OGC® DOCUMENT: 16-032R3

External identifier of this OGC® document: http://www.opengis.net/doc/IS/GWML/2.2.1

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OGC WATERML 2: PART 4 - GROUNDWATERML 2 (GWML2)

STANDARD
Implementation

APPROVED

Version: 2.2.1
Submission Date: 2019-04-15
Approval Date: 2019-09-15
Publication Date: 2021-01-20
Editor: Boyan Brodaric

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I ABSTRACT

This standard describes a conceptual and logical model for the exchange of groundwater data, as well as a GML/XML encoding with examples.

II KEYWORDS

The following are keywords to be used by search engines and document catalogues.

ogcdoc, OGC document, groundwater, hydrogeology, aquifer, water well, observation, well construction, groundwater flow, groundwater monitoring, UML, GML, GroundwaterML, GWML2

III PREFACE

III.A. MOTIVATION

A significant portion of the global water supply can be attributed to groundwater resources. Effective management of such resources requires the collection, management and delivery of related data, but these are impeded by issues related to data availability, distribution, fragmentation, and heterogeneity: collected data are not all readily available and accessible, available data is distributed across many agencies in different sectors, often thematically fragmented, and similar types of data are diversely structured by the various data providers. This situation holds both within and between political entities, such as countries or states, impairing groundwater management across all jurisdictions. Groundwater data networks are an emerging solution to this problem as they couple data providers through a unified data delivery vehicle, thus reducing or eliminating distribution, fragmentation, and heterogeneity through the incorporation of standards for data access and data content. The relative maturity of OGC data access standards, such as the Web Feature Service (WFS) and Sensor Observation Service (SOS), combined with the rise of water data networks, have created a need for GroundWaterML2 (GWML2), a common groundwater data standard.

III.B. HISTORICAL BACKGROUND

Several activities have influenced the development of GWML2.

- GWML1: a GML application schema for groundwater data developed at Natural Resources Canada and used to exchange groundwater data within Canada, between Canada and the USA, and in some other international efforts (Boisvert & Brodaric, 2012).
- GWIE1: an interoperability experiment within the OGC HDWG, in which groundwater data was shared across the USA-Canada border (Brodaric & Booth, 2011).
- GW2IE: a second interoperability experiment within the OGC HDWG, that designed and tested a precursor of GroundWaterML2 (GWML2, version 2.1): a conceptual, logical, and encoding specification for the representation of core groundwater data (OGC, 2016).
- INSPIRE Data Specification on Geology — hydrogeology package: a conceptual model and GML application schema for hydrogeology (INSPIRE, 2013), with regulatory force in the European Union and for which GWML2 is expected to be an encoding candidate.

- BDLISA: the French Water Information System information models for water wells and hydrogeological features (BDLISA, 2013).

The primary goal of this standard is to capture the semantics, schema, and encoding syntax of key groundwater data, to enable information systems to interoperate with such data.

IV SECURITY CONSIDERATIONS

No security considerations have been made for this standard.

V SUBMITTING ORGANIZATIONS

The following organizations submitted this Document to the Open Geospatial Consortium (OGC):

- Geological Survey of Canada (GSC), Canada
- U.S. Geological Survey (USGS), United States of America
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
- Bureau of Meteorology (BOM), Australia
- Federation University Australia (FedUni), Australia
- Bureau de Recherches Géologiques et Minières (BRGM), France
- Salzburg University (U Salzburg), Austria

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1

SCOPE

1 SCOPE

This document is an OGC® conceptual, logical and encoding standard for GWML2, which represents key groundwater data. GWML2 is implemented as an application schema of the Geography Markup Language (GML) version 3.2.1, and re-uses entities from other GML application schema, most notably the OGC Observations & Measurements standard and the OGC/IUGS GeoSciML 4.0 (16-008) standard. GWML2 version 2.2 (this document) updates version 2.1, which was developed by the GW2IE (OGC, 2016), by importing GeoSciML 4.0 instead of GeoSciML 3.2.0, and by using TimeseriesML (15-042r3) instead of OGC WaterML2.0 part 1 — Timeseries.

GWML2 is designed to enable a variety of data exchange scenarios. These scenarios are captured by its five motivating use cases, including:

a) a commercial use-case focused on drilling water wells with knowledge of aquifers,

b) a policy use case concerned with the management of groundwater resources,

c) an environmental use-case that considers the role of groundwater in natural eco-systems,

d) a scientific use-case concerned with modeling groundwater systems, and

e) a technologic use-case concerned with interoperability between diverse information systems and associated data formats.

GWML2 is designed in three stages, each consisting of a schema that builds on the previous stages. The three schemas include:

a) **Conceptual** (UML): a technology-neutral schema denoting the semantics of the domain,

b) **Logical** (UML): a GML-specific schema that incorporates the OGC suite of standards,

c) **XML** schema (XSD): a GML syntactical encoding of the logical schema.

In addition, this standard describes general and XML-specific encoding requirements, general and XML-specific conformance tests, and XML encoding examples. The standard is designed for future extension into other non-XML encoding syntaxes, which would require each such encoding to describe the related schema, requirements and conformance classes, as well as provide examples.

The GWML2 Logical and XML schemas are organized into 6 modular packages:

a) GWML2-Main: core elements such as aquifers, their pores, and fluid bodies,

b) GWML2-Constituent: the biologic, chemical, and material constituents of a fluid body,

c) GWML2-Flow: groundwater flow within and between containers,

d) GWML2-Well: water wells, springs, and monitoring sites,

e) GWML2-WellConstruction: the components used to construct a well,

f) GWML2-AquiferTest: the elements comprising an aquifer test (e.g., a pumping test).

Altogether, the schemas and packages represent a machine-readable description of the key features associated with the groundwater domain, as well as their properties and relationships. This provides a semantics and syntax for the correct machine interpretation of the data, which promotes proper use of the data in further analysis. Existing systems can use GWML2 to 'bridge' between existing schema or systems, allowing consistency of the data to be maintained and enabling interoperability.

2

CONFORMANCE

2 CONFORMANCE

This standard has been written to be compliant with the OGC Specification Model — A Standard for Modular Specification (08-131r3). Extensions of this standard shall themselves be conformant to the OGC Specification Model.

2.1. XML IMPLEMENTATION

The XML implementation (encoding) of the conceptual and logical groundwater schemas is described using the XML Schema language and Schematron.

Requirements for **one standardization target type** are considered:

- data instances.

i.e., XML documents that encode groundwater data. As data *producing* applications should generate conformant data instances, the requirements and tests described in this standard effectively also apply to that target.

Conformance with this standard shall be checked using all the relevant tests specified in Annex A (normative) of this document. The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in ISO 19105: Geographic information — Conformance and Testing. In order to conform to this OGC encoding standard, a standardization target shall implement the core conformance class, and choose to implement any one of the other conformance classes (i.e., extensions).

All requirements-classes and conformance-classes described in this document are owned by the standard(s) identified.

2.2. USE OF VOCABULARIES

Controlled vocabularies, also known as code-lists, are used in data exchange to identify particular concepts or terms, and sometimes relationships between them. For example, an organization may define a controlled vocabulary for all observed phenomena, such as water quality parameters, that are to be exchanged between parties. Some of these definitions may be related by hierarchical relationships, such as specialization, or through other relationships such as equivalence.

GroundWaterML2.0 does not define a set of vocabularies for groundwater data exchange in this version. It is envisaged that specific communities will develop local vocabularies for data exchange within the community. Future work within the Hydrology Domain Working

Group could address standardized controlled vocabularies for the groundwater domain. Such vocabularies require a governance structure that allows changes to be made as definitions evolve, possibly using the OGC definition namespace (**http://www.opengis.net/def/gwml/2.2**), which is governed by the OGC Naming Authority (OGC-NA). The OGC-NA is responsible for processing requests to change or add new definitions to this namespace. The procedures for the OGC-NA are outlined in OGC document 09-046 (OGC-NA – Procedures) and the structure of URIs is outlined in OGC 09-048 (OGC-NA – Name type specification – definitions). Any URIs for vocabulary items (e.g. identifiers for various property values, properties, roles or other fixed labels) in this specification are included as examples only, for illustration purposes, and will not resolve, because GWML2 vocabularies are not defined. However, some such URIs in various example encodings may resolve if data providers have defined and implemented vocabularies for particular services.

The following convention has been used throughout the document to identify attributes requiring controlled vocabularies:

- In the conceptual model, such attributes are typed with a name ending by `Type` (ex: `PorosityType`); and
- In the logical model this suffix becomes `TypeTerm` (ex: `PorosityTypeTerm`).

2.3. GROUNDWATER DATA

Groundwater data conforming to this standard are encoded in GML-conformant XML documents, for this version of GWML2. It is anticipated that future versions or extensions will develop additional encodings such as JSON or RDF. The standard MIME-type and sub-type for GML data should be used to indicate the encoding choice as specified in *MIME Media Types for GML*, namely: `application/gml+xml`.

Conformance with this standard shall be checked using all the relevant tests specified in Annex A (normative) of this document. The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance are specified in the OGC Compliance Testing Policies and Procedures and the OGC Compliance Testing web site[1].

In order to conform to this OGC™ interface standard, a software implementation shall choose to implement:

1) Any one of the conformance levels specified in Annex A (normative).

All requirements-classes and conformance-classes described in this document are owned by the standard(s) identified.

[1] www.opengeospatial.org/cite

3

NORMATIVE REFERENCES

3 NORMATIVE REFERENCES

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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XML Schema — Version 1.0 (Second Edition) (2004)

4

TERMS AND DEFINITIONS

4 TERMS AND DEFINITIONS

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

This document uses the terms defined in 06-121r9, Clause 5.3, 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.

This document also uses terms defined in the OGC Standard for Modular specifications (OGC 08-131r3), also known as the ‘ModSpec’. The definitions of terms such as standard, specification, requirement, and conformance test are provided in the ModSpec.

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

4.1. coverage

Feature that acts as a function to return values from its range for any direct position within its spatial, temporal or spatiotemporal domain.

Source: ISO 19123:2005, Clause 4.17

4.2. domain feature

Feature of a type defined within a particular application domain.

Note 1 to entry: This may be contrasted with observations and sampling features, which are features of types defined for cross-domain purposes.

Source: ISO 19156:2011, Clause 4.4

4.3. element <XML>

Basic information item of an XML document containing **child elements**, **attributes** and character data.

Note 1 to entry: From the XML Information Set — each XML document contains one or more elements, the boundaries of which are either delimited by start-tags and end-tags, or, for empty

elements, by an empty-element tag. Each element has a type, identified by name, sometimes called its “generic identifier” (GI), and may have a set of attribute specifications. Each attribute specification has a name and a value.

Source: ISO 19136:2007

4.4. feature

Abstraction of a real-world phenomena.

Source: ISO 19101-1:2014, Clause 4.11

4.5. GML application schema

Application schema written in XML Schema in accordance with the rules specified in ISO 19136:2007.

Source: ISO 19136:2007

4.6. GML document

XML document with a root element that is one of the elements AbstractFeature, Dictionary or TopoComplex, specified in the GML schema or any element of a substitution group of any of these elements.

Source: ISO 19136:2007

4.7. GML schema

Schema components in the XML namespace http://www.opengis.net/gml/3.2 as specified in ISO 19136:2007.

Source: ISO 19136:2007

4.8. measurement

Set of operations having the objective of determining the value of a quantity.

Source: ISO 19101-2, Clause 4.20

4.9. observation

Act of observing a property.

Note 1 to entry: The goal of an observation may be to measure or otherwise determine the value of a property.

Source: ISO 19156:2011, Clause 4.10

4.10. observation procedure

Method, algorithm or instrument, or system which may be used in making an observation.

Source: ISO 19156:2011, Clause 4.11

4.11. observation result

Estimate of the value of a property determined through a known procedure.

Source: ISO 19156:2011

4.12. property <General Feature Model>

Facet or attribute of an object referenced by a name.

Example Abby's car has the colour red, where "colour red" is a property of the car instance.

4.13. sampled feature

The real-world domain feature of interest, such as a groundwater body, aquifer, river, lake, or sea, which is observed.

Source: ISO 19156:2011

4.14. sampling feature

Feature, such as a station, transect, section or specimen, which is involved in making observations of a domain feature.

Note 1 to entry: A sampling feature is purely an artefact of the observational strategy, and has no significance independent of the observational campaign.

Source: ISO 19156:2011, Clause 4.16

4.15. schema <XML Schema>

XML document containing a collection of schema component definitions and declarations within the same target namespace.

Example Schema components of W3C XML Schema are types, elements, attributes, groups, etc.

Note 1 to entry: The W3C XML Schema provides an XML interchange format for schema information. A single schema document provides descriptions of components associated with a single XML namespace, but several documents may describe components in the same schema, i.e., the same target namespace.

Source: ISO 19136:2007

4.16. sensor

Type of observation procedure that provides the estimated value of an observed property at its output.

Note 1 to entry: A sensor uses a combination of physical, chemical or biological means in order to estimate the underlying observed property. At the end of the measuring chain electronic devices often produce signals to be processed.

5

CONTRIBUTING ORGANIZATIONS

5 CONTRIBUTING ORGANIZATIONS

The organizations that submitted this standard are listed in **Section iv**.

The following organizations contributed to the initiation or development of this standard:

- Geological Survey of Canada (GSC), Canada
- U.S. Geological Survey (USGS), United States of America
- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
- Federation University Australia (FedUni), Australia
- Bureau of Meteorology (BOM), Australia
- European Commission, Directorate General — Joint Research Centre (JRC), European Union
- Polish Association for Spatial Information
- Polish Geological Institute (PGI), Poland
- Geological Surveys of Germany (GSG), Germany
- Salzburg University (U Salzburg), Austria
- Bureau de Recherches Géologiques et Minières (BRGM), France
- British Geological Survey (BGS), U.K.
- International Groundwater Resources Assessment Centre (IGRAC), UNESCO

6

CONVENTIONS

6 CONVENTIONS

6.1. REQUIREMENTS CLASS

Each normative statement (requirement or recommendation) in this standard is a member of a requirements class. Each requirements class is described in a discrete clause or sub-clause, and summarized using the following template:

Table 2

REQUIREMENTS CLASS: [LABEL]	
/req/{classM}	
Obligation	requirement
Target type	[artefact or technology type]
Dependency	[identifier for another requirements class]
Requirement	/req/{classM}/{reqN}
Recommendation	/req/{classM}/{recO}
Requirement	/req/{classM}/{reqP}
Requirement /Recommendation	[repeat as necessary]

All requirements in a class must be satisfied. Hence, the requirements class is the unit of re-use and dependency, and the value of a dependency requirement is another requirements class. All requirements in a dependency must also be satisfied by a conforming implementation. A requirements class may consist only of dependencies and introduce no new requirements.

6.2. REQUIREMENT

All requirements are normative, and each is presented with the following template:

Table 3

REQUIREMENT [SERIAL NUMBER]:
/req/[classM]/[reqN]
[Normative statement]

where /req/[classM]/[reqN] identifies the requirement or recommendation. The use of this layout convention allows the normative provisions of this standard to be easily located by implementers.

6.3. CONFORMANCE CLASS

Conformance to this standard is possible at a number of levels, specified by conformance classes (Annex A). Each conformance class is summarized using the following template:

Table 4

CONFORMANCE CLASS	/CONF/{CLASSM}
Dependency	[identifier for another conformance class]
Requirements	/req/{classA}
Tests	[reference to clause(s) containing tests]

All tests in a class must be passed. Each conformance class tests conformance to a set of requirements packaged in a requirements class.

W3C Schema (XSD) and ISO Schematron (SCH) files are considered as part of this standard, although available online only, due to concerns about document size. Many requirements are expressed in a single XSD or SCH file although tests are listed individually in the conformance annex (one test for XSD and one test for SCH).

Schematron files explicitly specify which requirements are being tested in the title of the schematron pattern.

<pattern id="origin_elevation">

<title>Test requirement: /req/well-xsd/origin-elevation</title>

<rule context="gwml2w:GW_Well">

<assert test="count(gwml2w:gwWellReferenceElevation/gwml2w:Elevation[gwml2w:elevationType/@xlink:href='http://www.opengis.net/req/well/origin_elevation']) = 1">A GW_Well needs at least one origin Elevation</assert>

</rule>

</pattern>

6.4. IDENTIFIERS

Each requirements class, requirement and recommendation is identified by a URI. The identifier supports cross-referencing of class membership, dependencies, and links from each conformance test to the requirements tested. In this standard, identifiers are expressed as partial URIs or paths, which can be appended to a base URI that identifies the specification as a whole in order to construct a complete URI for identification in an external context.

The URI for each requirements class has the form:

http://www.opengis.net/spec/groundwaterml/2.2/**req/[classM]**.

The URI for each requirement or recommendation has the form:

http://www.opengis.net/spec/groundwaterml/2.2/**req/[classM]/[reqN]**.

The URI for each conformance class has the form:

http://www.opengis.net/spec/groundwaterml/2.2/**conf/[classM]**.

The URI for each conformance test has the form:

http://www.opengis.net/spec/groundwaterml/2.2/**conf/[classM]/[testN]**.

6.5. EXTERNAL PACKAGE ABBREVIATIONS

Concepts from schemas defined in some other International Standards are designated with names that start with alpha codes as follow:

Table 5

GF	ISO 19109:2005 General Feature Model
GFI	ISO 19156:2011 General Feature Model Instances
TM	ISO 19108:2002 Temporal Schema, Temporal Objects
MD	ISO 19115 Metadata
CV	ISO 19123:2005 Schema for Coverage Geometry and Functions
OM	ISO 19156:2011 Observations and Measurements

DQ	ISO 19157:201X Data Quality
WML2	OGC® WaterML 2.0: Part 1- Timeseries
GW	GroundwaterML 2.0
TS	TimeseriesML

6.6. ABBREVIATED TERMS

In this document the following abbreviations and acronyms are used or introduced:

Table 6

API	Application Program Interface
GeoSciML 3.2	GeoScience Mark-up Language version 3.2
GeoSciML 4.0	GeoScience Mark-up Language version 4.0
GML	OGC Geography Mark-up Language
GWML1	Groundater Markup Language version 1.0 (Natural Resources Canada)
GWML2	Groundwater Markup Language version 2.0 (this standard)
GWML2-Main	UML Logical Model of the primary GroundWaterML2 elements (namespace http://www.opengis.net/gwml-main/2.2)
GWML2-Flow	UML Logical Model of the elements required to capture groundwater flow (namespace http://www.opengis.net/gwml-flow/2.2)
GWML2-Constituent	UML Logical Model of the groundwater fluid body constituents and their relationships (namespace http://www.opengis.net/gwml-constituent/2.2)
GWML2-Well	UML Logical Model of the features and properties associated with water well (namespace http://www.opengis.net/gwml-well/2.2)
GWML2-WellConstruction	UML Logical Model of the well drilling and construction details (namespace http://www.opengis.net/gwml-wellconstruction/2.2)
GWML2-AquiferTest	UML Logical Model of the features and properties associated with aquifer test (namespace http://www.opengis.net/gwml-aquifertest/2.2)
INSPIRE	Infrastructure for Spatial Information in the European Community (Directive 2007/2/EC)
ISO	International Organization for Standardization

IUGS	International Union of Geological Sciences
NACSN	North American Commission on Stratigraphic Nomenclature
NADM	North American geological Data Model
OGC	Open Geospatial Consortium
O&M	OGC Observations and Measurements Conceptual Model
OMXML	Observations and Measurements XML Implementation
SensorML	Sensor Model Language
SOS	Sensor Observation Service
SWE	Sensor Web Enablement
TSML	TimeseriesML
UML	Unified Modeling Language
UTC	Coordinated Universal Time
URI	Universal Resource Identifier
URL	Universal Resource Locator
WML2	WaterML 2.0 – Part 1
XML	Extensible Markup Language
XSD	W3C XML Schema Definition Language

6.7. UML NOTATION

The diagrams that appear in this standard, including the GWML2 Conceptual and Logical schemas, are presented using the Unified Modeling Language (UML), in compliance with ISO/IEC 19505-2.

Note: Within the GWML2 conceptual and logical diagrams, the following color scheme is used to identify packages in some cases. This is just for information purposes.

Amber: GWML2 defined within this standard

Green and Purple: from GeoSciML 4.0

Blue: from O&M

6.8. FINDING REQUIREMENTS AND RECOMMENDATIONS

This standard is identified as http://www.opengis.net/spec/groundwaterml/2.2. For clarity, each normative statement in this standard is in one and only one place, and defined within a requirements class table and identified with a URI, whose root is the standard URI. In this standard, all requirements are associated to tests in the abstract test suite in Annex A. using the URL of the requirement as the reference identifier. Recommendations are not tested but are assigned URLs and are identified using the 'Recommendation' label in the associated requirements table.

Requirements classes are separated into their own clauses, named, and specified according to inheritance (direct dependencies). The Conformance test classes in the test suite are similarly named to establish an explicit and mnemonic link between requirements classes and conformance test classes.

7

BACKGROUND

7 BACKGROUND

7.1. TECHNICAL BASIS

This standard builds on a number of standards for encoding XML data, including:

- OMXML (10-025r1)
- sweCommon (08-094r1)
- GML ISO 19136:2007 (07-036r1)
- ISO/TS 19139:2007 (Metadata)
- W3C XSD

This standard also builds on existing schema, primarily Observations & Measurements (OMXML) and GeoSciML 4.0 (16-008). It accomplishes this by (a) extending these schemas with groundwater specializations, (b) referring to a class in these schema in order to type a named property, or © using a class from the schemas as one of the two participants in a binary relationship.

7.2. OVERVIEW OF OBSERVATIONS & MEASUREMENTS

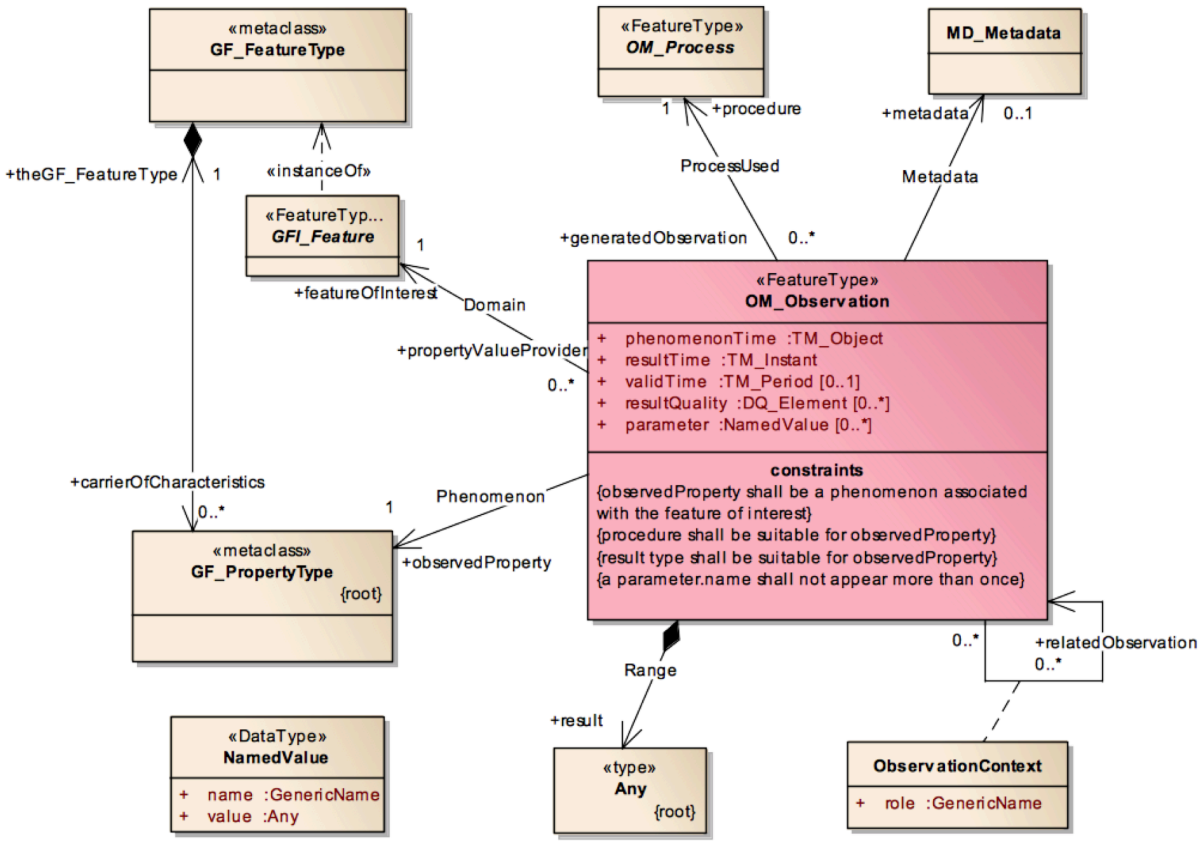
ISO 19156:2011 — Observations and Measurements is a generic GML schema for observations. As shown in Figure 1, it defines an observation as "*...an act associated with a discrete time instant or period through which a number, term or other symbol is assigned to a phenomenon. It involves application of a specified procedure, such as a sensor, instrument, algorithm or process chain. The procedure may be applied in-situ, remotely, or ex-situ with respect to the sampling location. The result of an observation is an estimate of the value of a property of some feature.*"

7.2.1. Sampling features

Sampling features in O&M are defined as a "*feature, such as a station, transect, section or specimen, which is involved in making observations concerning a domain feature.*" Sampling features in the groundwater domain are features along which, or upon, observations are made. The

most relevant are water wells and boreholes, which effectively host observations along staged intervals; a collection of these intervals and their observations constitutes a log.

Figure 1 — Observation in O&M (from ISO 19156:2011)



7.3. OVERVIEW OF GEOSCIML 4.0

GeoSciML 4.0 is a GML schema for core geological entities including geological units, structures, and earth materials. It is particularly relevant to GWML2 because bodies of rock serve as containers for subsurface water bodies. Such rock bodies possess variable hydrogeologic properties according to their material composition and topological organization. Thus, geological units and earth materials are the key GeoSciML 4.0 entities required by GWML2.

GeoSciML 4.0 defines a geological unit as "*a body of material in the Earth whose complete and precise extent is inferred to exist (NADM GeologicUnit, Stratigraphic unit in sense of NACSN or International Stratigraphic Code), or a classifier used to characterize parts of the Earth (e.g., lithologic map unit like 'granitic rock' or 'alluvial deposit', surficial units like 'till' or 'old alluvium').*"

GeoSciML 4.0 defines an earth material as "*naturally occurring substance in the Earth*" and intuitively refers to various types of rocks such as sandstone, granite, and gneiss.

8

CONCEPTUAL MODEL

8 CONCEPTUAL MODEL

The GWML2 conceptual model is designed to be technology-neutral, and focused on the semantics of the groundwater domain. It consists of five components, as well as related properties and other entities: hydrogeological units, fluid bodies, voids, fluid flow, and wells. Conceptually, these entities form a simple template for a subsurface water container: the fluid container (a unit or its materials), the fluid itself (fluid body), the spaces in the container occupied by the fluid (void), the flow of fluid within and between containers and their spaces (flow), and the natural and artificial artifacts used to withdraw, inject, or monitor fluid with respect to a container (wells, springs, monitoring sites).

Well construction details are excluded from the conceptual model, but are included in the logical model for two reasons: (1) thematic, inasmuch as well construction was considered on the periphery of groundwater science, but important to resource management as well as important to significant data exchange scenarios, and (2) practical, as it is sufficiently modeled in GWML1 and could thus be directly imported with few changes. This eliminates the need for its re-conceptualization in the GWML2 conceptual model, keeping it tightly focused.

8.1. HYDROGEOLOGICAL UNITS

These are distinct volumes of earth material that serve as containers for subsurface fluids. The boundaries of a unit are typically discriminated from those of another unit using properties related to the potential or actual ability to contain or move water. The properties can be geological or hydraulic, and typically include influences from the surrounding hydrological environment. More specifically, the conceptual model delineates two types of hydrogeological units, with slightly different orientations: aquifer-related units have boundaries delimited by the hydrogeological properties of the rock body, while groundwater basins have boundaries delimited by distinct flow regimes. Aquifer-related units are subdivided into aquifer systems, which are collections of aquifers, confining beds, and other aquifer systems. Confining beds are units that impede water flow to surrounding units, and supersede notions such as aquitards, aquicludes, and aquifuges, which are not included herein, as it is difficult to differentiate these in practice.

Several significant properties are typically attributed to hydrogeological units, such as porosity, permeability, and conductivity, but these and others are modeled more accurately here as occurring necessarily concurrent with (dependent on) voids or fluid bodies. For example, porosity, in its various forms, requires both the presence of a unit (container) and its voids, as it is typically defined as the proportion of void volume to total unit volume (i.e., volume of solid material plus voids). Likewise, properties such as hydraulic conductivity and yield require the presence of units and fluid bodies, as they are concerned with the rate of movement of a fluid through a unit. Note that permeability and hydraulic conductivity are differentiated here: permeability refers to intrinsic permeability, which measures the ability of a unit to host fluid flow, independent of fluid properties and based solely on the connectivity and size of voids, whereas hydraulic conductivity additionally considers fluid properties.

Likewise, management areas are also relational entities in the sense that they are typically necessarily linked with a unit (or system) and possibly a fluid body. Management areas are earth bodies identified for groundwater management purposes and their boundaries can be delineated by social factors, such as policy or regulation, in addition to physical factors related to hydrogeology or hydrology.

8.2. FLUID BODIES

These are distinct bodies of fluid (liquid or gas) that fill the voids in hydrogeological units. Fluid bodies are made of biologic (e.g., organisms), chemical (e.g., solutes), or material constituents (e.g., sediment). While it is expected that the major constituent of a fluid body will be water, the conceptual model allows for other types of major constituents such as petroleum. Minor constituents are not necessarily fluids, but can be gases, liquids, or solids (including organisms), and are included in the fluid body in various forms of mixture, such as solution, suspension, emulsion, and precipitates. Fluid bodies can also have other fluid bodies as parts, such as plumes or gas bubbles. Surfaces can be identified on a fluid body, such as a water table, piezometric or potentiometric surface, and some such surfaces can contain divides, which are lines projected to the fluid surface denoting divergence in the direction of flow systems within the fluid.

8.3. VOIDS

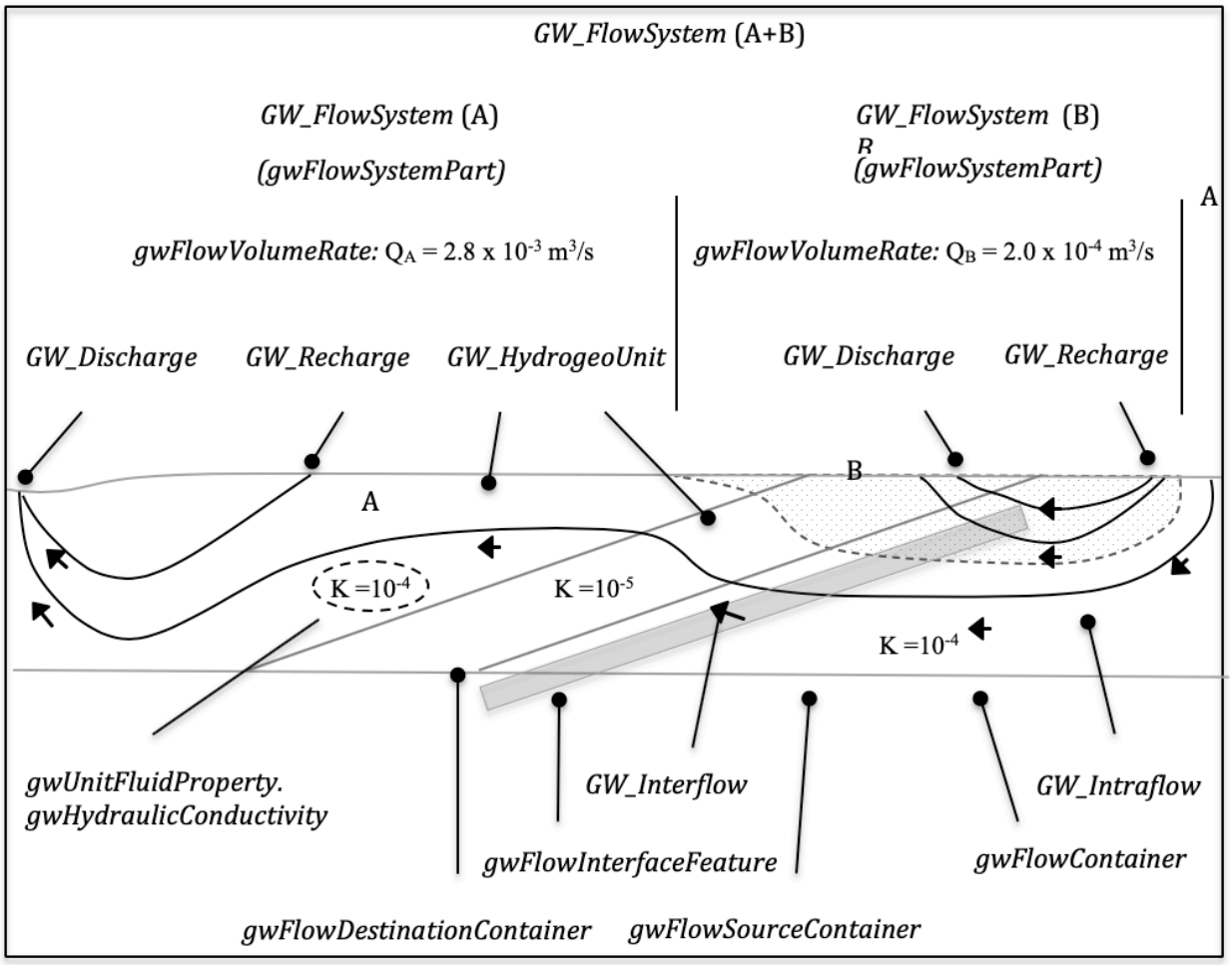
Voids are the spaces inside a unit (e.g., aquifer) or its material (e.g., the sandstone material of an aquifer), and might contain fluid bodies. Voids are differentiated from porosity, in that porosity is a ratio of void volume to total volume of unit plus voids, while voids are the spaces themselves. It is important to conceptually differentiate voids from units and their containers, in order to represent, for example, the volume of fractures, caves, or pores in a particular unit or its portion.

8.4. FLOW

Groundwater flow denotes the process by which a fluid enters or exits a container (unit) or its voids, or flows within them. Flow **between** one container or void and another is named *InterFlow*, and flow **within** a container or void is named *IntraFlow*. Recharge is the flow into a groundwater container or void, and discharge is flow out of a groundwater container or void. The reciprocal source or destination entity can be any appropriate container or void such as a river, lake, pipe, reservoir, canyon, flood plain, ground surface, etc. A flow system is then a collection of flows ordered in a sequence from recharge to discharge, such that the flow segments of the system make up a connected flow path from source to destination. A water budget is a measure of the balance of recharge and discharge valid for a specific time and relative to a specific groundwater feature, such as a basin, aquifer, management area, or well.

Many of these concepts are depicted in Figure 2. Shown is a flow system (A+B) and two subsystems (A, B) that are its parts. Each subsystem is composed of interior flows, indicated by the solid lines with arrows, as well as input and output flows indicated as recharge and discharge, respectively. These flow systems are contained by three distinct hydrogeologic unit bodies, with the middle body oriented at an angle and having a K (hydraulic conductivity) value of 10^{-5}. *Intraflow* is exemplified by a flow line within the right hydrogeologic unit body, while *Interflow* is exemplified by the flow from right body (the source container) to middle body (the destination container). The boundary between the bodies serves as the interface through which the flow occurs. While not shown, the three hydrogeologic unit bodies contain a groundwater body (i.e., a fluid body) in their pores (i.e., voids), and it is this groundwater body that is flowing.

Figure 2 — Example flow system with two subsystems (after Freeze & Cherry, 1978, p. 204)



8.5. WELLS

Well-related entities include water wells, springs, and monitoring sites. Water wells are man-made constructions for monitoring, withdrawing, or injecting water from/into a hydrogeological unit, while springs are features where water discharges to the surface naturally. Both wells and

springs possess important links to the hydrogeological environment, including their host units and materials, as well as the intersecting fluid body. Monitoring sites are locations where devices are placed to measure various properties of significance to hydrogeology, such as water level, flow rate, water temperature, or chemical composition, or to take samples. As such, monitoring sites are roles played by other features, for example, water wells or springs.

