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OGC® WaterML 2 – Part 3: Surface Hydrology Features (HY\_Features) – Conceptual Model

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Abstract

The OGC Surface Hydrology Features (HY\_Features) implementation standard defines a standard information model for the identification of surface hydrologic features independent of geometric representation and scale. The conceptual model describes hydrologic features by defining the fundamental relationships among major components of the hydrosphere. This includes relationships such as the hierarchy of catchments, the segmentation of watercourses, and the topological connectivity of hydrologic features such as catchment and water bodies.

The standard is based on the concept that a given hydrologic feature may have multiple representations. This supports referencing the same feature(s) in different information systems or products assisting the organization on having integrated information system. Moreover, this model also supports the cataloging of observations, model results, or other studies of a feature. The ability to represent the same catchment, river, or other hydrologic feature in several ways is critical to aggregation of cross-referenced features into integrated datasets and data products on global, regional, or basin scales.

Hydrologic feature types are defined using the OGC General Feature Model (ISO 19109:2006) with reference to definitions from the International Glossary for Hydrology. The conceptual model is expressed in the Geographic Information Conceptual Schema Language (ISO 19103:2005) using the Unified Modeling Language (UML).

Keywords

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

ogcdoc, OGC document, hydrology, feature, identification, conceptual model, UML, implementation standard, hydrology model.

Preface

This standard defines the HY\_Features common hydrologic feature model for the identification of hydrologic features. It is intended to be used to document and share information about the objects of study and reporting in Hydrology in many applications. This standard was originally commissioned to link hydrologic information across the scientific and technical programs of the World Meteorological Organization (WMO), and to assist the WMO Members to discover, access and use hydrologic data from different sources.

This standard has been designed to support the need for governance and guidance by national and international authorities. Aspects of the standard that support this end are; 1) its canonical form, 2) its implementation neutrality, 3) conformity to internationally recognized standards of geographic information, and its use of semantics inferred from terminology endorsed by the WMO and the UN Educational, Scientific and Cultural Organization (UNESCO).

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Submitting organizations

The following organizations contributed to the initiation or development of this standard and submitted this Document to the Open Geospatial Consortium OGC):

* U.S. Geological Survey (USGS), USA
* Federal Institute of Hydrology (BfG) , Germany
* CSIRO Land and Water, Australia
* Bureau of Meteorology, Australia
* Metalinkage, Australia
* French Geological Survey (BRGM), France
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|  |  |

Changes to the OGC® Abstract Specification

The HY\_Features conceptual model described in this standard references at some parts general concepts defined within the OGC Abstract Specification. Conformance to the OGC Abstract Specification is provided either by specialization of these concepts such as for the General Feature model, by referencing the relevant concept for example a geometric representation of a hydrologic feature, or by expressing the semantic correspondence using a simple ‘descriptive mapping’ as provided for referencing along a nominal flowpath similar to the linear referencing along any linear element..

This standard requires no changes to the OpenGIS ® Abstract Specification.

# Scope

This OGC Implementation Standard defines a common feature model for the identification and description of surface hydrologic features using established models and patterns in use in the Hydrology domain and endorsed by WMO and UNESCO such as those documented in the "International Glossary of Hydrology".

This standard will form the third part of an intended ‘OGC WaterML 2’ suite of standards which will group the water-related OGC standards. Following Part 1: Timeseries, Part 2: Ratings, Gaugings and Sections, this standard will form Part 3: Surface Hydrology Features.

This document introduces the HY\_Features conceptual model itself. The normative model is a machine-readable UML artifact published by the OGC in conjunction with this document at: **[insert URL here]**.

A future document is expected to define a semantic representation (OWL/RDF) of the conceptual model suitable for defining links between data that reference the HY\_Features conceptual model. This semantic model is expected to support documentation and discovery of data and to aid future data transformation efforts. This work may provide a basis for further work in the wider OGC on a methodology (tooling) to publish ontologies to support their practical use.

The initial scope is defined by the WMO Commission for Hydrology (WMH-CHy): to facilitate data sharing within the hydrologic community of the WMO Member countries and to improve the quality of data products based on these data by defining hydrologic features to convey the identification of water-objects through the data processing chain "from measurement to hydrological information" [8].

To enable semantic interoperability of hydrologic data and services, it is necessary to agree on common concepts and methods for machine interpretation of the concepts. To this goal, the HY\_Features model was developed in order to formalize the concepts and relationships of hydrologic features using the WMO/UNESCO "International Glossary of Hydrology" as a starting point.

This standard is meant to support the linkage of data products distributed across differing applications and jurisdictions. To enable this, a holistic concept of catchment is defined and the surface-water aspects of the concept are modeled. This will allow a particular surface catchment to be represented in different data products while retaining its identity. In addition to unique identification of features in multiple systems, a second objective is to provide a standard terminology and an ontology to describe relationships between hydrologic features. This may be useful in building a data transfer format for specific subsets, particularly catchment hierarchy and river network topology but such data transfer format development is not in scope for this standard.

The HY\_Features model provides a basis for common and stable references to hydrologic features in a wide variety of applications:

* to link hydrologic observations to their feature-of-interest, e.g. link a streamflow observation to the river or catchment being observed,
* to allow aggregation of cross-referenced features into integrated datasets and data products on global, regional, or basin scales,
* to enable information systems to unambiguously link data across distributed systems and domains,
* to enable cross-domain or multi-discipline services to communicate through reference to standard concepts.

This standard defines a set of Application Schemas (normative) containing feature type definitions that conform to the OGC General Feature Model (GFM) (ISO 19101:2002 and ISO 19109:2006), expressed in the Geographic Information Conceptual Schema Language (ISO 19103:2005) using the Unified Modeling Language (UML).

The GFM is a meta-model developed to serve as the general conceptual model for features and feature properties in the context of geographic information. A feature type is identified by a set of typical characteristics (property type) such as attributes, association, or operations as well as by possible constraints. Each attribute, association or operation is identified on its own by properties and constraints. Conformity to the GFM is assured by instantiating the general feature type as feature classes specific to the application domain.

As shown in Figure 1, the HY\_Features conceptual model realizes the GFM by providing a domain-specific instance of the general GF\_FeatureType (aka FeatureType) «metaclass» capturing the Hydrology phenomenon. Since its concern is primarily the issue of feature identification, a basic type HY\_HydroFeature is defined to reflect the overall properties hydrologic features have such as identifier and name. Special feature types are defined to reflect different aspects of hydrology by the typical characteristics each specialization carries. Given the complexity of the domain, a wide range of possible properties may be relevant for a given hydrologic feature type.

Figure 1 also shows how the HY\_Features model allows the feature-of-interest concept of the Observation and Measurement (O&M) model (ISO 19156:2011) to be realized for hydrologic observations. Depending on the application, the target of an observation may be a Domain Feature, like a water body, or a Sampling Feature, such as a stream gage, used as a proxy for a Domain Feature. Specifically, observation-centric data models such as the WaterML2.0 implementation profiles of O&M [4] may use the concepts provided in this standard to identify domain-specific relationships between a sampling feature and the ultimate sampled feature.

The model concepts may be used to describe the relationships of observation results to the hydrologic feature of interest they are meant to represent and in this way to link spatial and non-spatial hydrologic data. In particular, this model will support interoperability at semantic level through providing a standard terminology, and formalizing the information relationships and constraints on behalf the data sharing and system communication. This allows links to be implemented in a standard way between resources on the Web. For example, a discovery service such as a catalog of catchments could use the concepts defined here to provide machine interpretable pointers to services that provide differing geospatial representations of the same catchments as well as data from water quality and water quantity observations that characterize some aspects of the catchments. A client could then use those links for automated workflows and data product generation.

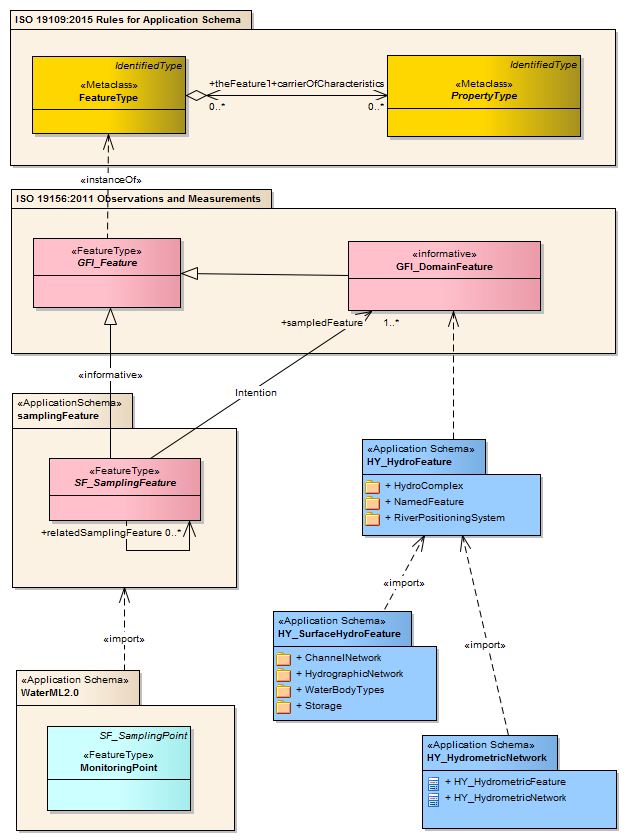


Figure 1: HY\_Features in the context of the OGC Abstract Specifications

# Conformance

This standard defines the conceptual model for identification of hydrologic features and their fundamental relationships. The conceptual model may be used in two ways: a) to derive implementation classes for data exchange or b) via reference (referred to here as mapping) from terms used in an implementation to the equivalent terms in the HY\_Features model. The form of such a mapping is not specified in this standard, but in general there is correspondence expected between particular implementations of hydrologic features and realized HY\_Features concepts. There will be an exact correspondence or a correspondence to a specialization of a HY\_Features class with narrower scope. Since no technical semantic mapping standard is supported by the OGC standards baseline at this time, only the expressivity requirements of mappings are specified in relevant conformance classes. However, a semantic mapping implementation itself could be considered to be a OGC HY\_Features standardization target, but is not in the scope of this standard.

The annexes C-F of this document provide examples for a ‘descriptive mapping’ for the

* Australian Hydrological Geospatial Fabric (AHGF) [11],
* USGS National Hydrography Dataset Plus (NHD Plus)[10],
* INSPIRE Hydrography theme [2],
* French National Service for Water Data and Reference-dataset Management (SANDRE) [12].

These mappings are intended to provide an understanding of the basic relationship of relevant HY\_Features concepts and a particular hydrologic feature implementation. An intended OWL encoding (future document) of the HY\_Features application schema will formalize the mapping from the implementation to this specification through use of encoding rules that allow direct correspondence of schema elements with the UML elements defined.

Requirements for OGC HY\_Features standardization target types are considered:

* Implementations (encodings such as OWL and RDF) of the HY\_Features conceptual UML model described in this standard and
* Implementation schemas formally mapped to HY\_Features concepts including Feature Type classes and associative relationships.

For brevity, the terminology **implement** is used to indicate either a direct encoding or the existence of a formalized mapping that would enable a client, at run-time, to determine that a particular implementation class implements a specific HY\_Features concept.

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

In order to conform to this OGC™ interface standard, a software implementation shall choose to implement any one of the conformance levels specified in Annex A (normative).

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

# Normative References

The following normative documents contain provisions that, through reference in this text, constitute provisions 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.

OGC Abstract Specification Topic 1, Feature Geometry   
(aka ISO 19107:2003, Geographic Information — Spatial schema)

OGC Abstract Specification Topic 2, Spatial referencing by coordinates   
(aka ISO 19111:2007, Geographic Information — Referencing by coordinates)

OGC Abstract Specification Topic 5, Features   
(aka ISO 19101:2002, Geographic Information—Reference Model)

OGC Abstract Specification Topic 11, Metadata (aka ISO 19115:2012, Geographic Information — Metadata – Fundamentals)

OGC Abstract Specification Topic 19, Geographic information - Linear referencing (akaISO 19148:2012, Geographic Information — Linear referencing)

OGC Abstract Specification Topic 20, Observations and Measurements (aka ISO 19156:2011, Geographic Information — Observations and Measurements)

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

ISO 19108:2006, Geographic Information — Temporal schema

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

ISO 19133:2005, Geographic Information — Location-based services – Tracking and navigation

# Terms and Definitions

This document uses the terms defined in Sub-clause 5.3 of [OGC 06-121r8], which is based on the ISO/IEC Directives, Part 2, Rules for the structure and drafting of International Standards. In particular, the word SHALL (not "must") is the verb form used to indicate a requirement to be strictly followed to conform to this standard.

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



application schema

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

boundary (line)

Geometric representation of the (topological) catchment boundary, usually a geometric composite curve

NOTE: This definition references the definition of a *divide* described as summit or boundary line [9].

catchment

A physiographic unit where hydrologic processes take place. This class denotes a physiographic unit, which is defined by a hydrologically determined outlet to which all waters flow. While a catchment exists, it may or may not be clearly identified for repeated study.

NOTE: This approach considers the catchment concept to be the basic unit of study in hydrology, water resources management, and environmental reporting. The approach is meant to be holistic, referring to the continuous interaction of surface and subsurface waters within a catchment, even if a particular representation of the catchment refers to only surface or subsurface aspects of the catchment. Special subtypes such as drainage basin and groundwater basin may be defined with a particular application.

The synonym use of the terms catchment and catchment area as documented in the WMO/UNESCO International Glossary of Hydrology (which is the key reference for the definitions in the HY\_Features model does not clearly distinguish between the catchment concept and its geometric representations such as catchment area, nor between catchment and its possible specializations like drainage basin and groundwater basin.

The essential logical separation of concerns between a common concept and its representation (interpretable data) is dealt with by defining separate features for the catchment and its representation and may be understood as a refinement of the complex, ambiguous definition given in the glossary. See also clause 5.4 of this standard on the use of WMO terminology.

catchment area

Two-dimensional (areal) topological feature realizing the logical catchment in terms of a face bounded by catchment boundary and flow path edges. The concept of a face bounded by edges is described in detail in the ISO topology model [ISO19107].

NOTE: Hydrologically, the catchment area references the catchment having a common outlet for its runoff [9] through using the synonym *catchment area* to express the two-dimensional representation of the catchment [4.2]. The catchment area is usually represented as a geometric surface, and the measure of the catchment area may be denoted as surface area (if required).

catchment boundary

One-dimensional (linear) feature realizing the logical catchment) in terms of a topological edge bounded by inflow and outflow nodes, and associated with catchment faces inside of the boundary. The concept of an edge bounded by nodes is described in detail in the ISO topology model [ISO19107]. A catchment boundary is usually represented as boundary line.

NOTE: Hydrologically, the catchment boundary references the *divide* separating adjacent catchments [9].

catchment topology

Topological pattern of a catchment interacting with another catchment at its outfall. Catchment topology references the topological closure of catchment and outfall determined hydrologically through the union of a catchment and its common outlet.

channel

Natural or artificial waterway, clearly distinguished, which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water [9].

channel network

Aggregate of depressions and channels which continuously or periodically contain water.

contour (line)

Geometric representation of the (topological) water edge, usually a set of curves (multi-curve).

NOTE: This definition references the definition of a *contour-line* on a map indicating the locus of points at which a certain property is constant (e.g. elevation, salinity) [9].

cross section (of a stream)

Section of a stream at right angles to the main (average) direction of flow [9].

cross Section (of a stream bed)

transversal section of a stream bed in a vertical plane.

NOTE: This definition references the definition of a *bed profile* describing the shape of a stream bed in a vertical plane [9].

data

Documented value of some characteristics of a real-world phenomenon.

data set

Data compiled and arranged into a set.

data product

Data set compiled for a specific purpose, e.g. for global dissemination using Web services.

dendritic catchment

Catchment wherein all waters flow to a single common outlet. A dendritic catchment is permanently connected to others in a dendritic (tree) network.

NOTE: This definition references the most common *drainage pattern* of streams ultimately flowing into the ocean after joining together at confluences into larger streams.

depression

Landform lower than the surrounding land, containing water, or not.

domain feature

Feature of a type defined within a particular application domain. [ISO 19156].

endorheic (drainage)

Draining [ultimately] into interior catchments [9].

exorheic (drainage)

Draining [ultimately] into the ocean [WMO, 2016).



feature

Abstraction of real-world phenomena. [ISO 19101]

flow path (also flowpath)

One-dimensional (linear) feature realizing the logical catchment in terms of a topological edge bounded by inflow and outflow nodes, and associated with left-bank and right-bank catchment faces. The concept of an edge bounded by nodes is described in detail in the ISO topology model [ISO19107].

NOTE 1: With respect to the river positioning system described in this standard, the flow path forms the axis in a linear coordinate system. This corresponds to the linear element ‘that serves as the axis along which linear referencing is performed’ as described in the OGC Abstract Specification Topic 19, Linear referencing [aka ISO 19148].

NOTE 2: Hydrologically, the flow path references the *path line* described by a moving particle of water [9].

flow line (also flowline)

Geometric representation of the (topological) flow path, usually a geometric curve.

NOTE: This definition references the definition of a *path-line* [9] through using the synonym *flow line* to express the geometric representation of the flow path.

hydrographic network

Aggregate of rivers and other permanent or temporary water bodies, including lakes and reservoirs [9], standing in depressions or moving in channels.

NOTE: Not to be confused with the network of hydrological stations and observing posts.

hydrologic complex

Collection of separate hydrologic features forming a closed, hydrologically determined system where the union of catchment(s) and a common outlet (conceptualized as an outfall) is realized by a ‘complex’ of hydrologic features. This concept is rooted in the idea of topological closure of catchment and outfall such that a realization of the logical catchment is always of higher topological dimension than the realization of the corresponding outfall. For example, a linear flowpath realizing a catchment may be understood as an edge between inflow and outflow nodes; the areal realization of a catchment as a face bounded by linear inflow and outflow.

NOTE: Hydrologic determination means that any catchment has a common outlet for its runoff. Any place to which water may flow can be associated with a corresponding catchment, even if catchment and outfall may be unknown or not represented in a particular application.

hydrologic feature

Feature of a type defined in the hydrology domain, whose identity needs to be maintained and tracked through a processing chain from measurement to distribution of hydrologic information.

hydrologic realization

Hydrologic feature that realizes a logical concept within the hydrologic complex. Example: Hydrographic network realizing the logical catchment as network of one-dimensional flowpaths.

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. [9]

hydrometric feature

Feature of a type which denotes a physical structure intended to observe properties of a hydrologic feature.

NOTE: This definition references the definition of a *hydrometric station* at which data on water in rivers, lakes or reservoirs are obtained on physical and chemical properties of water [9]. A hydrometric feature may be a composite station configured by arranging several monitoring components. Used to sample a hydrologic feature, a hydrometric feature may be considered a *sampling feature* of defined in the ISO Observation model. A sampling feature is described in general in ISO 19156: Observation and Measurement, the special monitoring point of hydrologic observation is described in the OGC WaterML 2.0: Part 1- Timeseries standard [4].

hydrometric network

Aggregate of logically connected monitoring stations used for hydrologic observation.

NOTE: This definition references the definition of a *hydrological network* hydrological stations and observing posts situated within catchment in such a way as to provide the means of studying the hydrological regime [9].

hydrometry

Science of the measurement and analysis of water including methods, techniques and instrumentation used in hydrology [9].

indirect position

position describing the location of a feature relative to the known location of another feature.

Indirect position implies a logical link between the feature to be placed and the referenced feature, along which the position can be determined. Recognizing the catchment as the logical link between inflow and outflow, the topological path realizing the catchment between inflow and outflow nodes can be used to place features along it. Common examples in hydrology are the mileposts along a river referencing the source or/and the mouth.

NOTE: This definition corresponds to the linear referencing concept as described in the OGC Abstract Specification Topic 2, Spatial referencing by coordinates [ISO 19111].

interior catchment

Catchment wherein all waters are collected endorheic; an interior catchment is not connected to other catchments.

NOTE: This definition is rooted the *blind drainage* pattern of collecting water in sinks or lakes not connected to streams [9].

longitudinal section (of a stream)

Vertical section of a stream in longitudinal direction.

NOTE: Note: This definition is rooted in the definition of a *longitudinal section* along a channel at its center line [9], but generalized for all types of vertical section along a line.

longitudinal section (of a stream bed)

Longitudinal section of a stream bed in a vertical plane.

NOTE: This definition references the definition of a *bed profile* describing the shape of a stream bed in a vertical plane [9].

main stem

Main course along which a stream flows, usually the main section of a stream from headwaters to the mouth, except tributaries.

mapping

Establishing a semantic relationship between particular implementations of a common concept and the realized normative concept using a formalism that specifies how elements from a source model may be transformed to a target model.

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.

nillable

Nillable is meant in this standard to signify that the a feature property logically exists but is unknown in a given implementation.

outfall

Logical outlet of a catchment. The outfall represents the logical place where a catchment interacts with another catchment. The outfall denotes the union of a catchment and its common outlet which means in general that each catchment exists with an (logical) outfall, and that an outfall cannot exists without a corresponding (logical) catchment.

NOTE: The existence of a logical outfall which is unknown, un-realized, or not represented, in a given implementation is termed ‘nillable’ in this standard. For example, a logical outfall exists in the form of flow to the subsurface or atmosphere but is unknown in implementation focused on surface water hydrology.

representation

Any processible data, data set, or data product, which can be used in the place of an existing feature concept.

river positioning system

System applied to place a feature on a watercourse by using a linear referencing along it. This requires a one-dimensional coordinate system, and a local datum which defines its origin and direction in relation to the watercourse, on which the feature is to be placed.

