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Editors: Irina Dornblut, Rob Atkinson

OGC HY_Features:

a Common Hydrologic Feature Model

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i. Abstract

Common semantics support the reference of features to the concept they represent and the integration of data proceed using the semantic framework such mappings provide. However there is no standard conceptual model for hydrologic feature identification. Different models of hydrologic processes, and different scales of detail, lead to a variety of information models to describe these features, and to different and mostly incompatible sets of feature identifiers.

This document describes requirements and a proposed design for a domain model of hydrologic features as a set of interrelated Application Schemas using the ISO 19109 General Feature Model,

ii. Keywords

hydrology; feature; feature identification; common; semantic; reference model; information model; data integration; linked data; application schema; WMO

iii. Preface

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.

iv. Submitting organizations

The following organizations submitted this Document to the Open Geospatial Consortium

a) CSIRO (Australia)

b) Global Runoff Data Centre, GRDC, at the Federal Institute of Hydrology, BfG, (Germany).

v. Document contributor contact points

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

Contact	Company	Address	Phone	Email
Rob Atkinson	CSIRO	..	+61 419202973	Rob.atkinson<at>csiro.au
Irina Dornblut	GRDC	..	+49 261 16035265	dornblut<at>bafg.de

vi. Changes to the OpenGIS→ Specification

This document required no changes to the OpenGIS ® Abstract Specification.

Concerns are raised regarding governance of utility classes that are not specific to this domain, but not currently available in the OGC and ISO model baseline.

Foreword

This is an OGC Discussion Document. This document is not an OGC Standard. Suggested additions, changes, and comments on this report are welcome and encouraged. Such suggestions may be submitted by OGC portal message, email message, or by making suggested changes in an edited copy of this document.

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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.

Introduction

The WMO is the UN system's authoritative voice on the state and behavior of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources. It facilitates the free and unrestricted exchange of data, products and services and contributes to policy formulation at national and international levels.

The WMO promotes the utilization of international industry standards for transfer protocols, hardware and software enabling the routine data collection and automated dissemination of observed data as well as ad-hoc requests for data and products. Being a recognized international standardization body, WMO has the mandate to set standards in these areas.

The water related activities of the WMO are shaped by the Commission for Hydrology (WMO-CHy). This includes advice on the standardization of various aspects of hydrologic observations, as well as on the sharing and exchanging of hydrologic data using modern information and communication technology.

The need for a domain-specific feature model emerges from the requirement to integrate data and information across multiple systems, emerging from the global geographic distribution of jurisdiction over water resources and the multiple systems and sub-domains that concern or interact with the hydrology domain. To communicate compatible data and information about a distinct state of a hydrologic process, to integrate multiple or cross-reference alternative representations of a hydrologic feature, it becomes necessary to identify the concepts shared in different application contexts and to express the semantics of hydrologic features commonly used in disparate and differently structured data products.

1. Scope

This is an OGC Discussion Paper for review by OGC members and other interested parties. It is a working draft document and may be updated, replaced by other documents at any time. It is inappropriate to use OGC Discussion Papers as reference material or to cite them as other than “work in progress.”

This document was produced as part of the joint WMO/OGC Hydrology Domain Working Group activity. It is intended to become a candidate for a *WMO Best Practice* for implementation under the auspices of the WMO-CHy and release to the hydrologic community of WMO Member countries.

This document describes a conceptual model for the identification of hydrologic features independent from geometric representation and scales. This model allows common reference to hydrologic features across scientific sub-disciplines in hydrology. The Hydrologic Feature Model, *HY_Features*, is designed as a set of interrelated Application

Schemas using ISO 19103 Conceptual Schema Language and ISO 19109 General Feature Model. It is factored into relatively simple components that can be reviewed, tested and extended independently.

2. Conformance

The standardization (conformance) target of the *HY_Features* model is a related application schema for a data product describing hydrologic features. Such an application schema may be either the direct encoding of *HY_Features* or another schema formally mapped to *HY_Features* equivalent classes and properties. The conceptual model addresses the general requirements to integrate hydrologic data and information available across the scientific and technical programs of the WMO, to assist the WMO Members to discover, access und use hydrologic data from different sources.

However, the conceptual model raises a series of opportunities and requirements for testing in the context of many application domains related to hydrologic processes. Appropriate conformance requirements need to be defined in respect to the use of the model to support hydrologic referencing and system interoperability of information services and in data infrastructures.

Conformance to the *HY_Features* model requires that an implementation is able to:

- a) map the feature type of each implemented *GF_Feature* to the equivalent concept in *HY_Features*, wherever such an instance of such a feature may be referenced as a hydrologic feature

- b) map all properties of the implemented feature to the equivalent property expressed by feature properties within the *HY_Features* model where such a mapping exists

  The precise mechanism for such a mapping is not defined at this stage.

3. Normative references

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

ISO 19101:2002, Geographic Information—Reference Model

ISO/TS 19103:2005, Geographic Information — Conceptual schema language

ISO 19107:2003, Geographic Information — Spatial schema

ISO 19108:2006, Geographic Information — Temporal schema

ISO 19109:2006, Geographic Information — Rules for application schemas

ISO 19115:2012, Geographic Information — Metadata – Fundamentals (Draft)

4. Terms and definitions

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

The *HY_Features* model uses as far as possible the terminology recommended for use in the WMO Member countries and represented by the "UNESCO/WMO International Glossary of Hydrology" [1].Whenever an appropriate definition is provided in this glossary, the model captures this meaning and relationships to define relevant features and feature properties.

4.1 application schema

conceptual schema for data required by one or more applications
[ISO 19101].

NOTE: In general, a schema is an abstract representation of an object's characteristics and relationship to other objects. An XML schema represents the relationship between the attributes and elements of an XML object (for example, a document or a portion of a document)

4.2 basin

hydrologic unit wherein all incoming water is channeled to a common outlet.

NOTE: The common outlet of a basin may be a particular location, but also a body of water. It may be a real place or a fictive one built from joining several places.

4.3 catchment

distinct unit catching something, e.g. water.

NOTE: Across scientific disciplines in the domain of hydrology, a catchment is commonly recognized as the basic unit of study and reporting. .

4.4 domain feature

feature of a type defined within a particular application domain.
[ISO19156]

4.5 feature

abstraction of real-world phenomena
[ISO19101]

4.6 hydrographic network

aggregate of water bodies, aggregated using a connecting system.

4.7 hydrography

science dealing with the description and measurement of open bodies of water.
[WMO1992]

NOTE: In this context, hydrography refers to the description of water bodies. Its measurement in terms of surveying, e.g. for navigational purposes, is not in the concern of the HY-Features model.

4.8 hydrologic feature

abstract notion of the hydrology phenomenon.

4.9 hydrology

science that deals with the waters above and below the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, their reaction with their environment, including their relation to living beings.
[WMO1992]

4.10 hydrometric feature

real-world phenomenon which forms part of a hydrometric network.

NOTE: The hydrometric feature refers to a physical structure intended to observe properties of a hydrologic feature. Used to sample a hydrologic feature, a hydrometric feature may be considered a sampling feature of observation. A sampling feature is described in general in ISO 19156, the special monitoring point of hydrologic observation is described in the *WaterML 2.0* Specification.

4.11 hydrometry

science of the measurement and analysis of water including methods, techniques and instrumentation used in hydrology.
[WMO1992]

4.12 mapping

mapping of elements of disparate representations of a hydrologic feature.

NOTE: In the context of common semantics, it refers to concept mapping particularly to an agreed reference concept.

4.13 multilingual keyword

keyword used in a multilingual context.

NOTE: A keyword is generally described in ISO 19115.

4.14 named feature

feature identified by a name.

NOTE: Hydrologic features and their real-world representations have names within common experience, but may have different names in their cultural, political and historical contexts.

4.15 observable property

characteristic of a phenomenon subject to observation.
[ISO 19156]

NOTE: The observable property may be indirect, relying on direct observation of a more convenient parameter [observed property], which is a proxy for the ultimate [observable] property of interest.

4.16 representation

real-world phenomenon representing an abstract feature.

4.17 river positioning system

linear system used to reference indirect positions along a watercourse.

NOTE: The concept of indirect position describes a location on the land surface relative to or as a distance to a reference point located in a hydrographic network on a hydrographic feature applying a linear coordinate system. Position may be described relative to the reference point as distance , percentage of this, , or expressed verbally.

4.18 sampling feature

artifacts of an observational strategy … intended to sample some feature of interest in an application domain.
[ISO 19156]

4.19 storage

impounding of water in surface or underground reservoirs, for future use.
[WMO1992]

NOTE: Storage refers to a water body in terms of a usable water resource. The management of the reservoir as human action with the objective to efficient and sustainable use the resource, is not in the scope of the *HY_Features* model. Yet, often an indication is required whether a water body is used for storage.

4.20 variable

characteristic carried by a real-world phenomenon liable to change.

NOTE: Values expressing the change are usually obtained by observing the variable. A variable may take any value in a range of possible values.

NOTE: A variable may be a quantity having a magnitude, additive or non-additive, or multitude whose values can be expressed by a number, but also a nominal property expressed using words, alpha-numeric codes, or Boolean values.

4.21 water body

mass of water distinct from other masses of water is considered a water body.
[WMO1992]

NOTE: A water body represents a hydrologic feature in the real world. A water body may be segmented in single parts which are real-world phenomena itself.

5. Conventions

5.1 Symbols (and abbreviated terms)

CHy WMO Commission for Hydrology

GML Geography Markup Language

GRDC Global Runoff Data Centre

HDWG OGC Hydrology Domain Working Group

ISO International Organization for Standardization

OGC Open Geospatial Consortium

OWL Web Ontology Language

UML Unified Modeling Language

WaterML 2 *WaterML 2.0* – an observations model for hydrology

WIS WMO Information System

WIGOS WMO Integrated Global Observing System

WMO World Meteorological Organization

XML eXtensible Markup Language

5.2 UML notation

Most diagrams that appear in this specification are presented using the Unified Modeling Language (UML) static structure diagram, as described in Subclause 5.2 of the OGC Web Services Common Implementation Specification [OGC 04-016r2].

6. *HY_Features*: A Common Hydrologic Feature Model

6.1 Scope of the hydrologic feature model

The *HY_Features* model defines the semantics of features which are the overall objects of study and reporting in hydrology and its associated scientific disciplines. It provides a means to identify these features independent from scale of geographic representation. It also enables multiple representations of these (real-world) features, with alternative data models, to be linked to the ultimate object of study or reporting.

The initial scope of this model is defined by the concerns of the WMO-CHy to facilitate the data sharing within the hydrologic community of the WMO Member countries and to improve the quality of data products based in these data. Interoperability of observing systems needs standardized formats and transfer routines, such as WaterML 2, however the compatibility of data products also requires agreed concepts to describe the features of shared interest. In the hydrology domain these features represent results of the hydrologic processes at various stages of the water cycle, relevant to study and report the "waters above and below the land surfaces of the Earth, their occurrence, circulation and distribution, both in time and space, their biological, chemical and physical properties, and their reaction with their environment"[1]. This scope includes well-established data models and patterns in use in the hydrology domain, since the intended goal is to support these using a common conceptual model.

The *HY_Features* model is intended to sufficiently describe hydrologic features referenced in the various data sets in current use and to form a basis for a common and stable referencing of these features to assist the organization of their observation and modeling as well as the aggregation of generated data into integrated suites of datasets on a global, regional, or basin scale.

The model encompasses different approaches of modeling hydrologic features, but enforces the semantics of relationships between different levels of detail. This provides a semantic framework for feature identifiers to be developed and embedded in individual data products without constraining the flexibility required to model complex hydrological processes at fine detail.

6.1.1 *HY_Features* in the overall context of OGC standards

The *HY_Features* model defines hydrology domain-specific implementations of the general *FeatureType* (aka *GF_FeatureType*) metaclass. Since its concern is primarily the issue of feature identification, a basic class *HY_HydroFeature* is defined wherever hydrological features are required to be references. (*Figure 1*) This class is intended to specify the *GFI_Feature* in terms of the sampled feature of observation as currently required by the ISO 19156 Observation and Measurements model (O&M). Specifically, this is expected to provide a model for use in applications of *WaterML 2.0* Implementation Profile of *O&M*.[3]

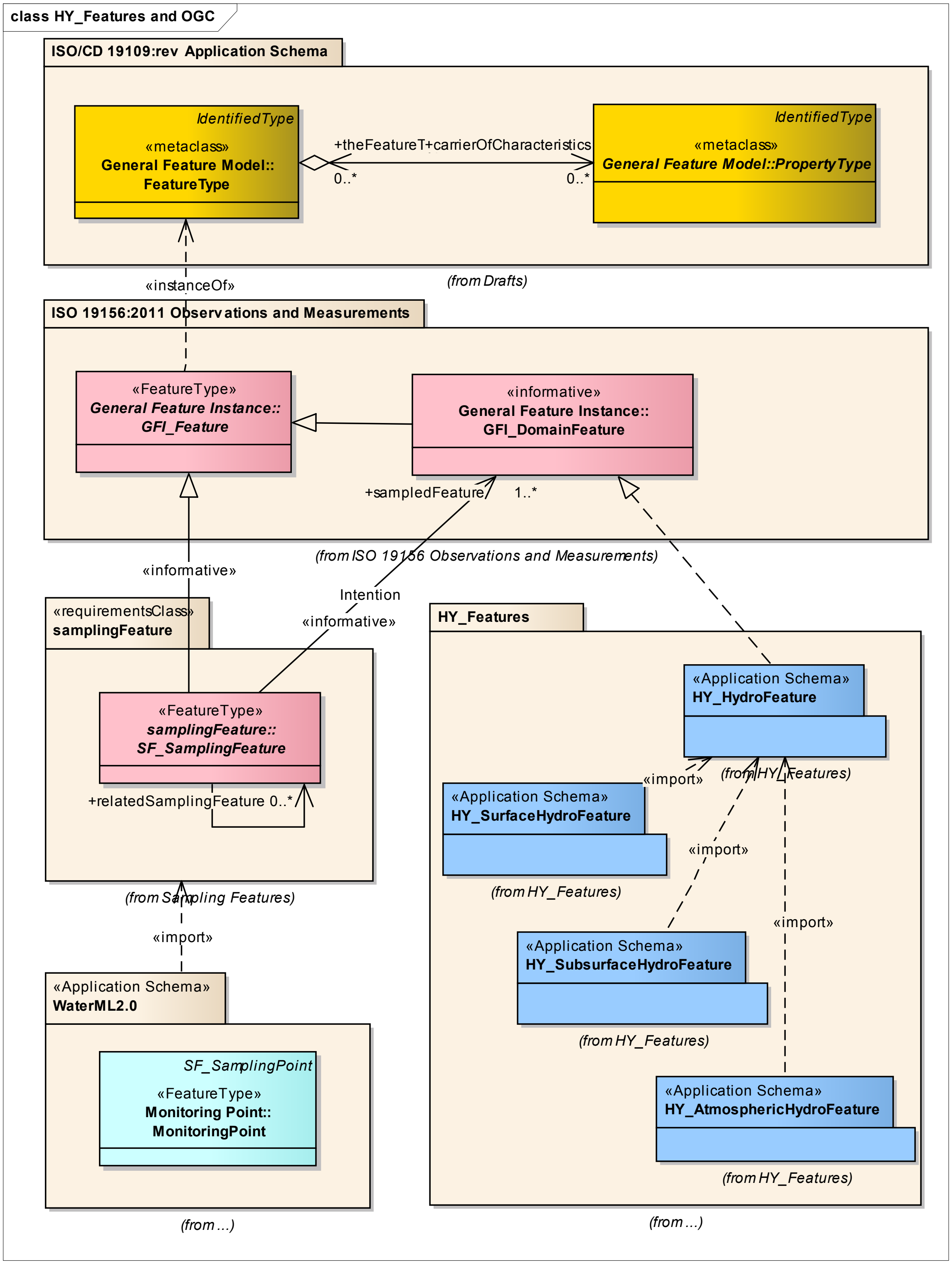

Figure 1 *HY_Features* in the context of the OGC Abstract Specifications

*Figure 1*shows how the *HY_Features* model might fit into the existing OGC feature landscape. For applications in hydrology, particularly in the context of hydrologic observation and sampling, the proposed *HY_HydroFeature* will represent the ultimate subject of observation, the intended sampled *DomainFeature* and may be used by observation-centric applications such as *WaterML2*.

