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GW2IE: The GWML2 Conceptual Model

Warning

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Preface

This document is an output of the Groundwater 2 Interoperability Experiment (GWIE2). GW2IE operates within the OGC Hydro Domain Working Group (HDWG), and its main objective is the development of a GML application for the groundwater data community, named Groundwater Markup Language 2 (GWML2). It is anticipated that this report will form the basis for a subsequent OGC standard specification, and that this specification will serve as an *encoding* standard for the INSPIRE hydrogeology information model.

GWML2 consists of three components: (1) a technology-neutral UML conceptual model, (2) a GML-specific UML logical model, and (3) an XML schema with encoding specifications. This document specifies the GWML2 conceptual model (GWML2 CM), which serves as a foundation for the remaining models (Logical, XML).

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OGC® GW2IE: The GWML2 Conceptual Model

1 Introduction

1.1 Scope

This OGC document specifies the GWML2 Conceptual Model (GWML2 CM) using UML syntax. As a conceptual information model, GWML2 CM is concerned with the semantics of the groundwater domain and strives to remain technology-neutral. Thus, it avoids design considerations related to, for example, GML or XML representation.

1.2 Document contributor contact points

All questions regarding this document should be directed to the editor or the contributors:

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Etc.	

1.3 Revision history

Date	Release	Editor	Primary clauses modified	Description
20-11-2013	0.2	Brodaric	--	Draft “seed” conceptual model

1.4 Future work

GWML2 CM will be used to develop increasingly technology-centric representations: the GWML2 Logical Model and the GWML2 XML encoding.

1.5 Forward

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights.

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the standard set forth in this document, and to provide supporting documentation.

2 References

The following documents are referenced in this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OGC 06-121r9, *OGC® Web Services Common Standard*.

3 Terms and definitions

For the purposes of this report, the definitions specified in the UML Reference Manual shall apply.

4 Conventions

4.1 Abbreviated terms

None.

4.2 UML notation

Diagrams that appear in this standard are presented using the Unified Modeling Language (UML) static structure diagram, as described in Subclause 5.2 of [OGC 06-121r9], and following the conventions of the UML Reference Manual 2nd edition.

Additional conventions include:

- Entity names within the groundwater domain are prefaced with “GW” and written in camel-case.
- Attribute and role names within the groundwater domain are prefaced with “gw” and written in camel-case.

- Relation names are not specified.
- Attribute datatypes refer to entities in GWML2 CM, or to named but as yet undefined entities such as various enumerations, datatypes, or external entities.
- The “char” standard datatype refers to a character string of unspecified length.
- The <<Implementation>> stereotype refers to attributes included for convenience only. Such attributes are not required conceptually because they can be derived from other attributes or relations.

4.3 Platform-neutral standards

This document includes a platform-neutral draft standard, specified using UML and including attributes and relations for each entity in the domain. This document does not specify a logical model nor an encoding standard -- these will be developed in subsequent reports.

4.4 Data dictionary tables

The GWML2 CM is specified herein in a series of UML diagrams and related tables. The contents of the columns in these tables are described in Table 1.

Table 1 — Contents of data dictionary tables

Column title	Column contents
Attribute (left column)	Name of the attribute.
Type and Mutiplicity (second column)	The datatype, multiplicity, and default or static value of the attribute.
Defnition (third column)	The definition of the attribute. Note that some definitions are missing references, but these should be added eventually.
Relation (first column)	Type of relation, e.g. generalization, aggregation, association.
Source (second column)	Includes the name of the source entity and the name of its corresponding role in the relation.
Target (third column)	Includes the name of the target entity and the name of its corresponding role in the relation.
Direction (fourth column)	The direction of the relation. If a direction is specified then the relation is unidirectional. An unspecified direction implies bi-directionality.

5 GWML2 CM Overview

This document is an output of the Groundwater 2 Interoperability Experiment (GWIE2). GW2IE operates within the OGC Hydro Domain Working Group (HDWG), and its main objective is the development of a GML application for the groundwater data community, named Groundwater Markup Language 2 (GWML2). It is anticipated that this report will form the basis for a subsequent OGC standard specification, and that this specification will serve as an *encoding* standard for the INSPIRE hydrogeology information model.

GWML2 consists of three components: (1) a technology-neutral UML conceptual model, (2) a GML-specific UML logical model, and (3) an XML schema with encoding specifications. This document specifies the GWML2 conceptual model (GWML2 CM), which serves as a foundation for the remaining models (Logical, XML).

The entities specified in this conceptual model are derived from a requirements analysis carried out by GW2IE participants. The analysis consists of five use-cases, which were mined for key entities whose definitions were refined iteratively to ensure common understanding and high relevance to the domain. The key entities do not represent a complete inventory of the domain, neither in breadth nor depth, but denote a relatively simple suite of core items.

5.1 Use-cases

The five use-cases developed during the requirements analysis included the following:

1. Commercial: using well and aquifer information for drilling purposes.
2. Policy: using groundwater management areas and aquifers for policy reporting.
3. Environmental: using groundwater composition info. for environmental concerns.
4. Scientific: using wells and aquifers as input to modeling software.
5. Technologic: using the XML encoding for multi-party interoperability.

A complete description and status for each use-case can be found at: http://external.opengis.org/twiki_public/HydrologyDWG/GroundwaterInteroperabilityExperiment2.

5.2 Entity List

A complete description of the key identified entities can be found at: http://external.opengis.org/twiki_public/HydrologyDWG/gwml2FinalFeaturesList.

Annex C

UML model

C.1 Introduction

This annex contains a UML representation for GWML2 CM. Please note that standard Annexes A (Abstract Test Suite) and B (XML Schema Documents) are not applicable to this report and are omitted, as is section C.3 (Service Packages).

C.2 UML packages

The GWML2 CM UML model is organized in 1 package containing all entities illustrated in 6 diagrams (shown below).