NOTE: A (hydrologic) feature of interest which is located along the locating one-dimensional flowpath between inflow and outflow nodes, corresponds in general to the linear referencing described in the OGC Abstract Specification Topic 19, Linear referencing ‘specifying a location relative to a linear element along that element’ [ISO 19148].

river reference system

Linear coordinate system in which the one-dimensional topological realization of a catchment forms the axis, and the origin is located at the outfall of the realized catchment.

NOTE: This corresponds to the concept of a linear coordinate system as described in the OGC Abstract Specification Topic 2, Spatial referencing by coordinates [ISO 19111] specifying that a linear feature has to form the axis.

storage (of water)

Impounding of water in surface or underground reservoirs, for future use. [WMO,, 2016]

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

stream

Water, generally flowing in a natural surface channel, or in an open or closed conduit, a jet of water issuing from an orifice, or a body of flowing groundwater [9].

water body

Mass of water distinct from other masses of water [9].

water edge

One-dimensional (linear) feature realizing the logical catchment in terms of a topological edge bounded by inflow and outflow nodes. The concept of an edge bounded by nodes is described in detail in the ISO topology model [ISO19107].

NOTE: Hydrologically, the water-edge references the *shore-line* of intersection between a water body and the confining land [WMO. 2016].

watercourse

Natural or man-made channel through or along which water may flow [9], including large interstices in the ground, such as cave, cavern or a group of these.

# Conventions

This section provides details and examples for any conventions used in the document. Examples of conventions are symbols, abbreviations, use of XML schema, or special notes regarding how to read the document.

## Identifiers

The normative provisions in this specification are denoted by the URI:

[http://www.opengis.net/spec/{standard}/{m.n}](http://www.opengis.net/spec/%7Bstandard%7D/%7Bm.n%7D)

All requirements and conformance tests that appear in this document are denoted by partial URIs which are relative to this base.

## Symbols (and abbreviated terms)

CHy WMO Commission for Hydrology

GML Geography Markup Language

GRDC Global Runoff Data Centre (GRDC)

GWML2 GroundwaterML 2

HDWG OGC Hydrology Domain Working Group

ISO International Organization for Standardization

OGC Open Geospatial Consortium

OWL Web Ontology Language

RDF Resource Description Framework

UML Unified Modeling Language

WaterML 2 working title for the indented suite of water-related OGC standards

WIS WMO Information System

WIGOS WMO Integrated Global Observing System

WMO World Meteorological Organization

XML eXtensible Markup Language

## UML notation

Most diagrams that appear in this specification are presented using the Unified Modeling Language (UML) static structure diagram, as described in Sub-clause 5.2 of the OGC Web Services Common Implementation Specification (OGC 04-016r2). UML classes are named in UpperCamelCase and property names in lowerCamelCase.

## WMO Terminology

The HY\_Features model uses—as far as possible—terminology recommended by the WMO Commission for Hydrology for use in the WMO Member countries. The key reference is the "International Glossary of Hydrology" [9] [[2]](#footnote-2), a joint publication of the WMO and the UNESCO (hereinafter referred to as WMO/UNESCO glossary of hydrology). Wherever appropriate, terms from this glossary are applied to the feature concepts in this standard to capture meaning and contextual relationships. The synonym approach widely used in this glossary is interpreted in that way that glossary terms, when explicitly defined as synonyms, were defined as such even if they are not synonymous in every respect. Differences in terminology were explored through reconciling the explicit definitions documented in the glossary with aspects reflected in various data sets and products in use. The accepted terms were augmented with the relationships inferred from other terminology in order to define complex terms that do not clearly distinguish between a specific logical concept and its geometric representation or between a general term and its specific conceptual meaning. The definitions used in the conceptual model described in this standard may be understood as a conceptual refining of the definitions given in the WMO/UNESCO Glossary of Hydrology.

Though basically rooted in the definitions given in the WMO/UNESCO Glossary of Hydrology, for the purpose of testing the applicability of the conceptual model in the context of surface water hydrology, the definitions applied to hydrologic features defined in this standard refer to surface water.

Some requirements classes defined in this standard refer to the Scoped Name concept of ISO 19103: Conceptual Schema. Intended to form a basis for information and data sharing in the community of the WMO member countries, the Scoped Name should reflect a name endorsed by the WMO.

## Naming convention

The HY-prefix used in the UML model follows the ISO naming conventions for UML elements. There is no explicit requirement to use this name in an implementation for the same semantic elements, but it is required to provide an explicit mapping between terminology used and HY\_Features to unambiguously indicate hydrologic feature concepts to support unambiguous interpretation in cross-domain applications. While there is not a recognized standard method for recording mappings between abstract element names and implementations; it is expected that semantic and system interoperability will be facilitated by making such mappings available as part of a dataset's documentation.

# Clauses not Containing Normative Material

## The abstract idea of the hydrology phenomenon

Processes that continuously deplete and replenish water resources cause or result in a wide range of phenomena that are the subject of monitoring, modeling and reporting in hydrology and related sciences. These distinctly named or otherwise uniquely identified real-world hydrologic phenomena are conceptualized and referred to as hydrologic features in this standard. This standard applies to data and data products that represent these hydrologically defined features.



Figure 2: Processes of the Hydrologic Cycle

Water is moving from the atmosphere to the Earth and back to the atmosphere due to the processes forming the Water Cycle (Figure 2). 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. Excess water overflows these formations and is driven downhill by gravity. Water flowing over soil or rock causes erosion to occur. This erosion tends to concentrate flowing water into water bodies that flow downhill using a connecting system of channels intersecting other water bodies along their way to a common outlet, conceptualized as a potentially complex outfall feature.

Looking back upstream from the outfall, the corresponding catchment feature can be described as a main linear flowpath feature, an areal feature, a boundary feature that encompasses the drained area, a network of water body features, a network of channel features, or a network of hydrometric station features, all representing the catchment. The concepts and terminology used in the preceding sentences form the conceptual and semantic basis for this standard.

As described above, the most general abstraction of the hydrology phenomenon is the catchment. A catchment is a recognized unit of study where hydrologic processes form physiographic features that are realized in various data products. In this specification, the term realization is used to imply that a catchment is recognized and identified for the purpose of referencing it by name or within a network of catchments. The term representation is used where geometry is used to represent a catchment's physical features. Using these definitions, we can say that a catchment is an unrealized conceptual feature that can be realized by features for use in topological networks and features with explicit geometry.

Depending on application and (spatial) scale, the same catchment may be realized in many different ways. The following describe different examples where this multiple realization concept is important:

* The most typical example is that scaling a map-visualization up or down leads to multiple more or less detailed representations of the same realized hydrologic feature.
* Analyses and reports from various disciplines reference differing spatial representations of the same conceptual catchment.
* Some applications require cartographic (visual) representations while others are focused on topological (network connectivity) realizations only.
* A catchment may be represented geometrically by streamlines, drainage area or the bounding polygon, or realized topologically as a face, edge, and/or nodes.

Catchments can be realized as geographic streams and outfalls, simplified geographic stream representations, schematics of streams and outfalls, an aggregate of catchments, simplified representations of catchment aggregates, or schematics showing how catchments relate (Figure 3).



Figure 3: Illustration of multiple representations of a catchment

The concept of catchment used in this standard is that it is described physically as illustrated above. It can also be described as the recognized unit of water resources assessment and management across administrative jurisdictions. In multi-stakeholder collaboration and cross-domain research projects, the catchment is recognized as a shared monitoring and reporting unit, in that monitoring stations are usually on a river in a recognized catchment, attributes of the catchment may be in reference to its geometry, and its inflow and outflow are network locations connecting it to other catchments in a topology. Examples of catchments include "Hydrologic Unit Code" (HUC) catchments defined by the U.S. Geological Survey for research and regulatory data systems to use as a reference [7] and "River Basin Districts" of the European Water Framework Directive [1].

## Catchment and multiple realizations of the catchment concept

The core concept of the HY\_Features model is that a study of the Hydrology phenomenon will reference common conceptual entities of the real world such as catchment, water body, channel, or stream gaging site, through the use of features according to a specific model (as per ISO 19109 General Feature Model). Depending on the field of study or application, complex hydrology phenomenon features may be realized in many ways. Recognizing the catchment as the holistic unit of study leads to the idea that each study of a catchment may realize it in a particular way, leading to multiple realizations of the same conceptual entity. Depending on the scientific concern, the specific hydrologic feature is understood as one of many potential realizations of the conceptual entity being studied.



Figure 4: Idealized catchment. This idealized catchment diagram is used to represent the catchment concept with no emphasis on any realization or representation. In the diagrams below, aspects of this diagram are highlighted to emphasize particular concepts of the HY\_Features conceptual model.

The catchment model described in this standard conceptualizes the hydrologic determination of a catchment by its common outlet to which all waters flow by defining an outfall (feature) as the logical outlet of a corresponding catchment (feature). Referencing this union of a catchment and outfall, the catchment can be thought of as a logical link between a catchment’s inflow and outflow, whereby these may be joined from diffuse inflow, or spread outflow. Given that this logical link can be topologically realized, a catchment topology pattern is implied expressing the connectivity of catchments interacting at outfalls recognized as their topological boundary.

All hydrologic features which realize a catchment referencing this catchment topology pattern form a hydrologic complex comprising the catchment and outfall features, as well as any feature realizing the logical catchment and its outfall. This includes topological realizations such as flowpath and catchment area, as well as hydrologic realizations like water body or channel, or typical networks connecting these.



Figure 5: Multiple graphical representations of a catchment (from top left to bottom right): a) catchment boundary, b) catchment area, c) flowpath of catchment d) network of sub catchments, e) cartographic view, f) geo-schematic view, g) hydrographic network, h) network of logically connected monitoring stations.

Catchment boundary, catchment area, and a linear flowpath are the most common topological realizations of a logical catchment, and are widely used to create cartographic representations of a catchment. Map layers that separately visualize the hydrographic network of water bodies (typically as blue lines for small rivers and blue polygons for larger rivers and lakes) and of channels (typically lines displaying a drainage pattern indicating the path flow may follow), or a network of hydrometric monitoring stations, are usually combined to represent the catchment as a whole. Such cartographic data products are usually exposed in map services, while the water body or channel features are provided with an appropriate geometry and location usually in features services. To illustrate these ideas, Figure 5 shows an idealized catchment (Figure 4) with different graphical representations highlighted.

Each of these graphical representations is a different way of looking at the catchment and its interaction with other features. It is generally not possible to inspect a particular realization and understand all characteristics of the catchment because the different types of features are often realized using identical data models. For example, a map showing a set of catchment polygons may display an aggregate of sub-catchments, or a collection of catchment polygons that overlap each other occupying the same space. In order to understand what catchment concept is being realized, the more detailed information about their type and role in a data model needs to be declared. Such relationships and potential constraints may be declared between a high-order catchment and the catchments generally nested therein, or between an aggregate network of catchments that encompasses nested catchments without any overlap, or the upstream-downstream direction of flow applied to a set of catchment polygons.

In some cases, a catchment may be realized as an identified feature without specified geometry that takes part in a topological network of catchments. This is common, for example, in data systems supporting hydrologic modeling. Catchment attributes needed to parameterize a model, may be generated using various geospatial data sets, but the geometric information is not necessary for the actual modelling. In applications like this, and in data systems supporting such applications, a catchment can be realized by an identifier, attributes, and topological connections that are not necessarily the same as would be implied by the geometric representation of a catchment. That is, while a catchment has a geometric representation that is an area, which would imply it is a topological face, the catchment can have a coexisting non-geometric realization that is a topological edge which conveys flow from inflow to outflow. This flexibility, where a realization of a catchment feature does not need to have an explicit geometric representation allows a decoupling of representational and conceptual concerns with the ability to explicitly link data products that would not otherwise be easily related.

Specific feature types are defined to describe the named or otherwise uniquely identified, hydrologic feature, as well as the catchment and its feature realization(s). The HY\_HydroFeature feature type is described, in section 7.4.2, the HY\_Catchment, HY\_Outfall, HY\_CatchmentRealization and HY\_OutfallRealization feature types are described in section 7.4.3 as well as the special feature realizations of the holistic catchment idea HY\_CatchmentArea, HY\_CatchmentBoundary, HY\_Flowpath, HY\_WaterEdge, HY\_HydroNetwork and HY\_CartographicRealization.

## Catchment hierarchy and catchment topology

Catchments may be connected in topological networks which provide continuity between catchments, the ability to aggregate catchments, and to trace catchment networks up- or down-stream. In geometric representations, topological connectivity is typically indicated by adjacent polygon edges, nesting of polygons, or through connection of linear features at nodes. However, since geometric realization of hydrography serves many purposes and may not be needed at all, it is not appropriate to rely only on geometry as the basis for topology. Instead, topology can be expressed as relationships between conceptual features of a particular type which may or may not have explicit geometric realizations.



Figure 6 (C1-C5, from left to right): C1, Typical catchments with one inflow and one outflow each; C2, Joined (conjoint) catchments flowing into a single downstream catchment; C3, catchments joining in a water body or wetland with no clear network; C4, catchments joining through intermittent or subsurface flows C5, catchments that join through areas of complex or braided channels.

In a network of catchments, morphological detail may be specified in many ways. Inflows are generally conceptual in headwaters, and outflows are often complex where water flows out of a network. As shown in Figure 6 catchments may connect through simple confluences (Figure 6, C1), water bodies or wetlands (Figure 6, C3), intermittent or subsurface flows (Figure 6, C4) or complex braided streams (C5). Like diffuse (multiple) inflow conceptually joined in a ‘conjoint’ catchment (Figure 6, C2), spread (multiple) outflow may be joined in a catchment flowing out at a single, logical outflow. Although these cases require different geographic representations, they can be represented using the same pattern of the catchment bound with its common outlet. Since all these cases can be specified referencing a simple catchment topology, no special treatment is required to handle the variation of flow processes.

### Hierarchy of catchments

Any catchment may be nested or aggregated in a larger containing catchment or split into multiple sub units forming a hierarchy of catchments. Two types of catchment hierarchy are supported in HY\_Features: basic nesting and dendritic aggregation: 1) Basic nesting allows any catchment to have a reference to a containing catchment (Figure 7). This allows collections of sub-catchments to be grouped into larger units, but does not define any particular interconnections between these sub-catchments. 2) Dendritic hierarchies are aggregates of catchments (Figure 8) with simple topological relationships that allow determination of contribution of flow to downstream catchments. To reflect the organization of catchments in dendritic networks, a special dendritic catchment is defined that permanently contributes exorheic flow to a receiving catchment, and an interior catchment of endorheic flow that contributes temporarily to a receiving catchment.

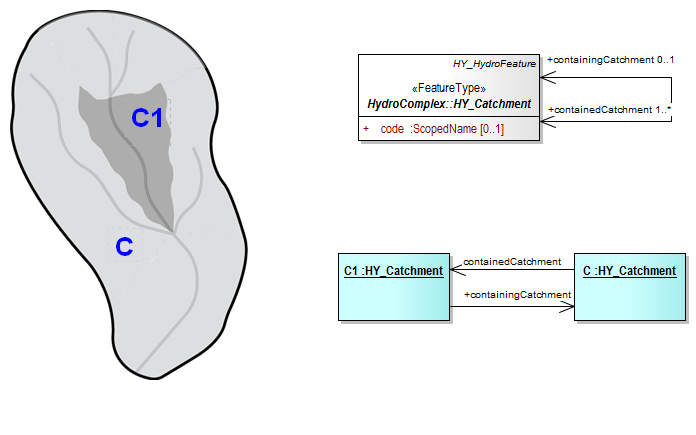


Figure 7: Catchment hierarchy – A catchment (dark grey), may be nested within a containing catchment which is another catchment (light grey)

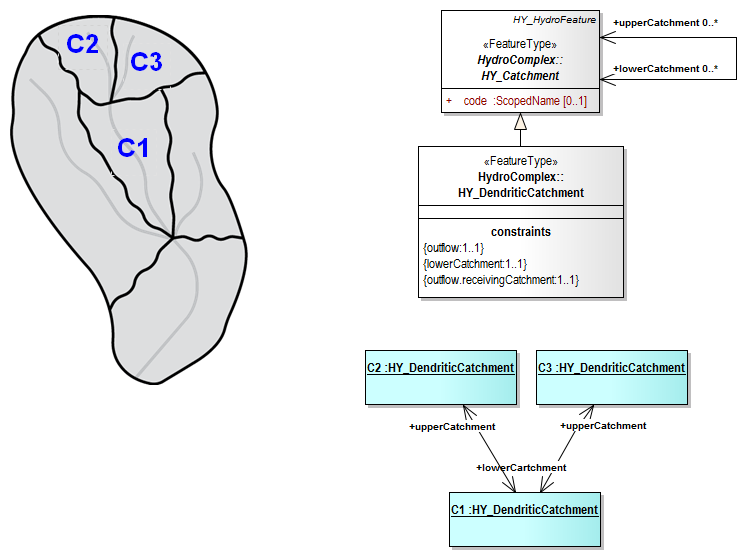


Figure 8: Catchment hierarchy – A catchment (C1, C2, or C3) may be part of a simple dendritic network of catchments which is also a catchment

### Logical network of catchments

Given the idea that a non-geospatial schematic representation of a feature can show its connection in a topological network, a catchment can be thought of as a hydrologic unit whose terrain and morphology results in a topological link between inflow and outflow.

Applying the catchment topology pattern described in section 6.2 of this standard, a logical network of catchments interacting at their outfalls can be built, and realized as network of the topological realizations each catchment may have. For example, the network of logical catchments which are each realized as one-dimensional flowpath, is realized as the network of these flowpaths, and may be represented as a sequence of lines.

The red line in Figure 9 illustrates how a single catchment which is realized as catchment boundary represented by a (darker grey) boundary line, a catchment area represented by darker grey) surface, and a part of a (light grey) network, could also be represented by displaying a topological path that is not geospatially representative but is a valid schematic representation of the connection between inflow and outflow.

Figure 9 shows to the left the catchment C1 realized as catchment area (A) and flowpath (F) depicting the definable unit where hydrologic processes take place, and to the right how these realizations of the logical catchment are expressed in UML.

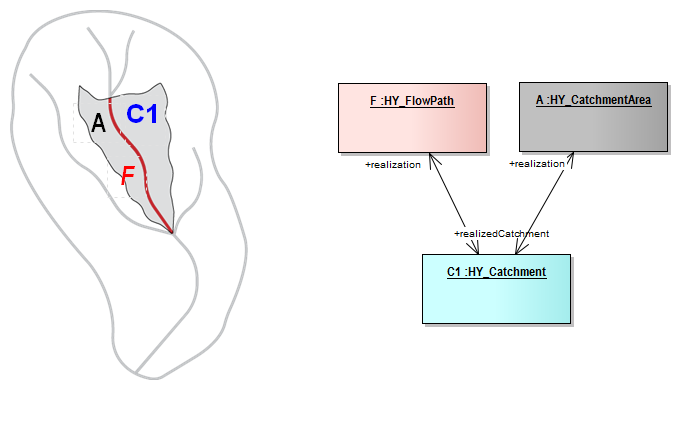


Figure 9: A catchment area (grey) and a flowpath connecting inflow to outflow (red) depicting a definable unit where hydrologic processes take place.

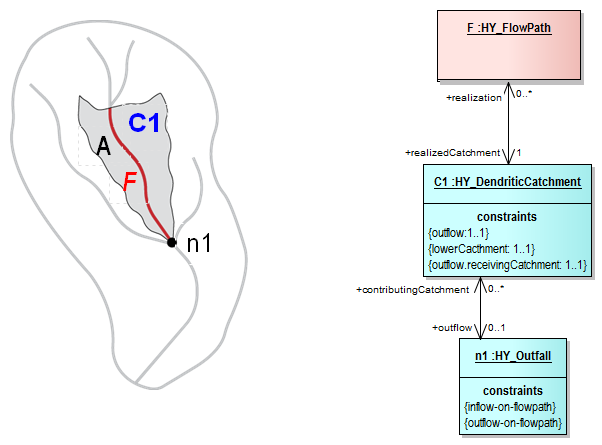


Figure 10: Catchments contributing to an identified outflow node. Note that some catchments contribute to a common outflow node.

The catchment C1, shown in Figure 10, contributes flow to an outfall n1. Outfall n2, shown in Figure 11, contributes inflow to catchment C1. Networks of catchments can be constructed using this pattern and the idea that two or more catchments that flow into the same downstream catchment, first flow to the same outflow which is the inflow of the receiving downstream catchment. In a network of dendritic catchments, an outflow serves only one receiving catchment.

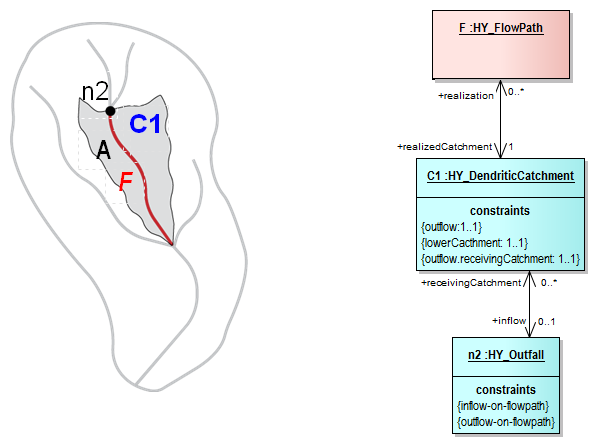


Figure 11: Catchments receive inflow via an identified inflow node. Note that nodes are not necessarily geographic features, but are rather nodes in a graph representation of the river network.

