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Feature Concept Dictionary of geographic information in aquatic animal health and surveillance

Working draft 0.6 - May 2024

Table of contents

Preface

Geographic information is defined within the context of an Information Community. According to Open Geospatial Consortium (https://www.ogc.org/), an Information Community (IC) is a "*collection of systems or individuals who share a common understanding of information and processes for their specific domain*". This implies that members of the information community have common definitions, vocabularies, and technologies used to create and manage information [1]. For example, veterinarians and non-veterinarians with interests in defining and using Geographic Information System (GIS) in aquaculture animal health constitute an IC. Members of this IC share the same interest in spatially representing disease events, aquaculture management areas, farm distribution, sampling point, and so forth.

In the development of GIS projects in the aquaculture animal health domain, it is highly recommended to align the data model used to represent spatial objects included in the GIS project with the available vocabularies and semantics developed within the IC. This alignment enables GIS users to take advantage of common concept definitions and recommended attribute bindings, assists the integration of geospatial data and applications into geospatial solutions, provides help in creating geospatial datasets that are easily understandable and fit for their intended purpose, and also aids in generating metadata information, which is essential for potential users to evaluate the dataset and determine its sustainability for their specific needs.

Vocabularies and semantics of spatial objects can be defined by means of a *Feature Concept Dictionary (FCD).* An FDC provides basic definitions and related information about a set of concepts that may be used to describe geographic features used within a GIS project.

A good example of FCD has been developed by the International Hydrographic Organization (IHO) within the S-100 based Product Specification work program (https://iho.int/en/s-100-based-product-specifications). S-100 provides a theoretical framework of components that can be used by GIS experts to implement efficient production methods, optimise the quality of an organisation's products and services, and enable interoperability between disparate data providers and users. The FCD of S-100 includes the specification of bathymetric surface, maritime limits and boundaries, marine protected areas, etc. The image on the left provides a graphical idea of the features managed by the IHO's FCD. Other FCD experiences have been developed by international organisations such as NATO (Defence Geospatial Feature Concept Dictionary) and the European Union (INSPIRE directive), or by ICs like the geologist (GeoSciML of the OneGeology work plan). All these initiatives aim to promote common principles, methods, mechanisms and standards to facilitate the creation and the interchangeability of geospatial data within their communities and beyond.

The present FCD aims to provide basic definitions and related information about a set of features that may be used in GIS projects dedicated to supporting aquaculture animal health.

Scope

The Aquatic Animal Health Feature Concept Dictionary (hereinafter referred to as FCD) provides descriptions of spatial object types and data types applicable for the development of GIS projects within the aquaculture animal health domain.

The FCD encompasses spatial objects referenced in scientific and grey literature focused on GIS applications in animal disease response and surveillance for fish diseases (reference: scoping review https://www.mdpi.com/2076-2615/13/22/3525).

However, it is important to note that the FCD does not aim to model all possible spatial objects that might be used in various GIS aquatic applications. In particular, it does not include information on wild animals,

navigation or navigability, groundwater, state of aquatic environment, water quality, and site suitability parameters.

Terms, definitions, and abbreviations

1) Definitions

Centerline: A line that approximates the centre of a real-world object. It would be prohibitively expensive and impractical to faithfully record the true centreline of a river, as it would result in an irregular line with an excessive number of data points. Therefore, a pragmatic approach is often taken, resulting in a smoother line that requires the minimum number of data points to represent the object.

Centroid: Centroid or geometric centre of a polygon is the arithmetic mean position of all the points within the shape.

Convex hull: The smallest convex polygon that encloses a group of objects.

Farm Register Database: A farm is considered to exist if it is included in an officially recognised farm registry database, typically managed by the veterinary service. This registry ensures adherence to the administrative process required for establishing an aquaculture farm, including obtaining the specific consents and licences necessary for the operation. One essential piece of information derived from farm registration is the farm code, which uniquely identifies each farm within a given country. The farm code is used to link and harmonise farm registry information with other datasets such as fish farm spatial objects and LIMS data.

In Annex “Fish farm registry data”, a brief description of the information required in a Farm Registry for fish farms is provided.

Feature Catalogue: A feature catalogue serves as a repository for a set of definitions to classify real-world phenomena of significance within a specific domain. This catalogue provides a means for organising the abstract data representations, ensuring that the resulting information is as unambiguous, comprehensible, and useful as possible. [Reference: ISO 19110:2016(E) – Geographic information – Methodology for feature cataloguing].

Feature Type: Feature types are categories representing classes of real-world phenomena that share common properties. In the concept of features, we include “vector data” (a feature type that deals with discrete phenomena, each represented by one or more geometric primitives, such as points, curves, surfaces or solids) and “raster data” (a feature type that pertains to real-world phenomena that exhibit continuous variations across space, comprising a set of values associated with elements in a regular array of points or cells).

Hydrographic elements: This includes sea areas and all other water bodies, including rivers, lakes, channels, river basins and transitional waters.

Inland water: All standing or flowing water on the surface of the land, as well as all groundwater on the landward side.

Join: A join operation is used to add additional attributes to the attribute table of a geographic layer. When you need information that is not present in the current spatial object attribute table, you can use the JOIN operator to append the required attributes from another table through a common attribute shared by both tables.

Laboratory Information Management System (LIMS): LIMS is a software system developed to facilitate and manage laboratory operations. It is used to oversee and streamline the management of scientific test data and processes, from sample registration to the generation of test results.

