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HY_Features: a Common Hydrologic Feature Model Discussion Paper

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Abstract

This document describes a conceptual model for the identification of hydrologic features independent from geometric representation. 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.

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Preface

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 describes a conceptual model for the identification of hydrologic features independent from geometric representation. 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.

Submitting organizations

The following organizations submitted this document to the Open GIS Consortium Inc.

a) CSIRO (Australia)

b) Global Runoff Data Centre - GRDC (Germany).

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Revision history

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2011-03-22	0.2	Irina Dornblut	Scope, Conformance Definitions Requirements HY_Features Further work	Draft Draft Draft Draft Draft
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2012-02-23	1.0.0	Rob Atkinson Irina Dornblut	Formatting Scope Formatting	

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.

Future work

This specification raises a series of opportunities and requirements for testing in the context of many application domains related to hydrologic processes. The proposed standardization pathway into WMO implies further activities, described in the Future Work section below.

HY_Features in the overall context of OGC standards

The *HY_Features* model is intended to provide a hydrology domain-specific instance of the *GF_GeneralFeatureType* metaclass, *the HY_HydroFeature*. The class is intended to provide a realisation of the *GFI_DomainFeature*, as currently required by theISO 19156 Observation and Measurements model (O&M) [1]. Specifically, this is expected to provide a model for use in applications of *WaterML 2.0* Implementation Profile of *O&M*.[2]

Further clarification regarding the role of the OGC in governance, integration and binding of individual domain models and related controlled vocabularies is required in order to address how the model may be used by the stakeholder community.

Figure 1 proposes 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* embodies the intended sampled feature and may be used by observation-centric applications such as *WaterML2*.

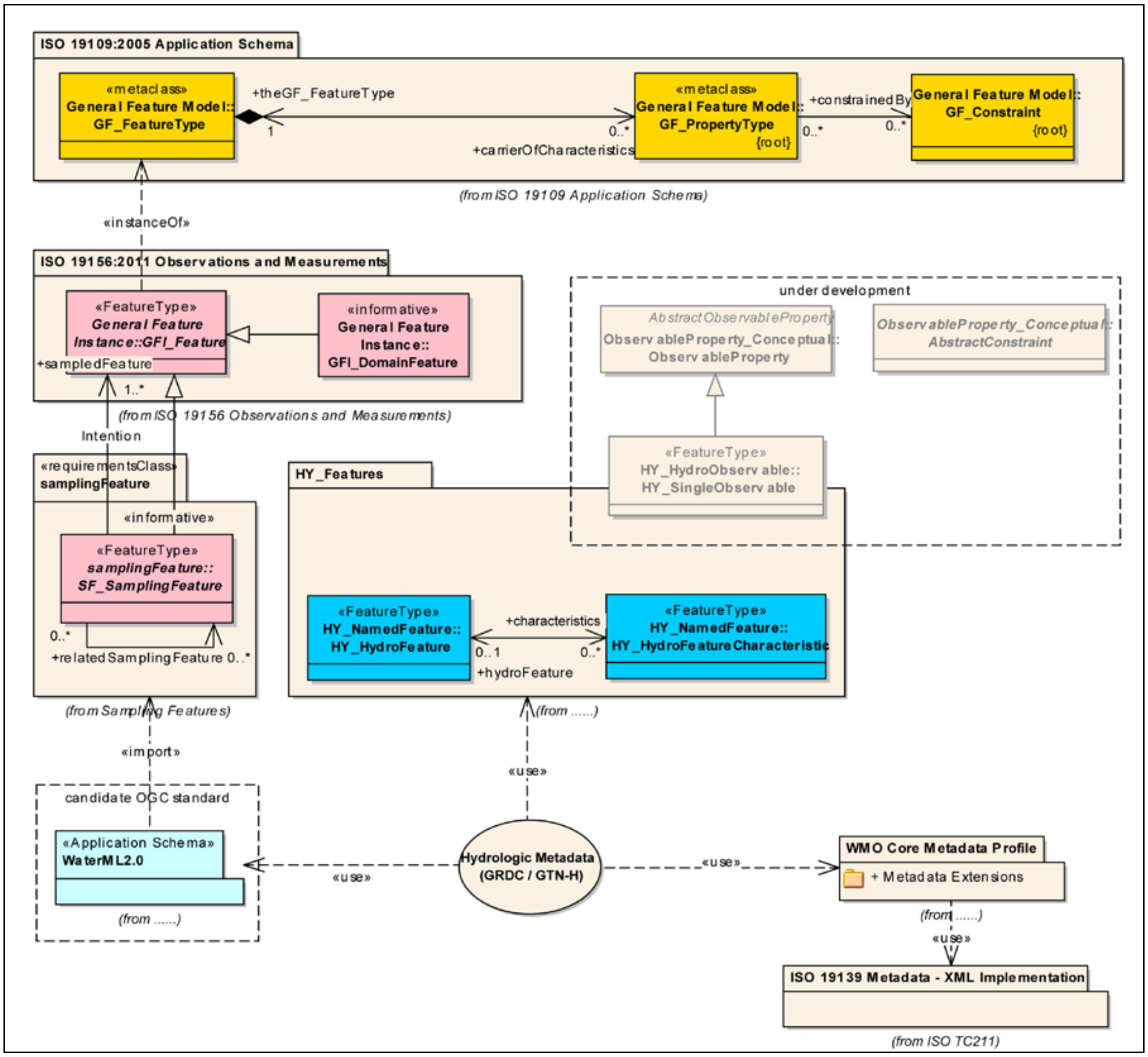

Figure 1 Placement of *HY_Features* in the existing OGC Feature landscape

The *HY_Features* model will provide a required component of a metadata model describing hydrological data 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. *Figure 1* illustrates the context of GRDC activities in GTN-H, composed of the descriptions of the data set, i.e. metadata in the sense of *ISO 19115 [3]*, the generating observation, implementing *WaterML2*, and the intended objects of study: features identified using the *HY_Features Feature Types*.

HY_RiverPositioningSystem and ISO 19111

Re-factoring work is required to reconcile the concept of *indirect positioning* where each location on the land surface will be described relative to, or as a distance to, a reference point located in a hydrographic network, using the relevant ISO standards for positioning and referencing by coordinates (ISO 19111) [4].

_HY_HydrometicNetwork_ and _WaterML2_

Re-factoring work is required to reconcile the concept of *hydrometric network* of logically connected sampling stations and observing posts each located on the hydrographic feature relative to a reference point, with ISO 19156: Observation & Measurement and the evolving *WaterML2* standard.

_HY_SubsurfaceWater_ and _GroundwaterML_

S*ubsurface water* concept refers to the continuous interaction of surface and subsurface water within a basin whose entire waters are flowing to a common outlet. This needs to be compared and refactored to support *GroundwaterML[5], which largely deals with observations on such processes.*

_HY_HydroObservable_ and observation

Conceptual work is required to develop an agreed model to identify hydrologic observables, i.e. properties that are carried by a hydrologic feature and able to be observed using an appropriate procedure. Considering the hydrologic observable as a connector between an observation event and the sampled feature, this model needs to be put into the overall context of observation and measurement.

Foreword

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-endorsed *Best Practice* for implementation under the auspices of the WMO-CHy and release to the hydrologic community of WMO Member countries.

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.

The changes made in this document version, relative to the previous published versions, will be tracked by Microsoft Word, and can be viewed if desired. If you choose to submit suggested changes by editing this document, please first accept all the current changes, and then make your suggested changes with change tracking on.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. Open Geospatial Consortium shall not be held responsible for identifying any or all such patent rights. However, to date, no such rights have been claimed or identified.

Introduction

The WMO is the UN system's authoritative voice on the state and behaviour 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 utilisation 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 standardisation body, WMO has the mandate to set standards in these areas. *Figure 2* shows the processes generally required to access data using interoperable services, exemplarily a data portal, and parties that may be involved to standardise these.

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

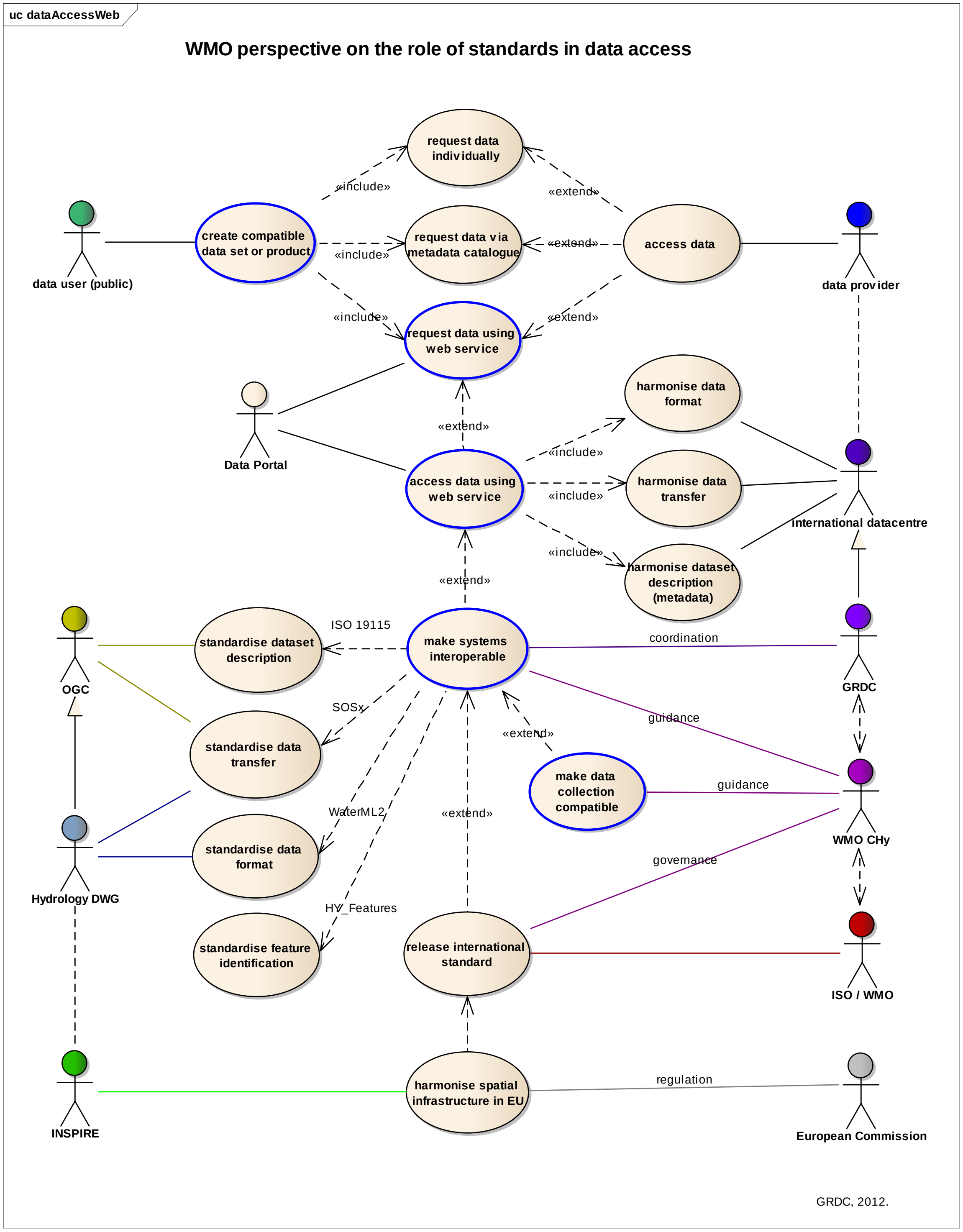

Figure 2 WMO perspective on the role of standards in data access.

This specification emerges from the need 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.