Topological nodes as displayed in the examples above may seem to stand alone as points of interaction in the network, but in reality, they are (potentially complex) catchment outlets, denoted as outfall features. Whether an outfall is referred to as an inflow or outflow is always in reference to a particular catchment. This means that an outfall serves as the outflow of some contributing catchment(s) and the inflow of some receiving catchment(s). In this standard, the inflow and outflow role names of the conceptual outfall are used to unambiguously describe the role of an outfall with respect to a catchment.

In a dendritic network, the outflow that one or more dendritic catchments flow to (which is not necessarily a single geometric point) must contribute to one and only one receiving catchment, unless it is a terminal catchment. Given that the dendritic catchment is defined as a special type of the more general catchment concept, it inherits the general nesting as defined for the catchment as shown in Figure 7.

Being logical places, inflow and outflow have no explicit positions but are potentially complex catchment outlets. In fact, inflow and outflow may be represented by a complex geometry with multiple parts. This is important in the case of a catchment that contains a broad river bottom with complex braided channels and two or more primary inflows. There may be no clear way to identify an inflow location, but from a topological perspective each contributing catchment can be said to contribute to the same outflow and that diffused inflow can be said to contribute to the catchment in question. There might be two ways that catchments with multiple inflows can share a common outlet: 1) as separate catchments, each realized as a flowpath connecting a single inflow and the common outflow, or 2) as a non-divided catchment contributing as a whole to the outflow node. The latter case, referred to here as a conjoint catchment, requires to determine the main flowpath, or to perform linear referencing (along the main flowpath). However, a conjoint catchment is often easier to delineate and more convenient. Note that in this case, the complexity required to support geospatially accurate linear referencing may be lost in the interest of easy network navigation capabilities.

Figure 12 (C6-C7, from left to right): Encapsulation of non-dendritic stream network topology. C6: The left figure shows a case where it is not possible to determine to what extent flow from catchment F contributes to catchments E, B or C. C7: The right figure shows how catchments E, B, and C can be aggregated so nodes N2 and N3 are treated as a single virtual inflow node, so that all the flow from catchments D and F accumulate in the resulting catchment X.

It is worth noting that non-dendritic networks are often realized as a dendritic catchment network by introducing joint catchments that contain the non-dendritic parts. Figure 12 shows an example of a non-dendritic stream network, where it is not possible to determine to what extent flow from catchment F contributes to catchments E, B or C (Figure 12,C6). Aggregating the catchments E, B, and C (Figure 12, C7) and collapsing the nodes N2 and N3 into a single virtual inflow node, will accumulate all the flow from catchments D and F in the resulting catchment X contributing inflow into catchment A via the node N1. Using this encapsulation approach, catchments can be represented using a simple tree structure where an upstream-downstream relation can be built without the need for complex hydrography between inflow and outflow nodes.

The topological pattern of a catchment connecting inflow and outflow applies to all possible realizations of a catchment, whereby the realizations of inflow or outflow are always of lower topological dimension than the realization of the corresponding catchment. A catchment may be topologically realized as a solid bounded by inflow/outflow faces, each face bounded by inflow/outflow edges, and each edge bounded by inflow/outflow nodes. Each of these realizations may be represented using an appropriate geometry type. For example, an outflow node may be represented as geometric point located at the beginning of the flowline representing the flowpath (edge) which realizes the contributing catchment. This corresponds to the topology model defined within the OGC Abstract Specification Topic 1, Feature geometry (aka ISO 19107: Spatial Schema) which is considered as the general framework to describe the scale-independent unity of catchment and outfall.

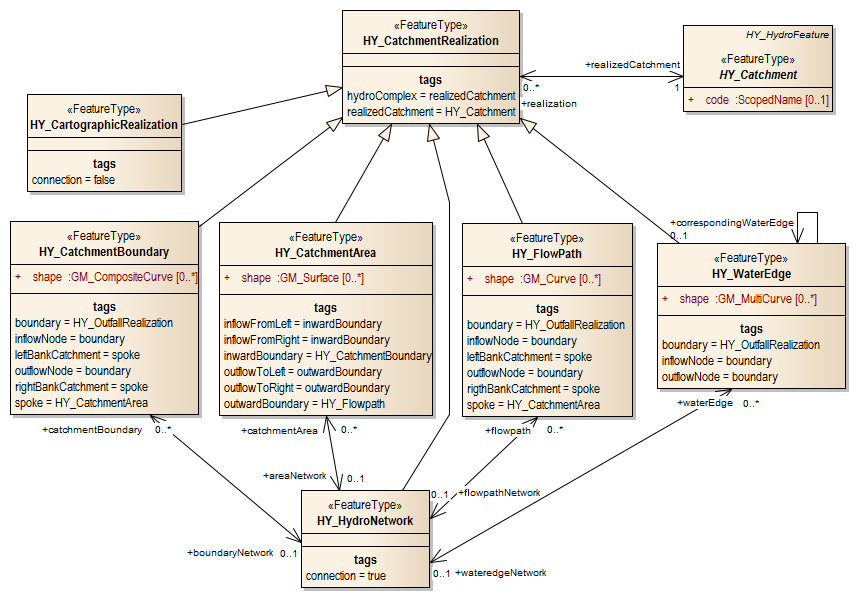


Figure 13: Catchment realization features with ‘tags’ expressing catchment topology

To emphasize this catchment topology pattern, the correspondence to the general topology model is expressed by means of ‘tagged values’ describing the topological *boundary* and *spoke* properties using terms common in hydrology. ‘Tagged values’ are also used to indicate in general the connectivity of catchment realization features. The ‘tags’ shown (Figure 13) in may be understood as guidance for mapping rather than an implementation requirement. For example, the flowpath which realizes a catchment as topological edge has an inflow node and an outflow node as boundary, and forms simultaneously the outflow-edge boundary of a left- or right-bank catchment area which realizes the catchment as topological face.

Specific feature types defined to reflect the logical network of catchments are described in section 7.4.3 of this standard: HY\_CatchmentAggregate, HY\_DendriticCatchment and HY\_InteriorCatchment. The domain-specific feature types defined in this standard may also be used to express catchment topology expressed in linked data and data products. Such data and products will normally represent a specific aspect of the hydrosphere or a particular place or time where water occurs or is distributed. Furthermore, special network or routing models may be related to the hierarchical network of catchments.

## Indirect Position and river reference system

It is common practice in hydrology to add new features (typically observation stations, but also designated reaches, or flood plain zones) to an existing network of such features, and to reference such features along a watercourse. Recognizing any identified location on a network as the outflow of a contributing catchment, or the inflow of a receiving catchment, an arbitrary new location can be placed on the network based on catchment topology alone through reference to an existing outfall upstream or downstream. Understanding such a reference as a positioning ’along a river’, the one-dimensional flowpath realization of a catchment can be used for linear referencing. This concept of indirect position requires a ‘referencing along a river’ providing a specific linear coordinate system, and a local datum which defines its origin and direction in relation to the linear feature, on which the feature is to be placed.

The HY\_Features conceptual model defines a river reference system which has three components: 1) an origin at an inflow or outflow outfall; 2) a shape defined by the flowpath of a catchment that starts at the origin; and 3) a linear distance or relative (percentage) measure. Each catchment has its own reference system which can be combined as necessary using catchment topology; each river reference system must have one outfall (origin) and one representing flowpath (shape).

### Indirect position

Provided that the network of catchments is realized as network of its topological realizations, and that each catchments is realized as a one-dimensional flowpath, any feature can be located along such a ‘linear’ realization. This is possible considering that any location on the land surface can be an outfall of a catchment. In this case, the new location is placed as outfall node bounding the a flowpath at one side relative to an already established outfall node bounding the same flowpath at the other side.

Provided that the location to be placed is declared to be a new outfall in an existing network, the already existing catchment will be split into catchments upstream and downstream of the ‘new’ outfall, each realized as one-dimensional flowpath . The upstream catchment is realized as a flowpath starting at the new location to be placed and directed to the already located inflow of the now split catchment; the downstream catchment is realized by a flowpath shape starting at the new location, but is directed to the already located outflow of the now split catchment. The unknown position of the ‘new’ location is provided relative as the distance from there to the reference location, i.e. as length of the flowpath in direction to the known inflow or outflow. In this way a position may be assigned to any outfall.

Figure 14, and Figure 15 illustrate how a newly introduced network location can be located downstream of a catchment inflow, or upstream of a catchment outflow.

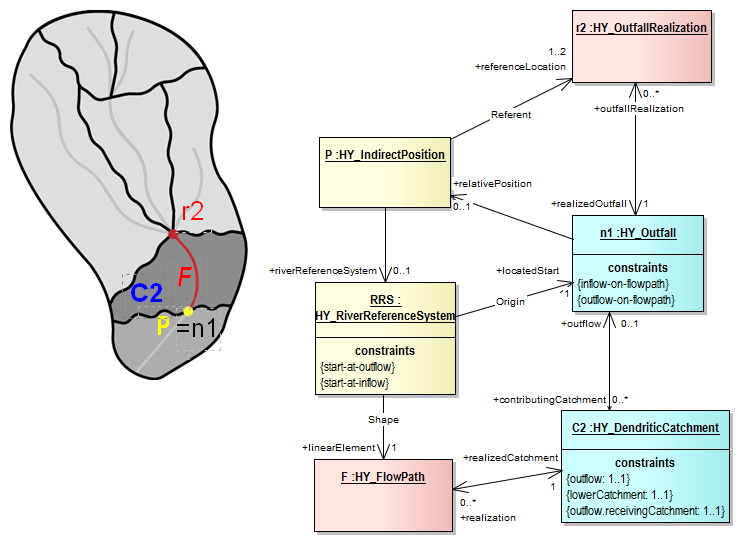


Figure 14: Position (yellow dot) downstream of a reference point (red dot). While referenced positions (P) are usually referenced to permanent locations like confluences (r2), they can also be considered to be the outflow of contributing catchment and thus, the origin of a river reference system of their own.

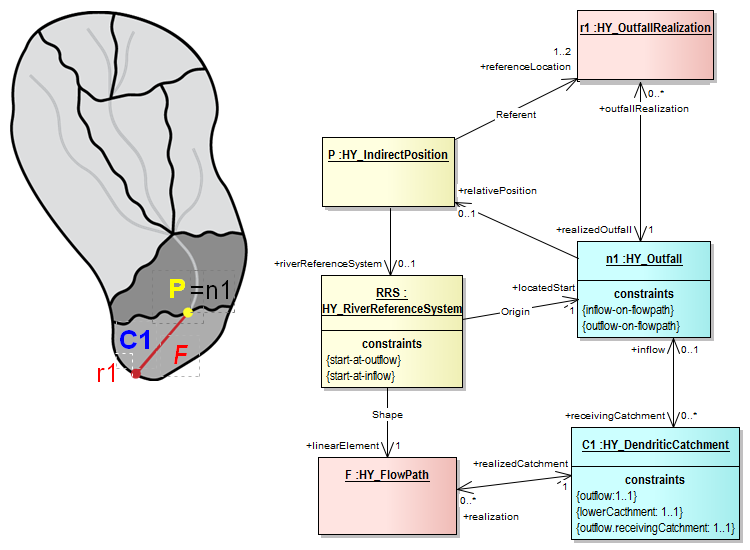


Figure 15: Position (yellow dot) upstream of a reference point (red dot). Typically, r1 would be the origin and P, the referenced point; however, the river reference system model allows for the referenced point to be the origin of its own river reference system.

Alternatively, the position of a new location can be determined interpolative as a percentage of the known distance between two already located outfalls bounding a flowpath in upstream and downstream direction, whereby the origin where the flowpath starts is set at one of these, and directed to the other outfall upstream or downstream of this. This approach may be used in the case that the new location itself is not declared to be an inflow or outflow of a catchment, as shown in Figure 16 below.



Figure 16: NEW Position (yellow dot) between two a reference points (red dots).

The river positioning system is described in detail in section 7.4.4 of this standard. It corresponds generally to the OGC standard model for linear referencing described within the OGC Abstract Specification Topic 19, Linear referencing (aka ISO 19148) which is considered as the general framework to assign a position to a catchment’s outfall along the one-dimensional topological realization of the corresponding to the outfall.

In terms of the standard Linear referencing model, the position of the outfall to be placed is comparable with the event (feature) occurring somewhere on a locating linear element, where it is located either AT a single location or between two FROM-TO locations. Given this, the existing inflow and outflow nodes may form a pair of linearly referenced locations specifying where a feature (event) is located along a locating linear element, here the flowpath, specifying the start and end location of the flowline representing the flowpath. Table 1 provides a descriptive ‘mapping’ intended to provide a basic understanding of how the HY\_Features river positioning may specify the OGC Linear referencing model.

Table 1: HY\_Features concepts comparable with the OGC Linear referencing model

|  |  |  |
| --- | --- | --- |
| **HY\_Features concept** | **Description** | **OGC LR concept** |
| RiverReferenceSystem (associates the located-start datum, and the linear-element shape) | linear coordinate system whose axis is the one-dimensional flowpath along which the feature is placed, and whose origin and direction is defined in relation to the catchment realized by the flowpath, |  |
| IndirectPosition (associates the river reference system and the reference location) | position (of the outfall to be paced) ‘occurring’ relative to a reference location along the flowpath (linear element) | event (feature) occurring along a linear element located relative to a referent |
| Outfall (associates a relative position) | located outfall AT which, or FROM which a position is assigned along the flowpath; the outfall sets up the origin of the river reference system of which the flowpath forms the axis | already located feature (referent) AT, or FROM-TO which an event feature is located along the linear feature |
| OutfallRealization (associates the realized outfall) | already existing (real) outfall used as reference location relative to which the position is assigned; | already located feature (referent) AT, TO or FROM which an event feature is located along the linear feature |
| Flowpath (associates the realized catchment) | one-dimensional flowpath along which a position is assigned to an outfall, between two outfalls; the flowpath forms the axis of the reference system whose datum is defined by the realized catchment | locating (linear) feature along which an event is located |
| DistanceToReferent | Data type, ‘measure’ expressing the indirect position as an absolute value | (absolute) measure of distance |
| RelativePosition | Data type, ‘measure’ expressing the indirect position interpolative as percentage, or descriptive | (interpolative) measure of distance |
| RelativePositionDescription | Code list, terms expressing the offset from the assigned position | offset (partly) |

### River reference system

This standard defines a simple linear river reference system using the one-dimensional realization of a catchment as its shape and the outfall of the realized catchment as its origin. Recognizing the feature of interest as outfall of a corresponding catchment, the unknown position of this outfall can be determined relative to an already existing outfall used as reference location.

Each outfall is potentially the origin of a river reference system owned by the realized catchment and uses the flowpath realization as axis. The orientation of the flowpath axis is always from origin towards the reference location, and always declared in relation to the catchment realized by the flowpath. This given, the river reference system defined by a contributing catchment has an origin at outflow node and flowpath directed towards the inflow node upstream, vice versa a receiving catchment sets up an origin at inflow node from where the flowpath is directed to the outflow node downstream.

The position is provided as the distance (length) of the curve representing the flowpath between both outfalls, or as percentage of the entire distance. In order to use an interpolative (percentage along a flowpath) linear referencing method, the flowpath used as the river reference system's shape must be bounded by an inflow and outflow node, whereby one of these must be the origin.

The HY\_RiverReferenceSystem , HY\_IndirectPosition feature types defined to reflect the positioning ‘along a river’, as well as the data types HY\_DistanceToReferent and HY\_RelativePosition and HY\_RelativePositionDescirption code list are described in section 7.4.4 of this standard.

## Surface water hydrology networks

Maps displaying a representation of a catchment are very common in hydrology research and engineering. Depending on the scientific concern, different aspects of the hydrology phenomenon are represented using application specific map symbols. Respecting the separation of scientific concerns, HY\_Features distinguishes between these by defining separate realizations of the catchment and outfall concepts which may be represented as simple points, lines, or polygons, and may be complex aggregate networks made up of collections of point, line, or polygon representations. The need to support such collections across scales is supported through the general concept of the Hydro Network described below.

The holistic idea of catchment, where a conceptual catchment has many real-world realizations, allows us to consider realizations of a catchment that correspond to different phenomena as variations of a common catchment pattern. Using this approach, the relationship of a catchment to a set of catchments can be transferred to any realization of that catchment regardless of the geometric representation in a particular data product. For example, an entire hydrographic network realization of a catchment can have simple relationships to the hydrographic network of its upstream and downstream catchments if the network itself is understood to adopt the basic catchment topology pattern.

This standard defines a hydrologically determined topology model of directed outfalls, acting as inflow or outflow nodes, and the catchment which can act as the link between them. This topological catchment network pattern can be transferred to context-specific network realizations such as hydrographic networks of water bodies or channel networks that may convey water, as well as to their various geometric representations as (poly)lines and polygons. For example, a fixed landmark on a water body, a cross-section separating a watercourse, or a station along the network, can be considered to be outfalls (outflow nodes) of a contributing catchment (link); a flowpath realizing a catchment may be drawn from an ‘inflow‘ node to the ‘outflow‘ node linking the nodes through the realized catchment. As with the hydrographic (water body) and channel (conveyance) network, the abstract catchment topology pattern can be applied to any logical or virtual network, e.g. a network of logically connected hydrometric stations.



Figure 17: Cyclic nature of the HY\_Features basic model

Figure 17 illustrates the circular relationship between five functional components of the HY\_Features model: the (logical) catchment concept (at any scale), simple topological realization of catchment and outfall, hydrological networks, waterbodiesand containers associated with realized outfalls. The cyclic nature of the basic model supports crossing scale through nesting of more or less detailed catchment realizations.

Hydrographic data is commonly organized into networks. The following sections first describe the hydrographic network of waterbodies, channel network connected conveyances, and hydrometric network of monitoring stations realizing a catchment, and how these networks relate to each other in the context of the overall HY\_Features model. The main function of these network models is to allow an aggregate of hydrologic features at one scale to act as a single encapsulated entity at another scale.

### Hydrographic and channel network

Following the definitions in the UNESCO-WMO "International Glossary of Hydrology" [9] a water body is understood as the mass of liquid water accumulated on or below the land surface as a body of flowing water, which in some parts may have stagnant water that is not moving or flowing. The water body concept formalized in this specification is consistent with this definition, but focuses on surface-water bodies only. A conceptual model capturing the specifics of bodies of groundwater as well as aquifers containing groundwater are provided by the WaterML2 Part 4 - GroundwaterML2 specification [6].

A watercourse is commonly understood as a natural or man-made channel through or along which water may or may not flow [9]. A water body is generally a flowing body of water contained in a natural watercourse, but could also be in a manmade open or closed conduit [9]. Given that the channel network (or drainage pattern) exists independent of whether it contains water, the conceptual model separates natural and manmade hydrographic features into the body of water and the unit that contains the water body. This distinction is helpful to separate concerns of hydrology--studying the occurrence, accumulation, and circulation of water--and hydraulics--focused on the analysis and design of watercourses**. Note that flow-through lakes and lakes without outflows are considered to be water bodies whose container is modeled as a surface depression.**

Water bodies with their associated water courses can be aggregated into hydrographic and channel networks identified as the hydrographic or channel network of the catchment the network drains. Individual waterbodies can be described with vertical cross- or longitudinal sections. A water body may also be stratified into distinct horizontal layers for distinct thermal, salinity, oxygen, nutrient, or storage characteristics. Water may be stored and managed in reservoirs for future use, regulation, or control. Conceptually, each water body accumulating water may be managed as a reservoir. To model reservoir capacities at multiple reservoir stages or elevations, the water-body stratum associates a reservoir feature type.**. The concept of stratum could also be applied to bathymetric contours of a lake to describe the container of a lake water body.**

To place waterbodies topologically or geographically in a network, the HY\_Features model provides a mechanism to associate waterbodies with a realization of a catchment outfall. In the case of a hydrographic network that realizes an entire catchment, the defined catchment relationships can be used for both the larger catchment realized by the whole hydrographic network and the catchment(s) whose outfalls are used to locate waterbodies within the hydrographic network. This builds the idea outlined in section 6.3 in that every identified water body has a conceptual catchment that can be arranged topologically within a catchment network and is described in greater detail in section 6.5.3.

Based on the idea, that catchment is drained by a river, it is common practice to realize a catchment as a single ‘main-stem’ flowpath (Figure 5c). Some elevation-derived hydrographic datasets define one river per catchment such that every line connecting two confluences has a single associated drainage area. Others have an identifiable ‘main-stem’ river that flows from headwaters to the common outlet. In either case, the catchment typically carries the name of the main river and its outlet is considered the mouth of the river.

The one-dimensional flowpath defined in this standard supports a simple linear representation of the catchment concept that is meant to encompass the idea of the ‘main-stem’ river. Hydrologically, the flowpath describes the path of a moving particle of water. Topologically, the one-dimensional flowpath realizes the idea of a catchment as a link connecting its inflow and outflow nodes. Catchments connected together at inflow or outflow nodes can be thought of as a network of connected flowpaths.

The flowpath concept may realize a hydrographic or channel network in that any hydrographic or channel network can have one identified flowpath connecting its inflow to outflow node. In this way, at large scales, complex networks of watercourses can have one main-stem flowpath made up of many smaller scale reaches. At very small scales a network made up of one reach also has a single main flowpath. In both cases, the flowpath is associated with the catchment it realizes and should be understood to be the one-dimensional connection between inflow and outflow. Because hydrographic and channel networks are aggregates of waterbodies and channels, it follows that the flowpath concept is related to waterbodies and channels through the networks that aggregate them.

The specific feature types HY\_ChannelNetwork, HY\_Channel and HY\_Depression feature types, and HY\_DrainagePattern code list are described in section 7.5.1 of this standard; the HY\_HydrographicNetwork, HY\_WaterBody and HY\_WaterBodyStratum, HY\_CrossSection and HY\_LongitudinalSection, HY\_Water\_LiquidPhase and HY\_Water\_SolidPhase in section 7.5.2. Section 7.5.3 describes special types of bodies of surface water.