Lake: A body of standing inland surface water.

Lattice/Areal Data: This data consists of attribute values, such as population counts, assigned to a defined geographical area. This area may take the form of regular shapes, such as grids of pixels, or irregular shapes, such as states, counties or basin areas.

Monitoring point – Monitoring site: A location, such as a specific point used for the collection of representative samples. The purpose is to observe and measure the health status of a whole or part of a water body.

Monitoring fixed stations: A monitoring point established and used periodically to collect samples. There is a strong relationship between a monitoring fixed station and a representative monitoring point.

Operator: An individual responsible for: (i) ensuring compliance with veterinarian regulation requirements, (ii) supervising the health status of the animals under their control; and (iii) taking due care to minimise the risk of disease introduction and spread in order to protect human, animal and environmental health.

Physical water application: Physical water application is used to create base maps related to hydrography.

Pond: Natural or man-made impoundment of water with a water surface area.

Positional consistency: Positional consistency pertains to the correctness of the spatial relationship between two or more objects based on specific spatial rules. For instance, a freshwater fish farm located in the middle of an ocean is certainly an error, whereas a freshwater fish farm integrated into a river network is not an error.

Public water system: A public water system provides water for human consumption through pipes or other constructed conveyances. A public water system may be publicly or privately owned.

Representative monitoring point: A monitoring point identified by the veterinary authority, which is used to define the health status of the whole or part of a water body.

Representative sample: A sample of a universe or whole (e.g. fish farm, sub-basin, lagoon) which can be expected to exhibit the average properties of the universe or whole.

Reservoir: Water of the body used to store water when it is available and serve as a water source during dry periods.

River: A body of inland water flowing for the most part on the surface of the land but which may flow underground for part of its course. It includes streams, creeks, and impoundments/small lakes thereon.

River Basin: Any portion of the earth's surface within a physical boundary defined by topographic slopes that divert all runoff to the same drainage outlet. A basin may consist of smaller basins that merge at river confluences, forming a hierarchical pattern. Other terms for a river basin are catchment area, catchment basin, drainage area, river basin, water basin, impluvium, and watershed.

River network: A river network is composed of a series of linear objects linked together. For every line, the GIS data model stores the start point and the end point of the line. The data model stores other additional points, one at each breakpoint, where the line changes direction. There are no rules on how a river-line should be broken into smaller breakpoints. This will vary with data suppliers but will also depend on the relation with the network and orography. In GIS terminology, the start point and end point of a line are called “nodes” and the breakpoints in between are called “vertex” (vertices in plural).

Sea: An area that is covered by an ocean, sea or similar saltwater body.

Self-declaration of freedom from disease: Declaration by the Competent Authority of the Member Country concerned that the country or zone is free from a disease based on implementation of the provisions of the Aquatic Code and the Aquatic Manual.

Sub-basin: The area of land from which all surface runoff flows through a series of streams, rivers, and possibly lakes to a particular point in a water course (normally a lake or a river confluence).

Transitional waters: Bodies of water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows.

Territorial sea: The territorial waters, or territorial sea as defined by the 1982 United Nations Convention on the Law of the Sea, extend up to a limit not exceeding 12 nautical miles (22.2 km), measured from the baseline. The normal baseline is the low-water line along the coast. From an ecological point of view, transitional waters are ecotones between the terrestrial, freshwater and marine ecosystems, characterised by high spatial heterogeneity and temporal variability.

Territorial waters: The zone between the limit of the coastal water bodies and the limit of the territorial sea.

Veterinary authority: the governmental authority having the primary responsibility in the whole territory for coordinating the implementation of the standards of the Aquatic Code by Competent Authorities.

2) Abbreviations

GIS	Geographic Information System
LIMS	Laboratory Information Management System
WOAH	World Organization of Animal Health
FAO	Food and Agriculture Organization

3) Disclaimer

This document has been prepared by the working group “WP1 - GIS in surveillance and diseases response for aquatic animal disease” within the framework of the WOAH project entitled “Strengthening capacity on aquatic animal health and epidemiological surveillance” (http://gis.izsvenezie.it/cooperation/woah/aquae-strength/index.php). The working group comprises a multi-national team of experts in this field, drawn from WOAH collaborating centres and Italian network of *Istituti Zooprofilattici Sperimentali*. The document is aimed at creating a document that would be easily understood and adopted in aquaculture GIS projects aimed at supporting surveillance and disease responses for aquaculture animal diseases.

Informal description

FCD describes spatial objects, which can characterise the real-world phenomena relevant to the aquaculture animal health domain. By using these concepts, GIS users can specify the geographic features to incorporate into the GIS project designed to support disease response and epidemiological surveillance activities.

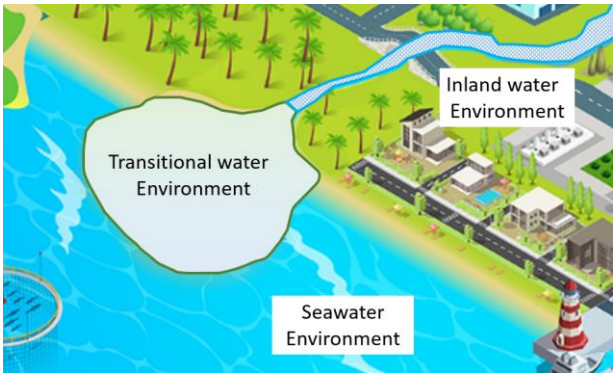
Figure 1. Aquatic animal health geospatial world. This image represents the simplified geospatial features used by the aquatic animal health information community.

