range
Test Purpose: Verify that the gpkg_data_column_constraints minIsInclusive and maxIsInclusive column values are NOT NULL and either 0 or 1 for rows with a constraint_type value of "range".
Test Method:

1) SELECT minIsInclusive, maxIsInclusive FROM gpkg_data column_constraints WHERE constraint_type = ‘range’
2) Not testable if returns an empty result set
3) For each set of values returned by step 1
   a. Fail if minIsInclusive IS NULL
   b. Fail if maxIsInclusive IS NULL
   c. Fail if minIsInclusive is NOT IN (0,1)
   d. Fail if maxIsInclusive is NOT IN (0,1)
4) Pass if no fails.

Reference: Clause 2.3.3.1.2 Req 65:
Test Type: Capability

Test Case ID:
/opt/schema/data_column_constraints/data/data_values_min_max_inclusive_for_enum_glob
Test Purpose: Verify that the gpkg_data_column_constraints min, max, minIsInclusive and maxIsInclusive column values are NULL for rows with a constraint_type value of "enum" or “glob”.
Test Method:

1) SELECT min, max, minIsInclusive, maxIsInclusive FROM gpkg_data column_constraints WHERE constraint_type IN (‘enum’,’glob)
2) Not testable if returns an empty result set
3) For each set of values returned by step 1
   a. Fail if min IS NOT NULL
   b. Fail if max IS NOT NULL
   c. Fail if minIsInclusive IS NOT NULL
   d. Fail if maxIsInclusive IS NOT NULL
4) Pass if no fails.

Reference: Clause 2.3.3.1.2 Req 66:
Test Type: Capability

Test Case ID: /opt/schema/data_column_constraints/data/data_values_value_for_enum_glob
Test Purpose: Verify that the gpkg_data_column_constraints value column values are NOT NULL for rows with a constraint_type value of "enum" or “glob”.
Test Method:

1) SELECT value FROM gpkg_data column_constraints WHERE constraint_type IN (‘enum’,’glob)
2) Not testable if returns an empty result set
3) For each value returned by step 1
   a. Fail if value IS NULL
4) Pass if no fails.

Reference: Clause 2.3.3.1.2 Req 67:
Test Type: Capability

A.2.4 Metadata

A.2.4.1 Metadata Table

A.2.4.1.1 Data

A.2.4.1.1.1 Table Definition

Test Case ID: /opt/metadata/metadata/data/table_def
Test Purpose: Verify that the gpkg_metadata table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_metadata'
2) Fail if returns an empty result set.
3) Pass if the column names and column definitions in the returned Create TABLE statement in the sql column value, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents of Table 33. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.
4) Fail otherwise.

Reference: Clause 2.4.2.1.1 Req 68:
Test Type: Basic

A.2.4.1.1.2 Table Data Values

Test Case ID: /opt/metadata/metadata/data/data_values_md_scope
Test Purpose: Verify that each of the md_scope column values in a gpkg_metadata table is one of the name column values from Table 15 in clause 2.4.2.1.2.
Test Method:

1) SELECT md_scope FROM gpkg_metadata

2) Not testable if returns an empty result set
3) For each row returned from step 1
   a. Fail if md_scope value not one of the name column values from Table 15 in clause 2.4.2.1.2
4) Pass if no fails

Reference: Clause 2.4.2.1.2 Req 69:
Test Type: Capabilities

A.2.4.2 Metadata Reference Table

A.2.4.2.1 Data

A.2.4.2.1.1 Table Definition

Test Case ID: /opt/metadata/metadata_reference/data/table_def
Test Purpose: Verify that the gpkg_metadata_reference table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_metadata_reference'
2) Fail if returns an empty result set.
3) Pass if the column names and column definitions in the returned Create TABLE statement in the sql column value, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents of Table 34. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.
4) Fail otherwise.

Reference: Clause 2.4.3.1.1 Req 70:
Test Type: Basic

A.2.4.2.1.2 Data Values

Test Case ID: /opt/metadata/metadata_reference/data/data_values_reference_scope
Test Purpose: Verify that gpkg_metadata_reference table reference_scope column values are valid.
Test Method:

1) SELECT reference_scope FROM gpkg_metadata_reference
2) Not testable if returns an empty result set
3) SELECT reference_scope FROM gpkg_metadata_reference WHERE reference_scope NOT IN (‘geopackage’,’table’,’column’,’row’,’row/col’)
4) Fail if does not return an empty result set
5) Pass otherwise.

Reference: Clause 2.4.3.1.2 Req 71:
Test Type: Capability

Test Case ID: /opt/metadata/metadata_reference/data/data_values_table_name
Test Purpose: Verify that gpkg_metadata_reference table_name column values are NULL for rows with reference_scope values of ‘geopackage’, and reference gpkg_contents table_name values for all other reference_scope values.
Test Method:

1) SELECT table_name FROM gpkg_metadata_reference
2) Not testable if returns an empty result set
3) SELECT table_name FROM gpkg_metadata_reference WHERE reference_scope = 'geopackage'
4) Fail if result set contains any non-NULL values
5) SELECT table_name FROM metadata_reference WHERE reference_scope != 'geopackage' AND table_name NOT IN (SELECT table_name FROM gpkg_contents)
6) Fail if result set is not empty
7) Pass otherwise.

Reference: Clause 2.4.3.1.2 Req 72:
Test Type: Capability

Test Case ID: /opt/metadata/metadata_reference/data/data_values_column_name
Test Purpose: Verify that gpkg_metadata_reference column_name column values are NULL for rows with reference scope values of ‘geopackage’, ‘table’, or ‘row’, and contain the name of a column in table_name table for other reference scope values.
Test Method:

1) SELECT column_name FROM gpkg_metadata_reference
2) Not testable if returns an empty result set
3) SELECT column_name FROM gpkg_metadata_reference WHERE reference_scope IN ('geopackage', ‘table’, ‘row’)
4) Fail if result set contains any non-NULL values
5) SELECT <table_name>, <column_name> FROM metadata_reference WHERE reference_scope NOT IN ('geopackage', ‘table’, ‘row’)
6) For each row from step 5
   a. SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = '<table_name>'
   b. Fail if returns an empty result set.
   c. Fail if the one of the column names in the returned sql Create TABLE statement is not <column_name>
   d. Log pass otherwise
7) Pass if logged pass and no fails.

Reference: Clause 2.4.3.1.2 Req 73:
Test Type: Capability

Test Case ID: /opt/metadata/metadata_reference/data/data_values_row_id_value

Test Purpose: Verify that gpkg_metadata_reference row_id_value column values are NULL for rows with reference scope values of ‘geopackage’, ‘table’, or ‘row’, and contain the ROWID of a row in the table_name for other reference scope values.
Test Method:

1) SELECT row_id_value FROM gpkg_metadata_reference
2) Not testable if returns an empty result set
3) SELECT row_id_value FROM gpkg_metadata_reference WHERE reference_scope IN ('geopackage', ‘table’, ‘row’)
4) Fail if result set contains any non-NULL values
5) For each SELECT <table_name>, <row_id_value> FROM gpkg_metadata_reference WHERE reference_scope NOT IN ('geopackage', ‘table’, ‘row’)
6) For each row from step 5
   a. SELECT * FROM <table_name> WHERE ROWID = <row_id_value>
   b. Fail if result set is empty
   c. Log pass otherwise
7) Pass if logged pass and no fails.

Reference: Clause 2.4.3.1.2 Req 74:
Test Type: Capability

Test Case ID: /opt/metadata/metadata_reference/data/data_values_timestamp
Test Purpose: Verify that every gpkg_metadata_reference table row timestamp column value is in ISO 8601 UTC format.
Test Method:

1) SELECT timestamp from gpkg_metadata_reference.
2) Not testable if returns an empty result set
3) For each row from step 1
   a. Fail if format of returned value does not match yyyy-mm-ddThh:mm:ss.hhhZ
   b. Log pass otherwise
4) Pass if logged pass and no fails.

Reference: Clause 2.4.3.1.2 Req 75:
Test Type: Capability

Test Case ID: /opt/metadata/metadata_reference/data/data_values_md_file_id
Test Purpose: Verify that every gpkg_metadata_reference table row md_file_id column value references a gpkg_metadata id column value.
Test Method:

1) PRAGMA foreign_key_check(‘geometry_columns’)
2) Fail if returns any rows with a fourth column foreign key index value of 0

Reference: Clause 2.4.3.1.2 Req 76:
Test Type: Capability

Test Case ID: /opt/metadata/metadata_reference/data/data_values_md_parent_id
Test Purpose: Verify that every gpkg_metadata_reference table row md_parent_id column value that is not null is an id column value from the gpkg_metadata_table that is not equal to the md_file_id column value for that row.
Test Method:

1) SELECT md_file_id FROM gpkg_metadata_reference
2) Not testable if returns an empty result set
3) SELECT gmr.md_file_id, gmr.md_parent_id
   FROM gpkg_metadata_reference AS gmr
   WHERE gmr.md_file_id == gmr.md_parent_id
4) Fail if result set is not empty
5) SELECT gmr.md_file_id, gmr.md_parent_id, gm.id
   FROM gpkg_metadata_reference AS gmr
   LEFT OUTER JOIN gpkg_metadata gm ON gmr.md_parent_id =gm.id
6) Fail if any result set gm.id values are NULL
7) Pass otherwise

Reference: Clause 2.4.3.1.2 Req 77:
Test Type: Capability

A.2.5 Extension Mechanism

A.2.5.1 Extensions

A.2.5.1.1 Data

A.2.5.1.1.1 Table Definition

Test Case ID: /opt/extension_mechanism/extensions/data/table_def
Test Purpose: Verify that a gpkg_extensions table exists and has the correct definition.
Test Method:

1) SELECT sql FROM sqlite_master WHERE type = 'table' AND tbl_name = 'gpkg_extensions'
2) Fail if returns an empty result set.
3) Pass if the column names and column definitions in the returned Create TABLE statement in the sql column value, including data type, nullability, default values and primary, foreign and unique key constraints match all of those in the contents ofTable 36. Column order, check constraint and trigger definitions, and other column definitions in the returned sql are irrelevant.
4) Fail otherwise.

Reference: Clause 2.5.2.1.1 Req 78:
Test Type: Basic

A.2.5.1.1.2 Table Data Values

Test Case ID: /opt/extension_metchanism/extensions/data/data_values_for_extensions
Test Purpose: Verify that every extension of a GeoPackage is registered in a row in the gpkg_extensions table

Test Method:

1) For each SELECT DISTINCT geometry_type_name FROM geometry_columns
   a. Fail if geometry_type_name IN Annex E Table 43 and gpkg_extensions does not contain a row where extension_name = gpkg_geom_<geometry_type_name>
   b. Fail if geometry_type_name NOT IN Annex E Table 42 or Table 43 and gpkg_extensions does not contain a row where the extension_name does not begin with "gpkg" and the extension_name ends with "_geom_<geometry_type_name>
2) For each SELECT tbl_name FROM sqlite_master WHERE tbl_name LIKE 'rtree_%'
   a. Fail if gpkg_extensions does not contain a row where extension_name = "gpkg_rtree_index"
3) For each SELECT tbl_name FROM sqlite_master WHERE name LIKE 'fgti_%'
   a. Fail if gpkg_extensions does not contain a row where extension_name = "gpkg_geometry_type_trigger"
4) For each SELECT tbl_name FROM sqlite_master WHERE name LIKE 'fgsi_%'
   a. Fail if gpkg_extensions does not contain a row where extension_name = "gpkg_srs_id_trigger"
5) Do test / reg_ext/tiles/zoom_levels/data/zoom_other_ext_row
6) Do test /reg_ext/tiles/tile_encoding_webp/data/webp_ext_row
7) Pass if no fails

Reference: Clause 2.5.2.1.2 Req 79:
Test Type: Capability

Test Case ID: /opt/extension_metchanism/extensions/data/data_values_table_name
Test Purpose: Verify that the table_name column values in the gpkg_extensions table are valid.
Test Method:

1) SELECT table_name, column_name FROM gpkg_extensions
2) Not testable if returns an empty result set
3) For each row from step one
   a. Fail if table_name value is NULL and column_name value is not NULL.
   b. SELECT DISTINCT ge.table_name AS ge_table, sm.tbl_name FROM gpkg_extensions AS ge LEFT OUTER JOIN sqlite_master AS sm ON ge.table_name = sm.tbl_name
   c. Log pass if every row ge.table_name = sm.tbl_name (MAY both be NULL).
4) Pass if logged pass and no fails.

Reference: Clause 2.5.2.1.2 Req 80:
Test Type: Capability

Test Case ID: /opt/extension_metchanism/extensions/data/data_values_column_name
Test Purpose: Verify that the column_name column values in the gpkg_extensions table are valid.
Test Method:

1) SELECT table_name, column_name FROM gpkg_extensions
2) Not testable if returns an empty result set
3) SELECT table_name, column_name FROM gpkg_extensions WHERE table_name IS NOT NULL AND column_name IS NOT NULL
4) Pass if returns an empty result set
5) For each row from step 3
   a. PRAGMA table_info(table_name)
   b. Fail if gpkg_extensions.column_name value does not equal a name column value returned by PRAGMA table_info.
   c. Log pass otherwise
6) Pass if logged pass and no fails.

Reference: Clause 2.5.2.1.2 Req 81:
Test Type: Capability

Test Case ID: /opt/extension_mechanism/extensions/data/data_values_extension_name
Test Purpose: Verify that the extension_name column values in the gpkg_extensions table are valid.
Test Method:

1) SELECT extension_name FROM gpkg_extensions
2) Not testable if returns an empty result set
3) For each row returned from step 1
   a. Log pass if extension_name is one of those listed in Annex J or Annex L through Annex P.
   b. Separate extension_name into <author> and <extension> at the first "_"
   c. Fail if <author> is "gpkg"
   d. Fail if <author> contains characters other than [a-zA-Z0-9]
   e. Fail if <extension> contains characters other than [a-zA-Z0-9_]
   f. Log pass otherwise
4) Pass if logged pass and no fails.

Reference: Clause 2.5.2.1.2 Req 82:
Test Type: Capability

Test Case ID: /opt/extension_mechanism/extensions/data/data_values_definition
Test Purpose: Verify that the definition column value contains or references extension documentation
Test Method:

1) SELECT definition FROM gpkg_extensions
2) Not testable if returns an empty result set
3) For each row returned from step 1
   a. Inspect if definition value is not like "Annex %", or "http%" or mailto:% or "Extension Title%"
   b. Fail if definition value does not contain or reference extension documentation

4) Pass if no fails

Reference: Clause 2.5.2.1.2 Req 83:
Test Type: Capability

Test Case ID: /opt/extension_mechanism/extensions/data/data_values_scope
Test Purpose: Verify that the scope column value is “read-write” or “write-only”
Test Method:

1) SELECT scope FROM gpkg_extensions
2) Not testable if returns an empty result set
3) For each row returned from step 1
   a. Fail is value is not “read-write” or “write-only”
4) Pass if no fails

Reference: Clause 2.5.2.1.2 Req 84:
Test Type: Capability

A.3 Registered Extensions

A.3.1 Features

A.3.1.1 Geometry Types

A.3.1.1.1 Data

A.3.1.1.1.1 GeoPackage Extension Types

Test Case ID:
/reg_ext/features/geometry_encoding/data/geopackage_extension_types/existing_sparse_data
Test Purpose: Verify that existing extended non-linear geometry types are stored in valid StandardGeoPackageBinary format encodings.
Test Method:

1) SELECT table_name FROM gpkg_geometry_columns
2) Not testable if returns an empty result set
3) SELECT table_name AS tn, column_name AS cn FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type = ‘features’),
4) Fail if returns an empty result set
5) For each row from step 3
   a. SELECT cn FROM tn;
   b. For each row from step a, log fail if GeoPackageBinary “X” type flag is 1
   c. For each row from step a, if bytes 2-5 of cn.wkb as uint32 in endianness of gc.wkb byte 1of cn from #1 are a geometry type value from Annex E Table 43, then
      i. Log cn.header values, wkb endianness and geometry type

ii. If cn.wkb is not correctly encoded per ISO 13249-3 clause 5.1.46 then log fail
iii. If cn.flags.E is 1 - 4 and some cn.wkbx is outside of cn.envelope.minx,maxx then log fail
iv. If cn.flags.E is 1 - 4 and some gc.wkby is outside of cn.envelope.miny,maxy then log fail
v. If cn.flags.E is 2,4 and some gc.wkb.z is outside of cnenvelope.minz,maxz then log fail
vi. If cn.flags.E is 3,4 and some gc.wkb.m is outside of cn.envelope.minm,maxm then log fail
vii. If cn.flags.E is 5-7 then log fail
viii. Otherwise log pass

6) Log pass if log contains pass and no fails

Reference: Clause 3.1.1.1.1 Req 85:
Test Type: Capability

Test Case ID:
/reg_ext/features/geometry_encoding/data/geopackage_extension_types/all_types_test_data
Test Purpose: Verify that all extended non-linear geometry types and options are stored in valid GeoPackageBinary format encodings.
Test Method:

1) Open GeoPackage that has feature geometry values of geometry type in Annex E, for an assortment of srs_ids, for an assortment of coordinate values, without and with z and / or m values, in both big and little endian encodings:
2) /reg_ext/features/geometry_encoding/data/extension_types_existing_sparse_data
3) Pass if log contains pass record for big and little endian GP headers containing big and little endian WKBs for 0-1 envelope contents indicator codes for every geometry type value from Annex E Table 43 without and with z and/or m values.
4) Fail otherwise

Reference: Clause 3.1.1.1.1 Req 85:
Test Type: Capability

A.3.1.1.1.2 GeoPackage Geometry Types -- Extensions Name

Test Case ID:
/reg_ext/features/geometry_encoding/data/geopackage_extension_types/extension_name
Test Purpose: Verify that an extension name in the form gpkg_geom_<gname> is defined for each <gname> extension geometry type from Annex E Table 43 used in a GeoPackage.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == ‘features'))

2) Not testable if result set is empty
3) For each row result set table_name, column_name from step 3
    a. SELECT result_set_column_name FROM result_set_table_name
    b. For each geometry column value from step a
        i. If the first two bytes of each geometry column value are "GP", then
            1. /opt/extension_mechanism/extensions/data/table_def
            2. Fail if failed
            3. SELECT ST_GeometryType(geometry column value) AS <gtype>;
            4. SELECT extension_name FROM gpkg_extensions WERE table_name = result_set_table_name AND column_name = result_set_column_name AND extension_name = 'gpkg_geom_' || <gtype>
                a. Fail if result set is empty
                b. Log pass otherwise
4) Pass if logged pass and no fails

Reference: Clause 3.1.1.1.2 Req 86:
Test Type: Basic

A.3.1.1.1.3 GeoPackage Geometry Types -- Extensions Row

Test Case ID:
/reg_ext/features/geometry_encoding/data/geopackage_extension_types/extension_row
Test Purpose: Verify that the gpkg_extensions table contains a row with an extension_name in the form gpkg_geom_<gname> for each table_name and column_name in the gpkg_geometry_columns table with a <gname> geometry_type_name.
Test Method:

/reg_ext/features/geometry_encoding/data/extension_name

Reference: Clause 3.1.1.1.3 Req 87:
Test Type: Capability

A.3.1.2 User-Defined Geometry Types

A.3.1.2.1 Data

A.3.1.2.1.1 Extensions Encoding

Test Case ID: /reg_ext/features/geometry_encoding/data/user_defined-geometry_types/existing_sparse_data
Test Purpose: Verify that existing extended geometry types not listed in Annex E are stored in valid ExtendedGeoPackageBinary format encodings.
Test Method:

1) SELECT table_name FROM gpkg_geometry_columns
2) Not testable if returns an empty result set

3) SELECT table_name AS tn, column_name AS cn FROM gpkg_geometry_columns WHERE geometry_type_name NOT IN (all geometry types listed in Annex E) AND table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type = ‘features’),
4) Fail if returns an empty result set
5) For each row from step 3
    a. SELECT cn FROM tn;
    b. For each row from step a,
        i. log fail if GeoPackageBinary “X” type flag is 0
        ii. Otherwise log pass
6) Log pass if log contains pass and no fails

Reference: Clause 3.1.1.1.1 Req 88:
Test Type: Capability

A.3.1.2.1.2 Extensions Name

Test Case ID:
/reg_ext/features/geometry_encoding/data/user_defined_geometry_types/extension_name
Test Purpose: Verify that an extension name in the form <author>_geom_<gname> is defined for each extended geometry type not listed in Annex E used in a GeoPackage.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == ‘features'))
2) Not testable if result set is empty
3) For each row result set table_name, column_name from step 3
    a. SELECT result_set_column_name FROM result_set_table_name
    b. For each geometry column value from step a
        i. If the first two bytes of each geometry column value are “GP”, then
            1. /opt/extension_mechanism/extensions/data/table_def
            2. Fail if failed
            3. SELECT ST_GeometryType(geometry column value) AS <gtype>;
            4. SELECT extension_name FROM gpkg_extensions WERE table_name = result_set_table_name AND column_name = result_set_column_name AND extension_name NOT LIKE ‘gpkg_%’ and extension_name LIKE '%_geom_’ || <gtype>
                a. Fail if result set is empty
                b. Log pass otherwise
4) Pass if logged pass and no fails

Reference: Clause 3.1.1.1.2 Req 89:
Test Type: Basic

A.3.1.2.1.3 Extensions Row

Test Case ID:
/reg_ext/features/geometry_encoding/data/user_defined_geometry_types/extension_row
Test Purpose: Verify that the gpkg_extensions table contains a row with an extension_name in the form <author>_geom_<gname> for each table_name and column_name in the gpkg_geometry_columns table with a <gname> geometry_type_name.
Test Method:
Do test /reg_ext/features/geometry_encoding/data/extension_encoding/extension_name
Reference: Clause 3.1.1.1.3 Req 90:
Test Type: Capability

A.3.1.2.1.4 Geometry Columns Row

Test Case ID:
/reg_ext/features/geometry_encoding/data/user_defined_geometry_types/geometry_columns_row
Test Purpose: Verify that the gpkg_geometry_columns table contains a row with a geometry_type_name in the form <author>_geom_<gname> for each feature table that contains user-defined geometry types specified in the gpkg_extensions table.
Test Method:

1) SELECT extension_name FROM gpkg_extensions WHERE extension_name LIKE '%_geom_%' AND extension_name NOT LIKE 'gpkg_geom_%'
2) FOR EACH extension_name from #1
    a. SELECT * FROM gpkg_geometry_columns WHERE geometry_type_name = extension_name
    b. Fail if returns an empty result set
3) Pass if no fails.

Reference: Clause 3.1.2.1.4 Req 91:
Test Type: **Capability**

A.3.1.3 Spatial Indexes

A.3.1.3.1 Data

A.3.1.3.1.1 Spatial Indexes Implementation

Test Case ID: /reg_ext/features/spatial_indexes/implementation
Test Purpose: Verify the correct implementation of spatial indexes on feature table geometry columns.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == 'features'))
2) Not testable if result set is empty
3) For each row table_name, column_name from step 1
    a. SELECT sql FROM sqlite_master WHERE tbl_name = 'rtree_' || result_set_table_name || '_' || result_set_column_name
    b. Not testable if result set is empty

c. Fail if returned sql != 'CREATE VIRTUAL TABLE rtree_' ' || result_set_table_name || '_' || result_set_column_name || USING rtree(id, minx, maxx, miny, maxy)
d. SELECT sql FROM sqlite_master WHERE type = 'trigger' AND tname = 'rtree_' || result_set_table_name || '_' || result_set_column_name || '_insert'
e. Fail if returned sql != result of populating insert triggers template in Annex L using result_set_table_name for <t> and result_set_column_name for <c>
f. SELECT sql FROM sqlite_master WHERE type = 'trigger' AND name LIKE 'rtree_' || result_set_table_name || '_' || result_set_column_name || '_update%'
g. Fail if returned sql != result of populating 4 update triggers templates in Annex L using result_set_table_name for <t> and result_set_column_name for <c>
h. SELECT sql FROM sqlite_master WHERE type='trigger' AND name = 'rtree_' || result_set_table_name || '_' || result_set_column_name || '_delete'
i. Fail if returned sql != result of populating delete trigger template in Annex L using result_set_table_name for <t> and result_set_column_name for <c>
j. Log pass otherwise

4) Pass if logged pass and no fails

Reference: Clause 3.1.3.1.1 Req 92:
Test Type: Capability

Test Case ID: /reg_ext/features/spatial_indexes/implementation/sql_functions
Test Purpose: Verify the correct implementation of sql functions used in spatial indexes on feature table geometry columns.
Test Method:

1) Open Geometry Test Data Set GeoPackage with GeoPackage SQLite Extension
2) For each Geometry Test Data Set <gtype_test> data table row for each geometry type in Annex E, for an assortment of srs_ids, for an assortment of coordinate values including empty geometries, without and with z and / or m values, in both big and little endian encodings:
   a. SELECT 'Fail' FROM <gtype_test> WHERE ST_IsEmpty(geom.) != empty
   b. SELECT 'Fail' FROM <gtype_test> WHERE ST_MinX(geom) != minx
   c. SELECT 'Fail' FROM <gtype_test> WHERE ST_MaxX(geom) != maxx
   d. SELECT 'Fail' FROM <gtype_test> WHERE ST_MinY(geom) != miny
   e. SELECT 'Fail' FROM <gtype_test> WHERE ST_MaxY(geom) != maxy
   f.
3) Pass if no 'Fail' selected from step 2

Reference: Clause 3.1.3.1.1 Req 92:
Test Type: Capability

A.3.1.3.1.2 Spatial Indexes – Extensions Name

Test Case ID: /reg_ext/features/spatial_indexes/extension_name

Test Purpose: Verify that the “gpkg_rtree_index” extension name is used to register spatial index extensions.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == ‘features'))
2) Not testable if result set is empty
3) For each row table_name, column_name from step 3
    a. SELECT sql FROM sqlite_master WHERE tbl_name = ‘rtree_’ || result_set_table_name || ‘_’ || result_set_column_name
    b. Not testable if returns an empty result set
    c. /opt/extension_mechanism/extensions/data/table_def
    d. Fail if failed
    e. SELECT extension_name from gpkg_extensions WHERE table_name = result_set_table_name AND column_name = result_set_column_name
    f. Log pass if result is “gpkg_rtree_index”
    g. Fail otherwise
4) Pass if logged pass and no fails

Reference: Clause 3.1.3.1.2 Req 93:
Test Type: Basic

A.3.1.3.1.3 Spatial Indexes – Extensions Row

Test Case ID: /reg_ext/features/spatial_indexes/extension_row
Test Purpose: Verify that spatial index extensions are registered using the “gpkg_rtree_index” name in the gpkg_extensions table.
Test Method:

Do test /reg_ext/features/spatial_indexes/extension_name

Reference: Clause 3.1.3.1.3 Req 94:
Test Type: Capability

A.3.1.4 Geometry Type Triggers

A.3.1.4.1 Data

A.3.1.4.1.1 Geometry Type Triggers Implementation

Test Case ID: /reg_ext/features/geometry_type_triggers/implementation
Test Purpose: Verify that user feature data table geometry type triggers are implemented correctly.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == ‘features'))

2) Not testable if returns an empty result set
3) For each row table_name, column_name from step 1
    a. SELECT sql FROM sqlite_master WHERE type = 'trigger' AND tbl_name = 'fgti_' || result_set_table_name || '_' || result_set_column_name
    b. Not testable if returns an empty result set
    c. Fail if sql != result of populating the first trigger template in Annex M with <t> as result_set_table_name and <c> as result_set_column_name
    d. SELECT sql FROM sqlite_master WHERE type = 'trigger' AND tbl_name = 'fgtu_' || result_set_table_name || '_' || result_set_column_name
    e. Fail if sql != result of populating the second trigger template in Annex M with <t> as result_set_table_name and <c> as result_set_column_name
    f. Log pass otherwise
4) Pass if logged pass and no fails

Reference: Clause 3.1.4.1.1 Req 95:
Test Type: Capability

Test Case ID: /reg_ext/features/geometry_type_triggers/implementation/sql_functions
Test Purpose: Verify the correct implementation of sql functions used in geometry type triggers on feature table geometry columns.
Test Method:

1) Open Geometry Test Data Set GeoPackage with GeoPackage SQLite Extension
2) For each Geometry Test Data Set <gtype_test> data table row for each assignable (gtype, atype) and non-assignable (ntype, atype) combination of geometry type in Annex E, for an assortment of srs_ids, for an assortment of coordinate values, without and with z and / or m values, in both big and little endian encodings:
    a. SELECT 'Fail' FROM <gtype_test> WHERE GPKG_IsAssignable(gtype, atype) =0
    b. SELECT 'Fail' FROM <gtype_test> WHERE GPKG_IsAssignable(ntype, atype) = 1
    c. SELECT 'Fail' FROM <gtype_test> WHERE ST_GeometryType(geom) != atype
3) Pass if no 'Fail' selected from step 2

Reference: Clause 3.1.4.1.1 Req 95:
Test Type: Capability

A.3.1.4.1.2 Geometry Type Triggers – Extensions Name

Test Case ID: /reg_ext/features/geometry_type_triggers/extension_name
Test Purpose: Verify that the "gpkg_geometry_type_trigger" extension name is used to register geometry type triggers.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == 'features'))

2) Not testable if result set is empty
3) For each row table_name, column_name from step 1
   a. SELECT sql FROM sqlite_master WHERE type = ‘trigger’ AND tbl_name = ‘fgti_’ || result_set_table_name || ‘_’ || result_set_column_name
   b. Not testable if result set is empty
   c. /opt/extension_mechanism/extensions/data/table_def
   d. Fail if failed
   e. SELECT extension_name from gpkg_extensions WHERE table_name = result_set_table_name AND column_name = result_set_column_name
   f. Log pass if result is “gpkg_geometry_type_trigger”
   g. Fail otherwise
4) Pass if logged pass and no fails

Reference: Clause 3.1.4.1.2 Req 96:
Test Type: Basic

A.3.1.4.1.3 Geometry Type Triggers – Extensions Row

Test Case ID: /reg_ext/features/geometry_type_triggers/extension_row
Test Purpose: Verify that geometry type triggers are registered using the “gpkg_geometry_type_trigger” extension name.
Test Method:

Do test /reg_ext/features/geometry_type_triggers/extension_name

Reference: Clause 3.1.4.1.3 Req 97:
Test Type: Capability

A.3.1.5 SRS_ID Triggers

A.3.1.5.1 Data

A.3.1.5.1.1 SRS_ID Triggers – Implementation

Test Case ID: /reg_ext/features/srs_id_triggers/implementation
Test Purpose: Verify that user feature data table srs_id triggers are implemented correctly.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == ‘features'))
2) Not testable if result set is empty
3) For each row table_name, column_name from step 1
   a. SELECT sql FROM sqlite_master WHERE type = ‘trigger’ AND tbl_name = ‘fgsi_’ || result_set_table_name || ‘_’ || result_set_column_name
   b. Not testable if result set is empty
   c. Fail if sql != result of populating the first trigger template in Annex N with <t> as result_set_table_name and <c> as result_set_column_name
   d. SELECT sql FROM sqlite_master WHERE type = ‘trigger’ AND tbl_name = ‘fgsu_’ || result_set_table_name || ‘_’ || result_set_column_name

e. Fail if sql != result of populating the second trigger template in Annex N with <t> as result_set_table_name and <c> as result_set_column_name
f. Log pass otherwise

4) Pass if logged pass and no fails

Reference: Clause 3.1.5.1.1 Req 98:
Test Type: Capability

Test Case ID: /reg_ext/features/srs_id_triggers/implementation/sql_functions
Test Purpose: Verify the correct implementation of sql functions used in srs_id triggers on feature table geometry columns.
Test Method:

1) Open Geometry Test Data Set GeoPackage with GeoPackage SQLite Extension
2) For each Geometry Test Data Set <gtype_test> data table row for each geometry type in Annex E, for an assortment of srs_ids, for an assortment of coordinate values, without and with z and / or m values, in both big and little endian encodings:
   a. SELECT 'Fail' FROM <gtype_test> WHERE ST_SRID(geom) != srs_id
3) Pass if no 'Fail' selected from step 2

Reference: Clause 3.1.5.1.1 Req 98:
Test Type: Capability

A.3.1.5.1.2 SRS_ID Triggers – Extensions Name

Test Case ID: /reg_ext/features/srs_id_triggers/extension_name
Test Purpose: Verify that the "gpkg_srs_id_trigger" extension name is used to register srs_id triggers.
Test Method:

1) SELECT table_name, column_name FROM gpkg_geometry_columns WHERE table_name IN (SELECT table_name FROM gpkg_contents WHERE data_type == 'features'))
2) Not testable if result set is empty
3) For each row table_name, column_name from step 1
   a. SELECT sql FROM sqlite_master WHERE type = 'trigger' AND tbl_name = 'fgsi_' || result_set_table_name || '_' || result_set_column_name
   b. Not testable if result set is empty
   c. /opt/extension_mechanism/extensions/data/table_def
   d. Fail if failed
   e. SELECT extension_name from gpkg_extensions WHERE table_name = result_set_table_name AND column_name = result_set_column_name
   f. Pass if result is "gpkg_srs_id_trigger"
   g. Fail otherwise

Reference: Clause 3.1.5.1.2 Req 99:
Test Type: Basic

A.3.1.5.1.3 SRS_ID Triggers – Extensions Row

Test Case ID: /reg_ext/features/srs_id_triggers/extension_row
Test Purpose: Verify that srs_id triggers are registered using the "gpkg_srs_id_trigger" extension name.
Test Method:

Do test /reg_ext/features/srs_id_triggers/extension_name

Reference: Clause 3.1.5.1.3 Req 100:
Test Type: Capability

A.3.2 Tiles

A.3.2.1 Zoom Levels

A.3.2.1.1 Data

A.3.2.1.1.1 Zoom Other Intervals—Extensions Name

Test Case ID: /reg_ext/tiles/zoom_levels/data/zoom_other_ext_name
Test Purpose: Verify that the "gpkg_zoom_other" extension name is used to register tiles tables with other than factors of two zoom intervals.
Test Method:

1) SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles'
2) Not testable if empty result set
3) For each row table_name from step 1
    a. SELECT zoom_level, pixel_x_size, pixel_y_size FROM gpkg_tile_matrix WHERE table_name = selected table name ORDER BY zoom_level ASC
    b. Not testable if returns empty result set
    c. Not testable if there are not two rows with adjacent zoom levels
    d. Not testable if no pair of rows for adjacent zoom levels have pixel_x_size or pixel_y_size values that differ by other than factors of two
    e. /opt/extension_mechanism/extensions/data/table_def
    f. Fail if failed
    g. SELECT * FROM gpkg_extensions WHERE table_name = selected table name AND extension_name = 'gpkg_zoom_other'
    h. Fail if returns an empty result set
    i. Log pass otherwise
4) Pass if logged pass and no fails

Reference: Clause 3.2.1.1.1 Req 101:
Test Type: Basic

A.3.2.1.1.2 Zoom Other Intervals – Extensions Row

Test Case ID: /reg_ext/tiles/zoom_levels/data/zoom_other_ext_row

Test Purpose: Verify that tiles tables with other than factors of two zoom intervals are registered using the “gpkg_zoom_other” extension name.
Test Method:

Do test /reg_ext/tiles/zoom_levels/data/zoom_other_ext_name

Reference: Clause 3.2.1.1.2 Req 102:
Test Type: Capabilty

A.3.2.2 Tile Encoding WEBP

A.3.2.2.1 Data

A.3.2.2.1.1 WEBP – Extensions Name

Test Case ID: /reg_ext/tiles/tile_encoding_webp/data/webp_ext_name
Test Purpose: Verify that the “gpkg_webp” extensions name is used to register WEBP tile encoding implementations.
Test Method:

1) SELECT table_name FROM gpkg_contents WHERE data_type = 'tiles'
2) Not testable if empty result set
3) For each row table_name from step 1
    a. Select tile_data FROM row table_name
    b. For each row tile_data from step a
        i. Log webp if tile data in MIME type image/webp
    c. Not testable if no logged webps
    d. /opt/extension_mechanism/extensions/data/table_def
    e. Fail if failed
    f. SELECT * FROM gpkg_extensions WHERE table_name = selected table name AND extension_name = 'gpkg_webp’
    g. Fail if returns an empty result set
    h. Log pass otherwise
4) Pass if logged pass and no fails

Reference: Clause 3.2.2.2.1 Req 103:
Test Type: Basic

A.3.2.2.1.2 WEBP – Extensions Row

Test Case ID: /reg_ext/tiles/tile_encoding_webp/data/webp_ext_row
Test Purpose: Verify that WEBP tile encodings are registered using the “gpkg_webp” extensions name.
Test Method:

Do test /reg_ext/tiles/tile_encoding_webp/data/webp_ext_name

Reference: Clause 3.2.2.2.2 Req 104:
Test Type: Capability

Annex B Background and Context (Normative)

B.1 Background

An open standard non-proprietary platform-independent GeoPackage container for distribution and direct use of all kinds of geospatial data will increase the cross-platform interoperability of geospatial applications and web services. Standard APIs for access and management of GeoPackage data will provide consistent query and update results across such applications and services. Increased interoperability and result consistency will enlarge the potential market for such applications and services, particularly in resource-constrained mobile computing environments like cell phones and tablets. GeoPackages will become the standard containers for "MyGeoData" that are used as a transfer format by users and Geospatial Web Services and a storage format on personal and enterprise devices.

This OGC® GeoPackage Encoding Standard defines a GeoPackage as a self-contained, single-file, cross-platform, serverless, transactional, open source SQLite data container with table definitions, relational integrity constraints, an SQL API exposed via a "C" CLI and JDBC, and manifest tables that together act as an exchange and direct-use format for multiple types of geospatial data including vector features, features with raster attributes and tile matrix pyramids, especially on mobile / hand held devices in disconnected or limited network connectivity environments.

Table formats, definitions of geometry types and metadata tables, relational integrity constraints, and SQL API are interdependent specification facets of the SF-SQL [9][10][11] and SQL-MM (Spatial) [12] standards that serve as normative references for the vector feature portion of this specification.

This specification attempts to support and use relevant raster types, storage table definitions, and metadata from widely adopted implementations and existing standards such as WMTS [16] and ISO metadata [28], to integrate use of rasters as attributes of geospatial features, and to define relational integrity constraints and an SQL API thereon to provide a raster analogy to the SF-SQL and SF-MM data access and data quality assurance capabilities.

Conformance classes for this specification are classified as core (mandatory) and extension (optional). The simple core of an Empty GeoPackage contains two SQL tables.

Future versions of this specification may include requirements for elevation data and routes. Future enhancements to this specification, a future GeoPackage Web Service specification, and modifications to existing OGC Web Service (OWS) specifications to use GeoPackages as exchange formats may allow OWS to support provisioning of GeoPackages throughout an enterprise or information community.