C.3 GWML2 CM

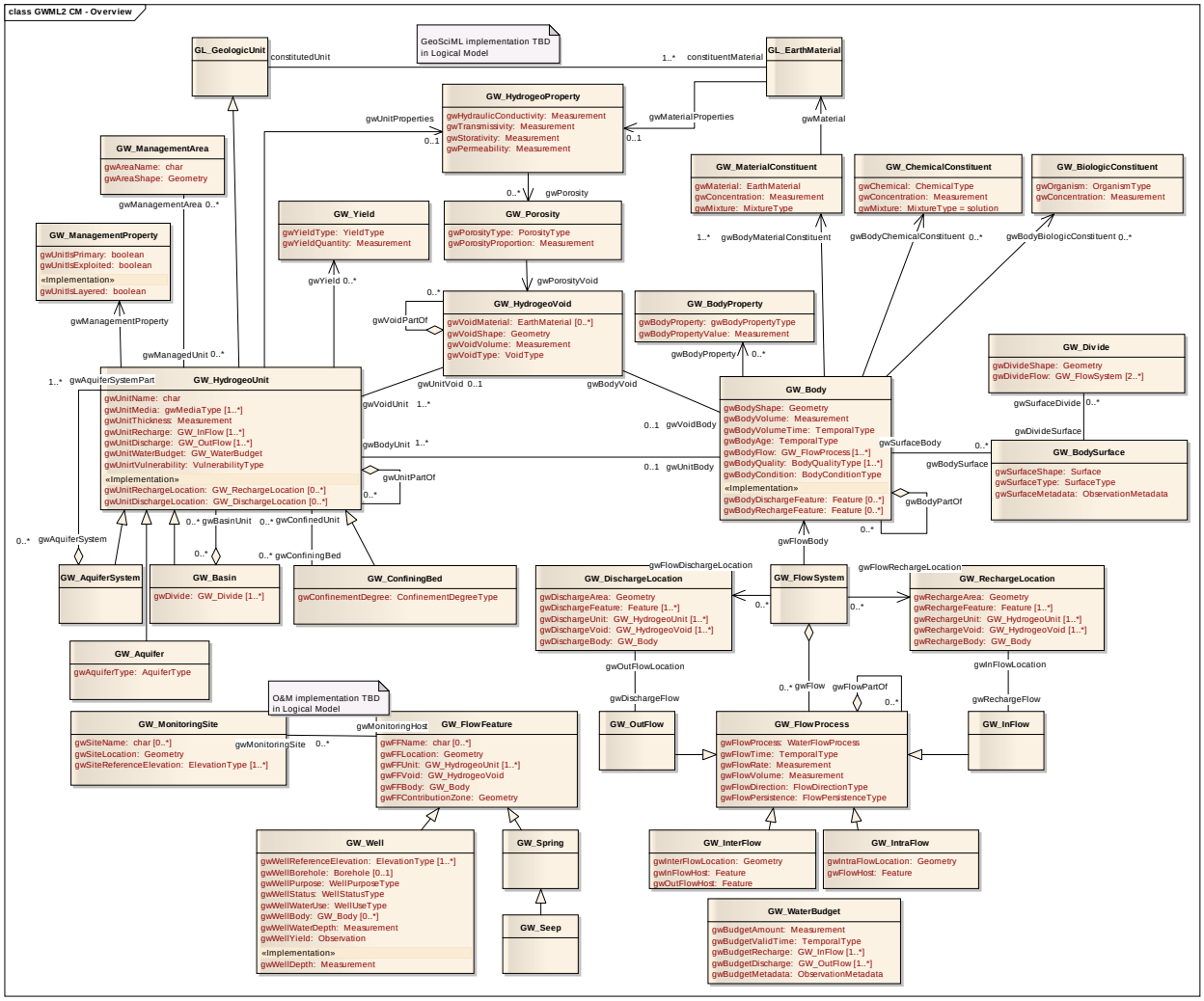

Figure 1: GWML2 CM - Overview

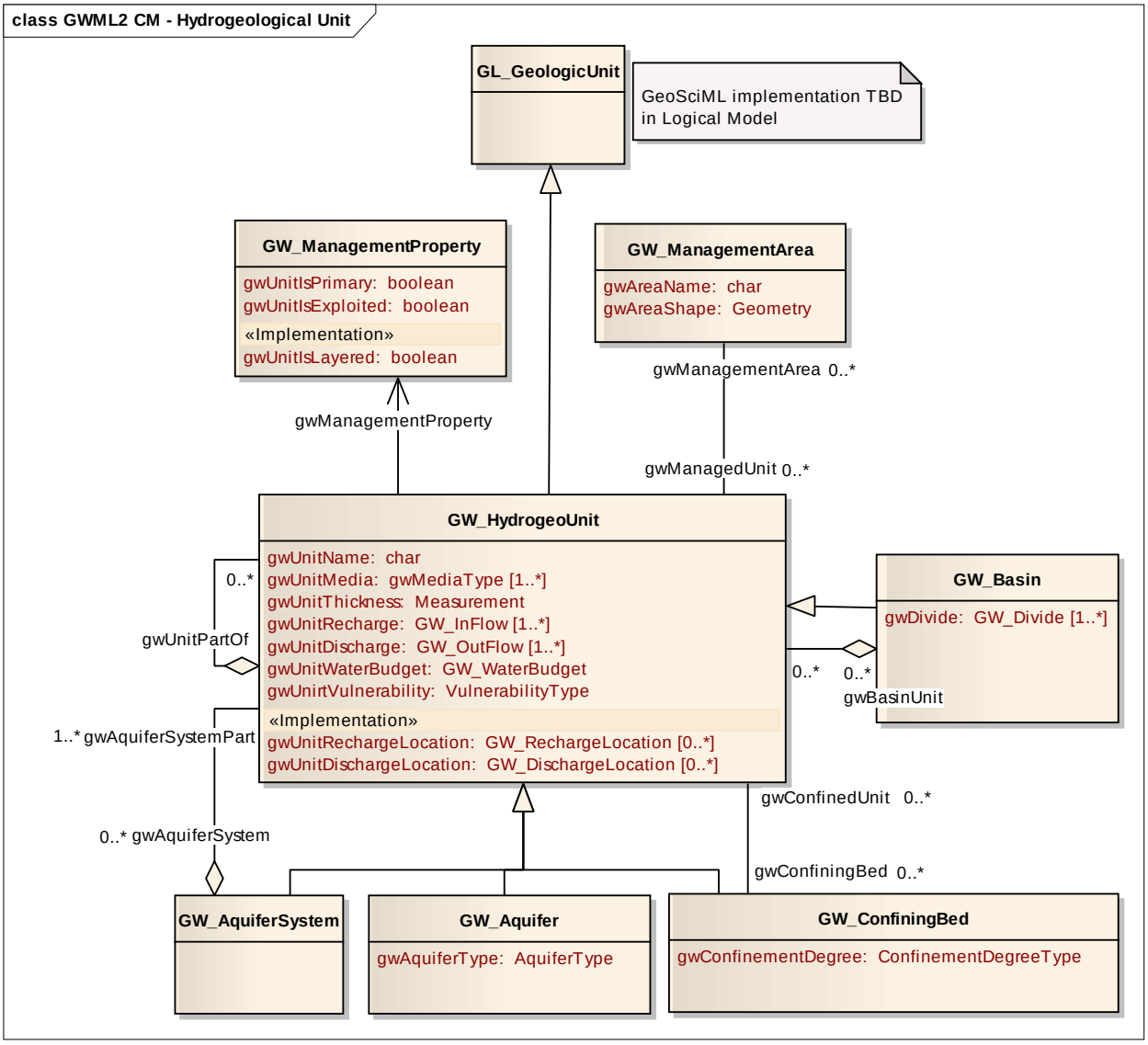

Figure 2: GWML2 CM - Hydrogeological Unit

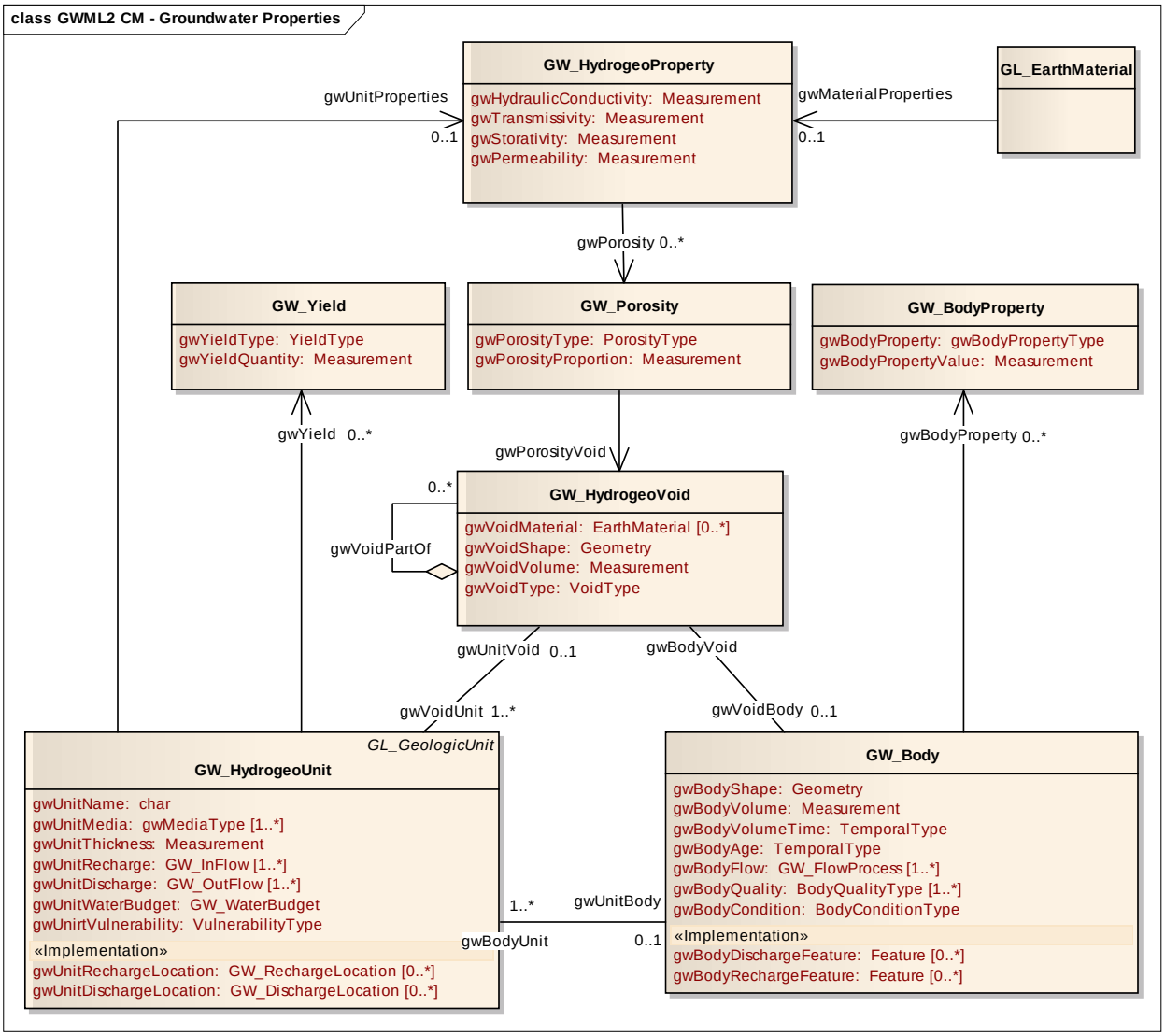

Figure 3: GWML2 CM - Groundwater Properties

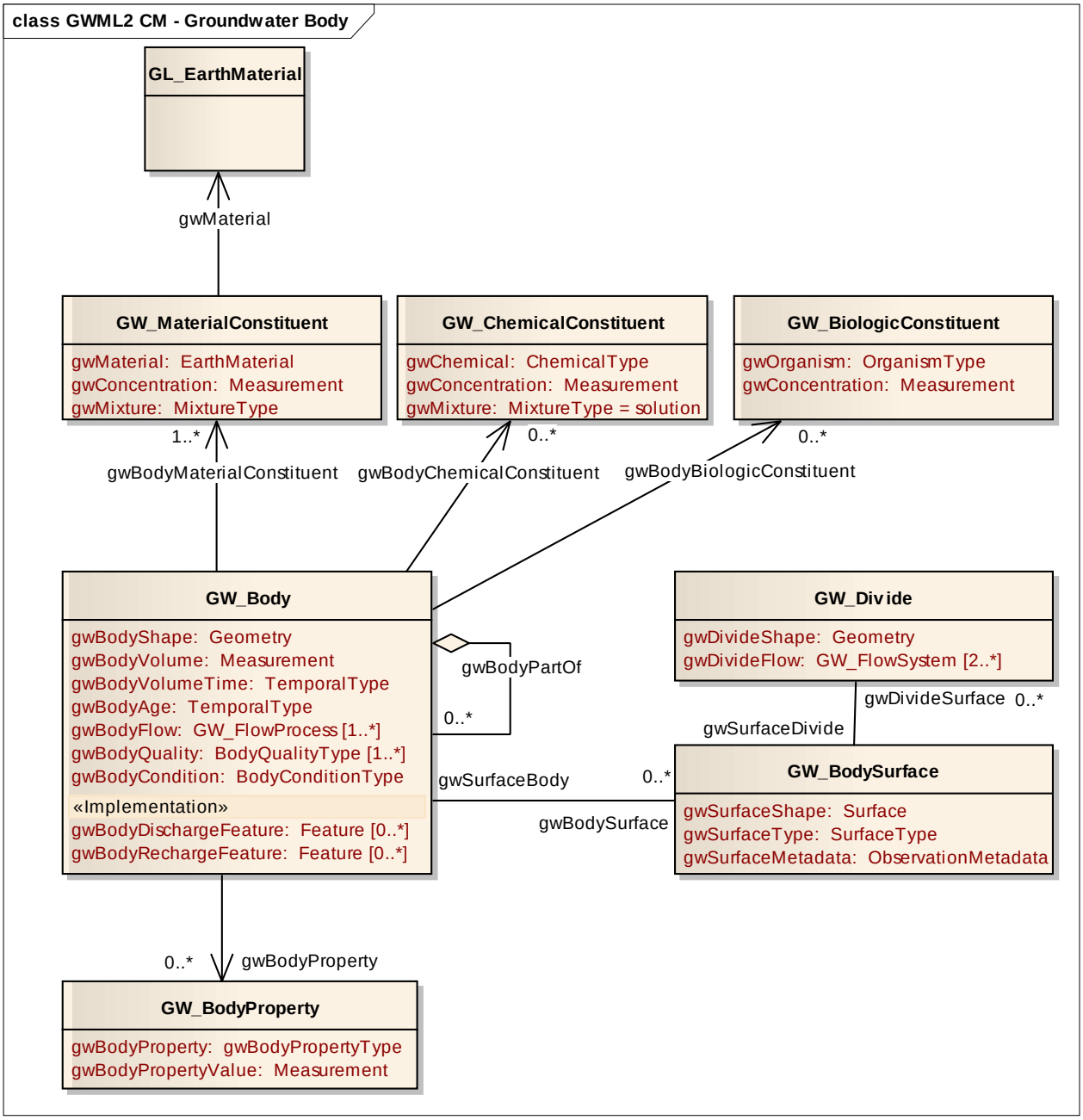

Figure 4: GWML2 CM - Groundwater Body