FCD includes two classes of objects:

1. Basic hydrographic elements.
2. Specific aquatic animal health geographic entities.

Basic hydrographic elements are the real-world phenomena used as a framework to define the aquatic spatial environment in the GIS project. This framework primarily provides background spatial information (i.e. geographical names and shapes) and ensures consistent positional accuracy for specific aquaculture animal health geographic entities. Basic hydrographic elements consider three types of hydro morphological environments: inland water (i.e. basins, rivers and channels, lakes), seawater (i.e. oceans, seas or similar saltwater bodies) and transitional water (i.e. fjords, river deltas, etc.).

Describing the *seawater environment* is relatively straightforward, as it pertains to the aquatic environment extending from the coastal line onwards. The upper limit is typically defined as the territorial waters limit. According to the 1982 United Nations Convention on the Law of the Sea, territorial waters extend up to a limit not exceeding 12 nautical miles (22.2 km), measured from the coastline. Seawater can further be subdivided into sea regions to facilitate the identification. For example, regions like the “North Sea'', “Adriatic Sea”, etc. Additionally, seawater can



also be subdivided based on specific physical parameters such as “temperature”, “tidal currents'', “salinity”, etc.

The *inland water environment* is grounded on spatial information related to rivers. This information typically encompasses the riverbed/channels of continuously moving water and can be portrayed with different geometries depending on their dimensions and the level of detail or resolution required. The inland water environment includes lakes. Another relevant component of spatial information used to describe the inland water environment is the concept of basins. A basin not only defines the drainage limit associated with a watercourse but can also be employed to aggregate information and derive gridded/aerial data. Leveraging the hierarchical structure of basins and sub-basins allows the calculation of various statistics, including averages, minimums, maximums, sums, or counts of data associated with a specific basin.

Another type of aquatic environment is *transitional water*. Transitional waters are bodies of surface water approximately river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows. It is clear that one of the hydro morphological quality elements for transitional waters is the association with the river basin district.

Specific aquatic animal health geographic entities consist of a series of spatial objects that are crucial for the development of GIS projects in the aquatic animal health domain. They encompass various spatial objects related to the fish population (e.g. fish farm, wild fish distribution), events of epidemiological interest (e.g. outbreak, sampling collection) or other epidemiological information (e.g. infected area, free from disease area). It is essential to emphasise that these specific aquatic animal health geographic entities must be positionally consistent with the basic hydrographic elements in which they are located. This alignment ensures not only an accurate representation of the real-world phenomena but also the correctness of the spatial analysis performed with respect to the available environmental information.

Spatial objects

FDC is composed of the following spatial objects:

- Basic hydrographic elements
    - Hydrography (river, water point, lake , basin/sub-basin)
    - Sea region
    - Transitional (brackish) water
- Specific aquatic animal health geographic entities
    - Farm
    - Monitoring site
    - Aquaculture Management Area
    - Zone (ref. chapter 4.2 of the aquatic animal health code)

The following items are used to describe the spatial objects data content:

- **Name**: A compact and easily understandable label used to denote the spatial object.
- **Definition**: A precise statement outlining the nature, properties, scope, or essential characteristics of the spatial object.
- **Description**: This enhances comprehension of the object by describing its potential uses. Descriptions may include visuals, illustrations or drawings.

- **Data source**: Defines a possible origin of the dataset. In practical terms, it indicates whether the data is defined, captured, and managed "internally" by the aquatic animal health IC or if it can be acquired from an "external" source (i.e. cartographic department).
- **Geometry**: Type of spatial representation, such as raster, vector, point, polygon, or line.
- **Attributes**: Provide a list and definition of information that characterises the spatial object. The attribute can be mandatory [**M**], or optional [**O**].
- **Related features**: Specify the spatial relationship predicates. This concept may include topological considerations. The list of the spatial relationship predicates is provided in annex 1.

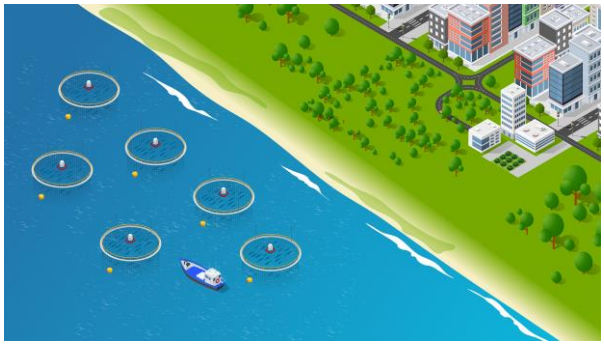
Specific aquatic animal health geographic entities

This section describes the main characteristics of geographic data needed for fisheries or aquaculture GIS works and how they are recorded in a geospatial data form.