6.1.2 *HY_Features* in the overall context of the WMO Information System

WIS, the WMO Information System, provides mechanisms for the international exchange of information related to weather, climate and water. In this framework, the *WMO Core Metadata Profile* version 1.3 [4] was developed. This specification defines the content, structure and encoding of discovery metadata published within the WIS Discovery-Access-Retrieval (DAR) Catalogue. The metadata standard defined as an informal category-1 profile of the ISO 19115:2003 'Geographic information – Metadata'

WIGOS, the WMO Integrated Global Observing System, is a coordinated system which is comprised of the present WMO global observing systems. Complementary to the WMO Core Metadata Profile, a WIGOS Core Metadata Standard is under development that allows the essential observational information to be exchanged unambiguously, regardless of the format used for the transfer.

In this context, the *HY_Features* model will provide a required component of a metadata model describing hydrologic data sets and products generated from observation. Other controlled vocabularies will be required, and a binding mechanism to specify how these independently governed and published components can be combined.

An approach under consideration is the concept of *GRDC Hydrologic Metadata* [5] for the description of data sets, particularly time series, created by further processing of data from a preceding observation. This concept under development by the Global Runoff Data Centre (GRDC) of the WMO refers to the basic concepts of the *O&M* model [2] and will use ISO19115-1:2012 'Metadata-Fundamentals' (under development) [6] and the time series description of *WaterML2* [4]. The *HY_Features* features types are used to relate the spatial or temporal coverages to the river basin they represent (*Figure 2*) .

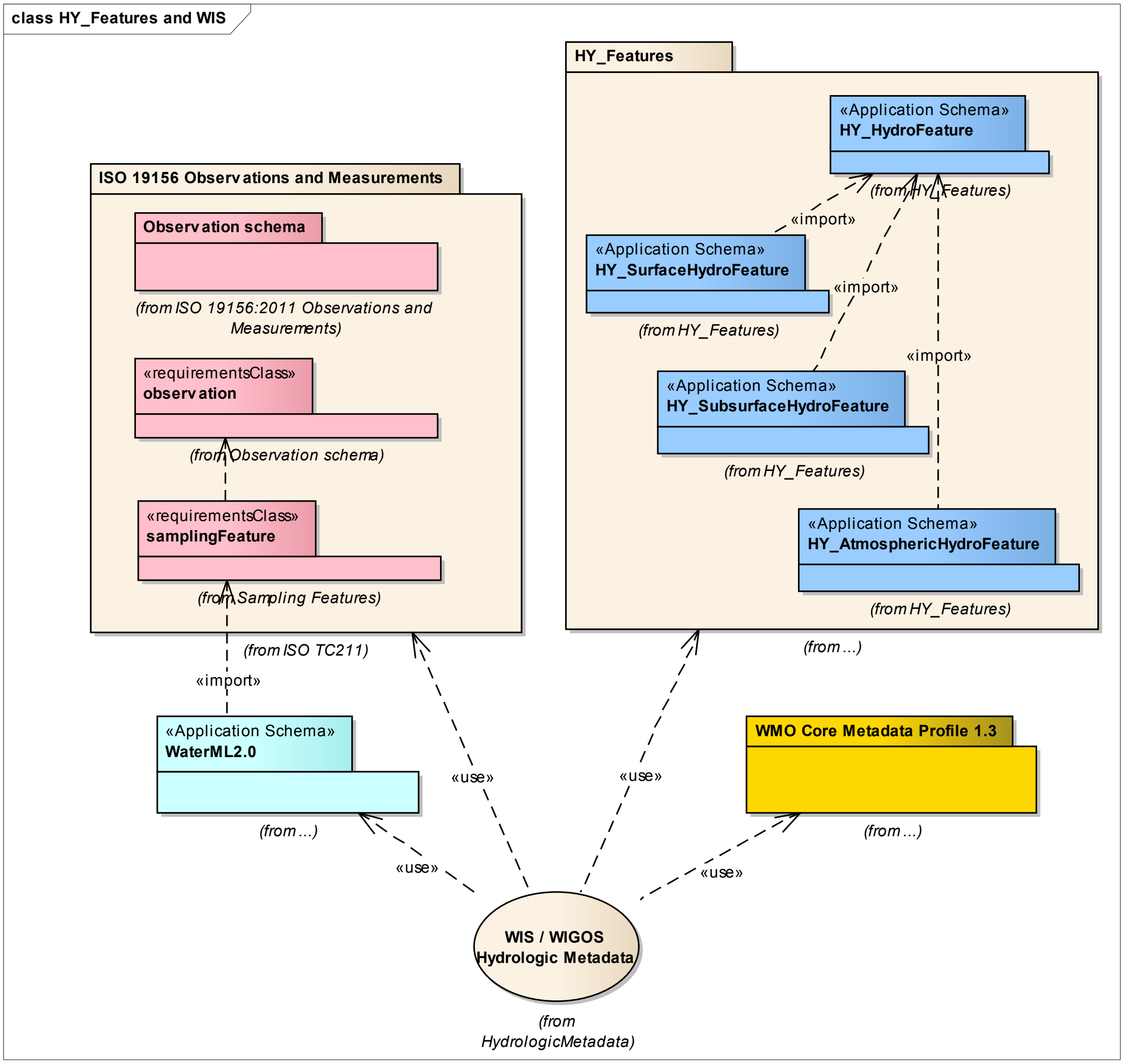

Figure 2 Placement of *HY_Features* in the context of WIS / WIGOS

6.1.3 Properties of hydrologic features and its observation

Hydrologic objects (real-world phenomena) have characteristic properties that change according to continuous hydrologic processes. Values expressing this change are usually obtained by observing a *Variable* related to these characteristics. Such a *Variable* may have different roles in different contexts: observable property, observed property, measurand of an instrument, reported characteristic, base of a derived variable, a process variable under control, an assessment criterion, etc.. Different concepts at different levels of detail from different perspectives are in use to identify these variables, quantities as well as nominal properties.

O&M defines observation as “an act that results in the estimation of a feature property” [2], thus in principle each such *Variable* shall be an instance of the general *PropertyType* (aka *GF_PropertyType*) metaclass. The determination of what such a named property may be called or mean is bound to observation processes themselves, and the variety of these cannot be determined in advance, Thus, observable characteristics are not generally in the scope of the *HY_Features* model. The relation between the hydrologic feature and its observable variables needs to be specified at the application level. *HY_Features* supports this allowing alternative sets of properties to be bound to a common concept of a named feature.

6.2 General requirements for a Common Hydrologic Feature Model

Hydrologic processes are constrained by and interact with the landscape and the medium in which they occur. These interactions are complex and variable through time. It is common practice to identify and refer to specific instances of a hydrologic feature when describing the state of any of these hydrologic processes or associated human activities. Persistent landscape features such as *catchment*, *basin*, *watershed* or *water body* are classic examples of concepts, common in many fields of discourse, but yet different according to the focus on various aspects of the hydrology phenomenon.

Hydrologic processes commonly are studied and reported in logical units related to the behavior of water. Depending on application and scale these units are multiple represented in the real world by a variety of phenomena, either single objects or a composite or network of these. The reference to the shared unit of study by different applications may be challenging if different semantics and identifiers are used for different delineations. Stable and persistent identifiers are required to reflect hydrologic significance and topological connectivity of features across disparate representations and different scales.

A re-usable core of generally applicable concepts, capable of being partially realized in existing implementations, may increase the acceptance of the model in the addressed community. The required governance by an accepted, internationally acting authority, like the WMO, will be supported by a canonical form, implementation neutrality and conformity to internationally recognized standards.

6.2.1 General Applicability

To be generally applicable to a wide range of applications where hydrologic feature identification needs to be persisted or shared, feature characterizations given in different systems must be supported without specifying what characteristics may be assigned in a specific context. Instead of being a comprehensive set of all, or commonly used characteristics, a re-usable core model is required that supports application specific specializations. For example, an application concerned with rainfall runoff could extend the model to include soil moisture and land cover parameters that are not necessary to define the unit of study itself. A representation such as a remote-sensed grid field can be added for any parameter, as could a simple attribute for a characteristic value. Numerical model starting conditions and parameters may be provided on the basis of characterization of e.g. basin features, and model outputs may be reported at basin scale or combined into a single result on the basis of the hydrologic connectivity of basins.

In cross-border applications and as part of global information frameworks the naming of a feature within different cultures and languages is a fundamental issue. The same feature may be named differently according to locale and usage. Names may apply to part of a feature only. Provided practitioners in the field of hydrology can successfully share meaning and feature identifiers, a full conceptual model of toponymy is not required. Nevertheless, the cultural, political and historical variability and the relationships between alternative names needs to be handled.

6.2.2 Stability of Identifiers

Stability of identifiers means that factors that change the representation of a feature in an information system, should not change the identifier of the feature itself. Such factors may be the improved resolution or accuracy of representation, minor changes to physical characteristics of the feature that occur over time, but also changes of technology platform, implementation or custodian. It is a core requirement of general applicability (6.2.1) to support stability of identifiers across different representations to allow multiple systems to use, or map to, these identifiers.

With regard to hydrology, identifiers must be able to stably reflect the hydrologic significance of a feature regarding both its contributing catchment and its topological connectivity to upstream and downstream features. Those features that can be given stable identifiers in this context must be distinguished from those that are defined within the context of a specific representation. For example, a DEM derived drainage network will have many predicted flow lines, but these may be simply a function of the resolution of the DEM, and not reflect physical reality. Key features such as major confluences may be represented, often due to drainage enforcement from vector representations, but nevertheless identifiable features.

6.2.3 Scale-independence

Hydrologic features exist at any scale, from a continental scale river basin to the basin upstream of any point in a detailed river network. Whether observing, modeling or reporting, the choice of the scale made by the user depends on the special purpose of its study. Some scales seems to be more or less general because of their wide range of use, but always chosen for a specific purpose, e.g. for mapping or comparative reporting, they are still distinct.

Scaling up or down leads to multiple representations of the same hydrologic feature. A common model must support simplifications at small scales and details at large scales allowing hydrologic feature complexes to be potentially encapsulated within simpler features at a less detailed scale. The co-existence of multiple hierarchical aggregations of features into alternative networks needs to be supported.

The requirement for identifier stability (6.2.2) implies that the same features must be identifiable where present in different scales of mapping. Reporting on a coarse scale needs to be supported as well as aggregating features at finer levels of detail in a consistent fashion to generate information at coarser scales.

6.2.4 Governance

The introduction and enforcement of standard practices in a large, heterogeneous community require promotion, guidance and advice by an authority accepted within the addressed community. Being the authoritative voice of UN, the WMO provides the framework for the leadership of the WMO-CHy in administration and management of best practices in the hydrologic community of WMO Member countries.

To be accepted as a *Best Practice* by the WMO-CHy, a common model shall not contradict existing positions of the WMO. This implies two other requirements. The first and most important is conformity, where applicable, to existing definitions defined and endorsed by the WMO–CHy. The key reference here is the UNESCO/WMO International Glossary of Hydrology [1]. The second implication is that the model has no dependencies on aspects not recognized by the WMO within its standardization agenda. This is addressed by the plan to submit the model to the WMO-CHy for implementation into WIS and WIGOS, upon satisfactory results of testing.

6.2.5 Implementation Neutrality

Intended to be released to a community of sovereign WMO Member countries, no national data standard or proprietary technology for implementation should be directly referenced. Furthermore, existing standard implementations, industry or open, and implementations that are approved within the WMO standardization context are preferred. Implementation neutrality, i.e. no recommendation of a specific implementation or, particular technology, is fundamental to import new components in existing implementations.

The use of ISO 19103 Conceptual Schema Language and Application Schema modeling idiom [7] is commonly expected as well as the provision of XML schema definitions of the individual model components.

6.3 The Hydrology phenomenon and its abstract notion

6.3.1 The Hydrology Phenomenon

Hydrology is the science dealing with waters above, on and below the land surfaces of the Earth, their occurrence, circulation and distribution in time and space, their biological, chemical and physical properties, and their reaction with the environment [1]. This definition applies to water in all of its phases moving from the atmosphere to the Earth and back to the atmosphere due to the processes forming the Water Cycle.

The processes governing the continuous depletion and replenishment of water resources result at various stages in a wide range of hydrologic objects which are subject to monitoring, modeling and reporting in hydrology. Water from precipitation reaching the land surface is accumulated in water bodies occupying empty space on the land surface or in water bearing formations of soil and rock. Due to continuous interaction with soil water and groundwater, a water body permanently gains or loses water.

Water bodies interact with each other in basins wherein all incoming water is channeled towards a common outlet. Caused by gravity or by pumping water passes through soil and underground interstices, moves in open channels or closed conduits, or aquifers. The common outlet may be a particular location, but also a body of water. It may be a real place or a fictive one built from joining several locations.

Water bodies may be aggregated into a hydrographic network using a connecting system of channels expressed in flow or drainage patterns. This system of channels exists independently of whether water flows therein or not. It does not define whether a water body interacts with water bodies upstream and downstream. For example, normally stagnant waters may or may not be connected to streams during flood events, or streams may be interrupted to pools of stagnant water in periods of drought or not. Likewise, an aquifer system determines the potential connection between bodies of groundwater, but not causes the interaction.

Water may be stored and managed in surface or underground reservoirs in terms of a resource for future use, for regulation and control. Conceptually, each water body, or the layers therein, may be managed as a reservoir. Referring to the mass of water usually managed in particular layers, storage reservoirs are typically considered as stratified water bodies. Also due to differences in thermal or salinity characteristics, or by oxygen or nutrient content a water body may be stratified vertically into distinct layers.

Water bodies have individual names within common usage, but these may be variant in different cultural, political or historical contexts. In international programs and projects geographic names are usually fixed by convention.

Water bodies are observed using monitoring stations and observing posts. Almost all stations are physical artifacts, or collections of these. Yet, some stations may be fictive ones. Monitoring stations may be connected logically in hydrometric networks which usually represent a distinct unit of monitoring or reporting at local or regional scale. It is common practice to locate a monitoring station with respect to local landmarks and permanent reference points, or in relation to the extent of the monitored water body.