### Hydrometric network

Water bodies are observed using monitoring stations which are typically physical locations with a well-established cross section they monitor. It is common practice to locate a monitoring station in relation to local landmarks and permanent reference points along a stream or in relation to the outlet of the monitored water body. The river reference system, described in section 6.4, gives a mechanism to locate such points in relation to establish catchment outfall locations such as confluences. When aggregated into a network, monitoring stations within a catchment can be said to make up a logically connected hydrometric network which monitors a catchment.

For the purpose of linking identified monitoring stations, (thought to be the sampling feature in terms of the observations and measurements standard) and a river or other hydrologic feature (thought to be the domain or sampled feature in terms of observations and measurements) a specific hydrometric feature participating in a hydrometric network is defined. The monitoring feature role of hydrometric features is unique in contrast to all other outfall realizations in HY\_Features, which would be used as observed domain features in observations and measurements.

Specific feature types HY\_HydrometricNetwork and HY\_HydrometricFeature are described in section 7.5.4 of this standard.

### Network navigation

Thinking about catchments realized as topological edges bounded by outfall nodes, a dendritic network of catchments may be traced upstream from the sea or a sink to the inflow/outflow nodes of (multiple) upper catchments. From there, one can navigate further ‘upstream’ eventually arriving at the outflow node of the headwater catchments. Starting at a spring, the catchment network can be traced in the ‘downstream’ direction, first to the single outflow node to which the catchment contributes then further downstream eventually arriving at the inflow node of a branching (non-dendritic), estuary or delta. In a given realization, a sequence of linear flowpaths, each realizing a catchment connected in the catchment network, may be drawn as streams or watercourses, which may or may not be geometrically connected in the representation. For example, water bodies and channel parts of a particular network may be displayed using different geometric shapes, and may look connected on a map even if they are not.

The network navigation approach described here corresponds generally to the standard network (navigation) model defined within ISO 19133: Location-based services – Tracking and navigation which is considered as a general framework to trace a dendritic network of catchments. Provided that a catchment is topologically realized comparable with the ISO topology model as directed edge (flowpath) and the outfall as directed (inflow/outflow) node, the catchment network (as well as its hydrographic, geomorphologic or hydrometric realizations) can be navigated comparable with the concepts of the ISO network (navigation) model. With reference to catchment topology, this allows to navigate from realized outfall to realized outfall along the flowpath, from fixed landmark to fixed landmark along a water body, from section to section along a channel, or from station to station along a virtual line.

In terms of the network (navigation) model, the hydrographic, channel or station network can be thought of as a set junctions and links that connect these junctions. The realization of an inflow/outflow node is comparable with the 0-dimensional junction associating ‘incoming and outgoing links’, and the flowpath is comparable with 1-dimensional link associated with a ‘start’ and an ‘end’ set by the inflow or outflow node

Table 2 provides a descriptive ‘mapping’ intended to provide a basic understanding of how the HY\_Features network navigation may specify the Tracking and navigation model.

Table 2: HY\_Features concepts comparable with the OGC Network navigation model

|  |  |  |
| --- | --- | --- |
| **HY\_Features concept** | **Description** | **ISO 19133 concept** |
| Hydro Network | aggregate of hydrologic features realizing a catchment | set of junctions and links |
| Flowpath (one-dimensional realization of a catchment) | connects inflow node and outflow node, starting at the located origin of the associated reference system, and directed towards a located reference location | link connecting ‘start’ and ‘destination’ junctions |
| Outfall realization (0-dimensional realization) | realized outflow/inflow node associated with a realizations of a contributing/receiving catchment | junction associating incoming and outgoing links |

# Clause containing normative material

## The HY\_Features conceptual model

This standard defines the HY\_Features conceptual model as a standard for the identification and description of hydrologic features reflecting both hydrologic significance and topological connectivity of hydrologic features. HY\_Features formalizes the fundamental relationships between components of the hydrosphere describing the hydrosphere as a hierarchical network of hydrologically connected catchments, the various realizations a catchment may have and the organization in networks of catchments, waterbodies or channels.

Core concepts of HY\_Features are: 1) an abstract idea of 'catchment' which has many possible 'realizations', 2) an hierarchical network of catchments realized in networks of watercourses and streams , and 3) a linear referencing along a river using a nominal main flow path. The single concept that governs HY\_Features is the hydrologically determined union of a catchment and its outfall, and that any place on the land surface can be thought of as the outfall of a corresponding catchment and be placed into a network of connected, usually named, hydrologic features.

The conceptual model is designed in several discrete modules. It is intended that implementations of the conceptual model need to consider only those parts of the model required by the implementation target. An implementation may include or exclude feature properties, or allow changing cardinality of one or more associations to ‘nillable’, expressing that these logically exist but are not realized in a particular implementation. Table 3 lists the application schemas, the leaf packages included and the concepts reflected therein.

Table 3: HY\_Features modules, concepts reflected, and leaf packages included

|  |  |  |
| --- | --- | --- |
| **Application schema** | **Concepts reflected** | **Leaf packages included** |
| HY\_HydroFeature | fundamental properties and relationships between features governed by the physical laws of Hydrology, naming of hydrologic features, location of hydrologic feature along a linear flowpath | Named Feature,  Hydro Complex,  River Positioning System |
| HY\_SurfaceHydroFeature | hydrologic features on the Earth’s land surface without the complexity and detail of hydrologic and hydraulic models | Channel Network, Hydrographic Network,  Water Body Types,  Storage |
| HY\_HydrometricNetwork | hydrometric network of logically connected hydrometric features located on or along a hydrologic feature | --- |

The conceptual model is expressed in the Geographic Information Conceptual Schema Language (ISO 19103:2005) based on the Unified Modeling Language (UML). The organization into packages and package dependencies are shown in Figure 17. The following sections describe requirements classes valid for each application schema, whereby each feature addressed in the requirements SHALL be understood as an instance of the GF\_FeatureType (aka FeatureType) «metaclass».



Figure 18: HY\_Features modules and packages

## The HY\_Features conceptual conformance (mapping)

|  |  |
| --- | --- |
| **Requirements Class** | [**/req/hy\_features\_conceptual\_model**](https://github.com/opengeospatial/HY_Features/blob/master/req/hy_features_conceptual_model) |
| Target type | Implementation Schema |
| Name | HY\_Features Conceptual Conformance |
| Dependency | [/iso/19109/](https://inspire-twg.jrc.it/svn/iso) |
| Requirement | /req/ hy\_features\_conceptual\_model/mapping  An implementation schema conforming to HY\_Features SHALL provide a formal mapping from one or more Feature Types present in the implementation schema to Feature Types defined in this standard specification, including all mandatory properties defined by the realized HY\_Features concept. Default values to be assumed must be specified in this mapping. |

The HY\_Features model is a 'conceptual model', and not intended to be directly implementable for data exchange or persistence. The conformance target of the HY\_Features model is therefore an implementation that encodes the mapping of a particular implementation schema with concepts defined in the HY\_Features model.

Conformance to the HY\_Features model is a matter of being able to unambiguously identify what elements of an implementation schema map to the HY\_Features model, and inclusion of all mandatory properties of the defined Feature Types in such mappings.

The HY\_Features conceptual model provides the basis for determining whether two references to hydrologic features are references to the same feature independent of their implementation or format. More specifically, it provides a means to distinguish between the reference concept and its different realizations as geographic features, and hence to declare that different realizations share common hydrological connectivity.

Disparate systems describing hydrologic features may be mapped to the equivalent HY\_Features definitions to disambiguate the local usage of terminology and specific implementation choices made.

Note that a direct encoding of HY\_Features to an implementation format such as RDF may be implemented through annotation or direct correspondence of names to the HY\_Features elements.

## The HY\_Features data conformance (encoding)

|  |  |
| --- | --- |
| **Requirements Class** | [**/req/hy\_features\_content**](https://github.com/opengeospatial/HY_Features/blob/master/req/hy_features_content) |
| Target type | Dataset |
| Name | HY\_Features Data Conformance |
| Dependency | [/req/hy\_features\_conceptual\_model](https://github.com/opengeospatial/HY_Features/blob/master/req/hy_features_conceptual_model) |
| Dependency | [/iso/19109/](https://inspire-twg.jrc.it/svn/iso) |
| Dependency | [/iso/19150/](https://inspire-twg.jrc.it/svn/iso) |
| Dependency | [/iso/19136/](https://inspire-twg.jrc.it/svn/iso) |
| Requirement | /req/ hy\_features\_conceptual\_model/identifiers  Implementations of HY\_Features SHALL either require the use of common identifiers for instances of Feature Types mapped to the same underlying HY\_Features Feature Type, OR require provision of a mechanism to match identifiers from different identification schemes. |

As a conceptual model HY\_Features does not specify conformance requirements regarding the structure of possible encodings. It does however specify that equivalence of feature instances can be expressed. The requirement that arises is therefore that the content of feature identification elements can be matched among implementations. This does not demand the use of identical identifiers across different implementations, but it does require that implementations provide a mechanism to match identifiers from different schemes.

## The Hydro Feature application schema

The Hydro Feature application schema provides the core concepts of a named hydrologic feature (shown in Yellow), of a hydrologic complex wherein the union of catchment and its common outlet (conceptualized as outfall) is multiple realized through a collection of hydrologic features (shown in Blue), and of a river positioning system which allows to place an arbitrary feature ‘along a river’ using a linear referencing (shown in Green) along a topological, flowpath realization.

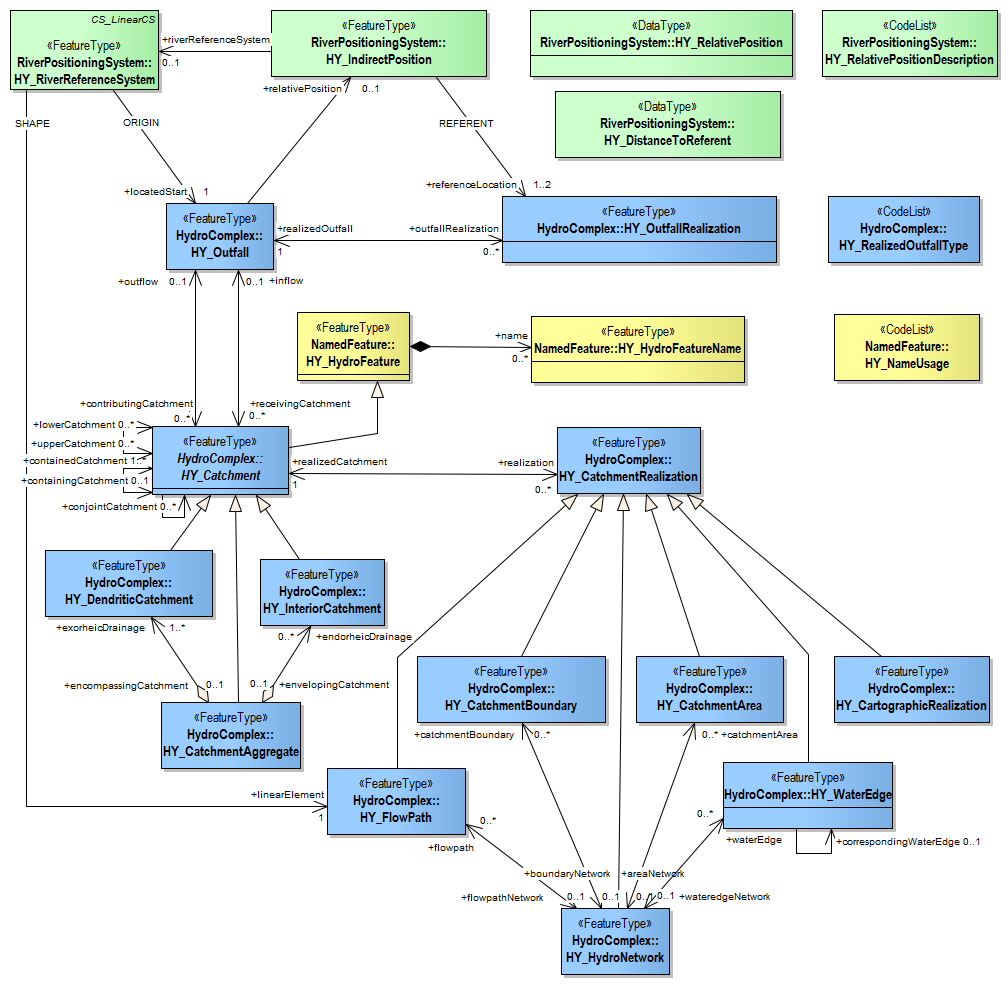


Figure 19: Hydro Feature requirements Class Diagram

### Requirements class: HY\_HydroFeature

The general requirements /req/ hy\_features\_conceptual\_model/mapping and /req/ hy\_features\_conceptual\_model/identifiers defined in clauses 7.2 and 7.3 of this standard apply to all feature types (UML classes) defined in the Hydro Feature core requirements class (Figure 19). Additional requirements need to be considered with respect to correspondence to core data types as defined in ISO 19103:2005, geometry types as defined in the OGC Abstract Specification Topic 1, to the Linear Coordinate System as defined in OGC Abstract Specification Topic 2, and the Linear Referencing as defined in OGC Abstract Specification Topic 19. Figure 20 shown the external dependencies.

If required, an implementation should use terms from the code lists in Annex B of this standard, defined specifically to conform to a terminology common in the hydrology domain. Note that alternative code lists may be used but should be related to the terms in using an appropriate formalism.

|  |  |
| --- | --- |
| **Requirements Class** | **/req/hy\_hydrofeature** |
| Target type | Implementation Schema |
| Name | HY\_Features Conceptual Conformance |
| Dependency | /iso/19103/ |
| Dependency | /doc/AS/Topic1 |
| Dependency | /doc/AS/Topic2 |
| Dependency | /doc/AS/Topic19 |
| Requirement | /req/hy\_hydrofeature/19103  Implementations of HY\_Features SHALL express correspondence to the elements as specified in the ISO 19103: Conceptual SchemaLanguage. |
| Requirement | /req/hy\_hydrofeature/topic1  Implementations of HY\_Features SHALL express correspondence to geometry types specified in the OGC Abstract Specification Topic 1, Feature geometry. |
| Requirement | /req/hy\_hydrofeature/topic2  Implementations of HY\_Features SHALL express correspondence to the CS\_LinearCS type defined in the OGC Abstract Specification Topic 2, Spatial referencing by coordinates. |
| Requirement | /req/hy\_hydrofeature/topic19  Implementations of HY\_Features SHALL express correspondence to Linear Referencing model specified in the OGC Abstract Specification Topic 19, Linear referencing. |



Figure 20: Hydro Feature – external dependencies

The HY\_HydroFeature feature type is defined as hydrology-specific instance of the General Feature metaclass (as defined in the OGC General Feature Model, GFM), whose identity needs to be maintained and tracked through a processing chain from measurement to distribution of hydrologic information.

Being an intended instance of the General Feature metaclass any feature type is identified by an unique identifier and typical properties. Typically, a hydrologic feature is additionally identified through names in common usage and through hydrologically significant characteristics.

The HY\_HydroFeature feature type is further specialized by domain-specific feature types, which specify properties a specialization has to define one or more aspects of the hydrology phenomenon (Figure 21).

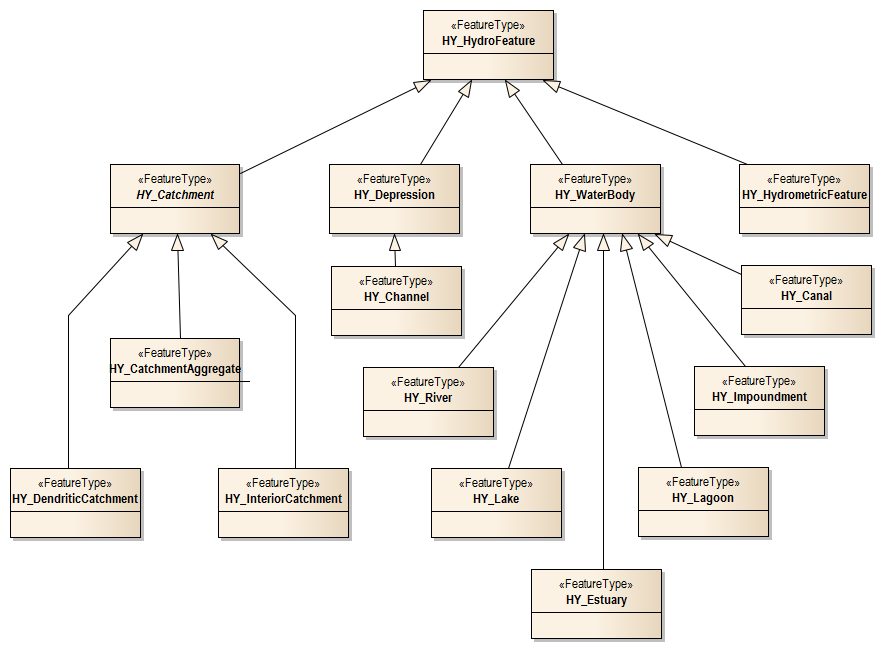


Figure 21: Hydrologic features describing separate aspects of the hydrology phenomenon

The definitions applied in the Hydro Feature schema are rooted in the definitions documented in the WMO/UNESCO Glossary of Hydrology. They are applied regardless of their application context in respect to the Earth's surface. For the purpose of testing the applicability of the HY\_Features conceptual model in the context of surface water hydrology, the definitions in this standard refer to surface water hydrology. A conceptual model capturing the specifics of features associated with the groundwater domain is developed with reference to the OGC WaterML 2: Part 4 – GroundwaterML2 standard [6]**.**

Providing a standard terminology for the typical relationships between hydrologic features allows the hydrosphere to be expressed in a consistent way across multiple data products, regardless of various spatial or temporal representations.

### The Named Feature model

The Named Feature model (Figure 22) defines the HY\_HydroFeature type as basic feature to reflect overall properties hydrologic features have such as names in cross-jurisdictional and multi-lingual contexts. The HY\_HydroFeature type has one association: name.

**name** (association)

name given to the hydrologic feature in cultural, political or historical context. This supports to take into account multiple names and identifiers by considering the cultural, political and historical aspects of names assigned to an instance of the HY\_HydroFeature type using the HY\_HydroFeatureName type.

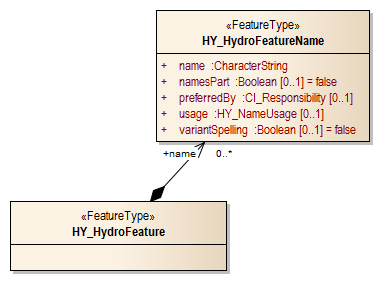


Figure 22: Named Feature (UML class diagram)

The HY\_HydroFeatureName type provides an abstract pattern to handle cultural, political and historical variability of names. This supports the assignment of a referenceable name for all or parts of a hydrologic feature without necessarily having a formal model for the naming.

HY\_HydroFeatureName carries five attributes: *name*, *namesPart*, *preferredBy*, *usage* and *variantSpelling*.

**name** (attribute):

provides the individual name used in a country or region under the conditions of nation and language, using the basic CharacterString type.

**namesPart** (attribute):

indicates whether the name applies to a part of feature only or not, using the Boolean value type.

**preferredBy** (attribute):

specifies that the name is the preferred name according to the named entity. The CI\_Responsibility type may be used to further structure the information about the responsible party and their role.

**usage** (attribute):

expresses the kind of name usage in a specific community, using a term from the HY\_NameUsage code list, or a controlled vocabulary. Alternative code lists may be used but should be related to the terms in Annex B.4 using an appropriate formalism.

**varianteSpelling** (attribute):indicates whether the name is a variant spelling or not using the Boolean value type.

### The Hydro Complex model

The Hydro Complex model implies a collection of hydrologic features that form a hydrologically closed system. This includes the catchment, its inflow and outflow (conceptualized as outfalls) as well as various realizations of catchment and outfall by typical hydrologic features. In this complex, the union of catchment and its common outlet determines the topological closure of the logical catchment and its outfall. The catchment topology pattern, expressed for example as a flowpath bounded by inflow and outflow nodes, is then applied to realize the connectivity in hydrographic, channel networks, or hydrometric networks.

The Hydro Complex model also allows for catchments to be recognized through reference to an outfall even if stream networks, catchment areas or catchment boundary are not available. It is intended that hydrological reporting applications may use this model without the full complexity and detail of scientific catchment models.

#### Catchment

The Catchment model conceptualizes the hydrologic determination of a catchment through an 'outfall' feature with the role of getting flow from a contributing catchment, or providing inflow to a receiving catchment (Figure 23 and Figure 24). Conceptually, each catchment has an outfall, and any outfall has a corresponding catchment, even if catchment and/or outfall may not be present in a particular application. A catchment interacts with upper and lower catchments via associated outfalls, and ultimately contributes flow to the outfall of a containing catchment. The catchment should be understood as the logical link between two outfalls.

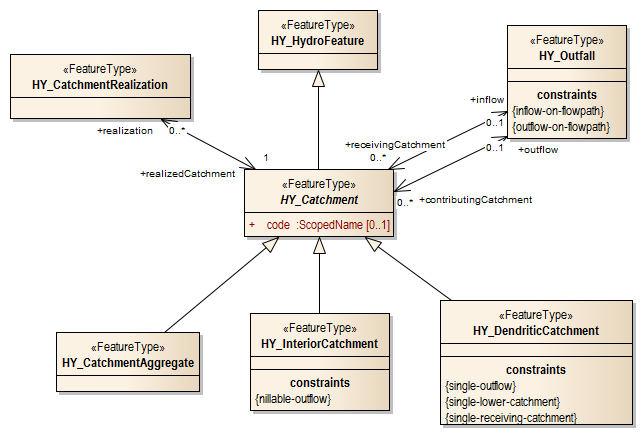


Figure 23: Catchment model (UML class diagram)

The HY\_Catchment feature type captures the union of catchment and outfall, and the multiple realization of the logical catchment. These realizations include both topological realizations, as well as their geometric representation. HY\_Catchment is an abstract class and needs further specialization with respect to catchment interaction.