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 [6],

Common Hydrologic Feature Model

1 Scope

The *HY_Features* model defines the semantics of features which are the overall object of study and reporting in hydrology across scientific sub-disciplines. It provides a means to identify these features independent form scales and enables multiple representations of these features in the real world to be linked to the ultimate object of study or reporting.

The initial scope of this model is defined by the concerns of 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. Such as interoperability of observing systems needs standardised formats and transfer routines, the compatibility of data products requires common semantics to describe the domain-specific features of interest, i.e. features 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”[7]. 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 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 features to assist the organisation of their observation and modelling as well as the aggregation of generated data into integrated suites of datasets on a global, regional, national or basin scale.

The model encompasses different approaches of modelling 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.

2 Conformance

2.1 Overview

This Specification uses the Unified Modelling Language (UML) to present the conceptual schemas. This schema defines conceptual classes that (i) may be considered to comprise a cross-domain application schema, or (ii) may be used in application schemas, profiles and implementation specifications.

2.2 Domain-specific terminology

This specification uses as far as possible the terminology recommended for use in the WMO Member countries and represented by the "International Glossary of Hydrology" [7].Whenever an appropriate definition is provided in this glossary, the model captures this meaning and relationships to define relevant features and feature properties.

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 19109:2006, Geographic Information — Rules for application schemas

4 Terms and definitions

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

4.1 schema

formal description of a model
[ISO 19101]

4.2 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)

4.3 schema

collection of schema components within the same target namespace

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

4.4 catchment

basic unit of study and reporting in hydrology.

NOTE: Across scientific disciplines in the domain of hydrology, a catchment is recognised as the basic unit of study and reporting. Depending on the application catchment needs to be specialised into subtypes, e.g. basin.

4.5 domain feature

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

4.6 feature

abstraction of real-world phenomena.
[ISO19101]

4.7 hydrographic network

aggregate of water bodies, aggregated using a connecting system.

4.8 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.

4.9 hydrologic feature

abstract notion of the hydrology phenomenon.

4.10 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]

4.11 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.

4.12 hydrometry

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

4.13 mapping

mapping of elements of disparate representations of a hydrologic feature.

NOTE: In the context of common semantics, it refers to the mapping of semantic concepts.

4.14 multilingual keyword

keyword used in a multilingual context.

NOTE: A keyword is generally described in ISO 19115.

4.15 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.

4.16 observable property

property carried by a real-world phenomenon ready to be stated in an observation event.

NOTE: In the context of hydrology, an observable is considered an aggregate of (1..*) single observables which are real-world phenomena itself. A single observable may be determined applying one or more constraints to a base phenomenon, which is also a single observable

4.17 representation

real-world phenomenon representing an abstract feature.

4.18 river positioning system

linear referencing system used to reference indirect positions along a watercourse from a referenced starting point.

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 provided as distance (length) to reference point, as percentage of this distance or may be expressed verbally.

4.19 sampling feature

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

4.20 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 a reservoir as human action with the objective to efficient and sustainable use the resource, is not in the scope of the hydrologic feature model. Yet, often an indication is required whether a hydrologic feature is stored in a reservoir.

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 part 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

UML Unified Modeling Language

WaterML 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 Modelling Language (UML) static structure diagram, as described in Subclause 5.2 of the OGC Web Services Common Implementation Specification [OGC 04-016r2].

5.3 Document terms and definitions

This document uses the specification terms defined in Subclause 5.3 of [OGC 04-016r2].

6 Requirements for a Common Hydrologic Feature Model

6.1 Overview

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 behaviour of water. Such units may be defined at local, regional, national or international scales. Different applications may need to share the same unit of study, but this may be challenging if different semantics and identifiers are used for different delineations of these units. Depending on application and scale these units are multiply represented in the real world by a variety of phenomena, either single objects or a composite or network of these. Stable and persistent identifiers are required to reflect hydrologic significance and topological connectivity of features across disparate representations and different scales.

Hydrologic processes result at different stages into identifiable objects. Recognising this and the data obtained at an observation event as a “snapshot” of a process, the *HY_Features* model refers to the identifiable and observable object.

A re-usable core of generally applicable concepts, capable of being partially realised 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 recognised standards.

6.2 Domain Relevance (thematic validity)

6.2.1 The Hydrology Phenomenon

Hydrology is the science dealing with waters above, on and below the land surfaces of the Earth, whose occurrence, circulation and distribution in time and space, whose biological, chemical and physical properties, and whose reaction with the environment [7].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 hydrologic cycle;
- interacting in physiographic units, i.e. basins, wherein channelled to a common outlet;

- accumulated in the occupied landform as a water body;
- aggregated in hydrographic networks using a connecting system like a channel network expressed in flow or drainage pattern;
- may be managed and used as water resources;
- forming part of common discourse as named feature;
- studied and reported in hydrologic „water“ units, i.e. catchments, at local, regional, national or international levels.

Hydrology is the science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the Earth, and treats the various phases of the hydrological cycle[7].

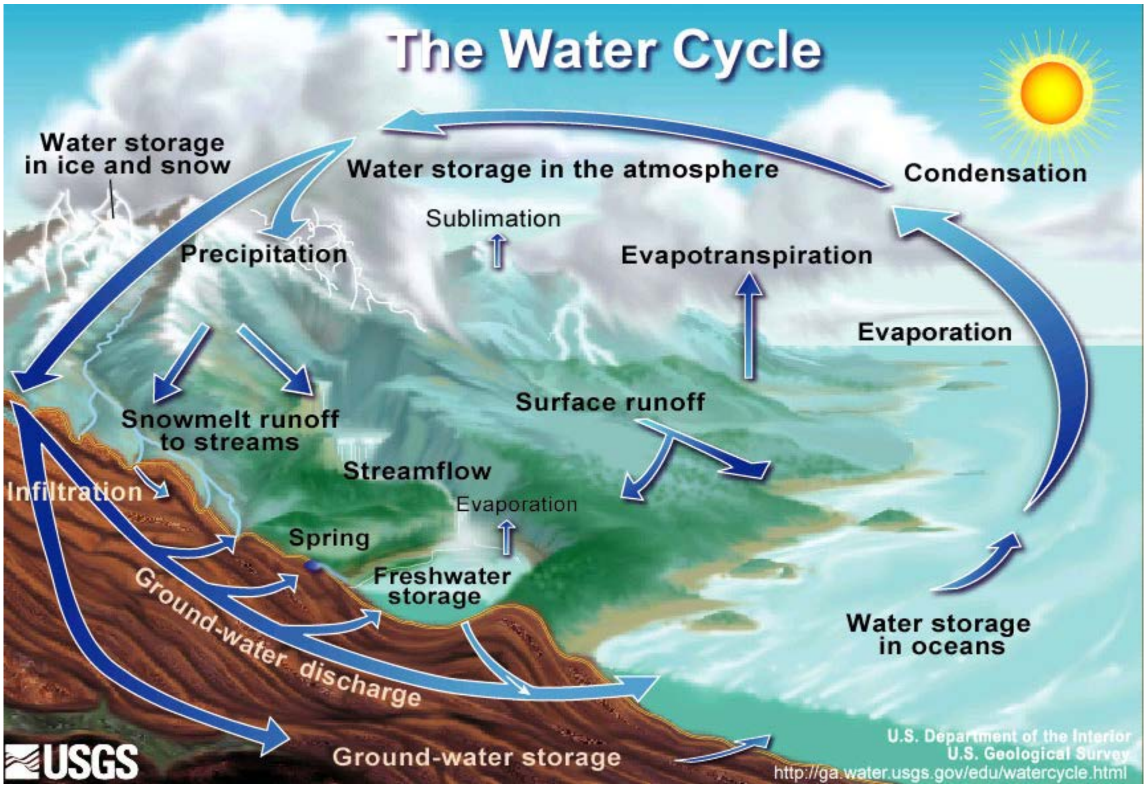

Figure 3 Processes of the Hydrologic Cycle

The processes forming the complex Hydrological Cycle (*Figure 3*) at its various stages result into identifiable objects such as a material, i.e. surface and subsurface water, a body of accumulated water, a containing landform, a water bearing formation or a connecting network. Each object is considered ready to be examined by observation. The resulting dataset provides a state of the object and a “snapshot“ of the process. The *HY_Features* model refers to this identifiable and observable object resulting from a hydrological process. For example, the body of accumulated water is considered as hydrologic feature, and not the process of accumulation that created the water body.

6.2.2 Water, Water bodies, Connecting networks

A body of water by definition refers to a mass of water distinct from other masses of water[7]. A water body is result of interacting processes in a basin and represents a certain stage of inter-basin processes expressed as a gain or loss of water. Water from precipitation reaching the land surface is accumulated in water bodies, which fill holes on the land surface or in water bearing formations. Extent and shape of a water body are defined by the occupied landform. Dropping below or exceeding the normal confines, extent and shape of a water body may reversibly deform and the nature of flow may change temporarily.

Different types of water bodies are aggregated into a hydrographic network using a connecting system determined by the confining landforms. Depending on the application, the network may be segmented in smaller units; depending on scale it may be displayed in a wide range from a notional centreline to a cross-linked branched network.

The confining landforms determine the system to potentially connect water bodies. This system of channels, expressed in flow or drainage patterns, exists independently of whether water flows or not. It does not define whether and how a water body interacts with the upstream and downstream water bodies. 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 connecting water-bearing formations hydraulically determines the potential connection between surface and sub-surface water, but not the type of interaction or the effects on a water body.

Water bodies have names and form part of common discourse. The same feature may be named differently according to locale and usage. Otherwise, names may apply to single parts only. In the field of hydrology it is usual practice to apply a water body name to the overall unit of study. Even if practitioners can successfully share meaning and identifiers, the cultural, political and historical variability of names and the relationships between alternative names needs to be handled.

Water bodies have properties ready to be observed. Whenever a value of such a feature property is obtained by observation, e.g. by measurement, any observable property becomes the *observed property* of the now *sampled feature*. Being observable, a water body may become the intended object of observation. In order to examine a certain stage of a hydrologic process, hydrometric stations and observing posts are established close to the water body which resulted from the process. The hydrographic network of water bodies provides the basis for the logic network of stations, which may be positioned absolutely by coordinates, but also indirectly as a distance to or position relative to a fixed reference point in the network.

Water bodies may store and yield water, regardless of whether the contained water flows or not and regardless of its aggregate state. Independent of its origin and network connectivity a water body may be considered a reservoir used for storage, regulation and control of water resources.

6.2.3 Units of study and reporting

Hydrologic processes and the resulting phenomena are studied and reported at local, regional, national or international levels. At a local scale processes may form complex structures and interactions, which may be safely ignored at a broader scale of analysis. Observations of water and water bodies are made in the responsibility of national or sub-national agencies, whereas the recorded data will be processed and managed on regional or even global scales. Reporting and analysis of landscape interactions is typically done using boundaries of an area of study.

In the context of environmental reporting, the boundaries are not necessarily determined by hydrologic processes and landscape constraints, but rather defined by the boundaries of the evoking institutional or jurisdictional framework. A reporting region may be a river basin, but also a country, an administrative or management unit.

Depending on application and scale, the same unit may be displayed in different ways. A basin may be described geometrically by the bounding watershed 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.

Cartographic representations do not always reflect the network connectivity of features explicitly. Even where connectivity is recorded (as opposed to unconnected linework) cartographic representations may be incomplete, as seen in *Figure 4*. This may be due to ephemeral nature of streams, land cover, underground connections or simply digitising 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.