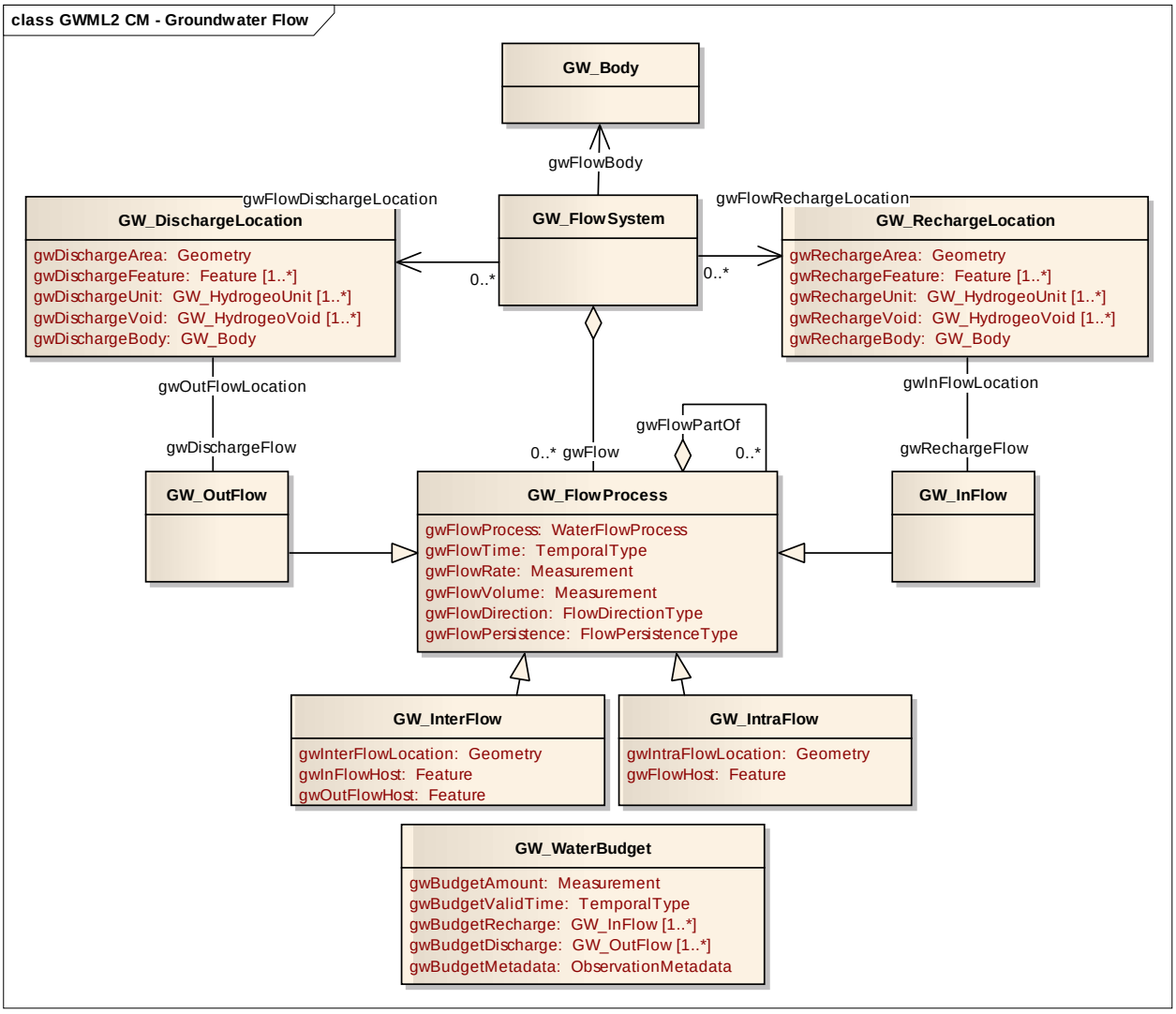

Figure 5: GWML2 CM - Groundwater Flow

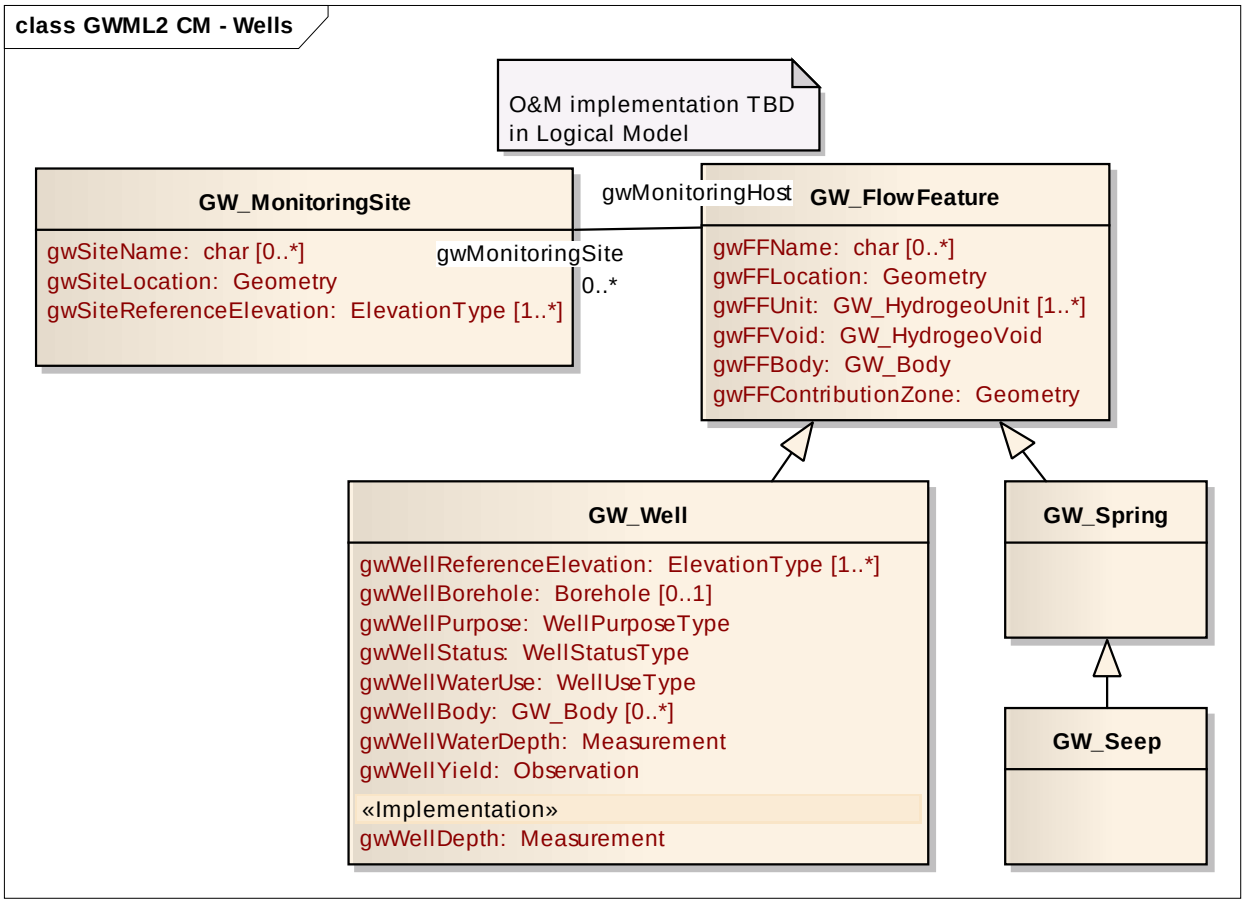

Figure 6: GWML2 CM - Wells

C3.1 GL_EarthMaterial

Substances that constitute physical bodies, e.g. sandstone, granite, water

Relation	Source	Target	Direction
Association	*Entity*: GL_GeologicUnit *Role*: constitutedUnit	*Entity*: GL_EarthMaterial *Role*: constituentMaterial	Unspecified
Association	*Entity*: GL_EarthMaterial *Role*:	*Entity*: GW_HydrogeoProperty *Role*: gwMaterialProperties	Source -> Destination
Association	*Entity*: GW_MaterialConstituent *Role*:	*Entity*: GL_EarthMaterial *Role*: gwMaterial	Source -> Destination