Water and water bodies are studied and reported in hydrologic „water“ units shared across disciplines and domains at national or international levels. Examples are the so-called “River Basin Districts” of the European Water Framework Directive [8] designated not according to administrative or political boundaries, but rather according to the river basin as a natural hydrologic unit, or at national scale the “Hydrologic Unit Codes” (HUC) used by the US Geological Survey for the National Water Information System (NWIS) [9].

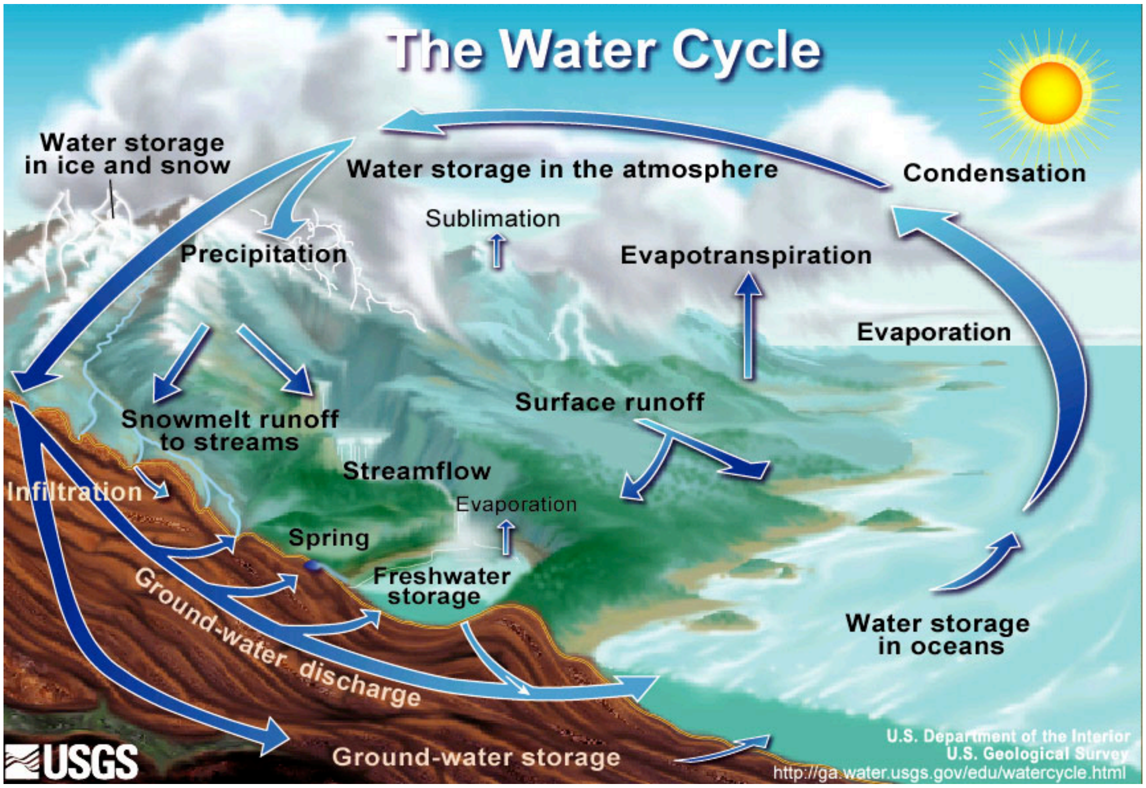

Figure 3 Processes of the Hydrologic Cycle

6.3.2 The abstract notion: Catchment and Basin

It is common practice in today's environmental reporting to report the hydrologic processes and their results in a holistic approach at catchment scale. The catchment is the abstract notion of the hydrology phenomenon *(Figure 3)* commonly recognized across hydrologic disciplines and cross-domain. It is the shared unit of study usually addressed in inter-disciplinary programs, inter-program collaboration and cross-domain research projects, and also the management unit agreed across administrative jurisdictions and the unit of joint monitoring and reporting.

A special type of catchment is the hydrologically determined basin. The term "basin" is used inconsistently in the literature, sometimes to denote an entire river system, sometimes a sub-basin or an inter-basin between key features such as major confluences in the river system. In terms of conformity to the WMO endorsed semantics, a definition is applied which refers to the physiographic unit wherein all incoming water is channeled to a common outlet.

It is common practice to determine the position of the outlet in relation to a reference point. This reference point may be a permanent landmark, a station, or the point where groundwater enters the surface, but also a point projected onto the surface or created from collapsing individual points. For example, vertically arranged points may be aggregated and projected onto surface, the estuary of a stream may be logically aggregated to a point located at the mouth (*Figure 4*). The geometric representation varies with the application: it may be a point but also a curve or a surface.

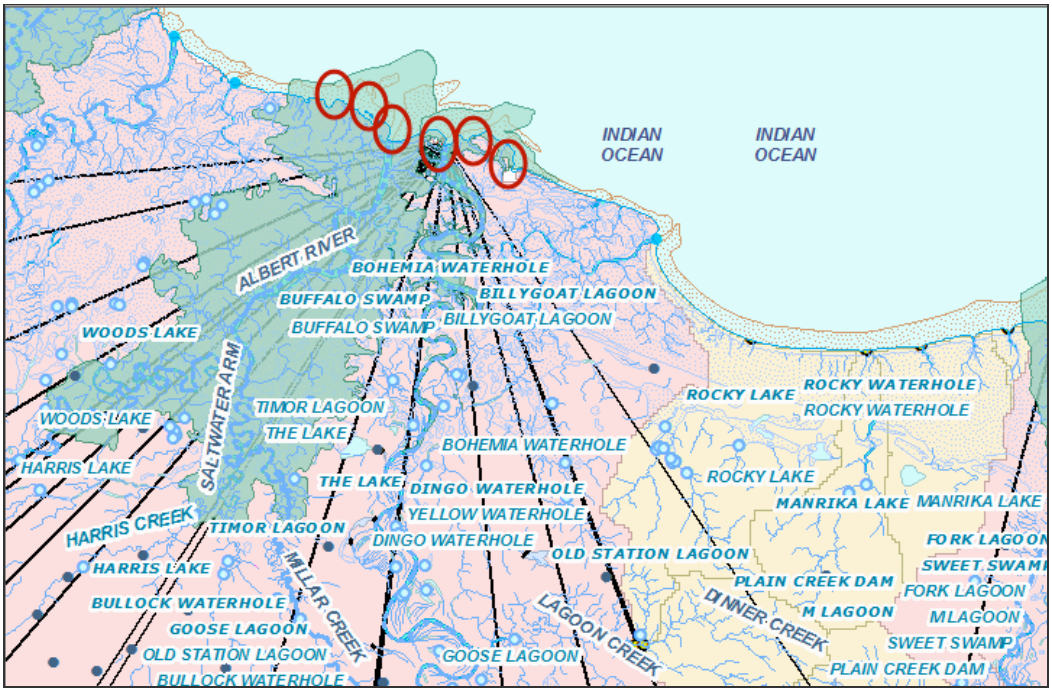

Figure 4 Many network nodes mapped to single logical node

Basins are organized in hierarchies and related topologically in networks. They may be aggregated to complete river basins or to intermediate hydrologically discrete upper-level systems like management units. For example, generally recognized river basins are often partitioned in discrete sub-basins within a larger basin, with different approaches to aggregating up the lower level of hydrological detail. In terms of network connectivity, a basin gets inflow from a contributing upstream basin and flows out into a receiving basin downstream.

Catchments and basins have inherent characteristics induced from interactions with other domains assigned in spatial, temporal or classification contexts. Almost all of these are indicators of cross-domain applicability for example the geological region wherein the basin is situated, the shared space in an encompassing WMO Region, or a temporary reporting region.

6.3.3 Multiple representations of catchment in the real world

Depending on application and scale, the same catchment may be displayed in different ways. Reporting and analysis of landscape interactions refers typically to areas of study or its boundaries. A basin may be described geometrically e.g. by the bounding watershed, drainage area or streamlines, or topologically as a graph of nodes and links, a reporting region as member of a regional hierarchy. Some applications require cartographic representations while others are focused merely on topological relationships

(*Figure 5*).

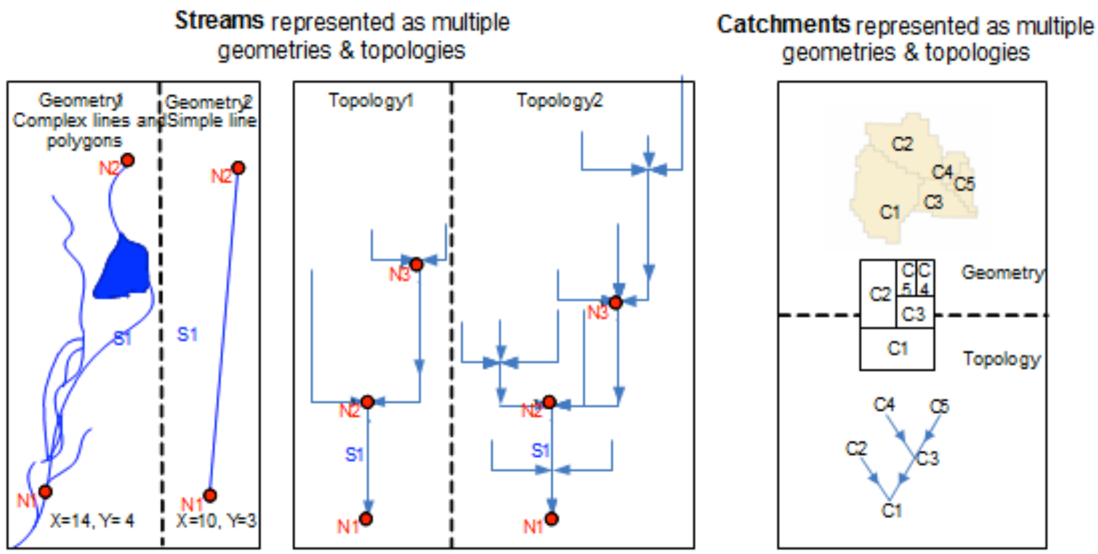

Figure 5 Cartographic representation vs. topology

Cartographic representations without topology can still be partitioned using the boundary on the river-system scale, forcing a simple relationship between a trivial topology and the spatial representation of these coarse features (*Figure 6*).

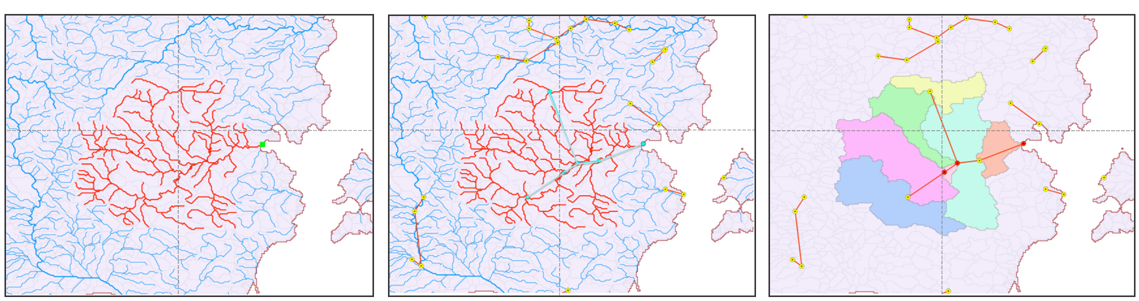

Figure 6 Alternative cartographic representations of a catchment / basin

Cartographic representations do not always reflect the network connectivity of features explicitly. Even where connectivity is recorded (as opposed to unconnected lines) cartographic representations may be incomplete, as seen *Figure 7*. [10] This may be due to ephemeral nature of streams, land cover, underground connections or simply digitizing errors. Sometimes features may not be topologically connected, but represent the best available representation, another time the segmentation of features carries no semantic content in terms of representation or naming.

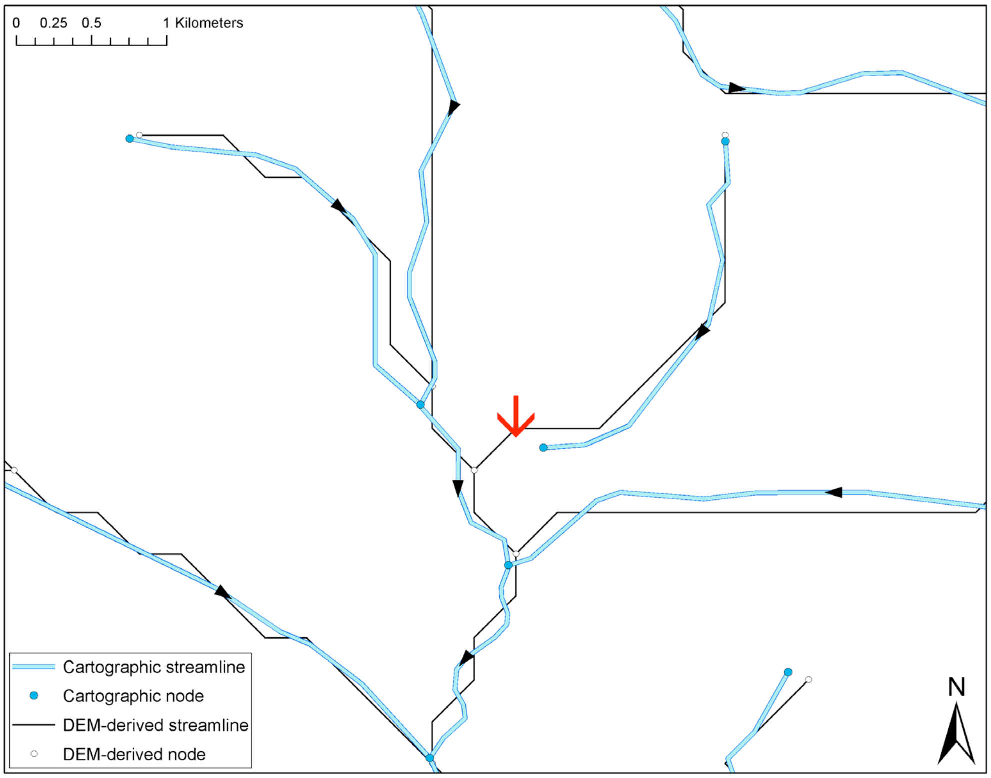

Figure 7 Cartographic and grid cell connectivity representation of streamlines

7. *HY_Features*, conceptual model

The *HY_Features* model describes the major components of the hydrosphere and their fundamental relationships according to the semantics expressed in definitions endorsed by the WMO. It provides referencable concepts that may be addressed by applications reflecting a wide range of hydrologic features in different scientific disciplines in the hydrology domain and cross-domain.

The model concept allows either the description of a logic hydrologic feature like the catchment, as often required in reporting applications, but also the identification of this ultimate hydrologic feature via its multiple real-world representations.

The conceptual model is expressed in the ISO 19103 Geographic Information Conceptual Schema Language [7] and ISO 19109 General Feature Model as a set of Application Schemas containing Feature Type definitions[11]). It is based on a broad industry standard, the Unified Modeling Language (UML) [12].