5) Fish farm

Two types of fish farms have been identified as marine and freshwater. Farms located in transitional water environments such as fjords, estuaries and lagoons are included in the marine type.

a. Marine fish farm

Name	**marineFishFarm**
Definition	Commercial facility for raising aquatic animals in **marine water** mainly for human food.
Description	The whole area and all infrastructures under the control of an operator organised for conducting aquaculture activities in the marine waters. Registration of a fish farm in the **fish farm register** managed by a fisheries resources authority is not only a legislative requirement for starting a marine farm but also a crucial condition to develop any surveillance and disease control plan. Farms located in transitional water environments are included in this spatial object. In terms of location, marine aquaculture establishments can be sea-based and land-based. Sea-based. Sea-based aquaculture typically takes place in floating sea cages/pens, which are open on the surface yet equipped with cover nets to mitigate escapees and predation, and anchored securely to the seabed. These open pens/cages can be square, rectangular, or circular.  *Figure 1.1. Sea cages*.

	Land-based. Ashore marine aquaculture sites operate by pumping seawater into biological and/or mechanical water treatment systems before they are distributed into inland holding systems such as ponds or tanks.  *Figure 1.2. Land-based aquaculture facility equipped with extraction pumps to transport seawater into production units.* - Recirculating systems: water is continually circulated within the holding units, thereby minimising water use due to ongoing filtration and treatment.  *Figure 1.3. Broodstock facility operating as a closed system.*  *Figure 1.4. Tanks in a recirculating aquaculture system. (source saraya.tavornpanich@vetinst.no)*
Data source	Depending on the jurisdiction, fish farm data is typically captured and managed by competent authorities such as the veterinary authorities. The data can be captured directly using a GPS receiver or indirectly using satellite images such as Google Earth satellite images and digitising the farm location with GIS editing tools. Other data sources can be fishery resources authorities or other sources (e.g. ASC initiative - https://gis-asc-aqua.opendata.arcgis.com/, FAO NASO - https://www.fao.org/fishery/naso-maps/naso-home/en/).
Geometry	Three types of geographic representation are possible:

1) Multi polygon: a farm can be represented with multiple polygons, with each polygon describing a single cage or tank edge that belongs to the farm.

Figure 1.5. Fish farms are represented as polygons.

This is a very accurate geometrical representation of a farm, as it can be used to calculate the surface that belongs to the farm. However, it requires particular attention to the use of the spatial data, as selecting a farm involves selecting all polygons associated with it. It also requires more resources in the management of spatial data, such as more data to digitise and difficulties in keeping the data updated.

2) Single polygon: a farm can be represented by a single polygon that encloses all cages and/or tanks that belong to the farm.

Figure 1.6. Fish farms are represented as polygons.

This is a simpler way to represent a farm and can be obtained using the convex hull function. However, particular attention should be given to the spatial relation with other objects, as a farm polygon must not overlap with another farm-polygon.

3) Point: a farm is represented by a single point.

Figure 1.7. Fish farms are represented as points.

This is the simplest way to represent a farm with a low level of spatial accuracy. It can be used to simplify the geographical distribution in small scale maps (i.e. 1:1.000.000

	or below). The point can be calculated as the centroid of the polygon that encloses all cages and/or tanks that belong to the farm.
Attributes	● **Farm owner [M]:** name of the farm or the name of the company owning the farm. ● **Phone number [O]**: phone number of the farm owner. ● **Administrative location [O]**: appropriate administrative location of the farm (e.g. state, district or province). ● **Farm code [M]**: unique farm identification code managed by the fish farm registry. The code is used to identify farms across the country. ● **Farm licence number [O]**: reference to the permit or licence issued by the competent authority. This information is used to create an external reference to other fish farm datasets. ● **Starting date [M]**: date when the farm has been registered in the fish farm registry. ● **End date [O]:** date when the fish farm registry has been closed. ● **Business orientation [M]**: define the type of business orientation: ○ Non-commercial: small farm that relies primarily on household members for labour, and the potential sale of any surplus of aquaculture products is generally performed on-site. Usually, fish farming is not the core economic activity, but is practised to diversify production, improve resource utilisation and reduce risks such as harvest failures or market falls. ○ Commercial: presence of a business orientation, in addition to the adoption of remunerated factors of production, such as labour. Commercial aquaculture should therefore not be considered synonymous with large companies or corporations. ● **Culture system [O]**: define how aquaculture makes use of local photosynthetic production (extensive) or fish that are fed with external food supply (intensive). ○ Extensive culture: relies on primary production in the water. Fish seed is usually obtained from hatcheries, other aquaculture facilities or from the wild. ○ Semi-intensive culture: involves using supplementary feed materials provided by humans, alongside natural food sources from the water. ○ Intensive culture: the farmer provides all of the nutritional requirements of the cultured species. ● **Technology used [M]**: the farming system used to rear the fishes. ○ Sea-based: cages placed directly in seawater. ○ Land-based: holding units such as ponds and tanks are situated inland. The seawater is pumped from the sea into the holding units. In recirculating systems, there is continuous circulation in holding units as the water is filtered and treated biologically and/mechanically. Systems without recirculating systems have intermittent water exchange. ● **Type of Culture [O]:** specify if the cultured species is just one or more aquatic species. ○ Monoculture: just one species is reared.