The **HY\_Catchment** feature type (Figure 24) specializes the general HY\_HydroFeature type. Through generalization, HY\_Catchment inherits the name property. It carries a code attribute and the associations: outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, realization.

**code (attribute):**

unique identifier to the catchment in given context. The code attribute should be implemented using a controlled classification or coding system. Example: WMO Basin Codes.

**outflow** and **inflow (associations):**

outfall in terms of an outflow of the contributing catchment, or inflow to the receiving catchment. For a dendritic network of catchments, the outflow of a contributing catchment coincides with the inflow to a receiving catchment. This supports description of upstream-downstream relationships between catchments.

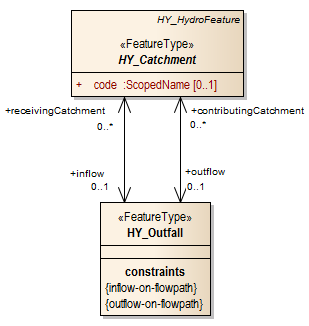


Figure 24: Catchment and outfall (UML class diagram)

**containingCatchment and containedCatchment (associations):**

nesting of catchments in a simple “is-in” containment hierarchy as typically used for high-order organization of management and reporting units.

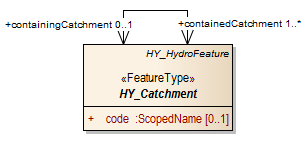


Figure 25: Containing / contained catchment (UML class diagram)

**conjointCatchment (association):**

catchment interacting with another catchment across an internal boundary, and contributing together with these to a single, common outfall.. This internal boundary may be a divide separating adjacent catchments, or a diffuse divide between non-delineated sub-catchments within an encompassing catchment, or a fictive boundary between distant catchments. A dendritic network of catchments provided, where each catchment is determined by its single outflow, this association can be used to summarize diffuse inflow into a catchment, as typical for headwater catchments, or spread outflow occurring for example in estuary catchments.

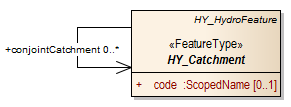


Figure 26: Conjoint catchment (UML class diagram)

**upperCatchment** and **lowerCatchment (association)**:

neighboring catchment immediately above or below of the catchment. This allows to trace the catchment network in an upstream direction from mouth to source, or downstream from source to mouth.

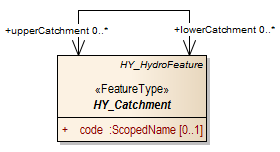


Figure 27: Upper / lower catchment (UML class diagram)

**realization (association):**

topological or geographic feature which realizes the logical catchment .

#### Catchment Aggregate

The HY\_CatchmentAggregate feature type (Figure 28) specializes the HY\_Catchment type as set of non-overlapping dendritic and interior catchments arranged in an encompassing catchment. This can be used to describe multiple inflows into a catchment aggregate through several hydrologically discrete sub-catchments each with a single inflow, and contributing to a joined outflow of the catchment aggregate, including the 'nillable' outflow of interior catchments. Nillable is meant here to signify that the outfall logically exists in the form of flow to the subsurface or atmosphere but is unknown in a given implementation.

Being a special type of the HY\_Catchment, the catchment aggregate may be part of a containing catchment at the next higher level of hierarchy, which consists of similar-scale neighboring catchments. The catchment aggregate does not necessarily imply a series of nested containing catchments. It primarily allows navigation to the 'highest' level system (total drainage basin) as typically used for reporting purposes.

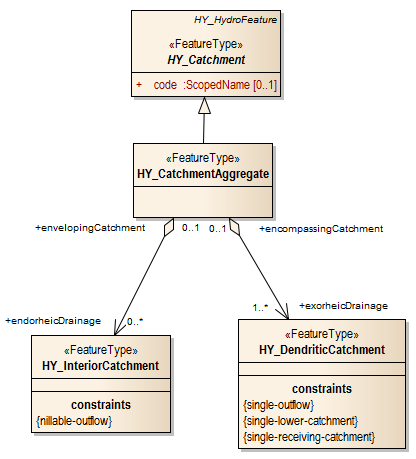


Figure 28: Catchment aggregate (UML class diagram)

HY\_CatchmentAggregate inherits through generalization the outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, and realization properties, and associates an exorheicDrainage and endorheicDrainage.

**exorheicDrainage** (association):

should be used to identify an exorheic drained catchment which is not, but may be temporarily connected to enveloping catchments.

**endorheicDrainage (association)**

should be used to identify an endorheic drained catchments, which is permanently connected **to the enveloping aggregate**.

#### Dendritic Catchment

The HY\_DendriticCatchment feature type (Figure 29) specializes the general HY\_Catchment class as a catchment which is determined by a single common downstream catchment. It represents the catchment as the topological link between an inflow and an outflow. This allows catchments to be connected in a dendritic network by upstream-downstream relationships without knowing the complex hydrology between inflow and outflow. This concept requires a stable identifier purposefully assigned to the catchment and that catchments are delineated as a simple tree hierarchy.

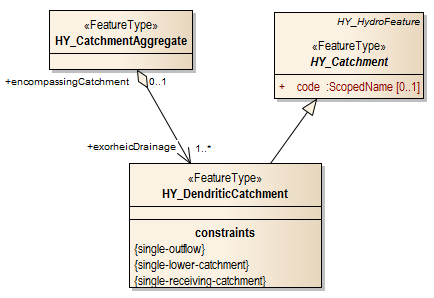


Figure 29: Dendritic catchment (UML class diagram)

HY\_DendriticCatchment inherits from generalization the code, outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, and realization properties, and associates with the encompassingCatchment. The dendritic nature of this feature is enforced through *singleOutflow, receivingCatchment* and  *lower catchment* constraints.

**encompassingCatchment** (association)

identifies the catchment encompassing one or more dendritic catchments contributing together flow to the common outlet.

**single-Outflow** (constraint)

defines a cardinality of ‘1’ indicating that the dendritic catchment contributes to one and only one single outflow. A single outflow can be unknown (nillable) in a particular application, for example in case of a delta to which a virtual outflow is assigned. An implementation SHOULD unambiguously specify whether the logical outflow exists, or is nillable.

**single-Receiving-Catchment** (constraint)

defines a cardinality of ‘1’ indicating that one and only one single catchment receives flow via the outflow of the catchment. A receiving catchment can be unknown (nillable) in a particular application, for example in case of the latest catchment contributing flow to the ocean or an internal sink. An implementation SHOULD unambiguously specify whether the logical receiving catchment exists, or is nillable.

**single-Lower-Catchment** (constraint)

defines a cardinality of ‘1’ indicating that one and only one lower catchment exists neighboring the catchment. A lower catchment can be unknown (nillable) in a particular application, for example in case of the latest catchment contributing flow to the ocean or an internal sink. An implementation SHOULD unambiguously specify whether the logical lower catchment exists, or is nillable.

#### Interior Catchment

The HY\_InteriorCatchment feature type (Figure 30) specializes the general HY\_Catchment class as a catchment which is generally not connected to other catchments. This class describes the interior catchment as a catchment enveloped by other catchments to which it may temporarily contribute. While the interior catchment concept precludes flow to neighboring surface catchments, holistically it is a candidate for establishing connections to groundwater or atmospheric systems.

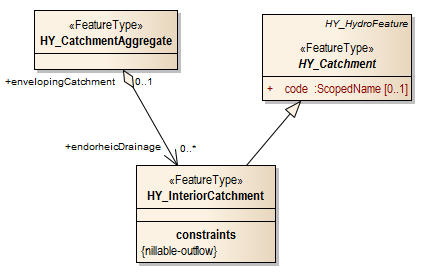


Figure 30: Interior catchment (UML class diagram)

HY\_InteriorCatchment inherits from generalization the code, outflow, inflow, containingCatchment, containedCatchment, conjointCatchment, upperCatchment, lowerCatchment, and realization properties, and associates the envelopingCatchment. A *nillable-outflow* constraint emphasizes the non-existing outflow.

**envelopingCatchment** (association):

identifies a catchment surrounding the interior catchment.

**nillable-outflow** (constraint):

defines a cardinality of ‘0’ indicating the not existing outflow.

#### Outfall

The HY\_Outfall feature type (Figure 31) conceptualizes the hydrologically determined outfall of a corresponding catchment (Figure 24). The outfall represents the logical place where a catchment interacts with another catchment, i.e. where the outflow of a contributing catchment becomes inflow into a receiving catchment. A catchment may receive flow from several upstream catchments or contribute flow to several downstream catchments through a single logical outfall. Through unique identity, each outfall feature may associate different outfall realizations within an hydrologic complex given that each realization has the same hydrologic determination. This includes the topological realization as a node on the one-dimensional flowpath (edge) in terms of a topological 'boundary'.

Logically placed in reference to a catchment which links inflow and outflow, an outfall has a position relative to another outfall that is 'fixed' by the catchment Referencing the union of catchment and outfall, the topological realization can be used to define a linear river reference system with the inflow/outflow node as origin and the flowpath realizing the catchment as linear element along which a position can be determined.

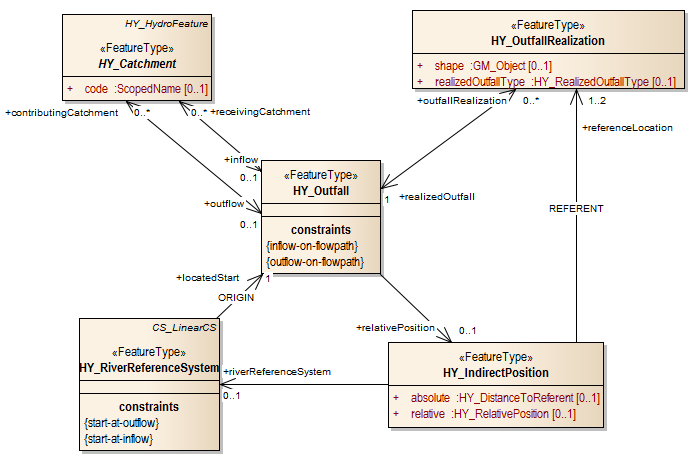


Figure 31: Outfall (UML class diagram)

HY\_Outfall carries the associations: contributingCatchment, receivingCatchment, relativePosition and outfallRealization. The linear referencing along a flowpath is enforced by outflow-on-flowpath and an *inflow-on-flowpath* constraints.

**contributingCatchment** (association)

identifies the catchment that contributes flow to this outfall. This allows to connect a catchment's outflow to an identified inflow and to determine its position through referencing the inflow.

**receivingCatchment** (association):

identifies the catchment that receives flow from this outfall. This allows to connect a catchment's inflow to an identified outflow and to determine its position through referencing the outflow.

**relativePosition** (association):

assigns a position to the outfall relative to a reference location fixed in the logical network of catchments, i.e. to another, already existing (realized) outfall. Commonly, this is used to locate an outfall such as at a hydrometric station, to a reference outfall such as a confluence but it can be used to locate any outfall relative to another.

**outfallRealization** (association):

identifies a hydrologic feature which realizes the logical outfall. In case of a topological realization, the realization of the outfall is of lower dimension than the realization of the corresponding catchment. Example: an outflow node realizing the outfall is of lower dimension than the flowpath realizing the contributing catchment.

**inflow-on-flowpath** (constraint):

defines that whenever a relative position is assigned to an inflow using the river reference system, the receiving catchment is realized as linear flowpath.

**outflow-on-flowpath** (constraint):

defines that whenever a relative position is assigned to an outflow using the river reference system, the contributing catchment is realized as linear flowpath.

#### Catchment Realization

The HY\_CatchmentRealization feature type (Figure 32) conceptualizes the multiple realization of an 'un-realized', logical catchment, by typical features used to describe a catchment as a unit of study shared across sub-domains and studies.

The catchment realization concept implies a hydrologic complex in that, if a catchment realization exists, this exists in the same hydrologic complex as the catchment it realizes. In this way, any feature realization of a logical catchment references the hydrologic determination of the realized catchment. If the realized catchment is connected with other catchments via its outfall, possible feature realizations are also connected. A topological realization of the logical catchment is always of higher topological dimension than the realization of the corresponding outfall in terms of a topological boundary. For example, a linear flowpath realizing a catchment may be understood as an edge between inflow and outflow nodes; the areal realization of a catchment as a face bounded by linear inflow and outflow.

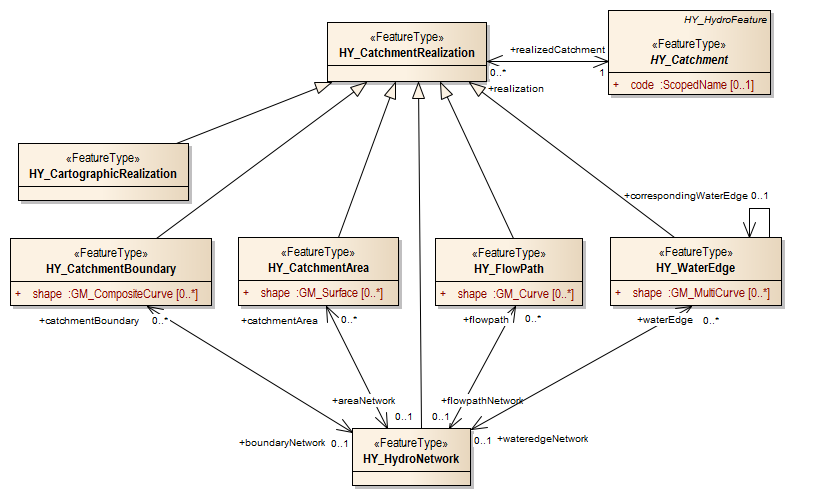


Figure 32: Catchment realization and its specialization (UML class diagram)

The catchment realization features defined in this standard refer to objects on the land surface for the purpose of surface water hydrology. In other contexts, other types of catchment realization may exist. Catchment realizations that do not conform to those defined in this standard, for instance realizations in 3 or 4 dimensional perspectives, may be implemented using the general HY\_CatchmentRealization type. HY\_CatchmentRealization carries the realizedCatchment association.

**realizedCatchment** (association):

identifies the one and only one catchment that is realized by a particular feature. Referencing the hydrologic complex containing the catchment and all of its realizations, supports a catchment's existence to be recognized and linked to multiple realizations without the complexity and full detail of a scientific model. By referencing the catchment topology, topological relationships can be established and common identifiers assigned.

The **HY\_Flowpath** feature type realizes an 'un-realized' catchment specifically as a path connecting the inflow and outflow of the logical catchment it realizes. HY\_Flowpath specializes HY\_CatchmentRealization with respect to an implied linear geometric representation including a straight or curved line. Topologically, the flowpath connects the inflow and outflow of the logical catchment, and is understood as an edge bounded by an inflow node and an outflow node, and corresponding to left-bank and right-bank catchment faces. Hydrologically, the flowpath is a line describing a moving particle of water. Through generalization, HY\_Flowpath inherits the realizedCatchment association. It carries the properties: shape, and flowpathNetwork.

**shape** (attribute):

linear geometric representation of the one-dimensional flowpath, usually a curve. The GM\_Curve type SHOULD be implemented to meet the overall requirement /req/hy\_hydrofeature/topic1 defined in section7.4.1 of this standard.

**flowpathNetwork** (association):

sequence of flowpaths forming a connected network, which realizes as a whole the catchment that contains the catchment realized by the single flowpath. This concept requires a non-branching 'main-stem' of watercourses, and a single linear representation of each of these

The **HY\_WaterEdge** feature type realizes an 'un-realized' catchment specifically as path connecting the inflow and outflow of the logical catchment it realizes. HY\_WaterEdge feature type specializes HY\_CatchmentRealization with respect to an implied linear geometric representation, including a closed line. Topologically, the water edge realizes the catchment as an edge connecting inflow and outflow realized as nodes fixed at the inflow node and outflow node of the corresponding flowpath. Hydrologically, the water edge follows the line of intersection between a water body stratum and the confining depression, or channel. Through generalization, HY\_WaterEdge inherits the realizedCatchment association, and carries the properties: shape, *correspondingWaterEdge*, and waterEdgeNetwork.

**shape** (attribute):

linear geometric representation of the one-dimensional water edge, usually an aggregate of curves . The GM\_MultiCurve type SHOULD be implemented to meet the overall requirement /req/hy\_hydrofeature/topic1 defined in section7.4.1 of this standard.

**corresponding water edge** (association):

water edge fixed at the inflow node and the outflow node of the water edge. By 'snapping' the inflow nodes into one node on and outflow nodes into one node, the representing curves may be closed.

**waterEdgeNetwork** (association):

aggregate of water edges forming a connected network, which realizes as a whole the catchment that contains the catchment realized by the single water edge. This concept requires an aggregate of non-overlaying water edges, and a single linear representation of each of these.

The **HY\_CatchmentBoundary** feature type realizes an 'un-realized' catchment specifically as catchment boundary connecting the inflow and outflow of the logical catchment it realizes, whereby inflow and outflow may overlay. Implying a linear geometric representation, a catchment boundary is topologically understood as an edge bounded by inflow node and outflow nodes, and corresponding to left-bank and right-bank catchment faces inside of the boundary. Hydrologically, the boundary refers to the summit line separating adjacent catchments. HY\_CatchmentBoundary inherits from generalization the realizedCatchment association, and carries the properties: shape, and boundaryNetwork.

**shape** (attribute):

linear geometric representation of the one-dimensional catchment boundary, usually an composition of succeeding curves. The GM\_CompositeCurve type SHOULD be implemented to meet the overall requirement /req/hy\_hydrofeature/topic1 defined in section7.4.1 of this standard.

**boundaryNetwork** (association):

mesh of boundary lines forming a connected network, which realizes as a whole the catchment that contains the catchment realized by a single boundary. This concept requires an mesh of non-overlapping boundary lines, and a single linear representation of each of these.

The **HY\_CatchmentArea** feature type realizes an 'un-realized' catchment specifically as a catchment area connecting the inflow and outflow of the logical catchment it realizes, including a plane surface. HY\_CatchmentArea specializes HY\_CatchmentRealization with respect to an implied areal geometric representation Topologically, the catchment area connecting the inflow and outflow of the logical catchment is a face bounded inwards by an inflow edge and outwards by an outflow edge. Hydrologically, catchment area refers to the area having a common outlet for its runoff, HY\_CatchmentArea inherits from generalization the realizedCatchment, and carries the properties: shape, and areaNetwork.

**shape** (attribute):

areal geometric representation of the two-dimensional catchment area, usually as a surface. The GM\_Surface type SHOULD be implemented to meet the overall requirement /req/hy\_hydrofeature/topic1 defined in section7.4.1 of this standard.

**areaNetwork** (association):

aggregate of catchment areas forming a connected network, which realizes as a whole the catchment that contains the catchment realized by the single catchment area. This concept requires an aggregate of non-overlapping catchment areas, and a single areal representation of each of these.

The **HY\_HydroNetwork** feature type realizes an 'un-realized' catchment as a network of connected hydrologic features. Such a network realizes in the hierarchical network of logically connected catchments contained in a higher-order catchment. It may be a sequence of flowpaths, an aggregate of water edges, an aggregate of catchment areas or a mesh of catchment boundaries. HY\_HydroNetwork feature type specializes HY\_CatchmentRealization. Through generalization it inherits the realizedCatchment association, and carries the associations flowpath, waterEdge, catchmentBoundary and catchmentArea.

**flowpath** (association): flowpath that participates in the network.

**waterEdge** (association): water edge that participates in the network.

**catchmentBoundary** (association): catchment boundary that participates in the network.

**catchmentArea** (association): catchment area that participates in the network.

The HY\_CartographicRealization feature type realizes a catchment as set of separate cartographic layers or maps, displaying a network of hydrologic features which may be connected at the representation level, or not. Specializing HY\_CatchmentRealization, it inherits from generalization the realizedCatchment association including hydroComplex.

#### Outfall Realization

The HY\_OutfallRealization feature type (Figure 33) conceptualizes the idea that the an outfall can be realized by practically any feature of interest. Using the outfall to define and reference the hydrologic determination of a catchment, hydrologic features may be associated to a corresponding catchment through reference to the feature that realizes its outfall. Any feature that can be identified as (said to be) the outfall of a catchment may realize the logical outfall. Typically this will be a permanent, stable location that is fixed and/or referenced by coordinates.

Landmarks such as confluences, points corresponding to vertical sections, or the position of a monitoring station on a river are typical outfall realizations. In other than surface water contexts other types may realize a catchment's logical outfall. Other kinds of outfall realizations that don't carry normal surface water characteristics as defined in this standard, e.g. a spring where groundwater enters the surface, an arbitrary point projected onto the surface, or an outfall that collects many disjoint locations may use or specialize the general HY\_OutfallRealization type.

Topologically, the HY\_OutfallRealization should be understood to be the boundary of the corresponding catchment, and always of lower topological dimension than the catchment. With respect to the typical topological realization of a catchment as an edge, a 'spoke' property of type HY\_Flowpath is described by means of a 'tagged value' and used to associate an outfall realization with its upstream and downstream flowpaths. Even though the topological realization of an outfall is typically as a node between catchment edges, an outfall realization may also have any geometric representation, including a single point.