8.6. CONCEPTUAL MODEL SPECIFICATION

Figure 3 — GWML2 CM — Hydrogeological Unit

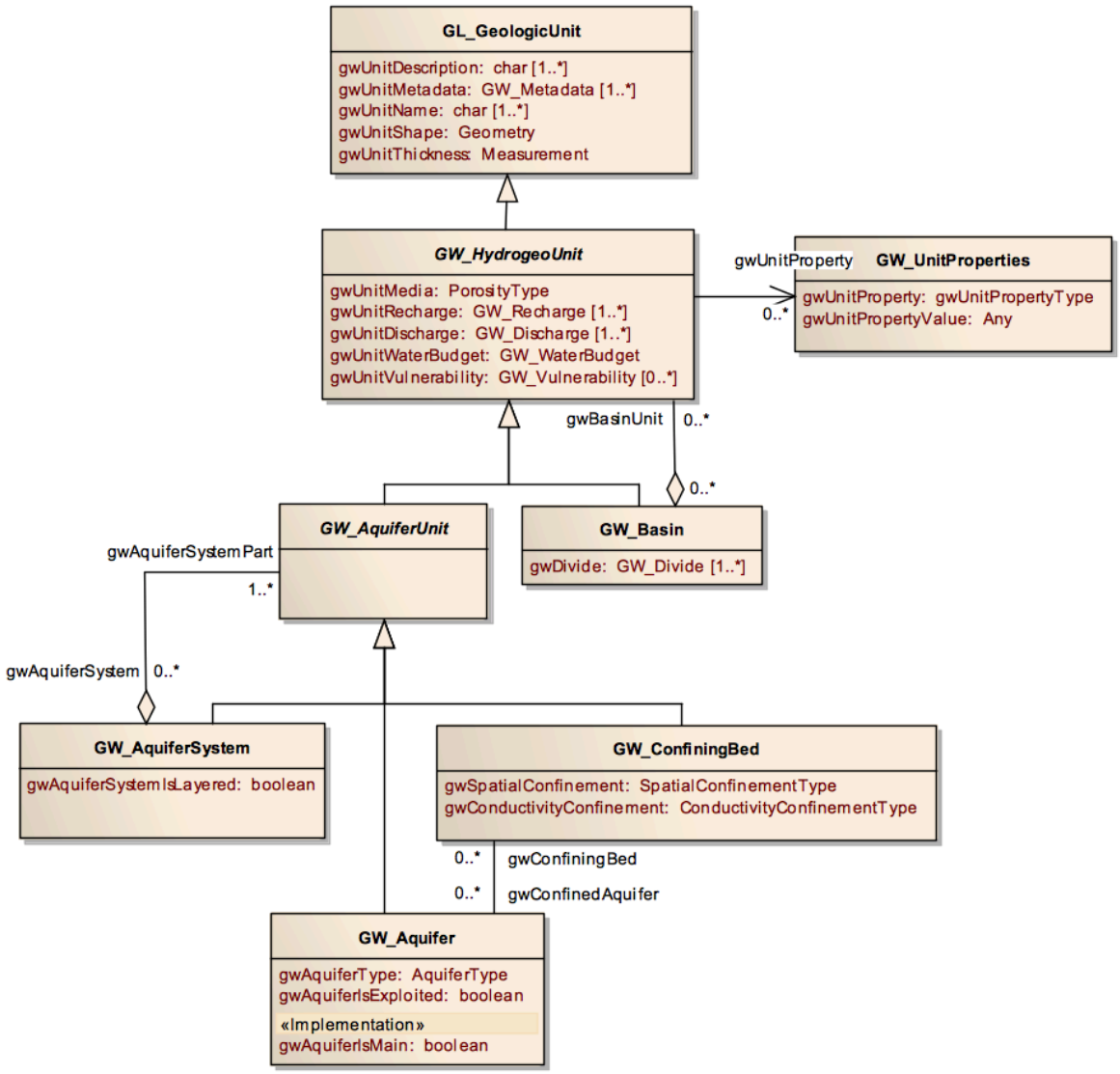


Figure 4 — GWML2 CM — Groundwater Properties

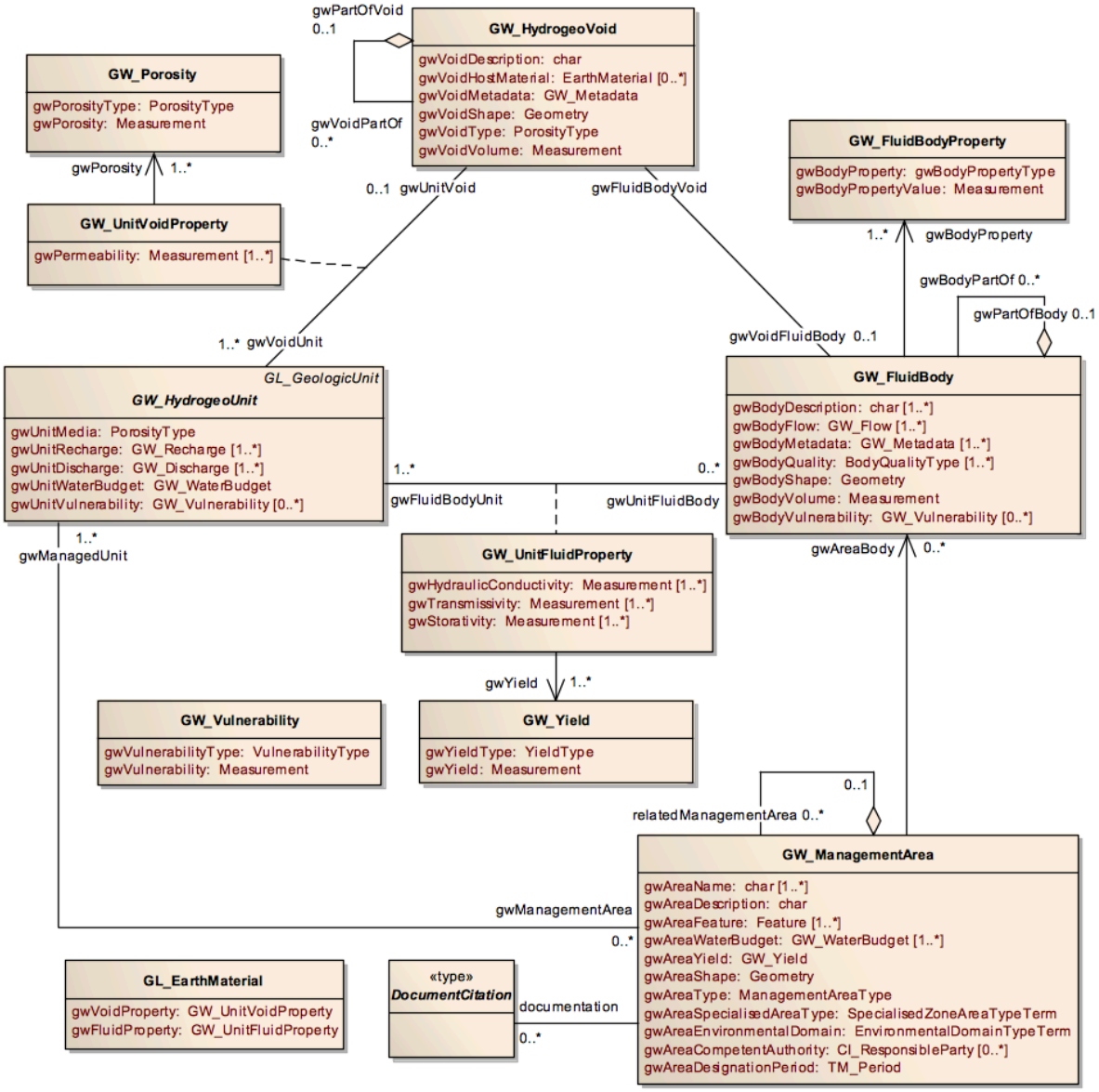


Figure 5 — GWML2 CM — Fluid Body

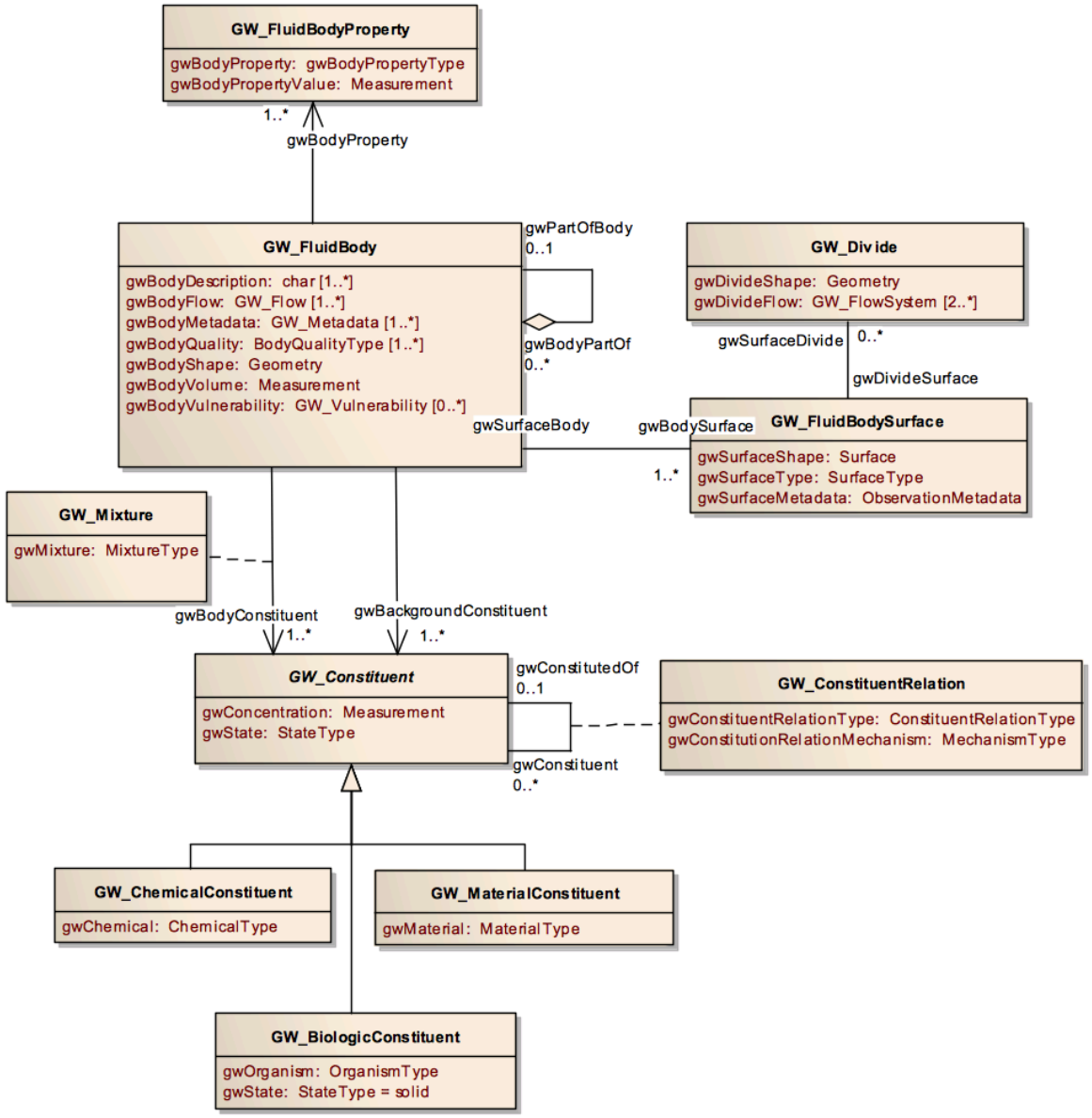


Figure 6 — GWML2 CM — Groundwater Flow

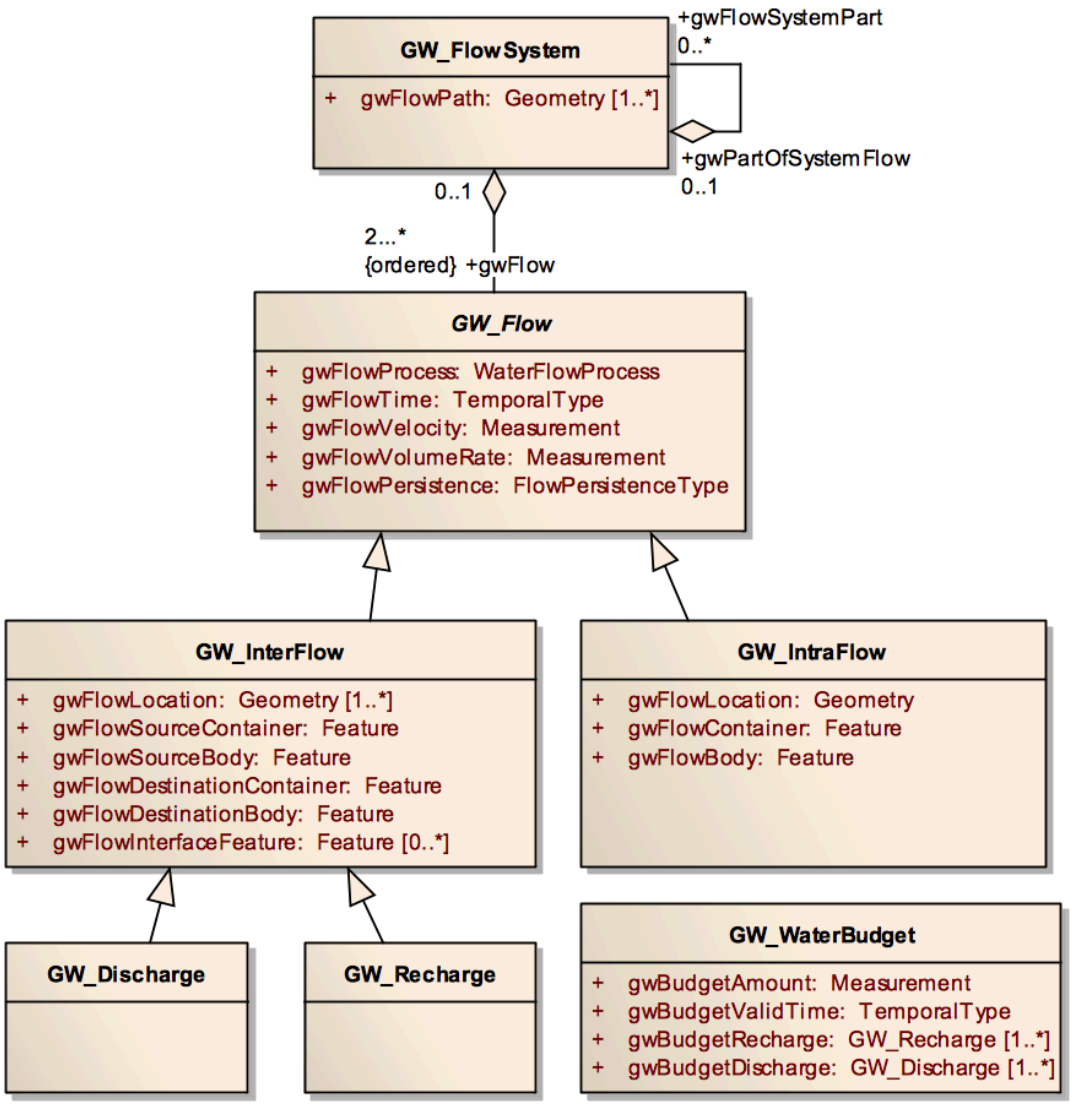


Figure 7 — GWML2 CM — Wells

8.6.1. DocumentCitation

The class DocumentCitation is abstract, and has no attributes, operations or associations. It serves as a placeholder for legislative and reference documentation for a management area. Legislative documentation refers to the legal instrument or document that required the establishment of the management area. Reference documentation might describe the environmental objectives and measures that are to be undertaken in the management area to

protect the environment (a reference to a management or action plan), licensing information, and associated maps.

The ‘Legislation References’ and ‘DocumentCitation’ classes from the INSPIRE Generic Conceptual Model are possible candidates for DocumentCitation.

Table 7

Relation	Source	Target	Description
Association	*Entity: GW_ManagementArea* *Role:*	*Entity: DocumentCitation* *Role: documentation*	Relates legislative and reference documentation to a management area.

8.6.2. Elevation

Elevation of a feature in reference to a datum.

Table 8

Attribute	Type and Multiplicity	Definition
elevation	*Geometry*	Numeric value and coordinate reference system (CRS), including the unit of measure (UoM) for the elevation.
elevationAccuracy	*PositionalAccuracyType*	Description of the accuracy of the elevation measurement.
elevationMeasurementMethod	*ElevationMeasurementMethodType*	Method used to measure the elevation, e.g., GPS, Survey, DEM, etc.
elevationType	*elevationTypeTerm*	Type of reference elevation, defined as a feature, e.g. , Top of Casing, Ground, etc.

8.6.3. GL_EarthMaterial

From GeoSciML 4.0:

Earth materials are substances, e.g., sandstone or granite, that constitute physical bodies, e.g., hydrogeological units. This class enables various hydrogeological properties to be attributed to a specific occurrence of a material, e.g., the sandstone of a specific aquifer.

Table 9

Attribute	Type and Multiplicity	Definition
gwVoidProperty	*GW_UnitVoidProperty*	The porosity or permeability of a particular earth material that hosts a void.
gwFluidProperty	*GW_UnitFluidProperty*	The hydraulic conductivity, transmissivity, or storativity of an earth material.

8.6.4. GL_GeologicUnit

From GeoSciML 4.0:

Conceptually, may represent a body of material in the Earth whose complete and precise extent is inferred to exist (NADM GeologicUnit, Stratigraphic unit in sense of NACSN or International Stratigraphic Code), or a classifier used to characterize parts of the Earth (e.g., lithologic map unit like 'granitic rock' or 'alluvial deposit', surficial units like 'till' or 'old alluvium').

Table 10

Attribute	Type and Multiplicity	Definition
gwUnitDescription	*char [1..*]*	Description of the unit.
gwUnitMetadata	*GW_Metadata [1..*]*	Metadata for the unit .
gwUnitName	*char [1..*]*	Name of the unit (common local name or formal name).
gwUnitShape	*Geometry*	The geometry of the unit.
gwUnitThickness	*Measurement*	Typical thickness of the unit.

Table 11

Relation	Source	Target	Description
Generalization	*Entity: GW_HydrogeoUnit* *Role:*	*Entity: GL_GeologicUnit* *Role:*	A hydrogeological unit is a type of geological unit.

8.6.5. GW_Aquifer

A body of earth material that contains / potentially contains / potentially contained sufficient saturated permeable material to yield significant quantities of water to wells and springs (after Lohman, 1972).

Table 12

Attribute	Type and Multiplicity	Definition
gwAquiferType	*AquiferType*	Several aquifer types can be distinguished: unconfined, confined, artesian, subartesian, or aquitard (after INSPIRE, 2013).
gwAquiferIsExploited	*boolean*	Denotes whether groundwater from the hydrogeological unit is being exploited by wells or other intakes (after INSPIRE, 2013).
gwAquiferIsMain	*boolean*	Denotes whether the unit is primary in an Aquifer System (after INSPIRE, 2013).

Table 13

Relation	Source	Target	Description
Association	*Entity: GW_Aquifer* *Role: gwConfinedAquifer*	*Entity: GW_ConfiningBed* *Role: gwConfiningBed*	Relates an aquifer and its confining beds.
Generalization	*Entity: GW_Aquifer* *Role:*	*Entity: GW_AquiferUnit* *Role:*	An aquifer is a type of aquifer-related unit.

8.6.6. GW_AquiferSystem

Aquifer system — a body of permeable and poorly permeable material that functions regionally as a water-yielding unit; it comprises two or more permeable beds separated at least locally by confining beds that impede groundwater movement but do not greatly affect the regional hydraulic continuity of the system; includes both saturated and unsaturated parts of permeable material (after ASCE, 1987).

Table 14

Attribute	Type and Multiplicity	Definition
gwAquiferSystemIsLayered	*boolean*	True if this aquifer / system is a layered

			system. (after INSPIRE, 2013).

Table 15

Relation	Source	Target	Description
Generalization	*Entity: GW_AquiferSystem* *Role:*	*Entity: GW_AquiferUnit* *Role:*	An aquifer system is a type of aquifer-related unit.
Association	*Entity: GW_AquiferSystem* *Role: gwAquiferSystem*	*Entity: GW_AquiferUnit* *Role: gwAquiferSystemPart*	Relates an aquifer system with its parts, which can be other systems, aquifers or confining beds.

8.6.7. GW_AquiferUnit

Denotes aquifer-related hydrogeological units: aquifer systems, aquifers, or confining beds.

Table 16

Relation	Source	Target	Description
Generalization	*Entity: GW_AquiferUnit* *Role:*	*Entity: GW_HydrogeoUnit* *Role:*	An aquifer unit is a type of hydrogeological unit.
Generalization	*Entity: GW_AquiferSystem* *Role:*	*Entity: GW_AquiferUnit* *Role:*	An aquifer system is a type of aquifer-related unit.
Association	*Entity: GW_AquiferSystem* *Role: gwAquiferSystem*	*Entity: GW_AquiferUnit* *Role: gwAquiferSystemPart*	Relates an aquifer system with its parts, which can be other systems, aquifers or confining beds.
Generalization	*Entity: GW_ConfiningBed* *Role:*	*Entity: GW_AquiferUnit* *Role:*	A confining bed is a type of aquifer-related unit.
Generalization	*Entity: GW_Aquifer* *Role:*	*Entity: GW_AquiferUnit* *Role:*	An aquifer is a type of aquifer-related unit.

8.6.8. GW_Basin

A large hydrogeologically defined body of ground typically consisting of hydraulically connected hydrogeological units, whose waters are flowing to a common or multiple outlets, and which is delimited by a groundwater divide.

Table 17

Attribute	Type and Multiplicity	Definition

gwDivide	*GW_Divide [1..*]*	"Line on a water table or piezometric surface on either side of which the groundwater flow diverges" (IGH0556).

Table 18

Relation	Source	Target	Description
Generalization	*Entity: GW_Basin* *Role:*	*Entity: GW_HydrogeoUnit* *Role:*	A basin is a type of hydrogeological unit.
Aggregation	*Entity: GW_Basin* *Role:*	*Entity: GW_HydrogeoUnit* *Role: gwBasinUnit*	Relates hydrogeological units and the basins that contain them, in full or part.

8.6.9. GW_BiologicConstituent

Characterisation of the biological composition of the fluid body, both natural and man-made.

Table 19

Attribute	Type and Multiplicity	Definition
gwOrganism	*OrganismType*	Biological species.
gwState	*StateType solid*	Organisms are always solids.

Table 20

Relation	Source	Target	Description
Generalization	*Entity: GW_BiologicConstituent* *Role:*	*Entity: GW_Constituent* *Role:*	A biologic constituent is a type of fluid body constituent. There are 3 types of fluid body constituents: chemical (e.g., arsenic), biologic (e.g., organisms), and material (e.g., sediment).

8.6.10. GW_ChemicalConstituent

Characterisation of the chemical composition of the fluid body, both natural and man-made.

Table 21

Attribute	Type and Multiplicity	Definition
gwChemical	*ChemicalType*	Chemical component type, e.g., arsenic.

Table 22

Relation	Source	Target	Description
Generalization	*Entity: GW_ChemicalConstituent* *Role:*	*Entity: GW_ Constituent* *Role:*	A chemical constituent is a type of fluid body constituent. The 3 types of fluid body constituent are: chemical (e.g., arsenic), biologic (e.g., organisms), and material (e.g., sediment).

8.6.11. GW_ConfiningBed

A layer of rock having very low porosity and in consequence hydraulic conductivity that hampers the movement of water into and out of an aquifer (Heath, 1983).

Table 23

Attribute	Type and Multiplicity	Definition
gwSpatialConfinement	*SpatialConfinementType*	Degree of spatial confinement (typically: "Unconfined-Confined", "Partially Confined").
gwConductivityConfinement	*ConductivityConfinementType*	Degree of hydraulic confinement (e.g., aquiclude).

Table 24

Relation	Source	Target	Description
Association	*Entity: GW_Aquifer* *Role: gwConfinedAquifer*	*Entity: GW_ConfiningBed* *Role: gwConfiningBed*	Relates an aquifer and its confining beds.
Generalization	*Entity: GW_ConfiningBed* *Role:*	*Entity: GW_AquiferUnit* *Role:*	A confining bed is a type of aquifer-related unit.

8.6.12. GW_Constituent

General (abstract) entity denoting a material, chemical or biological constituent of a fluid body.

Table 25

Attribute	Type and Multiplicity	Definition
gwConcentration	*Measurement*	The concentration of the constituent in the fluid body.
gwState	*StateType*	The physical state of the constituent, i.e., solid, liquid, or gas.

Table 26

Relation	Source	Target	Description
Association	*Entity: GW_FluidBody* *Role:*	*Entity: GW_Constituent* *Role: gwBackgroundConstituent*	Relates a fluid body to typical background constituent values for that body.
AssociationClass	*Entity: GW_Constituent* *Role: gwConstituent*	*Entity: GW_Constituent* *Role: gwConstitutedOf*	A general binary relation between constituents, in which the relation type can be specified in addition to the causal mechanism that caused the relationship.
Generalization	*Entity: GW_BiologicConstituent* *Role:*	*Entity: GW_Constituent* *Role:*	A biologic constituent is a type of fluid body constituent. There are 3 types of fluid body constituents: chemical (e.g., arsenic), biologic (e.g., organisms), and material (e.g., sediment).
Generalization	*Entity: GW_ChemicalConstituent* *Role:*	*Entity: GW_Constituent* *Role:*	A chemical constituent is a type of fluid body constituent. There

			are 3 types of fluid body constituents: chemical (e.g., arsenic), biologic (e.g., organisms), and material (e.g., sediment).
Generalization	*Entity: GW_MaterialConstituent* *Role:*	*Entity: GW_Constituent* *Role:*	A material constituent is a type of fluid body constituent. There are 3 types of fluid body constituents: chemical (e.g., arsenic), biologic (e.g., organisms), and material (e.g., sediment).
AssociationClass	*Entity: GW_FluidBody* *Role:*	*Entity: GW_Constituent* *Role: gwBodyConstituent*	Relates a fluid body to its chemical, biologic, or material constituents, and specifies the nature of the mixture of the constituent within the body, e.g., solution, suspension.

8.6.13. GW_ConstituentRelation

Relation between fluid body components, typically caused by a specific mechanism, e.g., coating (from adsorption), constitution (from chemical bonding forming a new material), aggregation (from physical bonding, e.g., pressure), containment (from absorption, digestion).

Table 27

Attribute	Type and Multiplicity	Definition
gwConstituentRelationType	*ConstituentRelationType*	Specific type of relation between fluid body components, e.g. , coating, constitution, aggregation, containment.
gwConstitutionRelationMechanism	*MechanismType*	Mechanisms by which materials (of various states) come into a relationship, e.g.,

sorption, precipitation, digestion, excretion, etc.

8.6.14. GW_Discharge

An outflow of fluid from a container such as an aquifer, watershed, pipe.

Table 28

Relation	Source	Target	Description
Generalization	*Entity: GW_Discharge* *Role:*	*Entity: GW_InterFlow* *Role:*	Discharge is a type of interflow in which fluid exits a feature.

8.6.15. GW_Divide

“A line on a water table or piezometric surface, on either side of which the groundwater flow diverges” (IGH0556).

Table 29

Attribute	Type and Multiplicity	Definition
gwDivideShape	*Geometry*	Shape / position of the divide (line, plane or point) intersecting a fluid body surface.
gwDivideFlow	*GW_FlowSystem [2..*]*	Flow system on each side of the divide.

Table 30

Relation	Source	Target	Description
Association	*Entity: GW_Divide* *Role: gwSurfaceDivide*	*Entity: GW_FluidBodySurface* *Role: gwDivideSurface*	Relates a fluid body surface to a line on e.g., a water table or piezometric surface, on either side of which the groundwater flow diverges.

8.6.16. GW_Flow

Process by which the fluid enters or exits a hydrogeological unit or a void, or flows within a unit or a void. Can flow from/to other natural or man-made features such as rivers, filtration stations, etc.

Table 31

Attribute	Type and Multiplicity	Definition
gwFlowProcess	*WaterFlowProcess*	The process causing the flow, e.g., evapotranspiration, evaporation, transpiration, runoff, baseflow, pumping, infiltration, injection, etc.
gwFlowTime	*TemporalType*	Refers to the duration, instant or interval of the flow (actual time, not observation time). E.g., "yearly", "summer", "2009" or "2009-2011".
gwFlowVelocity	*Measurement*	Measure of length traveled per time period.
gwFlowVolumeRate	*Measurement*	Measure of water quantity per time period.
gwFlowPersistence	*FlowPersistenceType*	The regularity of flow occurrence, e.g., ephemeral, intermittent, perennial, seasonal. After http://inspire.ec.europa.eu/codeList/WaterPersistenceValue/ (INSPIRE, 2013).

Table 32

Relation	Source	Target	Description
Generalization	*Entity: GW_InterFlow Role:*	*Entity: GW_Flow Role:*	An interflow is a type of directed flow between two features, e.g., flow between two units.
Generalization	*Entity: GW_IntraFlow Role:*	*Entity: GW_Flow Role:*	An intraflow is a type of flow within a single feature, e.g., flow within a unit.
Aggregation	*Entity: GW_FlowSystem Role:*	*Entity: GW_Flow Role: gwFlow*	Relates a flow system to the individual flows that comprise the system. Flows are atomic entities that cannot have parts, but which form parts of flow systems.

8.6.17. GW_FlowSystem

Flow path from recharge to discharge location, through hydrogeological units. It is related to a fluid body, and consists of a collection or aggregation of at least two specific flows, as well as possibly other flow systems.

Table 33

Attribute	Type and Multiplicity	Definition
gwFlowPath	*Geometry [1..*]*	The path of flow of a fluid through a container.

Table 34

Relation	Source	Target	Description
Association	*Entity: GW_FlowSystem* *Role: gwFlowSystemPart*	*Entity: GW_FlowSystem* *Role: gwPartOfSystemFlow*	Relates a flow system part to a flow system whole.
Aggregation	*Entity: GW_FlowSystem* *Role:*	*Entity: GW_Flow* *Role: gwFlow*	Relates a flow system to the individual flows that comprise the system. Flows are atomic entities that cannot have parts, but which form parts of flow systems.

8.6.18. GW_FluidBody

A distinct body of some fluid (liquid, gas) that fills the voids of a container such as an aquifer, system of aquifers, water well, etc. In hydrogeology this body is usually constituted by groundwater, but the model allows for other types of fillers e.g., petroleum.

Table 35

Attribute	Type and Multiplicity	Definition
gwBodyDescription	*char [1..*]*	General description of the fluid body
gwBodyFlow	*GW_Flow [1..*]*	Flows associated with the fluid body.
gwBodyMetadata	*GW_Metadata [1..*]*	Metadata about the fluid body.

gwBodyQuality	*BodyQualityType [1..*]*	Categorical assessment of quality of the fluid body as a whole: e.g., saline, brackish, fresh, turbide, sulfurous, mixed, … 1000-3000mg/l tds, etc. A normative quality description is an assesment based upon some guideline edited by a government or a quality standard.
gwBodyShape	*Geometry*	Shape and position of the fluid body.
gwBodyVolume	*Measurement*	Description of the volume/quantity of a fluid present in a container at a certain time.
gwBodyVulnerability	*GW_Vulnerability [0..*]*	The susceptibility of the fluid body to specific threats such as surface contamination, etc.

Table 36

Relation	Source	Target	Description
Association	*Entity: GW_HydrogeoVoid* *Role: gwFluidBodyVoid*	*Entity: GW_FluidBody* *Role: gwVoidFluidBody*	Relates a void and a fluid body contained by the void. Each void contains at most one fluid body, which can have multiple parts that could be disconnected. Likewise, each fluid body is contained by a single void, which could be an aggregation of disconnected void parts.
Association	*Entity: GW_ManagementArea* *Role:*	*Entity: GW_FluidBody* *Role: gwAreaBody*	Relates a management area to the fluid bodies contained within the area. As with units, the spatial boundaries of management areas do not necessarily coincide with the spatial boundaries of fluid bodies.
Association	*Entity: GW_FluidBodySurface* *Role: gwBodySurface*	*Entity: GW_FluidBody* *Role: gwSurfaceBody*	Relates a fluid body to a surface hosted by the body, e.g., the top of the water table.

Aggregation	*Entity: GW_FluidBody* *Role: gwPartOfBody*	*Entity: GW_FluidBody* *Role: gwBodyPartOf*	Relates a fluid body part to a fluid body whole.
AssociationClass	*Entity: GW_HydrogeoUnit* *Role: gwFluidBodyUnit*	*Entity: GW_FluidBody* *Role: gwUnitFluidBody*	Relates hydrogeological units and the fluid bodies contained by the units.
Association	*Entity: GW_FluidBody* *Role:*	*Entity: GW_FluidBodyProperty* *Role: gwBodyProperty*	Relates a fluid body to additional properties such as age, temperature, density, viscosity, turbidity, color, hardness, acidity, etc.
Association	*Entity: GW_FluidBody* *Role:*	*Entity: GW_Constituent* *Role: gwBackgroundConstituent*	Relates a fluid body to typical background constituent values for that body.
AssociationClass	*Entity: GW_FluidBody* *Role:*	*Entity: GW_Constituent* *Role: gwBodyConstituent*	Relates a fluid body to its chemical, biologic, or material constituents, and specifies the nature of the mixture of the constituent within the body, e.g., solution, suspension.

8.6.19. GW_FluidBodyProperty

Additional properties that characterize a fluid body. Can include synoptic values for the whole body or location-specific observations such as age, temperature, density, viscosity, turbidity, color, hardness, acidity, etc.

Table 37

Attribute	Type and Multiplicity	Definition
gwBodyProperty	*gwBodyPropertyType*	Type of fluid body property, e.g., age, temperature, density, viscosity, turbidity, color, hardness, acidity, etc.
gwBodyPropertyValue	*Measurement*	Value of the fluid body property (with uom).

Table 38

Relation	Source	Target	Description

Association	*Entity: GW_FluidBody* *Role:*	*Entity: GW_FluidBodyProperty* *Role: gwBodyProperty*	Relates a fluid body to additional properties such as age, temperature, density, viscosity, turbidity, color, hardness, acidity, etc.

8.6.20. GW_FluidBodySurface

A surface on a fluid body within a local or regional area, e.g., piezometric, potentiometric, water table, salt wedge, etc.

Table 39

Attribute	Type and Multiplicity	Definition
gwSurfaceShape	*Surface*	Geometry / position of the surface.
gwSurfaceType	*SurfaceType*	Type of fluid body surface, e.g. , piezometric, potentiometric, water table, salt wedge, etc.
gwSurfaceMetadata	*ObservationMetadata*	Date, time, method, etc., of the observation or calculation of the surface.

Table 40

Relation	Source	Target	Description
Association	*Entity: GW_Divide* *Role: gwSurfaceDivide*	*Entity: GW_FluidBodySurface* *Role: gwDivideSurface*	Relates a fluid body surface to a line on e.g., a water table or piezometric surface, on either side of which the groundwater flow diverges.
Association	*Entity: GW_FluidBodySurface* *Role: gwBodySurface*	*Entity: GW_FluidBody* *Role: gwSurfaceBody*	Relates a fluid body to a surface hosted by the body, e.g., the top of the water table.

8.6.21. GW_HydrogeoUnit

Any soil or rock unit or zone that by virtue of its hydraulic properties has a distinct influence on the storage or movement of groundwater (after ANS, 1980).

Table 41

Attribute	Type and Multiplicity	Definition
gwUnitMedia	*PorosityType*	Type of material or, by proximity, type of voids (e.g., granular, fracture, karstic, or mixed).
gwUnitRecharge	*GW_Recharge [1..*]*	Volumetric flow rate of water that enters an hydrogeologic unit, at potentially multiple locations.
gwUnitDischarge	*GW_Discharge [1..*]*	Volumetric flow rate of water that goes out of an hydrogeologic unit, at potentially multiple locations.
gwUnitWaterBudget	*GW_WaterBudget*	Sum of water input and output of a hydrogeologic unit, at a particular point in time, with a description of inflows and outflows.
gwUnitVulnerability	*GW_Vulnerability [0..*]*	The susceptibility of the aquifer to specific threats such as various physical events (earthquakes), human processes (depletion), etc.

Table 42

Relation	Source	Target	Description
Generalization	*Entity: GW_Basin* *Role:*	*Entity: GW_HydrogeoUnit* *Role:*	A basin is a type of hydrogeological unit.
Generalization	*Entity: GW_AquiferUnit* *Role:*	*Entity: GW_HydrogeoUnit* *Role:*	An aquifer unit is a type of hydrogeological unit.
Generalization	*Entity: GW_HydrogeoUnit* *Role:*	*Entity: GL_GeologicUnit* *Role:*	A hydrogeological unit is a type of geological unit.
AssociationClass	*Entity: GW_HydrogeoUnit* *Role: gwVoidUnit*	*Entity: GW_HydrogeoVoid* *Role: gwUnitVoid*	Relates hydrogeological units with a void hosted by the units. A unit hosts one void, which can be an aggregation of multiple voids potentially spatially disconnected. Voids in turn can be hosted by many units, particularly when units are arranged in whole-part relations, such that a void hosted by a part is also hosted by any associated whole, e.g., a void is hosted by both an aquifer and a related aquifer system, or

			a member and a related formation.
Association	*Entity: GW_HydrogeoUnit* *Role:*	*Entity: GW_UnitProperties* *Role: gwUnitProperty*	Relates a hydrogeological unit to possibly many additional properties.
Aggregation	*Entity: GW_Basin* *Role:*	*Entity: GW_HydrogeoUnit* *Role: gwBasinUnit*	Relates hydrogeological units and the basins that contain them, in full or part.
AssociationClass	*Entity: GW_HydrogeoUnit* *Role: gwFluidBodyUnit*	*Entity: GW_FluidBody* *Role: gwUnitFluidBody*	Relates hydrogeological units and the fluid bodies contained by the units.
Association	*Entity: GW_ManagementArea* *Role: gwManagementArea*	*Entity: GW_HydrogeoUnit* *Role: gwManagedUnit*	Relates a management area to the hydrogeological units contained within it. Because the spatial boundaries of management areas can be determined by human concerns, e.g., regulatory, these boundaries do not necessarily align with the spatial boundaries of units, which are determined by physical criteria.