The model is developed in a multi-step process whereby the requirements for hydrologic referencing is reconciled with typical data set designs and semantics endorsed by the WMO-CHy. Module identification aims to simplify the scope of each part of the model in order to improve its accessibility and provide scope for testing. It is intended that each implemented data product needs to consider only those parts of the common model implicated by its scope. This is facilitated and made transparent by using only those modules that define concepts referenced by the data set.

Differences in terminology may be explored through reconciling accepted definitions endorsed by the WMO-CHy and represented by the "UNESCO/WMO International Glossary of Hydrology" (IGH) [1], with the different aspects reflected in various data sets and products. It is intended to apply, wherever appropriate, the terms from the IGH to the identified semantic constructs. This has the effect of augmenting the accepted definitions with explicit semantics for the relationships with other terminology.

7.1 Basic concept

A hydrologic feature is the abstract notion of the hydrology phenomenon. The core concept of *HY_Features* is that a study of the hydrology phenomenon will reflect common concepts of the real world by specific modeled features (as per ISO 19109 General Feature Model). Depending on the scientific concern, the relevant hydrologic feature may represent different aspects of the hydrology phenomenon.

Commonly recognized as the abstract unit of study and reporting in the hydrology domain, a catchment is considered as a hydrologic feature. Each catchment may be represented in any hydrologically meaningful sub-domain model, including by a simple tree network of „blue lines“, or the nested network of catchments. A catchment is multiple represented in the real world by a variety of hydrologic phenomena which are monitored, modeled and reported in typical applications. Catchment area, catchment boundary, flowpath, hydrographic network, channel network, or hydrometric network are alternative views representing a catchment.

The basin is defined as the catchment special due to its hydrologic determination by the common outlet which may be an arbitrary location on, or projected onto, the Earth's surface. A basin has by definition one single outflow node. It may have one single identified inflow node, which coincides with the outflow node of an upstream basin. The basic concept of a basin is that of a "link" between outflow nodes without knowing the complex hydrology between them. This concept requires a stable identifier that is not merely a function of an arbitrary delineation of the surface, and that basins are delineated within a simple hierarchy (tree structure).

Each basin may be nested in a containing basin in a simple "is-part-of" hierarchy as typically used for high order organization of management and reporting units. Each basin may be sub-basin of an all-encompassing basin, either as tributary basin without an identified inflow, or as inter-basin determined by inflow and outflow.

By definition, the common outlet of a basin has no explicit location and no explicit geometry. A basin may be represented geometrically by an area (e.g. drainage area), a boundary polygon (e.g. watershed), or a curve (e.g. flowpath, or an indicative straight line). Since the geometry will vary with application, it needs to be defined there.

7.2 Organization of the UML model

The *HY_Features* model is a set of inter-related modules containing definitions for key aspects of hydrologic systems. The model is managed in sub-domain specific packages, allowing extension to the core set and involvement of relevant expert groups in the governance of individual models.

The *HY_* prefix follows the ISO naming conventions for UML elements. There is no explicit requirement that these names to be used in implementing systems for the same semantic elements. It is not yet specified how mappings between abstract element names and implementations should be recorded. Nevertheless it is expected that future interoperability will be facilitated by making such mappings available as a component of dataset documentation.

NOTE: The HY-prefix refers to the Greek "hydro" and means water in general because of "waters above and below the land surfaces of the Earth" (WMO 2010) is the principal object of study in hydrology.

NOTE: The EXT-prefix refers to "external", common patterns that are required, but not hydrology-specific, and should be imported when available from an external source.

HY_Features model comprises the following packages:

- *HY_Utilities,* containing utility classes for common patterns required by the domain model that are not hydrology-specific*;*
- *HY_HydroFeature,* incl. *HY_Catchment, HY_HydrographicNetwork, HY_NamedFeature, HY_RiverPositioningSystem* and *HY_Storage;*
- *HY_AtmosphericFeature;*
- *HY_SubsurfaceHydroFeature,* incl. *HY_SubsurfaceWater* and *HY_SubsurfaceWaterConfines;*
- *HY_SurfaceHydroFeature,* incl. *HY_SurfaceWater and HY_SurfaceWaterConfines;*
- *HY_HydrometricNetwork.*

The organization into packages and their dependencies are shown in *Figure 8.*

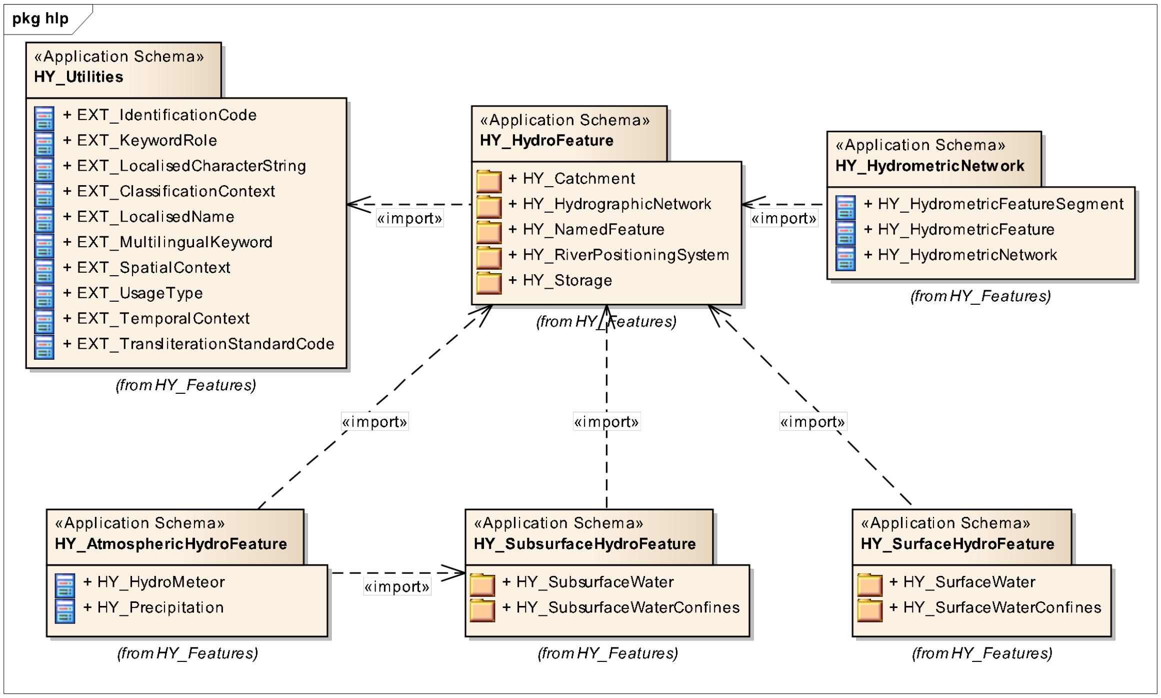

Figure 8 *HY_Features* – Package dependencies

7.3 HY_Utilities

HY_Utilities package (*Figure 9*) contains utility classes for common patterns expected to be important for cross-domain harmonization. They should be provided in an external library for cross-domain usage. It is expected that future evolution of the ISO standards will provide a replacement for these components. At that point this package can be replaced with references to this library.

These classes provide:

- Cross-cultural name support (*EXT_LocalisedName, EXT_MultilingualKeyword, EXT_TransliterationStandardCode, EXT_UsageType*)
- Context relationships, i.e. how different features may be related spatially, temporally or rank in a classification system (*EXT_*Context*)

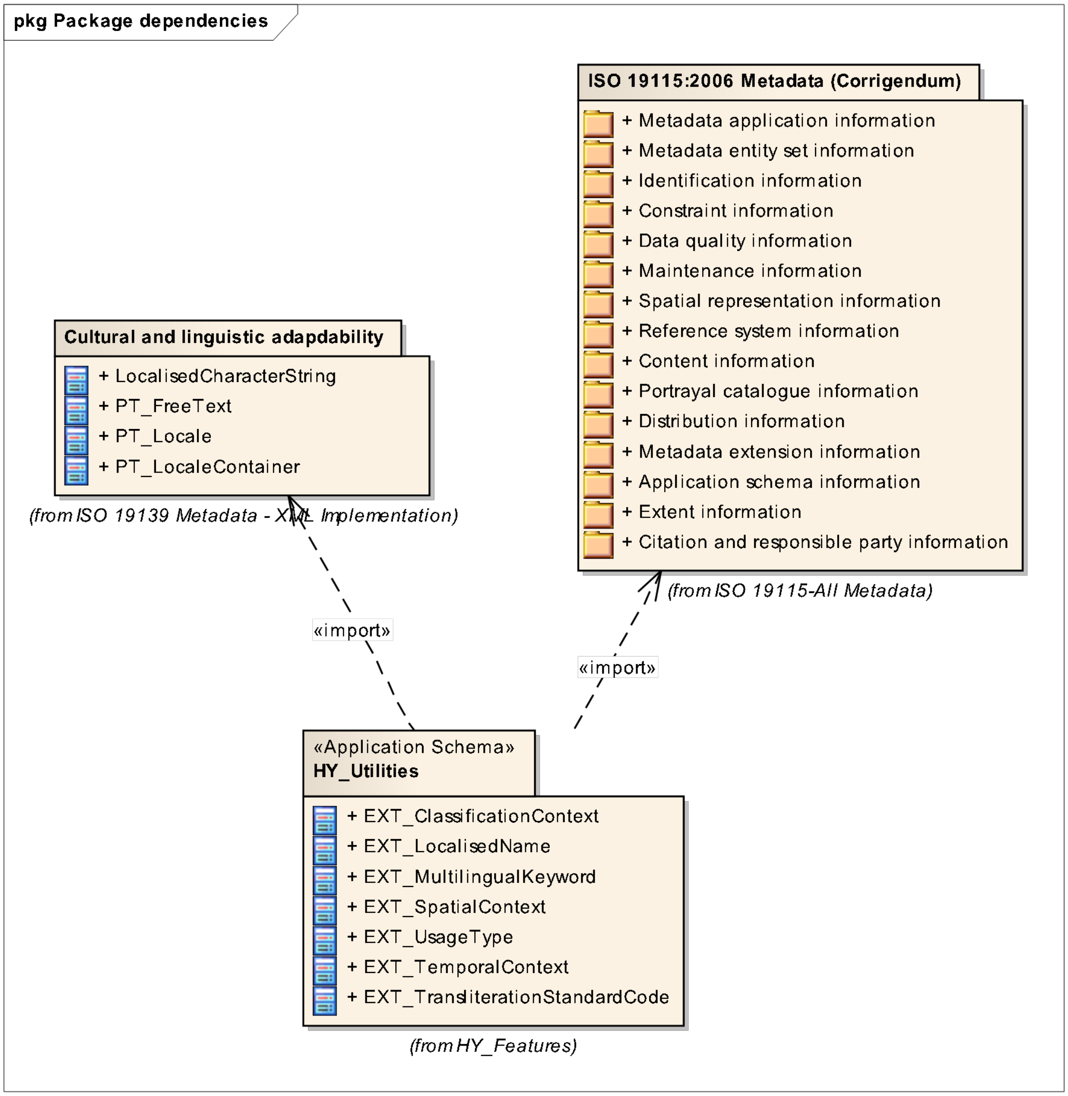

Figure 9 *HY_Utilities* – Package dependencies

7.4 HY_HydroFeature

HY_HydroFeature schema (Figure 10) defines the fundamental properties and relationships between features governed by the physical laws of hydrology. It connects the disparate representations of the hydrologic feature in the real world, allowing the hydrosphere to be divided into a hierarchy of catchments.

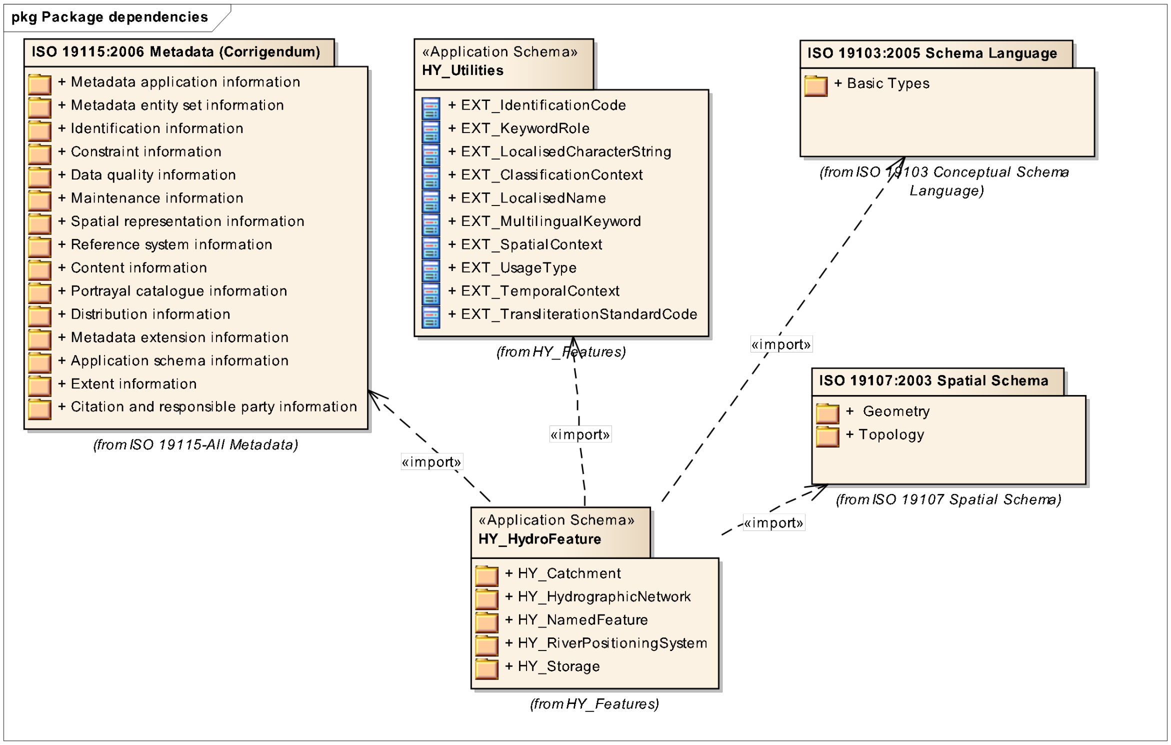

Figure 10 *HY_HydroFeature* – Package dependencies

HY_Catchment package defines a logical network of catchments. The catchment model is sufficient for the case of simplified hierarchies of catchments, particularly basins, without unnecessary detail of varying flow conditions and cartographic interpretation. It allows for the existence of basins to be recognized and identifiers assigned based on outflow nodes, even if stream networks, watershed boundaries and areas are not reliably determined. It is intended that hydrological reporting applications may use this model without the full complexity of the *HY_Features* model.

Figure 11 shows the hierarchy of *Catchment* and *Basin* allowing to address catchment or basin as part of a containing catchment, as well as a sub-basin (distinct from other sub-basins) encapsulated an all-encompassing *BasinAggregate*, either as tributary basin or inter-basin connected with an upstream basin.