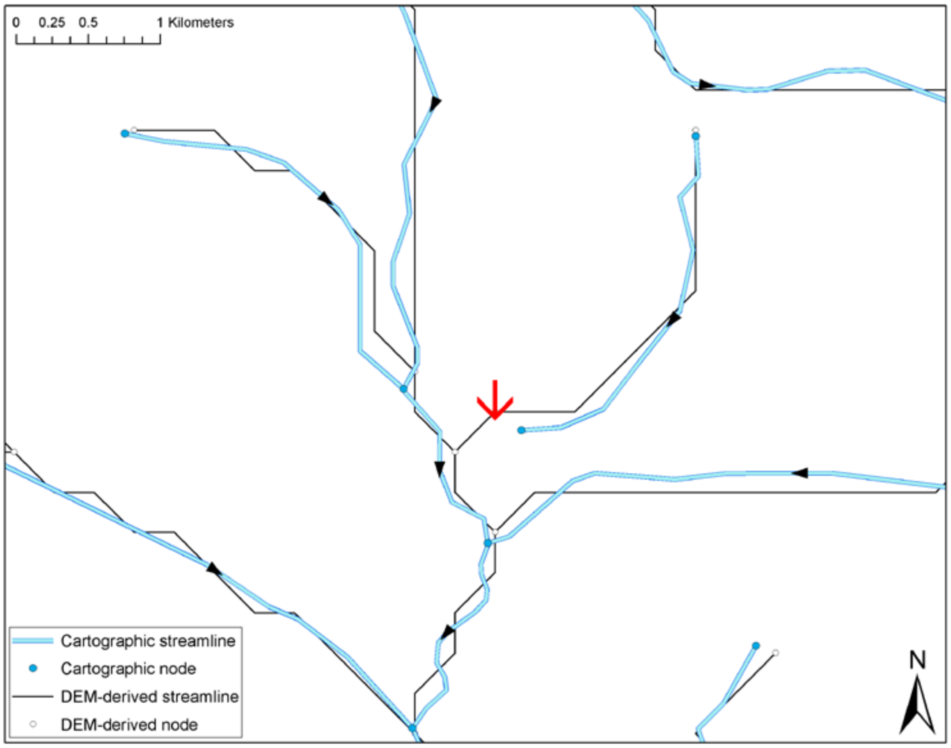

Figure 4 Example of cartographic and grid cell connectivity representations of streamlines [8]

Cartographic representations containing no 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.

6.2.4 The abstract notion: Catchment and Basin

The *catchment* is commonly recognised as the abstract unit of study and reporting in hydrology; a *basin* as the physiographic unit where hydrologic processes take place. The term “basin” is used inconsistently in the literature, sometimes to denote an entire river system, sometimes a sub-basin between key features, such as major confluences in a river system. In terms of conformity to WMO endorsed semantics, a definition is applied which refers to the physiographic unit whose overall runoff is channelled to a common outlet which determines the identifying *outfall* of the basin. For waters flowing due to gravitational forces the *outfall* coincides with the lowest point on the summit line bounding the corresponding basin.

Conceptually, the *outfall* is a logic point on the land surface. Topologically, each point on the land surface may be considered as the *outfall* of a corresponding basin. In this way, each phenomenon to which one a position can be assigned, is related to a corresponding basin. This may be a fixed landmark, a station, a point projected onto the surface, or a logic point created from collapsing other points.

Basins are organised 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 recognised 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.

Basins have inherent characteristics determined from interactions with other basins assigned in spatial, temporal or classification contexts, for example a range in a classification, an expression of permanence, or a shared space.

6.3 General Applicability

To be generally applicable to all cases where hydrologic feature identification needs to be persisted or shared, feature characterisations 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 specialisations. For example, an application concerned with rainfall runoff could extend the model to include soil moisture and landcover 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 characterisation 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 handled.

6.4 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 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.

6.5 Scale-independence

Hydrologic features exist at any scale, from a continental scale river basin to the basin of any point on a detailed river network. Whether observing, modelling 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 (6.4.) 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.

6.6 Governance

The introduction and enforcement of standard practices in a large, heterogeneous community require promotion, guidance and advice by an authority accepted within the community. Being the authoritative voice of UN, the WMO provides the framework for the leadership of 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 must 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 International Glossary of Hydrology [7]. The second implication is that the model has no dependencies on aspects not recognised by the WMO within its standardisation agenda. This is addressed by the plan to submit the model to WMO-CHy for implementation into WIGOS, upon satisfactory results of testing.

6.7 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 standardisation 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 modelling idiom [9] is commonly expected as well as the provision of XML schema definitions of the individual model components.

7 Common Hydrologic Feature Model - *HY_Features*

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

The conceptual model is expressed in the ISO TC211 19103 Geographic Information Conceptual Schema Language [9] and ISO 19109 General Feature Model as a set of Application Schemas containing Feature Type definitions[6]). It is based on a broad industry standard, the Unified Modelling Language (UML) [10].

7.1 Modelling Methodology

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 WMO-CHy. The model steps are:

1. Analysis of broad commonalities and differences in existing hydrologic data sets.

2. Analysis of implications of business requirement for hydrologic feature referencing.

3. Development of a draft model of key concepts required to meet business objectives.

4. Analysis of interdependencies and separation of the model into discrete modules.

5. Identification of, and reconciliation with, the semantics of terms published by the WMO.

6. Conformance checking of the model against ISO 19109 rules.

7. Community engagement through consultation with experts and the Open Geospatial Consortium (OGC) Hydrology Domain Working Group.

8. Design of data products conforming to the model.

Step 4, 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.

Steps 4-7 are repeated in an iterative process to ensure that modules are cleanly separated and meet the needs of hydrologic feature modellers. The model, whose key aspects are presented below, represents the results of the first iteration through this process.

Differences in terminology may be explored through reconciling accepted definitions for features in common use, endorsed by WMO-Chy and represented by the International Glossary of Hydrology (IGH) [7], with the different aspects represented 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.

7.2 Basic concept

A *hydrologic feature* is the abstract notion of the hydrology phenomenon to which monitoring, modelling and reporting applications refer. It is the ultimate object of study and reporting shared across sub-disciplines and administrative structures.

Commonly recognised as the abstract unit of study in the hydrology domain, a *catchment* is considered as a hydrologic feature. It may be specialised into a basin or a reporting region. A *Basin* is special due to its hydrologic determination as the physiographic unit whose waters, i.e. surface and subsurface waters, flow into a common outlet, the *outfall*. A reporting region is special due to its determination in a reporting context which may or may not meet the hydrologic determination. Basins are nested in “is-part-of” hierarchies and connected in tree networks, and may be aggregated into a set of hydrologically discrete upper-level systems. For reporting regions a logic outfall and a similar hierarchy concept may be assumed.

A particular hydrologic feature may be represented in the real world by a variety of observable phenomena (such as stream network, watershed, land surface etc), either by single objects or a composite or network of these *(Figure 5).*

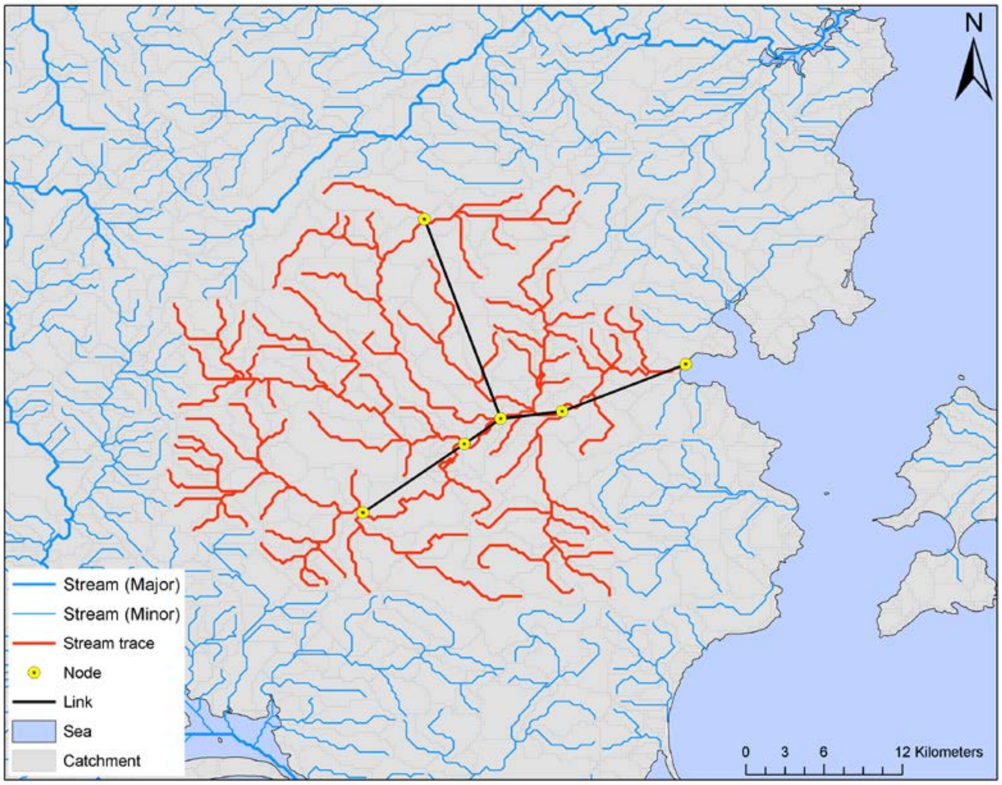

Figure 5 Alternative representations of hydrologic processes within a catchment [8]

Figure 6 shows an information model allowing the catchment concept to be represented differently. Catchment area, catchment boundary, or any network represents alternative views of the hydrologic processes for the same real world concept of a catchment. Special representations of a basin may be the drainage area, the watershed, the hydrographic network or an aquifer system.

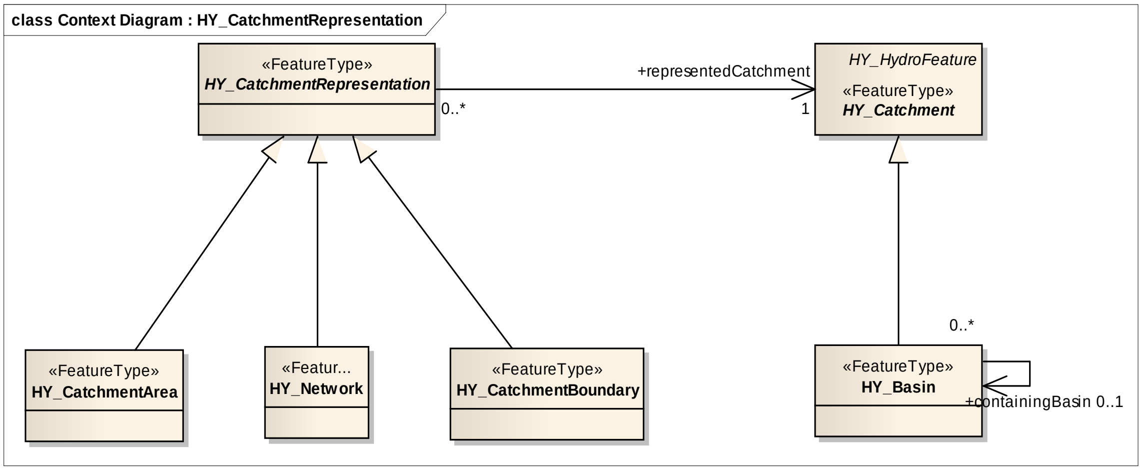

Figure 6 Catchment and catchment representation

The *Outfall* (*Figure 7*) is a topological concept which allows to consider an arbitrary point on, or projected onto, the land surface as the outlet of a corresponding basin. This point relates a basin to its contributing upstream or receiving downstream basins. The *outfall* is a point positioned in the hydrographic network. It may be may be a simple point but also a logic point into which other points may be collapsed.