B.2 Document terms and definitions

This document uses the standard terms defined in Subclause 5.3 of [OGC 06-121], which is based on the ISO/IEC Directives, Part 2. Rules for the structure and drafting of International Standards. In particular, the word "shall" (not "must") is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

For the purposes of this document, the following terms and definitions apply.

B.2.1 Empty GeoPackage

a GeoPackage that contains a gpkg_spatial_ref_sys table, a gpkg_contents table with row record(s) with data_type column values of "features" or "tiles", and corresponding features tables per clause 2.1 and/or tiles tables per clause 2.2 where the user data tables per clauses 2.1.6 and 2.2.8 exist but contain no rows.

B.2.2 Extended GeoPackage

a GeoPackage that contains any additional data elements (tables or columns) or SQL constructs (data types, indexes, constraints or triggers) that are not specified in this encoding standard.

B.2.3 geolocate

identify a real-world geographic location

B.2.4 GeoPackage

a platform-independent SQLite database file that contains GeoPackage data and metadata tables with specified definitions, integrity assertions, format limitations and content constraints.

B.2.5 GeoPackage SQLite Configuration

consists of the SQLite 3 software library and a set of compile- and runtime configurations options.

B.2.6 GeoPackage SQLite Extension

a SQLite loadable extension that MAY provide SQL functions to support spatial indexes and SQL triggers linked to a SQLite library with specified configuration requirements to provide SQL API access to a GeoPackage.

B.2.7 georectified

raster whose pixels have been regularly spaced in a geographic (i.e., latitude / longitude) or projected map coordinate system using ground control points so that any pixel can be geolocated given its grid coordinate and the grid origin, cell spacing, and orientation.

B.2.8 orthorectified

georectified raster that has also been corrected to remove image perspective (camera angle tilt), camera and lens induced distortions, and terrain induced distortions using camera calibration parameters and DEM elevation data to accurately align with real world coordinates, have constant scale, and support direct measurement of distances, angles, and areas.

B.2.9 Valid GeoPackage

a GeoPackage that contains features per clause 2.1 and/or tiles per clause 2.2 and row(s) in the gpkg_contents table with data_type column values of "features" and/or "tiles" describing the user data tables.

B.3 Conventions

Symbols (and abbreviated terms)

ACID Atomic, Consistent, Isolated, and Durable

ASCII	American Standard Code for Information Interchange
API	Application Program Interface
BLOB	Binary Large OBject
CLI	Call-Level Interface
COTS	Commercial Off The Shelf
DEM	Digital Elevation Model
GPKG	GeoPackage
GRD	Ground Resolved Distance
EPSG	European Petroleum Survey Group
FK	Foreign Key
IETF	Internet Engineering Task Force
IIRS	Image Interpretability Rating Scale
IRARS	Imagery Resolution Assessments and Reporting Standards (Committee)
ISO	International Organization for Standardization
JDBC	Java Data Base Connectivity
JPEG	Joint Photographics Expert Group (image format)
MIME	Multipurpose Internet Mail Extensions
NIIRS	National Imagery Interpretability Rating Scale
OGC	Open Geospatial Consortium
PK	Primary Key
PNG	Portable Network Graphics (image format)
RDBMS	Relational Data Base Management System
RFC	Request For Comments
SQL	Structured Query Language
SRID	Spatial Reference (System) Identifier
UML	Unified Modeling Language
UTC	Coordinated Universal Time
XML	eXtensible Markup Language
1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional

B.4 Submitting Organizations (Informative)

The following organizations submitted this Encoding Standard to the Open Geospatial Consortium Inc. as a Request for Comment (RFC).

- Envitia
- Luciad
- Sigma Bravo
- The Carbon Project
- U.S. Army Geospatial Center
- U.S. National Geospatial Intelligence Agency

B.5 Document contributor contact points (Informative)

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B.6 Revision history (Informative)

Date	Rel	Editor	Paragraph modified	Description
2012-11-15	r1	Paul Daisey	10.3	Remove min/max x/y fields from all tables and text in clause 10.3 Tile Table Metadata per change request 250 / 12-135.
2012-11-15	r1	Paul Daisey	10.2, Annex B	add compr_qual_factor and georectification columns to raster_columns table create statement and sample insert statement; add triggers for those columns matching those for _rt_metadata per change request 251 / 12-134
2013-01-15	r2	Paul Daisey	8.2	Change gpkg_contents description default value per change request 255 / 12-166
2013-01-15	r2	Paul Daisey	9.2, Annex A	SRS Table Name Change per change request 256 / 12-165
2013-01-16	r2	Paul Daisey	7, Figure 2	table diagram gpkg_contents min_y REAL instead of BLOB
2013-01-23	r2	Paul Daisey	11.3, 8.2	Clause reference corrections, change gpkg_contents.identifier default value to “”
2013-02-01	r2	Paul Daisey	Changes to AS	No changes to AS
2013-02-01	r2	Paul Daisey	8.2	new last sentence and NOTE1, additional table name triggers
2013-02-01	r2	Paul Daisey	9.6	drop tables 21, 22 and associated text
2013-02-01	r2	Paul Daisey	10.5	misc. editorial changes
2013-02-01	r2	Paul Daisey	11.2	REQ 71 should refer to clause 11.2 and not 11.1
2013-02-01	r2	Paul Daisey	12	new clause 12 other data
2013-02-01	r2	Paul Daisey	13.2	rename tables 56,57 remove “ows_” prefix
2013-02-08	r3	Paul Daisey	10.2, 10.7, 10.8	Use -1 as "magic" value indicating "unknown" for both compr_qual_factor and georectification columns, and make it the default value. Remove NOTE1 in 10.7. Delete the next to last row in Table 46 - Image Routines for gpkgBboxToTiles (). Delete the corresponding sub-clause 10.8.10 Renumber sub-clause 10.8.11 to 10.8.10
2013-02-22	R3	Paul Daisey	Normative References, Future Work, 6, Bibliography	The GeoPackage file format and SQL API are provided by SQLite, which is the GeoPackage container implementation, not just a a reference implementation.
2013-03-05	R3	Paul Daisey	6.4	Add Security Considerations clause.
2013-03-05	R3	Paul Daisey	Future Work	Streaming synchronization
2013-03-30	R3	Paul Daisey	Normative References, All, Bibliography	Move references to geos and proj4 libraries from Normative References to Bibliography, remove references to them from main text.
2013-03-30 2013-04-01	R3	Paul Daisey	Reorganize document and Annexes	New Core / Extension outline.
2013-03-30	R3	Paul Daisey	6.3.2.2	auth_name column case-insensitive
2013-03-30	R3	Paul Daisey		Add feature table layout example
2013-04-01	R3	Paul Daisey	All,Annex B	Move table definition SQL to Annex B
2013-04-01	R3	Paul Daisey	7.2.4	Remove requirements for SQL/MM functions, REQ

				21 – 33.
2013-04-03	R3	Paul Daisey	All	Renumber tables, figures, normative references
2013-04-09	R4	Paul Daisey	6.3.6	Make integer primary keys mandatory for user vector, raster and tile data tables.
2013-04-09	R4	Paul Daisey	6.3.3.2,	Rewrite clause, remove references to geometry_columns table columns that are superfuluous in SQLite implementation.
2013-04-09	R4	Paul Daisey	6.3.6.1	Rewrite clause, remove references to SF/SQL gS and gB architectures.
2013-04-18	R4	Paul Daisey	6.3.4.1, 6.3.4.2, 6.3.6.3	Remove normative references to RasterLite
2013-04-19	R4	Paul Daisey	6.3.6.3	GeoPackage description of other data tables.
2013-04-29	R4	Paul Daisey	All	Remove implementation references
2013-04-29	R4	Paul Daisey	6.3.6.3, Annex G	Remove manifest other data entries
2013-04-29	R4	Paul Daisey	6.3.2.4.2, Annex B, E	Allow metadata of specified MIME type
2013-04-29	R4	Paul Daisey	6.3.2.4.3, Annex B, E	Allow NULLs in metadata_reference table
2013-04-29	R4	Paul Daisey	6.3.3.2, new Annex F	Geometry type codes
2013-04-29	R4	Paul Daisey	6.3.2.4, new Annex L	Feature Schema Metadata example
2013-05-03	R5	Paul Daisey	Future Work	Geographic / Geodetic Geometries
201305-07	R5	Paul Daisey	6.3.4.2, Annex C, E	Remove compr_qual_factor and georectification columns from raster_columns table
2013-05-07	R5	Paul Daisey	6.3.2.4, 6.3.4.3, new Annex M	delete _rt_metadata tables add Annex M reference Annex M from note in 6.3.2.4
2013-05-07	R5	Paul Daisey	7.1.1, Normative References, Bibliography	Add NITF as an extension image format
2013-05-07	R5	Paul Daisey	6.3.1	Revise Table Diagram
2013-05-07	R5	Paul Daisey	7.3.3, Annex C	Remove raster functions
2013-05-11	R5	Paul Daisey	6.3.2.4.3	metadata_reference table is not required to contain any rows
2013-05-11	R5	Paul Daisey	6.3.2.4.2	Recommend ISO 19139 metadata
2013-05-11	R5	Paul Daisey	6.3, Annex B	Default values
2013-05-11	R5	Paul Daisey	7.3.3, Annex C	Minimal Runtime SQL Functions
2013-05-11	R5	Paul Daisey	7.3.4, Annex D	Spatial Indexes
2013-05-13	R5	Paul Daisey	6, 7	Reformat requirement tables, unduplicate requirement text
2013-05-15	R5	Paul Daisey	6.3.1, 6.3.2.4, 6.3.4.2, 7.3.5.5, Annex B, remove Annex L	Replace raster_columns table, Annex L with gpkg_data_columns table
2013-05-16	R5	Paul Daisey	6.3.2.3, 7.4, Annex G,H,I	Drop manifest table, schemas, sample document
2013-05-16	R5	Paul Daisey	Future Work	Add GeoPackage Abstract Object Model
2013-05-22	R5	Paul Daisey	6.2.1, 6.3.3.1, new 7.1.1, Annex F	Add optional support for non-linear geometry types
2013-05-22	R5	Paul Daisey	7.3.2	Add SQLite configuration requirements
2013-05-22	R5	Paul Daisey	6.3, 7.2	Require only gpkg_contents and spatial_ref_sys tables
2013-05-24	R5	Paul Daisey	7.2.1.3	Add gpkg_extensions table
2013-05-24	R5	Paul Daisey	7.3.4, Annex D	Provide spatial index templates instead of examples
2013-05-25	R5	Paul Daisey	Preface, Scope,	Simplify, rewrite, add terms, use terms

			Terms, 6, 7	
2013-05-26	R5	Paul Daisey	All	Incorporate terms, renumber requirements and tables
2013-05-28	R5	Paul Daisey	6.1.2	Add "GPKG" as SQLite application id
2013-05-28	R5	Paul Daisey	6.1.2	Add SQLITE PRAGMA integrity_check
2013-05-28	R5	Paul Daisey	6.2.1	Geometry format minor changes
2013-05-28	R5	Paul Daisey	6.3.2.2, Annex E	Remove references to raster_columns table (removed previously)
2013-05-28	R5	Paul Daisey	All	Clause number references and text changes required by 5/22 changes
2013-05-28	R5	Paul Daisey	All	Remove comments on accepted changes
2013-05-28	R5	Paul Daisey	Annex E E.4	Add non-linear geometry type codes
2013-05-29	R5	Paul Daisey	7.2.4.1	Change reference from SF/SQL to SQL/MM
2013-05-29	R5	Paul Daisey	All	Change core and extension requirement names required by 5/22 changes
2013-05-29	R5	Paul Daisey	Table 16	Change extension to API to avoid overloading extension term
2013-05-29	R5	Paul Daisey	A.2	Draft changes to A.2 Conformance Classes
2013-05-29	R5	Paul Daisey	B.3	Add gpkg_data_columns table SQL
2013-05-30	R5	Paul Daisey	Revision History	Record 5/29 changes
2013-06-06	R6	Paul Daisey	Preface, Submission Contact Points, Revision History, Changes to AS, Changes to IS, Future Work, Forward, Introduction, Clauses 1-5	Remove all forward material except title page, submitting orgs, and introduction, and put in annexes.
2013-06-07	R6	Paul Daisey	Old Clauses 6,7 -> New 1-3	Restructure document iaw draft Requirements Dependencies
2013-06-07	R6	Paul Daisey	Annex A	Revised Requirements Dependencies and Diagram
2013-06-10	R6	Paul Daisey	All	Fix clause and requirement references based on document restructure
2013-06-10	R6	Paul Daisey	Annex A	Add Abstract Test Suite (incomplete)
2013-06-11	R6	Paul Daisey	Clause 1,2, Annex A	Insert Base and Extension subclauses, renumber more deeply nested subclauses
2013-06-12	R6	Paul Daisey	Annex G	Remove names and codes for Z and M geometry types, add Figure 5 and geometry subtype definitions
2013-06-12	R6	Paul Daisey	Clause 1.2.2.6	Rewrite clause, add new Requirement 10, 11, renumber existing and subsequent ones.
2013-06-12	R6	Paul Daisey	Annex D	Add ST_Is3D() and ST_IsMeasured()
2013-06-12	R6	Paul Daisey	All	Add “gpkg_” prefix to all GeoPackage metadata tables
2013-06-12	R6	Paul Daisey	Figure 1, 2	Update with “gpkg_” prefix
2013-06-12	R6	Paul Daisey	Annex A	Add Abstract Test Suite (incomplete)
2013-06-13	R6	Paul Daisey	1.2.4.1	Add sentence to end of first paragraph describing gpkg_other_data_columns content..
2013-06-13	R6	Paul Daisey	Annex A	Add Abstract Test Suite (incomplete)
2013-06-17	R6	Paul Daisey	Clause 1,2,3	Revised notes and turned them into footnotes; moved normative text into requirement statements.
2013-06-20	R6	Paul Daisey	All	Restructure document iaw SpecificationStructureAlternative3

2013-06-24	R6	Pepijn Van Eeckhoudt	All	Created and applied Word Styles and Outline List Numbering
2013-06-26	R6	Paul Daisey	1.1.2, 2.1.1, 2.1.4, 3.1.2, Annex C, D, F, G	GeoPackage Geometry Encoding Revisions
2013-06-27	R6	Paul Daisey	3.1.3.1.1	Add footnote recommendation on Spatial Index drop/add if many updates.
2013-06-27	R6	Paul Daisey	Figure 1, 2.2.6, 2.2.7	Remove gpkg_tile_table_metadata table
2013-06-28	R6	Paul Daisey	All	Change requirement statement format to **Req # *s SHALL be in bold italic***
2013-06-28	R6	Paul Daisey	Annex B	Update definition of Empty GeoPackage, add definition of Valid GeoPackage
2013-06-28	R6	Paul Daisey	Figure 1, 2.2.7, Annex C, F	Change tile_matrxI_metadata t_table_name column name to table_name iaw changes to gpkg_geometry_columns column name changes.
2013-06-28	R6	Paul Daisey	Figure 1, 2.1.5, 2.2.7, Annex C, F	Add gpkg_geometry_columns and gpkg_tile_matrix_metadata table_name foreign key constraints referencing gpkg_contents table_name now that gpkg_contents rows may describe other data tables.
2013-06-28	R6	Paul Daisey	Clause 3	Tables with non “gpkg” author registered extensions not data_type “features” or “tiles”
2013-07-01	R7	Paul Daisey	Annex A	Change ATS format from numbered list to bold heading, add test definitions.
2013-07-02	R7	Paul Daisey	Annex A	Add test definitions.
2013-07-03	R7	Paul Daisey	Annex A	Revise, add test definitions.
2013-07-04	R7	Paul Daisey	1.1.1, Annex A	Change .geopackage to .gpkg
2013-07-24	R7	Paul Daisey	Annex B	Add “Potential” to “Future Work”, “MAY” to items.
2013-07-24	R7	Paul Daisey	Annex B	Add support for UTFGrid as a future work item.
2013-07-24	R7	Paul Daisey	1.1.1.1.1	Add footnote to REQ 1 that SQLite is in the public domain.
2013-07-24	R7	Paul Daisey	2.1.3.1.1	Add footnote to Table 4 that OGC WKB is subset of ISO WKB
2013-07-24	R7	Paul Daisey	2.1.3.1.1	Revise definition of geometry type in Table 4 to include is_empty flag; add paragraph on encoding empty point geometries.
2013-07-24	R7	Paul Daisey	Annex E	Revise spatial index triggers to handle NULL values.
2013-07-31	R7	Paul Daisey	Annex C, F	Correct SQL errors in tables 13, 32, 43
2013-07-31	R7	Paul Daisey	Annex D	Add ST_IsEmpty(geom. Geometry)
2013-07-31	R7	Paul Daisey	Annex E Table 39	Revise spatial index triggers to handle empty geometries, changed ROWID values.
2013-07-31	R7	Paul Daisey	Annex A A.3.1.3.1.1	Revise test method iaw changes to spatial index triggers
2013-07-31	R7	Paul Daisey	2.1.3.1.1	Envelope in geopackage geometry binary for empty geometry
2013-07-31	R7	Paul Daisey	Annex A A.2.1.2.1.1	Revise test method to test for NaN values in envelope of empty geometries
2013-08-01	R8	Paul Daisey	Submitting Organizations, Submission Contact Points	Moved Submitting Organizations to B2; deleted previous B2 Submission Contact Points
2013-08-01	R8	Paul Daisey	1.1.3.1.1	Nullable gpkg_contents columns

			Table 3, 2.1.6.1.2, Annex A, C	One geometry column per feature table.
2013-09-09	R8	Paul Daisey	Clause 3	Add new Req 67 re gpkg_extensions table
2013-09-09	R8	Paul Daisey	2.1.6.1.1	remove footnote 1
2013-09-09	R8	Paul Daisey	2.1.6.1.1, Annex C	change no to yes for null in Table 6, 27 except for id column
2013-09-09	R8	Paul Daisey	1.1.3.1.1	Req 12 add gpkg_ prefix to gpkg_spatial_ref_sys
2013-09-09	R8	Paul Daisey	2.2	remove "with compression" and "without compression from footnote 1
2013-09-09	R8	Paul Daisey	2.6.1.1.1	"an all of" changed to "all"
2013-09-09	R8	Paul Daisey	2.2.6.1.2, Annex A	Add gpkg_ prefix to gpkg_tile_matrix_metdata
2013-09-09	R8	Paul Daisey	2.2.7.1.1	Space between 8and
2013-09-09	R8	Paul Daisey	2.2.6.1.1	Table 7 {RasterLayerName}_tiles change to Tile Matrix User Data Table Name
2013-09-09	R8	Paul Daisey	3.1.3.1.2, 3.2.1.1.2, Annex C	Change gpkg_extension to gpkg_extensions
2013-09-09	R8	Paul Daisey	3.2.3.1.1	Remove [29] from GeoTiff, change [31] to [29] for NGA Implementation Profile
2013-09-09	R8	Paul Daisey	Annex A	change "first three bytes of each gc are not “GPB”" to "first two bytes of each gc are not "GP"
2013-09-09	R8	Paul Daisey	Annex A	Change (1,2,3) to (0,1,2)
2013-09-09	R8	Paul Daisey	Annex D	add INTEGER return type to ST_ISEmpty, ST_Is3D, ST_ISMeasured functions
2013-09-09	R8	Paul Daisey	2.1.1	Add “more”
2013-09-09	R8	Paul Daisey	Annex C	Add the following constraint to the gpkg_geometry_columns table: CONSTRAINT uk_gc_table_name UNIQUE (table_name),
2013-09-09	R8	Paul Daisey	3.1.4.1.2, 3.1.5.1.2	Change geopackage_extension to gpkg_extensions
2013-09-18	R8	Paul Daisey	2.6.1, Annex A, Annex C	Add column 'scope text not null' to gpkg_extensions
2013-09-18	R8	Paul Daisey	2.5	Reword clause 2.5 to preclude reference to other data tables by rows in gpkg_geometry_columns or gpkg_tile_matrix_metadata tables. Add data_type constraint to Req 19. Add data_type constraint to Annex A tests.
2013-09-18	R8	Paul Daisey	3.1, 3.3, Annex A, Annex D	Rename clause 3.3 Other Tables Move clause 3.1.1 Geometry Encoding to clause 3.3.1 Other Geometry Encoding Move clause 3.2.5 Tile Encoding Other to clause 3.3.2 Other Tile Encoding Rename clause 3.3.1 Other Trigger to clause 3.3.3 Other Trigger Renumber contained requirements Add footnote to Annex D table Move corresponding tests in Annex A
2013-09-24	R8	Paul Daisey	Annex E	Replace all occurences of 'rowid' with '<i>' in trigger definitions.
2013-09-24	R8	Paul Daisey	All	Update normative [xx]and bibliographic [Byy] references
2013-09-25	R8	Paul Daisey	3.1, Annex A, Annex D, Annex F	Change geometry_columns to gpkg_geometry_columns and geometry_type to geometry_type_name
2013-09-25	R8	Paul Daisey	2.2.3, 3.2.1, new Annex I	Change “power” to “factor” in and add text to zoom level descriptions and requirements.
2013-09-25	R8	Paul Daisey	2.1.6, Annex A,	Add required data types for vector feature user data