8.6.22. GW_HydrogeoVoid

Voids represent the spaces inside (hosted by) a unit or its material. E.g., the pores in an aquifer, or in the sandstone of an aquifer. Voids can contain fluid bodies. Voids are differentiated from 'porosity' in that porosity is the proportion of void volume to total volume, while voids are the spaces themselves. Voids are required in GWML2, for example, to capture the volume of fractures in an aquifer.

Table 43

Attribute	Type and Multiplicity	Definition
gwVoidDescription	*char*	General description of the void
gwVoidHostMaterial	*EarthMaterial [0..*]*	The material that hosts the void, if specified. Note voids can be hosted by a unit (an aquifer) or its material (e.g., sandstone).
gwVoidMetadata	*GW_Metadata*	Metadata for the void.
gwVoidShape	*Geometry*	Shape and position of the void.
gwVoidType	*PorosityType*	Type of void e.g., fractured, intergranular, etc.

gwVoidVolume	*Measurement*	Volume of the void.

Table 44

Relation	Source	Target	Description
Association	*Entity: GW_HydrogeoVoid* *Role: gwFluidBodyVoid*	*Entity: GW_FluidBody* *Role: gwVoidFluidBody*	Relates a void and a fluid body contained by the void. Each void contains at most one fluid body, which can have multiple parts that could be disconnected. Likewise, each fluid body is contained by a single void, which could also be an aggregation of disconnected void parts.
AssociationClass	*Entity: GW_HydrogeoUnit* *Role: gwVoidUnit*	*Entity: GW_HydrogeoVoid* *Role: gwUnitVoid*	Relates hydrogeological units with a void hosted by the units. A unit hosts one void, which can be an aggregation of multiple voids potentially spatially disconnected. Voids in turn can be hosted by many units, particularly when units are arranged in whole-part relations, such that a void hosted by a part is also hosted by any associated whole, e.g., a void is hosted by both an aquifer and a related aquifer system, or a member and a related formation.
Aggregation	*Entity: GW_HydrogeoVoid* *Role: gwPartOfVoid*	*Entity: GW_HydrogeoVoid* *Role: gwVoidPartOf*	Relates a void part to a void whole.

8.6.23. GW_InterFlow

Fluid flow between features through an interface, exiting one feature and entering another. Features into which fluid is flowing are usually units, voids, or fluid bodies, but can be natural surface water features such as rivers or lakes, or even man-made features such as dams or canals. Likewise for features where water is exiting.

Table 45

Attribute	Type and Multiplicity	Definition
gwFlowLocation	*Geometry [1..*]*	The location at which water is being transferred from one feature into another.
gwFlowSourceContainer	*Feature*	The feature from which water is flowing.
gwFlowSourceBody	*Feature*	The fluid body from which water is flowing.
gwFlowDestinationContainer	*Feature*	The feature into which water is flowing.
gwFlowDestinationBody	*Feature*	The fluid body into which water is flowing.
gwFlowInterfaceFeature	*Feature [0..*]*	The feature that denotes the interface between, for example, the groundwater and surface, such as a well, spring, seep, etc., or between two aquifers.

Table 46

Relation	Source	Target	Description
Generalization	*Entity: GW_InterFlow Role:*	*Entity: GW_Flow Role:*	An interflow is a type of directed flow between two features, e.g., flow between two units.
Generalization	*Entity: GW_Recharge Role:*	*Entity: GW_InterFlow Role:*	Recharge is a type of interflow in which fluid enters a feature.
Generalization	*Entity: GW_Discharge Role:*	*Entity: GW_InterFlow Role:*	Discharge is a type of interflow in which fluid exits a feature.

8.6.24. GW_IntraFlow

Fluid flow within a feature such as a unit, void, gw body, or even a man-made feature such as a conduit of some kind.

Table 47

Attribute	Type and Multiplicity	Definition

gwFlowLocation	*Geometry*	The location where a fluid is flowing within a feature.
gwFlowContainer	*Feature*	The feature in which the fluid is flowing. Typically a unit, void, or gw body, but can also be a man made feature such as some conduit.
gwFlowBody	*Feature*	The fluid body that is flowing.

Table 48

Relation	Source	Target	Description
Generalization	*Entity: GW_IntraFlow* *Role:*	*Entity: GW_Flow* *Role:*	An intraflow is a type of flow within a single feature, e.g., flow in a unit.

8.6.25. GW_Licence

Licence relating to the drilling of a well, the extraction of groundwater, etc.

Table 49

Attribute	Type and Multiplicity	Definition
gwLicenceID	*CharacterString*	Licence ID, e.g., a number.
gwPurpose	*CharacterString*	Purpose of the licence.
gwAssociatedGWVolume	*QuantityRange*	Fluid volume associated with the licence.
gwTimePeriod	*TimeRange*	The period of time for which the licence is valid.

8.6.26. GW_ManagementArea

The GW_ManagementArea represents an area of ground identified for management purposes. The area can be delineated by human factors such as policy or regulation concerns, as well as by domain concerns (in this case hydrogeological or hydrological). The spatial boundaries of a management area do not necessarily align exactly with associated hydrogeological feature boundaries. GW_ManagementArea has the potential to provide a pattern for a more generic OGC 'trans-domain' feature management class. GW_ManagementArea is equivalent to InspireAM:ManagementRestrictionOrRegulationZone.

Table 50

Attribute	Type and Multiplicity	Definition
gwAreaName	*char [1..*]*	Name of the management area.
gwAreaDescription	*char [1.. *]*	General description of the management area.
gwAreaFeature	*Feature [1..*]*	Other features that are associated with the management area (watershed, ecological zones, etc) that are not hydrogeological units.
gwAreaWaterBudget	*GW_WaterBudget [1..*]*	Water budget associated with the management area.
gwAreaYield	*GW_Yield*	Yield associated with the management area.
gwAreaShape	*Geometry*	Geometric shape and position of management area.
gwAreaType	*ManagementAreaType*	General classification of the management area (e.g., restricted use zone, irrigation area, consumption area, etc.)
gwAreaSpecialisedAreaType	*SpecialisedZoneAreaTypeTerm*	Additional classification value which further specialises the gwAreaType.
gwAreaEnvironmentalDomain	*EnvironmentalDomainTypeTerm*	Classification of the environment domain(s) for which, through the establishment of the management area, certain environmental objectives are to be reached.
gwAreaCompetentAuthority	*CI_ResponsibleParty [0..*]*	Description of the organization(s) responsible for managing, restricting or regulating measures or activities within the management area.
gwAreaDesignationPeriod	*TM_Period*	Time period specifying when the management area was legally

			designated or became effective in the real world

Table 51

Relation	Source	Target	Description
Association	*Entity: GW_ManagementArea* *Role:*	*Entity: DocumentCitation* *Role: documentation*	Relates legislative and reference documentation to a management area.
Association	*Entity: GW_ManagementArea* *Role:*	*Entity: GW_FluidBody* *Role: gwAreaBody*	Relates a management area to the fluid bodies contained within the area. As with units, the spatial boundaries of management areas do not necessarily coincide with the spatial boundaries of fluid bodies.
Association	*Entity: GW_ManagementArea* *Role:*	*Entity: GW_ManagementArea* *Role: relatedManagementArea*	Relates a management area part to a management area whole.
Association	*Entity: GW_ManagementArea* *Role: gwManagementArea*	*Entity: GW_HydrogeoUnit* *Role: gwManagedUnit*	Relates a management area to the hydrogeological units contained within it. Because the spatial boundaries of management areas can be determined by human concerns, e.g., regulatory, these boundaries do not necessarily align with the spatial boundaries of units, which are determined by physical criteria.

8.6.27. GW_MaterialConstituent

Suspended or colloidal material in a fluid body, e.g sediment.

Table 52

Attribute	Type and Multiplicity	Definition
gwMaterial	*MaterialType*	Name of the suspended or colloid material in the fluid body, e.g., a lithology or mineral name.

Table 53

Relation	Source	Target	Description
Generalization	*Entity: GW_MaterialConstituent* *Role:*	*Entity: GW_Constituent* *Role:*	A material constituent is a type of fluid body constituent. There are 3 types of fluid body constituents: chemical (e.g., arsenic), biologic (e.g., organisms), and material (e.g., sediment).

8.6.28. GW_Mixture

The nature of the inclusion of the constituent in the fluid body, e.g., suspension, emulsion, etc.

Table 54

Attribute	Type and Multiplicity	Definition
gwMixture	*MixtureType*	The manner in which a constituent is within a fluid body, e.g., solution, suspension, emulsion, precipitate, colloidal.

8.6.29. GW_MonitoringSite

Site of observation related to groundwater.

Table 55

Attribute	Type and Multiplicity	Definition
gwSiteName	*char [0..*]*	Name (or identifier) of the monitoring site.
gwSiteLocation	*Geometry*	Spatial location of the site.
gwSiteReferenceElevation	*Elevation [1..*]*	Reference elevation for all observations at the site, e.g., ground elevation, casing elevation. This can differ from the host feature elevation, or be more specific.
gwSiteType	*SiteType*	Type of monitoring site, e.g., well, gauging station, etc.

gwMonitoringHost	*Feature*	The feature hosting the site, e.g., a well, spring, lake or stream.

8.6.30. GW_Porosity

Measure of the proportion of the volume occupied by voids over the total volume of material including the voids. Voids are differentiated from 'porosity' in that porosity is a proportion, while voids are the spaces themselves. Types of porosity include: primary, secondary, dual, specific, effective, granular, fractured, karstic, etc.

Table 56

Attribute	Type and Multiplicity	Definition
gwPorosityType	*PorosityType*	Type of porosity (primary, secondary, dual, specific, effective, granular, fractured, karstic, etc.)
gwPorosity	*Measurement*	Measure of the proportion of the volume occupied by specific voids over the total volume of material including the voids.

Table 57

Relation	Source	Target	Description
Association	*Entity: GW_UnitVoidProperty* *Role:*	*Entity: GW_Porosity* *Role: gwPorosity*	Relates possibly many types of porosity values to a unit and related void combination.

8.6.31. GW_Recharge

Fluid added to an aquifer by various means such as precipitation, injection, etc.

Table 58

Relation	Source	Target	Description
Generalization	*Entity: GW_Recharge* *Role:*	*Entity: GW_InterFlow* *Role:*	Recharge is a type of interflow in which fluid enters a feature.

8.6.32. GW_Spring

Any natural feature where groundwater flows to the surface of the earth.

Table 59

Attribute	Type and Multiplicity	Definition
gwSpringName	*CharacterString [0..*]*	Name or ID of the spring.
gwSpringLocation	*Geometry*	Geometry / position of the spring.
gwSpringReferenceElevation	*Elevation [1..*]*	Reference elevation for all observations at the site, e.g., ground elevation, casing elevation.
gwSpringType	*SpringType*	Type of spring e.g., mineral, thermal, saline, etc.
gwSpringCauseType	*SpringCauseType*	The cause of the spring e.g., artesian, geyser, perched, etc.
gwSpringPersistence	*SpringPersistenceType*	The periodicity of the spring e.g., ephemeral, perennial, intermittent, seasonal, etc.
gwSpringGeology	*GL_Feature [0..*]*	Related geology features.
gwSpringUnit	*GW_HydrogeoUnit [1..*]*	The hydrogeological unit(s) hosting the spring.
gwSpringBody	*GW_FluidBody [0..*]*	The fluid body being depleted by the spring.
gwSpringConstruction	*SpringConstruction [0..1]*	Spring construction details
gwSpringLicence	*GW_Licence [0..*]*	Any licence relating to the spring.

8.6.33. GW_UnitFluidProperty

A measured or calculated physical or hydraulic property that can be inherent in either an aquifer or its material, and some fluid body, e.g., hydraulic conductivity, transmissivity, storativity, permeability, porosity.

Table 60

Attribute	Type and Multiplicity	Definition

gwHydraulicConductivity	*Measurement [1..*]*	Hydraulic conductivity measures how easily a fluid can move through the voids in a material.
gwTransmissivity	*Measurement [1..*]*	The rate of groundwater flow laterally through an aquifer, determined by hydraulic conductivity and container thickness.
gwStorativity	*Measurement [1..*]*	Storativity is the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer.

Table 61

Relation	Source	Target	Description
Association	*Entity: GW_UnitFluidProperty* *Role:*	*Entity: GW_Yield* *Role: gwYield*	Relates possibly many types of yield values to a unit and fluid body combination.

8.6.34. GW_UnitProperties

Additional properties of an aquifer not included in the model.

Table 62

Attribute	Type and Multiplicity	Definition
gwUnitProperty	*gwUnitPropertyType*	The type of hydrogeological unit property, e.g., average well depth.
gwUnitPropertyValue	*Any*	The value of the hydrogeological unit property.

Table 63

Relation	Source	Target	Description
Association	*Entity: GW_HydrogeoUnit* *Role:*	*Entity: GW_UnitProperties* *Role: gwUnitProperty*	Relates a hydrogeological unit to possibly many additional properties.

8.6.35. GW_UnitVoidProperty

Properties inherent in the relation between a hydrogeological unit and a void: includes the proportion of voids to the unit (porosity) or to the connectivity / size of void openings (intrinsic permeability).

Table 64

Attribute	Type and Multiplicity	Definition
gwPermeability	*Measurement [1..*]*	Refers to intrinsic permeability: a measure of a material's ability to allow fluid flow that is independent of fluid properties, and based on connectivity of pores and size of their openings. This is different from hydraulic conductivity.

Table 65

Relation	Source	Target	Description
Association	*Entity: GW_UnitVoidProperty* *Role:*	*Entity: GW_Porosity* *Role: gwPorosity*	Relates possibly many types of porosity values to a unit and related void combination.

8.6.36. GW_Vulnerability

The susceptibility of a feature to specific threats such as various physical events (earthquakes), human processes (depletion), etc.

Table 66

Attribute	Type and Multiplicity	Definition
gwVulnerabilityType	*VulnerabilityType*	The type of vulnerability.
gwVulnerability	*Measurement*	A quantitative estimate of the susceptibility to contamination, e.g., a DRASTIC value. Should be accompanied by metadata about the method of calculation.

8.6.37. GW_WaterBudget

An accounting of the water input and output of a hydrogeological unit, at a particular point in time or over a period of time, with a description of inflows and outflows.

Table 67

Attribute	Type and Multiplicity	Definition
gwBudgetAmount	*Measurement*	Final quantity (sum) of the budget. If recharge = discharge, the sum is 0.
gwBudgetValidTime	*TemporalType*	Valid time of this budget (e.g, 2010).
gwBudgetRecharge	*GW_Recharge [1..*]*	Recharge (inflows) considered by the budget.
gwBudgetDischarge	*GW_Discharge [1..*]*	Discharge (outflows) considered in the budget.

8.6.38. GW_Well

A shaft or hole sunk, dug or drilled into the Earth to observe, extract or inject water (after IGH1397).

Table 68

Attribute	Type and Multiplicity	Definition
gwWellName	*char [0..*]*	Name or ID of the well.
gwWellLocation	*Geometry*	Surface location of the well.
gwWellReferenceElevation	*Elevation [1..*]*	Reference elevation for all observations at the site, e.g., ground elevation, casing elevation.
gwWellContributionZone	*Geometry*	The area or volume surrounding a pumping well or other discharge site that encompasses all areas and features that supply groundwater to the well or discharge site.
gwWellGeology	*GeologyLog [0..*]*	Related borehole, including lithology log.
gwWellUnit	*GW_HydrogeoUnit [1..*]*	The aquifers or confining beds intersecting the well.
gwWellBody	*GW_FluidBody [0..*]*	The fluid body occupying the well.

gwWellPurpose	*WellPurposeType [1..*]*	Purpose of well, e.g., extraction, injection, observation, dewatering, cathodic protection, decontamination, disposal, FlowingShot, Geotechnical, Mineral, MonitoringlevelHead, MonitoringQuality, Oil, OilExploratory, Seismic, WaterExploratory, etc.
gwWellStatus	*WellStatusType*	Status of the well, Can be new, unfinished, reconditioned, deepened, not in use, standby, unknown, abandoned dry, abandoned insufficient, abandoned quality. (gwml1)
gwWellWaterUse	*WellWaterUseType [1..*]*	E.g., Agricultural, Domestic, Industrial, Recreation.
gwWellTotalLength	*Measurement*	Total length of the well from reference elevation.
gwWellConstructedDepth	*Measurement [0..1]*	Constructed depth of the well.
gwWellStaticWaterDepth	*Measurement*	Depth of the fluid body (e.g., piezometric level).
gwWellYield	*GW_Yield*	Estimated or calculated yield from a well.
gwWellConstruction	*WellConstruction*	Construction details for a well.
gwWellLicence	*GW_Licence [0..*]*	Licence relating to the drilling of the well or to the extraction of groundwater.

8.6.39. GW_Yield

Yield is the rate of fluid withdrawal associated with a unit, well, etc., expressed as m^3. There are several types of yield, that can be considered: specific yield, sustainable yield, safe yield, aquifer yield, etc.

Table 69

Attribute	Type and Multiplicity	Definition
gwYieldType	*YieldType*	Type of aquifer yields: e.g., specific yield, safe yield, etc.
gwYield	*Measurement*	Measurement of the yield in units of volume per unit of time.

Table 70

Relation	Source	Target	Description

Association	*Entity: GW_UnitFluidProperty* *Role:*	*Entity: GW_Yield* *Role: gwYield*	Relates possibly many types of yield values to a unit and fluid body combination.

8.7. REQUIREMENTS

REQUIREMENT CLASS: GWML2 CONCEPTUAL MODEL	
/req/conceptual	
Obligation	requirement
Target Type	Logical Model
Dependency	ISO19101:2002 Reference Model Clause 7
Dependency	ISO19103 2015 Conceptual Model Language
Dependency	ISO19104:2008
Dependency	Unified Modeling Language (UML). Version 2.3. May 2010
Requirement 1:	/req/conceptual/similarity

Target logical models that are compliant with the conceptual model shall implement components of the conceptual model respecting their semantics, i.e., their definition and intent. In other words, the logical model must be highly semantically similar to components of the conceptual model and must not specify any requirements that would contradict or result in non-conformance to the conceptual model. Semantic similarity can be tested in multiple ways, including but not limited to: (i) direct comparison of UML components, (ii) comparison after mapping components to a common expressive knowledge representation language, such as first order logic or common logic, or (iii) comparison after mapping components to a reference ontology. The target can reuse and adapt existing logical models.

REQUIREMENT 1:
/req/conceptual/similarity
Target logical model when claiming compliance with this conceptual model SHALL implement its components (classes, attributes, relationships) respecting the conceptual model definitions and intent, such that high semantic similarity is obtained between the logical and conceptual model components, and the logical model must not specify any requirements that would contradict or result in non-conformance to the conceptual model.

9

LOGICAL MODEL

9 LOGICAL MODEL

The logical model incorporates all concepts from the conceptual model, and maintains their general intent. It differs from the conceptual model in its introduction of technology-specific artifacts from the OGC General Reference Model and derived schemas. These include additions such as classes, relations, properties, constraints, and usage principles. Another difference is the incorporation of the well construction package from GWML1.

The logical model is not a syntactical encoding, but is an OGC-compliant schema that is syntax-neutral. Syntactical encodings are derived from the logical model, such as the reference GML encoding described herein.

The addition of OGC constructs to the conceptual model amounts to the integration of several OGC-compliant GML schemas, primarily GeoSciML 4.0 and Observations & Measurements, but also MD_Metadata and others. These are adapted using the following strategies.

a) HydrogeologicalUnit in GWML2 specializes GeologicUnit from GeoSciML 4.0, recognizing that in its most basic sense a hydrogeological unit is a body of rock (a geological unit) exhibiting some hydrogeological properties including possibly fluid storage and transfer.

b) Water wells and boreholes specialize O&M:SF_SamplingCurve, which allows them to have a shape described by 3D points at the start and end of each segment along the well or borehole. Wells and boreholes differ by purpose and use: boreholes are physical engineering artifacts consisting of a hole and potentially materials fitted inside the hole for some human use, and wells are constructions for the extraction or injection of water from/into the ground, and have specific hydrogeological properties such as water yield and intended use. As a consequence, well and associated borehole lengths can differ for the same well. A well can be seen as a specific role played by a borehole.

c) Property values are assigned datatypes from O&M: properties that can be numeric and/or categorical are assigned the OM_Observation datatype. Two factors compel this choice: method metadata can be added to each value to describe determination of the value, and each property can be further soft-typed for greater precision. An example of the latter is the porosity property, which in pratice could refer to any of a wide range of porosity types such as effective porosity, primary porosity, or secondary porosity.

d) Fluid body constituent values are modeled as observations: for example, a chemical analysis of a groundwater sample might be represented in the following way:

- Each measured value is the result of an observation;
- The observedProperty would be e.g., “As_Concentration;” and
- The featureOfInterest would be an instance of e.g., GW_ChemicalConstituent with ChemicalTypeTerm = “As” and gwState = “solid.”

This approach is quite flexible: it allows for different mixture types (e.g., suspension, solution, emulsion), states (i.e., liquid, solid, gas), and measurement types (e.g., concentration) for a constituent type (e.g., “As”).

a) Aquifer Tests are completely modelled using O&M, except for the single signature class GW_AquiferTest. This class is a property-less extension of O&M Sampling Feature. The logical model for Aquifer Test is thus the O&M logical model, as illustrated further in Figure 17. Time series generated by aquifer tests are represented using TimeseriesML1.0 (15-042r3).

b) DocumentCitation is replaced by Any type (i.e., the ‘documentation’ role is assigned a datatype of Any), in order to satisfy the original intention of the DocumentCitation class of enabling re-use of relevant classes from other schemas. This allows, for example, use of classes such as GW_Licence, MD_Metadata, INSPIRE’s DocumentCitation or LegislativeReferences.

c) If an entity in the logical model is stereotyped as GMF_Feature (from the OGC General Feature Model), then any name, description and identifier attributes from the conceptual model are replaced by equivalents from GMF_Feature (e.g., GW_FluidBody::gwBodyDescription maps to AbstractFeature::description).

The logical model is organized into six application schema packages, as mentioned in Section 1.

a) GWML2-Main: core items, e.g., aquifers, their pores, fluid bodies, and management areas.

b) GWML2-Constituent: the biologic, chemical, and material elements of a fluid body.

c) GWML2-Flow: fluid flow within and between containers, and water budgets.

d) GWML2-Well: water wells, springs, and monitoring sites.

e) GWML2-WellConstruction: the components used to construct a borehole or well.

f) GWML2-AquiferTest: aspects associated with an aquifer test.

Because most of the differences between the logical and conceptual model can be inferred directly from the logical model UML diagrams, all diagrams are included below. Complete class descriptions are subsequently included only for additions or alterations to the conceptual model. Additions primarily include borehole construction elements and geology logs, while the alterations mainly consist of a cardinality revision: all attributes and relations are now optional, primarily to enable sparse encodings that avoid empty data fields if so desired.

9.1. LOGICAL MODEL SPECIFICATION

Figure 8 — GWML2 LM — Package Dependencies (Internal).

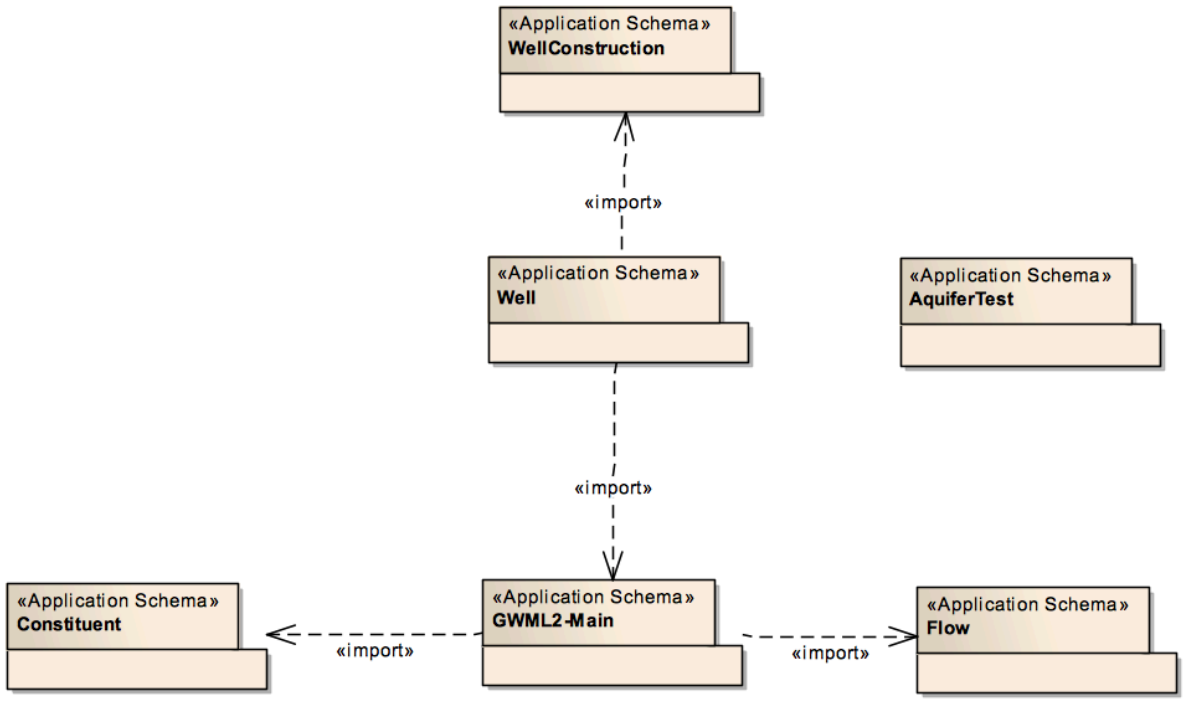


Figure 9 — GWML2 LM — Package Dependencies (External — indirect dependencies not shown).

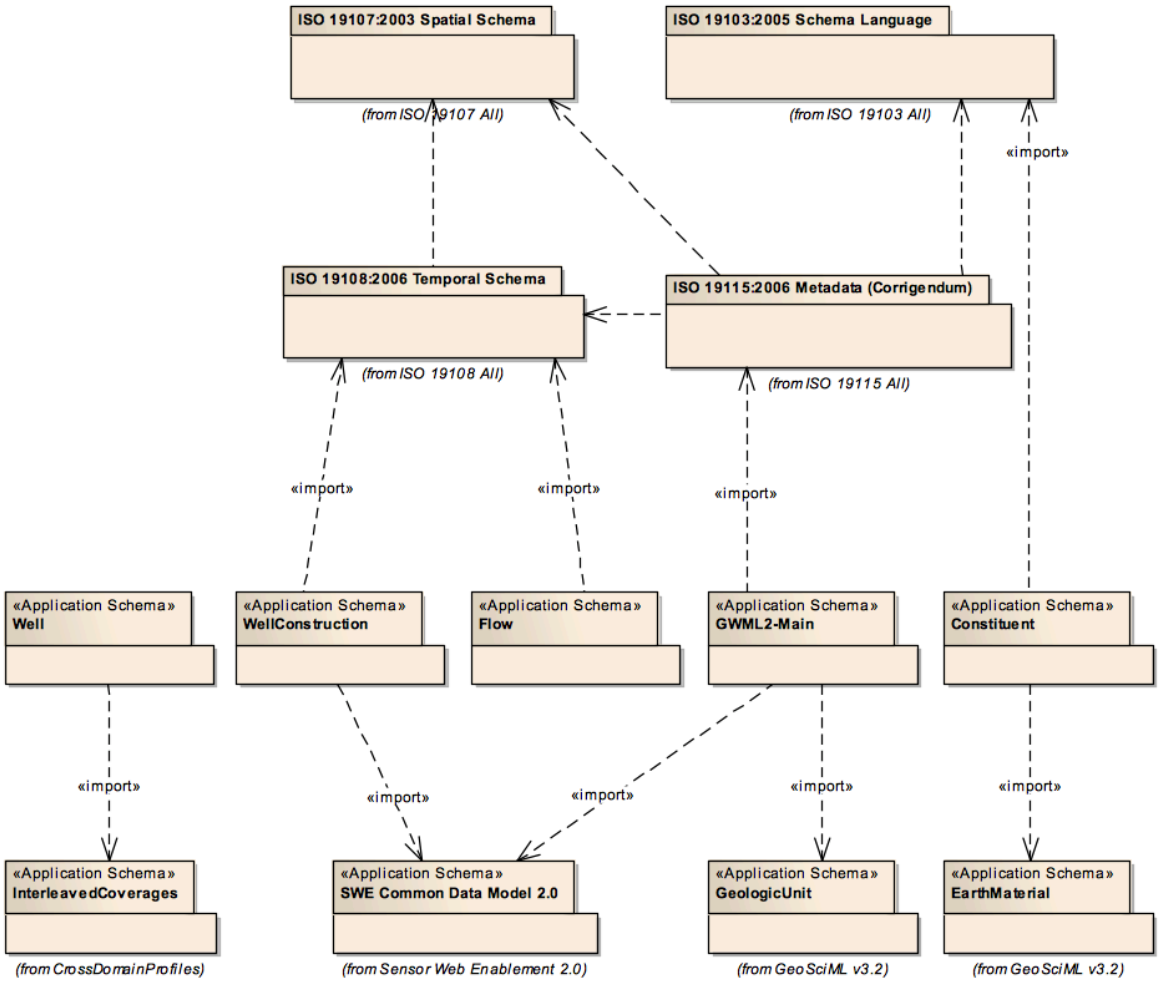


Figure 10 — GWML2 LM — Hydrogeological Unit.

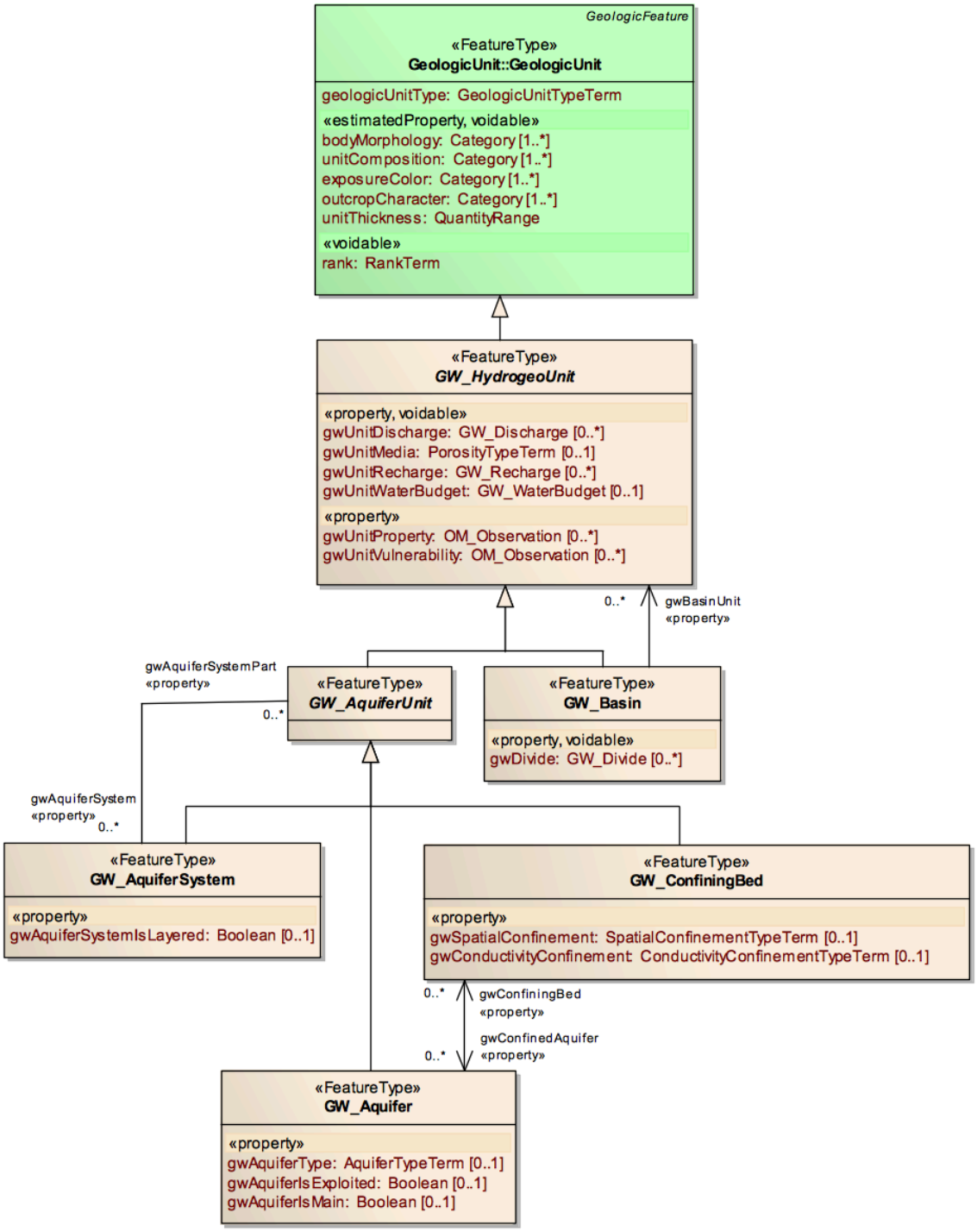


Figure 11 — GWML2 LM — Groundwater Properties.

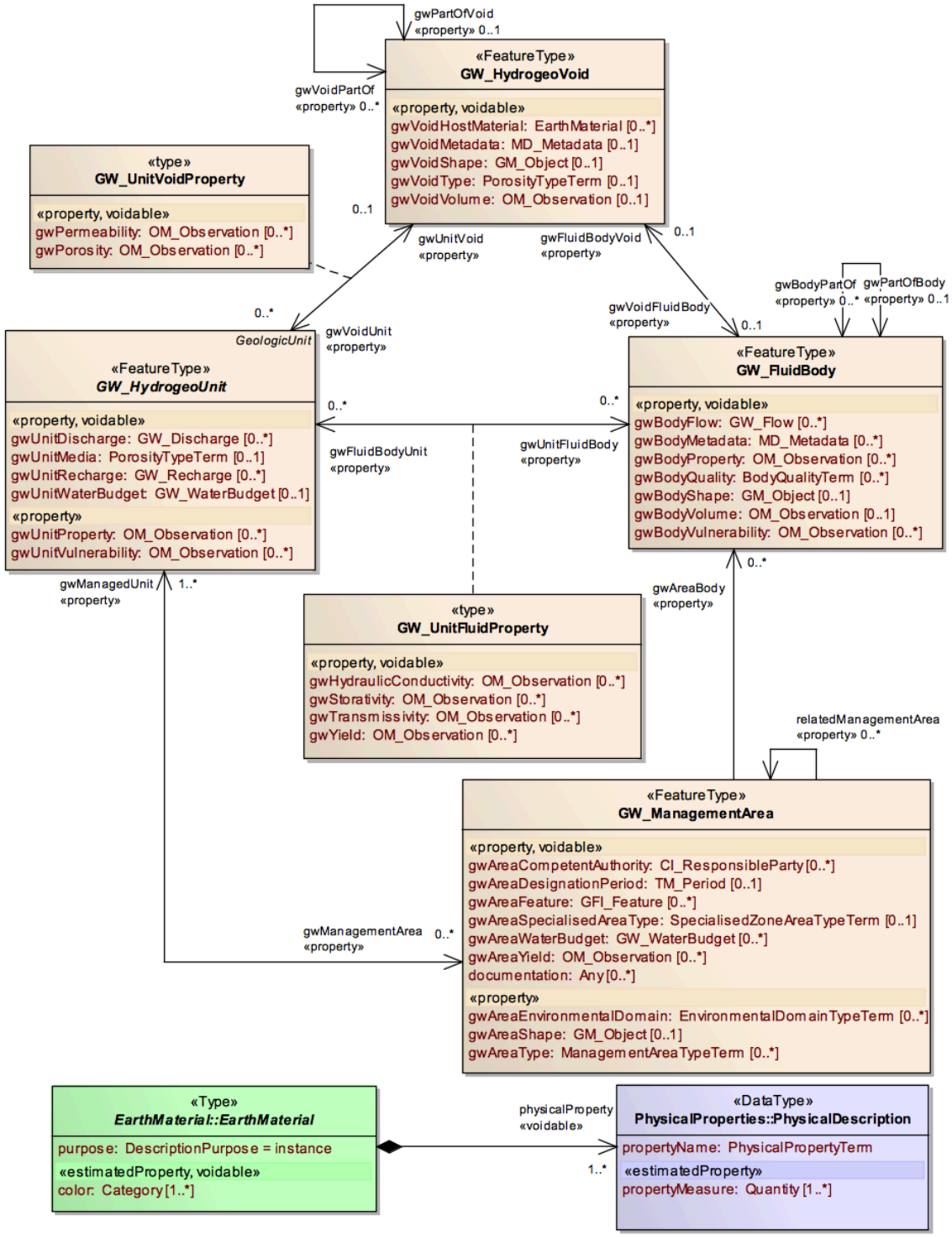


Figure 12 — GWML2 LM — Fluid Body.