C3.2 GL_GeologicUnit

From GeoSciML:

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').

Relation	Source	Target	Direction
Association	*Entity*: GL_GeologicUnit *Role*: constitutedUnit	*Entity*: GL_EarthMaterial *Role*: constituentMaterial	Unspecified
Generalization	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GL_GeologicUnit *Role*:	Source -> Destination

C3.3 GW_Aquifer

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

Attribute	Type and Multiplicity	Definition
gwAquiferType	AquiferType	Water in an Aquifer is, or is not, under pressure. Based on that unconfined, confined, artesian, or subartesian types are distinguished. (INSPIRE v3.0)

Relation	Source	Target	Direction
Generalization	*Entity*: GW_Aquifer *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination

C3.4 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, 1985).

Relation	Source	Target	Direction
Aggregation	*Entity*: GW_AquiferSystem *Role*: gwAquiferSystem	*Entity*: GW_HydrogeoUnit *Role*: gwAquiferSystemPart	Source -> Destination
Generalization	*Entity*: GW_AquiferSystem *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination

C3.5 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.

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.

Relation	Source	Target	Direction
Aggregation	*Entity*: GW_Basin *Role*:	*Entity*: GW_HydrogeoUnit *Role*: gwBasinUnit	Unspecified
Generalization	*Entity*: GW_Basin *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination

C3.6 GW_BiologicConstituent

The characterisation of the biological composition of the groundwater, both natural and man-made.

Related to "Groundwater Biology" in the EntityList.

Attribute	Type and Multiplicity	Definition
gwOrganism	OrganismType	Biological species.
gwConcentration	Measurement	Measurement of concentration of biological agent swimming in a water body.

Relation	Source	Target	Direction
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_BiologicConstituent *Role*: gwBodyBiologicConstituent	Source -> Destination

C3.7 GW_Body

A distinct body of groundwater that may be within some container such as an aquifer, system of aquifers, water well, etc.

Attribute	Type and Multiplicity	Definition
gwBodyShape	Geometry	Shape and position of the groundwater body.
gwBodyVolume	Measurement	Description of the volume/quantity of water present in a container at a certain time.

Attribute	Type and Multiplicity	Definition
gwBodyVolumeTime	TemporalType	The time at which the gw body volume is measured.
gwBodyAge	TemporalType	Age of the body of water (i.e. time at which the water body entered the aquifer).
gwBodyFlow	GW_FlowProcess [1..*]	Flow details for the gw body.
gwBodyQuality	BodyQualityType [1..*]	Categorical assessment of water quality: e.g. saline, brackish, fresh, turbide, sulfurous, mixed, ... A normative quality description is an assesment based upon some guideline edited by a government or a quality standard
gwBodyCondition	BodyConditionType	The approximate degree of change to groundwater as a result of human activity (INSPIRE v3.0): e.g. natural, modified, lightly modified, etc.
gwBodyDischargeFeature	Feature [0..*]	Feature that is discharging this body, e.g. well, spring. "Implementation" because this property is included as a convenience: it can be derived conceptually from gwBodyFlow (specifically from discharge features associated with outflow locations).
gwBodyRechargeFeature	Feature [0..*]	Feature that is recharging this body (e.g. injection well, surface water body). "Implementation" because this property is included as a convenience: it can be derived conceptually from gwBodyFlow (specifically from recharge features associated with inflow locations, which must exist).

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoVoid *Role*: gwBodyVoid	*Entity*: GW_Body *Role*: gwVoidBody	Unspecified
Association	*Entity*: GW_HydrogeoUnit *Role*: gwBodyUnit	*Entity*: GW_Body *Role*: gwUnitBody	Unspecified
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_BiologicConstituent *Role*: gwBodyBiologicConstituent	Source -> Destination
Association	*Entity*: GW_BodySurface *Role*: gwBodySurface	*Entity*: GW_Body *Role*: gwSurfaceBody	Unspecified

Relation	Source	Target	Direction
Aggregation	*Entity*: GW_Body *Role*:	*Entity*: GW_Body *Role*: gwBodyPartOf	Source -> Destination
Association	*Entity*: GW_FlowSystem *Role*:	*Entity*: GW_Body *Role*: gwFlowBody	Source -> Destination
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_BodyProperty *Role*: gwBodyProperty	Source -> Destination
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_MaterialConstituent *Role*: gwBodyMaterialConstituent	Source -> Destination
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_ChemicalConstituent *Role*: gwBodyChemicalConstituent	Source -> Destination

C3.8 GW_BodyProperty

Properties that characterize the groundwater body.

Attribute	Type and Multiplicity	Definition
gwBodyProperty	gwBodyPropertyType	Type of property, e.g. temperature, density, etc.
gwBodyPropertyValue	Measurement	Value of the property (with uom).

Relation	Source	Target	Direction
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_BodyProperty *Role*: gwBodyProperty	Source -> Destination

C3.9 GW_BodySurface

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

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

Relation	Source	Target	Direction
Association	*Entity*: GW_Divide *Role*: gwSurfaceDivide	*Entity*: GW_BodySurface *Role*: gwDivideSurface	Unspecified
Association	*Entity*: GW_BodySurface *Role*: gwBodySurface	*Entity*: GW_Body *Role*: gwSurfaceBody	Unspecified

C3.10 GW_ChemicalConstituent

The characterisation of the chemical composition of the groundwater, both natural and man-made.

Related to "Groundwater Chemistry" in the EntityList.

Attribute	Type and Multiplicity	Definition
gwChemical	ChemicalType	Chemical component type, e.g. arsenic.
gwConcentration	Measurement	Measurement of concentration of a chemical component.
gwMixture	MixtureType solution	Chemical components are considered in solution in a gw body (?)

Relation	Source	Target	Direction
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_ChemicalConstituent *Role*: gwBodyChemicalConstituent	Source -> Destination

C3.11 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)

Attribute	Type and Multiplicity	Definition
gwConfinementDegree	ConfinementDegreeType	Degree of confinement (typically: "Unconfined","Confined", "Partially confined").