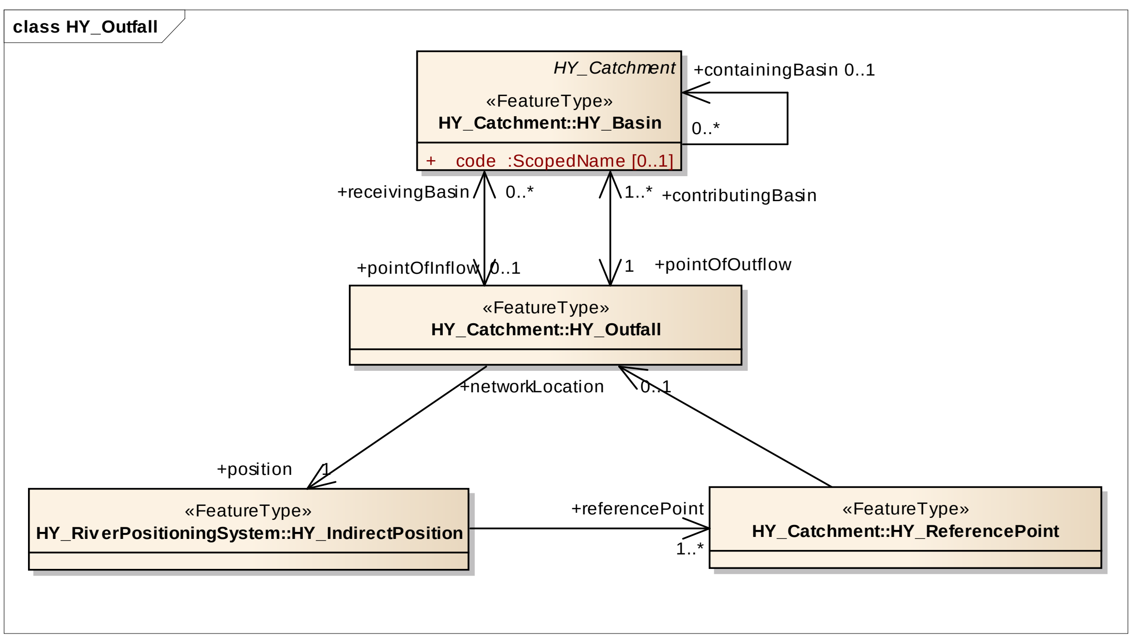

Figure 7 *outfall*, topological concept

Applied to a basin that is multiple represented in the real world, the *outfall* marks the identifiable *referencePoint* (*Figure 8*) to which different representations may be related, exemplarily as *downstream/upstreamReferencePoint*, *crossSectionPoint*, *extractionPoint*, or a *positionOnRiver*.

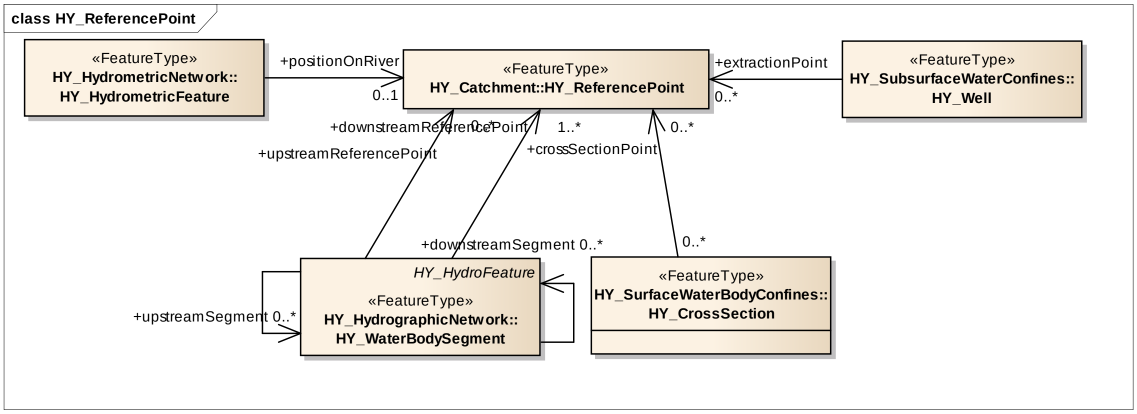

Figure 8 ***referencePoint*****, logical concept**

7.3 Scope considerations

Special applications with relevance to only one phenomenon usually create specific representations of a hydrologic feature, e.g. of a *basin.* These alternative representations may be connected through reference to the shared *outfall*.

To support a semantic mapping of different applications in use, typical relationships are defined (roles) for the most common real-world phenomena representing a *basin* to the identifying *outfall*:

- **downstream/upstreamReferencePoint** *(roles)* relates a water body of at least one segment to the corresponding basin.

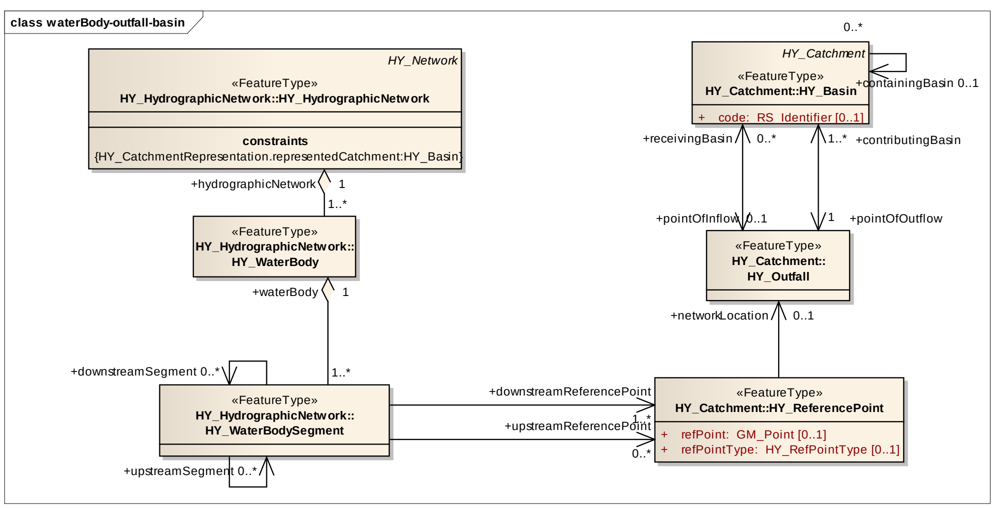

Figure 9 ***downstream / upstream reference point*** **relating a water body**

- **cross-sectionPoint** *(role)* relates a channel / reach to the corresponding basin.

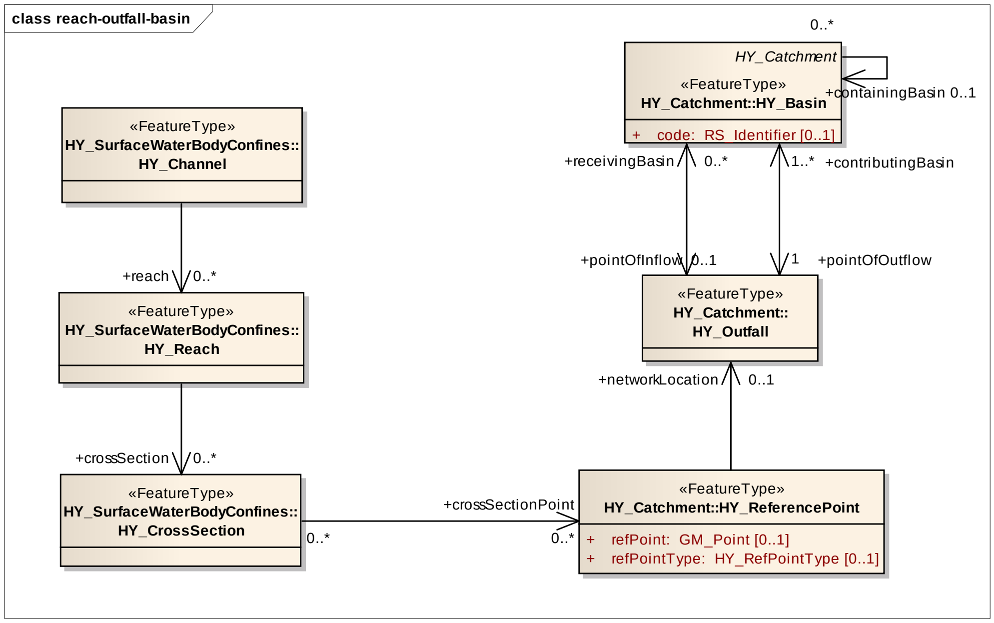

Figure 10 *cross-section point* relating a channel reach

- **extractionPoint** *(role)* relates an aquifer extracted by a well to the corresponding basin.

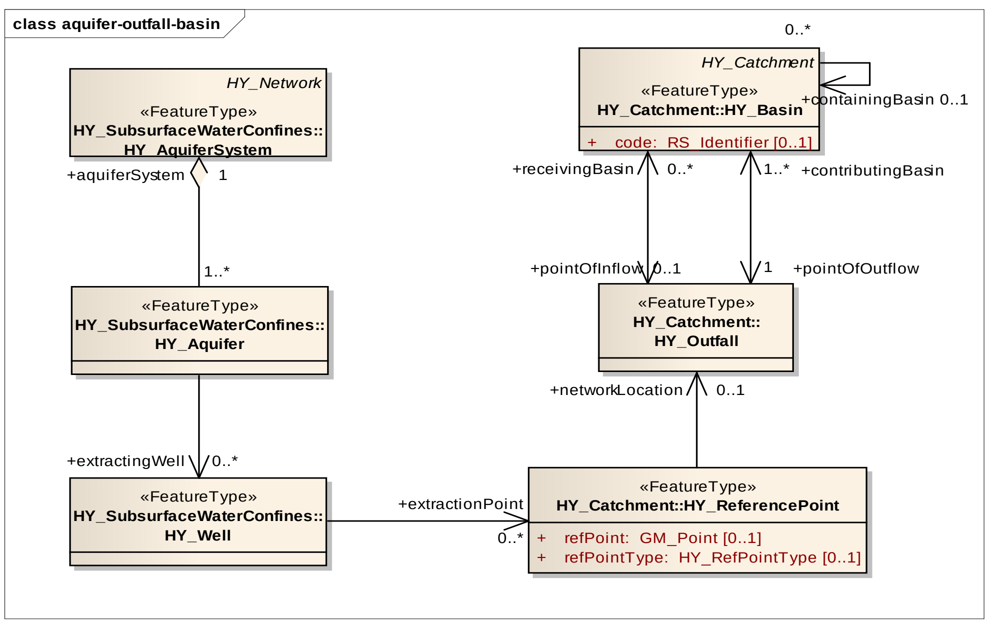

Figure 11 *extraction point* relating an aquifer

- **positionOnRiver** *(role)* relates a hydrometric network of at least one object to the corresponding basin.