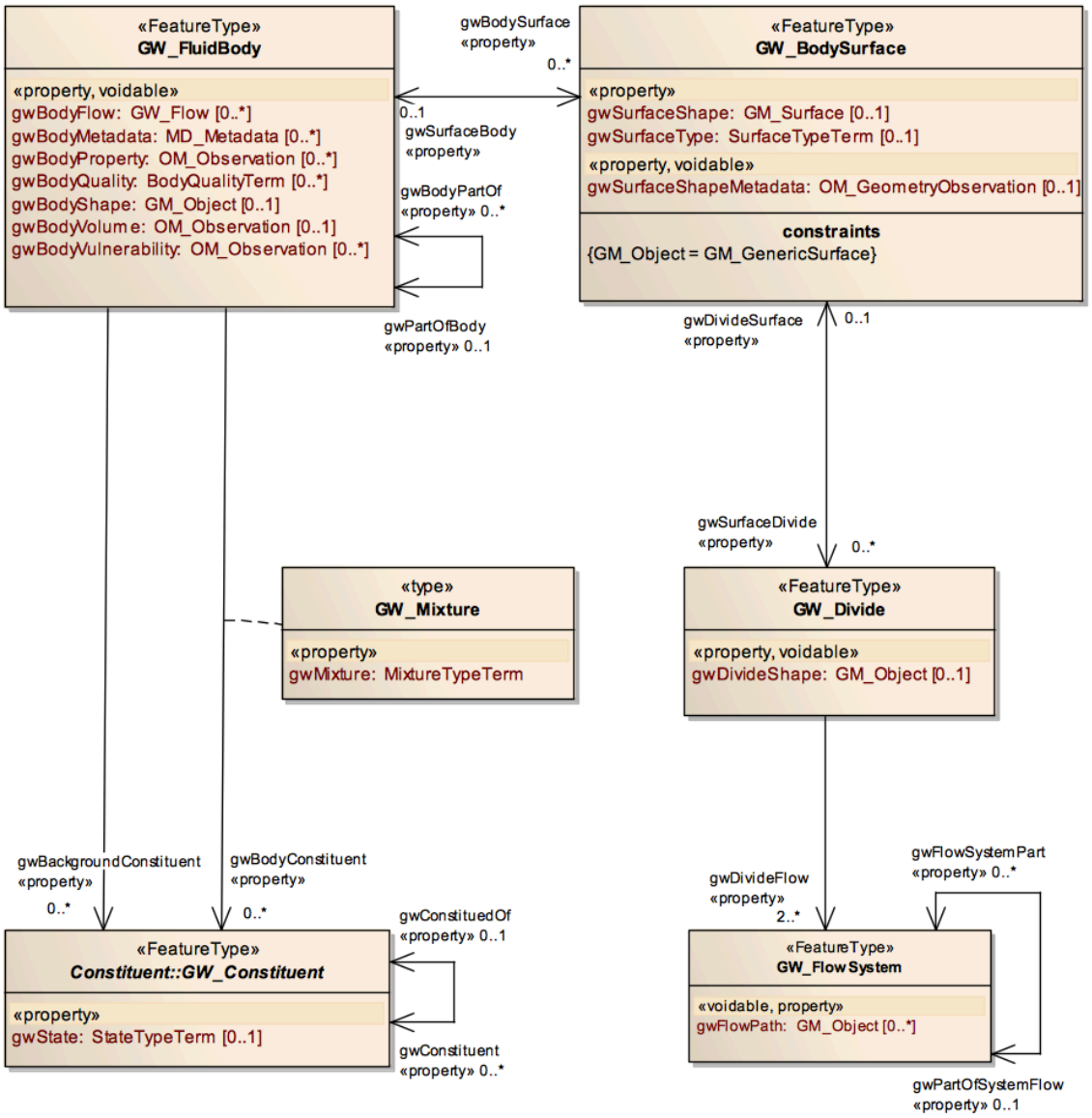


Figure 13 — GWML2 LM — GroundWaterML2-Constituent.

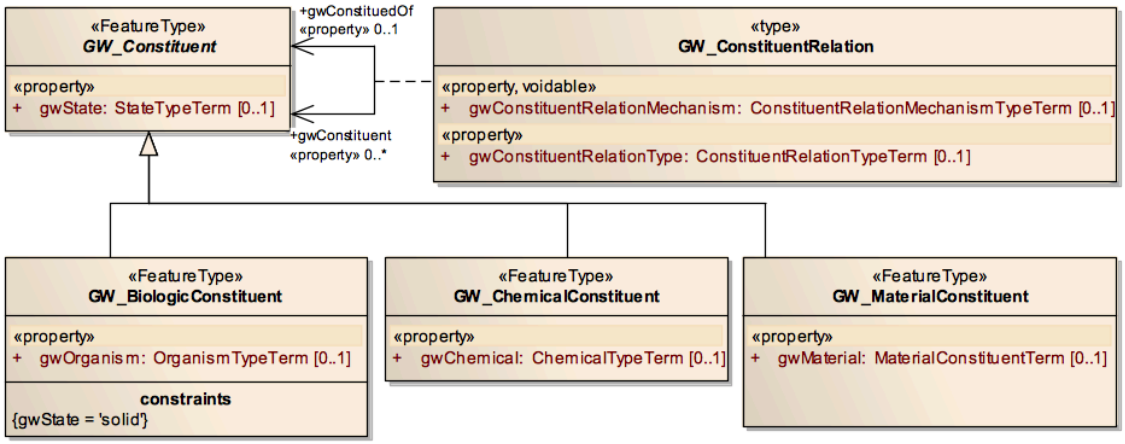


Figure 14 — GWML2 LM — Groundwater Flow.

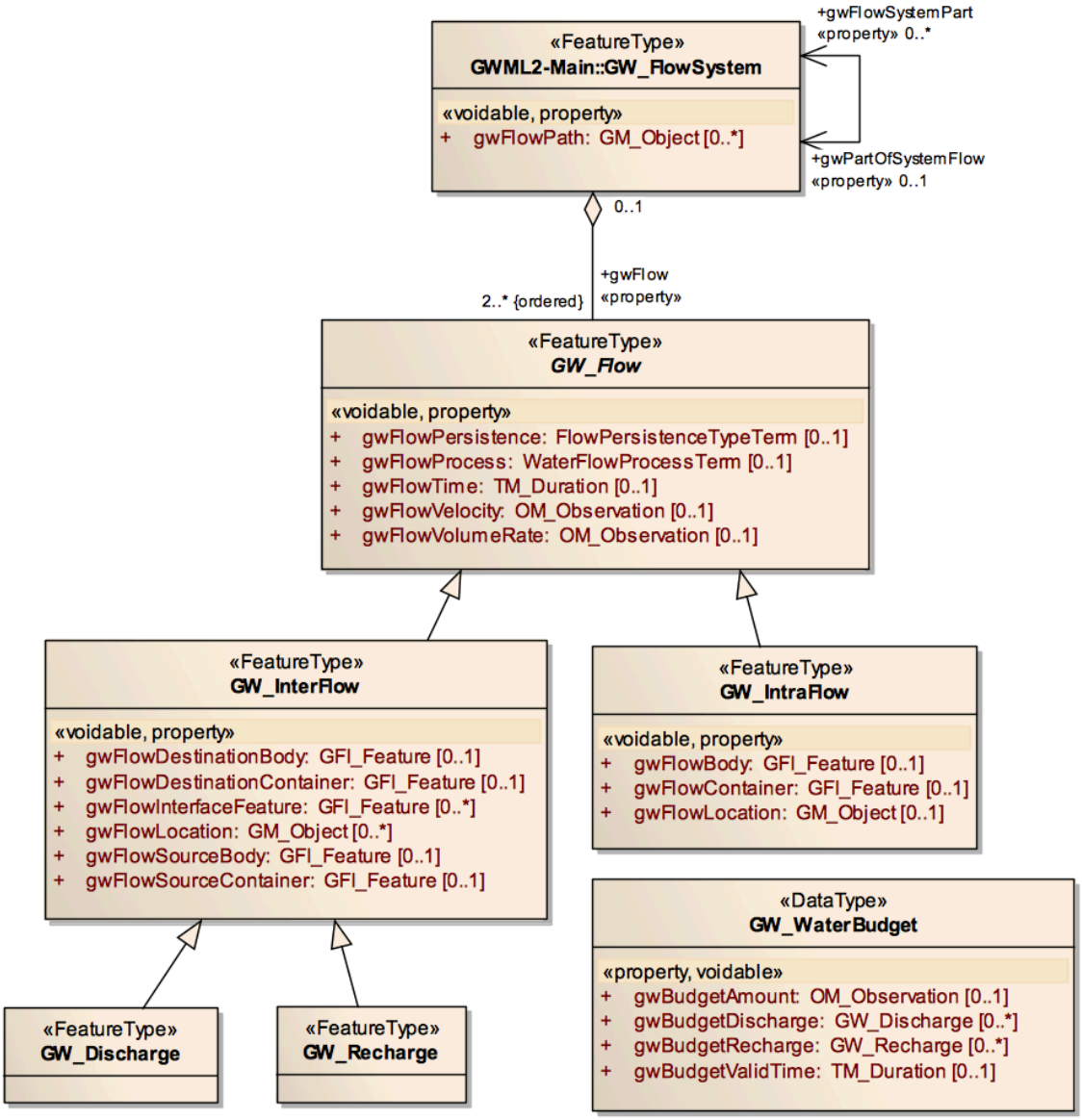


Figure 15 — GWML2 LM — Well.

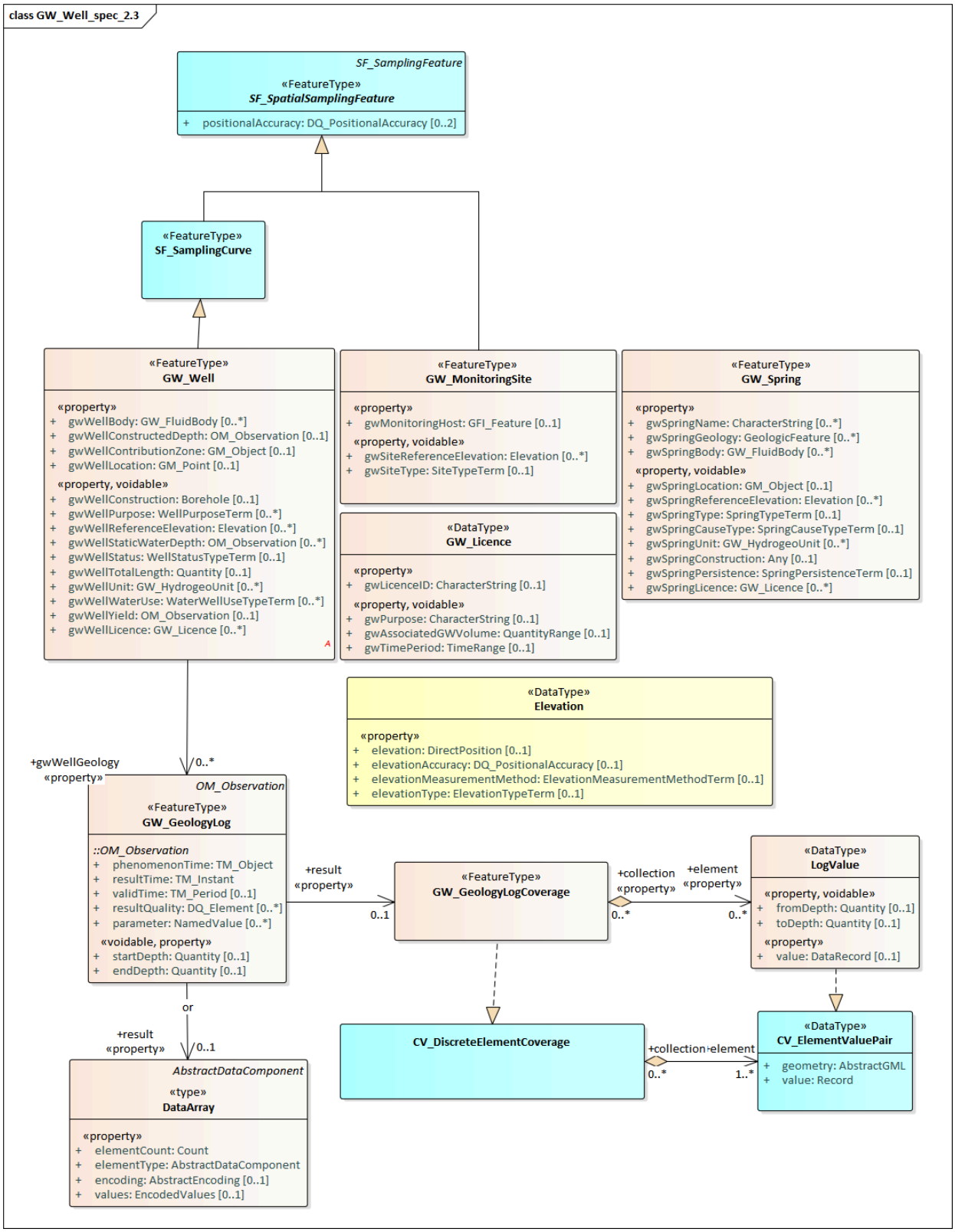


Figure 16 — GWML2 LM — WellConstruction.

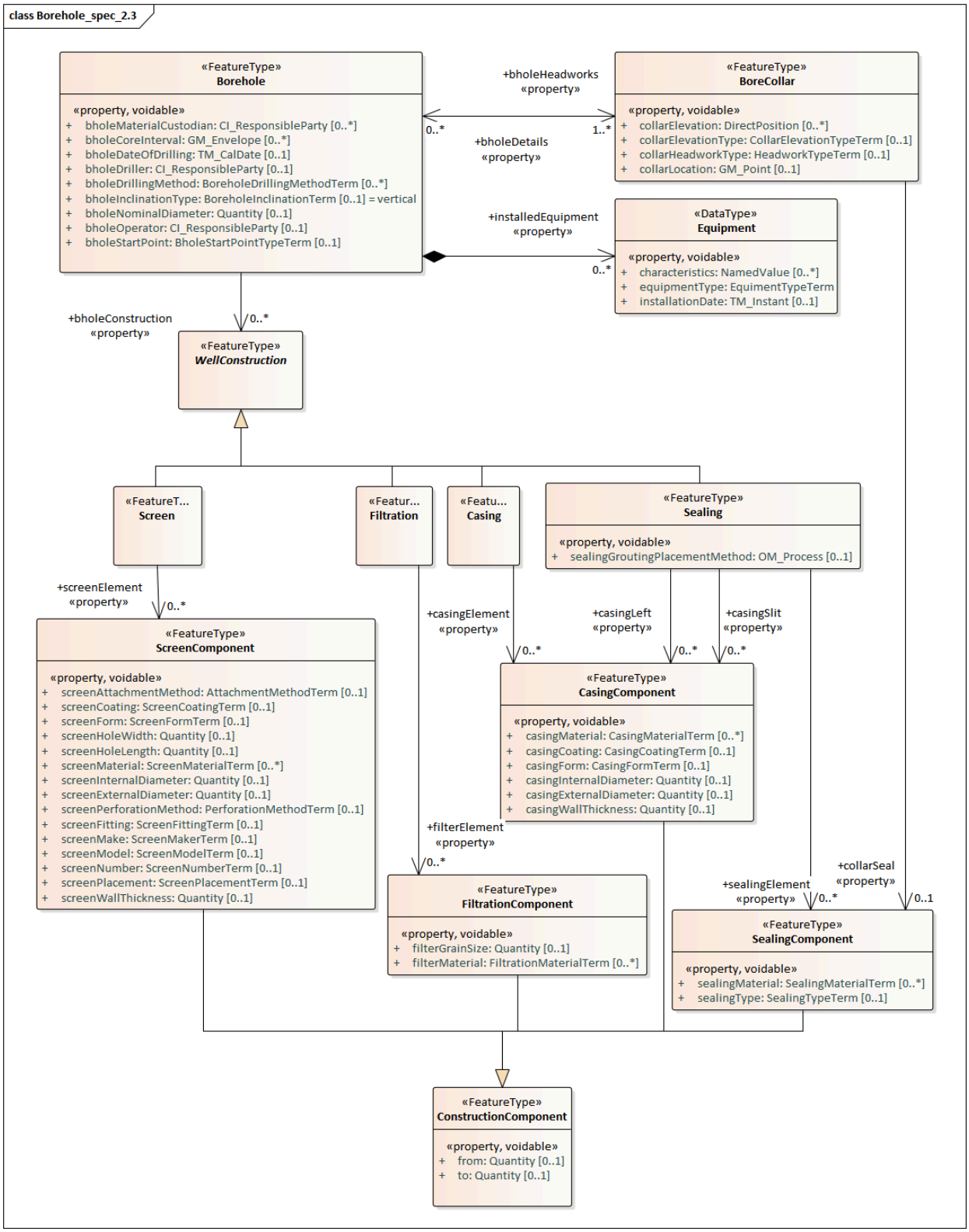
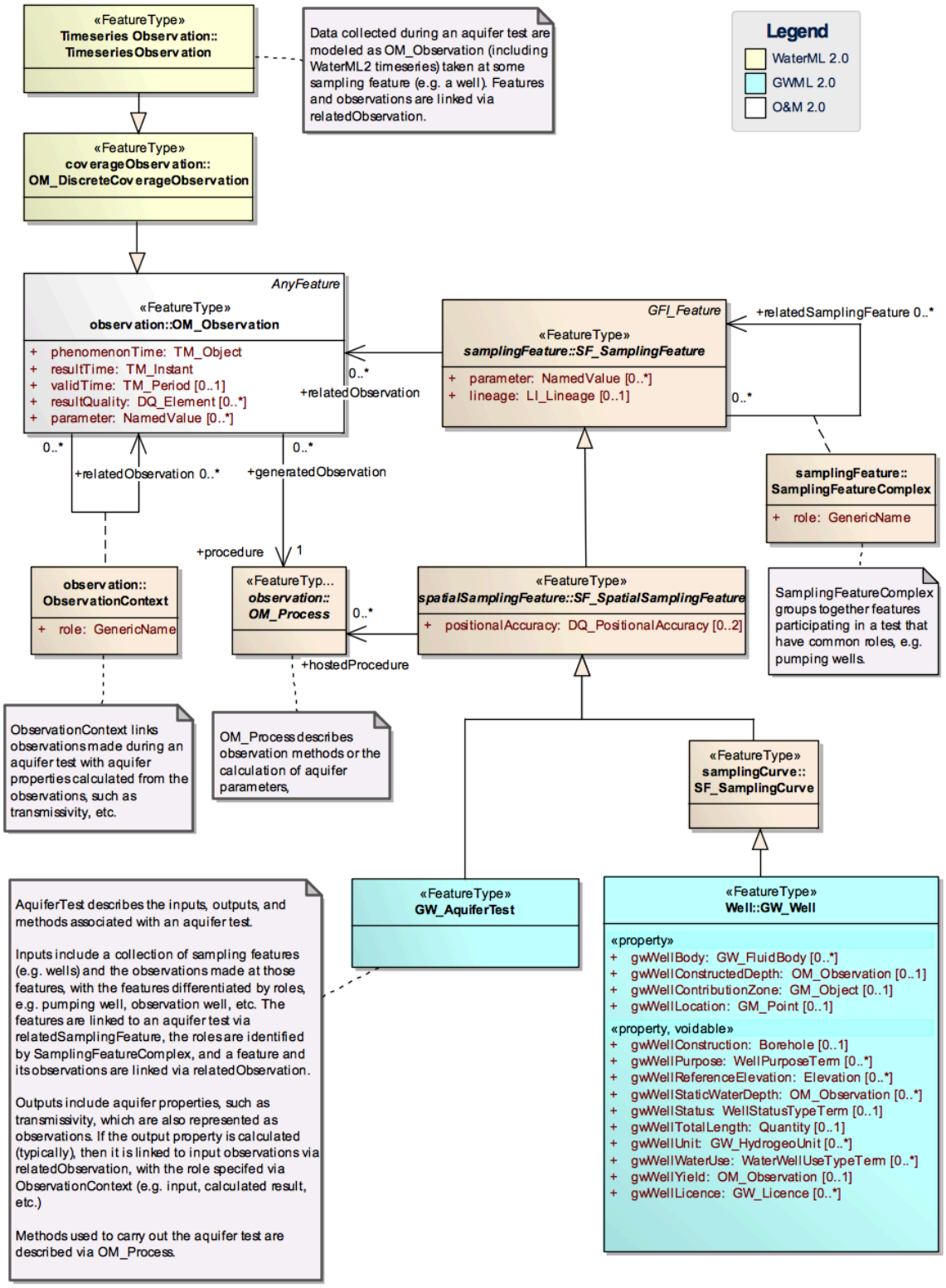


Figure 17 — GWML2 LM — Aquifer Test.



9.1.1. BoreCollar

Topmost component of a borehole construction.

Table 71

Attribute	Type and Multiplicity	Definition
collarElevation	*DirectPosition [0..*]*	The elevation of the bore collar with CRS including UOM.
collarElevationType	*CollarElevationTypeTerm [0..1]*	Type of reference elevation, defined as a feature, e.g., Top of Casing, Ground, etc.
collarHeadworkType	*HeadworkTypeTerm [0..1]*	Type of assembly bolted to the production casing to control the well, and to provide access and protection (e.g., from flooding, vandalism). Example: raised tube, covers, manhole, 'Gattick Cover' flush, concrete ring, etc. (after Fretwell, et al., 2006).
collarLocation	*GM_Point [0..1]*	The geographical location of the collar.

Table 72

Relation	Source	Target	Description
Association	*Entity: Borehole* *Role: bholeDetails*	*Entity: BoreCollar* *Role: bholeHeadworks*	Relation between a borehole and its collar, which represents the top construction component of the borehole.
Association	*Entity: BoreCollar* *Role:*	*Entity: SealingComponent* *Role: collarSeal*	Relation between a bore collar and its sealing parts.

9.1.2. Borehole

General term for a hole drilled in the ground for various purposes such extraction of a core, release of fluid, etc.

Table 73

Attribute	Type and Multiplicity	Definition
bholeMaterialCustodian	*CI_ResponsibleParty [0..*]*	The custodian of the drill core or samples recovered from the borehole.
bholeCoreInterval	*GM_Envelope [0..*]*	The geometries for the intervals from which core is extracted along the borehole.
bholeDateOfDrilling	*TM_CalDate [0..1]*	Date of drilling.
bholeDriller	*CI_ResponsibleParty [0..1]*	The organisation responsible for drilling the borehole (as opposed to commissioning the borehole).
bholeDrillingMethod	*BoreholeDrillingMethodTerm [0..*]*	Method of drilling.
bholeInclinationType	*BoreholeInclinationTerm [0..1] vertical*	Type of borehole inclination, e.g., vertical or horizontal.
bholeNominalDiameter	*Quantity [0..1]*	Diameter of the borehole.
bholeOperator	*CI_ResponsibleParty [0..1]*	Organisation responsible for commissioning the borehole (as opposed to drilling the borehole).
bholeStartPoint	*BholeStartPointTypeTerm [0..1]*	Describes the location of the start of the borehole, e.g., ground surface.

Table 74

Relation	Source	Target	Description
Association	*Entity: Borehole* *Role:*	*Entity: Equipment* *Role: installedEquipment*	Relation designating the equipment installed in a borehole.
Association	*Entity: Borehole* *Role:*	*Entity: WellConstruction* *Role: bholeConstruction*	Relation between a borehole and its construction components.

Association	*Entity: Borehole* *Role: bholeDetails*	*Entity: BoreCollar* *Role: bholeHeadworks*	Relation between a borehole and its collar, which represents the top construction component of the borehole.
Generalization	*Entity: Borehole* *Role:*	*Entity: SF_SamplingCurve* *Role:*	A borehole is a type of Sampling Curve.

9.1.3. Casing

Collection of linings of the borehole.

Table 75

Relation	Source	Target	Description
Generalization	*Entity: Casing* *Role:*	*Entity: WellConstruction* *Role:*	A casing is a type of well construction entity.
Association	*Entity: Casing* *Role:*	*Entity: CasingComponent* *Role: casingElement*	Relation between a casing and its parts.

9.1.4. CasingComponent

A single part of a borehole casing.

Table 76

Attribute	Type and Multiplicity	Definition
casingMaterial	*CasingMaterialTerm [0..*]*	Material in which the casing is made. E.g. , metal, steel, iron, concrete, wood, brick, plastic, teflon, PVC, ABS, fibreglass, etc.
casingCoating	*CasingCoatingTerm [0..1]*	Coating applied to the casing. E.g., galvanized, stainless, mild, low carbon, copper bearing, black, etc.
casingForm	*CasingFormTerm [0..1]*	Form of material used in the casing. E.g., curbing, cribbing, corrugated, culvert, hose, etc.
casingInternalDiameter	*Quantity [0..1]*	Internal diameter of the casing.

casingExternalDiameter	*Quantity [0..1]*	External diameter of the casing.
casingWallThickness	*Quantity [0..1]*	Thickness of the wall of the casing.

Table 77

Relation	Source	Target	Description
Generalization	*Entity: CasingComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A casing part is a type of construction component.
Association	*Entity: Sealing* *Role:*	*Entity: CasingComponent* *Role: casingSlit*	Casing slit opposing water bearing zones before plugging.
Association	*Entity: Casing* *Role:*	*Entity: CasingComponent* *Role: casingElement*	Relation between a casing and its parts.
Association	*Entity: Sealing* *Role:*	*Entity: CasingComponent* *Role: casingLeft*	Casing left after plugging.

9.1.5. ConstructionComponent

Elements used in borehole construction.

Table 78

Attribute	Type and Multiplicity	Definition
from	*Quantity [0..1]*	Position of the top (nearest to the borehole start) of the component.
to	*Quantity [0..1]*	Position of the bottom (farthest to the borehole start) of the component.

Table 79

Relation	Source	Target	Description
Generalization	*Entity: CasingComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A casing part is a type of construction component.
Generalization	*Entity: ScreenComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A screen part is a type of construction component.
Generalization	*Entity: FiltrationComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A filtration part is a type of construction component.

Generalization	*Entity: SealingComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A seal part is a type of construction component.

9.1.6. Equipment

Equipment installed in a borehole (like a pump or any other device).

Table 80

Attribute	Type and Multiplicity	Definition
characteristics	*NamedValue [0..*]*	General characteristics of the equipment.
equipmentType	*EquimentTypeTerm*	Type of equipment.
installationDate	*TM_Instant [0..1]*	Date of installation of the equipment.

Table 81

Relation	Source	Target	Description
Association	*Entity: Borehole* *Role:*	*Entity: Equipment* *Role: installedEquipment*	Relation designating the equipment installed in a borehole.

9.1.7. Filtration

Collection of filtration components used to filter a fluid body in a well.

Table 82

Relation	Source	Target	Description
Association	*Entity: Filtration* *Role:*	*Entity: FiltrationComponent* *Role: filterElement*	Relation between a filtration device and its parts.
Generalization	*Entity: Filtration* *Role:*	*Entity: WellConstruction* *Role:*	A filtration device is a type of well construction entity.

9.1.8. FiltrationComponent

Material used to filter the fluid in a borehole or well.

Table 83

Attribute	Type and Multiplicity	Definition
filterGrainSize	*Quantity [0..1]*	Size of the particles of the filtration material.
filterMaterial	*FiltrationMaterialTerm [0..1]*	Material used in the filtration device. E.g. , gravel, pit run, silica sand, washed sand, crushed rock, etc.

Table 84

Relation	Source	Target	Description
Association	*Entity: Filtration* *Role:*	*Entity: FiltrationComponent* *Role: filterElement*	Relation between a filtration device and its parts.
Generalization	*Entity: FiltrationComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A filtration part is a type of construction component.

9.1.9. GW_GeologyLog

Specialization of the OM_Observation containing the log start and end depth for coverages. GW_GeologyLog is a specialisation of OM_Observation and therefore inherits all its properties. A log is a complex collection of observations organised temporally or longitudinally along the borehole path. The entire log is bundled into the OM_Observation::result as a complex structure. This specification provides two possible data models using CV_DiscreteElementCoverage (Clause 10.8) and SWE DataArray (Clause 10.9).

Table 85

Attribute	Type and Multiplicity	Definition
startDepth	*Quantity [0..1]*	The start of the log measured as a depth from the reference elevation.
endDepth	*Quantity [0..1]*	The end of the log measured as a depth from the reference elevation.

Table 86

Relation	Source	Target	Description
Generalization	*Entity: GW_GeologyLog* *Role:*	*Entity: OM_Observation* *Role:*	A geology log is a type of observation.

Association	*Entity: GW_GeologyLog* *Role:*	*Entity: GW_GeologyLogCoverage* *Role: result*	Relates a geology log with a particular coverage of values (the result) that represent the group of measurements taken in intervals along the length of the log.
Association	*Entity: GW_GeologyLog* *Role:*	*Entity: DataArray* *Role: result*	Relates a geology log with a particular array of values (the result) that represent the group of measurements taken in intervals along the length of the log.
Association	*Entity: GW_Well* *Role:*	*Entity: GW_GeologyLog* *Role: gwWellGeology*	Relates a GeologyLog with a well.

9.1.10. GW_GeologyLogCoverage

A particular collection of values that represent the group of measurements taken in intervals along the length of the log. Overrides DiscreteElementCoverage to enable LogValues to be elements of the collection (GeologyLogCoverage).

Table 87

Relation	Source	Target	Description
Realization	*Entity: GW_GeologyLogCoverage* *Role:*	*Entity: CV_DiscreteElementCoverage* *Role:*	A GeologyLogCoverage is a realization of a DiscreteElementCoverage.
Association	*Entity: GW_GeologyLogCoverage* *Role: collection*	*Entity: LogValue* *Role: element*	Relates a collection with the values that are part of the collection and that represent the measurements taken in intervals along the length of the log.
Association	*Entity: GW_GeologyLog* *Role:*	*Entity: GW_GeologyLogCoverage* *Role: result*	Relates a geology log with a particular collection of values (the result) that represent the group of measurements taken in intervals along the length of the log.

9.1.11. LogValue

The value of the log property at a depth interval along the log.

Table 88

Attribute	Type and Multiplicity	Definition
fromDepth	*Quantity [0..1]*	Start depth of the interval along a log.
toDepth	*Quantity [0..1]*	End depth of the interval along a log.
value	*DataRecord [0..1]*	Value of the log property.

Table 89

Relation	Source	Target	Description
Association	*Entity: GW_GeologyLogCoverage* *Role: collection*	*Entity: LogValue* *Role: element*	Relates a collection with the values that are part of the collection and that represent the measurements taken in intervals along the length of the log.
Realization	*Entity: LogValue* *Role:*	*Entity: CV_ElementValuePair* *Role:*	A LogValue is a realization of a CV_ElementValuePair from O&M.

9.1.12. Screen

Collection of components of the water pump screen.

Table 90

Relation	Source	Target	Description
Generalization	*Entity: Screen* *Role:*	*Entity: WellConstruction* *Role:*	A screen is a type of well construction entity.
Association	*Entity: Screen* *Role:*	*Entity: ScreenComponent* *Role: screenElement*	Relation between a screen and its parts.

9.1.13. ScreenComponent

Component of the well lining where water enters the well.

Table 91

Attribute	Type and Multiplicity	Definition
screenAttachmentMethod	*AttachmentMethodTerm [0..1]*	Screen attachment method. E.g.,

		telescoped, on casing, on riser pipe, neoprene (K) packer, Lead packer, etc.
screenCoating	*ScreenCoatingTerm [0..1]*	Thin outer layer applied to the screen. E.g., galvanized, stainless, copper bearing, low carbon, black, porous, etc.
screenForm	*ScreenFormTerm [0..1]*	Form of the screen. E.g., slotted casing, perforated casing, bridge slot casing, wire wrap or continuous slot, wire mesh, shutter or louvered, well point, tube, etc.
screenHoleWidth	*Quantity [0..1]*	Width of the slots or perforations of the screen.
screenHoleLength	*Quantity [0..1]*	Length of the slots or perforations of the screen.
screenMaterial	*ScreenMaterialTerm [0..*]*	Material that makes up the screen. E.g., metal, steel, iron, copper, brass, bronze, everdur, Armco metal, veriperm, stone, plastic, PVC, ABS, Fibreglass, etc.
screenInternalDiameter	*Quantity [0..1]*	Internal screen diameter.
screenExternalDiameter	*Quantity [0..1]*	External screen diameter.
screenPerforationMethod	*PerforationMethodTerm [0..1]*	Method used for perforating the screen. E.g., drill, grinder, axe / chisel, machine, saw, torch, other, etc.
screenFitting	*ScreenFittingTerm [0..1]*	The screen fitting (from the bottom). E.g., bail, open, plug, tail pipe, washdown, etc.
screenMake	*ScreenMakerTerm [0..1]*	Make of the screen.
screenModel	*ScreenModelTerm [0..1]*	Model of the screen
screenNumber	*ScreenNumberTerm [0..1]*	Screen number corresponds to hole

		size and is given in 0.001 inch. The value is expressed as an alphanumeric code.
screenPlacement	*ScreenPlacementTerm [0..1]*	Screen placement method. E.g., bail down, pull back, jetted, washed down, etc.
screenWallThickness	*Quantity [0..1]*	Thickness of the screen wall.

Table 92

Relation	Source	Target	Description
Generalization	*Entity: ScreenComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A screen part is a type of construction component.
Association	*Entity: Screen* *Role:*	*Entity: ScreenComponent* *Role: screenElement*	Relation between a screen and its parts.

9.1.14. Sealing

Collection of materials that prevent undesirable elements from entering the borehole or well.

Table 93

Attribute	Type and Multiplicity	Definition
sealingGroutingPlacementMethod	*OM_Process [0..1]*	Method of placing the sealing grouting.

Table 94

Relation	Source	Target	Description
Association	*Entity: Sealing* *Role:*	*Entity: CasingComponent* *Role: casingSlit*	Casing slit opposing water bearing zones before plugging.
Generalization	*Entity: Sealing* *Role:*	*Entity: WellConstruction* *Role:*	A sealing is a type of well construction entity.
Association	*Entity: Sealing* *Role:*	*Entity: CasingComponent* *Role: casingLeft*	Casing left after plugging.
Association	*Entity: Sealing* *Role:*	*Entity: SealingComponent* *Role: sealingElement*	Relation between a seal and its parts.

9.1.15. SealingComponent

A material used for sealing the construction of a borehole or well.

Table 95

Attribute	Type and Multiplicity	Definition
sealingMaterial	*SealingMaterialTerm [0..*]*	Material used in the sealing component of a water well. E.g., formation packer, welded ring, shale trap, drive shoe, driven casing, etc.
sealingType	*SealingTypeTerm [0..1]*	Type of sealing. E.g., annular sealing, plugging, etc.

Table 96

Relation	Source	Target	Description
Generalization	*Entity: SealingComponent* *Role:*	*Entity: ConstructionComponent* *Role:*	A seal part is a type of construction component.
Association	*Entity: BoreCollar* *Role:*	*Entity: SealingComponent* *Role: collarSeal*	Relation between a bore collar and its sealing parts.
Association	*Entity: Sealing* *Role:*	*Entity: SealingComponent* *Role: sealingElement*	Relation between a seal and its parts.

9.1.16. WellConstruction

Construction components of the well. These are particularly important when assessing results of pump tests.

Table 97

Relation	Source	Target	Description
Generalization	*Entity: Casing* *Role:*	*Entity: WellConstruction* *Role:*	A casing is a type of well construction entity.
Association	*Entity: Borehole* *Role:*	*Entity: WellConstruction* *Role: bholeConstruction*	Relation between a borehole and its construction components.

Generalization	*Entity: Screen* *Role:*	*Entity: WellConstruction* *Role:*	A screen is a type of well construction entity.
Generalization	*Entity: Filtration* *Role:*	*Entity: WellConstruction* *Role:*	A filtration device is a type of well construction entity.
Generalization	*Entity: Sealing* *Role:*	*Entity: WellConstruction* *Role:*	A sealing is a type of well construction entity.

10

REQUIREMENTS CLASSES (NORMATIVE)

10 REQUIREMENTS CLASSES (NORMATIVE)

This section describes requirement classes for any target implementation conforming to GWML2. Target implementations must meet related conformance class tests for at least one **concrete** requirements class (in Clause 10.2 and greater). The core requirement class (Section Clause 10.1) is **abstract,** therefore solely meeting the core requirements is insufficient to claim compliance with GWML2. Note, this section documents only those requirements that cannot be read directly from the UML logical model—**the logical model denotes the first suite of canonical requirements, which are supplemented by those below**.