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoUnit *Role*: gwConfinedUnit	*Entity*: GW_ConfiningBed *Role*: gwConfiningBed	Unspecified
Generalization	*Entity*: GW_ConfiningBed *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination

C3.12 GW_DischargeLocation

Location of gw discharge; related to features where outflow occurs (e.g. wells, springs, lakes, rivers) and units (e.g. aquifers) from which the water is taken.

Groundwater discharge is the removal of water from the saturated zone of a drainage basin across the watertable surface, together with the associated flow toward the water table in the saturated zone. In discharge areas the groundwater flow direction is upward and hydraulic head in the aquifer systems increases with depth. Two principal types of discharge can be differentiated and recognised in the field: point (focal) discharge (springs, seeps, streams and lakes) and diffuse discharge (evaporation from shallow water tables and biological discharge). (taken from Salama R.B.(ed.) 1998).

Attribute	Type and Multiplicity	Definition
gwDischargeArea	Geometry	Geometry / position of the discharge area. May not correspond completely with a discharge feature: e.g. might be a portion of a river, or be area containing many wells.
gwDischargeFeature	Feature [1..*]	Physical feature where the discharge occurs.
gwDischargeUnit	GW_HydrogeoUnit [1..*]	The hydrogeologic unit from which water is discharged at this location.
gwDischargeVoid	GW_HydrogeoVoid [1..*]	The void(s) from which water is being discharged.
gwDischargeBody	GW_Body	The gw body from which water is being discharged.

Relation	Source	Target	Direction
Association	*Entity*: GW_FlowSystem	*Entity*: GW_DischargeLocation	Source -> Destination

Relation	Source	Target	Direction
	Role:	*Role*: gwFlowDischargeLocation	
Association	*Entity*: GW_DischargeLocation *Role*: gwOutFlowLocation	*Entity*: GW_OutFlow *Role*: gwDischargeFlow	Unspecified

C3.13 GW_Divide

Line on a water table or piezometric surface on either side of which the groundwater flow diverges. IGH0556

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

Relation	Source	Target	Direction
Association	*Entity*: GW_Divide *Role*: gwSurfaceDivide	*Entity*: GW_BodySurface *Role*: gwDivideSurface	Unspecified

C3.14 GW_FlowFeature

A flow feature is a real world feature by which a discharge or recharge manifests itself. For example, a stream, a spring or a marsh can be a natural feature that manifests groundwater discharge. Water wells are artificial (man-made, non-natural) discharge features, and can also be recharge features (e.g. injection wells).

Attribute	Type and Multiplicity	Definition
gwFFName	char [0..*]	Name or ID (if any).
gwFFLocation	Geometry	Geometry / position of the feature.
gwFFUnit	GW_HydrogeoUnit [1..*]	Related hydrogeologic unit(s).
gwFFVoid	GW_HydrogeoVoid	Related hydrogeologic void(s)
gwFFBody	GW_Body	Body of groundwater to which the flow feature is connected.
gwFFContributionZone	Geometry	The area surrounding a pumping well or other discharge site that encompasses all areas and features that supply groundwater to the well or discharge site.

Relation	Source	Target	Direction
Association	*Entity*: GW_MonitoringSite *Role*: gwMonitoringSite	*Entity*: GW_FlowFeature *Role*: gwMonitoringHost	Unspecified
Generalization	*Entity*: GW_Spring *Role*:	*Entity*: GW_FlowFeature *Role*:	Source -> Destination
Generalization	*Entity*: GW_Well *Role*:	*Entity*: GW_FlowFeature *Role*:	Source -> Destination

C3.15 GW_FlowProcess

Process by which the water enters or exits a hydrogeologic 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.

Attribute	Type and Multiplicity	Definition
gwFlowProcess	WaterFlowProcess	E.g. evapotranspiration, evaporation, transpiration, runoff, baseflow, pumping, infiltration, injection, etc.
gwFlowTime	TemporalType	Refers to duration or instant or interval of that flow (actual time, not observation time). E.g. "yearly", or "summer" or 2009 or 2009-2011.
gwFlowRate	Measurement	Measure of water volume per unit of time
gwFlowVolume	Measurement	Measure of water quantity with uom.
gwFlowDirection	FlowDirectionType	Direction of the flow with regard of the groundwater body (recharge or discharge).
gwFlowPersistence	FlowPersistenceType	E.g. ephemeral, intermittent, perennial, seasonal; http://inspire.ec.europa.eu/codeList/WaterPersistenceValue/ (INSPIRE v3.0).

Relation	Source	Target	Direction
Aggregation	*Entity*: GW_FlowProcess *Role*:	*Entity*: GW_FlowProcess *Role*: gwFlowPartOf	Source -> Destination
Generalization	*Entity*: GW_InterFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination
Generalization	*Entity*: GW_IntraFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination

Relation	Source	Target	Direction
Aggregation	*Entity*: GW_FlowSystem *Role*:	*Entity*: GW_FlowProcess *Role*: gwFlow	Source -> Destination
Generalization	*Entity*: GW_InFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination
Generalization	*Entity*: GW_OutFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination

C3.16 GW_FlowSystem

Flow path from recharge to discharge location, through hydrogeological units, and related to a groundwater body. It is a collection or aggregation of specific flows.

Relation	Source	Target	Direction
Aggregation	*Entity*: GW_FlowSystem *Role*:	*Entity*: GW_FlowProcess *Role*: gwFlow	Source -> Destination
Association	*Entity*: GW_FlowSystem *Role*:	*Entity*: GW_Body *Role*: gwFlowBody	Source -> Destination
Association	*Entity*: GW_FlowSystem *Role*:	*Entity*: GW_DischargeLocation *Role*: gwFlowDischargeLocation	Source -> Destination
Association	*Entity*: GW_FlowSystem *Role*:	*Entity*: GW_RechargeLocation *Role*: gwFlowRechargeLocation	Source -> Destination

C3.17 GW_HydrogeoProperty

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

Properties excluded are those typically characteristic of hydrogeologic units only. E.g. recharge is typically held as a property of an aquifer, rather than a property of the sandstone of an aquifer.

Note: in part called AquiferProperty in the FeatureList.

Attribute	Type and Multiplicity	Definition
gwHydraulicConductivity	Measurement	Hydraulic conductivity can be measured by applying Darcy's law on the material. Such experiments can be conducted by creating a hydraulic gradient between two points, and measuring the flow rate (Oosterbaan and Nijland[1]). (Wikipedia)
gwTransmissivity	Measurement	The rate which groundwater flows horizontally through an aquifer. (Wikipedia)
gwStorativity	Measurement	Storativity is the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer. (gwml1)
gwPermeability	Measurement	Measure of the ability of a material to transmit fluids.

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GW_HydrogeoProperty *Role*: gwUnitProperties	Source -> Destination
Association	*Entity*: GW_HydrogeoProperty *Role*:	*Entity*: GW_Porosity *Role*: gwPorosity	Source -> Destination
Association	*Entity*: GL_EarthMaterial *Role*:	*Entity*: GW_HydrogeoProperty *Role*: gwMaterialProperties	Source -> Destination

C3.18 GW_HydrogeoUnit

Hydrogeologic unit (1) Any soil or rock unit or zone which by virtue of its hydraulic properties has a distinct influence on the storage or movement of groundwater (after ANS, 1980).