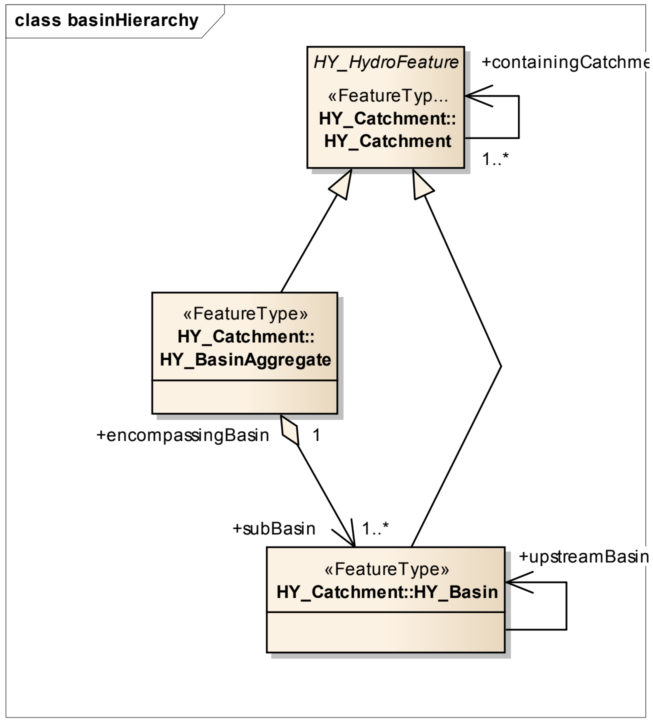

Figure 11 UML diagram: *Catchment* and *Basin*

HY_Catchment defines the most common concepts of catchment representation including the formation of soil or rock with hydrologically significant characteristics (hydrogeologic unit). This allows the catchment concept to be referenced from a wide range of applications. If required, subtypes may be defined at the application level. *Figure 12* shows the information model allowing the catchment to be represented differently in the real world.

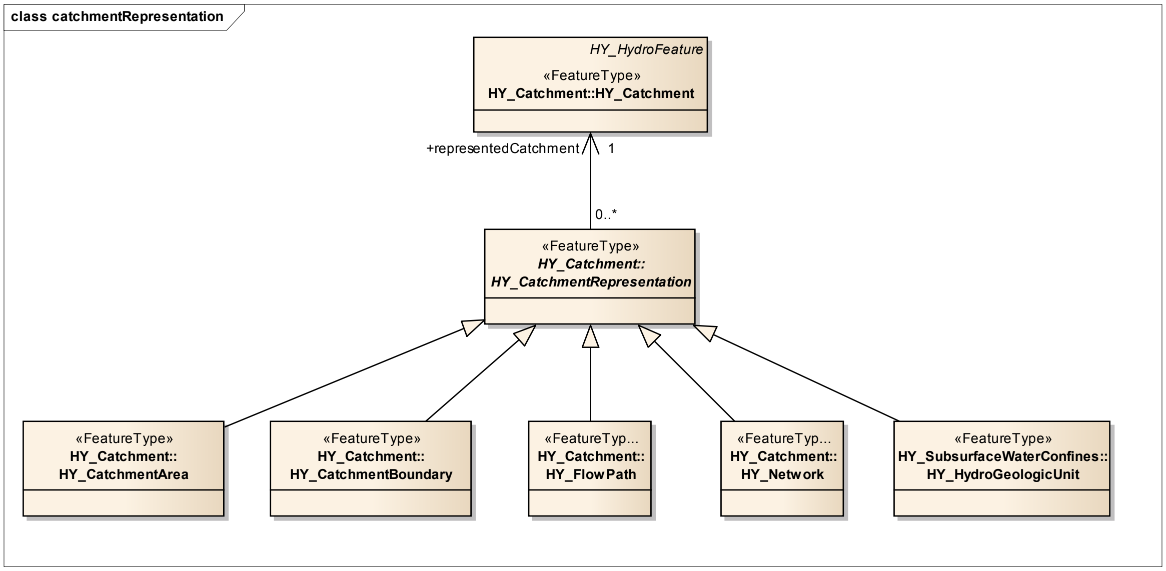

Figure 12 UML class diagram: *Catchment* and *CatchmentRepresentation*

The *Outfall* (*Figure 13*) is the topological concept which allows to consider an arbitrary location as the common outlet of a corresponding basin. Since the common outlet by definition has no explicit location and geometry, *Outfall* does not support a specific geometry attribute. For the *Outfall* to be positioned in the hydrographic network, a concept of *IndirectPosition* is introduced which provides a means to describe a position in relation to a *ReferencePoint*, either as the distance (length), or relative to as percentage of the total distance, or through verbal description of the spatial relationship.

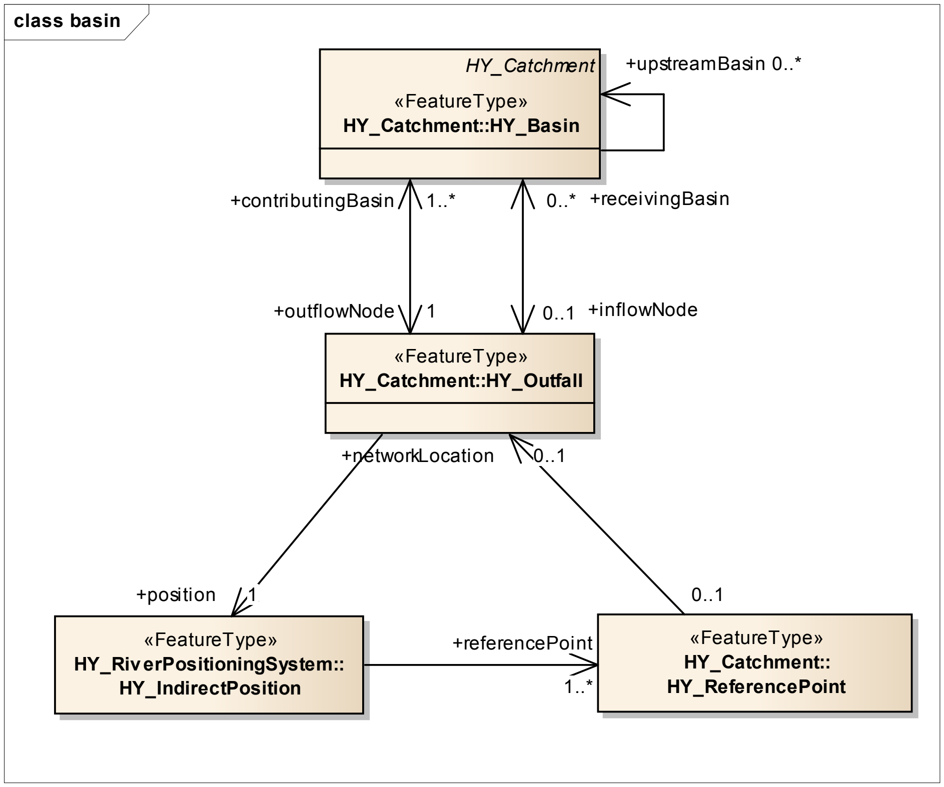

Figure 13 UML class diagram: *Basin, Outfall, IndirectPosition*

Fixed by coordinates (related to the land surface via datum), the *ReferencePoint* itself is outfall of a corresponding basin in the network of basins. Defining typical reference points, such as *fixedLandmark*, *crossSectionPoint*, or *extractionPoint*, particular real-world phenomena may be associated to the basin they represent. The concept allows for the topological relationship between hydrometric stations to be established based on the *positionOnRiver* without detail of hydrography, hydraulic conditions, and cartographic interpretation.

Figure 14 shows typical roles defined to support a semantic mapping with relevance to a water body (of at least one segment), the cross or longitudinal sections (of the channel network), or a well (extracting an aquifer). Further specific roles may be defined at the application level, if required.

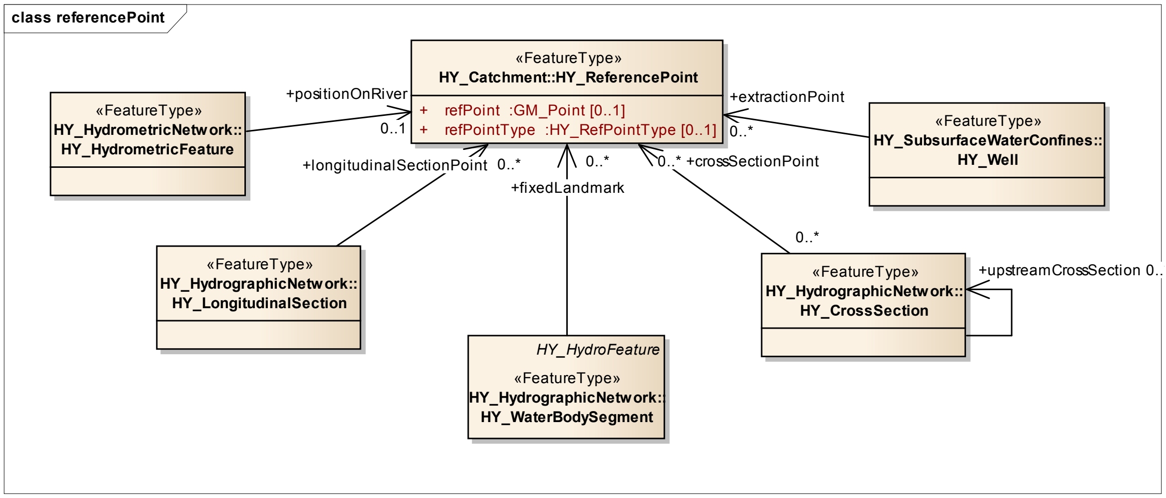

Figure 14 UML class diagram: *ReferencePoint* and associated phenomena

HY_HydrographicNetwork package provides for the topological relationships to be declared between the major elements of the hydrosphere, including the segmentation of the hydrographic network into water bodies without imposing a particular network scale (*Figure 15*). It is defined in the context of a higher order identification of the network each element participates, hence the dependency on the abstract catchment model.

HY_HydrographicNetwork introduces concepts of *WaterBody* and *WaterBodySegments* which may or may not be topologically connected at the representational level, as well as of the vertical partition into cross or longitudinal sections and the horizontal stratification into distinct layers. Liquid water (*Water_LiquidPhase*) may be accumulated in water bodies, ice (*Water_SolidPhase*) may be accumulated in glaciers, or cover a water body. *Glacier* is introduced here to provide a means to take the multiple relationships between glacier and water body into account at the application level. As glaciology is a science for its own, the relationships between glacier and water body are not in the scope of the *HY_Features* model, and need to be described in detail with implementation.

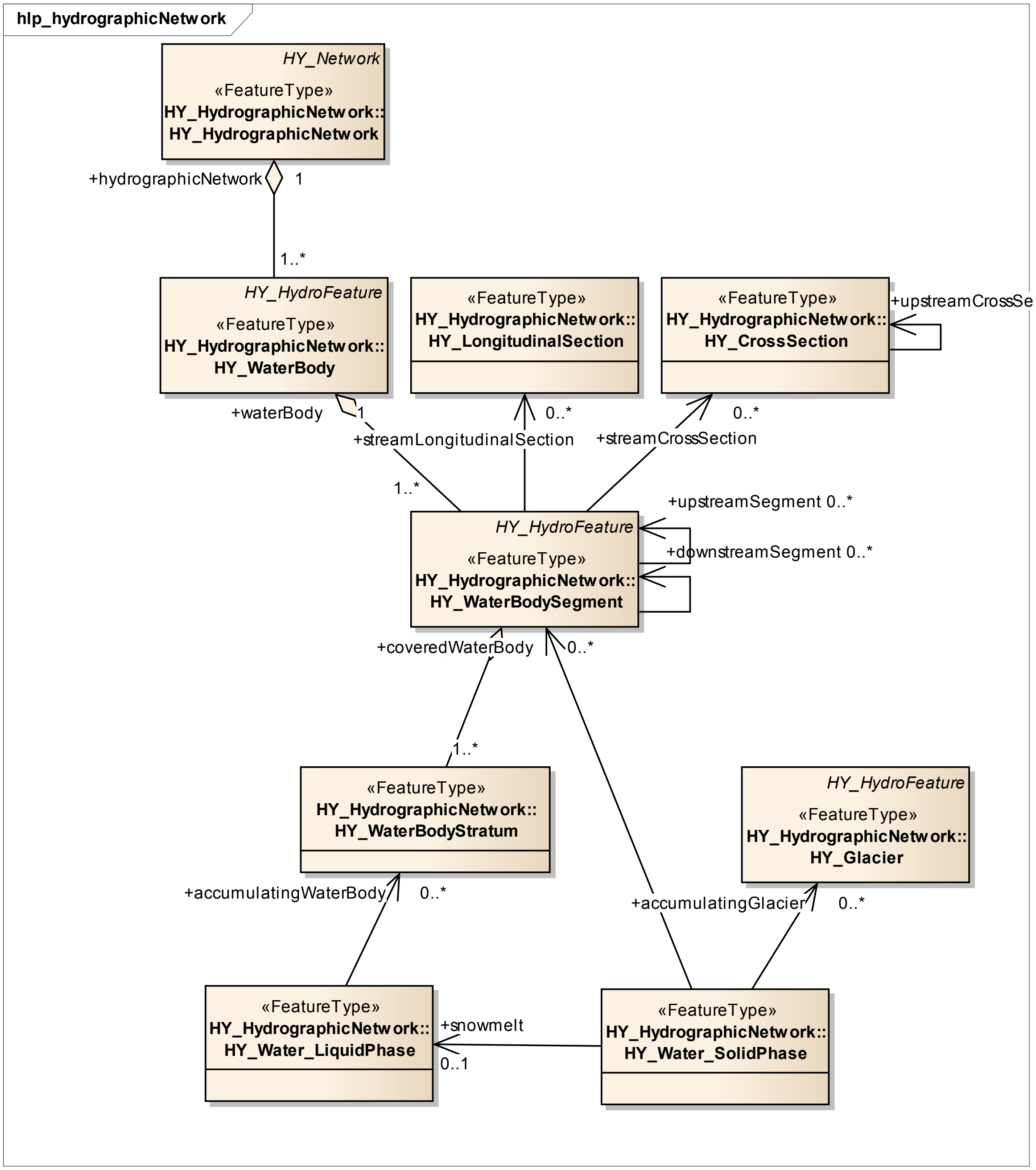

Figure 15 UML class diagram: *HY_HydrographicNetwork*

HY_NamedFeature package provides an abstract pattern shared by all hydrologic features where names are given to a feature, through common usage, without necessarily have a formal toponymy model. HydroFeatureName provides a model with to handle the issues of cultural, political and historical variability, HydroFeatureContext generally applicable characteristics assigned to the hydrologic feature in different spatial, temporal or classification contexts (*Figure 16*).