10.1. ABSTRACT REQUIREMENTS CLASSES: GWML2 CORE LOGICAL MODEL

This core requirement class describes requirements that must be met by all target implementations that claim compliance with GWML2 (this standard). It also sets common requirements for all extensions of this standard. Since this requirement class is abstract, a conformant target implementation SHALL also implement at least one concrete requirements class from Clause 10.2 and greater.

REQUIREMENT CLASS: GWML2 CORE LOGICAL MODEL	
/req/core	
Obligation	requirement
Target Type	Encoding of logical models
Dependency	urn:iso:dis:iso:19156:clause:7.2.2
Dependency	urn:iso:dis:iso:19156:clause:8
Dependency	http://www.opengis.net/doc/IS/GML/3.2/clause/2.4
Dependency	O&M Abstract model, OGC 10-004r3, clause D.3.4
Dependency	http://www.opengis.net/spec/SWE/2.0/req/core/core-concepts-used
Requirement 2:	/req/core/encoding
Requirement 3:	/req/core/quantities-uom
Recommendation 1:	/req/core/codelist

REQUIREMENT CLASS: GWML2 CORE LOGICAL MODEL	
Requirement 4:	/req/core/codelistURI
Requirement 5:	/req/core/identifier
Requirement 6:	/req/core/feature

The properties, constraints, cardinalities and associations documented in the UML will be honoured by all the target implementations.

REQUIREMENT 2:
/req/core/encoding
All target implementations SHALL conform to the appropriate GroundWaterML2 Logical Model UML defined in Section 8.

10.1.1. Quantities

The Quantities and Measurements units of measure shall be taken from a standard vocabulary governed by an appropriate community.

REQUIREMENT 3:
/req/core/quantities-uom
Quantities and measurements SHALL have explicit units of measure specified using the URI for an individual from a class governed as an external ontology.

10.1.2. Code lists

All properties that should use formal vocabularies are modelled in UML as classes having the stereotype Clause 10.1.2. The list of valid terms should be taken from a standard vocabulary governed by an appropriate community. Vocabulary term identifiers should be HTTP URI conformant to RFC 3986.

RECOMMENDATION 1:
/req/core/codelist
Classes of stereotype Clause 10.1.2 SHOULD be encoded as externally governed vocabularies using HTTP URIs conformant to RFC 3986.

10.1.3. Code list URIs

The URI used to identify vocabulary terms SHOULD be resolvable using Linked Data Principles, such that a URI identifier can resolve to multiple representations (or formats) for the term using HTTP content codings, MIME-type, and language negotiation mechanisms.

REQUIREMENT 4:
/req/core/codelistURI
URI used for vocabulary terms SHOULD be resolvable using Linked Data principles, such that a URI identifier can resolve to multiple representations (or formats) for the term using HTTP content, MIME-type, and language negotiation mechanisms.

10.1.4. Identifiers

Features that use an HTTP URI as their identifier SHALL be resolvable following Linked Data principles (the HTTP URI is a link to possibly multiple representations of the resource). It is expected that a HTTP URI that is a feature identifier can be used to extract one or more representations of that feature by deferencing that URI, because the URI represents both its online location and its identity.

REQUIREMENT 5:
/req/core/identifier
HTTP URIs used as identifiers SHALL be resolvable following Linked Data principles, such that a URI identifier can resolve to multiple representations (or formats) for the term using HTTP content, MIME-type, and language negotiation mechanisms.

10.1.5. Feature

A valid instance document SHALL contain at least one valid GWML 2.2 feature.

REQUIREMENT 6:
/req/core/feature
A valid GWML 2.2 document SHALL contain at least one valid GWML 2.2 feature.

10.2. REQUIREMENT CLASS: GWML2-MAIN

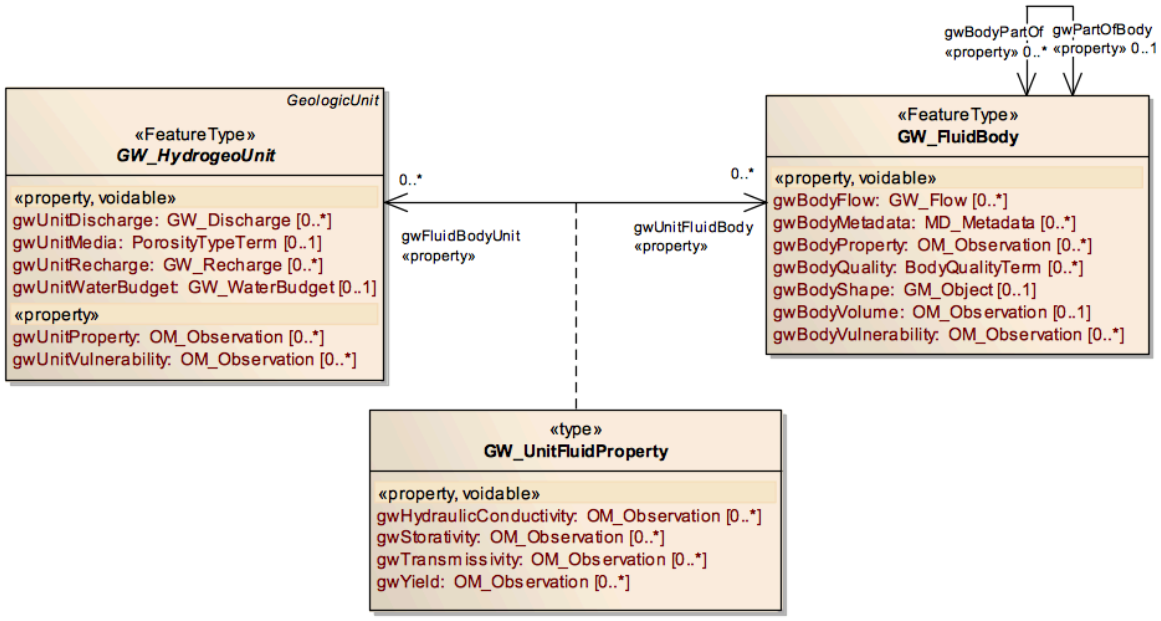
REQUIREMENT CLASS: MAIN LOGICAL MODEL	
/req/main	
Obligation	requirement
Target Type	Encoding of logical model
Dependency	/req/core
Dependency	ISO-19115
Dependency	GeoSciML-Basic 4.0
Dependency	/req/flow-uml
Dependency	/req/constituent-uml
Requirement 7:	/req/main/observed-unit-fluid-property-foi
Requirement 8:	/req/main/observed-unit-void-property-foi
Requirement 9:	/req/main/managementArea

10.2.1. Feature of interest for Association classes

OM_Observation is extensively used to represent property values wherever it is useful to include supporting metadata such as the methods used to obtain the values. As stated in ISO 19156:2011/10-004r3, the OM_Observation's feature of interest should be the bearer of the observed property (10-004r3, Clause 7.2.2.7). All properties in GWML 2.2 that use OM_Observation in the model are carried by Features; the relationship between the observation and the bearer of properties is obvious, except for two cases: **GW_UnitFluidProperty** (Figure 18) and **GW_UnitVoidProperty** (Figure 19).

GW_FluidProperty is an association class linking a GW_HydroGeoUnit and a GW_FluidBody and carries properties that are inherently related to the association of a geological unit and the fluid occupying its voids. Not being a feature, this class cannot be the feature of interest of the properties it bears.

Figure 18 — Association class between a GW_HydrogeoUnit and GW_FluidBody.

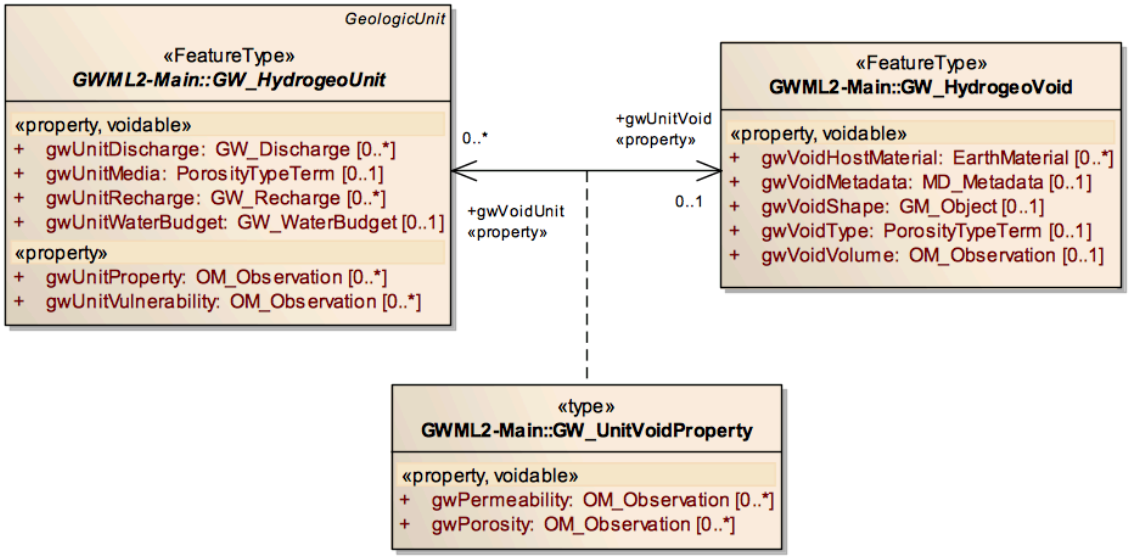


Traditionally, those properties (gwHydraulicConductivity, gwStorativity, gwTransmissivity and gwYield) are assigned by convenience to the hydrogeological unit (GW_HydrogeoUnit), because the fluid is a body of groundwater (GW_FluidBody) that is rarely explicitly identified. Therefore, the feature of interest of all the values of GW_UnitFluidProperty SHALL be the GW_HydrogeoUnit instance at the gwFluidBodyUnit end of the GW_UnitFluidProperty association.

REQUIREMENT 7:
/req/main/observed-unit-fluid-property-foi
The feature of interest of OM_Observation values for GW_UnitFluidProperty properties (gwHydraulicConductivity, gwStorativity, gwTransmissivity and gwYield) SHALL be the GW_HydrogeoUnit instance at the gwFluidBodyUnit end of the GW_UnitFluidProperty association.

Similarly, GW_UnitVoidProperty is an association class linking a GW_HydroGeoUnit with a GW_HydrogeoVoid, and this association class also then cannot be the feature of interest for the properties it bears (Figure 19).

Figure 19 — Association class between a GW_HydrogeoUnit and GW_HydrogeoVoid.



As void properties are traditionally assigned to the hydrogeologic unit, the feature of interest of all property values of GW_UnitVoidProperty SHALL be the GW_HydrogeoUnit instance, which is located at the gwVoidUnit end of the GW_UnitVoidProperty association.

REQUIREMENT 8:
/req/main/observed-unit-void-property-foi
The feature of interest of OM_Observation values for GW_UnitVoidProperty properties (gwPermeability and gwPorosity) SHALL be the GW_HydrogeoUnit instance at the gwVoidUnit end of the GW_UnitVoidProperty association.

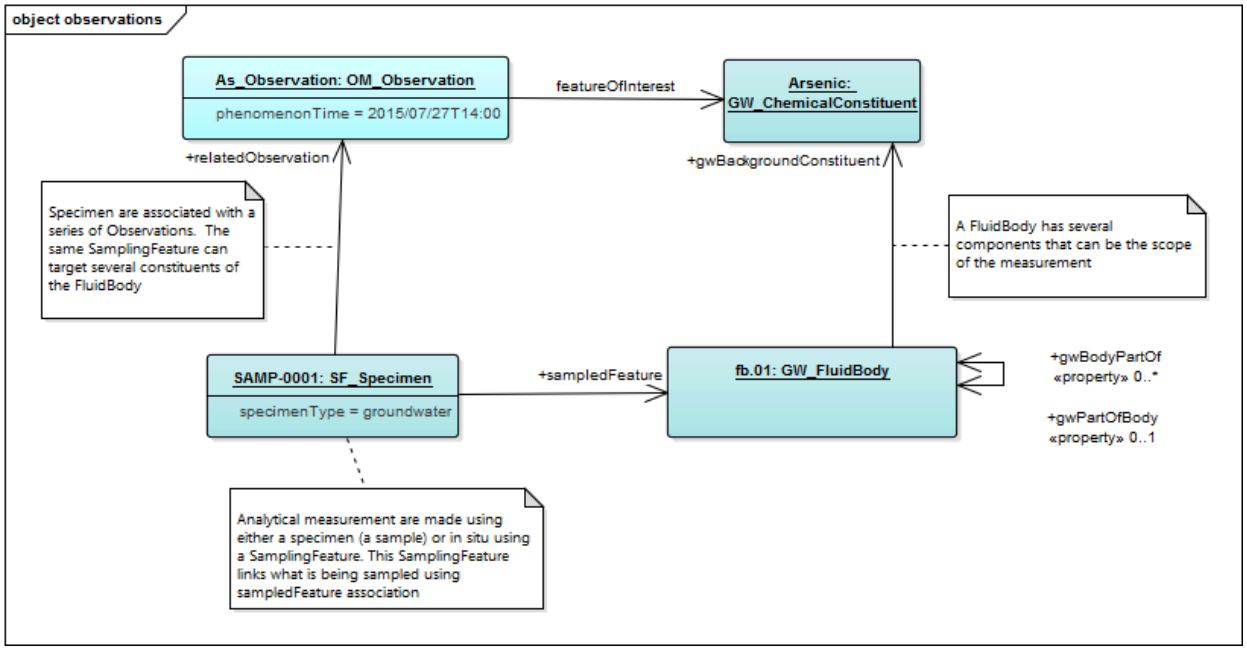
REQUIREMENT 9:
/req/main/managementArea
GW_Management's gwAreaFeature SHALL NOT be a subtype of GW_HydrogeoUnit.

10.3. REQUIREMENT CLASS: GWML2-CONSTITUENT

REQUIREMENT CLASS: CONSTITUENT LOGICAL MODEL	
/req/constituent	
Obligation	requirement
Target Type	Encoding of logical model
Dependency	/req/core
Dependency	ISO-19115
Recommendation 2:	/req/constituent/sampled-fluid-body

Analytical results are modelled as OM_Observation having GW_Constituent as features of interest (see Figure 20). A typical analytical procedure involves a sampling feature (such as a SF_Specimen) and a series of OM_Observations reporting on some properties of the feature of interest.

Figure 20 — The pattern for analytical results.



By referring to the real world identifiable feature using the sampledFeature property, and using the observation's featureOfInterest to refer to the constituent of the fluid body, this pattern permits a detailed description of the composition of various parts of the fluid body.

RECOMMENDATION 2:
/req/constituent/sampled-fluid-body
Sampling feature SHOULD link to a real world identifiable feature through sampledFeature, while individual observations should refer to the constituent that has been measured.

10.4. REQUIREMENT CLASS: GWML2-FLOW

REQUIREMENT CLASS: FLOW LOGICAL MODEL	
/req/flow	
Obligation	requirement
Target Type	Encoding of logical model
Dependency	/req/core
Dependency	/req/constituent

This requirements class does not contain any requirement. All the requirements are inherited from /req/core and /req/constituent.

10.5. REQUIREMENT CLASS: GWML2-WELL

This clause describes groundwater abstraction and monitoring through artificial features (water wells, monitoring stations) and natural features (springs). Artificial features are modelled as O&M sampling features (by the ISO 19156:2011 definition) as they are used as support for observations.

10.5.1. Water wells

REQUIREMENT CLASS: WATER WELL LOGICAL MODEL
/req/well

REQUIREMENT CLASS: WATER WELL LOGICAL MODEL	
Obligation	requirement
Target Type	Encoding of logical model
Dependency	/req/main
Dependency	/req/construction
Requirement 10:	/req/well/waterwell-elevationCRS
Requirement 11:	/req/well/waterwell-abs-shape-crs
Requirement 12:	/req/well/waterwell-rel-shape-crs
Requirement 13:	/req/well/waterwell-rel-shape-true-depth
Requirement 14:	/req/well/waterwell-rel-shape-downward
Requirement 15:	/req/well/waterwell-rel-shape-uom
Recommendation 3:	/req/well/waterwell-location-3D
Requirement 16:	/req/well/waterwell-depth-order
Requirement 17:	/req/well/waterwell-depth-point
Requirement 18:	/req/well/waterwell-observation-spatial-reference
Requirement 19:	/req/well/waterwell-observation-fromparam
Requirement 20:	/req/well/waterwell-observation-toparam
Requirement 21:	/req/well/waterwell-sf-spatial-reference
Requirement 22:	/req/well/waterwell-sf-fromparam
Requirement 23:	/req/well/waterwell-sf-toparam
Requirement 24:	/req/well/well-geology
Requirement 25:	/req/well/log
Requirement 26:	/req/well/monitoring-elevationCRS

A significant portion of this requirement class and the following requirement classes addresses the problem of spatially organizing features around a well. The shape of the well is a 3D curve, either in “absolute” (relative to a earth based datum) or relative (to some feature of the well) coordinates that represents the path of the hole in the ground. It is common practice to position observations, construction artefacts, and properties of the surrounding materials along this

3D path using a 1D coordinate system (usually called “depth” as of ISO19107) relative to the beginning of the path.

The origin from which the depth is measured can be the ground surface, some construction element or any other arbitrary feature. To convert depths to elevations, it must be identified and positioned with reference to a known vertical datum. Several reference elevation can be defined to allow a user to convert from one origin to another (from ground to “Kelly bushing” for instance). To avoid complexity, **all elements in a given well shall use the same vertical reference.**

This specification provides mechanism to

- report the location, the nature and the accuracy of the point of origin of depths
- position observations and samples in terms of depths
- report the geometry of the bore path in relative or absolute locations

Although water wells are often assumed to be straight vertical bores, this standard allows for the generic case, where the bore path is not a straight vertical line, and therefore positions must be calculated along an arbitrary complex curve. This specification provides a profile to handle the simpler case of vertical wells (see 9.7).

The following set of requirements defines how to report these values:

The elevation CRS must be a relevant EPSG vertical (1 dimension) CRS. Example: EPSG:5100 (Mean Sea Level : http://www.opengis.net/def/datum/EPSG/0/5100).

REQUIREMENT 10:
/req/well/waterwell-elevationCRS
GW_Well:gwWellReferenceElevation/Elevation:elevation CRS SHALL have a vertical datum.

10.5.2. Well shape

The shape of the well can be defined in either “absolute” coordinated (using an earth based datum) or using relative coordinates.

REQUIREMENT 11:
/req/well/waterwell-abs-shape-crs
An absolute GW_Well:shape SHALL be a 3D provide a valid 3D CRS

A shape defined as a relative geometry is positioned relative to the well. The origin of that curve (0,0,0) coincides with the GW_Well:gwWellLocation geometry. The geometry does not report any CRS to signal it is relative.

REQUIREMENT 12:
/req/well/waterwell-rel-shape-crs
A relative shape SHALL not report a CRS

The shape of a well normally refers to the third dimension as 'depth'. It is very important to not confuse "depth" — the distance along the length of the bore (measured depth) and true depth (depth from a vertical datum). While observations are often reported using measured depth, the shape of the bore SHALL use true depth. True depth is always ⇐ measure depth.

REQUIREMENT 13:
/req/well/waterwell-rel-shape-true-depth
The z axis of a relative shape SHALL be true depth

By convention, true depth are positive going **downward** (opposite direction from elevation).

REQUIREMENT 14:
/req/well/waterwell-rel-shape-downward
The z axis SHALL a positive value going downward

The unit of measure of the relative coordinates must be the same as the unit of measure used by the origin CRS.

REQUIREMENT 15:
/req/well/waterwell-rel-shape-uom
Units of measure of relative coordinates SHALL be the same as GW_Well::gwWellLocation/gml:Point

Ideally, the well location (GW_Well:gwWellLocation) should be a 3D point with a valid vertical CRS. But this information might be missing from old records. It is strongly recommended to data provider to assign an elevation, even if its approximate (and report this information in Elevation).

RECOMMENDATION 3:
/req/well/waterwell-location-3D
Well location SHOULD be a 3D point with relevant 3D CRS

Linear position on the bore path is expressed with the pair of properties “fromDepth” and “toDepth”, representing the distance from the origin. “fromDepth” is the value closest to the origin.

REQUIREMENT 16:
/req/well/waterwell-depth-order
The fromDepth of a LogValue SHALL be the closest along the path to gw_WellReferenceElevation while the toDepth shall be the farthest.

A “point” position is encoded with fromDepth and toDepth having the same value.

REQUIREMENT 17:
/req/well/waterwell-depth-point
A position along a borehole SHALL be composed of mandatory fromDepth and toDepth.

10.5.2.1. Observations

Any Observation that needs to be positioned along the well must provide a reference geometry (a GM_Curve) and a position along that curve. In a case where the path is the path of the well or a borehole, the reference geometry is expected to be the shape of that well or borehole, but it is not required. For instance, the relative location can be a “virtual path” somewhat related to a well or a group of wells.

REQUIREMENT 18:
/req/well/waterwell-observation-spatial-reference
The reference geometry of an Observation SHALL be encoded in a om:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry and a value of type GM_Curve.

The relative position shall be encoded in a specially named NamedValue.

REQUIREMENT 19:
/req/well/waterwell-observation-fromparam
The boundary of the interval closest to the well path origin, the “from” distance, SHALL be encoded in a om:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/fromDistance and a value of type swe:Quantity

REQUIREMENT 20:
/req/well/waterwell-observation-toparam
The boundary of the interval farthest from the well path origin, the “to” distance, SHALL be encoded in a om:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/toDistance and a value of type swe:Quantity

10.5.2.2. Related SamplingFeature

Any sampling feature that must be positioned along the linear path shall encode the reference GM_Curve and the relative position using sams:parameter.

REQUIREMENT 21:
/req/well/waterwell-sf-spatial-reference
The reference geometry of an Observation SHALL be encoded in a sams:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry and a value of type GM_Curve.

The relative position shall be encoded in specially labelled NamedValue.

REQUIREMENT 22:
/req/well/waterwell-sf-fromparam
The boundary of the interval, closest to the well path origin, the “from” distance, SHALL be encoded in a om:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/fromDistance and a value of type swe:Quantity

REQUIREMENT 23:
/req/well/waterwell-sf-toparam
The boundary of the interval farthest from the well path origin, the “to” distance, SHALL be encoded in a om:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/toDistance and a value of type swe:Quantity

10.5.3. Geology Log

GW_GeologyLog is an OM_Observation, with a start and end measured (along the borehole path) depth, that shall capture downhole geological observations (including geophysical and geochemical). Because GW_GeologyLog is a specialisation of OM_Observation, it can be use anywhere a OM_Observation is expected (unless explicitly forbidden) and therefore be a valid

value for relatedObservation (inherited from OM_Observation). To avoid confusing semantic, this specification limits the use of GW_GeologyLog togwml:gwWellGeology property only.

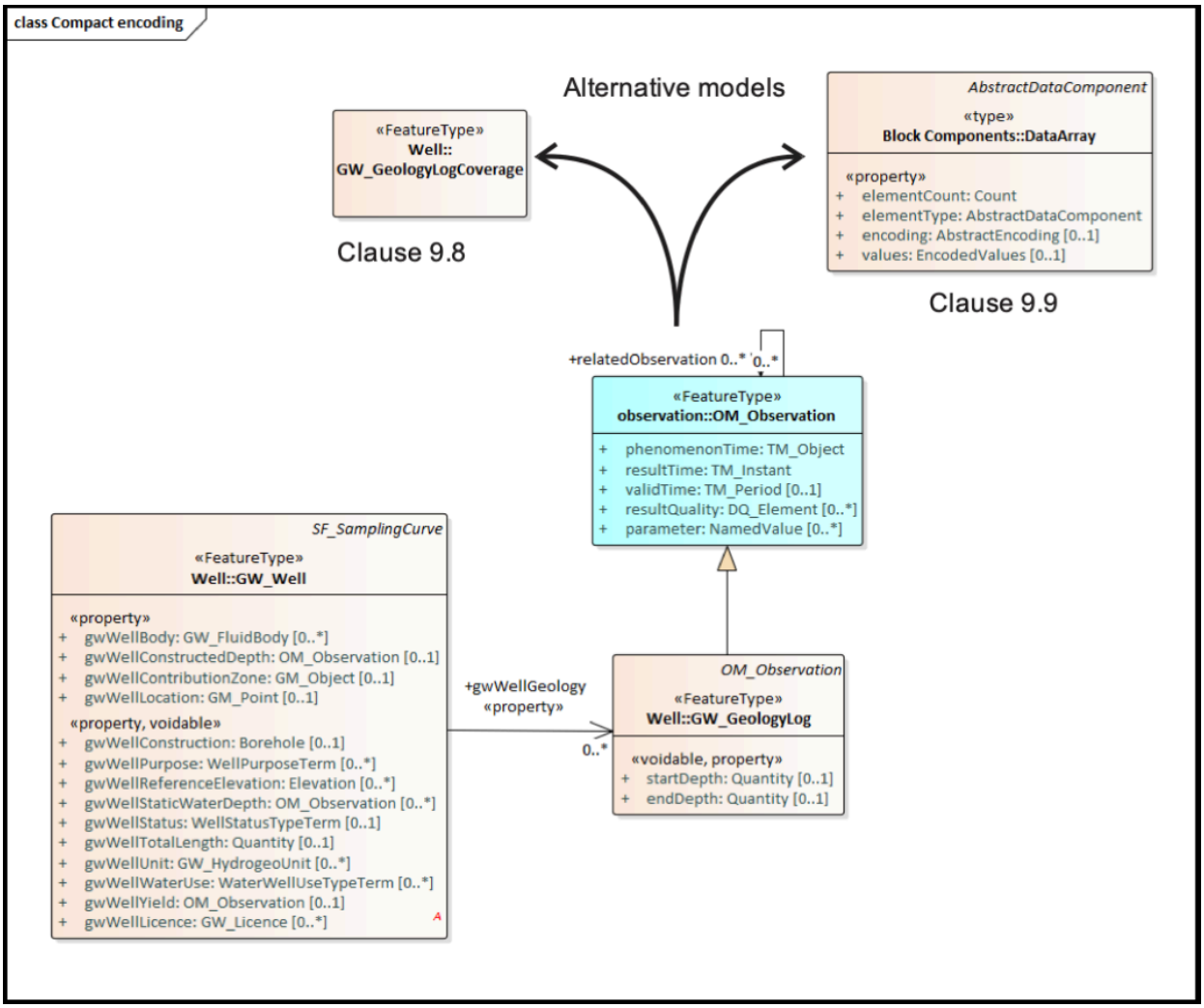
REQUIREMENT 24:

/req/well/well-geology

In a context of a GW_Well, instances of GW_GeologyLog SHALL only be used as values of GW_Well::gwWellGeology.

The geologic log is encoded as a GW_GeologyLogCoverage (Clause 9.1.10) or as a DataArray (Clause 10.9).

Figure 21 — Alternative Log encodings



REQUIREMENT 25:

/req/well/log

REQUIREMENT 25:
The value of om:result of GW_GeologyLog SHALL either be a GW_GeologyLogCoverage or swe:DataArray

10.5.4. Monitoring Sites

Elevation CRS must be a relevant EPSG vertical (1 dimension) CRS. Example EPSG:5100 (Mean Sea Level: http://www.opengis.net/def/datum/EPSG/0/5100).

REQUIREMENT 26:
/req/well/monitoring-elevationCRS
The elevation CRS SHALL be an appropriate vertical datum.

10.6. REQUIREMENT CLASS: GWML2-WELLCONSTRUCTION

REQUIREMENT CLASS: CONSTRUCTION LOGICAL MODEL	
/req/construction	
Obligation	requirement
Target Type	Encoding of logical model
Dependency	/req/core
Requirement 27:	/req/construction/collar-elevationCRS
Requirement 28:	/req/construction/construction-origin-elevation
Requirement 29:	/req/construction/borehole-shape
Requirement 30:	/req/construction/log-depth
Requirement 31:	/req/construction/log-depth-order
Recommendation 4:	/req/construction/relatedWell

10.6.1. Borehole

BoreCollar:collarElevation CRS must be a relevant vertical (1 dimension) CRS. Example EPSG:5100 (Mean Sea Level: http://www.opengis.net/def/datum/EPSG/0/5100).

REQUIREMENT 27:
/req/construction/collar-elevationCRS
Borehole:bholeHeadworks/BoreCollar:collarElevation CRS SHALL be a relevant vertical datum.

10.6.2. Construction

Borehole shall identify a BoreCollar that must be used as the reference location. The reference BoreCollar shall have a collarElevationType equal to http://resource.gwml.org/def/collarElevationType/originElevation .

Note that this BoreCollar need not be a physical feature, but would normally coincide with one. In a typical instance, we would find 2 or more collars, one or more real physical features, and another one as the reference collar that might or might not match one of the physical collars.

REQUIREMENT 28:
/req/construction/construction-origin-elevation
Each Borehole SHALL have one bholeHeadworks/BoreCollar:collarElevationType @xlink:href = “http://resource.gwml.org/def/collarElevationType/originElevation”

The Borehole shape SHALL be a 3D geometry that represents the complete well that includes any construction elements above the ground.

REQUIREMENT 29:
/req/construction/borehole-shape
Borehole:shape SHALL be a 3D geometry that represents the complete borehole that includes any Construction Component above the ground.

Depth shall be expressed as linear distance from the Borehole shape’s first vertex.

REQUIREMENT 30:
/req/construction/log-depth

REQUIREMENT 30:
The “from” and “to” of a Construction Component SHALL be the linear distance along the shape of the borehole.

The ‘from’ value must be closer to the Borehole origin than the ‘to’ value.

REQUIREMENT 31:
/req/construction/log-depth-order
The ‘from’ value of a Construction Component SHALL be the closest along the path to first vertex of the Borehole shape while the ‘to’ value SHALL be the farthest.

10.6.3. Related Wells

To avoid cyclic dependencies between the Well and WellConstruction packages, there is no explicit property to link a Borehole to a WaterWell. To provide such information, an encoding should use a relatedSamplingFeature and SamplingFeatureComplex (10-004r3, Clause 9.2.3) as both Borehole and GW_Well are subtypes of SF_SamplingFeature. This specification does not prescribe a role name.

RECOMMENDATION 4:
/req/construction/relatedWell
If a Borehole need to refer to a related GW_Well, a relatedSamplingFeature and SamplingFeatureComplex should be used

10.7. REQUIREMENT CLASS: VERTICAL WELL (PROFILE)

REQUIREMENT CLASS: VERTICAL WELL LOGICAL MODEL	
/req/vertical-well	
Obligation	requirement
Target Type	Model encoding
Dependency	/req/well
Requirement 32:	/req/vertical-well/waterwell-shape

REQUIREMENT CLASS: VERTICAL WELL LOGICAL MODEL	
Requirement 33:	/req/vertical-well/end-vertex

A vertical well is a special case where the shape of the well is a straight vertical line. The rationale to create a special profile is to inform the data consumer that calculation of relative position into absolute position is greatly simplified — or the well shape can be ignored since all the positional information can be inferred from the GW_Well::WellLocation, gwWellReferenceElevation and gw:WellTotalLength. This implies there is an alternative way to build "3D" query. Vertical wells are very common and several groundwater applications expect them to be vertical. GW_Well:shape shall have only 2 vertices.

REQUIREMENT 32:
/req/vertical-well/waterwell-shape
GW_Well:shape SHALL have only 2 vertices

The second vertex shall have the same x and y as the first vertex.

REQUIREMENT 33:
/req/vertical-well/end-vertex
The planar position (x,y) of the second vertex SHALL be the same as the first vertex

10.8. REQUIREMENT CLASS: GEOLOGYLOG (PROFILE)

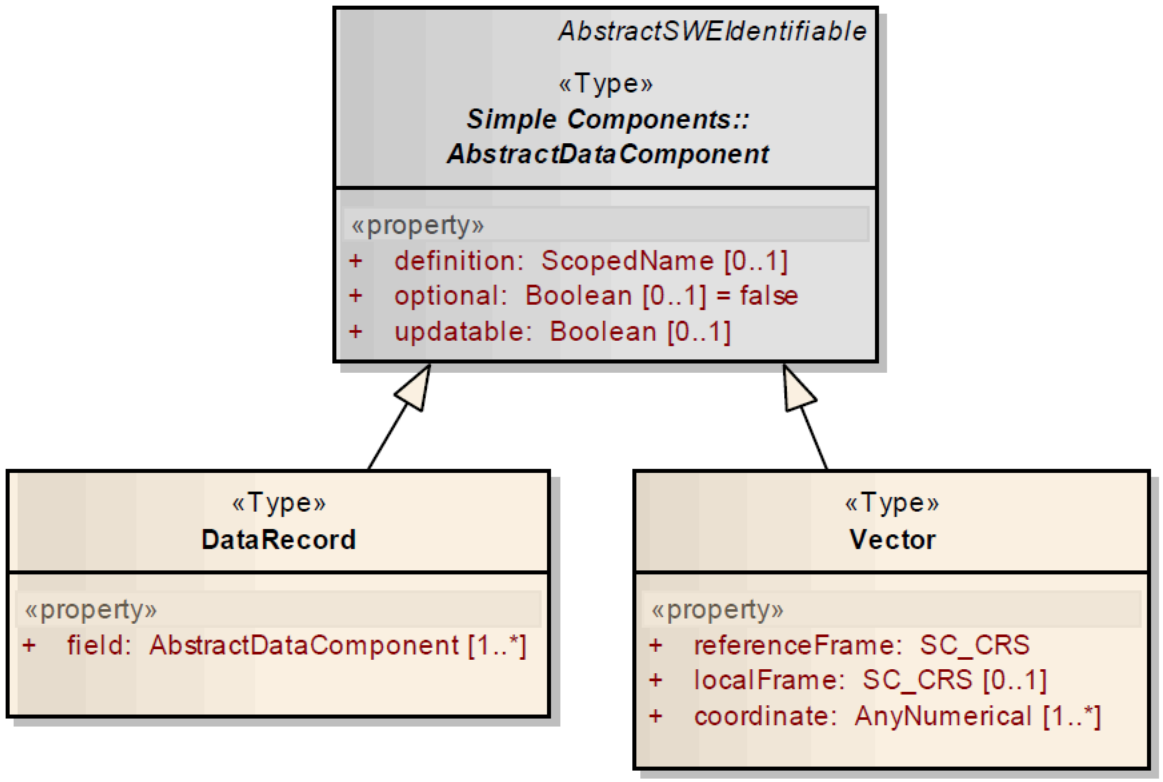
This requirement class describes a recommended pattern to encode a GeologyLog.

REQUIREMENT CLASS: GEOLOGIC UNIT LOGS DISCRETE COVERAGE ENCODING	
/req/well-log-cov	
Obligation	requirement
Target Type	Encoding of logical model
Dependency	/req/well
Dependency	http://www.opengis.net/spec/SWE/2.0/req/uml-record-components

REQUIREMENT CLASS: GEOLOGIC UNIT LOGS DISCRETE COVERAGE ENCODING	
Recommendation 5:	/req/well-log-cov/log-definition

In this profile, geological logs are modelled as GML discrete coverages (CV_DiscreteElementCoverage, 06-188r1) of elements of type LogValue. Each Log Value is composed of a pair of properties to locate the element along the Well path (fromDepth and toDepth) and a **SWE DataRecord** that contains an arbitrary set of fields to report properties of interest along the path (see Figure 22). This approach is verbose and exposes explicitly fromDepth and toDepth, making it more suitable to a WFS environment. which uses XPath to target filter properties. It also allows heterogenous coverages, since nothing prevents a different DataRecord in each element. This might or might not be considered a positive aspect. A community can enforce DataRecord to remain the same in the coverage by defining their own profile.

Figure 22 — SWE Data Record



SWE (08-094r1, Clause 7.3) describes the requirements to encode a DataRecord. A community that defines a common Geologic Log encoding should agree on a definition and scoped name for the DataRecord, as well as on definitions of the individual fields composing the record.

For example, a community that wants to use some GeoSciML 4.0 vocabulary to encode a geology log can agree on a field type (eg: SWE Category) and a definition (a URI) to flag that field in the DataRecord as having controlled content. Another community might chose to constrain the complete DataRecord by agreeing on the scoped name of the DataRecord itself.

RECOMMENDATION 5:
/req/well-log-cov/log-definition
The Log Value of a Geologic Log SHOULD use a community controlled definition for the DataRecord and / or the fields that compose it.

10.9. REQUIREMENT CLASS: DATAARRAY

This requirement class describes the recommended compact pattern to encode a GeologyLog.

REQUIREMENT CLASS: GEOLOGIC UNIT LOGS BLOCK ENCODING	
/req/well-log-array	
Obligation	requirement
Target Type	Encoding of logical model
Dependency	/req/well
Dependency	http://www.opengis.net/spec/SWE/2.0/req/uml-block-components
Requirement 34:	/req/well-log-array/fromDepthId
Requirement 35:	/req/well-log-array/toDepthId
Recommendation 6:	/req/well-log-array/log-definition

Block log encoding is an alternative to GeologicLogCoverage encoding (see clause Clause 10.8). Clause Clause 10.8 provides an explicit discrete coverage encoding that is rather verbose because of the nature of the combination of CV_DiscreteCoverage and DataRecord. Each member of the discrete coverage defines a new DataRecord, and describes the record structure. As logs usually describe the same variables along their length, this structure is extremely redundant.