			Annex C	table column definitions.
2013-09-26	R8	Paul Daisey	New 2.3.2, Annex A, Annex C	Add gpkg_data_column_constraints table
2013-09-26	R8	Paul Daisey	1.1.3, 2.2.1, 2.2.6, 2.2.7, 2.2.8, Annex A, Annex C	Add gpkg_tile_matrix_set, rename gpkg_tile_matrix_metadata to gpkg_tile_matrix, standardize tile pyramid, tile matrix set and tile matrix term usage.
2013-09-27	R8	Paul Daisey	Figure 1	Added gpkg_tile_matrix_set, gpkg_data_columns_constraints to Figure 1
2013-09-27	R8	Paul Daisey	2.1.5.1	Replace normative text in 2.1.5.1.1 with new requirement 19 in 2.1.5.1.2.
2013-09-27	R8	Paul Daisey	All	Clarify which tables may be implemented as views or extended with additional columns.
2013-09-27	R8	Paul Daisey	2.4.2.1.1	Drop md_standard_uri default value, add footnote and text paragraph.
2013-09-27	R8	Paul Daisey	All	Specify case sensitivity for required column values.
2013-09-27	R8	Paul Daisey	All	Change SQL trigger action from ROLLBACK to ABORT
2013-10-02	R9	Paul Daisey	1.1.2.1.1, Annex A	Add Null column to table 2 per table 22, remove default value, foreign and unique key tests from Annex A A.1.1.2.1.1
2013-10-02	R9	Paul Daisey	All	Misc. Editorial corrections.
2013-10-02	R9	Paul Daisey	Title Page	Changed title from Implementation Specification to Encoding Standard per Carl Reed email.
2013-10-04	R9	Paul Daisey	1.1.1.1.3, Annex A	Add new Req 4 requirement for SQLite PRAGMA foreign_key_check()
2013-10-04	R9	Paul Daisey	All	Disallow addition of columns to all gpkg tables except user data feature tables.
2013-10-05	R9	Paul Daisey	Introduction, All, Annex B	GeoPackage replaces GeoPackage file
2013-10-05	R9	Paul Daisey	Introduction, 1.1.1.1.1, Annex B	Add Extended GeoPackage definition
2013-10-05	R9	Paul Daisey	Introduction Figure 1, 2.6, Annex C	Add definition column to gpkg_extensions table.
2013-10-05	R9	Paul Daisey	Introduction, Annex B	Add GeoPackage SQLite Configuration definition
2013-10-05	R9	Paul Daisey	Introduction, Annex B	Modify definition of GeoPackage SQLite Extension
2013-10-05	R9	Paul Daisey	1	Revise Container Definition, add new Req 1 and Req 3
2013-10-05	R9	Paul Daisey	1.1.1.2.2	Remove rows from Table 1 SQLite Configuration
2013-10-05	R9	Paul Daisey	2.1.3.2	Drop clause. Required SQL functions to be defined in extension template documents.
2013-10-05	R9	Paul Daisey	2.5.1	New Introduction clause for Extension Mechanism
2013-10-05	R9	Paul Daisey	2.5.2.1.2	New Req 79, Req 83, revised Req 82, added explanatory text for Req 84, deleted Table 47
2013-10-07	R9	Paul Daisey	1.1.1.2.2	Move foreign key rows from Table 9 Safe GeoPackage to Table 1 SQLite Configuration
2013-10-07	R9	Paul Daisey	2.5.2.1	Extend Req 79 with semantic equivalence of empty and missing gpkg_extensions table.
2013-10-07	R9	Paul Daisey	2.5.2.2	Drop Clasue. Required SQL Configuration settings to be defined in extension template documents.
2013-10-07	R9	Paul Daisey	3.1.2	New clause for Geometry Encoding Extension
2013-10-07	R9	Paul Daisey	Annex J - S	New Extension Template and Extension Annexes

2013-10-08	R9	Paul Daisey	1.1.1.2.2, Annex M, N, O	Prohibit all SQLITE_OMIT_* compile time options instead of specific ones.
2013-10-09	R9	Paul Daisey	3.*.1.1	Simplify extension prerequisite descriptions, reference extension annexes.
2013-10-09	R9	Paul Daisey	Annexes J - S	Style subheadings as subtitles, add clause references
2013-10-09	R9	Paul Daisey	2.1.3, Annex L	Replace GeoPackageBinary definition with StandardGeoPackageBinary definition.
2013-10-09	R9	Paul Daisey	Introduction, 2.3.2, 2.3.3, Annex C	1. Drop constraint_type column from gpkg_data_columns, Req 60 2. Add Req 61 3. Change description of constraint name. 4. Revise Figure 1 Table Diagram
2013-10-09	R9	Paul Daisey	2.5.2.1.2	Add guidance for extension template
2013-10-09	R9	Paul Daisey	2.1.6.1.2	Add footnote re further restrictions on the geometry types that are allowed in a feature table
2013-10-09	R9	Paul Daisey	2.1.3.1.1	Add footnote that WKB geometries are not geographic / geodesic
2013-10-10	R9	Paul Daisey	1.1.1.1.2	Change Req 3 SQLite database header required contents to include version number.
2013-10-10	R9	Paul Daisey	Annex A	Add and revise tests in accordance with other R9 draft changes.
2013-10-10	R9	Paul Daisey	2.3.3, Annex A	Add unique key on gpkg_data_column_constraints constraint_name, constraint_type, constraint_value columns; Add new Req 63, ATS test
2013-10-15	R9	Paul Daisey	Annex D	Drop D.1 Geometry Column Triggers
2013-10-15	R9	Paul Daisey	Annex F	Drop Annex F
2013-10-15	R9	Paul Daisey	2.3.3.1.2	Remove first sentence on constrain name column values.
2013-10-15	R9	Paul Daisey	Introduction, 2.3.3.1.1, Annex C	Add description column to gpkg_data_column_constraints table.
2013-10-15	R9	Paul Daisey	2.3.3.1.2	Drop requirement 61
2013-10-15	R9	Paul Daisey	2.1.6.1.2	Drop footnote 2 on p.13
2013-10-15	R9	Paul Daisey	2.1.6.1.1	Delete DECIMAL_TEXT row from Table 6
2013-10-15	R9	Paul Daisey	1.1.1.1.1	Move to 1.1.1.1.3, renumber requirements.
2013-10-15	R9	Paul Daisey	2.1.6.1.1, 1.1.1.1.3	Move Req 30 and Table 6 to Req5 and Table 1
2013-10-15	R9	Paul Daisey	2.4.3.1.1, Annex C	Change timestamp column from TEXT to DATETIME
2013-10-15	R9	Paul Daisey	All	Change data types to those specified in Table 1
2013-10-15	R9	Paul Daisey	2.3.3.1.1	Add NUMERIC data type footnote for table gpkg_data_column_constraints
2013-10-15	R9	Paul Daisey	All	Misc editorial changes
2013-10-22	R9	Paul Daisey	3.2.3, 3.2.4, Annex A	Remove TIFF and NITF tile encodings
2013-10-22	R9	Paul Daisey	New 3.1.2.1.4 Annex A	New Req 91
2013-10-22	R9	Paul Daisey	Annex K	Rewrite requirement description
2013-10-22	R9	Paul Daisey	3.1.1, 3.1.2, Annex J, K	Renamed
2013-10-22	R9	Paul Daisey	All	Misc editorial changes
2013-10-22	R9	Paul Daisey	Introduction, Annex B	Replace detailed table diagram in Introduction with an overview diagram; move detailed table diagram to Annex B, add minimal features and tiles diagrams to Annex B.
2013-10-24	R9	Paul Daisey	1.1.1.1.3	Specify 8601 formats for DATE and DATETIME in

				Table 1
2013-10-24	R9	Paul Daisey	1.1.1.1.3	{(size)} specs for BLOB and TEXT data types in Table 1
2013-10-24	R9	Paul Daisey	2.1.3.1.1 Table 5	Bit layout of flags byte and flag bits use --additional text
2013-10-24	R9	Paul Daisey	All	Misc editorial changes
2013-10-24	R9	Paul Daisey	Annex Q, R	Removed
2013-10-24	R9	Paul Daisey	All, Annex S, T	Remove unused normative [xx]and bibliographic [Byy] references, update remaining ones
2013-11-11	R9	Paul Daisey	All	Misc editorial changes, mostly formatting.
2013-11-12	R9	Paul Daisey	Annex C, G	Correct gpkg_metadata table definition SQL default values, metadata column type from BLOB to TEXT
2013-11-12	R9	Paul Daisey	1.1.1.1.1	Add footnote (3) to Req 2
2013-11-12	R9	Paul Daisey	Annex L, O	Add http://www.sqlite.org/rtree.html
2013-11-12	R9	Paul Daisey	2.2.6.1.1, 2.2.6.1.2	Cut sentence from 2.2.6.1.1, paste revised version and additional sentence describing origin georeferenced coordinates to 2.2.6.1.2.
2013-11-12	R9	Paul Daisey	2.3.3.1.2	Add a new third sentence in first paragraph; add new Table 13 example
2013-11-12	R9	Paul Daisey	1.1.3.1.1, 2.1.3.1.1, 2.2.6.1.1	Add x/y axis definitions to min/max x/y column descriptions and WKB geometry description.
2013-11-13	R9	Paul Daisey	1.1.1.1.1	Revise footnote (3) to Req 2 to include byte values instead of long value.
2013-11-13	R9	Jeff Yutzler, Paul Daisey	All	Misc editorial changes, mostly formatting.
2013-11-18	R9	Jeff Yutzler, Paul Daisey	All	Misc editorial changes, mostly formatting.
2013-11-18	R9	Paul Daisey	1, 2.1.6.1.1, 2.2.8.1.1	Add “and table constraints” in clause 1, make INTEGER PRIMARY KEY AUTOINCREMENT explicit in Req 29 and Req 52 to avoid future “WITHOUT ROWID” SQLite v3.8.2 problems.
2013-11-19	R9	Jeff Yutzler, Paul Daisey	All	Misc formatting changes.
2013-11-21	R 10	Paul Daisey	1.1.1.4	Remove “()” from PRAGMA foreign_key_check()
2013-11-21	R 10	Paul Daisey	Annex C, G	Change metadata_standard_uri column name to md_standard_uri
2013-12-26	R 10	Paul Daisey	A.1.1.2.1.2	Use the current gpkg_spatial_ref_sys table and column name definitions
2013-12-28	R 10	Paul Daisey	Annex Q	Add normative reference [32] to OpenGIS® 01-009
2013-12-28	R 10	Paul Daisey	1.1.2.1.1	Add normative reference “[32]” to description of definition column in Table 3
2013-12-28	R 10	Paul Daisey	A.1.1.2.1.2	/base/core/gpkg_spatial_ref_sys/data_values_default revise step 3 SQL
2013-12-28	R 10	Paul Daisey	1.1.2.1.2	Add paragraph on definition column WKT values
2013-12-31	R 10	Paul Daisey	All	Misc editorial corrections.
2013-12-31	R 10	Paul Daisey	A.2.2.3.1.1, A.2.2.4.1.1	Change “extension_name IN ('gpkg_webp','gpkg_tiff','gpkg_nitf')” to “extension_name = ‘gpkg_webp’”
2013-12-31	R 10	Paul Daisey	A.2.5.1.1.2	delete test steps 7 and 8:re tile encoding TIFF and NITF
2013-12-31	R	Paul Daisey	2.2.7.1.1	remove the default column from Table 9

	10			
2013-12-31	R 10	Paul Daisey	2.2.8.1.1	remove 3.2.3, 3.2.4 from table 10 tile_data column description
2013-12-31	R 10	Paul Daisey	Annex D.5	Change t_table_name to table_name in Table 41
2013-12-31	R 10	Paul Daisey	2.1.5.1.2	Change “each geometry column” to “the geometry column” in Req 22
2014-01-10	R 10	Paul Daisey	1.1.2.1.1	Rename Table 3 Spatial Ref Sys Table Definition
2014-01-28	R 10	Paul Daisey	1.1.3.1.1, 2.4.3.1.1, Annex C, Annex H	strftime('%Y-%m-%dT%H:%M:%fZ', CURRENT_TIMESTAMP) changed to strftime('%Y-%m-%dT%H:%M:%fZ','now')
2014-07-14	R11	Paul Daisey	1.1.2.1.1	Remove “at a minimum” after “includes” in 2nd paragraph, 1st sentence; conflicts with Clause 1
2014-07-14	R11	Paul Daisey	2.1.4.1.1	Req 20 42in insert space between 42 and in
2014-07-14	R11	Paul Daisey	2.2.8.1.1	Change Table 30 to Table 29
2014-07-14	R11	Paul Daisey	2.5.2.1.1	Change access to accesses in 1st paragraph, 2nd sentence
2014-07-14	R11	Paul Daisey	Annex A, A.3.1.1.1	inAnnex E insert space between in and Annex
2014-07-14	R11	Paul Daisey	Annex A, A.3.1.1.1	43without insert space between 43 and without
2014-07-14	R11	Paul Daisey	Annex B, B.5	Change pepijn.vaneeckhoudt email from gmail to Luciad
2014-07-14	R11	Paul Daisey	Annex B, B.5	Change all "@" to “<at>”
2014-07-14	R11	Paul Daisey	Annex C, C.10	Remove UNIQUE from PK constraint
2014-12-12	R11	Paul Daisey	2.1.1	Add a footnote to "GeometryCollection" description
2014-12-12	R11	Paul Daisey	2.1.6.1.1	Add new Req 30b
2014-12-12	R11	Paul Daisey	Annex A, A.2.1.6.1.1	Add feature_table_geometry_column_type test
2014-12-12	R11	Paul Daisey	2.1.5.1.1	Add “and geometry types” to 1st paragraph 1st sentence
2014-12-12	R11	Paul Daisey	1.1.1.1.4	Add footnote to Req 6
2014-12-12	R11	Paul Daisey	2.1.3.1.1	replace ISO 13249-3 with OGC 06-103r4
2014-12-12	R11	Paul Daisey	2.1.3.1.1	Correct references in footnote 1: [13] becomes [9] and [16] becomes [12]
2014-12-12	R11	Paul Daisey	1.1.1.2.2	Remove “and run” from clause and Req 9
2014-12-12	R11	Paul Daisey	1.1.1.2.2	Remove PRAGMA foreign_keys runtime option from Table 2
2014-12-12	R11	Paul Daisey	Annex A, A.2.2.7.1.1	Change step 2 to “Not testable if less than 1”
2014-12-12	R11	Paul Daisey	Annex A, A.2.2.6.1.1	Remove obsolete provisions (unique, column order, other columns) from step 3
2014-12-12	R11	Paul Daisey	2.1.6.1.2	Add sentences specifying unit of measure determination for geometry Z and M values.
2014-12-12	R11	Paul Daisey	1.1.3.1.1, Table 4	Change description column default value to ‘’
2014-12-12	R11	Paul Daisey	Annex C, C.7, Table 29	Remove spurious “)” from tile_data column definition
2014-12-12	R11	Paul Daisey	Annex D, D.3, Table 39	Correct ISO 8601 timestamp GLOB expressions
2015-03-16	R11	Scott Simmons	entire document	Minor format corrections

B.7 Changes to the OGC® Abstract Specification

The OGC® Abstract Specification does not require changes to accommodate this OGC® standard.

B.8 Changes to OGC® Implementation Standards

None at present.

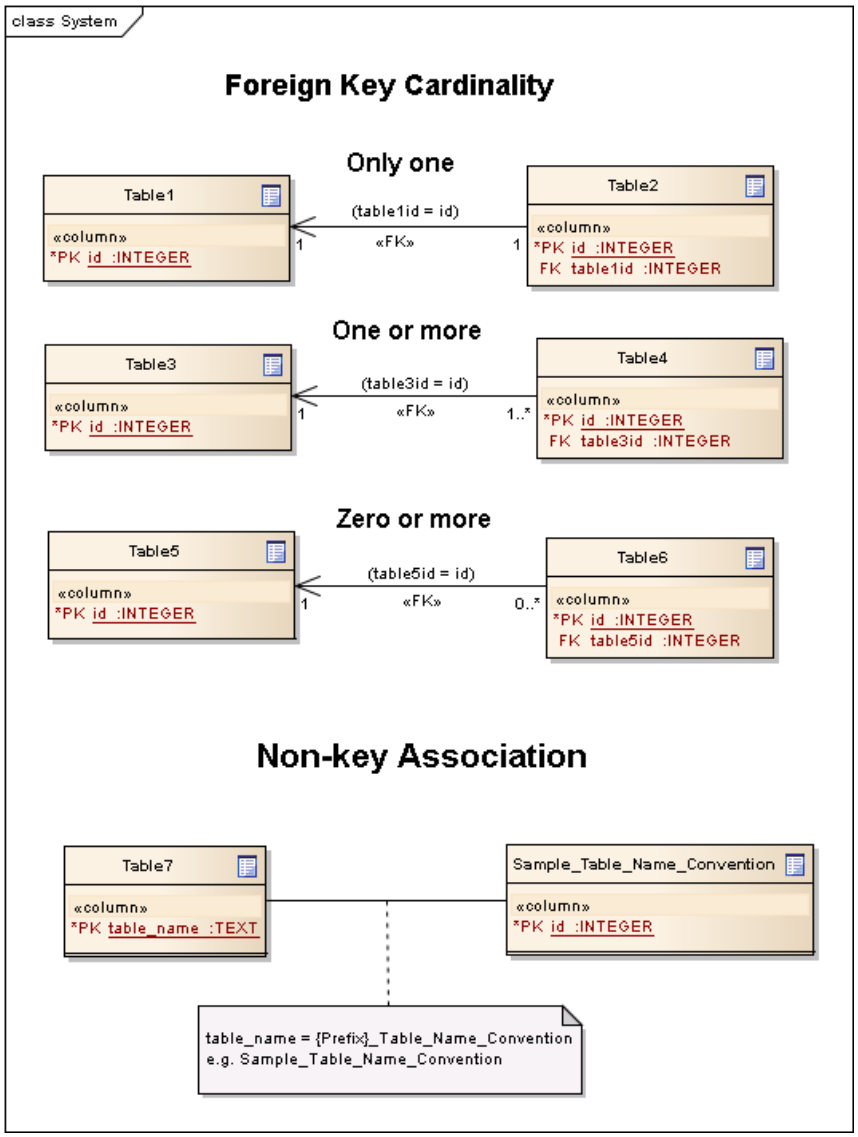
B.9 Potential Future Work (Informative)

- MAY investigate GeoPackage implementation on SQLite version 4 [B25].
- Future versions of this specification MAY include requirements for elevation data and routes.
- Future enhancements to this specification, a future GeoPackage Web Service specification and modifications to existing OGC Web Service (OWS) specifications to use GeoPackages as exchange formats MAY allow OWS to support provisioning of GeoPackages throughout an enterprise.
- Future versions of this specification MAY include additional raster / image formats, including fewer restrictions on the image/tiff format.
- Future versions of this specification MAY include additional SQL API routines for interrogation and conversion of raster / image BLOBs.
- Future versions of this specification and/or one for a GeoPackage Web Service MAY address utilities for importing and exporting vector, raster and tile data in various formats.
- Future versions of this specification and/or one for a GeoPackage Web Service MAY address encryption of GeoPackages and/or individual tables or column values.
- Future versions of this specification MAY add infrastructure to the metadata tables such as a temporal_columns table that refers to the time properties of data records.
- MAY specify a streaming synchronization protocol for GeoPackage as part of a future GeoPackage Web Service specification, and/or a future version of the GeoPackage and/or Web Synchronization Service specification(s).
- Future versions of this specification MAY address symbology and styling information.
- Future version of this specification MAY include geographic / geodesic geometry types.
- MAY create a GeoPackage Abstract Object Model to support data encodings other than SQL in a future version of this specification.
- MAY add UTFGrid (https://github.com/mapbox/utfgrid-spec) support in a future version of this specification.