	○ Polyculture: rearing two or more fish species with different food habits in the same culture unit. ● **Type of production [M]**: specify the type of farm production. ○ Grow-out: a facility at which fingerlings or juveniles are reared until the marketable size is reached. ○ Hatchery: a facility at which adult broodstock are held for their eggs to be collected and hatched or where eggs purchased are incubated for hatching. ○ Nursery: a facility where small larvae are reared until they reach fingerlings or juveniles sizes before uptake into grow-out units for further development. ● **Cultured species [M]**: species reared in the farm. ● **Surface area [M]**: total surface area (in hectares). It is the sum of surface area of each rearing unit (i.e. cage, tank). ● **Number of rearing units [M]**: number of rearing units available in the farm. Rearing units could be ponds, cages, tanks, etc. ● **Production [M]**: represents the fish biomass (in tonnes) produced in the farm over a particular period (usually tons per year). ● **Employees [O]**: number of temporary and permanent employees working in the farm. **For the land-based establishments only** ● **Water intake [O]:** describes the type of water supplies. ○ Sea: sea water conveyed to the farm through a series of channels. ○ Wells: sea water from underground wells. ● **Inlet water treatment [O]:** treatment for inlet water. ○ Filter: a grid or mesh of appropriate size to separate solid waste from the incoming water to be used for production. ○ Disinfection/UV treatment: used to eliminate pathogens from the inlet water. This includes use of biological filters such as biofilters. ○ No treatment: no inlet water treatment. ● **Discharged water treatment [O]:** treatment for discharged water. ○ Filter: a grid or mesh of appropriate size to separate solid waste from effluent water before discharge. ○ Disinfection/UV treatment: used to eliminate pathogens from the effluent water before discharge. This includes use of biological filters such as biofilters. ○ No treatment: no effluent water treatment.
Related features	Aquaculture Area. The farm is located within the aquaculture area (the polygon contains the point/polygon).

	Sea Region. In the case of a sea-based fish farm, the farm is located within the continental shelf or beyond in offshore waters (the polygon contains point/polygon).

b. Freshwater fish farm

Name	**freshwaterFishFarm**
Definition	Commercial facilities for raising aquatic animals in **freshwater** mainly for human food or restocking purposes. Sport/leisure fisheries and ornamental fish production are included.
Description	The whole area and all infrastructure under the control of an operator organised for conducting aquaculture by using fresh water as source of water. Potential water sources include dams, rivers and creeks, run-off, irrigation channels, underground bores. A fish farm must be registered in the **fish farm register** managed by a fisheries resources authority (*this is not only a legislative requirement for starting a marine farm, but also a crucial condition to develop any surveillance and disease control plan*). Freshwater fish farms differ according to their source of water, the way in which water can be drained from the pond or tank, the materials and method used to rear the fishes and the approach to fish farming. There are many kinds of freshwater fish farm from the epidemiological and GIS point of view, however freshwater fish farms can be grouped into three basic types: Sunken pond: built either as a dug-out pond or to make use of existing hollows or depressions in the ground, sometimes with additional embankments to increase depth. These ponds are not directly supplied with water from a water body (they are fed by groundwater, rainfall, surface runoff) and may be undrainable or only partially drainable.  *Figure 2.1. Freshwater pond.* Raceways: a water channel, especially an artificial one of running water in which fish are reared. These systems can be open (water passes through the fish basins only once and is then discharged) or as RAS (recirculating system). Water is diverted from a river upstream (or spring, or artesian wells, or lake, or reservoir, or a combination of these water sources), flows through all the tanks/ponds and finally returns to the river downstream (open system) or is conditioned through mechanical and biological filtration and reused (RAS).

Figure 2.2. Freshwater raceways.

Tanks: plastic or fibreglass containers where fish are reared. They are generally located inside a building and can be run in an open or closed/RAS system. Hatcheries generally employ tanks.

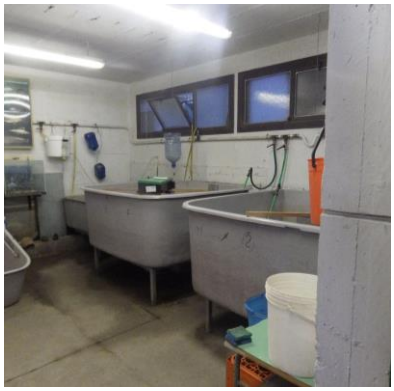


Figure 2.3. Freshwater tanks. (source:)

Recirculation systems: recirculation aquaculture is a technology for farming fish or other aquatic organisms by purifying and re-using the water in the production cycle. The technology relies on the use of mechanical and biological filters. The typical system is an indoor tank-based system that includes mechanical filters, biofilters, trickling filters, UV disinfection and oxygen enrichment technologies. Recirculation systems are usually intensive aquaculture methods with high fish stocking densities.

Figure 2.4. Freshwater recirculation.

Data source	Fish farm data are typically captured and managed by the veterinary authority. Data capture can be made by a direct means, using a GPS receiver, or indirectly, by using satellite images such as Google Earth satellite images and digitising the farm location with GIS editing tools.

	Other data sources can be fishery resources authorities, or other sources (e.g. ASC initiative - https://gis-asc-aqua.opendata.arcgis.com/, FAO NASO - https://www.fao.org/fishery/naso-maps/naso-home/en/).
Geometry	Three types of geographical representation are possible: 1) Multi polygon: a farm can be represented with multiple polygons, where each polygon describes a single pond, cage or tank edge that belongs to the farm.  *Figure 2.5. Freshwater ponds are represented as multi polygons.* This is a very accurate geometrical representation of a farm and can be used to calculate the surface area and volume of water. It requires particular attention to the use of spatial data and more resources in managing data. Geographical information about physical structures used to manage water within the farm (e.g. dikes, feeder canals, drains) are not necessary to be captured. 2) Single polygon: a farm can be represented with just a single polygon that encloses all ponds, cages and/or tanks within the farm.  *Figure 2.6. Freshwater ponds are represented as a single polygon.* This is a simple way to represent a farm and can be obtained using the convex hull function. A convex hull polygon is the smallest polygon that can be used to enclose a set of internal polygons or points, where none of the external angles of the polygon are less than 180°. Attention should be given to the spatial relation with other objects to ensure no overlap with other farm polygons. 3) Point: a farm is represented with a single point.