The SWE::DataArray (08-094r1, Clause 7.5) encoding is more compact because it describes fields only once in a header section. DataArray also provides alternative value encoding (xml, text block or binary) and external references to encoded data files. Because this encoding does not impose an explicit “from” and “to” field, it can also accommodates non-spatial logs (such as time series). Note that users seeking water related time series should consider WaterML Part 1 (10-126r4). Note that swe:Matrix is a subtype of swe:DataArray, making swe:Matrix a valid substitute.

For client applications ingesting a DataArray, this specification defines explicit identifiers for fromDepth and toDepth. A client can then locate the position properties by scanning the component definitions.

Compact encoding is composed of a series fields from which 2 might designated as fromDepth and toDepth, representing a section along the log.

REQUIREMENT 34:
/req/well-log-array/fromDepthId
The field that contains the location of the beginning of a segment along the borehole SHALL be identified with the URI http://www.opengis.net/def/gwml/2.2/observedProperty/fromDepth

REQUIREMENT 35:
/req/well-log-array/toDepthId
The field that contains the location of the end of a segment along the borehole SHALL be identified with the URI http://www.opengis.net/def/gwml/2.2/observedProperty/toDepth

DataArray::elementType provides a description of each field composing the array, The data type is defined using a SWE DataComponent used as data description (08-094r1, Clause 7.3.1). Each DataComponent has a definition property containing to a unique URI representing a specific property (eg: SWE::Quantity for a Temperature). It is recommended that a standard list of definition URI is defined by a community to uniquely identified properties of interest.

RECOMMENDATION 6:
/req/well-log-array/log-definition
Community should define a vocabulary of properties of interest

10.10. REQUIREMENT CLASS: AQUIFER TEST (PROFILE)

REQUIREMENT CLASS: AQUIFER TEST	
/req/aquifertest	
Obligation	requirement
Target Type	Encoding of logical model

REQUIREMENT CLASS: AQUIFER TEST	
Dependency	/req/core
Dependency	Observations and Measurements
Dependency	http://www.opengis.net/spec/waterml/2.0/req/uml-timeseries-observation
Dependency	http://www.opengis.net/spec/SWE/2.0/req/uml-record-components
Requirement 36:	/req/aquifertest/sampledfeature
Requirement 37:	/req/aquifertest/testfeature
Requirement 38:	/req/aquifertest/observationfeature
Recommendation 7:	/req/aquifertest/testparameter
Recommendation 8:	/req/aquifertest/observation
Requirement 39:	/req/aquifertest/observation-role
Recommendation 9:	/req/aquifertest/observedProperty
Requirement 40:	/req/aquifertest/timeseries
Requirement 41:	/req/aquifertest/timeseries-datarecord

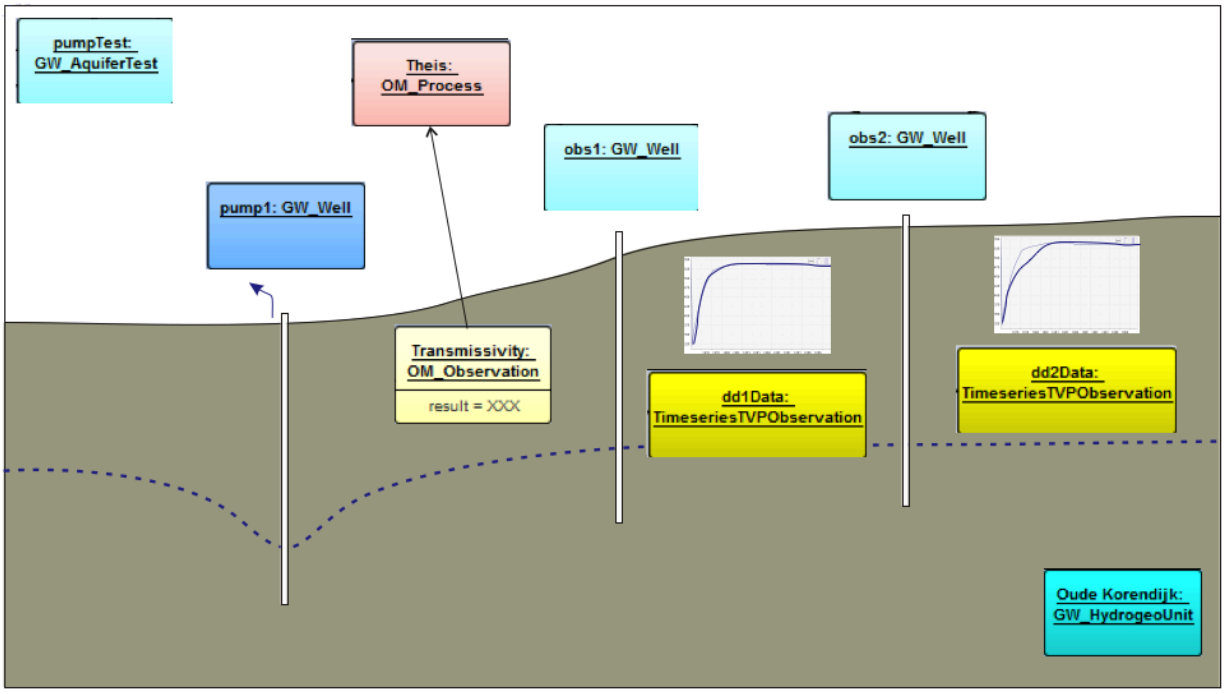
Aquifer hydraulic parameters are routinely evaluated by a series of tests that involves pumping or injecting water at known rates and by observing the changes in the water table. Other tests might involve injecting a tracer (radio element or dye) at some location and follow its progression at observation points. From these observations, various methods have been developed to compute aquifer properties. To adequately report an aquifer test, the data about initial conditions, test parameters, sampling features, measured and calculated observation must be packaged and put into context.

Figure 17, above, shows the elements required to encode an aquifer test. An AquiferTest assesses an Aquifer using a method (eg: Packer test) that is encoded as an OM_Process. The test is performed at a test site (the GW_AquiferTest defines a geometry corresponding to the test location) and consists of sampling features (usually the GW_Well) that are associated to the GW_AquiferTest through relatedSamplingFeature. Each sampling feature has a role in the test (observation or test features). Some sampling features are sites where test activities are performed (referred to as “test feature”), such as pumping water out of a bore. Other features are sites where more passive observations are made, such as measuring the impact of pumping made at the test sampling feature on the water table. From this activity, a series of observation are made, typically time series along the timespan of the test. Then from these observations, a method is used to infer some aquifer properties (such as transmissivity, storativity or yield). The

findings are then documented in a report that can be attached to GW_AquiferTest using generic metadata properties.

A typical AquiferTest might be sketched as follows in Figure 23:

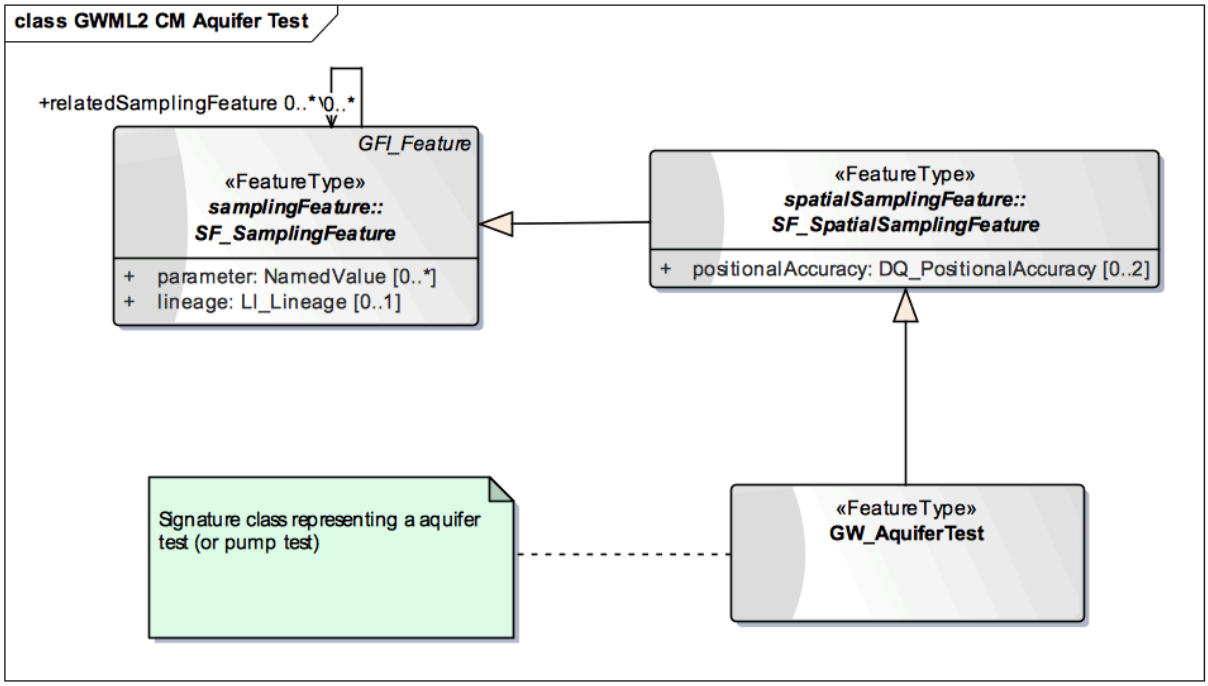
Figure 23 — A typical pumping test.



10.10.1. Aquifer Test O&M mapping

Observation and Measurement (O&M 2.0 : OGC 10-004r3), along with its GWML extensions, contains all the elements needed to model an aquifer test. A complete aquifer test can be built around SF_SamplingFeature and OM_Observation, with the addition of GW_AquiferTest, a subtype of SF_SpatialSamplingFeature (Figure 24), to distinguish aquifer tests from other sampling features and to package observations and sampling features.

Figure 24 — GW_AquiferTest.



10.10.2. GW_AquiferTest (O&M profile)

GW_AquiferTest is a specialized sampling feature representing an aquifer test (or pump test). It packages all the sampling features and observations generated by the test and the computed results from those observations. The following section describes implementation of aquifer test in O&M.

10.10.3. SF_SamplingFeature properties

10.10.3.1. sampledFeature

In the context of an aquifer test, it links to the real world feature being assessed by the aquifer test (generally a **GW_AquiferUnit**). O&M does not constrain **SF_SamplingFeature** to any particular feature type, but this standard requires that the **sampledFeature** shall be a subtype of a **GW_HydrogeoUnit**.

REQUIREMENT 36:
/req/aquifertest/sampledfeature

REQUIREMENT 36:
The sampledFeature of a GW_AquiferTest SHALL be an instance of (or a reference to) a subtype of GW_HydrogeoUnit.

10.10.3.2. relatedSamplingFeature

In the context of an aquifer test, the related sampling feature property identifies all the sampling features participating in the aquifer test. The role of each feature is assigned by the **SF_SamplingFeatureComplex:role** property. The role of the sampling feature is scoped by the test. Therefore the same sampling feature can have different roles in different tests, but also within the same test (by having multiple **SF_SamplingFeatureComplex** referring to the same **SF_SamplingFeature**). Single bore tests are examples where the observation bore and the test bore are the same feature. This standard proposes a list of core roles to identify the observation features and test features.

The test feature is the “active” sampling feature where the test is performed (e.g., the well that is pumped or injected).

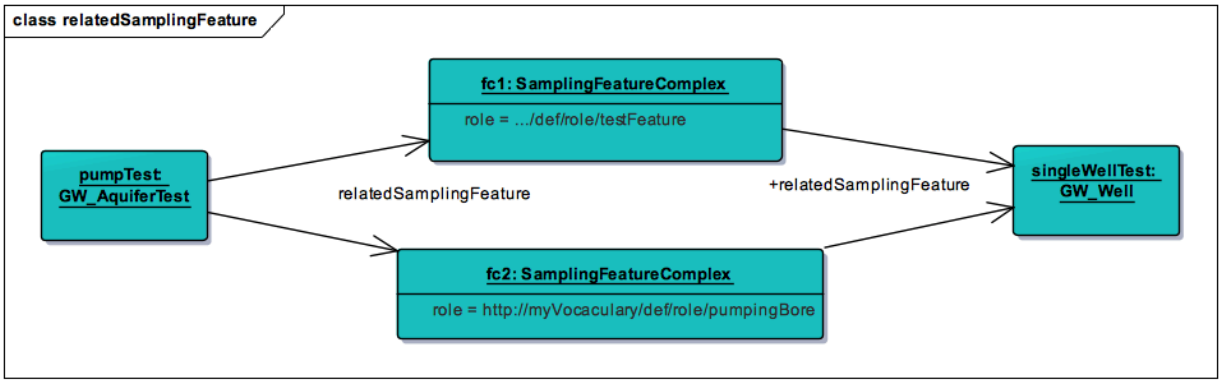
REQUIREMENT 37:
/req/aquifertest/testfeature
SF_SamplingFeatureComplex:role for the sampling feature where the test is performed SHALL have the value http://resource.gwml.org/def/role/testFeature

The observation feature is the “passive” feature where observations are made. It is the feature at which the effects of the test are measured.

REQUIREMENT 38:
/req/aquifertest/observationfeature
SF_SampleFeatureComplex:role for the sampling feature where the observations are made SHALL have the value http://resource.gwml.org/def/role/observationfeature

A single sampling feature can be the target of several SF_SamplingFeatureComplex. A data provider can add more than one SF_SamplingFeatureComplex to accommodate other roles (see Figure 25).

Figure 25 — Multiple roles for the same well using two SF_SamplingFeatureComplexes.



10.10.3.3. parameter

Test parameters, such as pumping rates during the test are not considered as being an observation, but as test parameters. To document test parameters, there are two options:

- Using **SF_SpatialSamplingFeature:hostedProcedure** of type OM_Process that can encode all possible details of a test using SensorML (OGC 12-000), MD_Metadata (ISO-19115) or any other suitable model; or
- Use **parameter** of type **SF_SamplingFeature:parameter:NamedValue** using agreed value types for well-known test parameters.

Although the formal mechanism to report test parameters is through **OM_Process**, this standard recommends reporting community defined values in simple parameter key-value pairs (KVP) using **sf:NamedValue**.

RECOMMENDATION 7:
/req/aquifertest/testparameter
When present, SF_SamplingFeature:parameter:NamedValue SHALL be encoded using community defined values

10.10.3.4. relatedObservation

All related observations, including the observations made at the test feature sites and observation derived from those observations should be available as related observations (**sf:relatedObservation**).

RECOMMENDATION 8:
/req/aquifertest/observation

RECOMMENDATION 8:
All observations relevant to an aquifer test SHOULD be available as relatedObservation

From the raw observations measured during a test, new observations can be inferred or calculated. The raw observations (related from the observation Features) and the derived observations (the result of the test) SHALL be related to each other using om:ObservationContext. The role of the observation context defines which observation derives or supports the other one. 'supportObservation' and 'derivedObservation' roles can be considered complementary: if A is supportObservation of B, then B is the derivedObservation of A.

REQUIREMENT 39:
/req/aquifertest/observation-role
Raw observations from the observation sampling feature SHALL be link to the test result observations using the roles defined in Table 98

Table 98 — ObservationContext roles.

ROLE	URI	DIRECTION
Support observation	http://www.opengis.net/def/role/supportObservation	Observation linking to other observation used to calculate, derive or infer a new values
Derived observation	http://www.opengis.net/def/role/derivedObservation	Observation linking to another observation that has calculated, inferred or derived values

10.10.3.5. hostedProcedure

A hostedProcedure is used to document such things as methods to identify or localise the sampling feature, but its use is not constrained to anything specific. The hostedProcedure property, of type OM_Process, may be used to accommodate detailed aquifer test parameters if needed by the data provider.

The O&M standard does not prescribe any model to encode OM_Process, but suggests:

ISO 19115-2 provides MI_Instrument, LE_Processing and LE_Algorithm, which could all be modelled as specializations of OM_Process. OGC SensorML [16] provides a model which is suitable for many observation procedures

OGC 10-0043 / ISO 19156, clause 7.2.3, p. 14

For instance, a pump (used to pump water from the borehole) can be modelled as a SensorML sml:PhysicalSystem.

10.10.3.6. shape

SF_SpatialSamplingFeature does not constrain the geometry type (Point, Curve, Polygon, etc), therefore any geometry can represent a test. In most situations, the geometry of the test is the test area, the zone of influence around the pumping test or even the volume of rock affected or in scope for the test.

This standard also does not constrain the geometry type. Communities that wish to constrain the geometry type should create a profile of this standard.

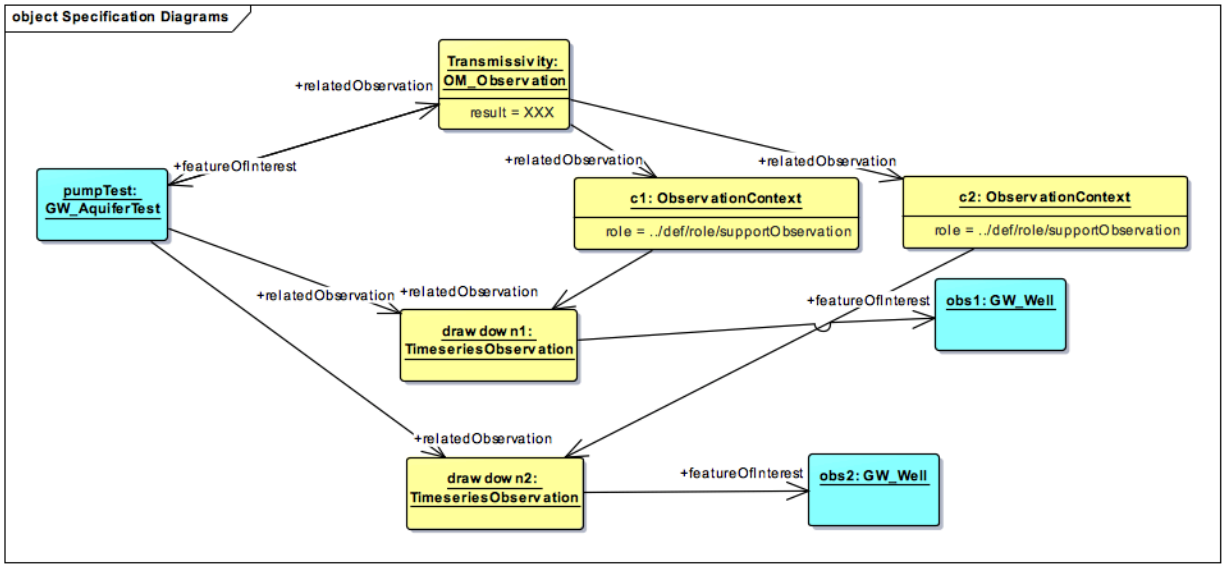
10.10.4. OM_Observation

OM_Observations are used to represent values of properties observed or computed in the context of this test. There are at least two categories of observations generated through an aquifer test:

- Raw observations, normally taken at the observationFeatures; and
- Derived observations, calculated from the raw observations.

These two kinds of observations differ by their respective feature of interest. For the former (raw data) the feature of interest is the sampling feature from which observations are made (e.g., observation bore). In the latter case, the feature of interest is the GW_AquiferTest itself. Observations can be linked together using related observations (**om:relatedObservation/ om:ObservationContext**), which provide a role (**om:ObservationContext/om:role**) for the targeted observation. Figure 26 shows an example of “raw” observations (Drawdown1 and Drawdown2) measured at two observation wells (obs1 and obs2). The same figure also shows a derived observation (transmissivity) having the aquifer test itself as its feature of interest. The derived observation provides a link back to the supporting observation used to compute the derived values.

Figure 26 — Relationships between observations and features of interest.



Observations made during the test and computed observations are modelled as OM_Observations.

10.10.4.1. phenomenonTime, resultTime and validTime

As specified in Observation and Measurement; **phenomenonTime** reflects the time that the result applies to the property; the **resultTime** is the time at which the value has been obtained or became available and **validTime** is the time during which the value is usable. Depending on the type of observation (raw or computed), those time might be different (see Table 99).

Table 99 — Types of observations and times.

TYPE OF OBSERVATION	PHENOMENONTIME	RESULTTIME	VALIDTIME
Raw	Duration of the test	End of the test	Period during which the condition are the same, so the same test would produce the same values
Derived	Duration of the test	When calculation are done (publication)	Depends on the parameters or test

10.10.4.2. observedProperty

This property describes the phenomenon being observed (e.g., groundwater level). The observed property is normally a reference to a property inherent in the feature of interest (“`*the real word feature is the subject of the observation and carries the observed property*, clause=7.2.2.7). But

because of subtle variations in the semantics of such properties (such as specific Yield versus maximum Yield versus sustainable Yield, etc.), the **observedProperty** meaning should be formally defined by a community. The value of **observedProperty** becomes a reference to that definition (expressed in SWE, SKOS or OWL for example).

ObservedProperty can also be a compound property (a collection of **observedProperty**). Again, because of the close tie to use cases, compound properties should be defined by a community.

RECOMMENDATION 9:
/req/aquifertest/observedProperty
The observedProperty SHOULD be a reference to a community managed vocabulary.

10.10.4.3. result

The result property reports the product of the observation process. In many cases, the aquifer test will produce a time series, such as drawdown data over time. When the result is a time series, it shall be modelled as a TimeSeriesML 1.0 (OGC 15-082r3).

REQUIREMENT 40:
/req/aquifertest/timeseries
Observation producing time series SHALL be modelled as TimeSeriesML 1.0 (OGC 15-042r3)

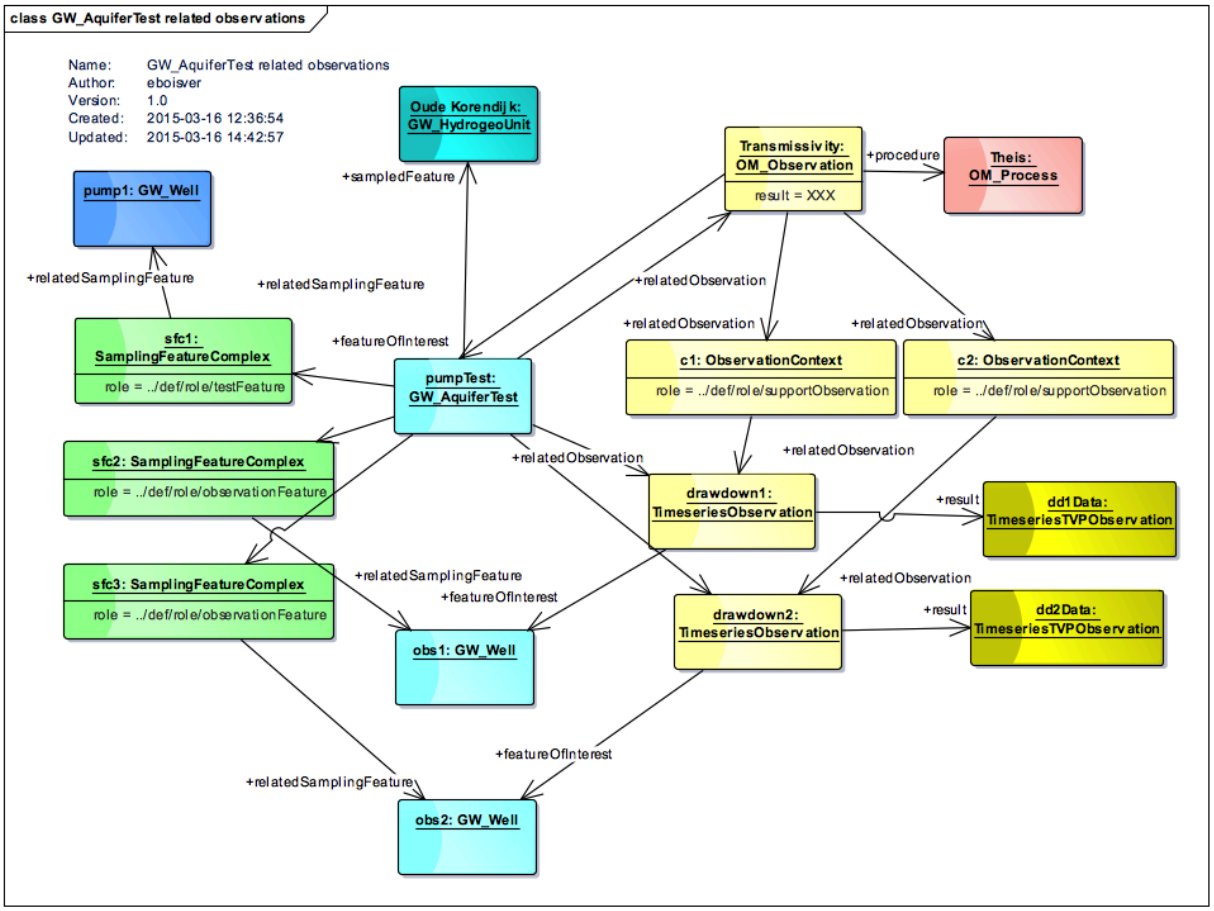
Derived (or computed) observations will often produce compound values. It is possible to report each result component as distinct observations, but GWML2 shall use the more efficient alternative of wrapping compound results into **swe:DataRecord.**

REQUIREMENT 41:
/req/aquifertest/timeseries-datarecord
Derived or computed observations SHALL be encoded as swe:DataRecord

10.10.5. Aquifer test overview

Figure 27 provides an example of the mapping of AquiferTest to O&M.

Figure 27 — Typical pump test instance: 1 sampling feature and 2 observation features.



11

XML IMPLEMENTATION (NORMATIVE)

11 XML IMPLEMENTATION (NORMATIVE)

11.1. GWML2-XSD

Groundwater features and their properties will be encoded in XML using standard GML encoding rules (Annex E of OGC Geography Markup Language v3.2 (ISO 19136:2007).

In examples, HTTP URIs that are used as resolvable resources (e.g. for vocabularies) may be included as examples only, for illustration purposes, and may not resolve, because the vocabularies are not defined. However, some such URIs in various example encodings may resolve if data providers have defined and implemented vocabularies for particular services.

XML snippets will use the following prefixes:

Table 100

gwml2	http://www.opengis.net/gwml-main/2.2
gwml2c	http://www.opengis.net/gwml-constituent/2.2
gwml2f	http://www.opengis.net/gwml-flow/2.2
gwml2w	http://www.opengis.net/gwml-well/2.2
gwml2at	http://www.opengis.net/gwml-aquifertest/2.2
gwml2wc	http://www.opengis.net/gwml-wellconstruction/2.2
gml	http://www.opengis.net/gml/3.2
cv	http://www.opengis.net/cv/0.2/gml32
om	http://www.opengis.net/om/2.0
sam	http://www.opengis.net/sampling/2.0
sams	http://www.opengis.net/samplingSpatial/2.0
spec	http://www.opengis.net/samplingSpecimen/2.0
swe	http://www.opengis.net/swe/2.0
gco	http://www.isotc211.org/2005/gco
gmd	http://www.isotc211.org/2005/gmd
gsmlb	http://xmlns.geosciml.org/GeoSciML-Basic/4.0

gsmlx	http://xmlns.geosciml.org/GeoSciML-Extension/4.0
xlink	http://www.w3.org/1999/xlink
wfs	http://www.opengis.net/wfs/2.0

REQUIREMENT CLASS: GML/XML ENCODING	
/req/xsd-xml-rules	
Obligation	requirement
Target Type	XML data document
Dependency	ISO-19118
Dependency	ISO/IEC 19757-3:2006 (Schematron)
Dependency	http://www.w3.org/TR/xmlschema-2
Dependency	http://www.opengis.net/doc/IS/GML/3.2/clause/2.4
Dependency	http://www.opengis.net/spec/SWE/2.0/req/xsd-simple-components
Dependency	urn:iso:dis:iso:8601:2004:clause:4
Dependency	req/core
Dependency	http://www.ietf.org/rfc/rfc2616
Dependency	http://www.opengis.net/spec/GML/3.3/req/definitions
Requirement 42:	/req/xsd-xml-rules/W3C_XSD
Requirement 43:	/req/xsd-xml-rules/ISO-schematron
Requirement 44:	/req/xsd-xml-rules/iso8601-time
Requirement 45:	/req/xsd-xml-rules/time-zone
Requirement 46:	/req/xsd-xml-rules/swe-types
Requirement 47:	/req/xsd-xml-rules/identifier
Recommendation 10:	/req/xsd-xml-rules/byrefproperty
Requirement 48:	/req/xsd-xml-rules/xlink-title
Recommendation 11:	/req/xsd-xml-rules/vocabulary-reference

ISO-19136_2007 provides a mapping between UML classifiers and XSD entities. All XSD types and elements must be created following those mapping rules. This standard considers the XSD files (the schema files) to be normative (they contain the official interpretation of 19136 conversion of the UML classifiers into XML).

REQUIREMENT 42:
/req/xsd-xml-rules/W3C_XSD
All elements and attributes in a namespace SHALL validate according to W3C XSD rules encoded in the xsd file associated with this namespace and its dependencies.

Other rules, that can't be expressed in XSD, are provided as schematron rules. As the XSD files, schematron rules files are considered normative.

REQUIREMENT 43:
/req/xsd-xml-rules/ISO-schematron
All elements and attributes covered by this standard SHALL pass schematron validation rules in http://schemas.opengis.net/gwml/2.2/xml-rules.sch

The date-time formats will conform to ISO standards. Although this is already a GML 3.2.1 encoding rule (clause 14.2.2.7), this format shall also be used in any string that is not normally checked for an occurrence of dates.

REQUIREMENT 44:
/req/xsd-xml-rules/iso8601-time
All date-time elements or occurrences within strings SHALL be encoded using ISO8601 extended time format

Note that this precludes the use of time-coordinate systems such as UNIX time. This is specified in order to be maximally consistent with WML2 requirements. The time zone will be included in the time element.

REQUIREMENT 45:
/req/xsd-xml-rules/time-zone
The value of each time element SHALL include a time zone definition using a signed 4 digit character or a 'Z' to represent Zulu or Greenwich Mean Time (GMT). This is defined by the following regular expression: (Z|[+-]HH:MM)

Greenwich Mean Time (GMT or Zulu)

<om:phenomenonTime>

<gml:TimeInstant gml:id="ab.ww.402557.wl.1.ti.1">

<gml:timePosition>1981-09-12T00:00:00Z</gml:timePosition>

</gml:TimeInstant>

</om:phenomenonTime>

Time Zone (example is Newfoundland time zone -3:30)

<om:phenomenonTime>

<gml:TimeInstant gml:id="nf.ww.34212.wl.1.ti.1">

<gml:timePosition>1981-09-12T00:00:00-03:30</gml:timePosition>

</gml:TimeInstant>

</om:phenomenonTime>

Some SWE Common types are restricted to avoid ambiguity.

REQUIREMENT 46:
/req/xsd-xml-rules/swe-types
When using the SWE Common types, the following elements SHALL NOT be used: swe:quality (AbstractSimpleComponentType), swe:nilValues (AbstractSimpleComponentType), swe:constraint (QuantityType, QuantityRangeType, CategoryType). The attributes 'optional' and 'updatable' from the base type 'AbstractDataComponent' SHALL also not be used.

11.1.1. Identifier

A feature that can be accessed through Linked Data using a resolvable HTTP URI must use this HTTP URI as its global unique identifier. In GML, this shall be encoded using gml:identifier and code space = "http://www.ietf.org/rfc/rfc2616". In other words, the gml:identifier shall point to a representation of itself.

REQUIREMENT 47:
/req/xsd-xml-rules/identifier
A resolvable resource SHALL expose its resolvable HTTP URI as a gml:identifier AND use http://www.ietf.org/rfc/rfc2616 for the codeSpace value.

Example of a feature that exposes its resolvable HTTP URI as a globally unique identifier

(...)

<gwml2w:GW_Well gml:id="ca.ab.gov.wells.402557">

<gml:description>Water well from Alberta water well database</gml:description>

<gml:identifier codeSpace="http://www.ietf.org/rfc/rfc2616">http://ngwd-bdnes.cits.nrcan.gc.ca/Reference/uri-cgi/feature/gsc/waterwell/ca.ab.gov.wells.402557</gml:identifier>

<gml:name codeSpace="urn:cgi:featureType:CA.AB:WaterWell">402557</gml:name>

<gml:name codeSpace="urn:x-gin">ca.ab.waterWell.402557</gml:name>

(...)

11.1.2. By-Reference properties

Properties can be constrained to be by-reference only, or either inline or by-reference. For a by-reference property that refers to an external feature, the reference shall be resolvable over the web. The reference shall be either a resolvable HTTP URI that might also match the feature's globally unique identifier (see **/req/core/identifier**) or an HTTP request (for instance, a WFS GetFeature with the stored query urn:ogc:def:query:OGC-WFS::GetFeatureById) to the a representation of the feature in GML.

RECOMMENDATION 10:
/req/xsd-xml-rules/byrefproperty
A reference to an external feature SHOULD be resolvable to a GML representation of the feature

(...)

<gwml2:gwAquiferSystemPart xlink:href="http://environment.data.gov.au/groundwater/feature/hydrogeologicalunit/hgu.nsw.5" xlink:title="Stuarts Point - Lower Quaternary Sands"/>

(...)

Note that elements under GWML2 namespaces can be mixed with other namespaces. For example, this standard does not have a dependency to WFS, but GWML can be serialised in a WFS document, along with features from other domains. Failure to validate such a document does not necessarily mean that the GWML XML requirements are not met, as other external indirect instances might fail. Therefore, this requirement class only addresses instances of GWML in an XML document.

All property by reference using xlink:href should provide a human readable label in xlink:title.

REQUIREMENT 48:
/req/xsd-xml-rules/xlink-title
If an xlink:href is used to reference a controlled vocabulary item, the xlink:title attribute SHOULD encode a text label of the referenced item.

Example of a casing material showing the use of xlink:href (**/req/xsd-xml-rules/vocabulary-references**) and xlink:title (**/req/xsd-xml-rules/xlink-title**):

<gwml2wc:casingMaterial xlink:href="http://www.sandre.eaufrance.fr/?urn=urn:sandre:donnees:154::CdElement:5:::referentiel:3.1:xml" xlink:title="PVC"/>

Vocabulary references for all classes of stereotype Clause 10.1.2 are implemented as gml:Reference using xlink:href and ought to be a resolvable URI in the form of an HTTP URL.

RECOMMENDATION 11:
/req/xsd-xml-rules/vocabulary-reference
A resolvable HTTP URL SHOULD be used in an xlink:href when specifying references to vocabulary (CodeList) items.

11.2. REQUIREMENT CLASS: GWML2-MAIN XML ENCODING

REQUIREMENT CLASS: MAIN XML ENCODING	
/req/main-xsd	
Obligation	requirement
Target Type	XML data document
Dependency	/req/xsd-xml-rules
Dependency	GeoSciML/GeoSciML-Basic
Dependency	ISO-19115
Dependency	/req/main-uml
Requirement 49:	/req/main-xsd/xsd
Requirement 50:	/req/main-xsd/observed-unit-fluid-property-foi
Requirement 51:	/req/main-xsd/observed-unit-void-property-foi
Requirement 52:	/req/main-xsd/managementArea

All xml elements under namespace http://www.opengis.net/gwml-main/2.2 must validate against the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-main.xsd.

REQUIREMENT 49:

/req/main-xsd/xsd

All the elements and types under namespace http://www.opengis.net/gwml-main/2.2 SHALL validate with schema located at http://schemas.opengis.net/gwml/2.2/gwml2-main.xsd

OM_Observation values, used as property values in GW_UnitFluidProperty must identify the instance of GW_HydrogeoUnit at the gwFluidBodyUnit end of the association between this feature and the GW_FluidProperty.

REQUIREMENT 50:

/req/main-xsd/observed-unit-fluid-property-foi

All OM_Observation:featureOfInterest for OM_Observation properties of one coherent GW_UnitFluidProperty instance SHALL reference the same feature as GW_UnitFluidProperty/gwFluidBodyUnit.

```
<?xml version="1.0" encoding="UTF-8"?>

<gwml2:GW_Aquifer gml:id="aq.1">

<gsmlb:geologicUnitType xlink:href="http://www.opengis.net/def/gwml/2.2/geologicunitype/aquifer_unit" xlink:title="Aquifer" xsi:type="gwml2:AquiferPropertyType"/>

<!-- (...) -->

<gwml2:gwUnitFluidBody>

<gwml2:GW_UnitFluidProperty>

<gwml2:gwYield>

<om:OM_Observation gml:id="aq.1.fp.1">

<om:phenomenonTime>

<gml:TimeInstant gml:id="aq.1.fp.1.ti.1">

<gml:timePosition>2015/7/28T12:00:00Z</gml:timePosition>

</gml:TimeInstant>

</om:phenomenonTime>

<!-- (...) -->

<om:featureOfInterest xlink:href="#aq.1" xlink:title="aquifer 1"/>

<!-- (...) -->
```

</om:OM_Observation>

</gwml2:gwYield>

<gwml2:gwUnitFluidBody xlink:href="http://resource.org/id/fluid-body/fb1" xlink:title="fluid body f1"/>

<gwml2:gwFluidBodyUnit xlink:href="#aq.1" xlink:title="aquifer 1"/>

</gwml2:GW_UnitFluidProperty>

</gwml2:gwUnitFluidBody>

</gwml2:GW_Aquifer>

OM_Observation values, used as property values in GW_UnitVoidProperty must identify the instance of GW_HydrogeoUnit at the gwVoidUnit end of the association between this feature and the GW_VoidProperty.