B.10 UML Notation

The diagrams that appear in this standard are presented using the Unified Modeling Language (UML) [B14] static structure diagrams. The UML notations used in this standard for RDBMS tables in a GeoPackage are described in Figure 3 below.

Figure 3 UML Notation for RDBMS Tables



In this standard, the following two stereotypes of UML classes are used to represent RDBMS tables:

a) <<table>> An instantiation of a UML class as an RDMBS table.

b) <<column>> An instantiation of a UML attribute as an RDBMS table column.

In this standard, the following standard data types are used for RDBMS columns:

a) NULL – The value is a NULL value.

b) INTEGER – A signed integer, stored in 1, 2, 3, 4, 6, or 8 bytes depending on the magnitude of the value.

c) REAL – The value is a floating point value, stored as an 8-byte IEEE floating point number.

d) TEXT – A sequence of characters, stored using the database encoding

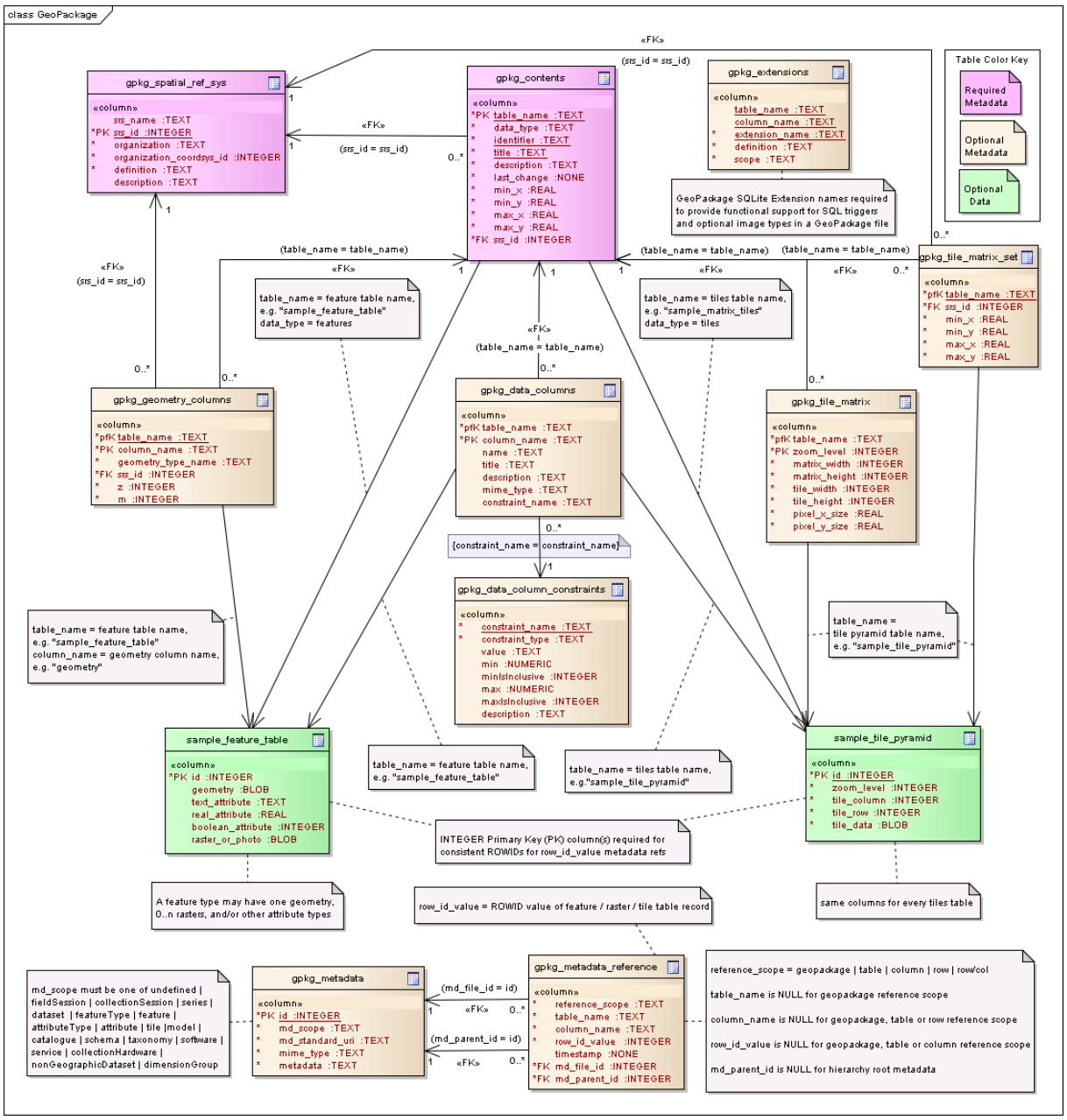
(UTF-8, UTF-16BE or UTF-16LE).

e) BLOB – The value is a blob of data, stored exactly as it was input.

f) NONE – The value is a Date / Time Timestamp.

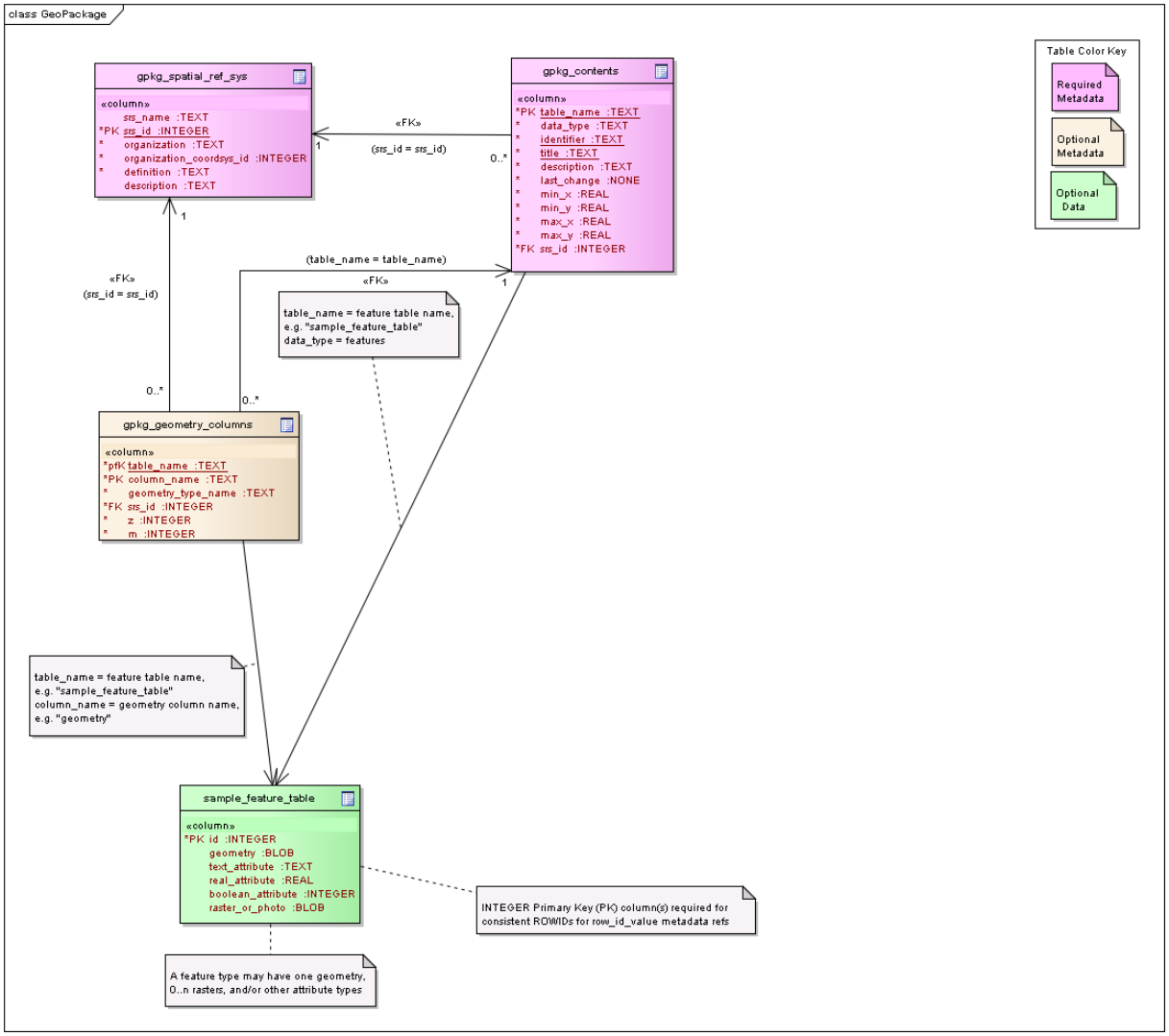
B.11 GeoPackage Tables Detailed Diagram

Figure 4 GeoPackage Tables Details



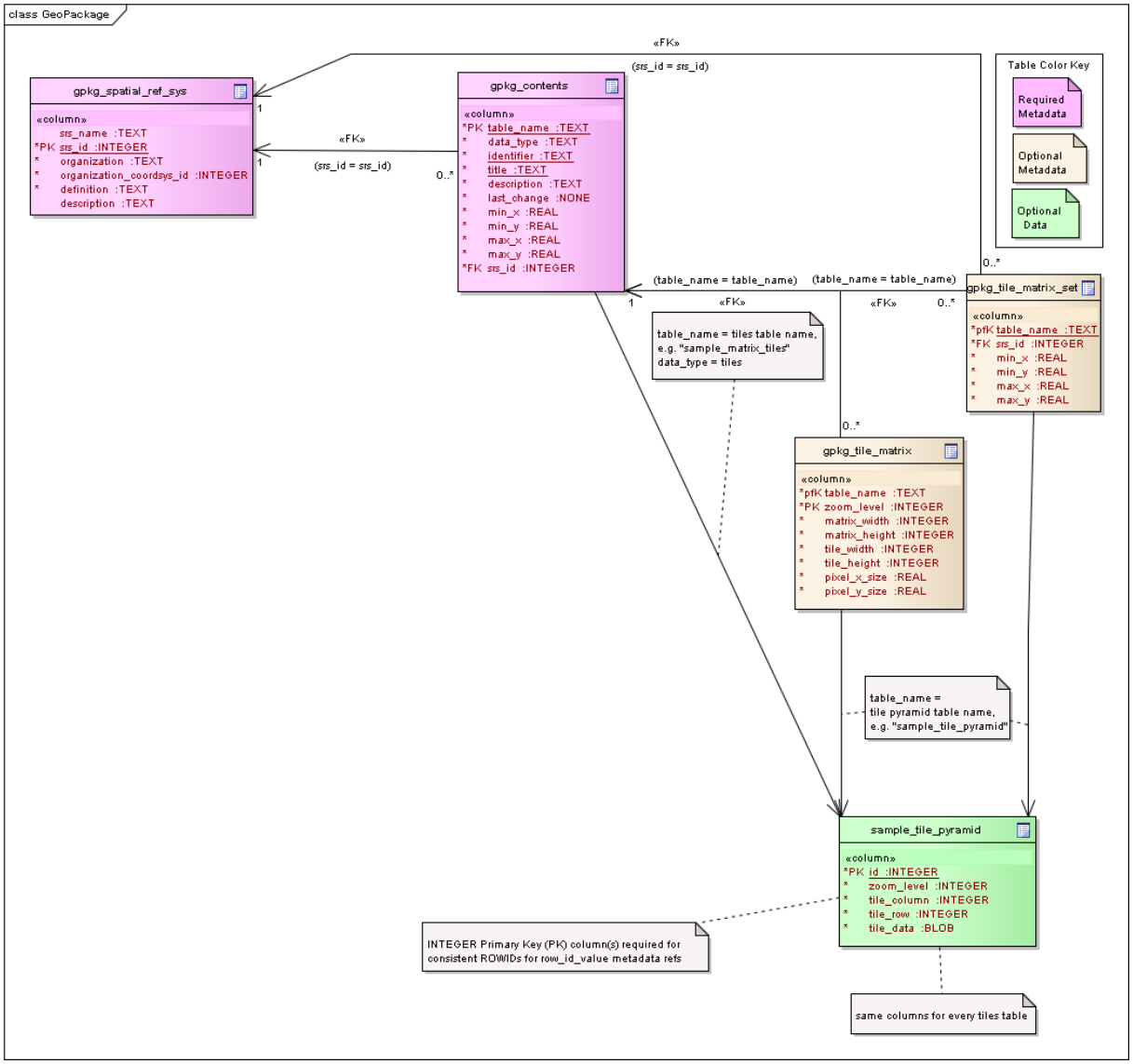
B.12 GeoPackage Minimal Tables for Features Diagram

Figure 5 GeoPackage Minimal Tables for Features



B.13 GeoPackage Minimal Tables for Tiles Diagram

Figure 6 GeoPackage Minimal Tables for Tiles



Annex C Table Definition SQL (Normative)

C.1 gpkg_spatial_ref_sys

Table 18 gpkg_spatial_ref_sys Table Definition SQL

```
CREATE TABLE gpkg_spatial_ref_sys (
  srs_name TEXT NOT NULL,
  srs_id INTEGER NOT NULL PRIMARY KEY,
  organization TEXT NOT NULL,
  organization_coordsys_id INTEGER NOT NULL,
  definition  TEXT NOT NULL,
  description TEXT
)
```

Table 19 SQL/MM View of gpkg_spatial_ref_sys Definition SQL (Informative)

```
CREATE VIEW st_spatial_ref_sys AS
SELECT
  srs_name,
  srs_id,
  organization,
  organization_coordsys_id,
  definition,
  description
FROM gpkg_spatial_ref_sys;
```

Table 20 SF/SQL View of gpkg_spatial_ref_sys Definition SQL (Informative)

```
CREATE VIEW spatial_ref_sys AS
SELECT
  srs_id AS srid,
  organization AS auth_name,
  organization_coordsys_id AS auth_srid,
  definition AS srtext
  FROM gpkg_spatial_ref_sys;
```

C.2 gpkg_contents

Table 21 gpkg_contents Table Definition SQL

```
CREATE TABLE gpkg_contents (
  table_name TEXT NOT NULL PRIMARY KEY,
  data_type TEXT NOT NULL,
  identifier TEXT UNIQUE,
  description TEXT DEFAULT '',
  last_change DATETIME NOT NULL DEFAULT
    (strftime('%Y-%m-%dT%H:%M:%fZ','now')),
  min_x DOUBLE,
  min_y DOUBLE,
  max_x DOUBLE,
```

```
  max_y DOUBLE,
  srs_id INTEGER,
  CONSTRAINT fk_gc_r_srs_id FOREIGN KEY (srs_id) REFERENCES
    gpkg_spatial_ref_sys(srs_id))
```

C.3 gpkg_geometry_columns

Table 22 gpkg_geometry_columns Table Definition SQL

```
CREATE TABLE gpkg_geometry_columns (
  table_name TEXT NOT NULL,
  column_name TEXT NOT NULL,
  geometry_type_name TEXT NOT NULL,
  srs_id INTEGER NOT NULL,
  z TINYINT NOT NULL,
  m TINYINT NOT NULL,
  CONSTRAINT pk_geom_cols PRIMARY KEY (table_name, column_name),
  CONSTRAINT uk_gc_table_name UNIQUE (table_name),
  CONSTRAINT fk_gc_tn FOREIGN KEY (table_name)
                          REFERENCES gpkg_contents(table_name),
  CONSTRAINT fk_gc_srs FOREIGN KEY (srs_id)
                          REFERENCES gpkg_spatial_ref_sys (srs_id))
```

Table 23 SQL/MM View of gpkg_geometry_columns Definition SQL (Informative)

```
CREATE VIEW st_geometry_columns AS
SELECT
  table_name,
  column_name,
  "ST_" || geometry_type_name,
  g.srs_id,
  srs_name
FROM gpkg_geometry_columns as g JOIN gpkg_spatial_ref_sys AS s
WHERE g.srs_id = s.srs_id;
```

Table 24 SF/SQL VIEW of gpkg_geometry_columns Definition SQL (Informative)

```
CREATE VIEW geometry_columns AS
SELECT
  table_name AS f_table_name,
  column_name AS f_geometry_column,
  code4name[1](geometry_type_name) AS geometry_type,
  2 + (CASE z WHEN 1 THEN 1 WHEN 2 THEN 1 ELSE 0 END)
    + (CASE m WHEN 1 THEN 1 WHEN 2 THEN 1 ELSE 0 END)
    AS coord_dimension,
  srs_id AS srid
FROM gpkg_geometry_columns;
```

[1] Implementer must provide code4name(geometry_type_name) SQL function

C.4 sample_feature_table (Informative)

Table 25 sample_feature_table Table Definition SQL (Informative)

```
CREATE TABLE sample_feature_table (
  id INTEGER PRIMARY KEY AUTOINCREMENT,
  geometry GEOMETRY,
  text_attribute TEXT,
  real_attribute REAL,
  boolean_attribute BOOLEAN,
  raster_or_photo BLOB
)
```