	 *Figure 2.7. Freshwater pond is represented as a single point.* This is the simplest way to represent a farm with low spatial accuracy. It can be used to simplify geographical distribution in small-scale maps (i.e. 1:1.000.000 or below). The point can be calculated as the centroid of the polygon that encloses all ponds and/or tanks that belong to the farm.
Attributes	● **Farm owner [M]:** name of the farm or the name of the company owning the farm. ● **Phone number [O]:** phone number of the owner. ● **Administrative location [M]**: appropriate administrative location of the farm (e.g. state, district or province). ● **Farm code [M]**: a unique farm identification code managed by the fish farm registry. The code is used to identify farms across the country. ● **Farm licence number [O]**: a reference to the permit or licence issued by the competent authority. This information serves as an external reference to other fish farm datasets. ● **Starting date [M]**: the date when the farm was registered in the fish farm registry. ● **End date [O]:** date when the fish farm registry has been closed. ● **Business orientation [M]**: defines the type of business orientation: ○ Non-commercial: small farm that relies primarily on household members for labour, and the potential sale of any surplus of aquaculture products is generally performed on-site. Usually, fish farming is not the core economic activity, but is practised to diversity production, improve resource utilisation and reduce risks such as harvest failures or market falls. ○ Commercial: indicates a business orientation, in addition to the adoption of remunerated factors of production, such as labour. Commercial aquaculture should therefore not be considered synonymous with large companies or corporations. ● **Culture system [O]**: define how aquaculture makes use of local photosynthetic production (extensive) or fish that are fed with external food supply (intensive).

	○ Extensive: relies on primary production in the water. Fish seed is usually obtained from hatcheries, other aquaculture facilities or from the wild. ○ Semi-intensive: involves using supplementary feed materials provided by humans, alongside natural food sources from the water. ○ Intensive: the farmer provides all the nutritional requirements of the cultured species. ● **Technology used [M]**: the farming system used to rear the fishes. ○ Sunken pond: a pond is directly fed by groundwater, rainfall and/or surface runoff, which may be supplemented by pumping but not normally. ○ Raceways: also known as semi-flow through systems have a water inlet from a reliable water source (like a reservoir, river, lake) and outlet to a wastewater discharge point (e.g. horticulture, river). ○ Tanks: they can be run as open or closed systems. Water can originate from any kind of source (including tap water). ○ Recirculation systems: these systems filter and clean the water for recycling through fish culture tanks, typically used to minimise water replacement, or maintain water quality conditions different from the supply water. ● **Type of Culture [O]:** specify if the cultured species is just one or more aquatic species. ○ Monoculture: just one species reared. ○ Polyculture: rearing two or more fish species with different food habits in the same culture unit. ● **Type of production [M]:** ○ Grow-out: a facility where fingerlings or juveniles are reared until they reach marketable size. ○ Hatchery: a facility where adult broodstock are held, eggs are collected and incubated, or where eggs are hatched and fish are reared. ○ Nursery: a facility where small larvae are reared until they reach fingerlings or juveniles size. ● **Water intake [M]:** describes the type of water supplies. ○ Spring-water: water that flows naturally out of the ground, including seepage. ○ Rain-fed: relies on rainfall for water. ○ River**:** natural stream of water, including artificial channels, streams, creeks, and impoundments/small lakes. ○ Public water system: a source of potable water that may need to be dechlorinated. ● **Inlet water treatment [O]:** treatment for inlet water. ○ Mechanical Filtration: a grid or mesh of the appropriate size to filter the water coming into the fish farm. ○ Disinfection: treatment to eliminate the presence of pathogens in the inlet water. ○ No treatment: no inlet water treatment. ● **Discharged water treatment [O]:** treatment for discharged water. ○ Mechanical Filtration: a grid or mesh of the appropriate size to filter the discharged water.

	○ Disinfection: treatment to eliminate the presence of pathogens in the discharged water. ○ No treatment: no inlet water treatment. ● **Cultured species [M]**: species reared in the farm. ● **Surface area [M]**: total surface area (in hectares). It is the sum of surface area of each rearing unit (e.g. ponds, cages, tanks). ● **Number of rearing units [M]**: number of rearing units available in the farm. Rearing units could be ponds, cages, tanks, etc. ● **Production [M]**: represents the fish biomass (in tonnes) produced in a farm over a particular period (usually tons per year). ● **Employees [O]**: number of temporary and permanent employees working in the farm. ● **Land tenure [O]**: the possession status of the land occupied by the farm.
Related features	Aquaculture Area. The farm is located within the aquaculture area (the polygon contains the point/polygon). Basin. The farm is located within a basin (the polygon contains the point/polygon).