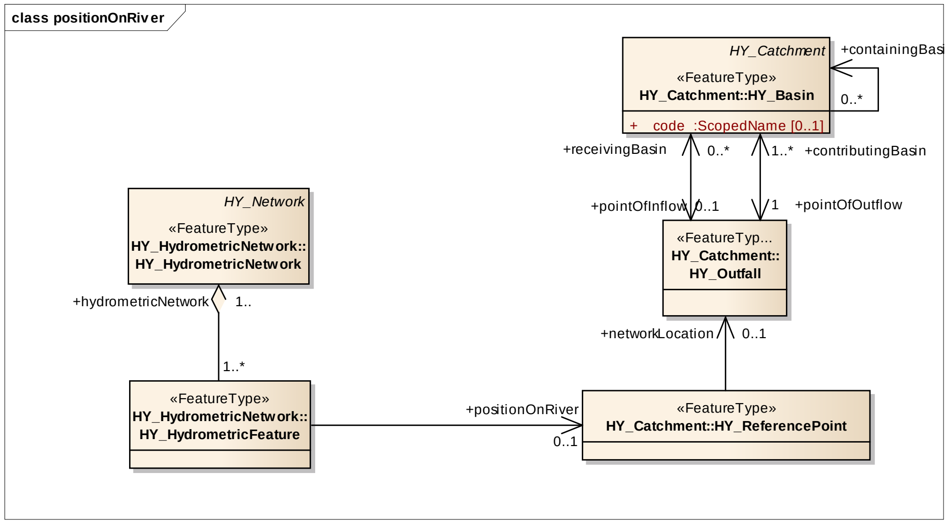

Figure 12 *position on river* relating a hydrometric feature

- **confinedWaterBody** *(role)* relates a water body of at least one segment to the corresponding basin.

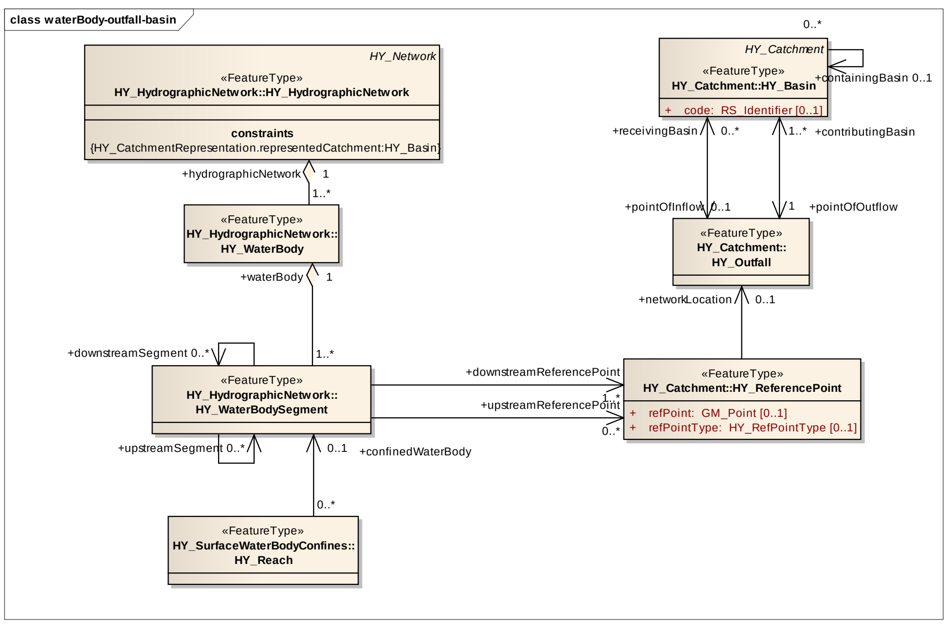

Figure 13 *confined water body* relating a channel reach

- **gainingWaterBody / losingWaterBody** *(roles)* relates a water body gaining / losing subsurface water to the corresponding basin.

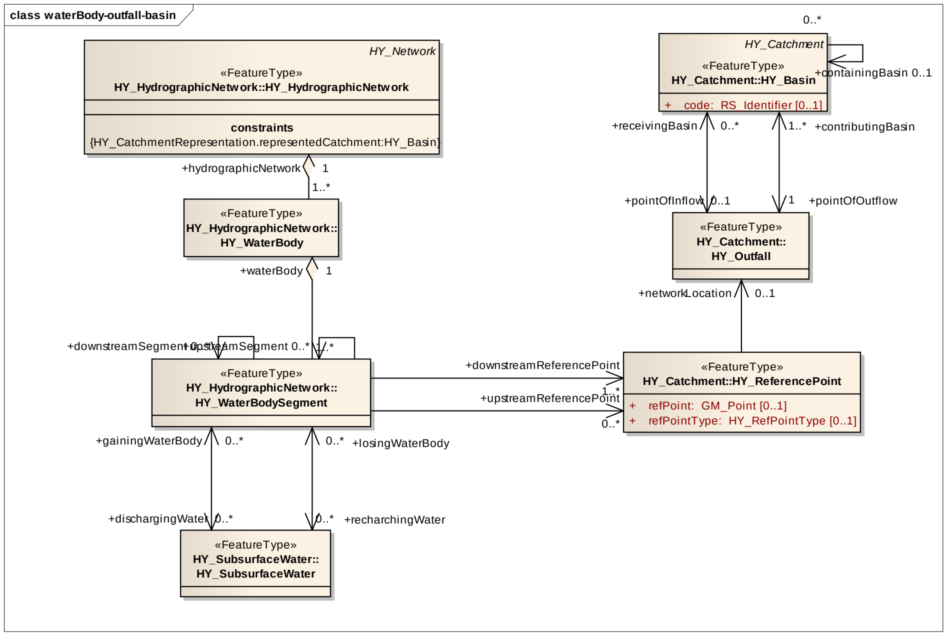

Figure 14 ***gaining / losing water body*** **relating subsurface water**

7.4 Organisation of the 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*, incl. *EXT_LocalisedName*, *EXT_MultilingualKeyword*, *EXT_SpatialContext*, *EXT_TemporalContext*, *EXT_ClassificationContext*, *EXT_UsageType;*

- *HY_HydroFeature,* incl. *HY_Catchment, HY_NamedFeature, HY_HydrographicNetwork, HY_RiverPositioningSystem* and *HY_Storage;*

- *HY_AtmosphericFeature,* incl. *HY_Precipitation* and *HY_Meteor* (placeholder)

- *HY_SubsurfaceHydroFeature*, incl. *HY_SubsurfaceWater* and *HY_SubsurfaceWaterConfines;*

- *HY_SurfaceHydroFeature*, incl. *HY_SurfaceWaterBody, HY_SurfaceWaterBodyConfines* and *HY_StorageReservoir;*

- *HY_HydrometricNetwork;*

The organisation into packages and their dependencies are shown in *Figure 15.*

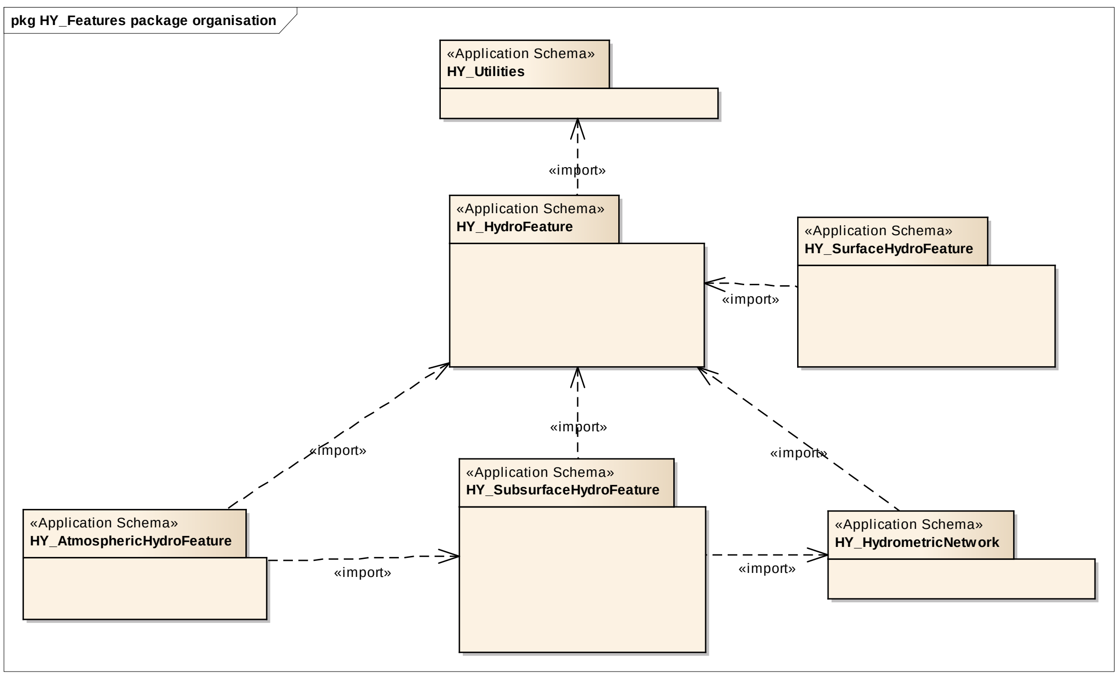

Figure 15 *HY_Features* – Package dependencies

7.5 HY_Utilities

HY_Utilities package (*Figure 16*)contains utility classes for common patterns required by the domain model that are not hydrology-specific. 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*)

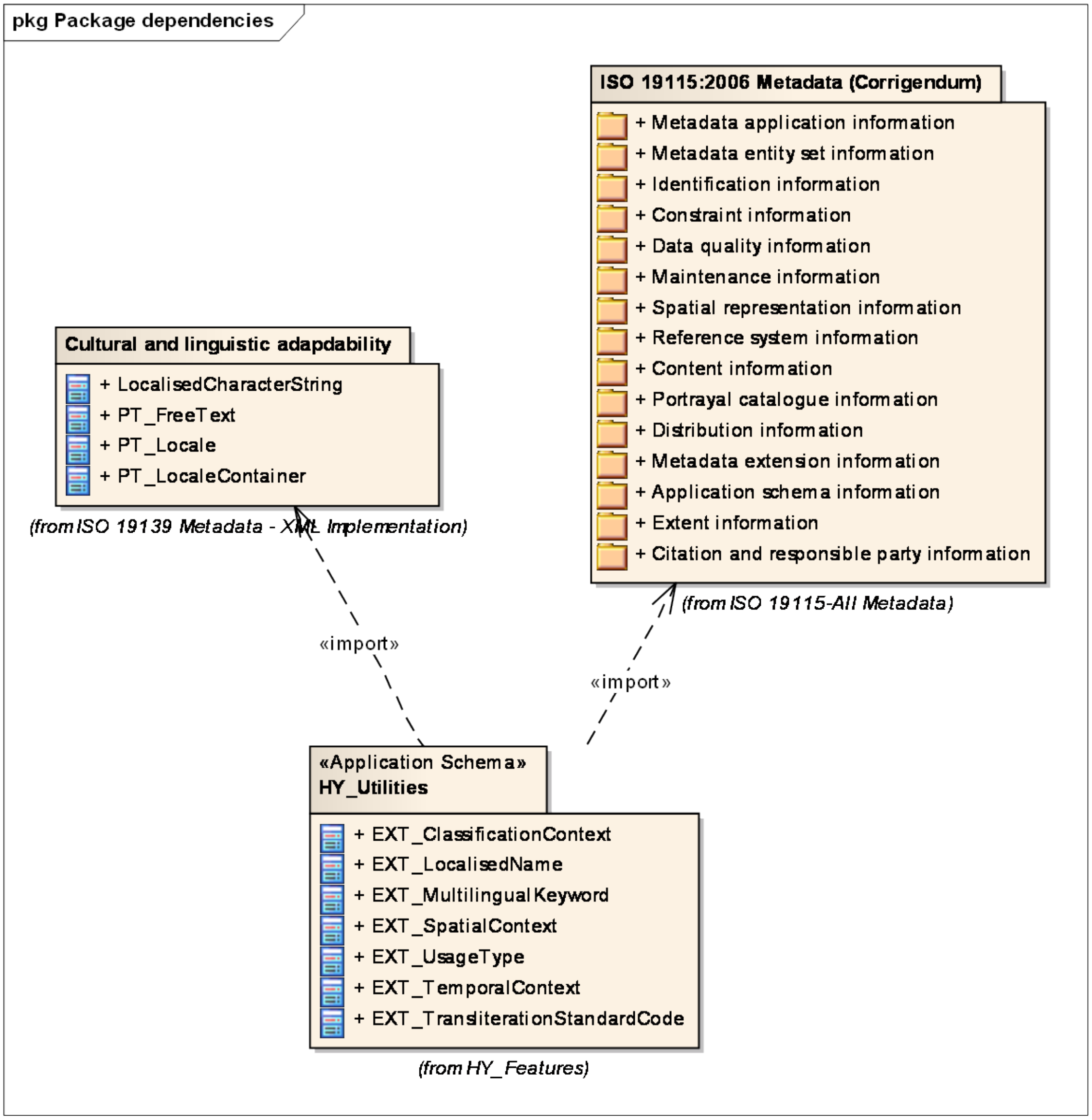

Figure 16 *HY_Utilities* – Package dependencies

These classes are expected to be important patterns for cross-domain harmonisation. They should be provided in an external library for cross-domain usage. At that point this package can be replaced with references to this library. Similar packages includes *GFI_FeatureModel* from ISO19156[1].