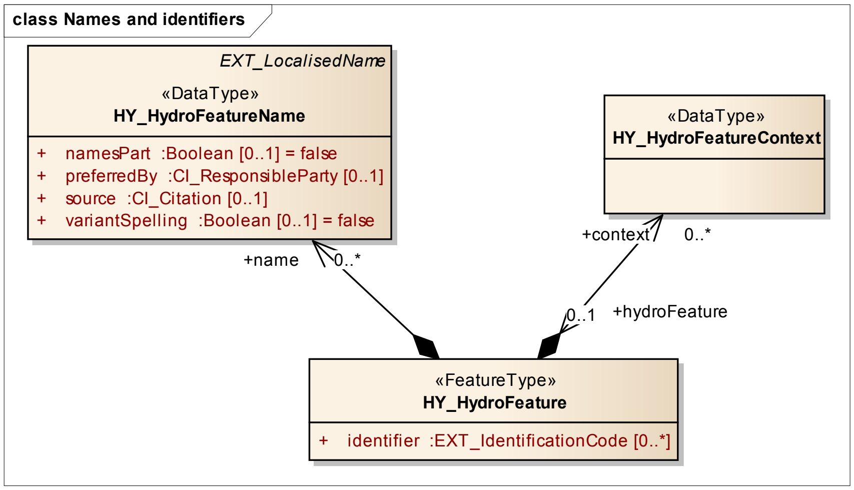

Figure 16 UML class diagram: *HY_HydroFeature*

These named features are further elucidated in concrete feature types which specify the properties each representation uses to define one or more aspects of the hydrology of a feature. This includes related phenomena that participate in hydrologic systems but have specific characteristics. Given the complexity of the domain, and the nature of real world physical phenomena, for any given feature a wide range of possible characteristics, states and representations may be relevant.

HY_RiverPositioningSystem (*Figure 17*) package provides a means to reference positions on a hydrographic feature via its topology and geometry. The package introduces the concept of *IndirectPosition* where each location on the land surface may be described relative to, or as a distance to, a reference point located in the hydrographic network. The distance to the reference point is provided as *Length*, the relative position described as a percentage of the distance or using terms common in the hydrology domain such as “upstream”, “downstream”, “nearby”, etc..

IndirectPosition requires a river mileage system whose origin is set at the position of the relevant point of interest, e.g. a water monitoring point, in the network. The coordinates are provided as distance upstream or downstream from this origin to the identified reference point. Since river mileage systems usually refer to a line (such as thalweg or stream centre line) assuming a horizontal curve, the river mileage system may use the one-dimensional *CS_LinearCS* of ISO 19111:Referencing by coordinates [4] . *RiverMileageCS* shall support at least one horizontal axis. The axis description should provide information about the direction (upstream, downstream) and the precision (smallest unit of axis division).

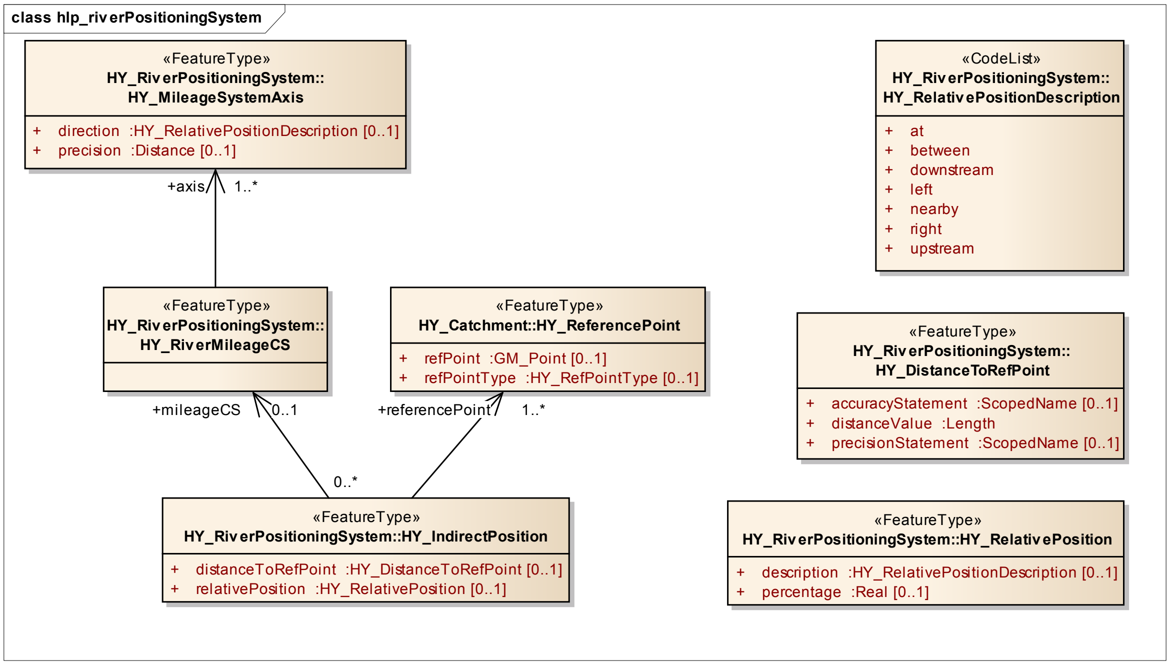

Figure 17 UML class diagram: *HY_RiverPositioningSystem*

This concept supports basins to be related topologically and allows the hydrosphere to be divided into a network of basins (links between outfalls). Considering an arbitrary hydrometric station as *Outfall* of a basin, it may be located depending on its *positionOnRiver* without having local coordinates.

HY_Storage (*Figure 18*) package provides an abstract pattern to describe a particular water body capable to store and yield water in terms of a resource for future use. This allows surface and subsurface reservoirs to be described independent of their representation within the hydrographic network, and hydrographic network elements without the details of storage capacities. Special types of reservoir may be defined with application.

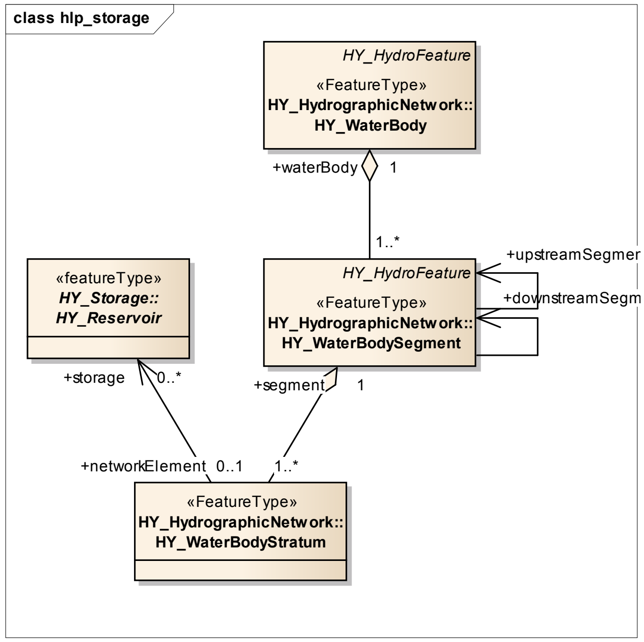

Figure 18 UML class diagram: *HY_Storage*

7.5 HY_AtmosphericHydroFeature

This application schema (*Figure 19*) defines concepts of the hydrology phenomenon above the Earth's land surface without the complexity of a rainfall-runoff model.

With respect to the hydrologic cycle, hydrometeors consisting of liquid or solid water particles falling through or suspended in the atmosphere are in the scope of the *HY_Features* model. Since water from precipitation is the main source of freshwater accumulated in water bodies, *Hydrometeor* is specialized into *Precipitation* consisting of liquid and solid water particles. Further specialization of is left to specific applications, as well as special concepts of water suspended in the atmosphere.

The *Precipitation* concept (Figure 20) simply differentiates between the liquid and solid phase of water. This allows to separately address both water accumulated in water bodies, and ice accumulated in glaciers. It is intended that applications in surface water or glacier hydrology, particularly runoff modeling, may use the model to reference the represented hydrologic feature.

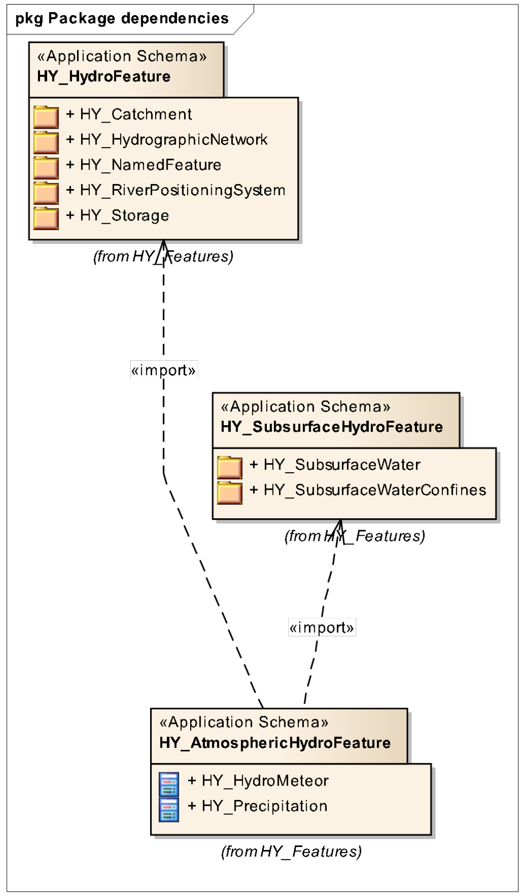

Figure 19 UML: *HY_AtmosphericFeature* – Package dependencies

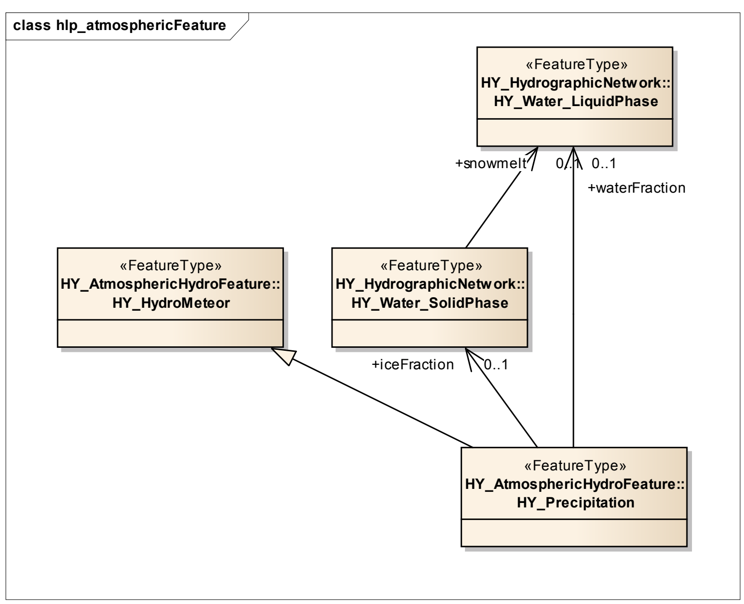

Figure 20 UML class diagram: *HY_Precipitation*

7.6 HY_SurfaceHydroFeature

This application schema (*Figure 21*) defines concepts of the hydrology phenomenon on the Earth's land surface with respect to water bodies aggregated in a hydrographic network using a connecting system of confining channels, but without complexity and detail of hydrologic and hydraulic models.

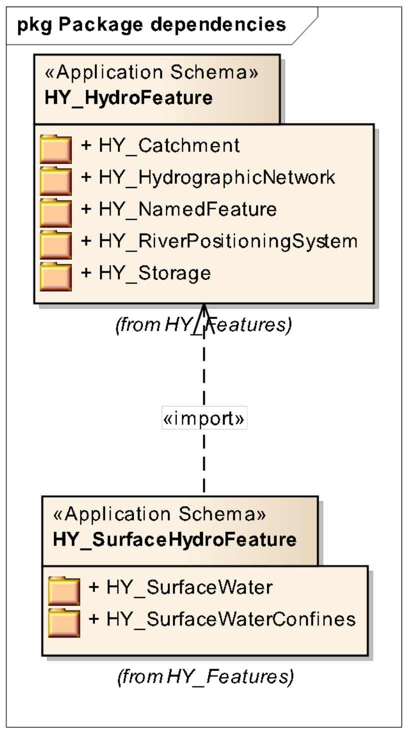

Figure 21 *HY_SurfaceHydroFeature* – Package dependencies

SurfaceWater (informative package) summarizes the most popular water bodies (mass of water) on the land surface each special by the property to permanently or temporarily move, by origin, by extent, by the phase of the contained water, or by their interaction with open sea. Depending on the implementation, each special type of hydrographic feature may be described by suitable attributes.

SurfaceWaterConfines (*Figure 22)* package contains key elements confining a surface water body such as bed and banks of the watercourse. Depending on specific use cases, the channel (of at least one segment) through or along which water may move, may be associated with the hydrographic network of water bodies.

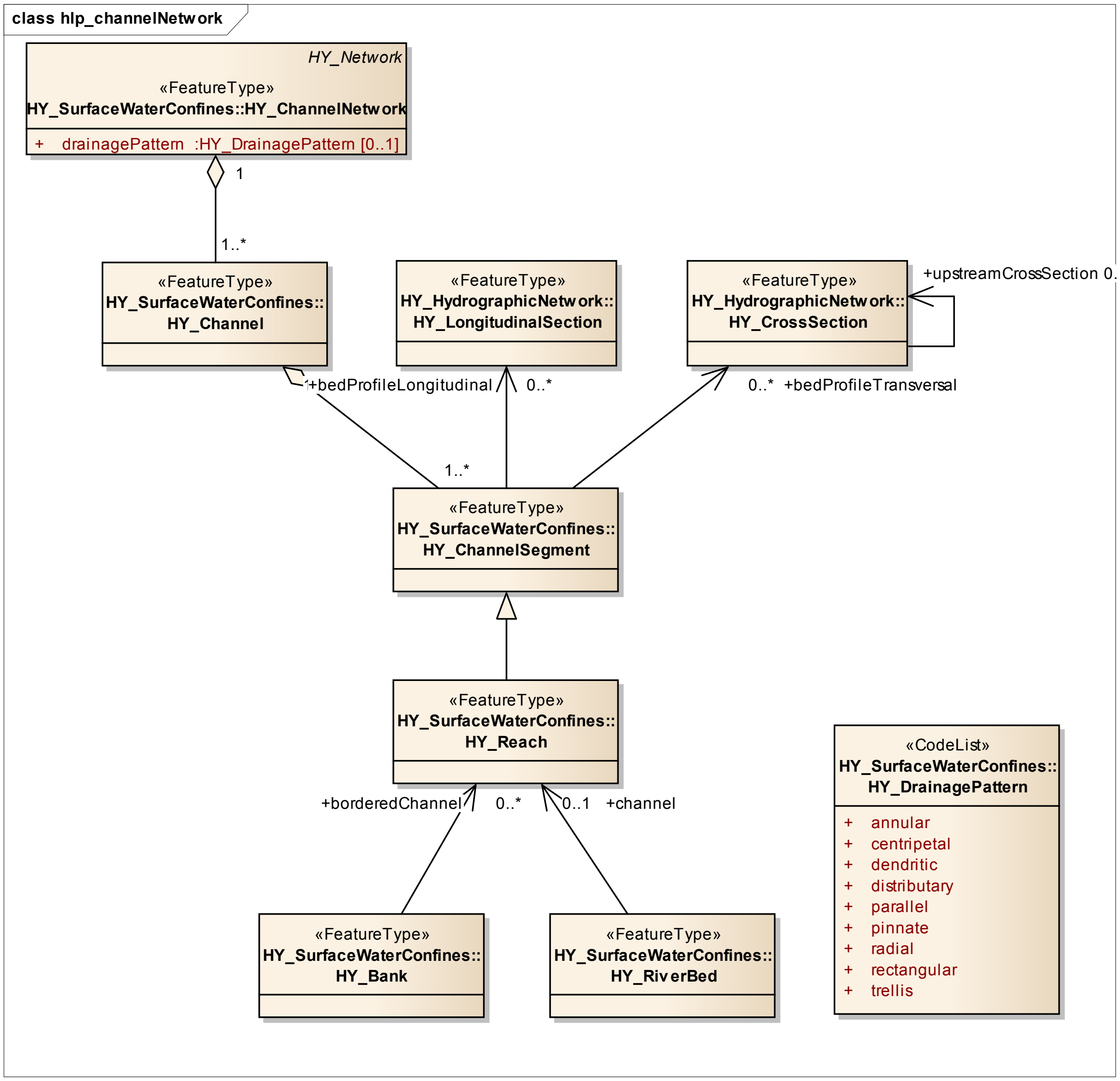

Figure 22 UML class diagram: *SurfaceWaterConfines*

The *SurfaceHydroFeature* model allows to separately address the water body and the connecting watercourse, or parts of these. It is intended that applications in surface water hydrology, modeling hydraulics and morphology of streams use this model to reference the represented hydrologic feature.