6) Aquaculture area

Name	**aquacultureArea**
Definition	Areas relevant for aquaculture stakeholders, established for environmental, animal health or socioeconomic issues. An area established by a **competent authority** to delineate subpopulations with distinct animal health statuses for **disease control** or **international trade** purposes does **not** fall under this object class but it is categorised as a zone spatial object.
Description	In aquaculture, various terms are used to describe different types of areas, such as Aquaculture zoning, Farm Management Area, Aquaculture Management Areas. Despite the diversity in names, these areas serve three main concepts: manage, regulate and report. ● manage: areas established to plan and perform activities dedicated to achieve specific aquaculture objectives. ● regulate: areas established to monitor and control certain aspects of aquaculture operation such as to permit, promote, prohibit, or restrict certain environmental, public health, socioeconomic objectives. ● report: areas defined to evaluate and publish a set of information including observations, statistics, indicators, that can be used to assess progress towards one or more objectives. Simultaneously, a specific area may be subject to various regulations or management regimes, which could specify a range of activities within those areas. For instance: the same

	physical areas may have restrictions, specific management actions, and reporting requirements. The boundaries of these areas may not align with natural geographic or natural phenomena.  *Figure 3.1. Designed aquaculture zone representing an estuary and the adjacent coastal marine area. Farms/sites are presented in different colours and four clusters of farms illustrate examples of aquaculture management areas (AMAs). (source: https://www.fao.org/3/I6834EN/i6834en.pdf.)*  *Figure 3.2. Existing aquaculture zone, representing individual land-based farms. Four aquaculture management areas (AMAs); the common water source could be the priority criteria to set boundaries of the AMAs. (source: https://www.fao.org/3/I6834EN/i6834en.pdf.)*
Data source	Aquaculture areas are typically captured and managed by the organisation responsible for defining the area. Data capture methods can include direct approaches using GPS receivers or indirect methods using GIS editing tools, satellite images, or cartographic maps as background references.
Geometry	Polygon
Attributes	• **Designation period [M]**: time period indicating when the management, restriction or regulation zone was designated or became effective in the real world.

	● **Organisation [M]**: entity responsible for managing, or regulating or reporting within the zone. ● **Area type [M]**: provides a high level classification of the area. Possible values for the area type include: ○ Aquaculture Management Areas (AMA): aquaculture parks or clusters, where farms share a common waterbody or source and may benefit from a unified management system aimed at minimising environmental, social and fish health risks. ○ Area Management Agreement: an agreement among stakeholders, including aquaculture companies, wild fish interests, fisheries interests and fisheries biologists on how an area of sea may be managed for mutual benefit. ○ Fish Health Management Reporting areas: areas used for reporting animal health status for one or more diseases based upon a monitoring plan. ○ Allocated Zone for Aquaculture (AZA): coastal area resulting from a zoning process within the framework of marine spatial planning which identifies sites that are suitable for aquaculture which also minimise conflicts with other users and uses (e.g. tourism, marine protected areas, small-scale fisheries, maritime routes, military zones). ● **Area type description [O]**: description of the objective(s) and principal activities conducted within the area. ● **geographicalName [O]**: a name used to identify the area in the real world, serving as a key for implicitly associating different representations of the object.
Related features	Farm. Farm is located within the area (the polygon contains the point/polygon). Monitoring site. Site is located within the area (the polygon contains the point).

7) Zone for disease

Name	**zone**
Definition	Area established by a competent authority to define subpopulations of distinct aquatic animal health status for the purpose of disease control or international trade.
Description	According to the WOAH Aquatic Animal Health Code, a zone is an area containing an aquatic animal population with a specific aquatic animal health status regarding a disease, where surveillance and control measures and basic biosecurity conditions are applied. The zone's definition is the responsibility of the competent authority. A zone can encompass the whole country or a portion thereof. For instance, it can include an entire basin, or a lake, or part of a sea region, or a transitional water body (e.g. estuary, fjord), etc.

Figure 4.1. Example of zone

A zone's delineation is geographically based and may rely on natural or artificial geographical barriers (e.g. basin, lake, sea region).

The main differences between the **zone** spatial object and the **aquaculture areas**:

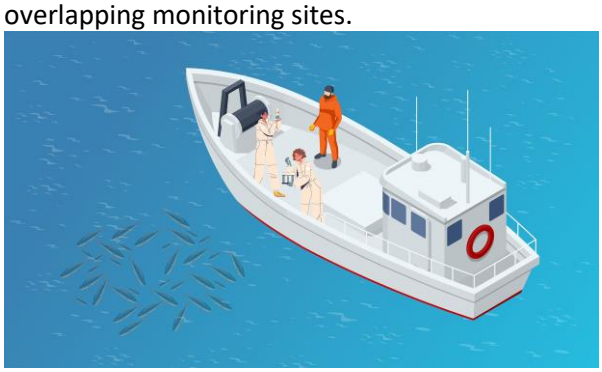
Zone	**Aquaculture area**
established by a competent authority	established by an organisation (e.g. fishermen's organisation, cluster of farmers, local communities)
for defining an animal subpopulation with a specific health status for a given disease	for a generic animal health purpose
for international trade or disease prevention or control purposes	for environmental, animal health, or other socioeconomic issues