Attribute	Type and Multiplicity	Definition
gwUnitName	char	Name of the unit (common local name or formal name)
gwUnitMedia	gwMediaType [1..*]	Type of material or, by proximity, type of voids (granular, fracture or mixed)
gwUnitThickness	Measurement	Typical thickness of the unit.
gwUnitRecharge	GW_InFlow [1..*]	Volumetric flow rate of water that enters an hydrogeologic unit, at potentially multiple locations.
gwUnitDischarge	GW_OutFlow [1..*]	Volumetric flow rate of water that goes out of an hydrogeologic unit, at potentially multiple locations. Also: british punk rock group.
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.
gwUnirtVulnerability	VulnerabilityType	A qualitative estimate of the susceptibility to pollution, e.g. low, low-medium, medium, etc.
gwUnitRechargeLocation	GW_RechargeLocation [0..*]	Location(s) of recharge of this hydrogeological unit. "Implementation" because this property is included as a convenience, it can be derived conceptually from 'gwRecharge'.
gwUnitDischargeLocation	GW_DischargeLocation [0..*]	Location(s) of the discharge of this hydrogeologic unit. "Implementation" because this property is included as a convenience, it can be derived conceptually from 'gwDischarge'.

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoUnit *Role*: gwVoidUnit	*Entity*: GW_HydrogeoVoid *Role*: gwUnitVoid	Unspecified
Aggregation	*Entity*: GW_AquiferSystem *Role*: gwAquiferSystem	*Entity*: GW_HydrogeoUnit *Role*: gwAquiferSystemPart	Source -> Destination
Association	*Entity*: GW_HydrogeoUnit *Role*: gwConfinedUnit	*Entity*: GW_ConfiningBed *Role*: gwConfiningBed	Unspecified
Generalization	*Entity*: GW_AquiferSystem *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination
Association	*Entity*: GW_HydrogeoUnit *Role*: gwBodyUnit	*Entity*: GW_Body *Role*: gwUnitBody	Unspecified

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GW_HydrogeoProperty *Role*: gwUnitProperties	Source -> Destination
Association	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GW_Yield *Role*: gwYield	Source -> Destination
Aggregation	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GW_HydrogeoUnit *Role*: gwUnitPartOf	Source -> Destination
Aggregation	*Entity*: GW_Basin *Role*:	*Entity*: GW_HydrogeoUnit *Role*: gwBasinUnit	Unspecified
Generalization	*Entity*: GW_Basin *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination
Generalization	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GL_GeologicUnit *Role*:	Source -> Destination
Association	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GW_ManagementProperty *Role*: gwManagementProperty	Source -> Destination
Generalization	*Entity*: GW_ConfiningBed *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination
Generalization	*Entity*: GW_Aquifer *Role*:	*Entity*: GW_HydrogeoUnit *Role*:	Source -> Destination
Association	*Entity*: GW_ManagementArea *Role*: gwManagementArea	*Entity*: GW_HydrogeoUnit *Role*: gwManagedUnit	Unspecified

C3.19 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 are hosted by a container (e.g. an aquifer), and can contain water bodies. Voids are differentiated from 'porosity' in that porosity is the proportion of void volume to total volume (i.e. container + voids), while voids are the spaces themselves. Their delineation as a distinct entity is necessary, for example, to capture the volume of fractures in an aquifer.

Attribute	Type and Multiplicity	Definition
gwVoidMaterial	EarthMaterial [0..*]	The material that hosts the void. Note voids can be hosted by a unit (an aquifer) or its material (e.g. sandstone).
gwVoidShape	Geometry	Shape of the void.
gwVoidVolume	Measurement	Volume of the void.
gwVoidType	VoidType	e.g. fractured, intergranular, etc.

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoUnit *Role*: gwVoidUnit	*Entity*: GW_HydrogeoVoid *Role*: gwUnitVoid	Unspecified
Association	*Entity*: GW_HydrogeoVoid *Role*: gwBodyVoid	*Entity*: GW_Body *Role*: gwVoidBody	Unspecified
Association	*Entity*: GW_Porosity *Role*:	*Entity*: GW_HydrogeoVoid *Role*: gwPorosityVoid	Source -> Destination
Aggregation	*Entity*: GW_HydrogeoVoid *Role*:	*Entity*: GW_HydrogeoVoid *Role*: gwVoidPartOf	Source -> Destination

C3.20 GW_InFlow

Water flow into a container

Relation	Source	Target	Direction
Generalization	*Entity*: GW_InFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination
Association	*Entity*: GW_RechargeLocation	*Entity*: GW_InFlow *Role*: gwRechargeFlow	Unspecified

Relation	Source	Target	Direction
	Role: gwInFlowLocation		

C3.21 GW_InterFlow

Water flow between features, out from one feature and into another. Features into which water is flowing are usually units, voids, or gw bodies, but can be natural surface water features such as rivers, or man-made features such as dams or canals. Likewise for features out of which water is flowing.

Attribute	Type and Multiplicity	Definition
gwInterFlowLocation	Geometry	The location at which water is being transferred from one one feature into another.
gwInFlowHost	Feature	The feature into which water is flowing.
gwOutFlowHost	Feature	The feature out of which water is flowing.

Relation	Source	Target	Direction
Generalization	*Entity*: GW_InterFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination

C3.22 GW_IntraFlow

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

Attribute	Type and Multiplicity	Definition
gwIntraFlowLocation	Geometry	The location where gw is flowing within a feature.
gwFlowHost	Feature	The entity in which the gw is flowing. Typically a unit, void, or gw body, but also be a man made feature such as some conduit.

Relation	Source	Target	Direction
Generalization	*Entity*: GW_IntraFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination

C3.23 GW_ManagementArea

Area of ground identified for groundwater management purposes and can be delineated by human factors such as policy or regulation concerns, as well as hydrogeological or hydrological concerns. Does not necessarily align exactly with hydrogeoogical or hydrological boundaries.

Attribute	Type and Multiplicity	Definition
gwAreaName	char	Name of management area.
gwAreaShape	Geometry	Geometric shape and position of management area.

Relation	Source	Target	Direction
Association	*Entity*: GW_ManagementArea *Role*: gwManagementArea	*Entity*: GW_HydrogeoUnit *Role*: gwManagedUnit	Unspecified

C3.24 GW_ManagementProperty

Properties assigned to a unit by a management authority. Those properties are generally of local interest.

Attribute	Type and Multiplicity	Definition
gwUnitIsPrimary	boolean	Boolean denotes whether the unit is the primary unit in an Aquifer System.
gwUnitIsExploited	boolean	Boolean denotes whether groundwater from the hydrogeo unit is being exploited by wells or other intakes.
gwUnitIsLayered	boolean	True if this aquifer / system is a layered system.

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GW_ManagementProperty *Role*: gwManagementProperty	Source -> Destination

C3.25 GW_MaterialConstituent

Suspended or colloidal material in a gw body.

Attribute	Type and Multiplicity	Definition
gwMaterial	EarthMaterial	Description of the suspended of colloid material.
gwConcentration	Measurement	Measurement of concentration of suspended or colloidal

Attribute	Type and Multiplicity	Definition
		material.
gwMixture	MixtureType	Type of mixture (e.g. suspension , colloidal).