7.6 HY_HydroFeature

HY_HydroFeature schema (*Figure 17*) defines fundamental properties and relationships between features governed by the physical laws of hydrology.

The core concept introduced here is that a study of hydrology will represent common concepts of real-world by specific modelled features (as per ISO 19019 General Feature

Model). Depending on the scientific concern, the relevant representation may be a single feature, but also a collection or a network of features. These features may represent single components of a network, or different aspects of the hydrology phenomenon, typically catchment, watershed, flowlines and connectivity. *HY_HydroFeature* connects the disparate representations, allowing the hydrosphere to be divided into a hierarchy of catchments (*Figure 18*).

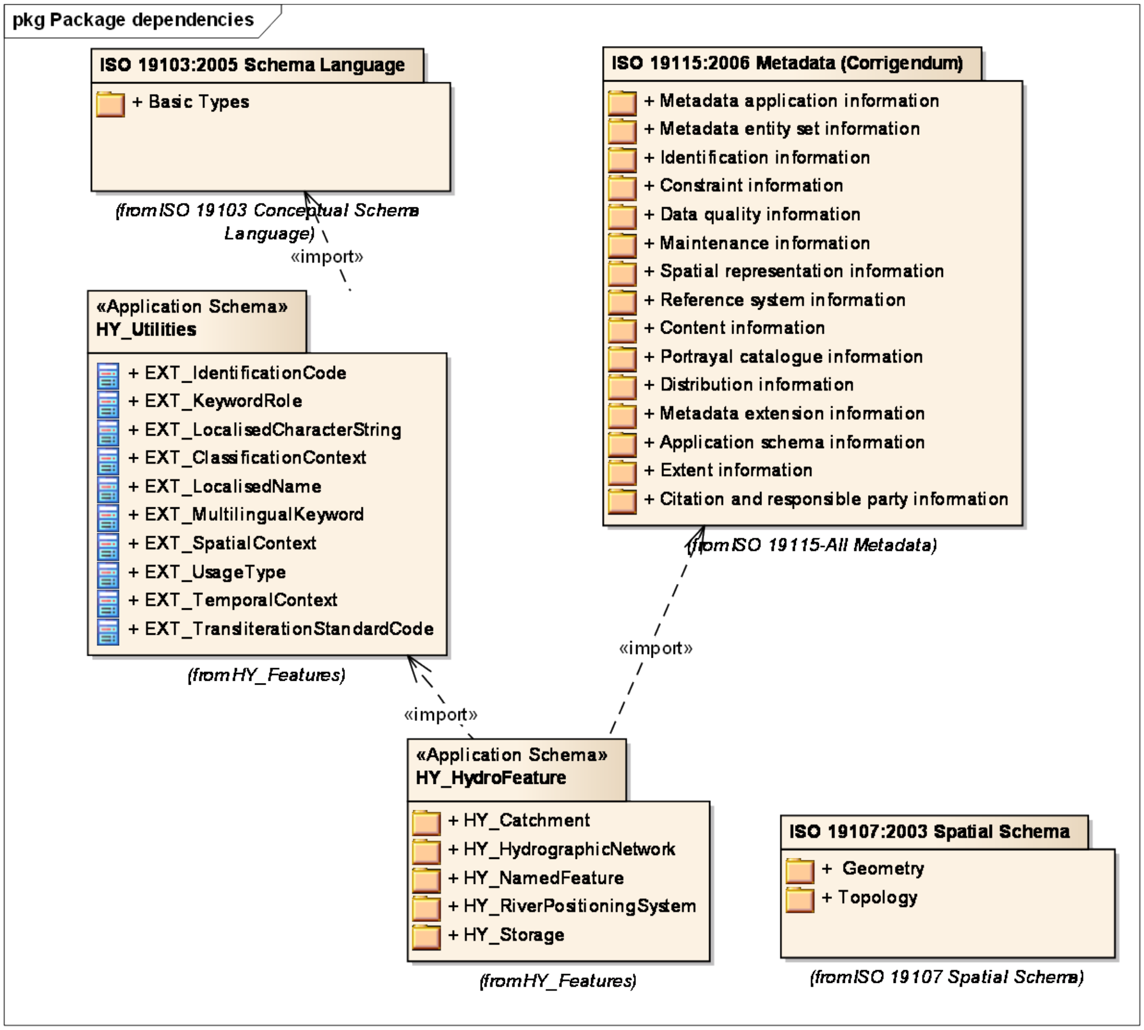

Figure 17 *HY_HydroFeature* – Package dependencies

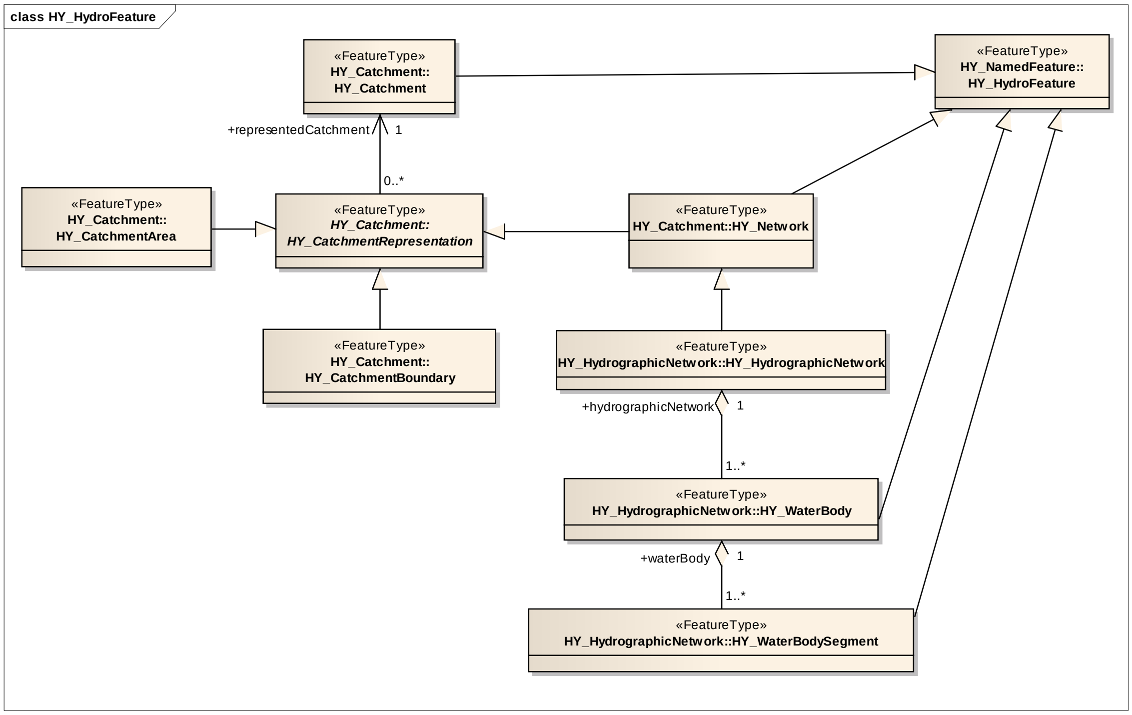

Figure 18 *HY_HydroFeature* – Class diagram

HY_NamedFeature (*Figure 19*) provides an abstract pattern shared by all hydrologic features where names are given to a feature, through common usage, without necessarily have a formal model. The names are localised within cultural, political and historical contexts.

The named features are further elucidated in different concrete feature types which specify the properties each representation uses to define one or more aspects of the hydrology phenomenon. This includes related phenomena that participate in hydrologic systems but have specific characteristics in spatial, temporal or classification contexts. 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.

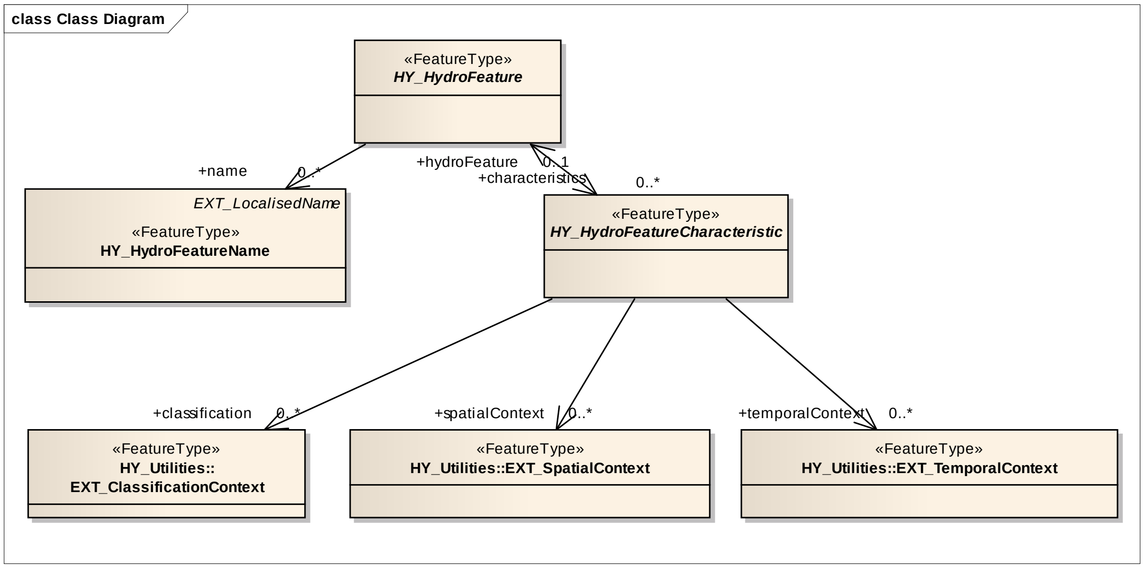

Figure 19 ***HY_NamedFeature*** **– Class diagram**

HY_Storage (*Figure 20*) is a sub-package providing an abstract pattern to describe a water body in terms of a resource stored for future use. Each water body may be considered capable to store and yield water independent of its network connectivity.