REQUIREMENT 51:
/req/main-xsd/observed-unit-void-property-foi
All OM_Observation:featureOfInterest for OM_ Observation properties of one coherent GW_UnitVoidProperty instance SHALL reference the same feature as GW_UnitVoidProperty/ gwVoidUnit.

<?xml version="1.0" encoding="UTF-8"?>

<gwml2:GW_AquiferSystem gml:id="as.1">

<!-- (...) -->

<gwml2:gwUnitVoid>

<gwml2:GW_UnitVoidProperty gml:id="v1">

<gwml2:gwPorosity>

<om:OM_Observation gml:id="aq.1.fp.1">

<om:phenomenonTime>

<gml:TimeInstant gml:id="aq.1.fp.1.ti.1">

<gml:timePosition>2015/7/28T12:00:00Z</gml:timePosition>

</gml:TimeInstant>

</om:phenomenonTime>

<!-- (...) -->

<om:featureOfInterest xlink:href="#as.1" xlink:title="Aquifer System 1"/>

<!-- (...) -->

</om:OM_Observation>

</gwml2:gwPorosity>

<gwml2:gwUnitVoid xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:title="Unknown"/>

<gwml2:gwUnitVoid xlink:href="#as.1" xlink:title="Aquifer System 1"/>

</gwml2:GW_UnitVoidProperty>

</gwml2:gwUnitVoid>

</gwml2:GW_AquiferSystem>

REQUIREMENT 52:
/req/main-xsd/managementArea
GW_ManagementArea/gwAreaFeature SHALL NOT refer to features of type 'GW_Aquifer', 'GW_AquiferSystem', 'GW_Basin' or 'GW_ConfiningBed'

11.3. REQUIREMENT CLASS: GWML2-CONSTITUENT XML ENCODING

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
/req/constituent-xsd	
Obligation	requirement
Target Type	XML data document
Dependency	/req/xsd-xml-rules
Dependency	/req/constituent
Requirement 53:	/req/constituent-xsd/xsd

All xml elements under namespace http://www.opengis.net/gwml-constituent/2.2 must validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-constituent.xsd.

REQUIREMENT 53:
/req/constituent-xsd/xsd
All the elements and types under namespace http://www.opengis.net/gwml-constituent/2.2 SHALL validate with schema located at http://schemas.opengis.net/gwml/2.2/gwml2-constituent.xsd

11.4. REQUIREMENT CLASS: GWML2-FLOW XML ENCODING

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
/req/-flow-xsd	
Obligation	requirement
Target Type	XML data document
Dependency	/req/xsd-xml-rules
Dependency	/req/flow
Requirement 54:	/req/flow-xsd/xsd

All xml elements under namespace http://www.opengis.net/gwml-flow/2.2 must validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-flow.xsd.

REQUIREMENT 54:
/req/flow-xsd/xsd
All the elements and types under namespace http://www.opengis.net/gwml-flow/2.2 SHALL validate with schema located at http://schemas.opengis.net/gwml/2.2/gwml2-flow.xsd

11.5. REQUIREMENT CLASS: GWML2-WELL XML ENCODING

REQUIREMENT CLASS: CONSTITUENT XML ENCODING
/req/well-xsd

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
Obligation	requirement
Target Type	XML data document
Dependency	/req/xsd-xml-rules
Dependency	/req/construction-xsd
Dependency	/req/well
Requirement 55:	/req/well-xsd/xsd
Requirement 56:	/req/well-xsd/origin-elevation
Requirement 57:	/req/well-xsd/waterwell-elevationCRS
Requirement 58:	/req/well-xsd/obs-relative-pos-spatial-reference
Requirement 59:	/req/well-xsd/waterwell-observation-fromparam
Requirement 60:	/req/well-xsd/waterwell-observation-toparam
Requirement 61:	/req/well-xsd/waterwell-sf-spatial-reference
Requirement 62:	/req/well-xsd/waterwell-sf-fromparam
Requirement 63:	/req/well-xsd/waterwell-sf-toparam
Requirement 64:	/req/well-xsd/monitoring-elevationCRS
Requirement 65:	/req/well-xsd/monitoring-elevation-uom

All xml elements under namespace http://www.opengis.net/gwml-well/2.2 must validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-well.xsd.

REQUIREMENT 55:
/req/well-xsd/xsd
All the elements and types under namespace http://www.opengis.net/gwml-well/2.0 SHALL validate with schema located at http://schemas.opengis.net/gwml/2.2/gwml2-well.xsd

Well shall provide an origin elevation as a reference for relative positions along the borehole path.

REQUIREMENT 56:
/req/well-xsd/origin-elevation

REQUIREMENT 56:

There SHALL be a gwWellReferenceElevation:Elevation:elevationType with a xlink:href equal to http://resource.gwml.org/def/elevationType/originElevation

Elevation geometries must have a relevant vertical 1D srsName.

REQUIREMENT 57:

/req/well-xsd/waterwell-elevationCRS

gwWellReferenceElevation:Elevation:elevation @srsName SHALL contain a 1D vertical SRS

Examples of reference elevations (measured using different methods); note, one of them is designated as the origin ('reference') elevation for relative positions:

```
<gwml2w:gwWellReferenceElevation>

<gwml2w:Elevation>

<gwml2w:elevation srsDimension="1" srsName="http://www.opengis.net/def/crs/EPSG/0/5711"
 uomLabels="m AHD">139.06</gwml2w:elevation>

<gwml2w:elevationAccuracy xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:
title="unknown"/>

<gwml2w:elevationType xlink:href="http://www.bom.gov.au/water/groundwater/ngis/elevation-
type/natural-ground-surface" xlink:title="natural ground surface"/>

<gwml2w:elevationMeasurementMethod xlink:href="http://www.bom.gov.au/water/groundwater/
ngis/elevation-method/dem" xlink:title="Digital Elevation Model"/>

</gwml2w:Elevation>

</gwml2w:gwWellReferenceElevation>

<gwml2w:gwWellReferenceElevation>

<gwml2w:Elevation>

<gwml2w:elevation srsDimension="1" srsName="http://www.opengis.net/def/crs/EPSG/0/5711"
 uomLabels="m AHD">139.06</gwml2w:elevation>

<gwml2w:elevationAccuracy xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:
title="unknown"/>

<gwml2w:elevationType xlink:href="http://resource.gwml.org/def/elevationType/originElevation"
 xlink:title="reference elevation"/>

<gwml2w:elevationMeasurementMethod xlink:href="http://www.bom.gov.au/water/groundwater/
ngis/elevation-method/dem" xlink:title="Digital Elevation Model"/>
```

</gwml2w:Elevation>

</gwml2w:gwWellReferenceElevation>

11.5.1. Observations

Any observation that is positioned relative to a geometry, such as well or borehole path, SHALL identify the geometry as a spatial reference.

REQUIREMENT 58:
/req/well-xsd/obs-relative-pos-spatial-reference
Any OM_Observation that is positioned relative to a GM_Curve SHALL provide this geometry using a om:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry and a value of type gml:GM_Curve

The relative position of the observation must be encoded in the om:parameter using a specific encoding.

REQUIREMENT 59:
/req/well-xsd/waterwell-observation-fromparam
The closest boundary of the interval, the “from” distance, SHALL be encoded in a om: NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/fromDistance and a value of type swe:Quantity

REQUIREMENT 60:
/req/well-xsd/waterwell-observation-toparam
The farthest boundary of the interval, the “to” distance, SHALL be encoded in a om: NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/toDistance and a value of type swe:Quantity

Example of Observation positioned along the path of a bore:

<om:OM_Observation gml:id="feduni.borehole.observation.51409.44574.32328">

<gml:identifier codeSpace="http://www.ietf.org/rfc/rfc2616">http://groundwater.victoria.com.au/feature/observation/feduni.borehole.observation.51409.44574.32328</gml:identifier>

<om:phenomenonTime>

<gml:TimeInstant gml:id="feduni.borehole.observation.time.51409.44574">

<gml:timePosition>1997-07-14+12:00:00</gml:timePosition>

</gml:TimeInstant>

```
</om:phenomenonTime>

<om:resultTime xlink:href="#feduni.borehole.observation.time.51409.44574"/>

<om:procedure xlink:title="PUM"/>

<om:parameter>

<om:NamedValue>

<om:name xlink:href="http://www.opengis.net/def/param-name/GWML/2.2/fromDistance " xlink:
title="from"/>

<om:value xsi:type="swe:QuantityPropertyType">

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre"/>

<swe:value>10.5</swe:value>

</swe:Quantity>

</om:value>

</om:NamedValue>

</om:parameter>

<om:parameter>

<om:NamedValue>

<om:name xlink:href="http://www.opengis.net/def/param-name/GWML/2.2/toDistance " xlink:title=
"to"/>

<om:value xsi:type="swe:QuantityPropertyType">

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre"/>

<swe:value>10.6</swe:value>

</swe:Quantity>

</om:value>

</om:NamedValue>

</om:parameter>

<om:parameter>
```

<om:NamedValue>

<om:name xlink:href="http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry "
xlink:title="geometry"/>

<om:value xsi:type="gml:GeometryPropertyType" xlink:href="#feduni.borehole.51409.shape.1"/>

</om:NamedValue>

</om:parameter>

<om:observedProperty xlink:href="http://environment.data.gov.au/def/property/pH_water" xlink:
title="pH"/>

<om:featureOfInterest xlink:href="#feduni.borehole.51409"/>

(...)

</om:OM_Observation>

11.5.2. Related Sampling Feature positioned along well path

Any sampling feature that is positioned along the well path shall encode a relative position in sams:parameters.

REQUIREMENT 61:
/req/well-xsd/waterwell-sf-spatial-reference
A SF_SamplingFeature that is positioned relative to a path SHALL provide the geometry in a om:NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry and a value of type gml:GM_Curve

If included, the relative positions along the GW_Well shall be encoded using NamedValue.

REQUIREMENT 62:
/req/well-xsd/waterwell-sf-fromparam
The closest boundary of the interval , the “from” distance, SHALL be encoded in a om: NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/fromDistance and a value of type swe:Quantity

REQUIREMENT 63:
/req/well-xsd/waterwell-sf-toparam

REQUIREMENT 63:

The farthest boundary of the interval , the “to” distance, SHALL be encoded in a om: NamedValue with the name http://www.opengis.net/def/param-name/GWML/2.2/toDistance and a value of type swe:Quantity

Example of a related sampling feature (the parent feature is a GW_Well) :

```
<sam:relatedSamplingFeature>

<sam:SamplingFeatureComplex>

<sam:role xlink:href="http://resource.gwml.org/def/role/waterSample" xlink:title="Water sample"/>

<sam:relatedSamplingFeature>

<spec:SF_Specimen gml:id="spc.1">

(...)

<sam:parameter>

<om:NamedValue>

<om:name xlink:href="http://www.opengis.net/def/param-name/GWML/2.2/fromDistance " xlink:
title="from"/>

<om:value xsi:type="swe:QuantityPropertyType">

<swe:Quantity>

<swe:uom xlink:href="http://www.opengis.net/def/uom/UCUM/0/m" xlink:title="metre" code="m"/>

<swe:value>8.12</swe:value>

</swe:Quantity>

</om:value>

</om:NamedValue>

</sam:parameter>

<sam:parameter>

<om:NamedValue>

<om:name xlink:href="http://www.opengis.net/def/param-name/GWML/2.2/toDistance" xlink:title=
"to"/>

<om:value xsi:type="swe:QuantityPropertyType">

<swe:Quantity>
```

< swe:uom xlink:href="http://www.opengis.net/def/uom/UCUM/0/m" xlink:title="metre" code="m"/>

<swe:value>8.4</swe:value>

</swe:Quantity>

</om:value>

</om:NamedValue>

</sam:parameter>

<sam:parameter>

<om:NamedValue>

<om:name xlink:href="http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry "
xlink:title="to"/>

<om:value xsi:type="gml:GeometryPropertyType" xlink:href="#well.path.1" />

</om:NamedValue>

</sam:parameter>

(...)

</spec:SF_Specimen>

</sam:relatedSamplingFeature>

</sam:SamplingFeatureComplex>

</sam:relatedSamplingFeature>

11.5.3. Monitoring Sites

Monitoring site elevation geometry must have a relevant vertical 1D srsName.

REQUIREMENT 64:
/req/well-xsd/monitoring-elevationCRS
GW_MonitoringSite:gwSiteReferenceElevation/Elevation:elevation @srsName SHALL contain a vertical SRS.

REQUIREMENT 65:
/req/well-xsd/monitoring-elevation-uom

REQUIREMENT 65:
GW_MonitoringSite:gwSiteReferenceElevation/Elevation:elevation @srsName datum units and coordinate system SHALL be the same as the **/req/well-xsd/monitoring-elevationCRS** units and coordinate system vertical axis

<gwml2w:gwSiteReferenceElevation>

<gwml2w:Elevation>

<gwml2w:elevation srsName="http://www.opengis.net/def/crs/EPSG/0/5711" uomLabels="m AHD" srsDimension="1">523.27</gwml2w:elevation>

<gwml2w:elevationAccuracy xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:title="unknown"/>

<gwml2w:elevationType xlink:title="Relative Level Natural Surface"/>

<gwml2w:elevationMeasurementMethod xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" nilReason="unknown" xlink:title="unknown"/>

</gwml2w:Elevation>

</gwml2w:gwSiteReferenceElevation>

11.6. GEOLOGY LOG (GW_GEOLOGICLOGCOVERAGE)

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
/req/well-xsd-cov	
Obligation	requirement
Target Type	XML data document
Dependency	/req/well-xsd
Dependency	/req/well
Requirement 66:	/req/well-xsd-cov/well-geology
Requirement 67:	/req/well-xsd-cov/log-coverage
Requirement 68:	/req/well-xsd-cov/log-depth-order

This standard forbids the use of relatedObservation to link a GW_Well to a GW_GeologyLog, the property gwWellGeology must be used.

REQUIREMENT 66:
/req/well-xsd-cov/well-geology
GW_Well SHALL NOT be associated with GW_GeologyLog using om:relatedObservation

The geologic log is encoded as a GW_GeologyLogCoverage.

REQUIREMENT 67:
/req/well-xsd-cov/log-coverage
The XML element om:result of GW_GeologyLog SHALL have a data type GW_GeologyLogCoverage

The fromDepth value must be less than or equal to the toDepth value.

REQUIREMENT 68:
/req/well-xsd-cov/log-depth-order
For any given value where both fromDepth and toDepth are non-null, the value of gww:fromDepth/swe:Quantity/swe:Value SHALL be less than or equal to gww:toDepth/swe:Quantity/swe:Value

<gwml2w:GW_GeologyLogCoverage gml:id="borehole.INDIANA.USGS.403836085374401.lithology.coverage">

<gwml2w:element>

<gwml2w:LogValue>

<gwml2w:fromDepth>

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit/FT" xlink:title="foot" code="ft"/>

<swe:value>0</swe:value>

</swe:Quantity>

</gwml2w:fromDepth>

<gwml2w:toDepth>

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit/FT" xlink:title="foot" code="ft"/>

<swe:value>9</swe:value>

</swe:Quantity>

</gwml2w:toDepth>

<gwml2w:value>

<swe:DataRecord definition="http://www.opengis.net/def/gwml/2.2/datarecord/earthMaterial">

<swe:field name="major_lithology">

<swe:Category definition="http://www.opengis.net/def/gwml/2.0/observedProperty/earthMaterial">

<swe:identifier>http://cida.usgs.gov/groundwater/def/lithology/CLAY</swe:identifier>

<swe:value>CLAY</swe:value>

</swe:Category>

</swe:field>

<swe:field name="lithology-description">

<swe:Category definition="http://www.opengis.net/def/gwml/2.0/observedProperty/earthMaterial">

<swe:value>BROWN</swe:value>

</swe:Category>

</swe:field>

</swe:DataRecord>

</gwml2w:value>

</gwml2w:LogValue>

</gwml2w:element>

</gwml2w:GW_GeologyLogCoverage>

11.7. GEOLOGICLOG (DATAARRAY)

REQUIREMENT CLASS: CONSTITUENT XML ENCODING
/req/well-xsd-array

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
Obligation	requirement
Target Type	XML data document
Dependency	/req/well-xsd
Dependency	/req/well

Example of a DataArray Geologic Log encoding (XML encoding).

<om:result>

<swe:DataArray definition="http://www.opengis.net/def/gwml/2.0/coverage/geologyLog">

<swe:elementCount>

<swe:Count>

<swe:value>4</swe:value>

</swe:Count>

</swe:elementCount>

<swe:elementType name="LogValue">

<!-- row is the name of each row -->

<swe:DataRecord definition="http://www.opengis.net/def/gwml/2.0/datarecord/earthMaterial" id="le.1">

<swe:field name="from">

<!-- name of the column -->

<swe:Quantity definition="http://www.opengis.net/def/gwml/2.2/observedProperty/fromDepth">

<swe:uom xlink:href="http://qudt.org/vocab/unit/M" xlink:title="m"/>

</swe:Quantity>

</swe:field>

<swe:field name="to">

<swe:Quantity definition="http://www.opengis.net/def/gwml/2.2/observedProperty/toDepth">

<swe:uom xlink:href="http://qudt.org/vocab/unit/M" xlink:title="m"/>

</swe:Quantity>

```
</swe:field>

<swe:field name="lithology">

<swe:Category definition="http://www.opengis.net/def/gwml/2.0/observedProperty/earthMaterial">

<swe:codeSpace xlink:href="http://resource.geosciml.org/classifierscheme/cgi/201211/
simplelithology" xlink:title="Simple lithology"/>

</swe:Category>

</swe:field>

</swe:DataRecord>

</swe:elementType>

<swe:encoding>

<swe:XMLEncoding/>

</swe:encoding>

<swe:values xmlns:d="http://www.opengis.net/def/gwml/2.0/coverage/geologyLog">

<d:LogValue>

<d:from>0.0</d:from>

<d:to>0.30</d:to>

<d:lithology>Soil</d:lithology>

</d:LogValue>

<d:LogValue>

<d:from>0.30</d:from>

<d:to>4.27</d:to>

<d:lithology>Clay</d:lithology>

</d:LogValue>

<d:LogValue>

<d:from>4.27</d:from>

<d:to>9.14</d:to>

<d:lithology>Till</d:lithology>

</d:LogValue>
```

<d:LogValue>

<d:from>9.14</d:from>

<d:to>11.58</d:to>

<d:lithology>Gravel</d:lithology>

</d:LogValue>

</swe:values>

</swe:DataArray>

</om:result>

Alternative encoding using Text block encoding (instead of <swe:XMLEncoding/> above).

<swe:encoding>

<swe:TextEncoding blockSeparator="
" tokenSeparator="," />

</swe:encoding>

<swe:values xmlns:d="http://www.opengis.net/def/gwml/2.0/coverage/geologyLog">

0.0,0.30,Soil

0.30,4.27,Clay

4.27,9.14,Till

9.14,11.58,Gravel

</swe:values>

11.8. REQUIREMENT CLASS: GWML2-WELLCONSTRUCTION XML ENCODING

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
/req/construction-xsd	
Obligation	requirement

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
Target Type	XML data document
Dependency	/req/xsd-xml-rules
Dependency	/req/construction
Requirement 69:	/req/construction-xsd/xsd
Requirement 70:	/req/construction-xsd/collar-elevationCRS
Requirement 71:	/req/construction-xsd/depth-order

All xml elements under namespace http://www.opengis.net/gwml-construction/2.2 must validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-wellconstruction.xsd.

REQUIREMENT 69:
/req/construction-xsd/xsd
All the elements and types under namespace http://www.opengis.net/gwml-construction/2.0 SHALL validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-wellconstruction.xsd

BoreCollar:collarElevation must have a relevant vertical 1D srsName.

REQUIREMENT 70:
/req/construction-xsd/collar-elevationCRS
BoreCollar:collarElevations SHALL have a relevant vertical srsName

REQUIREMENT 71:
/req/construction-xsd/depth-order
Each Borehole SHALL have one bholeHeadworks/BoreCollar:collarElevationType @xlink:href = “http://resource.gwml.org/def/collarElevationType/originElevation”

Example Borehole BoreCollar and collarElevationType encodings:

</gwml2wc:Borehole>

<gwml2wc:bholeHeadworks>

<gwml2wc:BoreCollar gml:id="borehole.construction.nsw.10019168.collar">

<gwml2wc:collarElevation axisLabels="m AHD" srsDimension="1" srsName="http://www.opengis.net/def/crs/EPSG/0/5711" uomLabels="metre">139.06</gwml2wc:collarElevation>

<gwml2wc:collarElevationType xlink:href="http://resource.gwml.org/def/collarElevationType/originElevation"/>

<gwml2wc:collarHeadworkType xlink:href="http://www.opengis.net/def/nil/OGC/0/missing" xlink:title="missing"/>

<gwml2wc:collarLocation>

<gml:Point gml:id="borehole.construction.nsw.10019168.location" srsDimension="2" srsName="http://www.opengis.net/def/crs/EPSG/0/4283">

<gml:pos>-35.50485492957156 146.2265360498699</gml:pos>

</gml:Point>

</gwml2wc:collarLocation>

<gwml2wc:bholeDetails xlink:href="http://environment.data.gov.au/groundwater/feature/borehole/nsw.10019168"/>

</gwml2wc:BoreCollar>

</gwml2wc:bholeHeadworks>

</gwml2wc:Borehole>

Construction element “from” value must be less than or equal to the “to” value.

REQUIREMENT 72:
/req/gwml-construction-xsd/depth-order
For any given value where both “from” and “to” are non-null, the value of bh:from/swe:Quantity/swe:Value SHALL be less or equal to bh:to/swe:Quantity/swe:Value

11.9. REQUIREMENT CLASS: GWML2-WELL-VERTICAL XML ENCODING (PROFILE)

REQUIREMENT CLASS: CONSTITUENT XML ENCODING
/req/vertical-well-xsd

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
Obligation	requirement
Target Type	XML data document
Dependency	/req/gwml2well-xsd
Dependency	/req/vertical-well
Requirement 73:	/req/vertical-well-xsd/waterwell-shape
Requirement 74:	/req/vertical-well-xsd/endvertex

Vertical wells are represented as simple gml:Curve, made of a single Segment having only 2 coordinates.

REQUIREMENT 73:
/req/vertical-well-xsd/waterwell-shape
The sams:shape value of a vertical GW_Well SHALL be of type gml:Curve, consisting of a single segment of type LineStringSegment, containing 2 3D vertices

Example of a 3D vertical curve:

<sams:shape>

<gml:Curve gml:id="ab.ww.402557.shape.1" srsDimension="3" srsName="http://www.opengis.net/def/crs/EPSG/0/4955">

<gml:segments>

<gml:LineStringSegment>

<gml:posList>49.671622 -114.625045 0.00 49.671622 -114.625045 11.58</gml:posList>

</gml:LineStringSegment>

</gml:segments>

</gml:Curve>

</sams:shape>

The first vertex (v0) of the LineStringSegment must have the same planar coordinate as the last vertex (v1).

REQUIREMENT 74:
/req/vertical-well-xsd/endvertex

REQUIREMENT 74:
The first vertex of the LineStringSegment SHALL have the same planar (x,y) coordinate as the last vertex.

11.10. REQUIREMENT CLASS: GEOLOGICLOG XML ENCODING

This requirement class specifies the requirements for encoding Geologic Logs.

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
/req/well-log-xsd	
Obligation	requirement
Target Type	XML data document
Dependency	/req/well-log-xsd
Dependency	http://www.opengis.net/spec/SWE/2.0/req/xsd-record-components
Recommendation 0-1:	/req/gwml2-well-log-xsd/log-definition

Log values are encoded as swe:DataRecord, which is an encoding of ISO 11404 Record. It is a composite datatype made of 1 to many fields that are defined along with the instance (not by the XSD). DataRecord allows any collection of fields of any SWE AbstractDataComponent.

The DataRecord definition URI defines the structure of the data record and the semantics of the fields. This standard recommends that the definition be controlled by a community with specific use cases to address.

REQUIREMENT 75:
/req/well-log-xsd/log-definition
The definition of a DataRecord and the fields that compose it SHOULD have a defining URI governed by an appropriate community

Example of a complete gwWellGeology/GW_GeologyLog for geologic units illustrating how swe:DataRecord/definition specifies the field and DataRecord content for the log.

<gwml2w:gwWellGeology>

<gwml2w:GW_GeologyLog gml:id="borehole.qld.14483A.1.1.stratigraphy">

<gml:identifier codeSpace="http://www.ietf.org/rfc/rfc2616">http://environment.data.gov.au/groundwater/feature/stratigraphy-log.qld.14483A.1.1</gml:identifier>

<om:phenomenonTime xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:title="unknown"/>

<om:resultTime xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:title="unknown"/>

<om:procedure xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:title="unknown"/>

<om:observedProperty xlink:href="http://resource.gwml.org/def/gwml/2.0/observedProperty/hydrostratigraphy" xlink:title="hydrostratigraphy"/>

<om:featureOfInterest xlink:href="http://environment.data.gov.au/groundwater/feature/borehole/qld.14483A"/>

<om:result>

<gwml2w:GW_GeologyLogCoverage gml:id="borehole.qld.14483A.1.1.stratigraphy.coverage">

<gwml2w:element>

<gwml2w:LogValue>

<gwml2w:fromDepth>

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre" code="m"/>

<swe:value>0.00</swe:value>

</swe:Quantity>

</gwml2w:fromDepth>

<gwml2w:toDepth>

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre" code="m"/>

<swe:value>14.02</swe:value>

</swe:Quantity>

</gwml2w:toDepth>

<gwml2w:value>

<swe:DataRecord definition="http://resource.gwml.org/def/gwml/2.0/datarecord/geologicUnit">

<swe:field name="geologic unit">

<swe:Category definition="http://resource.gwml.org/def/gwml/2.0/observedProperty/hydrostratigraphy">

<swe:identifier>http://environment.data.gov.au/groundwater/feature/hydrogeologicunit/hgu.1079</swe:identifier>

<swe:description>Lockyer Creek alluvium</swe:description>

<swe:codeSpace xlink:href="http://www.bom.gov.au/water/groundwater/hydrogeologicunit"/>

<swe:value>Lockyer Creek alluvium</swe:value>

</swe:Category>

</swe:field>

</swe:DataRecord>

</gwml2w:value>

</gwml2w:LogValue>

</gwml2w:element>

<gwml2w:element>\{more gwml2w:elements here}</gwml2w:element>

</gwml2w:GW_GeologyLogCoverage>

</om:result>

<gwml2w:startDepth>

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre" code="m"/>

<swe:value>0</swe:value>

</swe:Quantity>

</gwml2w:startDepth>

<gwml2w:endDepth>

<swe:Quantity>

<swe:uom xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre" code="m"/>

<swe:value>57</swe:value>

</swe:Quantity>

</gwml2w:endDepth>

</gwml2w:GW_GeologyLog>

</gwml2w:gwWellGeology>

Example of a complete gwWellGeology/GW_GeologyLog for lithology illustrating how swe:DataRecord/definition specifies the field and DataRecord content for the log:

<gwml2w:gwWellGeology>

<gwml2w:GW_GeologyLog gml:id="borehole.nsw.10019168.1.lithology">

<gml:identifier codeSpace="http://www.ietf.org/rfc/rfc2616">http://environment.data.gov.au/groundwater/feature/lithology-log/borehole.nsw.10019168.1</gml:identifier>

<om:phenomenonTime xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:title="unknown"/>

<om:resultTime xlink:href="http://www.opengis.net/def/nil/OGC/0/unknown" xlink:title="unknown"/>

<om:procedure xlink:href="http://environment.data.gov.au/groundwater/def/procedure/drillers_log" xlink:title="drillers_log"/>

<om:observedProperty xlink:href="http://www.opengis.net/def/gwml/2.0/observedProperty/earthMaterial" xlink:title="lithology"/>

<om:featureOfInterest xlink:href="http://environment.data.gov.au/groundwater/feature/borehole/nsw.10019168"/><om:result>

<gwml2w:GW_GeologyLogCoverage gml:id="borehole.nsw.10019168.1.lithology.coverage">

<gwml2w:element>

<gwml2w:LogValue>

<gwml2w:fromDepth>

<swe:Quantity>

<swe:uom code="m" xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre"/>

<swe:value>7.32</swe:value>

</swe:Quantity>

</gwml2w:fromDepth>

<gwml2w:toDepth>

<swe:Quantity>

<swe:uom code="m" xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre"/>

<swe:value>28.35</swe:value>

</swe:Quantity>

</gwml2w:toDepth>

<gwml2w:value>

<swe:DataRecord definition="http://www.opengis.net/def/gwml/2.2/datarecord/earthMaterial">

<swe:field name="major_lithology">

<swe:Category definition="http://www.opengis.net/def/gwml/2.0/observedProperty/earthMaterial">

<swe:identifier>http://environment.data.gov.au/groundwater/def/lithology/CLAY</swe:identifier>

<swe:value>CLAY</swe:value>

</swe:Category>

</swe:field>

<swe:field name="lithology-description">

<swe:Category definition="http://www.opengis.net/def/gwml/2.0/observedProperty/earthMaterial">

<swe:value>Clay white sandy</swe:value>

</swe:Category>

</swe:field>

</swe:DataRecord>

</gwml2w:value>

</gwml2w:LogValue>

</gwml2w:element>

<...> [more gwml2:element properties here]

</gwml2w:GW_GeologyLogCoverage>

</om:result>

<gwml2w:startDepth>

<swe:Quantity>

<swe:uom code="m" xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre"/>

<swe:value>0.0</swe:value>

</swe:Quantity>

</gwml2w:startDepth>

<gwml2w:endDepth>

<swe:Quantity>

<swe:uom code="m" xlink:href="http://qudt.org/vocab/unit#Meter" xlink:title="metre"/>

<swe:value>91.44</swe:value>

</swe:Quantity>

</gwml2w:endDepth>

</gwml2w:GW_GeologyLog>

</gwml2w:gwWellGeology>

11.11. REQUIREMENT CLASS: AQUIFER TEST XML ENCODING

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
/req/aquifertest-xsd	
Obligation	requirement
Target Type	XML data document
Dependency	/req/xsd-xml-rules
Dependency	/req/gwml-aquifer-test
Dependency	http://www.opengis.net/spec/SWE/2.0/req/xsd-record-components
Requirement 76:	/req/aquifertest-xsd/xsd
Requirement 77:	/req/aquifertest-xsd/sampledfeature
Requirement 78:	/req/aquifertest-xsd/testfeature
Requirement 79:	/req/aquifertest-xsd/observationfeature

REQUIREMENT CLASS: CONSTITUENT XML ENCODING	
Requirement 80:	/req/aquifertest-xsd/observation-role
Requirement 81:	/req/aquifertest-xsd/timeseries
Requirement 82:	/req/aquifertest-xsd/timeseries-datarecord

All XML elements under namespace http://www.opengis.net/gwml-aquifertest/2.2 must validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-aquifertest.xsd.

REQUIREMENT 76:
/req/aquifertest-xsd/xsd
All the elements and types under namespace http://www.opengis.net/gwml-aquifertest/2.2 SHALL validate with schema located at http://schemas.opengis.net/gwml/2.2/gwml2-aquifertest.xsd

XML encoding conforms to O&M XML encoding (10-025r1), sweCommon (08-094r1) and TimeSeriesML 1.0 (15-042r3) encoding. This extension introduces a single new class with no new property or association.

Note that, while O&M (10-004r3) proposes subtypes of (abstract) **SF_SpatialSamplingFeature**, based on their geometries (SF_SamplingPoint, SF_SamplingCurve, etc.), the XML encoding does not materialise any classes for these sub types, but maps (OGC 10-025r1) them all to a concrete **SF_SpatialSamplingFeature**. The sub types are “soft types” and reported using sam:type property. This property is an XML encoding artefact from 10-025r1 and is not described in the conceptual model (10-004r3).

<gwml2at:GW_AquiferTest xmlns:gwml2at="http://www.opengis.net/gwml-aquifertest/2.2" xmlns:sf="http://www.opengis.net/samplingSpatial/2.0" xmlns:swe="http://www.opengis.net/swe/2.0" xmlns:om="http://www.opengis.net/om/2.0" xmlns:gmd="http://www.isotc211.org/2005/gmd" xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:sam="http://www.opengis.net/sampling/2.0" gml:id="pump.wit.63" xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"

xsi:schemaLocation="http://www.opengis.net/gwml-aquifertest/2.2 http://schemas.opengis.net/gwml/2.2/aquifertest.xsd http://www.opengis.net/samplingSpatial/2.0 http://schemas.opengis.net/samplingSpatial/2.0/spatialSamplingFeature.xsd">

<gml:description>Multiple well pumping test using Thiems's method. Data from The Netherland (from Kruseman & deRitter, 2000). Pumping test done in Oude Korendijk documented by Wit (1963).</gml:description>

<gml:identifier codeSpace=" http://www.ietf.org/rfc/rfc2616 ">http://opengis.org/example/pumpingTest/wit63</gml:identifier>

<gml:name codeSpace="urn:gwml2:example:name">wik63</gml:name>

<gml:location>

<gml:LocationString>Oude Korendijk</gml:LocationString>

</gml:location>

<sam:type xlink:href="http://www.opengis.net/def/samplingFeatureType/OGC-OM/2.0/SF_SamplingSurface"/>

<sam:sampledFeature xlink:href="http://opengis.org/example/aquifer/OudeKorendijk" xlink:title="Oude Korendijk aquifer"/>

(...)

</gwml2at:GW_AquiferTest>

GW_AquiferTest, as a subtype of **SF_SpatialSamplingFeature**, inherits sam:type property.

The sampled feature of GW_AquiferTest SHALL be a reference to an instance of a GW_HydrogeoUnit.

REQUIREMENT 77:
/req/aquifertest-xsd/sampledfeature
The sam:sampledFeature SHALL have a xlink:href to an instance of GW_HydrogeoUnit.

SF_SamplingFeatures that are test features, as defined in 9.10.3.2, shall be associated with the GW_AquiferTest using a SF_SamplingFeatureComplex, with the role's xlink:href set to http://resource.gwml.org/def/role/testFeature

REQUIREMENT 78:
/req/aquifertest-xsd/testfeature
SF_SamplingFeatureComplex roles that associates GW_AquiferTest with test features SHALL have it's xlink:href set to http://resource.gwml.org/def/role/testFeature

<sam:relatedSamplingFeature>

<sam:SamplingFeatureComplex>

<!-- this one is the pumping well -->

<sam:role xlink:href="http://resource.gwml.org/def/role/testFeature" xlink:title="Well that is being pumped"/>

<sam:relatedSamplingFeature xlink:href="http://example.gw.com/samplingFeature/WellWit63"/>

</sam:SamplingFeatureComplex>

</sam:relatedSamplingFeature>

SF_SamplingFeatures that are observation features, as defined in 9.10.3.2, shall be associated with the GW_AquiferTest using a SF_SamplingFeatureComplex, with the role's xlink:href set to http://resource.gwml.org/def/role/observationFeature.

REQUIREMENT 79:
/req/aquifertest-xsd/observationfeature
SF_SamplingFeatureComplex roles that associates GW_AquiferTest with test features SHALL have it's xlink:href set to http://resource.gwml.org/def/role/observationFeature

<sam:relatedSamplingFeature>

<sam:SamplingFeatureComplex>

<sam:role xlink:href="http://resource.gwml.org/def/role/observationFeature" xlink:title="Well at which the observation is made"/>

<sam:relatedSamplingFeature xlink:href="http://example.gw.com/samplingFeature/WellWit63h215"/>

</sam:SamplingFeatureComplex>

</sam:relatedSamplingFeature>

OM_Observations are linked together using ObservationComplex in the specific case when new observations are derived from support observations. This standard imposes URI for those specifics roles.