7.7 HY_SubsurfaceHydroFeature

This application schema (*Figure 23*) defines concepts of the hydrology phenomenon below the Earth's land surface in respect to water accumulated in water bodies below the Earth's surface incl. their interaction with surface water bodies without the complexity of the groundwater or soil moisture models.

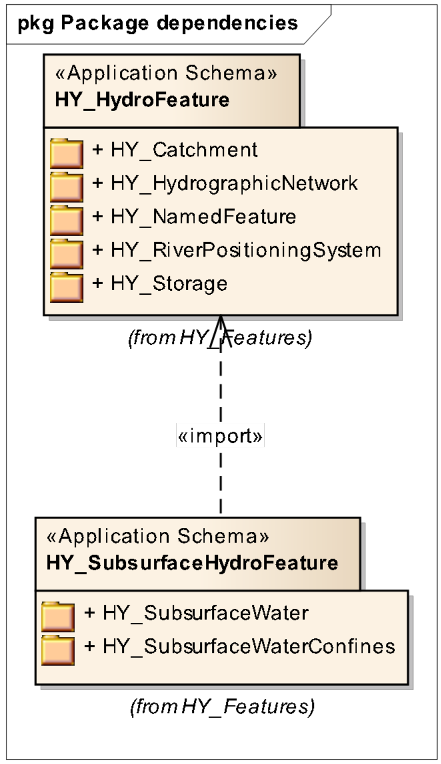

Figure 23 *HY_SubsurfaceHydroFeature* – Package dependencies

SubsurfaceWater (informative package) summarizes the most popular types of liquid water occupying empty space in soil and aquifers. Depending on the implementation, the special types of subsurface water in the saturated and unsaturated zone may be described by suitable attributes. As hydrogeology is a science on its own, the special relationships between groundwater and a water body are not in the scope of *HY_Features* model. To take into account the effects of groundwater interaction on a gaining/losing water body (-segment), *Groundwater* may be associated with the relevant water body at the application level.

SubsurfaceWaterConfines (Figure 24) includes the basic elements containing subsurface water such as a *HydrogeologicUnit* and *Aquifer*. Both are introduced here to provide a simple means for taking into account the hydrologically significant characteristics of geologic formations of soil or rock yielding water, particularly groundwater. *Well* is introduced to consider the well extracting water from aquifer as *ReferencePoint* that may be used to locate the *Outfall* of a basin.

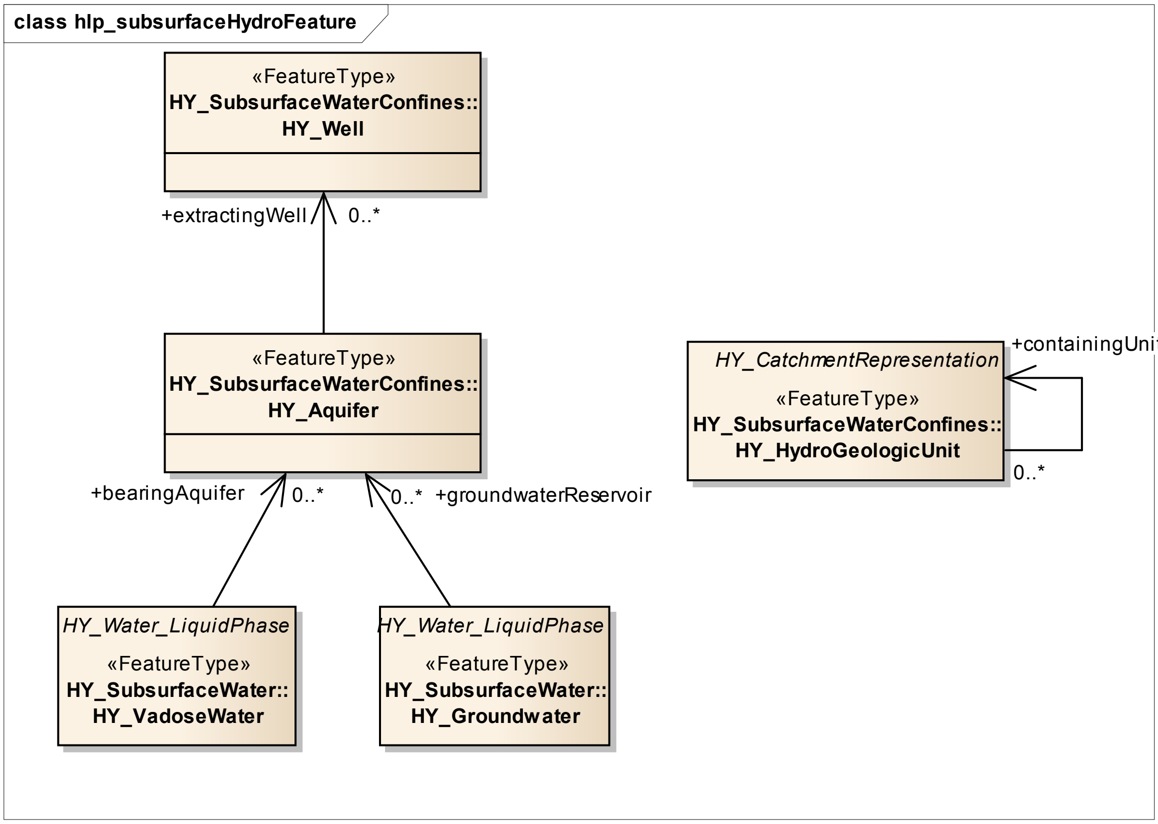

Figure 24 UML class diagram: SubsurfaceWaterConfines

The *SubsurfaceHydroFeature* model allows to separately address types of subsurface water as well as the containing aquifer without details of accumulation and movement of water. It is intended that applications dealing with groundwater and soil moisture may use this to reference the represented hydrologic feature.

7.8 HY_HydrometricNetwork

NOTE: Not to be confused with the natural network of hydrographic features.

NOTE: Not to be confused with network sampling as distinct method of sampling.

This application schema (*Figure 25*) defines a hydrometric network as an aggregate of hydrometric features which are logically connected, for example along a hydrographic feature. Hydrometric features may be physical artifacts, or a collection of these. Yet, some hydrometric features may be fictive ones. They may have localized names, typical properties and individual characteristics. In the observation context, the *HydrometricFeature* represents a sampling feature.

The *HydrometricFeature* itself is free from any position. It is located in the hydrographic network using the concept of *positionOnRiver* which associates the hydrometric feature with a reference point which coincides with the *Outfall* of a corresponding basin mandatory positioned in relation to a reference point fixed by coordinates.

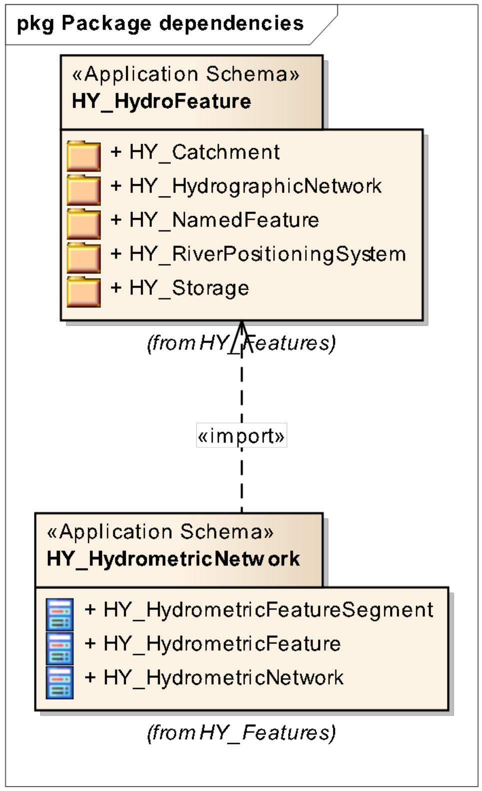

Figure 25 *HY_HydrometricNetwork* – Package dependencies

The *HydrometricNetwork* model allows to address a hydrometric network as a whole but also individual parts of this. Applications capturing the monitoring of hydrologic features, the observation and measurement of their properties may use this model to locate a *WaterMonitoringPoint* (as of *WaterML2*) [2] on the sampled hydrologic feature, as well as to reference the logic network of (fictive) hydrometric features representing the ultimate hydrologic feature like a catchment or basin. This is often required in the context of processing primary data, observed using real-world stations, into a new set of secondary data obtained using stations related to these.

8. Discussion

8.1 Compatibility of concepts

NOTE: Compatibility of concepts means that similar concepts are able to exist or perform together in combination without conflicts.

The *HY_Features* model is intended to form the basis for standard practices for feature identification under the auspices of the WMO Commission for Hydrology (WMO-CHy). To achieve this goal, compatibility to similar concepts must be supported. *HY_Features* provides generally applicable concepts for reference, to which application-specific concepts may refer either by specialization or by mapping.

8.1.1 *Basin* vs. *DrainageBasin* as of INSPIRE

The INSPIRE (Infrastructure for Spatial Information in the European Community) Directive addresses the Hydrology issues in the data specification "D2.8.I.8: INSPIRE Data Specification on Hydrography" v.3.0.1 [8] as the basic reference for use within the INSPIRE context. This specification defines an abstract *HydroObject* covering all *Physical Waters* including the relation between *DrainageBasin* and *SurfaceWaters* (*Figure 26*). *DrainageBasin* has 1..* outlets which are *SurfaceWaters*, and may contain sub-basins.

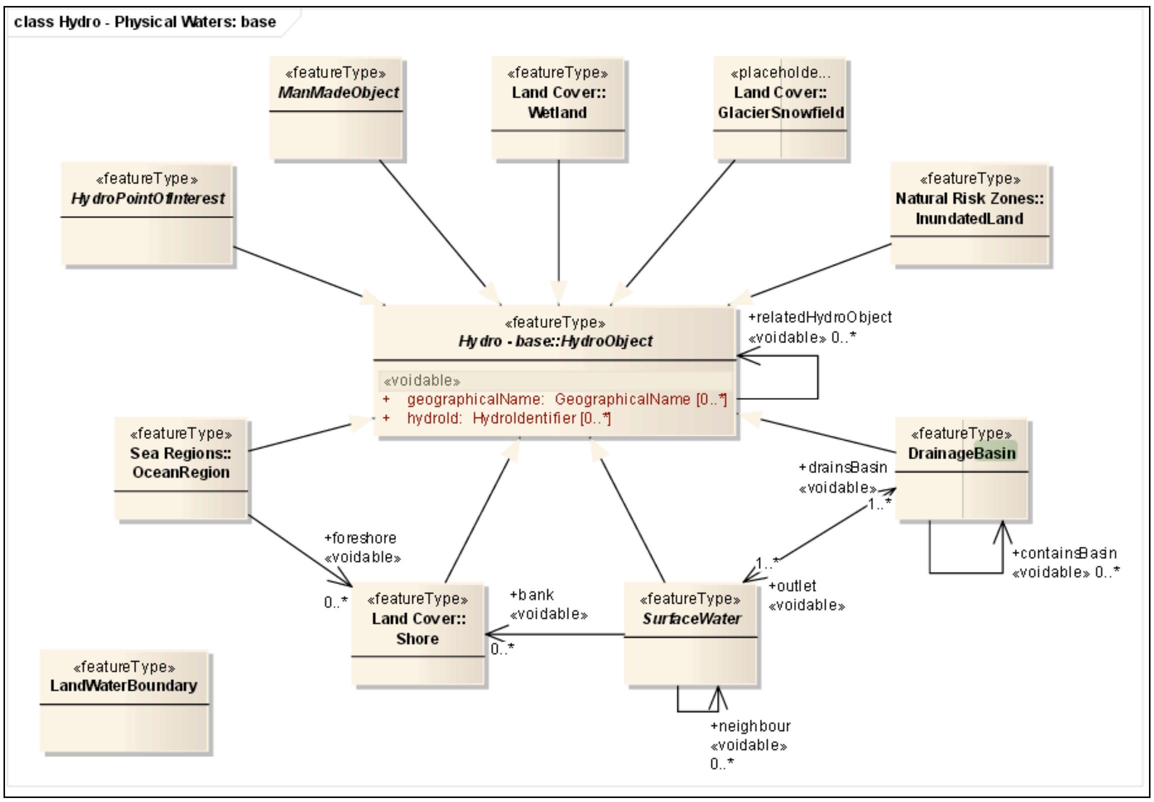

Figure 26 INSPIRE Hydrography, v3.0.1 [13]– HydroObject

NOTE: *SurfaceWaters* refers to any physical body of water.

NOTE: *DrainageBasin* refers to the area having a common outlet for its surface runoff.

This definition corresponds to the definition of *BasinAggregate* (in *HY_Features*), rather than *Basin* which is defined as a link between single inflow and outflow nodes. Therefore, for referencing *BasinAggregate* may be addressed, which aggregates (1..*)

subBasins each of them identified by an *Outfall* whose location may be a surface water body.

8.1.2 *Outfall* vs. *Contracted Node* as of AHGF

Australian Hydrological Geofabric (AHGF) [13] identifies important water features in the landscape as well as the connections between these features. Identifying persistent *ContractedNodes* that are points of hydrological significance that carry identity, the AHGF supports multiple representations of water features. Such a contracted node may be the *Outfall*s of a basin as defined in the *HY_Features* model.

The concepts of *Catchment*, *BasinAggregate*, *Basin* and *Outfall* of the *HY_Features* model have been implemented within the Geofabric as "HR_Catchments" (in terms of *Catchment*), as "Contracted Catchments" (in terms of *BasinAggregate*) and "AHGF Node" (in terms of *Outfall*). "Link" (in terms of *Basin* as a link) represents the topological connection between the catchment hierarchy.