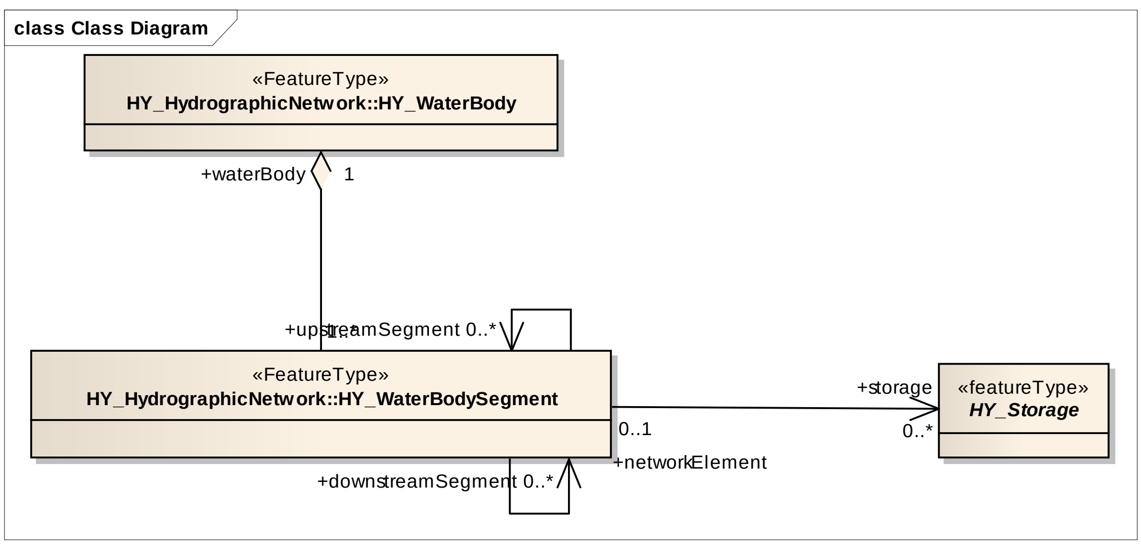

Figure 20 ***HY_Storage*** **– Class diagram**

HY_Catchment leaf (*Figure 21*) defines a logical network of catchments. Each catchment may be represented in any hydrologically meaningful sub-domain model, including a network of catchments.

The catchment model allows for the existence of catchments to be recognised, and identifiers assigned based on outflow nodes even if stream networks, watersheds and areas are not reliably determined.

The catchment model allows for the topological relationships between hydrometric stations to be established without unnecessary detail of hydrography, cartographic interpretation and varying conditions...

The catchment model is sufficient for the case of simplified hierarchies of basins to be defined. It is intended that hydrological reporting applications may use this model without the full complexity of the *HY_Features* model.

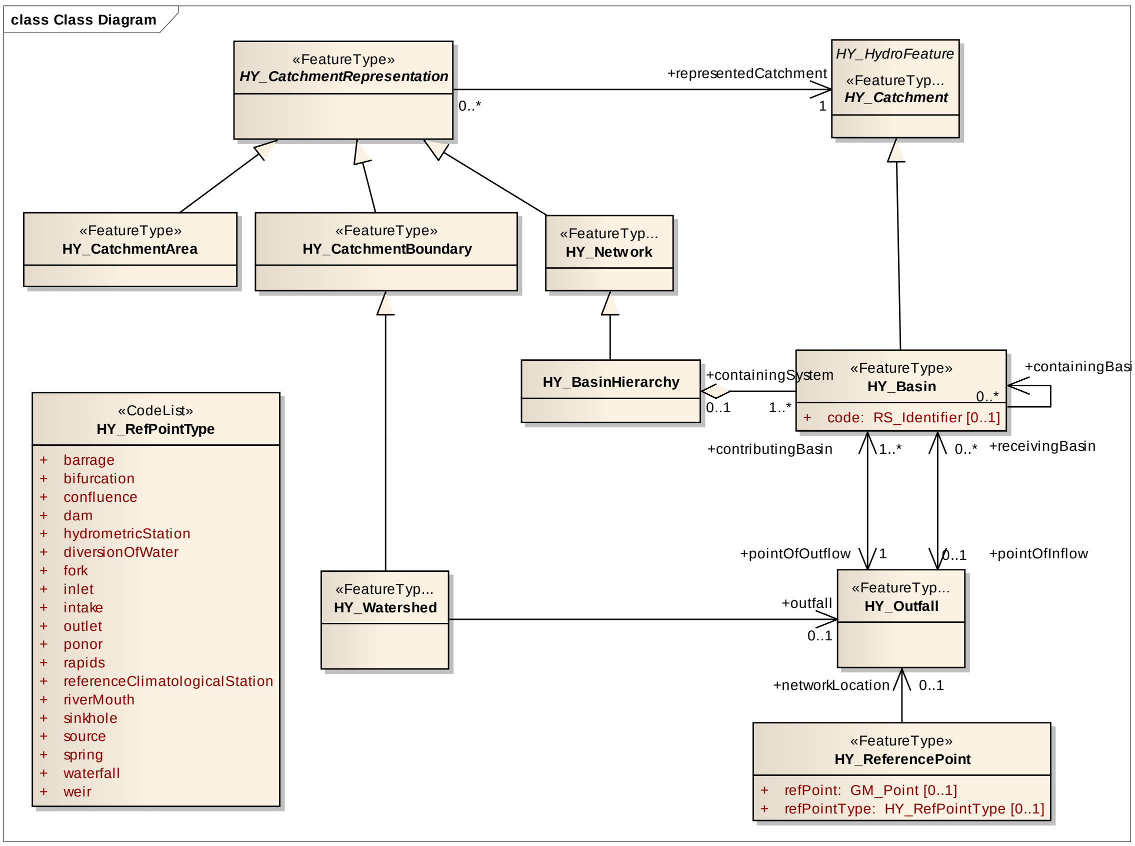

Figure 21 *HY_Catchment* – Class diagram

The *catchment* may be specialised depending on applications e.g. into basin or reporting region. These subtypes may require special types of representation. For example, the hydrologically determined *basin* may be represented in the real world by drainage area, watershed, or hydrographic network.

HY_HydrographicNetwork leaf (*Figure 22*) provides for topological relationships to be declared between the major components of the hydrosphere, including segmentation of a watercourse.

The *HY_HydrographicNetwork* introduces concepts of segmentation of hydrographic features and cartographic (geometrical) representations of segments, which may or may not be topologically connected at the representational level.

The *HY_HydrographicNetwork* is defined in the context of a higher order identification of the network each element participates in, hence the dependency on the abstract catchment model, *HY_Catchment*.

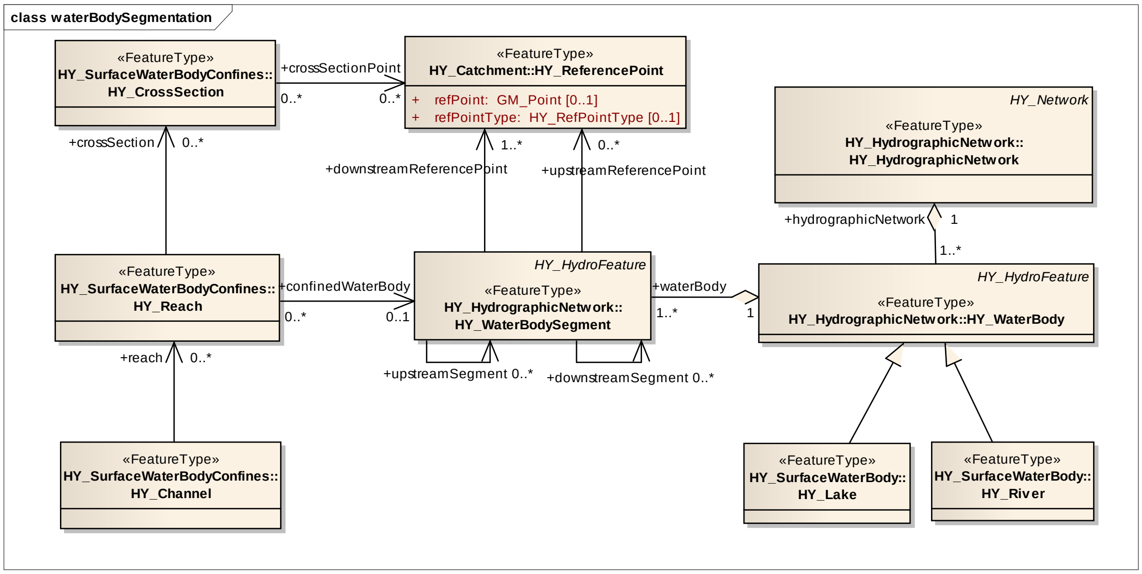

Figure 22 *HY_HydrographicNetwork* – Class Diagram, Segmentation

HY_RiverPositioningSystem (*Figure 23*) is intended to provide a means to reference positions on a river via topology and geometry similar to concepts used in the context of tracking and navigation.

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 a hydrographic network. The distance to the reference point is provided as *Length*, including an indication of accuracy (closeness to the true value) and precision (smallest unit of length). The relative position may be described as a percentage of the distance or using terms common in the hydrology domain such as upstream/downstream, left/right, at/between/nearby.

The concept of indirect position refers to a linear coordinate system whose origin is set at the position of the point of interest. Coordinates are provided as distance (length) upstream or downstream from this origin to a reference point in the hydrographic network.

The concept is allows to locate an arbitrary hydrometric station depending on its position on a hydrographic feature without having local coordinates. The reference point is identified by coordinates and may be a fixed landmark, but also a physical artefact like a reference hydrometric station.

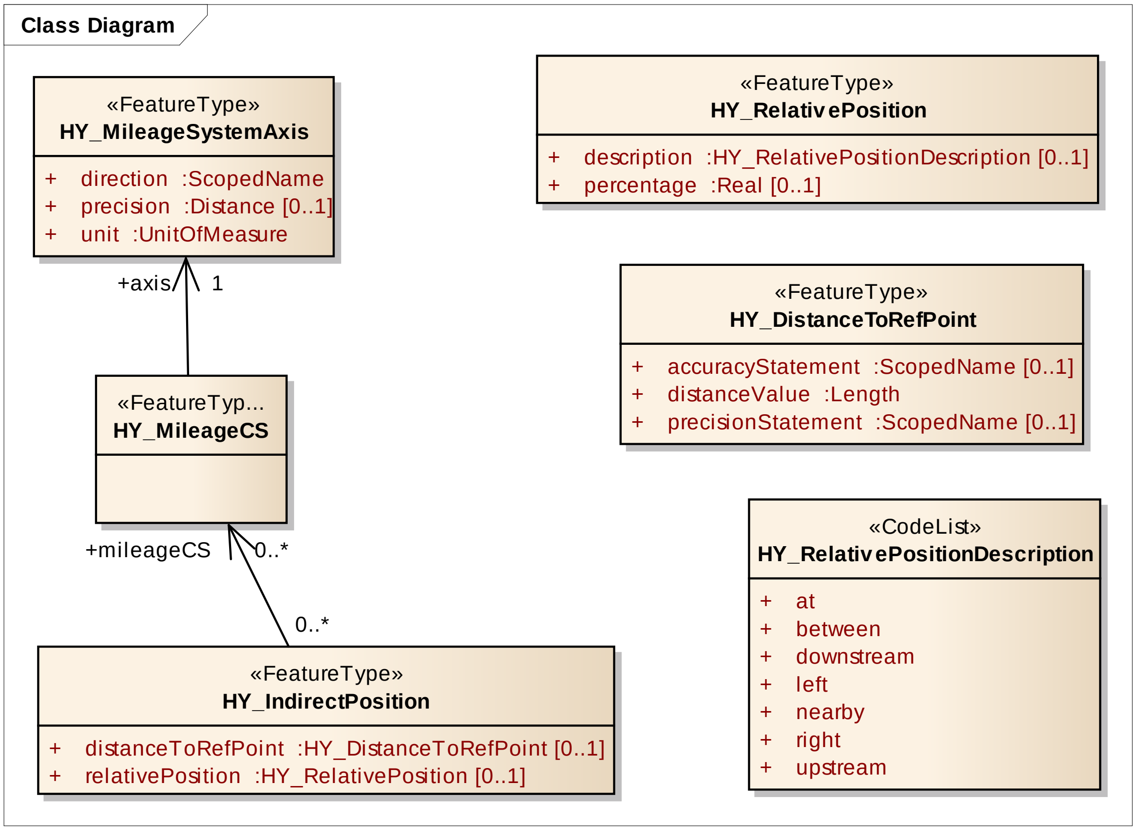

Figure 23 *HY_RiverPositioningSystem* – Class Diagram

Although required to link hydrometric objects without coordinates to a hydrographic network and through this to the r, the basic concept of positioning is not hydrology-specific. The classes defined in this package needs to be reconciled with concepts for positioning such as provided within the ISO19133(2005):LBS-Tracking and Navigation standard [11].