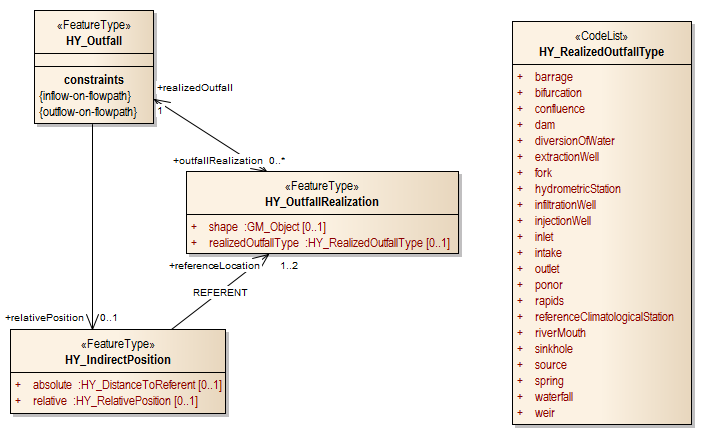


Figure 33: Outfall Realization (UML class diagram)

HY\_OutfallRealization carries the realizedOutfall association implying the hydroComplex feature collection, and carries two attributes: shape and realizedOutfallType.

**shape** (attribute):

geometric representation of the realized outfall with the option to use a geometry type defined in the OGC Abstract Specification Topic 1, Feature geometry to meet the overall requirement /req/hy\_hydrofeature/topic1 defined in section7.4.1 of this standard.

**realizedOutfallType** (attribute):

expresses the type of the realized outfall, using a term from the HY\_ RealizedOutfallType code list, or a controlled vocabulary. Alternative code lists may be used but should be related to the terms in Annex B.1 using an appropriate formalism.

**realizedOutfall** (association):

identifies the one and only one outfall that is realized by a particular feature. Referencing the hydrologic complex containing the outfall and all of its realizations, supports a an arbitrary feature of interest to be recognized as outfall of a catchment, and to be placed using the river positioning system defined in this standard.

### The River Positioning System

The River Positioning System (Figure 34) provides a simple model to place a feature of interest 'on a river'. It introduces the concept of indirect position where a position is determined relative to an already established reference location. This concept uses a linear river reference system whose origin is set at the outfall of a catchment, and whose linear shape is given by a flowpath realizing the catchment between the origin (outfall) and the reference location or another outfall. It is important to note, that each logical catchment has its own reference system, and must have one outfall (origin) and one linear flowpath realization (shape).

The River Positioning System references the one-dimensional topological realization of catchment and outfall within the implied hydrologic complex in such that the origin and referent of the reference system are nodes on the boundary of the flowpath shape. Given that a flowpath realizes a logical catchment between inflow and outflow nodes, the feature of interest being referenced realizes either the inflow or the outflow node of the catchment that is determined by the corresponding reference location upstream or downstream of the feature to be placed. Using reference locations in both directions allows placement of a feature of interest interpolative between inflow and outflow nodes on a flowpath even if the realized catchment is not explicitly delineated.

To meet the /req/hy\_hydrofeature/topic19 defined in section 7.4.1 of this standard, an implementation SHOULD express the semantic equivalence of features (see also section 6.4) defined in this standard with relevant types defined in the OGC Linear Referencing standard.

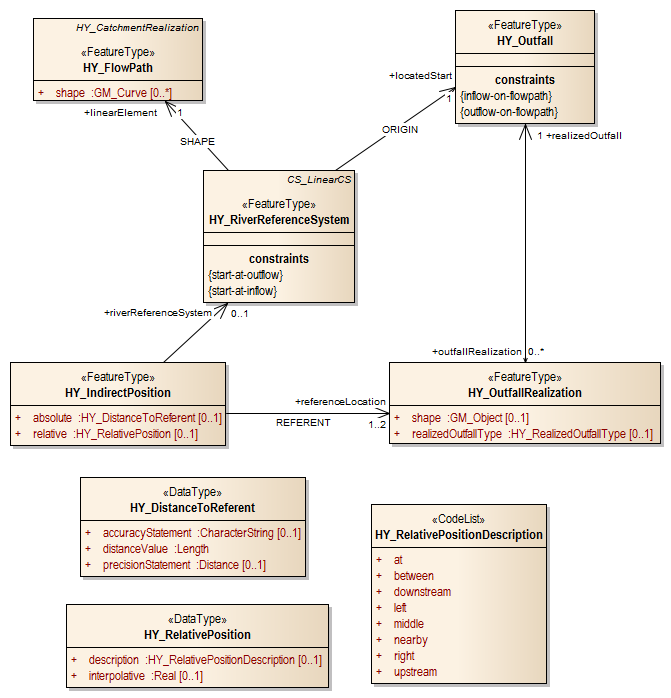


Figure 34: River Positioning System (UML class diagram)

#### Indirect Position

The HY\_IndirectPosition feature type defines the indirect position, expressed either as the absolute distance from origin to a reference location, or relative to the this. Indirect position assigns a position to an outfall in reference to an already existing, ’realized’ outfall using a linear river reference system. HY\_IndirectPosition carries the absolute, and relative attributes, and associates a referenceLocation and a riverReferenceSystem.

**absolute** (attribute):

distance expressed as an absolute value, including an indication of accuracy and precision of the absolute value. An implementation may use the HY\_DistanceToRefPoint (data type) referencing basic types to meet the req/hy\_hydrofeature/19103 requirement defined in section 7.4.1 of this standard.

**relative** (attribute):

expression for the relative interpolative distance value. To meet the req/hy\_hydrofeature/19103 requirement defined in section 7.4.1 of this standard, an implementation may use the HY\_RelativePosition (data type) referencing basic types and the HY\_RelativePositionDescription code list. Alternatively, the types, described in ISO 19103: Conceptual Schema may be used. Alternative code lists may be used but should be related to the terms in Annex B.2 using an appropriate formalism.

**referenceLocation** (association):

identifies an existing ‘realized’ outfall used as the permanent reference location relative to which a position is assigned to an outfall, or the feature of interest recognized as outfall.

**riverReferenceSystem** (association):

special linear reference system applied to assign a position ‘along a river’ using the outfall as origin, and the one-dimensional topological realization of a catchment as linear shape.

#### River Reference System

The HY\_RiverReferenceSystem feature class specializes the ISO LinearCS feature type for a linear coordinate system using inflow and outflow nodes on the linear flowpath. The origin of the river reference system is set by the located start of the flowpath realizing the catchment between the origin and the reference location. Provided that the located start of the flowpath is at the outfall of the catchment corresponding to the feature to be placed and the end is at an already located outfall upstream or downstream, the position on the flowpath is provided as the distance between its start and end. Alternatively, the position of a feature of interest can be determined interpolative between two already located outfalls bounding the flowpath in upstream and downstream direction, whereby the start is located at one of these and the flowpath is directed to the other already located outfall upstream or downstream of the start.

HY\_RiverReferenceSystem inherits the axis property, and carries the associations linearElement and locatedStart. Constraints *start-at-*outflow and *start-at-*inflow are defined enforcing the located start of the flowpath at the inflow or outflow of the realized catchment.

**linearElement** (association):

one-dimensional catchment realization, flowpath, used as the linear element in the river reference system. The flowpath starts at the declared origin of the river reference system.

**locatedStart** (association):

inflow or outflow of the catchment realized by the linear flowpath, which is used as the origin in the river reference system

**start-at-outflow** (constraint):

defines that whenever the flowpath (linear element) realizes a contributing catchment, this flowpath starts at the outflow (origin) of the realized catchment, and is directed towards the inflow (reference location)..

**start-at-inflow** (constraint):

defines that whenever the flowpath (linear element) realizes a receiving catchment, this flowpath starts at the inflow (origin) of the realized catchment, and is directed towards the outflow (reference location).

## The Surface Hydro Feature application schema

The Surface Hydro Feature application schema provides common concepts of hydrologic features occurring on the land surface and specifies the core concepts defined in the abstract Hydro Feature application schema. This will enable contextually linked information models to build relationships between multiple realizations of the same catchments. Typical realizations of the catchment concept and logical outfalls can be described in a consistent way using standard terminology for the relationships between surface water features defined in this application schema.

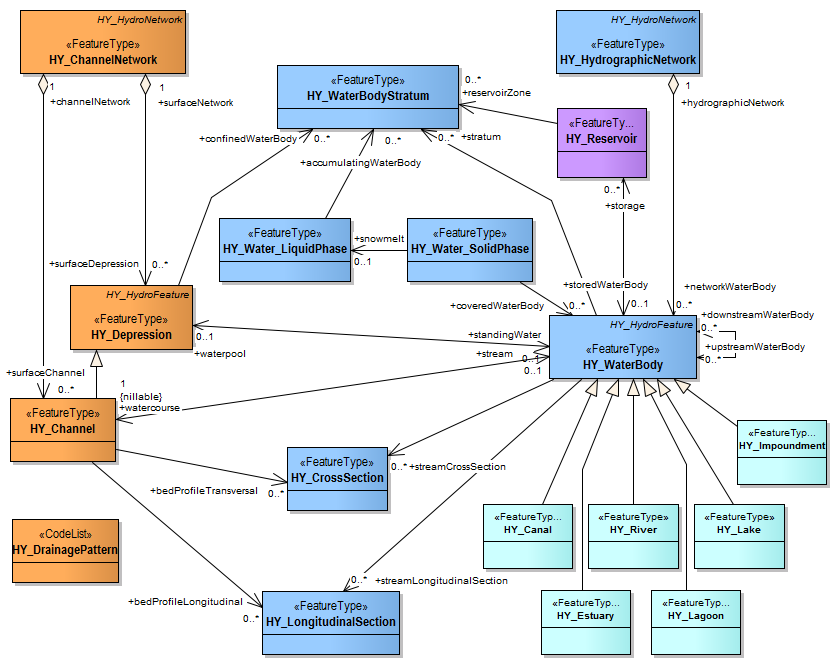


Figure 35: Surface Hydro Feature - Class Diagram

The general requirements /req/hy\_features\_conceptual\_model/mapping and /req/hy\_features\_conceptual\_model/identifiers defined in clauses 7.2 and 7.3, , and the requirements req/hy\_hydrofeature/19103 and /req/hy\_hydrofeature/topic1 defined in clause 7.4.1 of this standard apply to all feature types (UML classes) defined in the Surface Hydro Feature application schema (Figure 35).

The Surface Hydro Feature schema conceptualizes the accumulation of water on the land surface in water bodies (shown in Blue), each made unique by its origin, size, or movement. With respect to the management and storage of water resources, a concept of water storage is provided and allows any water body type to be considered a managed reservoir (shown in Purple).

Relying on a conceptual separation of water body and container, the Surface Hydro Feature schema defines a network of potentially connected depressions and channels on the land surface which periodically or continuously contain water (shown in Orange). Separate from the hydrographic network of permanent or temporary water bodies, the channel network can be used as the connecting system.

The definitions in this schema are rooted in the definitions given in the WMO/UNESCO Glossary of Hydrology which defines a network of watercourse regardless of the location in respect to the Earth's surface. The conceptual model defined here has been vetted in the context of surface water hydrology. In other words, in this standard, 'channel network' and 'hydrographic network' refer to surface channels or other containers for surface-water bodies.

The Surface Hydro Feature application schema contains the leaf packages: Channel Network, Hydrographic Network, Water Body Types and Storage. Figure 36 shows the external and internal dependencies.



Figure 36: Surface Hydro Feature - dependencies

### The Channel Network model

The Channel Network model defines a network of connected depressions and channels which, in its entirety, can realize a logical catchment (Figure 36). Usually this is a network of linear flowpaths and/or water edges realizing catchments connected to each other within the containing catchment realized by the entire network. This allows representation of the drainage pattern even if logically connected features may or may not be connected in the context of a particular representation.

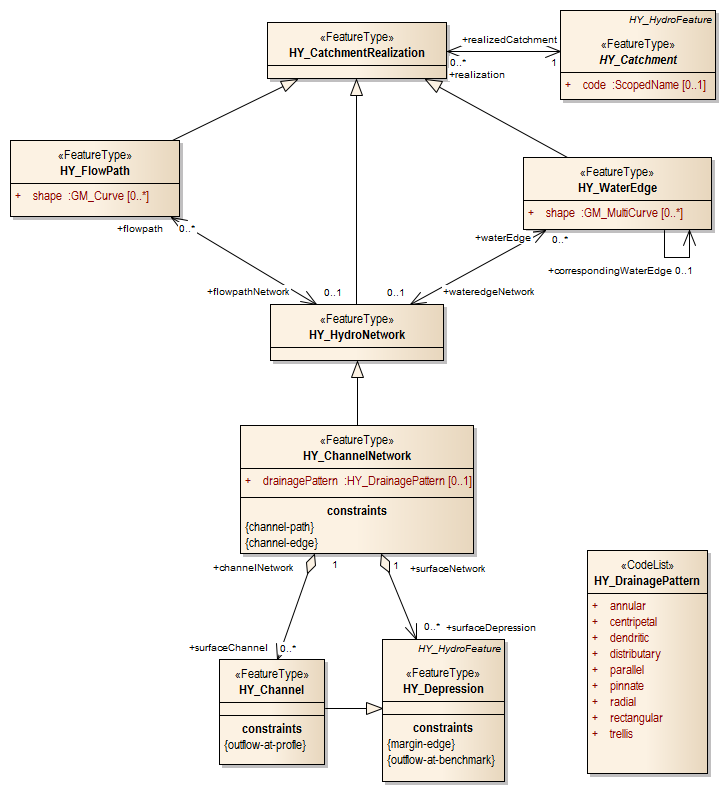


Figure 37: Channel Network realizing the catchment (UML class diagram)

The channel network is defined independent of the hydrographic network. This separates the concerns of hydraulics, focused on the analysis and design of channels and conduits, from the concerns of hydrology, focused on the occurrence and movement of water over land and in water bodies. It allows a logical catchment to be realized as a network of connected channels and depressions, regardless of water is contained therein or not.

A single depression or channel may realize the logical catchment, either as part of the network (Figure 37) or via a reference feature which realizes the conceptual outfall of the catchment (Figure 38). For example, a point at an associated cross or longitudinal section may be considered to realize the outflow of the catchment which is realized by the channel expressed as a flowpath.

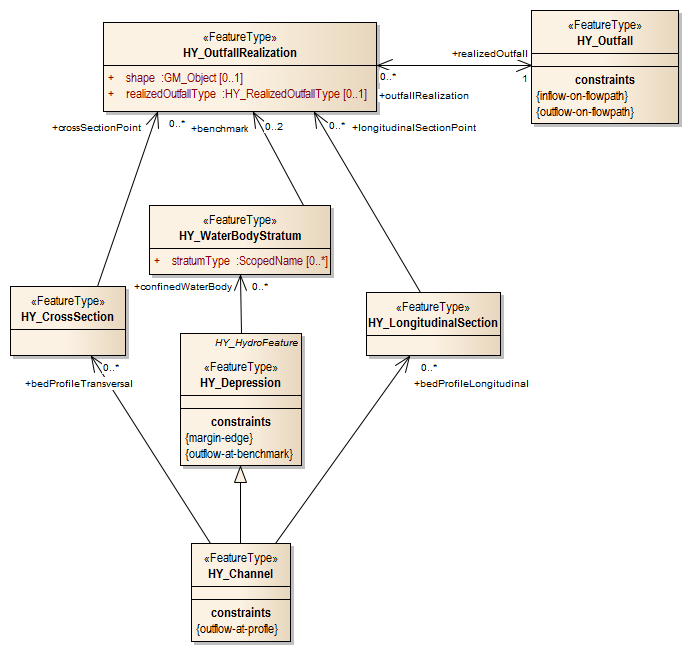


Figure 38: Depression and Channel realizing the outfall (UML class diagram)

#### Channel Network

The HY\_ChannelNetwork feature type specializes the HY\_HydroNetwork realization defined in the Hydro Feature core model, specifically as an aggregate of surface depressions and surface channels which continuously or periodically contain water, without imposing a particular drainage pattern. This allows to represent the network, even if logically connected features may or may not be connected at the representation level. If the realized catchment is connected with other catchments via outfall, the channel network is considered connected to the channel network realizing these catchments. If required, an application focused on the structures containing a water body may use the defined relationships s to describe the realization of a catchment by the channel network, or network parts associated with the hydrographic network.

HY\_ChannelNetwork associates the surfaceDepression and surfaceChannel, and carries a drainagePattern attribute; it inherits through generalization the realizedCatchment, flowpath and waterEdge associations as well as catchmentBoundary and catchmentArea associations. Depending on the application, the channel network and the related features may be described by suitable attributes. A channel-path and a channel-edge constraint are defined to support the recognition of channel and depression as flowpath realizing the catchment.

**drainagePattern** (attribute):

drainage pattern. An implementation may use a term from the HY\_DrainagePattern code list. Note that alternative code lists may be used but should be related to the terms in Annex B.3 using an appropriate formalism.

**surfaceDepression** (association):

depression on the land surface which realizes the logical catchment either separately, or as part of the channel network.

**surfaceChannel** (association):

channel on the land surface which realizes the logical catchment either separately, or as part of the channel network.

**channel-path** (constraint):

defines that whenever a flowpath exists as part of a network, the surface depression and surface channel should be recognized as a flowpath. Geometrically represented as a curve, channel-path will support to ‘measure’ a position on, or along, the channel using its centreline as shape.

**channel-edge** (constraint):

defines that whenever a water edge exists as part of a network, the surface depression and surface channel should be recognized as a water edge. Geometrically represented as a curve, channel-edge will support to ‘measure’ a position on, or along, the channel using the line of intersection with a water body.

#### Depression

The HY\_Depression feature type specializes the general HY\_HydroFeature class. It describes land lower than the surrounding land as container for standing water. A depression is part of the network of channels and depressions forming the connecting system for the wherein water bodies stand as parts of hydrographic network. HY\_Depression inherits from generalization the name property, and the channel-path and channel-edge constraints. It associates the surfaceNetwork in which it participates, a body of standingWater and a confinedWaterBody. A waterbody-edge constraint is defined to support the recognition of the confined water body as water edge realizing the catchment. An outflow-at-benchmark constraint emphasizes the recognition of a benchmark on the confined water body as outflow of the catchment realized by the channel network.

**surfaceNetwork (association):**

**network of surface channels and depressions, the depression is part of.**

**standingWater** (association):

identifies the body of stagnant water contained in the depression.

**confinedWaterBody** (association)

identifies a stratum of water body contained in the depression.

**margin-edge** (constraint):

defines that whenever a water edge exists as part of a network, the water body confined by the depression should be recognized as a water edge.

**outflow-at-benchmark** (constraint):

defines that a benchmark which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the surface network the depression is part of.

#### Channel

The HY\_Channel feature type specializes the HY\_Depression class with respect to a natural or man-made, open or closed channel through or along which water may flow, or not. A channel is part of the network of channels and depressions which forms the connecting system for the hydrographic network; a channel may have vertical sections at right angles to the main (average) direction of flow or along its centerline.

HY\_Channel associates the channelNetwork in which it participates. It carries the associations: stream, bedProfileTransversal and bedProfileLongitudinal. HY\_Channel inherits from generalization the confinedWaterBody association and the constraints waterbody-edge and outflow-at-benchmark. An outflow-at-profile constraint emphasizes the recognition of vertical section as outflow of the catchment realized by channel network.

**channelNetwork (association):**

**network of surface channels and depressions, the channel is part of.**

**stream** (association):

identifies the water body periodically or continuously flowing in the channel, including subterranean streams.

**bedProfileTransversal** and **bedProfileLongitudinal** (association):

identifies a transversal or longitudinal vertical shape of a channel, carrying a permanent reference location which realizes the outfall of the catchment which is realized by the channel.

**outflow-at-profile** (constraint):

defines that a location at a vertical section of a channel which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the surface network the channel is part of.

### The Hydrographic Network model

The Hydrographic Network model defines a logical network of water bodies which in its entirety realizes a logical catchment (Figure 39), usually as a network of linear flowpaths and/or water edges realizing catchments connected to each other within a containing catchment that is realized by the entire network. This allows to represent the network of ‘blue lines’, even if logically connected features may or may not be connected at the representation level.

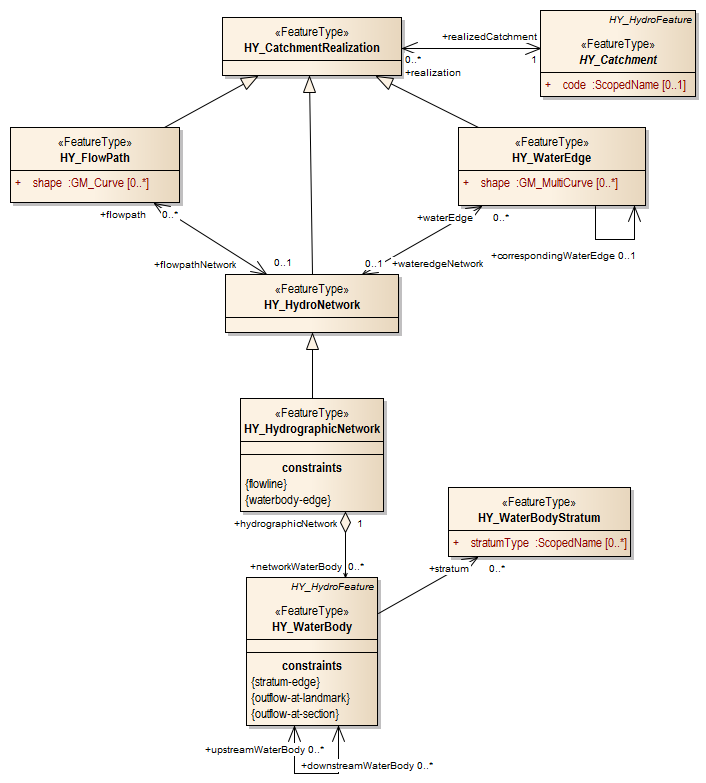


Figure 39: Hydrographic Network realizing the catchment (UML class diagram)

The hydrographic network is defined independent of the channel network. This conceptual separation references to the specific concerns of hydrology studying the occurrence, accumulation, and circulation of water. It and allows to realize the logical catchment as a network of moving or standing water bodies, regardless of the channel wherein it may move, or not.