C.5 gpkg_tile_matrix_set

Table 26 gpkg_tile_matrix_set Table Creation SQL

```
CREATE TABLE gpkg_tile_matrix_set (
  table_name TEXT NOT NULL PRIMARY KEY,
  srs_id INTEGER NOT NULL,
  min_x DOUBLE NOT NULL,
  min_y DOUBLE NOT NULL,
  max_x DOUBLE NOT NULL,
  max_y DOUBLE NOT NULL,
  CONSTRAINT fk_gtms_table_name FOREIGN KEY (table_name)
    REFERENCES gpkg_contents(table_name),
  CONSTRAINT fk_gtms_srs FOREIGN KEY (srs_id)
    REFERENCES gpkg_spatial_ref_sys (srs_id)
)
```

C.6 gpkg_tile_matrix

Table 27 gpkg_tile_matrix Table Creation SQL

```
CREATE TABLE gpkg_tile_matrix (
  table_name TEXT NOT NULL,
  zoom_level INTEGER NOT NULL,
  matrix_width INTEGER NOT NULL,
  matrix_height INTEGER NOT NULL,
  tile_width INTEGER NOT NULL,
  tile_height INTEGER NOT NULL,
  pixel_x_size DOUBLE NOT NULL,
pixel_y_size DOUBLE NOT NULL,
CONSTRAINT pk_ttm PRIMARY KEY (table_name, zoom_level),
CONSTRAINT fk_tmm_table_name FOREIGN KEY (table_name)
  REFERENCES gpkg_contents(table_name))
```

Table 28 EXAMPLE: gpkg_tile_matrix Insert Statement (Informative)

```
INSERT INTO gpkg_tile_matrix VALUES (
"sample_tile_pyramid",
0,
```

```
1,
1,
512,
512,
2.0,
2.0);
```

C.7 sample_tile_pyramid (Informative)

Table 29 EXAMPLE: tiles table Create Table SQL (Informative)

```
CREATE TABLE sample_tile_pyramid (
  id INTEGER PRIMARY KEY AUTOINCREMENT,
  zoom_level INTEGER NOT NULL,
  tile_column INTEGER NOT NULL,
  tile_row INTEGER NOT NULL,
  tile_data BLOB NOT NULL,
UNIQUE (zoom_level, tile_column, tile_row))
```

Table 30 EXAMPLE: tiles table Insert Statement (Informative)

```
INSERT INTO sample_tile_pyramid VALUES (
1,
1,
1,
1,
"BLOB VALUE")
```

C.8 gpkg_data_columns

Table 31 gpkg_data_columns Table Definition SQL

```
CREATE TABLE gpkg_data_columns (
  table_name TEXT NOT NULL,
  column_name TEXT NOT NULL,
  name TEXT,
  title TEXT,
  description TEXT,
  mime_type TEXT,
  constraint_name TEXT,
  CONSTRAINT pk_gdc PRIMARY KEY (table_name, column_name),
  CONSTRAINT fk_gdc_tn FOREIGN KEY (table_name)
           REFERENCES gpkg_contents(table_name))
```

C.9 gpkg_data_column_constraints

Table 32 gpkg_data_column_constraints Table Definition SQL

```
CREATE TABLE gpkg_data_column_constraints (
  constraint_name TEXT NOT NULL,
  constraint_type TEXT NOT NULL, // 'range' | 'enum' | 'glob'
  value TEXT,
  min NUMERIC,
  minIsInclusive BOOLEAN, /* 0 = false, 1 = true */
  max NUMERIC,
  maxIsInclusive BOOLEAN,  /* 0 = false, 1 = true */
  Description TEXT,
  CONSTRAINT gdcc_ntv UNIQUE
    (constraint_name, constraint_type, value)
)
```

C.10 gpkg_metadata

Table 33 gpkg_metadata Table Definition SQL

```
CREATE TABLE gpkg_metadata (
  id INTEGER CONSTRAINT m_pk PRIMARY KEY ASC NOT NULL~~ UNIQUE~~,
  md_scope TEXT NOT NULL DEFAULT 'dataset',
  md_standard_uri TEXT NOT NULL,
  mime_type TEXT NOT NULL DEFAULT 'text/xml',
  metadata TEXT NOT NULL
)
```

C.11 gpkg_metadata_reference

Table 34 gpkg_metadata_reference Table Definition SQL

```
CREATE TABLE gpkg_metadata_reference (
  reference_scope TEXT NOT NULL,
  table_name TEXT,
  column_name TEXT,
  row_id_value INTEGER,
  timestamp DATETIME NOT NULL DEFAULT (strftime('%Y-%m-
%dT%H:%M:%fZ','now')),
  md_file_id INTEGER NOT NULL,
  md_parent_id INTEGER,
  CONSTRAINT crmr_mfi_fk FOREIGN KEY (md_file_id)
    REFERENCES gpkg_metadata(id),
  CONSTRAINT crmr_mpi_fk FOREIGN KEY (md_parent_id)
    REFERENCES gpkg_metadata(id)
)
```

Table 35 EXAMPLE: gpkg_metadata_reference SQL insert statement (Informative)

```
INSERT INTO gpkg_metadata_reference VALUES (
'table',
```

```
'sample_rasters',
NULL,
NULL,
'2012-08-17T14:49:32.932Z',
98,
99)
```

C.12 gpkg_extensions

Table 36 gpkg_extensions Table Definition SQL

```
CREATE TABLE gpkg_extensions (
  table_name TEXT,
  column_name TEXT,
  extension_name TEXT NOT NULL,
  definition TEXT NOT NULL,
  scope TEXT NOT NULL,
  CONSTRAINT ge_tce UNIQUE
    (table_name, column_name, extension_name))
```

Annex D Trigger Definition SQL (Informative)

D.1 gpkg_tile_matrix

Table 37 gpkg_tile_matrix Trigger Definition SQL

```
CREATE TRIGGER 'gpkg_tile_matrix_zoom_level_insert'
BEFORE INSERT ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''gpkg_tile_matrix'' violates
constraint: zoom_level cannot be less than 0')
WHERE (NEW.zoom_level < 0);
END

CREATE TRIGGER 'gpkg_tile_matrix_zoom_level_update'
BEFORE UPDATE of zoom_level ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''gpkg_tile_matrix'' violates
constraint: zoom_level cannot be less than 0')
WHERE (NEW.zoom_level < 0);
END

CREATE TRIGGER 'gpkg_tile_matrix_matrix_width_insert'
BEFORE INSERT ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''gpkg_tile_matrix'' violates
constraint: matrix_width cannot be less than 1')
WHERE (NEW.matrix_width < 1);
END

CREATE TRIGGER 'gpkg_tile_matrix_matrix_width_update'
BEFORE UPDATE OF matrix_width ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''gpkg_tile_matrix'' violates
constraint: matrix_width cannot be less than 1')
WHERE (NEW.matrix_width < 1);
END

CREATE TRIGGER 'gpkg_tile_matrix_matrix_height_insert'
BEFORE INSERT ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''gpkg_tile_matrix'' violates
constraint: matrix_height cannot be less than 1')
WHERE (NEW.matrix_height < 1);
END

CREATE TRIGGER 'gpkg_tile_matrix_matrix_height_update'
BEFORE UPDATE OF matrix_height ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''gpkg_tile_matrix'' violates
constraint: matrix_height cannot be less than 1')
```

```
WHERE (NEW.matrix_height < 1);
END

CREATE TRIGGER 'gpkg_tile_matrix_pixel_x_size_insert'
BEFORE INSERT ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''gpkg_tile_matrix'' violates
constraint: pixel_x_size must be greater than 0')
WHERE NOT (NEW.pixel_x_size > 0);
END

CREATE TRIGGER 'gpkg_tile_matrix_pixel_x_size_update'
BEFORE UPDATE OF pixel_x_size ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''gpkg_tile_matrix'' violates
constraint: pixel_x_size must be greater than 0')
WHERE NOT (NEW.pixel_x_size > 0);
END

CREATE TRIGGER 'gpkg_tile_matrix_pixel_y_size_insert'
BEFORE INSERT ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''gpkg_tile_matrix'' violates
constraint: pixel_y_size must be greater than 0')
WHERE NOT (NEW.pixel_y_size > 0);
END

CREATE TRIGGER 'gpkg_tile_matrix_pixel_y_size_update'
BEFORE UPDATE OF pixel_y_size ON 'gpkg_tile_matrix'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''gpkg_tile_matrix'' violates
constraint: pixel_y_size must be greater than 0')
WHERE NOT (NEW.pixel_y_size > 0);
END
```

D.2 metadata

Table 38 metadata Trigger Definition SQL

```
CREATE TRIGGER 'gpkg_metadata_md_scope_insert'
BEFORE INSERT ON 'gpkg_metadata'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table gpkg_metadata violates
constraint: md_scope must be one of undefined | fieldSession |
collectionSession | series | dataset | featureType | feature |
attributeType | attribute | tile | model | catalogue | schema |
taxonomy  software | service | collectionHardware |
nonGeographicDataset | dimensionGroup')
WHERE NOT(NEW.md_scope IN
('undefined','fieldSession','collectionSession','series','dataset',
'featureType','feature','attributeType','attribute','tile','model',
'catalogue','schema','taxonomy','software','service',
```

```
'collectionHardware','nonGeographicDataset','dimensionGroup'));
END

CREATE TRIGGER 'gpkg_metadata_md_scope_update'
BEFORE UPDATE OF 'md_scope' ON 'gpkg_metadata'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table gpkg_metadata violates
constraint: md_scope must be one of undefined | fieldSession |
collectionSession | series | dataset | featureType | feature |
attributeType | attribute | tile | model | catalogue | schema |
taxonomy | software | service | collectionHardware |
nonGeographicDataset | dimensionGroup')
WHERE NOT(NEW.md_scope IN
('undefined','fieldSession','collectionSession','series','dataset',
'featureType','feature','attributeType','attribute','tile','model',
'catalog','schema','taxonomy','software','service',
'collectionHardware','nonGeographicDataset','dimensionGroup'));
END
```

D.3 metadata_reference

Table 39 gpkg_metadata_reference Trigger Definition SQL

```
CREATE TRIGGER 'gpkg_metadata_reference_reference_scope_insert'
BEFORE INSERT ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table gpkg_metadata_reference
violates constraint: reference_scope must be one of "geopackage",
table", "column", "row", "row/col"')
WHERE NOT NEW.reference_scope IN
('geopackage','table','column','row','row/col');
END

CREATE TRIGGER 'gpkg_metadata_reference_reference_scope_update'
BEFORE UPDATE OF 'reference_scope' ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table gpkg_metadata_reference
violates constraint: referrence_scope must be one of "geopackage",
"table", "column", "row", "row/col"')
WHERE NOT NEW.reference_scope IN
('geopackage','table','column','row','row/col');
END

CREATE TRIGGER 'gpkg_metadata_reference_column_name_insert'
BEFORE INSERT ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table gpkg_metadata_reference
violates constraint: column name must be NULL  when reference_scope
is "geopackage", "table" or "row"')
WHERE (NEW.reference_scope IN ('geopackage','table','row')
AND NEW.column_name IS NOT NULL);
SELECT RAISE(ABORT, 'insert on table gpkg_metadata_reference
```

```
violates constraint: column name must be defined for the specified
table when reference_scope is "column" or "row/col"')
WHERE (NEW.reference_scope IN ('column','row/col')
AND NOT NEW.table_name IN (
SELECT name FROM SQLITE_MASTER WHERE type = 'table'
AND name = NEW.table_name
AND sql LIKE ('%' || NEW.column_name || '%')));
END

CREATE TRIGGER 'gpkg_metadata_reference_column_name_update'
BEFORE UPDATE OF column_name ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table gpkg_metadata_reference
violates constraint: column name must be NULL when reference_scope
is "geopackage", "table" or "row"')
WHERE (NEW.reference_scope IN ('geopackage','table','row')
AND NEW.column_nameIS NOT NULL);
SELECT RAISE(ABORT, 'update on table gpkg_metadata_reference
violates constraint: column name must be defined for the specified
table when reference_scope is "column" or "row/col"')
WHERE (NEW.reference_scope IN ('column','row/col')
AND NOT NEW.table_name IN (
SELECT name FROM SQLITE_MASTER WHERE type = 'table'
AND name = NEW.table_name
AND sql LIKE ('%' || NEW.column_name || '%')));
END

CREATE TRIGGER 'gpkg_metadata_reference_row_id_value_insert'
BEFORE INSERT ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table gpkg_metadata_reference
violates constraint: row_id_value must be NULL when reference_scope
is "geopackage", "table" or "column"')
WHERE NEW.reference_scope IN ('geopackage','table','column')
AND NEW.row_id_value IS NOT NULL;
SELECT RAISE(ABORT, 'insert on table gpkg_metadata_reference
violates constraint: row_id_value must exist in specified table when
reference_scope is "row" or "row/col"')
WHERE NEW.reference_scope IN ('row','row/col')
  AND NOT EXISTS (SELECT rowid
   FROM (SELECT NEW.table_name AS table_name) WHERE rowid =
NEW.row_id_value);
END

CREATE TRIGGER 'gpkg_metadata_reference_row_id_value_update'
BEFORE UPDATE OF 'row_id_value' ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table gpkg_metadata_reference
violates constraint: row_id_value must be NULL when reference_scope
is "geopackage", "table" or "column"')
WHERE NEW.reference_scope IN ('geopackage','table','column')
```

```
AND NEW.row_id_value  IS NOT NULL;
SELECT RAISE(ABORT, 'update on table gpkg_metadata_reference
violates constraint: row_id_value must exist in specified table when
reference_scope is "row" or "row/col"')
WHERE NEW.reference_scope IN ('row','row/col')
  AND NOT EXISTS (SELECT rowid
   FROM (SELECT NEW.table_name AS table_name) WHERE rowid =
NEW.row_id_value);
END

CREATE TRIGGER 'gpkg_metadata_reference_timestamp_insert'
BEFORE INSERT ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table gpkg_metadata_reference
violates constraint: timestamp must be a valid time in ISO 8601
"yyyy-mm-ddThh-:mm-:ss.cccZ" form')
WHERE NOT (NEW.timestamp GLOB
'[1-2][0-9][0-9][0-9]-[0-1][0-9]-[1 0-3][0-9]T[0-2][0-9]:[0-5][0-
9]:[0-5][0-9].[0-9][0-9][0-9]Z'
AND strftime('%s',NEW.timestamp) NOT NULL);
END

CREATE TRIGGER 'gpkg_metadata_reference_timestamp_update'
BEFORE UPDATE OF 'timestamp' ON 'gpkg_metadata_reference'
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table gpkg_metadata_reference
violates constraint: timestamp must be a valid time in ISO 8601
"yyyy-mm-ddThh-:mm-:ss.cccZ" form')
WHERE NOT (NEW.timestamp GLOB
'[1-2][0-9][0-9][0-9]-[0-1][0-9]-[1 0-3][0-9]T[0-2][0-9]:[0-5][0-
9]:[0-5][0-9].[0-9][0-9][0-9]Z'
AND strftime('%s',NEW.timestamp) NOT NULL);
END
```

D.4 sample_feature_table

Table 40 EXAMPLE: features table Trigger Definition SQL

```
CREATE TRIGGER "sample_feature_table_real_insert"
BEFORE INSERT ON "sample_feature_table"
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''sample_feature_table''
violates constraint:  real_attribute must be greater than 0')
WHERE NOT (NEW.real_attribute > 0);
END

CREATE TRIGGER "sample_feature_table_real_update"
BEFORE UPDATE OF "real_attribute" ON "sample_feature_table”
FOR EACH ROW BEGIN
SELECT RAISE (ABORT, 'update of ''real_attribute'' on table
''sample_feature_table'' violates constraint: real_attribute value
must be > 0')
```

```
WHERE NOT (NEW.real_attribute > 0);
END
```

where <t> and <c> are replaced with the names of the feature table and geometry column being inserted or updated.

D.5 sample_tile_pyramid

Table 41 EXAMPLE: tiles table Trigger Definition SQL

```
CREATE TRIGGER "sample_tile_pyramid_zoom_insert"
BEFORE INSERT ON "sample_tile_pyramid"
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''sample_tile_pyramid''
violates constraint: zoom_level not specified for table in
gpkg_tile_matrix')
WHERE NOT (NEW.zoom_level IN (SELECT zoom_level FROM
gpkg_tile_matrix WHERE table_name = 'sample_tile_pyramid')) ;
END

CREATE TRIGGER "sample_tile_pyramid_zoom_update"
BEFORE UPDATE OF zoom_level ON "sample_tile_pyramid"
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''sample_tile_pyramid''
violates constraint: zoom_level not specified for table in
gpkg_tile_matrix')
WHERE NOT (NEW.zoom_level IN (SELECT zoom_level FROM
gpkg_tile_matrix WHERE table_name = 'sample_tile_pyramid')) ;
END

CREATE TRIGGER "sample_tile_pyramid_tile_column_insert"
BEFORE INSERT ON "sample_tile_pyramid"
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''sample_tile_pyramid''
violates constraint: tile_column cannot be < 0')
WHERE (NEW.tile_column < 0) ;
SELECT RAISE(ABORT, 'insert on table ''sample_tile_pyramid''
violates constraint: tile_column must by < matrix_width specified
for table and zoom level in gpkg_tile_matrix')
WHERE NOT (NEW.tile_column < (SELECT matrix_width FROM
gpkg_tile_matrix WHERE table_name = 'sample_tile_pyramid' AND
zoom_level = NEW.zoom_level));
END

CREATE TRIGGER "sample_tile_pyramid_tile_column_update"
BEFORE UPDATE OF tile_column ON "sample_tile_pyramid"
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''sample_tile_pyramid''
violates constraint: tile_column cannot be < 0')
WHERE (NEW.tile_column < 0) ;
```

```
SELECT RAISE(ABORT, 'update on table ''sample_tile_pyramid''
violates constraint: tile_column must by < matrix_width specified
for table and zoom level in gpkg_tile_matrix')
WHERE NOT (NEW.tile_column < (SELECT matrix_width FROM
gpkg_tile_matrix WHERE table_name = 'sample_tile_pyramid' AND
zoom_level = NEW.zoom_level));
END

CREATE TRIGGER "sample_tile_pyramid_tile_row_insert"
BEFORE INSERT ON "sample_tile_pyramid"
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'insert on table ''sample_tile_pyramid''
violates constraint: tile_row cannot be < 0')
WHERE (NEW.tile_row < 0) ;
SELECT RAISE(ABORT, 'insert on table ''sample_tile_pyramid''
violates constraint: tile_row must by < matrix_height specified for
table and zoom level in gpkg_tile_matrix')
WHERE NOT (NEW.tile_row < (SELECT matrix_height FROM
gpkg_tile_matrix WHERE table_name = 'sample_tile_pyramid' AND
zoom_level = NEW.zoom_level));
END

CREATE TRIGGER "sample_tile_pyramid_tile_row_update"
BEFORE UPDATE OF tile_row ON "sample_tile_pyramid"
FOR EACH ROW BEGIN
SELECT RAISE(ABORT, 'update on table ''sample_tile_pyramid''
violates constraint: tile_row cannot be < 0')
WHERE (NEW.tile_row < 0) ;
SELECT RAISE(ABORT, 'update on table ''sample_tile_pyramid''
violates constraint: tile_row must by < matrix_height specified for
table and zoom level in gpkg_tile_matrix')
WHERE NOT (NEW.tile_row < (SELECT matrix_height FROM
gpkg_tile_matrix WHERE table_name = 'sample_tile_pyramid' AND
zoom_level = NEW.zoom_level));
END
```

Annex E Geometry Types (Normative)

Table 42 Geometry Type Codes (Core)

CODE	NAME
0	GEOMETRY
1	POINT
2	LINESTRING
3	POLYGON
4	MULTIPOINT
5	MULTILINESTRING
6	MULTIPOLYGON
7	GEOMCOLLECTION

Table 43 Geometry Type Codes (Extension)

CODE	NAME
8	CIRCULARSTRING
9	COMPOUNDCURVE
10	CURVEPOLYGON
11	MULTICURVE
12	MULTISURFACE
13	CURVE
14	SURFACE

GEOMETRY subtypes are POINT, CURVE, SURFACE and GEOMCOLLECTION.