7.7 HY_SurfaceHydroFeature

HY_SurfaceHydroFeature (*Figure 24*) defines the components of the hydrosphere on the land surface without imposing a particular network scale.
The package contains the descriptions of the water body (mass of water), of the confines determining its extent and shape, and of the reservoir where water may be stored in terms of a resource for future use.

The package summarises the most popular water bodies 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, any special type of hydrographic feature may be described by suitable attributes.

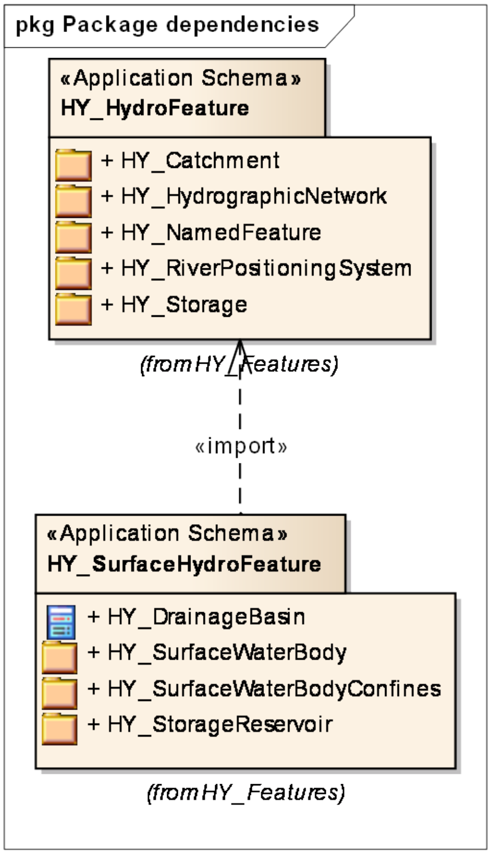

Figure 24 *HY_SurfaceHydroFeature* – Package dependencies

7.8 HY_SubSurfaceHydroFeature

The *HY_SubsurfaceHydroFeature* (*Figure 25*) package defines the components of the hydrosphere below the land surface without imposing a particular scale.

The package summarises the most popular types of water accumulated below the land surface using a system of aquifers which may or may not be connected. The effects of groundwater-surface water-interaction by discharging and recharging water are related to the relevant losing or gaining water body.

Depending on the implementation, any special type of subsurface water or bearing aquifer may be described by suitable attributes.

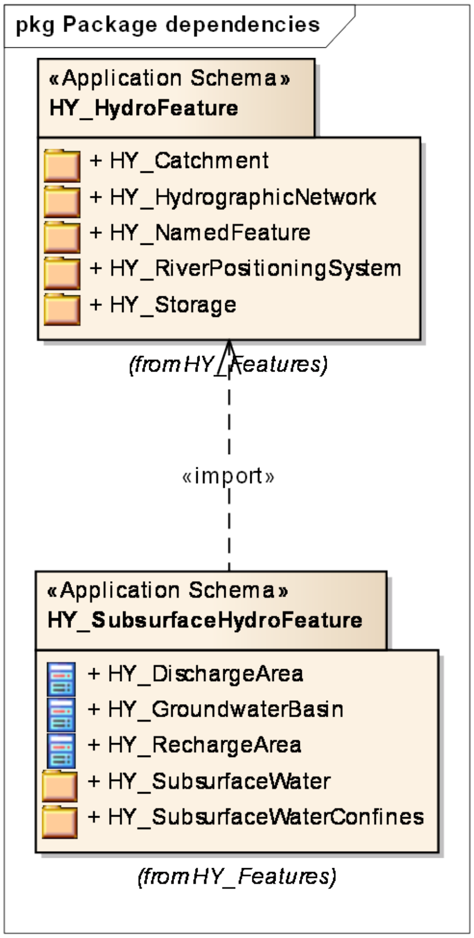

Figure 25 *HY_SuburfaceHydroFeature* – Package dependencies

7.9 HY_HydrometricNetwork

NOTE: (this is in very preliminary draft status)

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.

HY_HydrometricNetwork (*Figure 26*) provides for a network of hydrometric stations which are logically connected, e.g. stations along a watercourse.

The network of hydrometric features comprises stations and observing posts used to observe an observable property of a real-world phenomenon. In the observation context, the hydrometric feature embodies the special sampling feature, e.g. a monitoring point. Hydrometric features are physical artefacts, or a collection of these. Yet, some hydrometric features may be fictive ones.

A hydrometric feature is located in the hydrographic network using the concept of *positionOnRiver*, which relates the hydrometric feature to the *outfall* of the corresponding basin using a reference point. The hydrometric feature itself is free of any positioning, since *outfall* has a mandatory position determined by the coordinates of a sampling point, or any other referenced point.

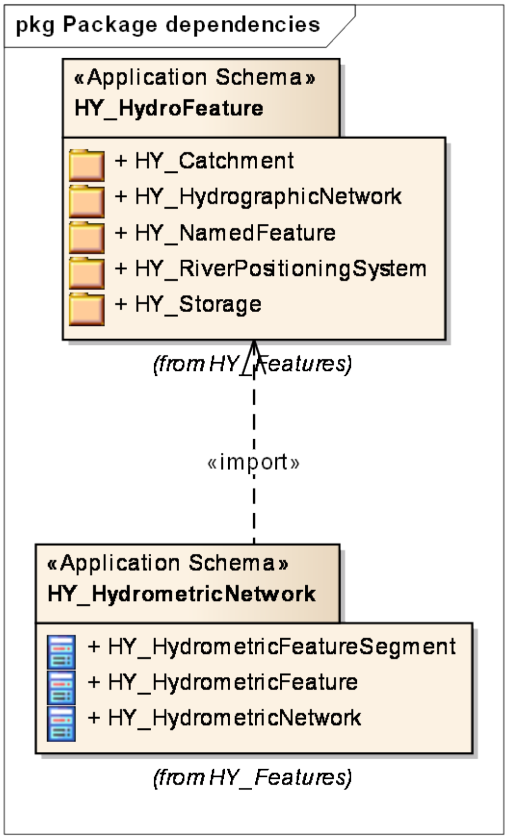

Figure 26 HY_HydrometricNetwork – Package dependencies

8 Further work

Validation of concepts

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). The WMO Integrated Global Observing System (WIGOS) or the Global Terrestrial Network - Hydrology (GTN-H) may implement the proposed feature model in their metadata concepts to evaluate and share information and data on a common basis. To this goal the conceptual model requires community engagement in the process of validation, feedback and submission as candidate *Best Practice* to WMO. *Figure27* shows in general how a domain-specific OGC Specification may be processed into a

WMO *Best Practice* for recommendation to WMO Member countries and release as an international standard.

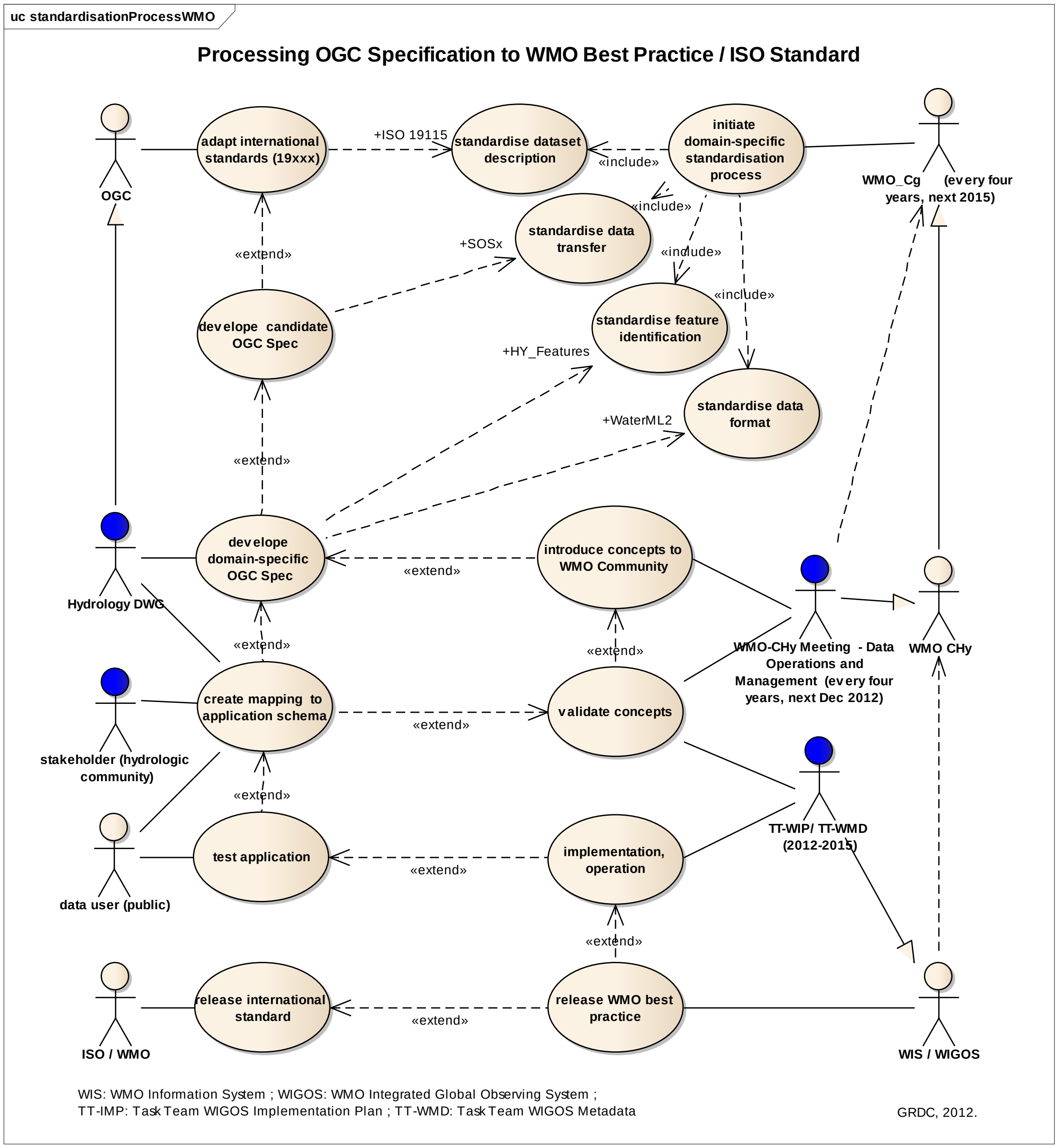

Figure 27 Processing OGC Specification to WMO *Best Practice* / ISO Standard

The conceptual model should be validated through establishing mappings to application schemas and implementation models of data products realising 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.

Such implementation models of note include:

- Australian Hydrological Geofabric (dataset and specification)[12]
- WIGOS Metadata theme (specification)
- INSPIRE Hydrography Theme (specification)
- FAO Global Rivers Database (dataset)
- DGIWG Feature Catalogue
- ArcHydro (implementation pattern)

The model has been described in a publication in the International Journal of Hydrology [8].

CSIRO is currently exploring use of this model in the context of Linked Data implementations, using HY_Features to establish stable URL identifiers for features in the Australian Geofabric Data Products.

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