A single water body realizes the logical catchment either as part of the hydrographic network (Figure 39), or via a reference location which realizes the conceptual outfall of the catchment realized by the water body (Figure 40). For example, a fixed landmark, or a point at an associated cross or longitudinal section is considered to realize the outflow of the catchment which is realized by the channel expressed as a flowpath.

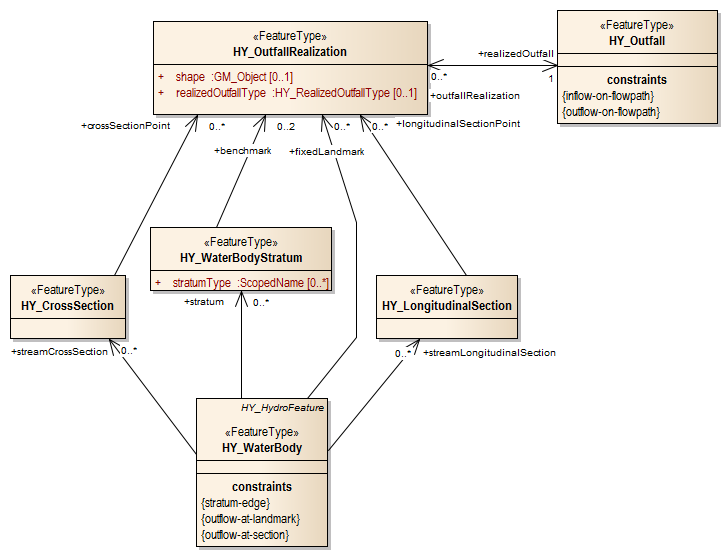


Figure 40: Water Body realizing the outfall (UML class diagram)

#### Hydrographic Network

The HY\_HydrographicNetwork feature type specializes the HY\_HydroNetwork realization defined in the Hydro Feature core model, specifically as aggregate of permanent or temporary bodies of water standing in depressions or moving in channels. If the realized catchment is connected with other catchments via outfall, the hydrographic network is considered connected to the network realizing these catchments. This allows to represent the network, even if logically connected features may or may not be connected at the representation level. If required, an application focused on surface-water bodies contained in channels or depressions may use the defined relationships s to describe the realization of a catchment by the hydrographic network, or network parts associated with the channel network.

HY\_HydrographicNetwork inherits from generalization the realizedCatchment, flowpath and waterEdge, as well as catchmentBoundary and catchmentArea associations, and associates a networkWaterBody. A flowline and a water-edge constraint support the recognition of the water body as flowpath realizing the catchment.

**networkWaterBody** (association):

water body which realizes the logical catchment either separately, or as part of the hydrographic network.

**flowline** (constraint):

defines that whenever a flowpath exists as part of a network, the water body should be recognized as a flowpath. Geometrically represented as a curve, flowline will support to ‘measure’ a position on, or along, the water body using a centreline as shape.

**water-edge** (constraint):

defines that whenever a water edge exists as part of a network, the water body should be recognized as a water edge. Geometrically represented as a curve, water-edge will support to ‘measure’ a position on, or along, the channel using the line of intersection with a water body.

#### Water Body

The HY\_WaterBody feature type specializes the general HY\_HydroFeature class. The water body as part of the hydrographic network, either standing in a water pool, or flowing as stream in a watercourse, which are parts of the channel network. A water body may be segmented in vertical sections at right angles to the main (average) direction of flow or along its centerline, and horizontal strata. Conceptually, each water body, or a stratum, is understood as a reservoir used for storage, regulation or control of water recourses.

HY\_WaterBody inherits from generalization the name property, and the flow line and water edge constraints. It associates the hydrographicNetwork in which it participates, the containing waterpool and watercourse, the vertical streamCrossSection, streamLongitudinalSection, a horizontal stratum, and a reservoir for storage of water. A stratum-edge constraint is defined such that whenever the water body is part of the hydrographic network, the confined stratum is of type HY\_WaterEdge. *Outflow-at-section* and outflow-at-landmark constraint emphasizes the recognition of a fixed landmark as outflow of the catchment realized by hydrographic network.

**waterpool** (association):

identifies the natural or artificial depression which contains standing water, including large interstices in the ground, such as cave, cavern or a group of these.

**watercourse** (association):

identifies the natural or man-made channel which continuously or periodically contains moving water, including large interstices in the ground, such as cave, cavern or a group of these

**stratum** (association):

identifies a horizontal layer of consistent characteristics, or a storage zone of a reservoir, carrying a permanent reference location which realizes the outfall of the catchment which is realized by the water body.

**upstreamWaterBody** and **downstreamWaterBody** (associations):

identifies another water body immediately upstream or downstream, allowing to trace the hydrographic network without knowing the inflow or outflow of the catchment realized by the water body.

**fixedLandmark** (association):

identifies a fixed landmark as permanent reference location which realizes the conceptual outfall of the catchment realized by the water body.

**streamCrossSection** and **streamLongitudinalSection** (associations):

identifies a vertical section either at right angles to the main (average) direction of flow, or along a centerline, carrying a permanent reference location which realizes the outfall of the catchment which is realized by the water body.

**storage** (association):

identifies a reservoir storing water as a resource for future use. This may be used to describe storage characteristics of the water body participating in the hydrographic network.

**stratum-edge** (constraint):

defines that whenever a water edge exists as part of a network, the stratum should be recognized as a water edge. Geometrically represented as a curve, stratum-edge will support to ‘measure’ a position on, or along, the stratum using the line of intersection with a depression.

**outflow-at-landmark** (constraint):

defines that a fixed landmark on a water body which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the hydrographic network the water body is part of.

**outflow-at-section** (constraint):

defines that a location at a vertical section of a water body which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the hydrographic network the water body is part of.

#### Water-Body Stratum

The HY\_WaterBodyStratum feature type describes a horizontal layer in a stratified water body determined by differences in thermal or salinity characteristics or by oxygen or nutrient content, or by virtual storage zones of a reservoir. HY\_WaterBodyStratum carries the properties: stratumType and benchmark.

**stratumType** (attribute):

characterizes the stratum using a term from a controlled vocabulary. To meet the req/hy\_hydrofeature/19103 requirement defined in section 7.4.1 of this standard, an implementation may use the ScopedName type described in ISO 19103: Conceptual Schema may be used.

**benchmark** (association):

identifies a benchmark which realizes the conceptual outfall of the catchment realized by the water body as permanent reference location.

#### Cross-Section and Longitudinal Section

The HY\_CrossSection and HY\_LongitudinalSection feature types conceptualize the segmentation of a water body or a containing channel through vertical sections. Taking into account the conceptual separation of a watercourse, the cross section concept refers to both the cross section of a water body orthogonal to the direction of flow, and to the transversal bed profile of a channel, The longitudinal section concept refers to both the vertical section of a water body along its centerline, and to the longitudinal bed profile of a channel.

Both types of vertical section associate crossSectionPoint and longitudalinalSectionPoint which should be used to identify a permanent reference location at a vertical section which realizes the conceptual outfall of the catchment realized by the associated channel or water body.

#### Water-LiquidPhase and Water-SolidPhase

The HY\_Water\_LiquidPhase and HY\_Water\_SolidPhase feature types provide simple concepts of the accumulation of water in water bodies. This definition refers to the matter accumulated to a mass of water. In its liquid form water is considered accumulated in water bodies; in its solid phase water may be accumulated after melting, or as a layer of ice or snow on an open water body. The accumulation of water in the atmosphere or below the land surface, e.g. rain, soil moisture or groundwater, is not in scope of this standard, as well as the accumulation of snow and ice in glaciers which is subject of glaciology science.

Contextually related information models may use the HY\_Water\_LiquidPhase and HY\_Water\_SolidPhase feature types to build relationships to an accumulating water body, and ultimately to the catchment realized either by the water body or by the network of which the water body is part.

HY\_Water\_LiquidPhase associates the *accumulatingWaterBody*; HY\_Water\_SolidPhase associates water from snowmelt and coveredWaterBody. These associations may be used to identify the water body (as part of the hydrographic network) where liquid water is accumulated.

### The Surface-Water Body types

The Surface Water model defines typical specializations of a water body on the land surface. Being a specialization of the HY\_WaterBody class each subtypes inherits the stratum, waterpool, watercourse, upstreamWaterBody, *downstreamWaterBody*, fixedLandmark, *streamCrossSection* and streamLongitudinalSection properties. From the general HY\_HydroFeature class the special water bodies inherit the name property, which allows to handle names given to them in cross-jurisdiction and multi-lingual contexts. Each specialization is understood to be part of the hydrographic network. In other contexts other specializations, or a typical segmentation may exist, that not conforms to the types defined in this standard.

The HY\_River feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its property to permanently or temporarily flow.

The HY\_Canal feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its artificial origin (man-made).

The HY\_Lake feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its considerable size.

The HY\_Impoundment feature type defines the existence of body of surface water, participating in a hydrographic network, special due to be formed by collecting water, as by a dam.

The HY\_Lagoon feature type defines the existence of body of surface water, participating in a hydrographic network, special due to its shallow depth and interaction with the open sea.

The HY\_Estuary feature type defines the existence of body of surface water, participating in a hydrographic network, special due to branching and its interaction with the open sea.

### The Storage model

The Storage model (Figure 41) provides a concept to describe any water body, in terms of a reservoir storing water for future use. The separate storage model allows to describe the hydrographic network without the details of storage capacities that a water body may have, and vice versa storage reservoirs to be referenced independent of their role within the hydrographic network.

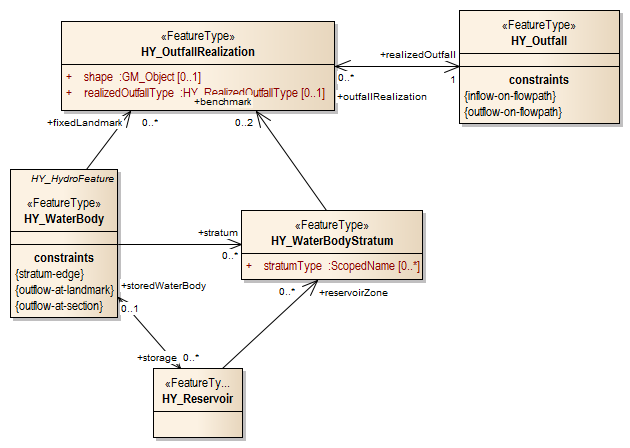


Figure 41: Reservoir realizing the outfall (UML class diagram)

The HY\_Reservoir feature type describes the water body, either natural or man-made, used for storage, regulation and control of water resources. The reservoir concept refers to a volume of water managed in zones between operating levels. HY\_Reservoir associates to a reservoir the storedWaterBody and a reservoirZone.

**storedWaterBody** (associations):

identifies the network water body that specifies the connectivity of the storage reservoir in the hydrographic network.

**reservoirZone** (association):

identifies the water body stratum used for storage, for example a management zone, or flood control zone.

## The Hydrometric Network application schema

The general requirements /req/hy\_features\_conceptual\_model/mapping and /req/hy\_features\_conceptual\_model/identifiers defined in clauses 7.2 and 7.3of this standard apply to all feature types (UML classes) defined in the Hydrometric Network application schema.

The Hydrometric Network application schema (Figure 42) defines a logical model to take into account a network of hydrometric stations as a specific realization of the catchment in the perspective of hydrologic observation, without the detail of an observation strategy.

The Hydrometric Network model specifies the concepts defined in the Hydro Feature core model (Figure 42). The general concept is that of a network of logically connected hydrometric stations realizing as a whole the catchment. This enables contextually related information models to relate monitoring stations and observing posts to hydrologic features, finally to the realized catchment, as usually required in the context of environmental reporting or when interpreting, comprising and processing observation results.



Figure 42: Hydrometric Network – dependencies

The hydrometric network model introduces the concept of a 'position on river' which allows an hydrologic station, even free from position, to be the realization of the logical outfall. This supports to establish upstream-downstream relationships between hydrometric features, to assign a position relative to a 'fixed' outfall, or to place a feature of interest relative to the hydrometric station.

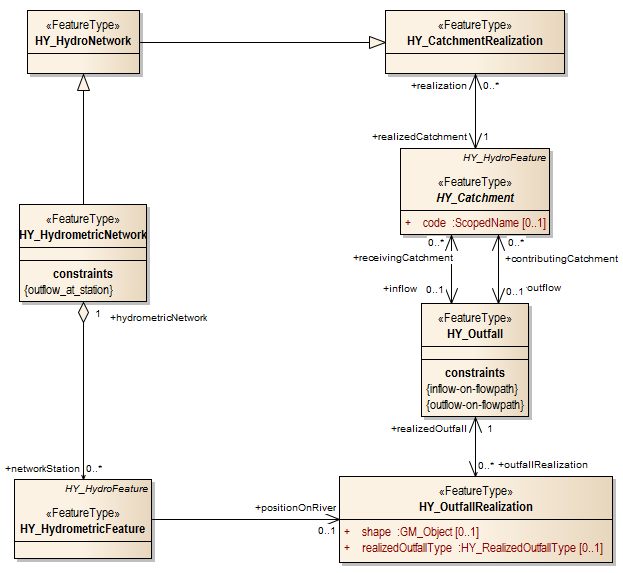


Figure 43: Hydrometric network and hydrometric feature realizing catchment and outfall (UML class diagram)

### Hydrometric Network

The HY\_HydrometricNetwork feature type specializes the HY\_HydroNetwork realization specifically as an aggregate of hydrometric features. HY\_HydrometricNetwork inherits through generalization the realizedCatchment, flowpath, waterEdge, catchmentBoundary and catchmentArea associations, and associates a *networkStation*. An outflow-at-station constraint emphasizes the recognition of a monitoring station as outflow of the catchment realized by hydrometric network

**networkStation** (association):

hydrometric feature which realizes the logical catchment either separately, or as part of the hydrometric network.

**outflow-at-station** (constraint):

defines that a monitoring station which realizes a logical outfall, should be recognized as outflow of the contributing catchment realized by the hydrometric network the station is part of.

### Hydrometric Feature

The HY\_HydrometricFeature feature type provides a concept of a monitoring station at which data on water are obtained, which realizes the logical catchment either separately, or as part of the hydrometric network (Figure 43). HY\_HydrometricFeature associates the hydrometricNetwork in which it participates, and a positionOnRiver.

**positionOnRiver** (association):

identifies the position of the hydrometric feature in the hydrographic network as permanent reference location which realizes the conceptual outfall of the catchment corresponding to the hydrometric feature.

identifies a fixed landmark which realizes the conceptual outfall of the catchment realized by the water body as permanent reference location.

# ANNEX A Conformance Class Abstract Test Suite (Normative)

## A.1 Introduction

These test suites ascertain the compliance of the conformance targets for the HY\_Features specification with the specification itself. Each instance of hydrologic feature data is encoded according to a specific interchange schema, so the role of conformance with the abstract specification is that such an implementation schema can be related to the common definitions of HY\_Features.

An implementation schema conforming to HY\_Features SHALL provide a formal mapping from one or more Feature Types present in the implementation schema to Feature Types defined in this standard specification, including all mandatory properties defined by the realized HY\_Features concept. Default values to be assumed must be specified in this mapping.

## A.2 Conformance class: HY\_HydroFeature application schema equivalence

|  |  |
| --- | --- |
| **Conformance Class** | [**/spec/hydrology/hydrofeature/1.0/conf/hy\_ hydrofeature**](https://github.com/opengeospatial/HY_Features/blob/master/spec/hydrology/hydrofeature/1.0/conf/hy_%20hydrofeature) |
| Test | [/conf/uml\_hydrofeature/namedfeature/\*](https://github.com/opengeospatial/HY_Features/blob/master/conf/uml_hydrofeature/namedfeature/*) |
| Test | [/conf/uml\_hydrofeature/hydrocomplex/\*](https://github.com/opengeospatial/HY_Features/blob/master/conf/uml_hydrofeature/hydrocomplex/*) |
| Test | [/conf/uml\_hydrofeature/positioning/\*](https://conf/uml_hydrofeature/positioning/*) |
| Requirement | All relevant elements of a data exchange schema including hydrologic features are mapped to equivalent HY\_Features elements. |
| Test purpose | All relevant elements of a data exchange schema including hydrologic features are mapped to equivalent HY\_Features elements. |
| Test method | Inspect the mapping between the data exchange schema and the HY\_Features model to determine that all relevant schema elements are mapped to HY\_Features equivalents. |
| Test type | Capability |

## A.3 Conformance class: HY\_SurfaceHydroFeature application schema equivalence

|  |  |
| --- | --- |
| **Conformance Class** | [**/ spec/hydrology/surfacehydrofeature/1.0/conf/hy\_ surfacehydrofeature**](https://github.com/opengeospatial/HY_Features/blob/master/%20spec/hydrology/surfacehydrofeature/1.0/conf/hy_%20surfacehydrofeature) |
| Test | [/conf/uml\_surfacehydrofeature/channelnetwork/\*](https://github.com/opengeospatial/HY_Features/blob/master/conf/uml_surfacehydrofeature/channelnetwork/*) |
| Test | [/conf/uml\_surfacehydrofeature/hydrographicnetwork/\*](https://github.com/opengeospatial/HY_Features/blob/master/conf/uml_surfacehydrofeature/hydrographicnetwork/*) |
| Test | [/conf/uml\_surfacehydrofeature/surfacewaterbodies/\*](https://github.com/opengeospatial/HY_Features/blob/master/conf/uml_surfacehydrofeature/surfacewaterbodies/*) |
| Test | [/conf/uml\_surfacehydrofeature/storage/\*](https://github.com/opengeospatial/HY_Features/blob/master/conf/uml_surfacehydrofeature/storage/*) |
| Requirement | All relevant elements of a data exchange schema including hydrologic features are mapped to equivalent HY\_Features elements. |
| Test purpose | All relevant elements of a data exchange schema including hydrologic features are mapped to equivalent HY\_Features elements. |
| Test method | Inspect the mapping between the data exchange schema and the HY\_Features model to determine that all relevant schema elements are mapped to HY\_Features equivalents. |
| Test type | Capability |

## A.4 Conformance class: HY\_HydrometricFeature application schema equivalence

|  |  |
| --- | --- |
| **Conformance Class** | [**/ spec/hydrology/hydrometricfeature/1.0/conf/hy\_ hydrometricfeature**](https://github.com/opengeospatial/HY_Features/blob/master/%20spec/hydrology/hydrometricfeature/1.0/conf/hy_hydrometricfeature) |
| Test | [/conf/uml\_ hydrometricfeature/hydrometricfeature/\*](https://github.com/opengeospatial/HY_Features/blob/master/conf/uml_hydrometricfeature/hydrometricfeature/*) |
| Requirement | All relevant elements of a data exchange schema including hydrologic features are mapped to equivalent HY\_Features elements. |
| Test purpose | All relevant elements of a data exchange schema including hydrologic features are mapped to equivalent HY\_Features elements. |
| Test method | Inspect the mapping between the data exchange schema and the HY\_Features model to determine that all relevant schema elements are mapped to HY\_Features equivalents. |
| Test type | Capability |

# ANNEX B - Code lists for the HY\_Features model

## B.1 Terms identifying a fixed landmark determined to realize the conceptual outfall

|  |  |
| --- | --- |
| **Code list** | **Realized Outfall Type** |
| barrage | barrier across a stream provided with a series of gates or other control mechanisms to control the water-surface level upstream, to regulate the flow or to divert water supplies into a canal. |
| bifurcation | division of a stream into two branches. |
| confluence | joining, or the place of junction, of two or more streams. |
| dam | barrier constructed across a valley for impounding water or creating a reservoir. |
| diversion of water | transfer of water from one watercourse to another, such watercourses being either natural or man-made. |
| fork | (1) place where two or more streams flow together to form a larger stream. (2) place where a stream divides into two or more streams. |
| hydrometric station | station at which data on water in rivers, lakes or reservoirs are obtained on one or more of the following elements: stage, streamflow, sediment transport and deposition, water temperature and other physical properties of water, characteristics of ice cover and chemical properties of water. |
| inlet | structure admitting water supplies from the source or through an intake structure built upstream. |
| intake | structure or site, the purpose of which is to control, regulate, divert, and admit water directly from the source, through an inlet built upstream. |
| outlet | opening through which water flows out or is extracted from a reservoir or stream. |
| ponor | hole or opening in the bottom or side of a depression where a surface stream or lake flows either partially or completely underground into a karst groundwater system |
| rapids | reach of a stream where the flow is very swift and shooting, and where the surface is usually broken by obstructions, but has no actual waterfall or cascade. |
| reference climatological station | climatological station the data of which are intended for the purpose of determining climatic trends. This requires long periods (not less than thirty years) of homogeneous records, where man-made environmental changes have been and/or are expected to remain at a minimum. Ideally the records should be of sufficient length to enable the identification of secular changes of climate. |
| river mouth | place of discharge of a river into a sea or a lake. |
| sinkhole | place where water disappears underground in a limestone region. It generally implies water loss in a closed depression or blind valley. |
| source | origin of river. |
| spring | place where water flows naturally from a rock or soil onto land or into a body of surface water. |
| waterfall | vertical fall or the very steep descent of a stream of water. |
| weir | overflow structure which may be used for controlling upstream water level or for measuring discharge or for both. |

## B.2 Terms commonly used in hydrology to describe a spatial relation between two points

|  |  |
| --- | --- |
| **Code list** | **Relative Position Type** |
| at | located at the (reference) point |
| between | located between two (reference) points |
| downstream | located downstream of the (reference) point, e.g. in the direction of the current in a river or stream. |
| left | located left-hand of the (reference) point when facing downstream. |
| nearby | located in a short distance to the (reference) point. |
| right | located right-hand of the (reference) point when facing downstream. |
| upstream | located upstream of the (reference) point, e.g. in the direction towards the source of a stream. |

## B.3 Terms commonly used in hydrology to describe a drainage pattern

|  |  |
| --- | --- |
| **Code list** | **Drainage Pattern** |
| annular | main rivers have circular pattern with subsidiary channels at right angles. |
| centripetal | streams flow inward to center. |
| dendritic | spreading treelike arrangement; no evident orientation of channels (random orientation). |
| distributary | one main channel divides into many channel-ways ending with many outlets. |
| parallel | main channels regularly spaced and parallel or sub-parallel to each other; tributaries join at very acute angles. |
| pinnate | featherlike, closely grouped , short tributaries (fine texture). |
| radial | streams flow outward from center. |
| rectangular | drainage forms a perpendicular net with the two directions equally developed. |
| trellis | a dominant drainage direction with a secondary direction perpendicular to this; primary tributaries join main stream at right angles, secondary tributaries parallel main stem. |

## B.4 Terms commonly used to indicate the type of name usage.

|  |  |
| --- | --- |
| **Code list** | **Usage Type** |
| conventional | accepted, used, or practiced by most people ('agreed by convention') |
| historical | restricted to or based on fact in history |
| official | ordered or allowed by those in authority |
| vernacular | used in or suitable for speech, usually not used in formal writing |

# ANNEX C: HY\_Features - AHGF Mapping

This is a descriptive mapping for the Australian Hydrological Geospatial Fabric (AHGF) [11]. It is intended to provide an understanding of the basic relationship of HY\_Features concepts and the AHGF hydrologic feature implementation.