CURVE subtypes are LINESTRING, CIRCULARSTRING and COMPOUNDCURVE.

SURFACE subtype is CURVEPOLYGON.

CURVEPOLYGON subtype is POLYGON.

GEOMCOLLECTION subtypes are MULTIPOINT, MULTICURVE and MULTISURFACE.

MULTICURVE subtype is MULTILINESTRING.

MULTISURFACE subtype is MULTIPOLYGON

Annex F Tiles Zoom Times Two Example (Informative)

Table 44 Zoom Times Two Example

table_name	zoom_level	matrix_width	matrix_height	tile_width	tile_width	pixel_x_size	pixel_y_size
“MyTiles”	0	8	8	512	512	69237.2	68412.1
“MyTiles”	1	16	16	512	512	34618.6	34206.0
“MyTiles”	2	32	32	512	512	17309.3	17103.0
“MyTiles”	3	64	64	512	512	8654.64	8654.64
“MyTiles”	4	128	128	512	512	4327.32	4275.75
“MyTiles”	5	256	256	512	512	2163.66	2137.87
“MyTiles”	6	512	512	512	512	1081.83	1068.93
“MyTiles”	7	1024	1024	512	512	540.915	534.469
“MyTiles”	8	2048	2048	512	512	270.457	267.234

Annex G Hierarchical Metadata Example (Informative)

The first example use case is from ISO19115 H.2.

Suppose we have this metadata:

```
CREATE TABLE gpkg_metadata (
  id INTEGER NOT NULL PRIMARY KEY,
  md_scope TEXT NOT NULL DEFAULT 'undefined',
  md_standard_uri TEXT NOT NULL,
  metadata TEXT NOT NULL
)
```

id	md_scope	md_standard_uri	metadata
0	undefined	http://www.isotc211.org/2005/gmd	TEXT
3	series	http://www.isotc211.org/2005/gmd	TEXT
4	dataset	http://www.isotc211.org/2005/gmd	TEXT
5	featureType	http://www.isotc211.org/2005/gmd	TEXT
6	feature	http://www.isotc211.org/2005/gmd	TEXT
7	attributeType	http://www.isotc211.org/2005/gmd	TEXT
8	attribute	http://www.isotc211.org/2005/gmd	TEXT

and this reference table definition:

```
CREATE TABLE gpkg_metadata_reference (
  reference_scope TEXT NOT NULL,
  table_name TEXT,
  column_name TEXT,
  row_id_value INTEGER,
  timestamp TEXT NOT NULL DEFAULT (strftime('%Y-%m-
%dT%H:%M:%fZ','now')),
  md_file_id INTEGER NOT NULL,
  md_parent_id INTEGER,
  CONSTRAINT crmr_mfi_fk FOREIGN KEY (md_file_id) REFERENCES
gpkg_metadata(id),
  CONSTRAINT crmr_mpi_fk FOREIGN KEY (md_parent_id) REFERENCES
gpkg_metadata(id)
)
```

H.2 1) Consider a geographic data provider generating vector mapping data for three Administrative areas(A, B and C). .. The metadata could be carried exclusively at Dataset Series level.

Then we need a record for each layer table for the three admin areas, like this:

```
INSERT INTO gpkg_metadata_reference VALUES (
'table', /* reference type */
'roads', /* table name */
```

```
'undefined', /* column_name */
-1, /* row_id_value  */
(datetime('now')),
3,  /* md_file_id  */
0  /* md_parent_id  */
)
```

H.2 2) After some time alternate vector mapping of Administrative area A becomes available. The metadata would then be extended for Administrative area A, to describe the new quality date values. These values would supersede those given for the Dataset series, but only for Administrative area A. The metadata for B and C would remain unchanged. This new metadata would be recorded at Dataset level.

Then we need a record for each layer table in "A" like this:

```
INSERT INTO gpkg_metadata_reference VALUES (
'table', /* reference type */
'roads', /* table name */
'undefined', /* column_name */
-1, /* row_id_value  */
(datetime('now')),
 4,  /* md_file_id  */
3  /* md_parent_id  */
)
```

H.2 3) Eventually further data becomes available for Administrative area A, with a complete re-survey of the road network. Again this implies new metadata for the affected feature types. This metadata would be carried at Feature type level for Administrative area A. All other metadata relating to other feature types remains unaffected. Only the metadata for roads in Administrative area A is modified. This road metadata is recorded at Feature type level.

Then we need a record for each layer table for the roads network, like this:

```
INSERT INTO gpkg_metadata_reference VALUES (
'table', /* reference type */
'roads', /* table name */
'undefined', /* column_name */
-1, /* row_id_value  */
(datetime('now')),
5,  /* md_file_id  */
4  /* md_parent_id  */
)
```

H.2 4) An anomaly in the road survey is identified, in that all Overhead clearances for the Administrative area A have been surveyed to the nearest metre. These are re-surveyed to the nearest decimetre. This re-survey implies new metadata for the affected attribute type ‘Overhead Clearance’. All other metadata for Administrative area A remains unaffected. This ‘Overhead Clearance’ metadata is recorded at Attribute Type level.

Then we need a record for each layer table in the roads network with attribute type 'Overhead Clearance', like this;

```
INSERT INTO gpkg_metadata_reference VALUES (
'column', /* reference type */
'roads', /* table name */
'overhead_clearance', /* column_name */
-1, /* row_id_value  */
(datetime('now')),
7,  /* md_file_id  */
4  /* md_parent_id  */
)
```

H.2 5) A new bridge is constructed in Administrative area A. This new data is reflected in the geographic data for Administrative area A, and new metadata is required to record this new feature. All other metadata for Administrative area A remains unaffected. This new feature metadata is recorded at Feature instance level.

Then we need a record for the bridge layer table row for the new bridge, like this:

```
INSERT INTO gpkg_metadata_reference VALUES (
'row', /* reference type */
'bridge', /* table name */
'undefined', /* column_name */
987, /* row_id_value  */
(datetime('now')),
6,  /* md_file_id  */
4  /* md_parent_id  */
)
```

H.2 6) The overhead clearance attribute of the new bridge was wrongly recorded, and is modified. Again this new attribute requires new metadata to describe the modification. All other metadata for Administrative area A remains unaffected. This new attribute metadata is recorded at Attribute instance level.

Then we need a record for the clearance attribute value, like this:

```
INSERT INTO gpkg_metadata_reference VALUES (
'row/col', /* reference type */
'bridge', /* table name */
'overhead_clearance', /* column_name */
987, /* row_id_value  */
(datetime('now')),
8,  /* md_file_id  */
4  /* md_parent_id  */
)
```

The second example use case is for a field data collection session. This use case demonstrates a mechanism to indicate which data in a GeoPackage that was originally loaded with data

from one or more services has been collected or updated since the initial load, and therefore MAY need to be uploaded to update the original services (e.g. WFS, WCS, WMTS).

Suppose a user with a mobile handheld device goes out in the field and collects observations of a new "Point of Interest" (POI) feature type, and associated metadata about the field session, the new feature type, some POI instances and some of their attributes (e.g. spatial accuracy, attribute accuracy) that results in the following additional metadata:

id	md_scope	md_standard_uri	metadata
1	fieldSession	http://www.isotc211.org/2005/gmd	TEXT
10	featureType	http://www.isotc211.org/2005/gmd	TEXT
11	feature	http://www.isotc211.org/2005/gmd	TEXT
12	attribute	http://www.isotc211.org/2005/gmd	TEXT
13	attribute	http://www.isotc211.org/2005/gmd	TEXT
14	feature	http://www.isotc211.org/2005/gmd	TEXT
15	attribute	http://www.isotc211.org/2005/gmd	TEXT
16	attribute	http://www.isotc211.org/2005/gmd	TEXT
17	feature	http://www.isotc211.org/2005/gmd	TEXT
18	attribute	http://www.isotc211.org/2005/gmd	TEXT
19	attribute	http://www.isotc211.org/2005/gmd	TEXT

(This example assumes that the field session data is still considered "raw" and won't be considered a data set or part of a data series until it has been verified and cleaned, but if that is wrong then additional series and data set metadata could be added.)

Then we need a gpkg_metadata_reference record for the field session for the new POI table, whose md_parent_id is undefined:

```
INSERT INTO gpkg_metadata_reference VALUES (
'table', /* reference type */
'poi', /* table name */
'undefined', /* column_name */
-1, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
1,  /* md_file_id  */
0  /* md_parent_id  */
)
```

Then we need a gpkg_metadata_reference record for the feature type for the new POI table, whose md_parent_id is that of the field session:

```
INSERT INTO gpkg_metadata_reference VALUES (
'table', /* reference type */
'poi', /* table name */
'undefined', /* column_name */
-1, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
10,  /* md_file_id  */
1  /* md_parent_id  */
)
```

Then we need gpkg_metadata_reference records for the poi feature instance rows, whose md_parent_id is that of the field session:

```
INSERT INTO gpkg_metadata_reference VALUES (
'row', /* reference type */
'poi', /* table name */
'undefined', /* column_name */
1, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
11,  /* md_file_id  */
1  /* md_parent_id  */
)
INSERT INTO gpkg_metadata_reference VALUES (
'row', /* reference type */
'poi', /* table name */
'undefined', /* column_name */
2, /* row_id_value  */
14,  /* md_file_id  */
1  /* md_parent_id  */
)
INSERT INTO gpkg_metadata_reference VALUES (
'row', /* reference type */
'poi', /* table name */
'undefined', /* column_name */
3, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
17,  /* md_file_id  */
1  /* md_parent_id  */
)
```

And finally we need gpkg_metadata_reference records for the poi attribute instance metadata, whose md_parent_id is that of the field session:

```
INSERT INTO gpkg_metadata_reference VALUES (
'row/col', /* reference type */
'poi', /* table name */
'point', /* column_name */
1, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
12,  /* md_file_id  */
1  /* md_parent_id  */
)
INSERT INTO gpkg_metadata_reference VALUES (
'row/col', /* reference type */
'poi', /* table name */
'point', /* column_name */
2, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
15,  /* md_file_id  */
1  /* md_parent_id  */
```

```
)
INSERT INTO gpkg_metadata_reference VALUES (
'row/col', /* reference type */
'poi', /* table name */
'point', /* column_name */
3, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
18,  /* md_file_id  */
1  /* md_parent_id  */
)
INSERT INTO gpkg_metadata_reference VALUES (
'row/col', /* reference type */
'poi', /* table name */
'category', /* column_name */
1, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
13,  /* md_file_id  */
1  /* md_parent_id  */
)
INSERT INTO gpkg_metadata_reference VALUES (
'row/col', /* reference type */
'poi', /* table name */
'category', /* column_name */
2, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
16,  /* md_file_id  */
1  /* md_parent_id  */
)
INSERT INTO gpkg_metadata_reference VALUES (
'row/col', /* reference type */
'poi', /* table name */
'category', /* column_name */
3, /* row_id_value  */
(strftime('%Y-%m-%dT%H:%M:%fZ','now')),
19,  /* md_file_id  */
1  /* md_parent_id  */
)
```

As long as all metadata collected in the field session either directly (as above) or indirectly (suppose there were a data set level metadata_reference record intermediary) refers to the field session metadata via md_parent_id values, then this chain of metadata references identifies the newly collected information, as Joan requested, in addition to the metadata.

So here is the data after both examples:

xml_metadata

id	md_scope	md_standard_uri	metadata
0	undefined	http://www.isotc211.org/2005/gmd	TEXT
1	fieldSession	http://www.isotc211.org/2005/gmd	TEXT
2	collectionSession	http://www.isotc211.org/2005/gmd	TEXT

3	series	http://www.isotc211.org/2005/gmd	TEXT
4	dataset	http://www.isotc211.org/2005/gmd	TEXT
5	featureType	http://www.isotc211.org/2005/gmd	TEXT
6	feature	http://www.isotc211.org/2005/gmd	TEXT
7	attributeType	http://www.isotc211.org/2005/gmd	TEXT
8	attribute	http://www.isotc211.org/2005/gmd	TEXT
10	featureType	http://www.isotc211.org/2005/gmd	TEXT
11	feature	http://www.isotc211.org/2005/gmd	TEXT
12	attribute	http://www.isotc211.org/2005/gmd	TEXT
13	attribute	http://www.isotc211.org/2005/gmd	TEXT
14	feature	http://www.isotc211.org/2005/gmd	TEXT
15	attribute	http://www.isotc211.org/2005/gmd	TEXT
16	attribute	http://www.isotc211.org/2005/gmd	TEXT
17	feature	http://www.isotc211.org/2005/gmd	TEXT
18	attribute	http://www.isotc211.org/2005/gmd	TEXT
19	attribute	http://www.isotc211.org/2005/gmd	TEXT

gpkg_metadata_reference

reference_type	table_name	column_name	row_id_value	timestamp	md_file_id	md_parent_id
table	roads	undefined	0	ts	3	0
table	roads	undefined	0	ts	4	3
table	roads	undefined	0	ts	5	4
column	roads	overhead_clearance	0	ts	7	4
row	bridge	undefined	987	ts	6	4
row/col	bridge	overhead_clearance	987	ts	8	4
table	poi	undefined	0	ts	1	0
row	poi	undefined	0	ts	10	1
row	poi	undefined	1	ts	11	1
row	poi	undefined	2	ts	14	1
row/col	poi	undefined	3	ts	17	1
row/col	poi	point	1	ts	12	1
row/col	poi	point	2	ts	15	1
row/col	poi	point	3	ts	18	1
row/col	poi	category	1	ts	13	1
row/col	poi	category	2	ts	16	1
row/col	poi	category	3	ts	19	1

Annex H Raster or Tile Metadata Example (Informative)

A number of raster image processing problems MAY require the support of more metadata that is contained in the image itself. Applications MAY use the gpkg_metadata and gpkg_metadata_reference tables defined in clause 1.2.5 to store raster image metadata defined according to standard authoritative or application or vendor specific metadata models. An example of the data items in such a model is shown in the following table.

- Rational Polynomial Coefficient
- Photometric Interpretation
- No Data Value
- Compression Quality Factor
- Georectification
- NIIRS
- Min X
- Min Y
- Max X
- Max Y

Annex I GeoPackage Extension Template (Normative)[1]

Extension Title

Title of the Extension

Introduction

Description of extension

Extension Author

Author of extension, author_name.

Extension Name or Template

Name of the extension or definition of the template to create the name of extensions that should be used in gpkg_extensions

Extension Type

"Extension of **Existing** Requirement in Clause(s) XXX" or

"**New** Requirement Dependent on Clause(s) YYY"

Applicability

Tables and/or columns on which this extension may be applied

Scope

Read-write or write-only with clarification if necessary

Requirements

Definition of extension and interdependencies with other extensions if any.

GeoPackage

Definition of extension data or MIME type(s)
Definition of extension tables or table templates
Definition of triggers or trigger templates

GeoPackage SQLite Configuration

[1] This template was used to create the following annexes. The form and outline heading numbering are irrelevant. ASCII output document format is preferred for inclusion in the gpkg_extensions definition column.

Definition of SQLite configuration settings

Setting compile or runtime	Option	Shall / Not (Value)	Discussion

GeoPackage SQLite Extension

Definition of SQL functions

SQL Function	Description	Use
foo(bar, baz) : datatype	Returns r when w	

Annex J GeoPackage Geometry Types Extension Template (Normative)

Extension Title

GeoPackage Non-Linear Geometry Types

Introduction

Clause 2.1.4 of the GeoPackage Version 1 Encoding Standard specifies support for the Geometry, Point, LineString, Polygon, MultiPoint, MultiLineString, MultiPolygon, and GeomCollection geometry types in the GeoPackageBinary geometry encoding format specified in clause 2.1.3. This extension specifies support for the additional CircularString, CompoundCurve, CurvePolygon, MultiCurve, MultiSurface, Curve, and Surface geometry types in the GeoPackage Binary geometry encoding format using the codes listed in Annex D.

Extension Author

GeoPackage SWG, author_name "gpkg"

Extension Name or Template

Extension names are constructed from the gpkg_geom_<gname> template where <gname> is the uppercase name of the extension geometry type in Annex D Table 52?

Extension Type

Extension of **Existing** Requirement in clause 2.1.4.

Applicability

This extension applies to any column specified in the gpkg_geometry_columns table.

Scope

Read-write

Requirements

GeoPackage

The GeoPackageBinary geometry encoding format specified in clause 2.1.3 SHALL be used to encode non-linear geometry types using the type codes in Annex E Table 43.

GeoPackage SQLite Configuration

None

GeoPackage SQLite Extension

SQL functions that operate on GeoPackageBinary geometries as specified in other extensions SHALL operate correctly on the non-linear geometries specified in this extension.

Annex K User-Defined Geometry Types Extension Template (Normative)

Extension Title

User Defined Geometry Types Extension of GeoPackageBinary Geometry Encoding

Introduction

This extension specifies a standard way to implement user defined extensions of the GeoPackageBinary geometry encoding format to encode geometry types not specified in clauses 2.1.4 and 3.1.1 and listed in Annex D. It is intended to be a bridge to enable use of geometry types like EllipiticalCurve in Extended GeoPackages until standard encodings of such types are developed and published for the Well Known Binary (WKB) format.

Extension Author

Name of implementer, author_name NOT "gpkg".

Extension Name or Template

Extension names are constructed from the <author_name>_geom_<gname> template where <gname> is the uppercase name of an extension geometry type NOT in Annex E.

Extension of Existing or New Requirement

Extension of **Existing** Requirements in clauses 2.1.3, 2.1.4, 2.1.5 and 3.1.1.

Applicability

This extension applies to any column specified in the gpkg_geometry_columns table.

Scope

Read-write

Requirements

This extension specifies use of an ExtendedGeoPackageBinary encoding format for geometry types not listed in Annex E, and use of the extension name in uppercase for the geometry_type_name column value in the gpkg_geometry_columns table.

GeoPackage

One of the reserved bits in the GeoPackageBinary header is used to indicate the presence of the ExtendedGeopackageBinary encoding format. In the extension case a four byte sequence follows the GPB header to disambiguate various extensions. This extension_code SHOULD identify the implementer of the extension and/or the particular geometry type extension, and

SHOULD be unique. The actual extension geometry body is not specified, but SHALL be described in the extension document.

```
ExtendedGeoPackageBinary {
  GeoPackageBinaryHeader header;  // The X bit in the header flags field
                                  // must be set to 1.
  byte[4] extension_code;  // To indicate different extensions or vendors.
                           // 0x47504B47 (GPKG in ASCII) is reserved.
  byte[] extension_specific;      // Extension specific contents
}
```

GeoPackage SQLite Configuration

None.

GeoPackage SQLite Extension

SQL functions that operate on GeoPackageBinary geometries as specified in other extensions SHALL operate correctly on user-defined geometry types encoded in the ExtendedGeopackageBinary format as specified in this extension.

Annex L Rtree Spatial Index Extension (Normative)

Extension Title

Rtree Spatial Indexes

Introduction

The rtree index extension provides a means to encode an rtree index for geometry values in a GeoPackage. An RTree index provides a significant performance advantage for searches with basic envelope spatial criteria that return subsets of the rows in a feature table with a non-trivial number (thousands or more) of rows.