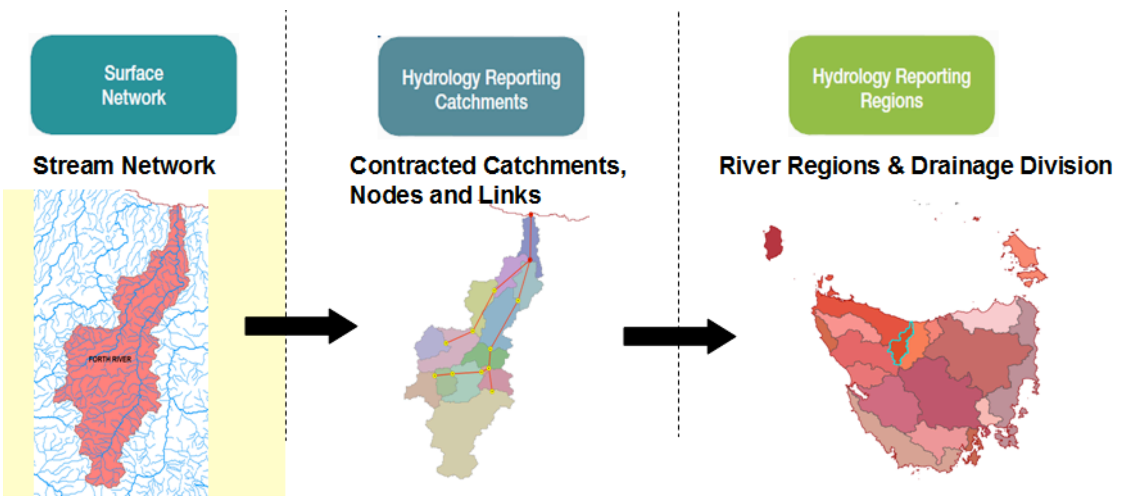

Figure 27 AHGF Hydrological Reporting Catchment

A hierarchical set of catchments from individual stream segments to Contracted Catchments are defined in the SH_Network and HR_Catchments products with each catchment defined by a polygon shape draining to an outfall contracted node. Contracted Catchments are then aggregated to create stable Hydrology Reporting Regions, as shown for the Tasmanian Forth River Basin.

8.1.3 *IndirectPosition* vs. *NetworkPosition* as of ISO19133

IndirectPosition is introduced to describe the position of *Outfall* in the hydrographic network using a river mileage system as linear reference system (LRS). The underlying concept is that of a distance between two locations. One, which is the origin of the LRS, is the *Outfall* determined by its network position; the other is the (geometric) *ReferencePoint* fixed directly by coordinates. Since Outfall may be of any geometry, IndirectPosition may address (via ReferencePoint) both the node or the link the position is on. *IndirectPosition* associates a *ReferencePoint, as* a specific “marker” and the *MileageSystem in sense of a* “link measure” (see also *Figure 17*)

Even if navigation on watercourses is not in the scope of the *HY_Features* model, this similarity allows to address Outfall or ReferencePoint as start and stop positions of a Route as of ISO19133 [14].

8.1.4 *HydrometricFeature* vs. *WaterMonitoringPoint* as of *WaterML2*

NOTE: *WaterMonitoringPoint* is defined within *WaterML 2.0* Part 1:Timeseries as (point) location where water flow or properties are reported, such as a stream gauge, rainfall gauge, or water quality monitoring site.

Hydrologic observations make use of hydrometric stations as proxy to measure the characteristic properties of the ultimate object of study. *WaterML2* [3] defines a *WaterMonitoringPoint* using the sampling features concept of ISO19156 [2]. Against this background, the description of sampling features is not in the scope of *HY_Features*.

However, *a HydrometricNetwork* is introduced to provide a means to relate a logic network of (fictive) hydrometric stations to the catchment they represent, without the detail of the observation strategy, as usually required in the context of processing primary data from preceding observations into new data products. *HydrometricFeature* is introduced to provide a means to define a persistent identifier positioned in the hydrographic network (see also 7.8).

8.1.5 RiverML (under development)

NOTE: The development of a RiverML is under discussion in the framework of the WMO/OGC Hydrology DWG for exchanging river channel and floodplain geometry in a standardized way.

Against the background of an evolving RiverML, the channel hydraulics and river morphology are not in the scope of *HY_Features*.

However, *Channel* and *ChannelSegment* as well as *RiverBed* and *Bank* are introduced to provide a means to generally take into account the hydrologically significant hydraulic and morphological characteristics of conduits and open channels. *CrossSection* and *LongitudinalSection* are introduced to provide a means to define a persistent identifier at longitudinal and transversal bed profiles (see also *Figure 22*)

8.1.6 GroundwaterML (under development)

NOTE: A groundwater interoperability experiment (GW2 IE) will develop and test the GroundWater Markup Language 2, by harmonizing and advancing existing modeling initiatives such as: GWML1, relevant EU-INSPIRE models (Geology, Hydrogeology, Environmental monitoring facilities), GeoSciML, and others. This IE is established in the framework of the WMO/OGC Hydrology DWG and will produce an engineering report for movement of the draft GWML2 specification to an OGC data standard.

Against the background of the evolving GroundwaterML [15], the accumulation of groundwater as well as the interaction between surface water and groundwater are not in the scope of *HY_Features*. Bodies of groundwater, or parts of these, may be related to *WaterBody*, *-Segment* or *–Stratum* for reference, or in case of storage to (underground) *Reservoir*.

However, *HydrogeologicUnit* is introduced to provide a means to generally take into account the hydrologically significant geologic characteristics of a formation of rock or soil representing a catchment. *VadoseWater*, *Groundwater*, *Aquifer* and *Well* are introduced to provide a means to define a persistent identifier at the representation level for groundwater and soil water related features (see also *Figure 24*)

8.1.7 *Outfall* vs. *Pour point* of *ArcHydro* GIS

Outfall is defined under the premises that all waters in the basin are channeled to a common outlet. The same meaning is applied to the "eight-direction pour point" of ArcHydro GIS [16], defined to model the flow from a grid cell into the adjacent cell according to the flow paths. Consequently, the drainage lines, catchment and watersheds created using ArcHydro GIS are representations of a *Basin* in terms of *HY_Features*.

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8.2 Hydrologic referencing and linked data

Hydrologic features are the sampled features of observation, the allocated features in water use, the reported features at local or regional scales, and as such key criteria for discovery of hydrologic data and products. Even if the *Feature* is recognized as the abstract notion of a real-world phenomenon, different semantic concepts from different perspectives at different levels of detail are applied when modeling the hydrology phenomenon. It is expected that the *HY_Features* model will support the alignment of different perspectives on the shared hydrologic feature and the linkage of application-specific concepts to hydrological features using standard patterns.

The *HY_Features* model provides commonly agreed concepts of the fundamental relationships between the most important hydrologic features, particularly of the relations to the catchment they represent. It provides a concept of persistent identifier across multiple representations independent from application and scale. Expressed in a platform-independent form, the model may be used as a basis for referencing hydrologic features that have persistent identity across multiple data systems. It is intended that applications in hydrology refer to the common concepts to relate specific features to the shared unit of study, management or reporting. Each concept may be specialized at the application-level for more detail, e.g. for groundwater, hydraulic or hydrometric features.

Figure 28 shows the example of the Australian Hydrological Geofabric (AHGF) [13], a set of consistent spatial data products that are stored in GIS, where alternative representations are linked through a set of common 'contracted nodes' persisted between representations, versions and scales of the Geofabric products. *HY_Features* is used to handle the semantics and to describe how 'contracted nodes' fit together.

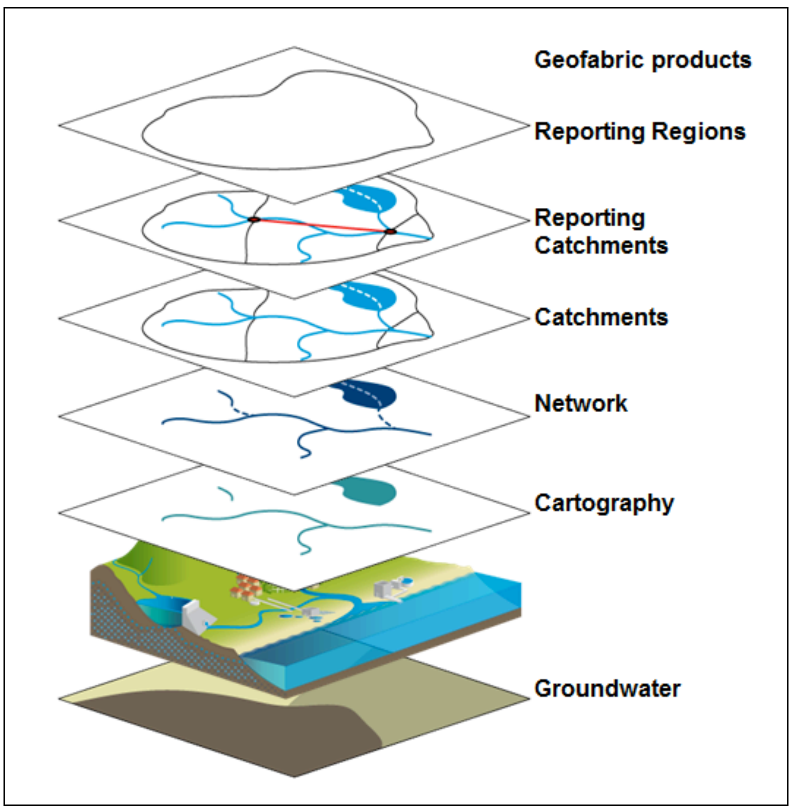

Figure 28 AU Hydrologic Geofabric - set of alternative representations

Linking data across multiple systems, e.g. on the Web, means "linking references". With respect to hydrologic data, topologic and hydrologic references are needed, rather than geometry. Identifiers must be able to stably reflect the hydrologic significance and network connectivity. Common semantics are required declaring these relationships.

Independent from specific application, scale and platform, *HY_Features* allows to realize the *Linked Data* principle: a hydrologic feature can be cross-referenced to a base concept and linked to a particular representation. For example, the name (URL) for a particular *Basin* may link to a resource (WFS) that provides information on what is known about the identified basin and “things” that relate to this (e.g. blue lines). This will support the development of common tools for discovery, access and sharing of hydrologic information.

9. Further work

9.1 XML Encoding

The *HY_Features* model is specified using UML according to ISO 19103. This allows a GML Application Schema to be generated by following the encoding rules in ISO DIS 19136 to assure conformity with GML requirements.

HY_Features is not intended for direct implementation as a data product, but the features it defines may be used as inline references to hydrologic features to avoid introducing platform specific schemas for referenced features into independent data products.

HY_Features classes may also be exposed from underlying data products using *HY_Features* to provide a well-known schema for hydrological features in distributed, federated contexts.

The GML schemas for *HY_Features* are provided in a separate download as an annex to this document.

9.2 OWL encoding

HY_Features specifies how instances of hydrologic features may be associated. Such a model may be encoded using formal semantics. A draft encoding of *HY_Features* model using a set of standard encoding rules being developed under ISO 19150 has been created, and is available along with the XML schemas.

A Feature Type Catalog service is being developed to provide a means to access the definitions of, and mappings between, conceptual models and multiple implementation models. It is intended to use this work to support validation and exploitation of the *HY_Features* model.

9.3 Validation

The conceptual model should be validated through establishing mappings to application schemas and implementation models of data products realizing similar concepts. Mappings can be exercised and tested by delivering *HY_Features* instance data from data repositories holding data that can itself be mapped to alternative implementations.

CSIRO is currently exploring using *HY_Features* to establish stable URL identifiers for features in the Australian Geofabric Data Products, and to link such identifiers to multiple representations of the concepts defined by *HY_Features* within different hydrologic data products, This work intends to use the relationships in *HY_Features* to characterize and associate related hydrologic features and establish a means to discover and access such data using the Linked Data principles.

10. References

1. WMO, *International glossary of hydrology/Glossaire international d'hydrologie*. WMO (Series) ; no. 385., ed. W.M. Organization. 1992, Paris, France : Geneve, Suisse :: United Nations Educational, Scientific and Cultural Organization ; World Meteorological Organization.
2. ISO, *ISO 19156:2011, Geographic information -- Observations and Measurements*. 2011, International Organization for Standardization (ISO).
3. OGC, *WaterML 2.0: Part 1- Timeseries*. 2012.
4. WMO, *WMO Core Metadata Profile version 1.3 Specification*. 2012, World Meterological Organisation: Geneva.
5. Dornblut, I., *Hydrologic Information – Metadata: Semantic structure for the description of hydrologic data (GRDC Hydrologic Metadata)*. 2013, Global Runoff Data Centre: Koblenz.
6. ISO, *ISO 19115 Geographic information — Metadata: - Part 1: Fundamental (under development)*. 2013, International Organization for Standardization (ISO).
7. ISO, *ISO 19103 Geographic information - Part 3: Conceptual schema language*. 1999, International Organization for Standardization (ISO).
8. EC. *D2.8.I.8 INSPIRE Data Specification on Hydrography. Version 3.0.1.* . 2010.
9. USGS, *Hydrologic units, hydrologic unit codes, and hydrologic unit names (Modified from Slack and Landwehr, 1992 and Seaber, Kapinos, & Knapp, 1987).* 1992.
10. Atkinson, R., I. Dornblut, and D. Smith, *An international standard conceptual model for sharing references to hydrologic features.* Journal of Hydrology, 2012. **424–425**(0): p. 24-36.
11. ISO, *ISO 19109.3 Geographic information - Rules for application schema*. 2000, International Organization for Standardization (ISO).
12. OMG, *Unified Modeling Language (UML). Version 1.4.2.* 2004.
13. McDonald, E.R. *A benchmark for the Australian Hydrological Geospatial Fabric.* in *Surveying & Spatial Sciences Institute BiennialInternational Conference*. 2009. Adelaide.
14. ISO, *ISO 19133:2005, LBS-Tracking and Navigation*. 2005, International Organization for Standardization (ISO).
15. Boisvert, E. and B. Brodaric. *GroundWater Markup Language (GWML): Extending GeoSciML for Groundwater*. 2007.
16. Maidment, D.R., *Arc Hydro: GIS for water resources*. Vol. 1. 2002: Esri Press.

11. Revision History

Date	Release	Editor	Primary clauses modified	Description
2011-02-02	0.1	Rob Atkinson	Initial version	Preliminary Draft
2011-03-22	0.2	Irina Dornblut	Scope, Conformance Definitions Requirements *HY_Features* Further work	Draft Draft Draft Draft Draft
2011-04-06	0.3	Irina Dornblut	*HY_Features*	Figures included
2011-04-08	0.4	Rob Atkinson	Preamble, headers References Requirements	Release in OGC discussion paper form Requirements section Editorial review
2011-09-12 2012_02_09	0.5	Irina Dornblut	Future works Introduction Terms and defs Scope Requirements *HY_Features* *HY_Features*	Rephrased, Figures included Rephrased, Figures included Updated and rephrased Rephrased Re-arranged, updated and rephrased Basic concept updated and rephrased SubsurfaceHydroFeature included
2012-02-23	1.0.0	Rob Atkinson Irina Dornblut	Formatting Scope Formatting	
2013-08-28	1.0.1	Irina Dornblut, Rob Atkinson	Future work Scope, 1-8 Discussion	Follow-up Textual work reflecting the re-factoring UML, Discussion included, rephrased, formatted