## C.1 Catchment Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **AHGF Class** | **Comment** |
| HY\_Catchment | ConCatID | Logical features identified via ConCatID with topological relationships defined via ConNodeID (HY\_Outfall). Can also be seen as the contributing set of logical features sharing a common ConCatID. |
| HY\_DendriticCatchment | ConCatID | All logical HY\_Catchment features are constrained to be dendritic in the Geofabric. |
| HY\_InteriorCatchment | Not represented | All catchment areas defined by a particular DEM are considered to flow to a single common outlet.  Note: Areas not flowing to a common outlet are aggregated with areas that do according to saddle points in the terrain model. |
| HY\_CatchmentAggregate | Collections of ConNodeID | Network following connectivity via ConNodeID encapsulating divergent flows to remain dendritic in nature. |
| HY\_Outfall | ConNodeID | All ConNodeID act in the role of outflow node (To\_Node) for one or more ConCatID catchment(s) and most also act in the role of inflow node (From\_Node) for a single ConCatID catchment. |
| HY\_Outfallrealization | AHGFNetworkNode | HY\_ReferenceLocation can be used as a reference location for any point associated with a feature. In reality this will normally be a realization of a ConNodeID (with associated coordinates) or the Geofabric realization of event locations (AHGFNetworkNode::GhostNode) used to register Hydrometric features on the network. |
| HY\_CatchmentRealization | Feature identified by ConCatID | Any feature or collection of features identified by a single ConCatID. Single instances of AHGFContractedCatchment and AHGFLink as well as collections of AHGFNetworkStream, AHGFNetworkNode, AHGFCatchment (low level sub-catchments) and AHGFWaterbody. **Note**: features of subtype AHGFContractedCatchment::NoFlowArea do not have a ConNodeID (i.e. No HY\_Outfall) |
| HY\_CatchmentArea | AHGF Contracted Catchment, AHGFCatchment | A single AHGFContractedCatchment or a collection of AHGFCatchment (both 2D simple surfaces derived from a common Digital Elevation model). |
| HY\_CatchmentBoundary | Not represented | Can be seen as the boundary (or boundaries) of the polygon feature(s) that realise HY\_CatchmentArea. |
| HY\_CartographicRealization | AHGFMappedStream | AHGFMappedStream is a feature class of the Geofabric Surface Cartography product, perhaps all feature classes in this product can be considered as HY\_CartographicRealization. |

## C.2 Hydrographic Network

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **AHGF Class** | **Comment** |
| HY\_Hydrographic Network | AHGFNetworkStream | Subset of AHGFNetworkStream features (subtypes: NetworkFlowSegment & NetworkWaterAreaSegment) provides a particular HY\_CatchmentRealization. This network realization can be supplemented with its corresponding HY\_ChannelNetwork instance. |
| HY\_WaterBody | AHGFNetworkStream | AHGFNetworkStream features (subtypes: NetworkFlowSegment & NetworkWaterAreaSegment) |
| HY\_ChannelNetwork | AHGFNetworkStream | Subset of AHGFNetworkStream:: NetworkArtificialFlowSegment provides a particular HY\_CatchmentRealization. This network realization is only complete when combined with the corresponding HY\_HydrographicNetwork instance. |
| HY\_Depression | Not represented |  |
| HY\_Channel | AHGFNetworkStream | AHGFNetworkStream features (subtype: NetworkArtificialFlowSegment). For version 3 products AHGFNetworkStream features are related to the relevant logical HY\_Catchment via ConCatID. |
| HY\_Reservoir | AHGFWaterbody::Reservoir | Reservoir subtype of AHGFWaterbody. |
| HY\_FlowPath | AHGFLink | Note: Geofabric currently has no FlowPath for headwater (AHGFContractedCatchment) areas. |
| HY\_WaterEdge | Not represented |  |
| HY\_LongitudinalSection | Not represented |  |
| HY\_CrossSection | Not represented |  |
| HY\_WaterBodyStratum | Not represented |  |
| HY\_Water\_LiquidPhase | Not represented |  |
| HY\_Water\_SolidPhase | Not represented |  |
|  |  |  |

## C.3 Hydrometric Network

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **AHGF Class** | **Comment** |
| HY\_HydrometricNetwork | Not represented | Possible future plans to produce a geoschematic representation of the hydrometric features at some stage. |
| HY\_HydrometricFeature | AHGFNetworkNode:: AHGFGhostNode | Ghost Nodes are a representation of Hydrometric features located on a Hydrographic Network representation. **Note**: Currently, V3 has a separate AHGFGhostNode feature class for ghost nodes. There are plans to include these features as part of the Hydrology Reporting Catchments product forming outfalls for AHGFContractedCatchment (HY\_DendriticCatchment) features. |
| HY\_RiverReferenceSystem | Not represented | Measures are not yet explicitly included in AHGF. |
| HY\_IndirectPostition | Not represented | Measures are not yet explicitly included in AHGF. |

# ANNEX D: HY\_Features - NHDPlus Mapping

This is a descriptive mapping for the USGS National Hydrography Dataset Plus (NHDPlus)[10]. It is intended to provide an understanding of the basic relationship of HY\_Features concepts and the NHDPlus hydrologic feature implementation.

## D.1 Catchment Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_Catchment | comid catchment | The comid catchment is the feature that takes part in PlusFlow topology table, has associated accumulated characteristics, etc. Could also be the collection of catchments that contribute to a given reachcode reach, HUC watershed outlet, or other identifiable watershed outlet. |
| HY\_DendriticCatchment | comid catchment | NHDPlus catchments not following any diversions in the flow tables |
| HY\_InteriorCatchment | comid catchment | NHDPlus catchments that do not contribute flow. |
| HY\_CatchmentAggregate | collection of comid catchments | Including interior catchments and not following diversions in the flow tables |
| HY\_Outfall | fromNode or toNode | NHDPlus nodes are inflow (fromNode) and outflow (toNode) nodes of a given comid catchment. |
| HY\_OutfallRealization | fromNode or toNode location, point location of point events, etc. | HY\_ReferenceLocation can be used as a reference location for any point associated with a feature. Typically this is for outfalls and monitoring locations, but may be used for many other feature types. |
| HY\_CatchmentRealization | Any entity that is identified by a comid | In NHDPlus, the comid identifier represents an unrealized catchment. Any geometric or topologic data that is referenced to a comid can be said to realize that catchment. This includes upstream aggregations of the network or catchment areas to form complete watersheds. |
| HY\_CatchmentArea | Not Represented | While the polygon representing a catchment might be thought of as an area, the subset of a DEM or another land cover dataset would be more in line with the meaning of CatchmentArea. |
| HY\_CatchmentBoundary | comid catchment polygon | The polygon representing a comid catchment should be thought of as both the catchmentBoundary |
| HY\_CartographicRealization | A map of a catchment | The NHDPlus dataset doesn't include any, but if a map view of a catchment is created at any scale, it could be said to be a cartographic visualization realization of the catchment. |

## D.2 Hydrographic Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_HydrographicNetwork | collection of flowlines and waterbodies | The collection of perennial and ephemeral flowlines as well as so-called double line streams and on-network lakes within any collection of catchments (an HY\_Catchment) can be considered it's hydrographic network. |
| HY\_WaterBody | Perennial flowlines and waterbodies | Perennial flowlines are thought to represent water bodies as well as waterbody polygons that represent wide streams and lakes. These features indicate that there is water contained in some channel or other container. |
| HY\_ChannelNetwork | Not represented |  |
| HY\_Depression | Not represented |  |
| HY\_Channel | Ephemeral flowlines. | While NHD doesn't have an explicit channel concept, ephemeral flowlines can be thought of as a channel in that they indicate that water can flow there, but may not be present in the flowline container at all times. |
| HY\_Reservoir | waterbodies that are reservoirs | Any waterbody that can be categorized as a reservoir |
| HY\_FlowPath | flowlines and reaches | A flowline or reach is the linear representation of a catchment. For NHD Events, the reach is the flowpath because it is the linear element used for linear referencing. |
| HY\_WaterEdge | Not represented |  |
| HY\_LinearSegment | flowline | For reachcode linear referencing, the reachcode flowpath is made up of a collection of linear segments that are flowlines |
| HY\_LongitudinalSection | Not represented |  |
| HY\_CrossSection | Not represented |  |
| HY\_WaterBodyStratum | Not represented |  |
| HY\_Water\_LiquidPhase | Not represented |  |
| HY\_Water\_SolidPhase | Not represented |  |

## D.3 Hydrometric Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_HydrometricNetwork | Not Represented |  |
| HY\_HydrometricFeature | event | A hydrometric feature, such as a stream gaging station, is represented as an event. |
| HY\_RiverReferenceSystem | reachcode and measure | A reachcode reach is the river reference system's shape, the origin is the outlet of the reach, and the indirect position is the measure. |
| HY\_IndirectPosition | measure | The measure is an indirect position of type relative position because it is a percent. |

# ANNEX E: HY\_Features - INSPIRE Hydrography Theme

This table assigns core features as defined in the INSPIRE Hydrography theme [2] to HY\_Features core concepts. It also indicates relationship between both terms and potential conditions in which they can be associated.

This table should not be understood in terms of a ‘conceptual mapping’ of clearly defined relationships between two logical concepts, but rather as a simple approach to show compatibility of concepts, based on the meaning expressed in the definitions, and without imposing a particular implementation. Since each dataset that implements the INSPIRE theme will have a different legacy of documentation and information modeling, a conceptual mapping would be expressed differently. Applications implementing the INSPIRE Hydrography theme can use this listing to understand how a particular dataset may relate to the HY\_Features concepts.

## E.1 Catchment Model

|  |  |  |  |
| --- | --- | --- | --- |
| **HY\_Features Name** | **Relationship between concepts** | **INSPIRE Hydrography Name + potential condition(s)** | **Definition / Description** |
| HY\_Catchment | Is like | DrainageBasin  In case that HY\_Catchment is realized by HY\_CatchmentArea | Area having a common outlet for its surface runoff.  NOTE 1 Regarding the different classifications of drainage basins, no distinction is made between drainage basins / sub-basins since this will vary with application. It is possible to build basins from other basins.  NOTE 2 The outlet of a drainage basin may be a canal or a lake.  NOTE 3 Synonyms for drainage basin include: catchment; catchment area; drainage area; river basin; watershed. |
| HY\_DendriticCatchment | Is narrower than | DrainageBasin  In case that HY\_Catchment is realized by HY\_CatchmentArea  With one outlet | Area having a common outlet for its surface runoff.  NOTE 1 Regarding the different classifications of drainage basins, no distinction is made between drainage basins / sub-basins since this will vary with application. It is possible to build basins from other basins.  NOTE 2 The outlet of a drainage basin may be a canal or a lake.  NOTE 3 Synonyms for drainage basin include: catchment; catchment area; drainage area; river basin; watershed. |
| HY\_InteriorCatchment |  | Not represented |  |
| HY\_CatchmentAggregate | Is like | RiverBasin  In case that HY\_Catchment is realized by HY\_CatchmentArea | The area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta. |
| HY\_Outfall | Is like | HydroNode  In case that HY\_Catchment is realized by HY\_FlowPath | A node within the hydrographic network.  NOTE May represent a physical confluence, bifurcation/confluence/vanishing point etc., or it may be associated with a hydrographic point of interest or facility. |
| HY\_OutfallRealization | Is like | HydroPOI | A natural place where water appears, disappears or changes its flow.  EXAMPLE Fluvial points (waterfall, cascade, rapids, breaker), spring/water hole (spring, source, geyser, thermal spring, natural fountain, well, also fumarole, artesian), sinkhole (sinkhole, drainage loss).  NOTE A hydro point of interest may create a flow constriction in the network. |
| HY\_CatchmentRealization |  | Not represented |  |
| HY\_CatchmentArea | Is like | DrainageBasin | Area having a common outlet for its surface runoff.  NOTE 1 Regarding the different classifications of drainage basins, no distinction is made between drainage basins / sub-basins since this will vary with application. It is possible to build basins from other basins.  NOTE 2 The outlet of a drainage basin may be a canal or a lake.  NOTE 3 Synonyms for drainage basin include: catchment; catchment area; drainage area; river basin; watershed. |
| HY\_CatchmentBoundary |  | Not represented |  |
| HY\_CartographicRealization |  | Not represented |  |

## E.2 Hydrographic Network Model

|  |  |  |  |
| --- | --- | --- | --- |
| **HY\_Features Name** | **Relationship between concepts** | **INSPIRE Hydrography Name + potential condition(s)** | **Definition / Description** |
| HY\_HydrographicNetwork | Is narrower than | WatercourseLinkSequence  In case that features of interest are water bodies and not channels.  AND  In case that network is non branching. | A sequence of watercourse links representing a non-branching path through a hydrographic network. |
| HY\_WaterBody | Is narrower than | WatercourseLink  In case that features of interest are water bodies and not channels. | A segment of a watercourse within a hydrographic network. A watercourse link may be fictitious, with no direct correspondence to a real-world object and included only to ensure a closed network. |
| HY\_ChannelNetwork | Is narrower than | WatercourseLinkSequence  In case that features of interest are channels and not water bodies.  AND  In case that network is non branching. | A sequence of watercourse links representing a non-branching path through a hydrographic network. |
| HY\_Depression | Is like | StandingWater  In case that geometry is surface or point. | Any known inland waterway body.  EXAMPLE Lake/pond, reservoir, river/stream, etc.  NOTE: May include islands, represented as 'holes' in its geometry. Islands may be surrounded by a shore and / or land-ware boundary. |
| HY\_Channel | Is narrower than | WatercourseLink  In case that features of interest are channels and not water bodies. | A segment of a watercourse within a hydrographic network. A watercourse link may be fictitious, with no direct correspondence to a real-world object and included only to ensure a closed network. |
| HY\_Reservoir | Is like | StandingWater  In case that geometry is surface or point. | Any known inland waterway body.  EXAMPLE Lake/pond, reservoir, river/stream, etc.  NOTE: May include islands, represented as 'holes' in its geometry. Islands may be surrounded by a shore and / or land-ware boundary. |
| HY\_FlowPath | Is like | WatercourseLink  With a fictitious representation | A segment of a watercourse within a hydrographic network. A watercourse link may be fictitious, with no direct correspondence to a real-world object and included only to ensure a closed network. |
| HY\_WaterEdge | Is like | LandWaterBoundary | The line where a land mass is in contact with a body of water. |
| HY\_LongitudinalSection |  | Not represented |  |
| HY\_CrossSection |  | Not represented |  |
| HY\_WaterBodyStratum |  | Not represented |  |
| HY\_Water\_LiquidPhase |  | Not represented |  |
| HY\_Water\_SolidPhase |  | Not represented |  |

# ANNEX F: HY\_Features - SANDRE Mapping

This is a descriptive mapping for the French National Service for Water Data and Reference-dataset Management (SANDRE) [12]. It is intended to provide an understanding of the basic relationship of HY\_Features concepts and the SANDRE hydrologic feature dictionary for Hydrography.

Please notice that terms for SANDRE are based on French words.

## F.1 Catchment Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **SANDRE Name** | **Comment** |
| HY\_Catchment | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro  OR  ZoneHydro | SANDRE make distinction between basins and sub-basins |
| HY\_DendriticCatchment | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro  OR  ZoneHydro | SANDRE: all catchments are dendritic |
| HY\_InteriorCatchment | Not represented |  |
| HY\_CatchmentAggregate | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro | SANDRE: RegionHydro are aggregation of SecteurHydro that are aggregation of SousSecteurHydro that are aggregation of ZoneHydro |
| HY\_Outfall | NoeudHydrographique | HY\_Outfall can be seen as a specific NoeudHydrographique |
| HY\_OutfallRealization | NoeudHydrographique | HY\_Outfall can be seen as a specific NoeudHydrographique |
| HY\_CatchmentRealization | Not represented |  |
| HY\_CatchmentArea | RegionHydro  OR  SecteurHydro  OR  SousSecteurHydro  OR  ZoneHydro | While the polygon representing a catchment might be thought of as an area, the subset of a DEM or another land cover dataset would be more in line with the meaning of CatchmentArea. |
| HY\_CatchmentBoundary | LimiteHydroBassin | SANDRE : LimiteHydroBassin is the boundary of a catchment. It has a linear representation. |
| HY\_CartographicRealization | Not represented |  |

## F.2 Hydrographic Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **SANDRE Name** | **Comment** |
| HY\_HydrographicNetwork | Not represented | SANDRE focuses on channels, not on water bodies |
| HY\_WaterBody | Not represented | SANDRE focuses on channels, not on water bodies |
| HY\_ChannelNetwork | CoursEau  OR  TronconHydrographique | SANDRE: CoursEau is an aggregation of TronconHydrographique that is an aggregation of TronconHydrograElt.  All of them have a linear representation. |
| HY\_Depression | EntiteHydroSurface  OR  EltHydroSurface | SANDRE: EntiteHydroSurface is an aggregation of EltHydroSurface. Both have a surfacic representation. |
| HY\_Channel | TronconHydrographique  OR  TronconHydrograElt  OR  EltHydroSurface | SANDRE: CoursEau is aggregation of TronconHydrographique that is an aggregation of TronconHydrograElt. All of them have a linear representation.  EntiteHydroSurface |
| HY\_Reservoir | EntiteHydroSurface  OR  EltHydroSurface  OR  PointEauIsole | SANDRE: EntiteHydroSurface is an aggregation of EltHydroSurface. Both have a surfacic representation.  PointEauIsole can be used in case that HY\_Reservoir is not linked to the hydrographic network and is represented by a point |
| HY\_FlowPath | Not represented |  |
| HY\_WaterEdge | Not represented |  |
| HY\_LongitudinalSection | Not represented |  |
| HY\_CrossSection | Not represented |  |
| HY\_WaterBodyStratum | Not represented |  |
| HY\_Water\_LiquidPhase | Not represented |  |
| HY\_Water\_SolidPhase | Not represented |  |

## F.3 Hydrometric Network Model

|  |  |  |
| --- | --- | --- |
| **HY\_Features Name** | **NHDPlus Name** | **Comment** |
| HY\_HydrometricNetwork | Not Represented |  |
| HY\_HydrometricFeature | Not Represented |  |
| HY\_RiverReferenceSystem | Not Represented |  |
| HY\_IndirectPosition | Not Represented |  |

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# ANNEX H: Revision history

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Date | Release | Author | Paragraph modified | Description |
| 08.10.2014 | 0.1 | Irina Dornblut | Initial version | Initial draft in OGC template |
| 12.11.2014 | 0.2 | Irina Dornblut | Section7, Annex D included | Editing requirements classes, Annex D included |
| 15.08.2016 | 0.3 | David Blodgett; Irina Dornblut | Completely revised version | Draft in OGC template |
| 18.08.2016 | 0.4 | Irina Dornblut | Section 6 | Catchment + UML figures added |
| 31.08.2016 | 0.5 | David Blodgett, Darren Smith, David Arctur | Entire Document | General edit for clarity and consistency. |
| 12.09.2016 | 0.6 | Irina Dornblut | Entire document | More edits for clarity and consistency  Translation into American English |
| 20.09.2016 | 0.7 | HYF-SWG at Orlando TC meeting  Irina Dornblut | Entire Document | Reconciling of comments from the initial OAB review  Review of conformance and requirements classes |

1. https://cite.opengeospatial.org/ [↑](#footnote-ref-1)
2. also online, http://webworld.unesco.org/water/ihp/db/glossary/glu/aglo.htm [↑](#footnote-ref-2)