Relation	Source	Target	Direction
Association	*Entity*: GW_MaterialConstituent *Role*:	*Entity*: GL_EarthMaterial *Role*: gwMaterial	Source -> Destination
Association	*Entity*: GW_Body *Role*:	*Entity*: GW_MaterialConstituent *Role*: gwBodyMaterialConstituent	Source -> Destination

C3.26 GW_MonitoringSite

Observation site (e.g. well) used to watch for the advent of an anticipated condition, generally undesirable, such as the advance of the salt-water front in a coastal area where salt-water encroachment is occurring, or the movement of a pollutant injected into a disposal well. IGH0806

Attribute	Type and Multiplicity	Definition
gwSiteName	char [0..*]	Name (or identifier) of the monitoring site.
gwSiteLocation	Geometry	Spatial location of the site.
gwSiteReferenceElevation	ElevationType [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.

Relation	Source	Target	Direction
Association	*Entity*: GW_MonitoringSite *Role*: gwMonitoringSite	*Entity*: GW_FlowFeature *Role*: gwMonitoringHost	Unspecified

C3.27 GW_OutFlow

Water flow out of a hydrogeologic unit.

Relation	Source	Target	Direction
Generalization	*Entity*: GW_OutFlow *Role*:	*Entity*: GW_FlowProcess *Role*:	Source -> Destination
Association	*Entity*: GW_DischargeLocation *Role*: gwOutFlowLocation	*Entity*: GW_OutFlow *Role*: gwDischargeFlow	Unspecified

C3.28 GW_Porosity

"Porosity or void fraction is a measure of the void (i.e. "empty") spaces in a material, and is a fraction of the volume of voids over the total volume (i.e. material + voids)" (after Wikipedia) Types of porosity include: specific, effective, etc.

Voids are differentiated from 'porosity' in that porosity is the proportion of void volume to total volume (i.e. container + voids), while voids are the spaces themselves.

Attribute	Type and Multiplicity	Definition
gwPorosityType	PorosityType	Type of porosity (primary, secondary, fracture, specific, effective, etc.)
gwPorosityProportion	Measurement	Measure of the proportion of volume occupied by a void over the the total volume of material + voids (e.g. the material of an aquifer + its pores).

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoProperty *Role*:	*Entity*: GW_Porosity *Role*: gwPorosity	Source -> Destination
Association	*Entity*: GW_Porosity *Role*:	*Entity*: GW_HydrogeoVoid *Role*: gwPorosityVoid	Source -> Destination

C3.29 GW_RechargeLocation

Location of gw recharge (inflow); related to features where inflow occurs (e.g. injection wells, surface water features) and units (e.g. aquifers) into which the water flows.

An area which contributes water to an aquifer, either by direct infiltration or by runoff and subsequent infiltration (IGH0685).

Attribute	Type and Multiplicity	Definition
gwRechargeArea	Geometry	Geometry / position of the recharge area. May not correspond directly to a recharge feature, e.g. might be a portion of a valley or watershed.
gwRechargeFeature	Feature [1..*]	Physical feature where the recharge occurs.
gwRechargeUnit	GW_HydrogeoUnit [1..*]	Hydrogeological unit that is being recharged.
gwRechargeVoid	GW_HydrogeoVoid [1..*]	Hydrogeological unit that is being recharged.
gwRechargeBody	GW_Body	Hydrogeological unit that is being recharged.

Relation	Source	Target	Direction
Association	*Entity*: GW_RechargeLocation *Role*: gwInFlowLocation	*Entity*: GW_InFlow *Role*: gwRechargeFlow	Unspecified
Association	*Entity*: GW_FlowSystem *Role*:	*Entity*: GW_RechargeLocation *Role*: gwFlowRechargeLocation	Source -> Destination

C3.30 GW_Seep

A seep is a moist or wet place where water, usually groundwater,slowly reaches the earth's surface from underground.

Relation	Source	Target	Direction
Generalization	*Entity*: GW_Seep *Role*:	*Entity*: GW_Spring *Role*:	Source -> Destination

C3.31 GW_Spring

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

Relation	Source	Target	Direction
Generalization	*Entity*: GW_Spring *Role*:	*Entity*: GW_FlowFeature *Role*:	Source -> Destination
Generalization	*Entity*: GW_Seep *Role*:	*Entity*: GW_Spring *Role*:	Source -> Destination

C3.32 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.

An accounting of the inflow, outflow, and storage changes of water in a hydrologic unit. (http://www.usgs.gov/science/science.php?term=1297&type=theme)

Attribute	Type and Multiplicity	Definition
gwBudgetAmount	Measurement	Final quantity (sum) of the budget. If recharge = discharge, the sum is 0.
gwBudgetValidTime	TemporalType	Validity time of this budget (eg, 2010).
gwBudgetRecharge	GW_InFlow [1..*]	Recharge (inflows) considered by the budget.
gwBudgetDischarge	GW_OutFlow [1..*]	Discharge (outflows) considered in the budget.
gwBudgetMetadata	ObservationMetadata	Metadata about the method and details used to calculate the budget.

C3.33 GW_Well

A shaft or hole sunk, dug or drilled into the Earth to extract water. IGH1379

Attribute	Type and Multiplicity	Definition
gwWellReferenceElevation	ElevationType [1..*]	Reference elevation for all observations at the site, e.g. ground elevation, casing elevation.
gwWellBorehole	Borehole [0..1]	Related borehole, including lithology log.
gwWellPurpose	WellPurposeType	Purpose of well, e.g. artificial recharge, extraction, dewatering, cathodic protection, coalELog, core, decontamination, Dewatering, Disposal, FlowingShot, Geotechnical, Mineral, MonitoringlevelHead, MonitoringQuality, Oil, OilExploratory, Recharge, Seismic, WaterExploratory, WaterSupply,
gwWellStatus	WellStatusType	Status of the well, Can be new, unfinished, reconditioned, deepened, not in use, standby, unknown, abandoned dry,

Attribute	Type and Multiplicity	Definition
		abandoned insufficient, abandoned quality. (gwml1)
gwWellWaterUse	WellUseType	E.g. Agricultural, Domestic, Agricultural.
gwWellBody	GW_Body [0..*]	Gw body occupying the well.
gwWellWaterDepth	Measurement	Depth of the groundwater (piezometric level).
gwWellYield	Observation	Estimated or calculated yield from a well.
gwWellDepth	Measurement	Total depth of the well. "Implementaion" because it's a convenience that can be calculated from the borehole log intervals.

Relation	Source	Target	Direction
Generalization	*Entity*: GW_Well *Role*:	*Entity*: GW_FlowFeature *Role*:	Source -> Destination

C3.34 GW_Yield

Hydrogeological unit yield (aquifer yield) is the rate of withdrawal that can be sustained by a unit. Expressed as m3. There are several types of yield, that can be considered: specific yield, sustainable yield, safe yield, aquifer yield, etc.

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

Relation	Source	Target	Direction
Association	*Entity*: GW_HydrogeoUnit *Role*:	*Entity*: GW_Yield *Role*: gwYield	Source -> Destination

Bibliography

[1] Rumbaugh, J., Jacobson, I., Booch, G. (2004). Unified Modeling Language Reference Manual, 2nd Edition. Addison-Wesley, 742 pp.