Extension Author

GeoPackage SWG, author_name "gpkg".

Extension Name or Template

"gpkg_rtree_index"

Extension Type

New Requirement dependent on clauses 2.1.3 and 3.1.2.

Applicability

This extension applies to any column specified in the gpkg_geometry_columns table.

Scope

Write-only, because it does not change the result of reads, although it may improve their performance.

Requirements

This extension uses the rtree implementation provided by the SQLite R*Tree Module extension documented at http://www.sqlite.org/rtree.html.

GeoPackage

The tables below contain SQL templates with variables. Replace the following template variables with the specified values to create the required SQL statements:

<t>: The name of the feature table containing the geometry column

<c>: The name of the geometry column in <t> that is being indexed

<i>: The name of the integer primary key column in <t> as specified in Req 29:

Create Virtual Table

Rtree spatial indexes on geometry columns SHALL be created using the SQLite Virtual Table RTree extension. An application that creates a spatial index SHALL create it using the following SQL statement template:

```
CREATE VIRTUAL TABLE rtree_<t>_<c>
 USING rtree(id, minx, maxx, miny, maxy)
```

where <t> and <c> are replaced with the names of the feature table and geometry column being indexed. The rtree function id parameter becomes the virtual table 64-bit signed integer primary key id column, and the min/max x/y parameters are min- and max-value pairs (stored as 32-bit floating point numbers) for each dimension that become the virtual table data columns that are populated to create the spatial rtree index.

Load Spatial Index Values

The indexes provided by the SQLite Virtual Table RTree extension are not automatic indices. This means the index data structure needs to be manually populated, updated and queried.

Each newly created spatial index SHALL be populated using the following SQL statement

```
INSERT OR REPLACE INTO rtree_<t>_<c>
SELECT <i>, st_minx(<c>), st_maxx(<c>),
            st_miny(<c>), st_maxy(<c>)
FROM <t>;
```

where <t> and <c> are replaced with the names of the feature table and geometry column being indexed and <i> is replaced with the name of the feature table integer primary key column.

Define Triggers to Maintain Spatial Index Values

For each spatial index in a GeoPackage, corresponding insert, update and delete triggers that update the spatial index SHALL be present on the indexed geometry column. These spatial index triggers SHALL be defined as follows:

```
/* Conditions: Insertion of non-empty geometry
   Actions   : Insert record into rtree */
CREATE TRIGGER rtree_<t>_<c>_insert AFTER INSERT ON <t>
  WHEN (new.<c> NOT NULL AND NOT ST_IsEmpty(NEW.<c>))

BEGIN
  INSERT OR REPLACE INTO rtree_<t>_<c> VALUES (
    NEW.<i>,
    ST_MinX(NEW.<c>), ST_MaxX(NEW.<c>),
    ST_MinY(NEW.<c>), ST_MaxY(NEW.<c>)
  );
END;

/* Conditions: Update of geometry column to non-empty geometry
               No row ID change
```

```
   Actions   : Update record in rtree */
CREATE TRIGGER rtree_<t>_<c>_update1 AFTER UPDATE OF <c> ON <t>
  WHEN OLD.<i> = NEW.<i> AND
      (NEW.<c> NOTNULL AND NOT ST_IsEmpty(NEW.<c>))
BEGIN
    INSERT OR REPLACE INTO rtree_<t>_<c> VALUES (
      NEW.<i>,
      ST_MinX(NEW.<c>), ST_MaxX(NEW.<c>),
      ST_MinY(NEW.<c>), ST_MaxY(NEW.<c>)
    );
 END;

/* Conditions: Update of geometry column to empty geometry
               No row ID change
   Actions   : Remove record from rtree */
CREATE TRIGGER rtree_<t>_<c>_update2 AFTER UPDATE OF <c> ON <t>
  WHEN OLD.<i> = NEW.<i> AND
      (NEW.<c> ISNULL OR ST_IsEmpty(NEW.<c>))
BEGIN
   DELETE FROM rtree_<t>_<c> WHERE id = OLD.<i>;
 END;

/* Conditions: Update of any column
               Row ID change
               Non-empty geometry
   Actions   : Remove record from rtree for old rowid
               Insert record into rtree for new rowid */
CREATE TRIGGER rtree_<t>_<c>_update3 AFTER UPDATE OF <c> ON <t>
  WHEN OLD.<i> != NEW.<i> AND
      (NEW.<c> NOTNULL AND NOT ST_IsEmpty(NEW.<c>))
BEGIN
    DELETE FROM rtree_<t>_<c> WHERE id = OLD.<i>;
    INSERT OR REPLACE INTO rtree_<t>_<c> VALUES (
      NEW.<i>,
      ST_MinX(NEW.<c>), ST_MaxX(NEW.<c>),
      ST_MinY(NEW.<c>), ST_MaxY(NEW.<c>)
    );
END;

/* Conditions: Update of any column
               Row ID change
               Empty geometry
   Actions   : Remove record from rtree for old and new rowid */
CREATE TRIGGER rtree_<t>_<c>_update4 AFTER UPDATE ON <t>
  WHEN OLD.<i> != NEW.<i> AND
      (NEW.<c> ISNULL OR ST_IsEmpty(NEW.<c>))
BEGIN
    DELETE FROM rtree_<t>_<c> WHERE id IN (OLD.<i>, NEW.<i>);
END;

/* Conditions: Row deleted
```

```
   Actions   : Remove record from rtree for old rowid */
CREATE TRIGGER rtree_<t>_<c>_delete AFTER DELETE ON <t>
WHEN old.<c> NOT NULL
BEGIN
   DELETE FROM rtree_<t>_<c> WHERE id = OLD.<id>;
END;
```

where <t> and <c> are replaced with the names of the feature table and geometry column being indexed and <i> is replaced with the name of the feature table integer primary key column.

GeoPackage SQLite Configuration

Setting	Option	Shall / Not (Value)	Discussion
compile	SQLITE_ENABLE_RTREE	Shall	Rtrees are used for GeoPackage Spatial Indexes
compile	SQLITE_RTREE_INT_ONLY	Not	Rtrees with floating point values are used for GeoPackage Spatial Indexes

GeoPackage SQLite Extension

SQL Function	Description	Use
ST_IsEmpty(geom. Geometry): INTEGER	Returns 1 if geometry value is empty, 0 if not empty, NULL if geometry value is NULL.	Test if a geometry value corresponds to the empty set
ST_MinX(geom. Geometry) : REAL	Returns the minimum X value of the bounding Envelope of a Geometry	Update the spatial index on a geometry column in a feature table.
ST_MaxX(geom. Geometry) : REAL	Returns the maximum X value of the bounding Envelope of a Geometry	Update the spatial index on a geometry column in a feature table.
ST_MinY(geom. Geometry) : REAL	Returns the minimum Y value of the bounding Envelope of a Geometry	Update the spatial index on a geometry column in a feature table.
ST_MaxY(geom. Geometry) : REAL	Returns the maximum Y value of the bounding Envelope of a Geometry	Update the spatial index on a geometry column in a feature table.

The SQL functions on geometries in this SQLite Extension SHALL operate correctly on extended geometry types specified by Annex J and/or Annex K when those extensions are also implemented.

Annex M Geometry Type Triggers Extension (Normative)

Extension Title

Geometry Type Triggers

Introduction

Geometry type triggers prevent the storage of geometries of types that are not assignable from the geometry types specified in the gpkg_geometry_columns table in the geometry columns of the specified tables.

Extension Author

GeoPackage SWG, author_name "gpkg".

Extension Name or Template

"gpkg_geometry_type_trigger"

Extension Type

New Requirement dependent on clauses 2.1.3 and 3.1.2.

Applicability

This extension applies to any column specified in the gpkg_geometry_columns table.

Scope

Write-only

Requirements

The <t> and <c> template parameters in the geometry type trigger definition SQL template in the table below are to be replaced with the names of the feature table and geometry column being inserted or updated.

GeoPackage

```
CREATE TRIGGER fgti_<t>_<c> BEFORE INSERT ON '<t>'
FOR EACH ROW
BEGIN
  SELECT RAISE (ABORT, 'insert on <t> violates constraint:
ST_GeometryType(<c>) is not assignable from
gpkg_geometry_columns.geometry_type_name value')
  WHERE (SELECT geometry_type_name FROM gpkg_geometry_columns
           WHERE Lower(table_name) = Lower('<t>')
           AND   Lower(column_name) = Lower('<c>')
```

```
          AND   gpkg_IsAssignable(geometry_type_name,
                                  ST_GeometryType(NEW.<c>)) = 0;

END

CREATE TRIGGER fgtu_<t>_<c> BEFORE UPDATE OF '<c>' ON '<t>'
FOR EACH ROW
BEGIN
SELECT RAISE (ABORT,
'update of <c> on <t> violates constraint: ST_GeometryType(<c>) is not
assignable from gpkg_geometry_columns.geometry_type_name value')
WHERE (SELECT geometry_type_name FROM gpkg_geometry_columns
          WHERE Lower(table_name) = Lower('<t>')
          AND   Lower(column_name) = Lower('<c>')
          AND   gpkg_IsAssignable(geometry_type_name,
                                  ST_GeometryType(NEW.<c>)) = 0;
```

GeoPackage SQLite Configuration

None.

GeoPackage SQLite Extension

SQL Function	Description	Use
ST_GeometryType(geom. Geometry) : TEXT	Returns the WKB geometry type name of a Geometry	Check that the geometry type matches what's specified in gpkg_geometry_columns.geometry_type_name
GPKG_IsAssignable(expected_type_name TEXT, actual_type_name TEXT): INTEGER	Returns 1 if a value of type expected_type_name is the same or a super type of type actual_type_name. Returns 0 otherwise.	Determine if the expected geometry type is the same as or a super type of the actual geometry type.

The SQL functions on geometries in this SQLite Extension SHALL operate correctly on extended geometry types specified by Annex J and/or Annex K when those extensions are also implemented.

Annex N Geometry SRS_ID Triggers Extension (Normative)

Extension Title

Geometry SRS_ID Triggers

Introduction

Geometry SRS_ID triggers prevent the storage of geometries with spatial reference system identifiers that are not specified in the gpkg_geometry_columns table in the geometry columns of the specified tables.

Extension Author

GeoPackage SWG, author_name “gpkg”.

Extension Name or Template

“gpkg_srs_id_trigger”

Extension Type

New Requirement dependent on clauses 2.1.3 and 3.1.2.

Applicability

This extension applies to any column specified in the gpkg_geometry_columns table.

Scope

Write-only

Requirements

The <t> and <c> template parameters in the SRS_ID trigger definition SQL template in the table below are to be replaced with the names of the feature table and geometry column being inserted or updated

GeoPackage

```
CREATE TRIGGER fgsi_<t> _<c> BEFORE INSERT ON '<t>'
FOR EACH ROW
BEGIN
  SELECT RAISE (ABORT, 'insert on <t>violates constraint:
ST_SRID(<c>) does not match gpkg_geometry_columns.srs_id value')
  WHERE (SELECT srs_id FROM gpkg_geometry_columns
       WHERE Lower(table_name) = Lower('<t>')
```

```
      AND   Lower(column_name) = Lower('<c>')
      AND   ST_SRID(NEW.'<c>') <> srs_id) ;
END

CREATE TRIGGER fgsu_<t>_<c> BEFORE UPDATE OF '<c>' ON '<t>'
FOR EACH ROW
BEGIN
SELECT RAISE (ABORT,
'update of <c> on <t> violates constraint: ST_SRID(<c>) does not
match gpkg_geometry_columns.srs_id value')
WHERE (SELECT srs_id FROM gpkg_geometry_columns
       WHERE Lower(table_name) = Lower('<t>')
      AND   Lower(column_name) = Lower('<c>')
      AND   ST_SRID(NEW.'<c>') <> srs_id);
END
```

GeoPackage SQLite Configuration

None.

GeoPackage SQLite Extensions

SQL Function	Description	Use
ST_SRID(geom. Geometry) : INTEGER	Returns the spatial reference system id of a Geometry	Check that geometry srid matches what's specified in gpkg_geometry_columns.srid

The SQL function on geometries in this SQLite Extension SHALL operate correctly on extended geometry types specified by Annex J and/or Annex K when those extensions are also implemented.

Annex O Zoom Other Intervals Extension (Normative)

Extension Title

Zoom Other Intervals

Introduction

In a GeoPackage, zoom levels are integers in sequence from 0 to n that identify tile matrix layers in a tile matrix set that contain tiles of decreasing spatial extent and finer spatial resolution. Adjacent zoom levels immediately precede or follow each other and differ by a value of 1. Pixel sizes are real numbers in the terrain units of the spatial reference system of a tile image specifying the dimensions of the real world area represented by one pixel. Pixel sizes MAY vary by a constant factor or by different factors or intervals between some or all adjacent zoom levels in a tile matrix set. In the commonly used "zoom times two" convention, pixel sizes vary by a factor of 2 between all adjacent zoom levels, as shown in the example in Annex F.

This extension enables use of "zoom other intervals" conventions with different factors or irregular intervals with pixel sizes chosen for intuitive cartographic representation of raster data, or to coincide with the original pixel size of commonly used global image products. See WMTS [16] Annex E for additional examples of both conventions.

Extension Author

GeoPackage SWG, author_name “gpkg”.

Extension Name or Template

“gpkg_zoom_other

Extension Type

Extension of **Existing** Requirement in clause 2.2.3.

Applicability

This extension applies to any table listed in the gpkg_contents table with a data_type of “tiles”.

Scope

Read-write

Requirements

GeoPackage

The pixel_x_size and / or pixel_y_size column values in the gpkg_tile_matrix table vary by irregular intervals or by regular intervals other than a factor of two (the default) between adjacent zoom levels for a particular tile matrix set pyramid table.

GeoPackage SQLite Configuration

None

GeoPackage SQLite Extension

None

Annex P Tile Encoding WebP Extension (Normative)

Extension Title

Tile Encoding WebP

Introduction

PNG and JPEG are the default MIME types for encoding images in tile pyramid user data tables. This extension allows the use of image/x-webp as an additional encoding type.

Extension Author

GeoPackage SWG, author_name “gpkg”.

Extension Name or Template

“gpkg_webp”

Extension Type

Extension of **Existing** Requirement in clauses 2.2.4 and 2.2.5.

Applicability

This extension applies to any table listed in the gpkg_contents table with a data_type of “tiles”.

Scope

Read-write

Requirements

GeoPackage

The MIME type of values of the tile_data column in tile pyramid user data tables SHALL be image/x-webp.

GeoPackage SQLite Configuration

None

GeoPackage SQLite Extension

None

Annex Q Normative References (Normative)

The following normative documents contain provisions which, through reference in this text, constitute provisions of OGC 12-128 For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of OGC 12-128 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

[1] ISO/IEC 9075:1992 Information Technology - Database Language SQL SQL92)

[2] ISO/IEC 9075-1:2011 Information Technology - Database Language SQL - Part 1: Framework

[3] ISO/IEC 9075-2:2011 Information Technology - Database Language SQL - Part 2: Foundation

[4] ISO/IEC 9075-3:2008 Information Technology - Database Language SQL - Part 3: Call-Level Interface (SQL/CLI)

[5] SQLite (all parts) http://www.sqlite.org/ (online) http://www.sqlite.org/sqlite-doc-3071300.zip (offline)

[6] http://sqlite.org/fileformat2.html

[7] http://www.sqlite.org/formatchng.html

[8] http://www.sqlite.org/download.html

[9] OGC 06-103r4 OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 1: Common architecture Version: 1.2.1 2011-05-28 http://portal.opengeospatial.org/files/?artifact_id=25355 (also ISO/TC211 19125 Part 1)

[10] OGC 06-104r4 OpenGIS® Implementation Standard for Geographic information - Simple feature access - Part 2: SQL option Version: 1.2.1 2010-08-04 http://portal.opengeospatial.org/files/?artifact_id=25354 (also ISO/TC211 19125 Part 2)

[11] OGC 99-049 OpenGIS® Simple Features Specification for SQL Revision 1.1 May 5, 1999, Clause 2.3.8 http://portal.opengeospatial.org/files/?artifact_id=829

[12] ISO/IEC 13249-3:2011 Information technology — SQL Multimedia and Application Packages - Part 3: Spatial (SQL/MM)

[13] http://www.epsg.org/Geodetic.html

[14] http://www.epsg-registry.org/

[15] MIL_STD_2401 DoD World Geodetic System 84 (WGS84), 11 January 1994

[16] OGC 07-057r7 OpenGIS® Web Map Tile Service Implementation Standard ersion 1.0.0 2010-04-06 (WMTS) http://portal.opengeospatial.org/files/?artifact_id=35326

[17] ITU-T Recommendation T.81 (09/92) with Corrigendum (JPEG)

[18] JPEG File Interchange Format Version 1.02, September 1, 1992 http://www.jpeg.org/public/jfif.pdf

[19] IETF RFC 2046 Multipurpose Internet Mail Extensions (MIME) Part Two: Media Types http://www.ietf.org/rfc/rfc2046.txt

[20] Portable Network Graphics http://libpng.org/pub/png/

[21] MIME Media Types http://www.iana.org/assignments/media-types/index.html

[22] WebP https://developers.google.com/speed/webp/

[23] IETF RFC 3986 Uniform Resource Identifier (URI): Generic Syntax http://www.ietf.org/rfc/rfc3986.txt

[24] W3C Recommendation 26 November 2008 Extensible Markup Language (XML) 1.0 (Fifth Edition) http://www.w3.org/TR/xml/

[25] W3C Recommendation 28 October 2004 XML Schema Part 0: Primer Second Edition http://www.w3.org/TR/xmlschema-0/

[26] W3C Recommendation 28 October 2004 XML Schema Part 1: Structures Second Edition http://www.w3.org/TR/xmlschema-1/

[27] W3C Recommendation 28 October 2004 XML Schema Part 2: Datatypes Second Edition http://www.w3.org/TR/xmlschema-2/

[28] ISO 19115 Geographic information -- Metadata, 8 May 2003, with Technical Corrigendum 1, 5 July 2006

[29] ISO 8601 Representation of dates and times http://www.iso.org/iso/catalogue_detail?csnumber=40874

[30] OGC® 10-100r3 Geography Markup Language (GML) simple features profile (with technical note) http://portal.opengeospatial.org/files/?artifact_id=42729

[31] SQLite R*Tree Module http://www.sqlite.org/rtree.html

[32] OpenGIS® 01-009 Implementation Specification: Coordinate Transformation Services Revision 1.0 http://portal.opengeospatial.org/files/?artifact_id=999

Annex R Bibliography (Informative)

[B1] http://developer.android.com/guide/topics/data/data-storage.html#db

[B2] https://developer.apple.com/technologies/ios/data-management.html

[B3] http://www.epsg.org/guides/docs/G7-1.pdf

[B4] http://en.wikipedia.org/wiki/ASCII

[B5] http://www.sqlite.org/lang_createtable.html#rowid

[B6] ISO 19115-2 Geographic information -- Metadata - Part 2: Metadata for imagery and gridded data

[B7] ISO 19139: Geographic information -- Metadata -- XML schema implementation

[B8] Dublin Core Metadata Initiative http://dublincore.org/ IETF RFC 5013

[B9] ISO 15836:2009 http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=52142

[B10] Content Standard for Digital Geospatial Metadata (CSDGM)

[B11] http://www.fgdc.gov/standards/projects/FGDC-standards-projects/metadata/base-metadata/index_html

[B12] Department of Defense Discovery Metadata Specification (DDMS) http://metadata.ces.mil/mdr/irs/DDMS/

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