REQUIREMENT 80:
/req/aquifertest-xsd/observation-role
Raw observations from the observation sampling feature SHALL be link to the test result observations using the roles defined in Table 98

<sam:relatedObservation>

<om:OM_Observation gml:id="obs.wik63.1">

<om:relatedObservation>

<om:ObservationContext>

<om:role xlink:href="http://resource.gwml.org/def/role/supportObservation" xlink:title="supporting Observation"/>

<!--LINK TO TRANSMISSIVITY IN GWML2 -->

<om:relatedObservation xlink:href="http://example.gw.com/observations/00001" xlink:title="Accepted Transmissivity for aquifer"/>

</om:ObservationContext>

```
</om:relatedObservation>

<om:phenomenonTime>

<gml:TimePeriod gml:id="tp.wik63.1">

<gml:beginPosition>1963-07-01T13:00:00Z</gml:beginPosition>

<gml:endPosition>1963-07-02T02:50:00Z</gml:endPosition>

</gml:TimePeriod>

</om:phenomenonTime>

<om:resultTime>

<gml:TimeInstant gml:id="ti.wik63.1">

<!-- result valid at the end of the test -->

<gml:timePosition>1963-07-02T02:50:00Z</gml:timePosition>

</gml:TimeInstant>

</om:resultTime>

<om:procedure xlink:href="http://resource.gwml.org/def/method/Thiem" xlink:title="Thiem
 method"/>

<!-- this is one option to pump test related properties, the other option is to have the procedure above
 to point to a full SensorML description of the test -->

<!-- links to a combo of typical pumptest results -->

<om:observedProperty xlink:href="http://resource.gwml.org/def/property/pumpTestProperties"
 xlink:title="Pump test results"/>

<om:featureOfInterest xlink:href="#pump.wit.63" xlink:title="Wit 63 Pump test"/>

<om:result>

<swe:DataRecord definition="http://resource.gwml.org/def/property/pumpTestProperties" id="le.1">

<!-- Since pump test can result in many parameters, they are grouped in a record -->

<swe:field name="transmissivity">

<swe:Quantity definition="http://resource.gwml.org/def/phenomenon/groundwaterTransmissivity">

<swe:uom code="m^2/d"/>

<swe:value>385</swe:value>
```

</swe:Quantity>

</swe:field>

</swe:DataRecord>

</om:result>

</om:OM_Observation>

</sam:relatedObservation>

Observation results that are time series must be encoded with TimeSeriesML 1.0 (OGC 15-042r3).

REQUIREMENT 81:
/req/aquifertest-xsd/timeseries
OM_Observation results that are timeseries SHALL be encoded as tsml:TimeseriesObservation

Derived (or computed) observation results SHALL be encoded using swe:DataRecord XML encoding.

REQUIREMENT 82:
/req/aquifertest-xsd/timeseries-datarecord
Derived or computed observations SHALL be encoded as swe:DataRecord as defined in 08-094r1 (http://www.opengis.net/spec/SWE/2.0/req/xsd-record-components)

<om:result>

<swe:DataRecord definition="http://resource.gwml.org/def/property/pumpTestProperties" id="le.1">

<swe:field name="transmissivity">

<swe:Quantity definition="http://resource.gwml.org/def/phenomenon/groundwaterTransmissivity">

<swe:uom code="m^2/d"/>

<swe:value>385</swe:value>

</swe:Quantity>

</swe:field>

</swe:DataRecord>

</om:result>

A

ANNEX A (NORMATIVE) CONFORMANCE CLASS ABSTRACT TEST SUITE (NORMATIVE)

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ANNEX A (NORMATIVE) CONFORMANCE CLASS ABSTRACT TEST SUITE (NORMATIVE)

A.1. INTRODUCTION

This test suite contains 7 conformance classes, including one abstract conformance class. Each test relates to one or more specific requirements, which are explicitly indicated in the description of the test.

A.2. CONFORMANCE CLASSES – CONCEPTUAL MODEL

Table A.1

CONFORMANCE CLASS	/CONF/CONCEPTUAL	
Requirements	/req/conceptual	
Test	/conf/conceptual/similarity	
	Requirement	/req/conceptual/similarity
	Test purpose	Ensure that the target logical model is compatible with the conceptual model.
	Test method	Determine semantic similarity between the logical model and conceptual model using an established method such as : (i) visual comparison of the UML diagrams, (ii) comparison of logical and conceptual components expressed in a common knowledge representation language such as first order

CONFORMANCE CLASS	/CONF/CONCEPTUAL	
		logic, or (iii) comparison after mapping to a reference ontology.
	Test type	Capability

A.3. CONFORMANCE CLASSES — LOGICAL MODEL

A.3.1. Conformance class: GWML 2.2 core logical model (Abstract)

Table A.2

CONFORMANCE CLASS	/CONF/CORE	
Requirements	/req/core	
Dependency	urn:iso:dis:iso:19156:clause:A.1.1	
Test	/conf/core/encoding	
	Requirement	/req/core/encoding
	Test purpose	Ensure that all mandatory classes and properties are encoded
	Test method	Verify that the target implementation has all mandatory classes and properties implemented. If mandatory class or property are missing, the test fails
	Test type	Capability
Test	/conf/core/quantities-uom	
	Requirement	/req/core/quantities-uom
	Test purpose	Ensure that all properties of type swe: Quantity or om:OM_ Observation contain an xlink:href with a URI to a valid unit of measurement
	Test method	Visually inspect the target implementation and validate that all properties of type Quantity or Measurement report a unit of measurement
	Test type	Capability

CONFORMANCE CLASS	/CONF/CORE	
Test	/conf/core/identifier	
	Requirement	/req/core/identifier
	Test purpose	Ensure that the HTTP URI used as a globally unique identifier actually resolves to an instance of the feature using Linked Open Data principles
	Test method	For each feature that has a HTTP URI as a globally unique identifier, resolve the URI and inspect the result to see if it matches the same instance. Note, this conformance class does not imply any specific format, nor a single format
	Test type	Capability
Test	/conf/core/feature	
	Requirement	/req/core/feature
	Test purpose	Ensure that an instance of GWML 2.2 contains at least one valid GWML 2.2 element
	Test method	Inspect the instance and check that a GWML 2.2 element is correctly encoded.
	Test type	Capability

A.3.2. Conformance class: GWML 2.2 main logical model

Table A.3

CONFORMANCE CLASS	/CONF/MAIN	
Requirements	/req/main	
Dependency	/conf/core	
Dependency	/conf/constituent	
Dependency	/conf/flow	
Test	/conf/main/observed-unit-fluid-property-foi	
	Requirement	/req/main/observed-unit-fluid-property-foi
	Test purpose	Ensure that GW_UnitFluidProperty properties have featureOfInterest referring to the GW_

CONFORMANCE CLASS	/CONF/MAIN	
		HydrogeoUnit that owns the association with GW_FluidBody
	Test method	Check that each OM_ Observation instance that uses a property value for gwHydraulicConductivity, gwStorativity, gwTransmissivity or gwYield has a featureOfInterest that matches the gwFluidBodyUnit property
	Test type	Capability
Test	/conf/main/observed-unit-void-property-foi	
	Requirement	/req/main/observed-unit-void-property-foi
	Test purpose	Ensure that GW_UnitVoidProperty properties have featureOfInterest referring to the GW_HydrogeoUnit that owns the association with GW_HydrogeoVoid
	Test method	Check that each OM_ Observation instance that uses a property value for gwPermeability or gwPorosity has a featureOfInterest that matches the gwVoidUnit property
	Test type	Capability
Test	/conf/main/managementArea	
	Requirement	/req/main/managementArea
	Test purpose	Ensure that GW_ManagementArea:: gwAreaFeauture is not a subtype of GW_HydrogeoUnit
	Test method	Visual inspection of target and insure that gwAreaFeature is not a subtype of GW_HydrogeoUnit
	Test type	Capability

A.3.3. Conformance class: GWML 2.2 constituent logical model

Table A.4

CONFORMANCE CLASS	/CONF/CONSTITUENT
Requirements	/req/constituent
Dependency	/conf/core

A.3.4. Conformance class: GWML 2.2 flow logical model

Table A.5

CONFORMANCE CLASS	/CONF/GWML2_FLOW
Requirements	/req/flow
Dependency	/conf/core

A.3.5. Conformance class: GWML 2.2 Well logical model

Table A.6

CONFORMANCE CLASS	/CONF/WELL	
Requirements	/req/well	
Dependency	/conf/main-uml	
Test	/conf/well/waterwell-elevationCRS	
	Requirement	/req/well/waterwell-elevationCRS
	Test purpose	Ensure that the all Elevation elevation geometry has a 1D CRS where the units and reference system matches vertical axis of the well shape's CRS
	Test method	Check, for each well, Elevation instance and check the elevation geometry CRS identifier. Check that this identifier is a valid EPSG code in the EPSG database (http://www.epsg-registry.org)
	Test type	Capability
Test	/conf/well/waterwell-abs-shape-crs	
	Requirement	/req/well/waterwell-abs-shape-crs
	Test purpose	Ensure that shape that is defined in absolute coordinates have a valid 3D CRS
	Test method	Check that the shape geometry has 3 coordinates and that it has a valid 3D CRS
	Test type	Capability
Test	/conf/well/waterwell-rel-shape-crs	

CONFORMANCE CLASS	/CONF/WELL	
	Requirement	/req/well/waterwell-rel-shape-crs
	Test purpose	Ensure that a well shape defined in relative coordinate does not have a CRS
	Test method	Check that the shape geometry does not report any CRS
	Test type	Capability
Test	/conf/well/waterwell-rel-shape-true-depth	
	Requirement	/req/well/waterwell-rel-shape-true-depth
	Test purpose	Ensure that positions on z axis represents true depth
	Test method	Check, deepest value is less or equals to largest position along depth used to position observations or samples or used in log values
	Test type	Capability
Test	/conf/well/waterwell-rel-shape-downward	
	Requirement	/req/well/waterwell-rel-shape-downward
	Test purpose	Ensure that values of depth are positive downward
	Test method	Check that all values are >= 0
	Test type	Capability
Test	/conf/well/waterwell-rel-shape-shape-uom	
	Requirement	/req/well/waterwell-rel-shape-uom
	Test purpose	Ensure that relative position values are in the same units as gwWellLocation CRS
	Test method	Check that values are consistent with origin CRS (by comparing with original dataset for instance)
	Test type	Capability
Test	/conf/well/waterwell-depth-order	
	Requirement	/req/well/waterwell-depth-order
	Test purpose	Ensure that fromDepth and toDepth are reported in the right order
	Test method	Check that fromDepth ⇐ toDepth
	Test type	Capability

CONFORMANCE CLASS	/CONF/WELL	
Test	/conf/well/waterwell-depth-point	
	Requirement	/req/well/waterwell-depth-point
	Test purpose	Ensure that fromDepth and toDepth are both present
	Test method	Check that fromDepth and toDepth are always reported
	Test type	Capability
Test	/conf/well/waterwell-observation-spatial-reference	
	Requirement	/req/well/waterwell-observation-spatial-reference
	Test purpose	Ensure that the reference geometry is encoded correctly in the NamedParameter of OM_Observation and is of the correct type
	Test method	For each Observation that is positioned relative to the bore path, check that the value of om:parameter has an instance of om::NamedParameter with two components; the name must be the string “http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry” and the value type is GM_Curve
	Test type	Capability
Test	/conf/well/waterwell-observation-fromparam	
	Requirement	/req/well/waterwell-observation-fromparam
	Test purpose	Ensure that the “from” distance is encoded correctly in the NamedParameter of OM_Observation
	Test method	For each Observation that is positioned relative to the bore path, check that the value of om:parameter has an instance of om::NamedParameter with two components; the name must be the string “http://www.opengis.net/def/param-name/GWML/2.2/fromDistance” and the distance from the origin must be an instance of swe:Quantity, properly encoded according to /conf/core/quantities-uom
	Test type	Capability
Test	/conf/well/waterwell-observation-toparam	
	Requirement	/req/well/waterwell-observation-toparam

CONFORMANCE CLASS	/CONF/WELL	
	Test purpose	Ensure that the “to” distance is encoded correctly in the NamedParameter of OM_Observation
	Test method	For each Observation that is positioned relative to the bore path, check that the value of om:parameter has an instance of om::NamedParameter with two components. the name must be the string “http://www.opengis.net/def/param-name/GWML/2.2/toDistance” and the distance from the origin must a instance of swe:Quantity, properly encoded according to /conf/core/quantities-uom
	Test type	Capability
Test	/conf/well/waterwell-sf-spatial-reference	
	Requirement	/req/well/waterwell-sf-spatial-reference
	Test purpose	Ensure that the reference geometry is encoded correctly in the NamedParameter of SF_SamplingFeature and is of type GM_Curve
	Test method	For each SamplingFeature that is positioned relative to the bore path, check that the value of sams:parameter has an instance of sams::NamedParameter with two components; the name must be the string “http://www.opengis.net/def/param-name/GWML/2.2/referenceGeometry” and the value must be a GM_Curve
	Test type	Capability
Test	/conf/well/waterwell-sf-fromparam	
	Requirement	/req/well/waterwell-sf-fromparam
	Test purpose	Ensure that the “from” distance is encoded correctly in the NamedParameter of SF_SamplingFeature
	Test method	For each SamplingFeature that is positioned relative to the bore path, check that the value of om:parameter has an instance of sams::NamedParameter with two components; the name must be the string “http://www.opengis.net/def/param-name/GWML/2.2/fromDistance” and the distance from the origin must a instance of swe:Quantity, properly encoded according to /conf/core/quantities-uom

CONFORMANCE CLASS	/CONF/WELL	
	Test type	Capability
Test	/conf/well/waterwell-sf-toparam	
	Requirement	/req/well/waterwell-sf-toparam
	Test purpose	Ensure that the “to” distance is encoded correctly in the NamedParameter of SF_SamplingFeature
	Test method	For each sampling feature that is positioned relative to the bore path, check that the value of om:parameter has an instance of sams:NamedParameter with two components. the name must be the string “http://www.opengis.net/def/param-name/GWML/2.2/toDistance” and the distance from the origin must a instance of swe:Quantity, properly encoded according to /conf/core/quantities-uom
	Test type	Capability
Test	/conf/well/well-geology	
	Requirement	/req/well/well-geology
	Test purpose	Ensure that an association between a GW_Well and a GW_GeologyLog is only made using a gwWellGeology.
	Test method	Check that there are no occurrences of GW_Well/om:relatedObservation/GW_GeologyLog
	Test type	Capability
Test	/conf/well/log	
	Requirement	/req/well/log
	Test purpose	Ensure that the om:result of GeologyLog is an instance of GW_GeologyLogCoverage OR SWE::DataArray
	Test method	Check the om:result of GeologyLog and check if it’s an instance of GW_GeologyLogCoverage or any of its subtypes or an instance of SWE::DataArray of any of its subtypes
	Test type	Capability
Test	/conf/well/monitoring-elevationCRS	
	Requirement	/req/well/monitoring-elevationCRS

CONFORMANCE CLASS	/CONF/WELL	
	Test purpose	Ensure that elevation is an appropriate vertical datum.
	Test method	Check elevation CRS definition for a the presence of an appropriate vertical datum
	Test type	Capability

A.3.6. Conformance class GWML 2.2 Construction logical model

Table A.7

CONFORMANCE CLASS	/CONF/CONSTRUCTION	
Requirements	/req/construction	
Test	/conf/construction/collar-elevationCRS	
	Requirement	/req/construction/collar-elevationCRS
	Test purpose	Ensure that the collar elevation geometry has a 1D CRS and its units and reference system matches the vertical axis of the borehole shape's CRS.
	Test method	Check in the EPSG database that CRS of collarElevation exists and is an elevation CRS.
	Test type	Capability
Test	/conf/construction/construction-origin-elevation	
	Requirement	/req/construction/construction-origin-elevation
	Test purpose	Ensure that the borehole has one bholeHeadworks/BoreholeCollar which collarElevationType equal to http://resource.gwml.org/def/collarElevationType/originElevation
	Test method	Check target and check Borehole has at one BoreCollar which collarElevationType is of correct type.
	Test type	Capability
Test	/conf/construction/borehole-shape	
	Requirement	/req/construction/borehole-shape
	Test purpose	Ensure that the geometry that describes the borehole path represents the complete length of the bore in such as way that all construction elements (above in below the ground) can be located along the path.

CONFORMANCE CLASS	/CONF/CONSTRUCTION	
	Test method	Check that the starting point is prior or at the location of the topmost element and the end point is beyond or at the location of the bottommost element.
	Test type	Capability
Test	/conf/construction/log-depth	
	Requirement	/req/construction/log-depth
	Test purpose	Ensure that construction component are positioned linearly from the first vertex of the bore shape, along its path
	Test method	Check that each construction components has a “from” and “to” value is between 0 (zero) and the length of Borehole::shape. If a value is unknown, a “nil” value can be used
	Test type	Capability
Test	/conf/construction/log-depth-order	
	Requirement	/req/well/log-depth-order
	Test purpose	Ensure that ConstructionComponent’s “from” value is always less (closer to origin) than “to” value
	Test method	When both “from” and “to” are non nil, check that “from” is less than or equal to “to” value
	Test type	Capability

A.3.7. Conformance class : GWML 2.2 Vertical Well logical model

Table A.8

CONFORMANCE CLASS	/CONF/VERTICAL-WELL	
Requirements	/req/vertical-well	
Dependency	/conf/well	
Test	/conf/vertical-well/waterwell-shape	
	Requirement	/req/vertical-well/waterwell-shape
	Test purpose	Ensure that the shape of a vertical well is made of only one segment (two vertices)
	Test method	Check that GW_Well::shape geometry has 6 and only 6 coordinates

CONFORMANCE CLASS	/CONF/VERTICAL-WELL	
	Test type	Capability
Test	/conf/vertical-well/endvertex	
	Requirement	/req/vertical-well/end-vertex
	Test purpose	Ensure that the shape of the GW_Well is vertical
	Test method	Considering that the GW_Well:shape is composed of two 3D points, [x0,y0,z0] and [x1,y1,z1]. Check coordinates x1 == x0 and y1 == y0
	Test type	Capability

A.3.8. Conformance class: GWML 2.2 Geologic logs

Table A.9

CONFORMANCE CLASS	/CONF/WELL-LOG
Requirements	/req/well-log
Dependency	/conf/well

A.3.9. Conformance class: GWML 2.2 Geologic logs Coverage

Table A.10

CONFORMANCE CLASS	/CONF/WELL-LOG-COV
Requirements	/req/well-log-cov
Dependency	/conf/well

A.3.10. Conformance class: GWML 2.2 Geologic array

Table A.11

CONFORMANCE CLASS	/CONF/WELL-LOG-ARRAY
Requirements	/req/well-log-array

CONFORMANCE CLASS	/CONF/WELL-LOG-ARRAY	
Dependency	/conf/well	
Test	/conf/well-log-array/fromDepthId	
	Requirement	/req/well-log-array/fromDepthId
	Test purpose	Ensure that fromDepth is reported using the correct identifier
	Test method	Check in the DataArray/DataRecord that fromDepth values is identified using http://www.opengis.net/def/gwml/2.2/observedProperty/fromDepth
	Test type	Capability
Test	/conf/well-log-array/toDepthId	
	Requirement	/req/well-log-array/toDepthId
	Test purpose	Ensure that toDepth is reported using the correct identifier
	Test method	Check in the DataArray/DataRecord that toDepth values is identified using http://www.opengis.net/def/gwml/2.2/observedProperty/toDepth
	Test type	Capability

A.3.11. Conformance class : GWML 2.2 Aquifer Test

Table A.12

CONFORMANCI CLASS	/CONF/AQUIFERTEST	
Requirements	/req/aquifertest	
Dependency	/conf/core	
Dependency	http://www.opengis.net/spec/waterml/2.0/conf/uml-timeseries-observation	
Dependency	http://www.opengis.net/spec/SWE/2.0/conf/uml-record-components	
Test	/conf/aquifertest/sampledfeature	
	Requirement	/req/aquifertest/sampledfeature
	Test purpose	Ensure that aquifer tests are about hydrogeological units
	Test method	Check that the sampledFeaure of the test refers to an instance of GW_HydrogeoUnit.

CONFORMANCI CLASS	/CONF/AQUIFERTEST	
	Test type	Capability
Test	/conf/aquifertest/testfeature	
	Requirement	/req/aquifertest/testfeature
	Test purpose	Ensure that the sampling features use to perform the test itself are correctly identified
	Test method	Check that the role of the SF_SamplingFeatureComplex is “http://resource.gwml.org/def/role/testFeature”
	Test type	Capability
Test	/conf/aquifertest/observationfeature	
	Requirement	/req/aquifertest/observationfeature
	Test purpose	Ensure that the sampling features use to monitor the test itself are correctly identified
	Test method	Check that the role of the SF_SamplingFeatureComplex is “http://resource.gwml.org/def/role/observationfeature”
	Test type	Capability
Test	/conf/aquifertest/observation-role	
	Requirement	/req/aquifertest/observation-role
	Test purpose	Ensure that observations gained from observation features are linked to derived observations
	Test method	Check that the value type use the correct URI when any of the roles are listed in 9.10.3.3
	Test type	Capability
Test	/conf/aquifertest/timeseries	
	Requirement	/req/aquifertest/timeseries
	Test purpose	Ensure that results that represent values taken over time are encoded using TimeSeriesML 1.0 (OGC 15-042r3)
	Test method	Check the encoding of the result and check it fits conformance classes of TimeSeriesML 1.0
	Test type	Capability
Test	/conf/aquifertest/timeseries-datarecord	
	Requirement	/req/aquifertest/timeseries-daterecord
	Test purpose	Ensure that derived observation results are encoded using a swe:DataRecord

CONFORMANCI /CONF/AQUIFERTEST CLASS		
	Test method	Check the encoding of derived observation and check they comply to swe:DataRecord
	Test type	Capability

A.4. CONFORMANCE CLASSES – XML ENCODING

A.4.1. Conformance class: xml-rules

Table A.13

CONFORMANCE CLASS	/CONF/XSD-XML-RULES	
Requirements	/req/xsd-xml-rules	
Dependency	08-131r3 Req 39	
Dependency	08-131r3 Req 40	
Dependency	http://www.opengis.net/spec/SWE/2.0/conf/xsd-simple-components	
Dependency	http://www.w3.org/TR/xmlschema-2	
Dependency	http://www.opengis.net/doc/IS/GML/3.2/clause/2.4	
Dependency	urn:iso:dis:iso:8601:2004:clause:4	
Test	/conf/xsd-xml-rules/W3C_XSD	
	Requirement	/req/xsd-xml-rules/W3C_XSD
	Test purpose	Ensure that the xml element are valid with XSD
	Test method	Use a XSD validation tool and check that validation does not return any error
	Test type	Capability
Test	/conf/xsd-xml-rules/sch	
	Requirement	/req/xsd-xml-rules/ISO-schematron
	Requirement	/req/xsd-xml-rules/swe-types

CONFORMANCE CLASS	/CONF/XSD-XML-RULES	
	Requirement	/req/xsd-xml-rules/xlink-title
	Test purpose	Validate the XML document using the schematron document http://schemas.opengis.net/gwml/2.2/xml-rules.sch. Passes if no errors are reported for '*unit-of-measure*' test. Fails otherwise.
	Test method	Use a schematron validation tool and check that validation does not return any error
	Test type	Capability
Test	/conf/xsd-xml-rules/iso8601-time	
	Requirement	/req/xsd-xml-rules/iso8601-time
	Test purpose	Ensure that all instance of date time, even in free text string, use the iso8601 encoding
	Test method	Inspect instance where date-time instance appears and check if they are encoded as iso8601
	Test type	Capability
Test	/conf/xsd-xml-rules/time-zone	
	Requirement	/req/xsd-xml-rules/time-zone
	Test purpose	Ensure that all time are flagged with time zone
	Test method	Inspect occurrence of date-time and check if it has a 4 digit character or a Z (Zulu). If absent, test fails
	Test type	Capability
Test	/conf/xsd-xml-rules/identifier	
	Requirement	/req/xsd-xml-rules/identifier
	Test purpose	Ensure that gml:identifiers with codeSpace http://www.ietf.org/rfc/rfc2616 have a http URI that resolves
	Test method	Check that HTTP URI, when invoked returns an HTTP code between 200 and 203, or 300 and 305
	Test type	Capability

A.4.2. Conformance class: GWML2-Main xml encoding

Table A.14

CONFORMANCE CLASS	/CONF/MAIN-XSD	
Requirements	/req/main-xsd	
Dependency	/conf/flow-xsd	
Dependency	/conf/constituent-xsd	
Dependency	http://www.opengis.net/spec/OMXML/2.0/conf/observation	
Dependency	http://www.opengis.net/spec/OMXML/2.0/conf/sampling	
Test	/conf/main-xsd/xsd	
	Requirement	/req/main-xsd/xsd
	Test purpose	Ensure that all elements under the namespace http://www.opengis.net/gwml-main/2.2 validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-main.xsd
	Test method	Use an XSD validator to validate the XML instance against the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-main.xsd and check that no errors are generated for elements under the namespace http://www.opengis.net/gwml-main/2.2 or its dependencies. Pass if no errors reported. Fail otherwise
	Test type	Capability
Test	/conf/main-xsd/sch	
	Requirement	/req/main-xsd
	Requirement	/req/main-xsd/observed-unit-fluid-property-foi
	Requirement	/req/main-xsd/observed-unit-void-property-foi
	Requirement	/req/main-xsd/managementArea
	Test purpose	Ensure that instance document validate agains schematron rules
	Test method	Use a schematron validator and test the instance document against http://schemas.opengis.net/gwml/2.2/gwml2-

CONFORMANCE CLASS	/CONF/MAIN-XSD	
		main.sch. The test fails if any schematron rules are broken
	Test type	Capability

A.4.3. Conformance class: GWML2-Constituent xml encoding

Table A.15

CONFORMANCE CLASS	/CONF/GWML2-CONSTITUENT-XSD	
Dependency	/conf/xsd-xml-rule	
Requirements	/req/constituent-xsd	
Test	/conf/constituent-xsd/xsd	
	Requirement	/req/constituent-xsd/xsd
	Test purpose	Ensure that all element under the namespace http://www.opengis.net/gwml-constituent/2.2 validates with schema located at http://schemas.opengis.net/gwml/2.2/gwml2-constituent.xsd
	Test method	Use a XSD validator to validate the XML instance against schema located at http://schemas.opengis.net/gwml/2.2/gwml2-constituent.xsd and check that no error are generate for elements under namespace http://www.opengis.net/gwml-constituent/2.2 or its dependencies. Pass if no errors reported. Fail otherwise
	Test type	Capability

A.4.4. Conformance class: GWML2-flow xml encoding

Table A.16

CONFORMANCE CLASS	/CONF/GWML2-FLOW-XSD
Dependency	/conf/xsd-xml-rule

CONFORMANCE CLASS	/CONF/GWML2-FLOW-XSD	
Requirement	/req/flow-xsd	
Test	/conf/flow-xsd/xsd	
	Requirement	/req/flow-xsd/xsd
	Test purpose	Ensure that all element under the namespace http://www.opengis.net/gwml-flow/2.2 validates with schema located at http://schemas.opengis.net/gwml/2.2/gwml2-flow.xsd
	Test method	Use a XSD validator to validate the XML instance against schema located at http://schemas.opengis.net/gwml/2.2/gwml2-flow.xsd and check that no error are generate for elements under namespace http://www.opengis.net/gwml-flow/2.2 or its dependencies. Pass if no errors reported. Fail otherwise
	Test type	Capability

A.4.5. Conformance class: GWML2-well xml encoding

Table A.17

CONFORMA CLASS	/CONF/GWML2-WELL-XSD	
Dependency	/conf/xsd-xml-rule	
Dependency	/conf/construction-xsd	
Requirement	/req/well-xsd	
Test	/conf/well-xsd/xsd/	
	Requirement	/req/well-xsd/xsd
	Test purpose	Ensure that the GW_Well instances conform to the rules expressed in the schema
	Test method	Use a XSD validator to validate instances. If the validator reports an error on a GWML 2.2 element, then the test fails
	Test type	Capability

CONFORMANCE CLASS	/CONF/GWML2-WELL-XSD	
Test	/conf/well-xsd/sch/	
	Requirement	/req/well-xsd
	Requirement	/req/well-xsd/obs-relative-pos-spatial-reference
	Requirement	/req/well-xsd/waterwell-observation-fromparam
	Requirement	/req/well-xsd/waterwell-observation-toparam
	Requirement	/req/well-xsd/waterwell-sf-spatial-reference
	Requirement	/req/well-xsd/waterwell-sf-fromparam
	Requirement	/req/well-xsd/waterwell-sf-toparam
	Requirement	/req/well-xsd/monitoring-elevation-uom
	Test purpose	Ensure that instance document validates agains schematron rules
	Test method	Use a schematron validator and test the instance document against http://schemas.opengis.net/gwml/2.2/gwml2-well.sch. The test fails if any schematron rules are broken
	Test type	Capability
Test	/conf/well-xsd/waterwell-elevationCRS	
	Requirement	/req/well-xsd/waterwell-elevationCRS
	Test purpose	Ensure that all Elevations have a relevant 1D vertical srsName
	Test method	Check the value of GW_Well/sam:gwWellReferenceElevation/Elevation/elevation/@srsName against the EPSG database or CRS specification to ensure it represents a 1D vertical SRS
	Test type	Capability
Test	/conf/well-xsd/monitoring-elevationCRS	
	Requirement	/req/xsd-gwml-well/ monitoring-elevationCRS
	Test purpose	Ensure that the monitoring site elevation has relevant 1D vertical CRS
	Test method	Check the value of GW_Well/gwSiteReferenceElevation/Elevation/elevation/@srsName against EPSG database or CRS specification to ensure it represents a 1D vertical SRS
	Test type	Capability

A.4.6. Conformance class: GWML2-construction xml encoding

Table A.18

CONFORMANCE CLASS	/CONF/CONSTRUCTION-XSD	
Requirement	/req/construction-xsd	
Dependency	/conf/xsd-xml-rule	
Test	/conf/construction-xsd/xsd	
	Requirement	/req/construction-xsd
	Test purpose	Ensure that all elements under the namespace http://www.opengis.net/gwml-construction/2.2 validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-wellconstruction.xsd
	Test method	Use an XSD validator to validate the XML instance against the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-well.xsd and check that no errors are generated for elements under the namespace http://www.opengis.net/gwml-construction/2.2 or its dependencies. Pass if no errors reported. Fail otherwise.
	Test type	Capability
Test	/conf/construction-xsd/sch	
	Requirement	/req/construction-sch
	Test purpose	Ensure that instance document validate agains schematron rules
	Test method	Use a schematron validator and test the instance document against http://schemas.opengis.net/gwml/2.2/gwml2-construction.sch. The test fails if any schematron rules are broken
	Test type	Capability
Test	/conf/construction-xsd/depth-order	
	Requirement	/req/construction/depth-order
	Test purpose	Ensure that instance document validates with rules expressed in schematron file.
	Test method	Validate the XML document using the Schematron document http://schemas.opengis.net/gwml/2.2/gwml2-construction.sch. Conformance passes if no error, fails otherwise.

CONFORMANCE CLASS	/CONF/CONSTRUCTION-XSD	
	Test type	Capability
Test	/conf/construction-xsd/collar-elevationCRS	
	Requirement	/req/construction/collar-elevationCRS
	Test purpose	Ensure that collar elevation uses a relevant 1D vertical CRS
	Test method	Check the values of BoreCollar/collarElevation/@srsName against EPSG database or CRS specification to Ensure it represents a 1D vertical SRS
	Test type	Capability

A.4.7. Conformance class: GWML2-vertical well xml encoding

Table A.19

CONFORMANCE CLASS	/CONF/VERTICAL-WELL-XSD	
Requirement	/req/vertical-well-xsd	
Dependency	/conf/xsd-xml-rule	
Dependency	/conf/well-xsdl	
Test	/conf/vertical-well-xsd/waterwell-shape	
	Requirement	/req/vertical-well-xsd/waterwell-shape
	Requirement	/req/vertical-well-xsd/endvertex
	Test purpose	Ensure that instance document validate with rules expressed in schematron file.
	Test method	Validate the XML document using the Schematron document http://schemas.opengis.net/gwml/2.2/gwml2-well-vertical.sch. Conformance passes if no error, fails otherwise.
	Test type	Capability

A.4.8. Conformance class: Geology-Log (GW_GeologicLogCoverage)

Table A.20

CONFORMANCE CLASS	/CONF/WELL-XSD-COV	
Requirement	/req/well-xsd-cov	
Dependency	/conf/well	
Test	/conf/vertical-well-xsd/waterwell-shape	
	Requirement	/req/well-xsd-cov/well-geology
	Requirement	/req/well-xsd-cov/log-coverage
	Requirement	/req/well-xsd-cov/log-depth-order
	Test purpose	Ensure that instance document validate with rules expressed in schematron file.
	Test method	Validate the XML document using the Schematron document http://schemas.opengis.net/gwml/2.2/gwml2-well-cov.sch. Conformance passes if no error, fails otherwise.
	Test type	Capability

A.4.9. Conformance class: GWML2-Aquifertest xml encoding

Table A.21

CONFORMANCE CLASS	/CONF/GWML2-AQUIFERTEST-XSD	
Dependency	/conf/xsd-xml-rule	
Requirement	/req/aquifertest-xsd	
Test	/conf/aquifertest-xsd/xsd	
	Requirement	/req/aquifertest-xsd/xsd
	Test purpose	Ensure that all elements under the namespace http://www.opengis.net/gwml-aquifertestt/2.2 validate with the schema located at http://schemas.opengis.net/gwml/2.2/gwml2-aquifertest.xsd
	Test method	Use an XSD validator to validate the XML instance against the schema located at http://

CONFORMANCE CLASS	/CONF/GWML2-AQUIFERTEST-XSD	
		schemas.opengis.net/gwml/2.2/gwml2-aquifertest.xsd and check that no errors are generated for elements under the namespace http://www.opengis.net/gwml-aquifertest/2.2 or its dependencies. Pass if no errors reported. Fail otherwise
	Test type	Capability
Test	/conf/aquifertest-xsd/sampledfeature	
	Requirement	/req/aquifertest-xsd/sampledfeature
	Test purpose	Ensure the instance document validates agains the schematron rules
	Test method	Use a schematron validator and test the instance document against http://schemas.opengis.net/gwml/2.2/gwml2-main.sch. The test fails if any schematron rules are broken
	Test type	Capability
Test	/conf/aquifertestxsd/testfeature	
	Requirement	/req/aquifertest-xsd/testfeature
	Test purpose	Ensure that test features are associated with the aquifer test using the correct role
	Test method	For all sampling features that are test features, check that the SF_SamplingFeatureComplex:: role is set to http://resource.gwml.org/def/role/testFeature
	Test type	Capability
Test	/conf/aquifertest-xsd/observationfeature	
	Requirement	/req/aquifertest-xsd/observationfeature
	Test purpose	Ensure that observation features are associated with the aquifer test using the correct role
	Test method	For all sampling features that are observation features, check that the SF_SamplingFeatureComplex role is set to http://resource.gwml.org/def/role/observationFeature
	Test type	Capability
Test	/conf/aquifertestxsd/observation-role	
	Requirement	/req/aquifertest-xsd/observation-role
	Test purpose	Ensure that the observations that are part of a chain, or support and derived observations, are

CONFORMANCE CLASS	/CONF/GWML2-AQUIFERTEST-XSD	
		linked together with OM_ObservationContext using the proper role
	Test method	For all observations that are part of a chain of transformation, check that the OM_ObservationContext has it's role xlink:href set to one of the values defined in Table 98
	Test type	Capability
Test	/conf/aquifertestxsd/timeseries	
	Requirement	/req/aquifertestxsd/timeseries
	Test purpose	Ensure that Observation results that are time series are encoded in TimeSeriesML 1.0 (OGC 15-042r3)
	Test method	Inspect instance documents and verify that any time series results are encoded in valid TimeSeriesML 1.0 (OGC 15-042r3)
	Test type	Capability
Test	/conf/aquifertest-xsd/timeseries-datarecord	
	Requirement	/req/aquifertest-xsd/timeseries-datarecord
	Test purpose	Ensure that the final aquifer test result, encoded as OM_Observation, delivers the result using a swe:DataRecord
	Test method	Scan the document for Observations that are the final outcome of the test, and check that the results are encoded according to http://www.opengis.net/spec/SWE/2.0/req/xsd-record-components
	Test type	Capability

B

ANNEX B (NORMATIVE) REVISION HISTORY

B

ANNEX B (NORMATIVE) REVISION HISTORY

Table B.1

DATE	RELEASE	EDITOR	PRIMARY CLAUSES MODIFIED	DESCRIPTION
2016-01-29	0.1.0	Bruce Simons	All	Initial internal version based on IE report
2016-01-29	0.1.1	Boyan Brodaric	All	Draft submission
2016-03-03	0.1.2	Bruce Simons	All	Version, namespaces, GeoSciML 4.0
2016-03-07	0.1.3	Boyan Brodaric	All	Final edits
2016-03-30	0.1.4	Scott Simmons	All	Moved to current OGC standard template
2016-05-02	r1	Boyan Brodaric	All	Changes as per OGC OAB review
2016-05-18	r1.1	Eric Boisvert	All	Changes as per OGC-NA review Left justified XML snippets Moved Conceptual Conformance in Annex
2018-03-26	r.2.3	Eric Boisvert	9.6.3	Added Borehole to GW_Well association pattern recommendation
2018-05-15		Eric Boisvert and Sylvain Grellet	9.5, 9.8, 9.9	Added a figure (9.5), modified some requirement classes.
2018-11-16		Eric Boisvert	Figures 15 and 16. Significant changes in 9.x and 10.x. Annex A.3.5 to A.3.10 and A.4.5 to A.4.8	Reorganised and changed documentation to fit compact encoding and some cardinality changes
2020-05-08	r.2.3	Eric Boisvert, Bruce Simmons, Sylvain Grellet and Boyan Brodaric	10.5, 10.6, A.4.5, A.4.8	Fixed typos and omissions, broken URLs and missing artefacts, clarified version number vs schema version

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