Data source	Zones are captured and managed by the competent authority (the Veterinary Authority or other Governmental Authority responsible for ensuring or supervising the implementation of animal health and welfare measures, international veterinary certification and other standards and recommendations).
Geometry	Polygon
Attributes	● **Disease [M]**: a disease forms the basis of the decision to establish the zone. ● **Zone type [M]**: it provides the classification of the zone according to the definition included in the WOAH Aquatic Code: ○ Free zone: zone that fulfils the requirements for self-declaration of freedom from disease with respect to the disease(s) under consideration in accordance with the relevant chapter(s) in the Aquatic Code. ○ Infected zone: a zone in which a disease has been diagnosed. ○ Protection zone: a zone established to protect the health status of aquatic animals in a *free country* or *free zone*, from those in a country or zone of a different aquatic animal health status. It employs measures based on the epidemiology of the disease under consideration to prevent spread of the pathogenic agent into a free country or free zone. These measures may include, but are not limited to, vaccination, movement control, and an intensified degree of surveillance. The FAO zone called

	buffer zones or surveillance zones that are established around an infected zone (in which surveillance activities are enhanced in order to prevent spread of the disease) belong to this zone type class. • **Designation period [M]**: the time when the zone is legally designated or became effective. The designation period requires a start date and an end date. Note that disease free zone needs only the starting date since it remains in force until surveillance is continued and no outbreaks occur. • **Control measures [O]**: measures implemented within the zone. The list of possible measures shall be defined in accordance with the relevant disease-specific chapter of the WOAH Aquatic Code. • **Legislation reference (legal basis) [O]:** reference to, or citation of the legislative instrument or document that required the establishment of a zone. • **Competent authority [O]:** description of the organisation in charge of establishing the zone. • **Reference document [O]:** link to the official document of the legislation reference. (e.g.: Aquatic Animal Health Code, Commission Delegated Regulation (EU) 2020/689, etc.) • **Geographical names [O]**: a geographical name used to identify the zone in the real world. It provides a 'key' for implicitly associating different representations of the object. If the zone coincides with one or more administrative boundaries, this attribute can be used to provide the list of administrative units' names.
Related features	Farm. Farms are located within the zone (the polygon contains the point/polygon). Monitoring site. Site is located within the area (the polygon contains the point).

8) Monitoring site

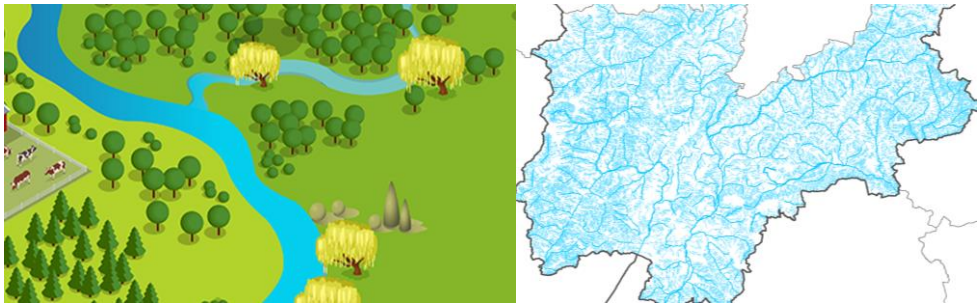
Name	**monitoringSite**
Definition	Location used for the collection of material and/or data useful for defining the health status of the wild animals.
Description	The purpose of this spatial object is to provide the geographical information about the location where samples used to define the wild animal health status have been collected. The information about the observation and measurement derived from the collected sample (e.g. species sampled and test results) are included in this specification. However, further information can be included by extending the attributes. This spatial object is characterised by an unsettle location type. Unsettle: not fixed/stable or unsettle point where a sample is collected (e.g. wild animal has been found dead or captured for monitoring purpose). It can be changed according to environmental/epidemiological conditions over time.

	The monitoring site is created as part of a monitoring plan, i.e. a plan that involves sampling for the detection of a specific pathogen in a specific species and/or geographical area. There may therefore be several plans in operation at the same location and thus several overlapping monitoring sites.  *Figure 5.1. Image with sampling from moving boat.* Each monitoring site must be associated with one and only one water body. If the water body is represented by a polygon (e.g. sea region, fish farm), then the monitoring site representative point must be contained within the water body polygon.
Data source	The monitoring site location is typically defined and managed by the veterinary authority.
Geometry	point, multipoints or line
Attributes	• **Disease (monitoring object) [M]:** specific disease referred to the monitoring activity (if there are more than 1 disease, duplicate the attributes); • **List of sampled species [M]:** The species collected at the monitoring site for laboratory analysis (if there are more than one species collected, write down every species); • **Number of sampled fish [O]:** The number or the amount (e.g. kg) of fish collected in the monitoring site; • **Laboratory test result [M]:** The result of the analysis carried out to detect the pathogen chosen, may be positive or negative; • **Date of the result [O]:** The date on which the laboratory provides the results of the analysis carried out; • **Date of the sampling [O]:** The date on which the samples are collected.
Related features	Zone. A monitoring site is within the zone (the polygon contains the point/line). Aquaculture Areas. A monitoring site is within an aquaculture area (the polygon contains the point/line).

Basic hydrographic elements

9) River

Name	**river**
Definition	Representation of the river network

Description	This spatial object is used to represent the rivers for mapping purposes. It provides the map background and the geographical name to support the spatial consistency of *freshwater fish farms* and *monitoring site* spatial objects. Rivers are modelled as a series of lines which represent the centreline of the riverbed. This type of model is used for hydrography scope. There exists also a river data model for hydrology scope that can be used for stream flow analysis (e.g. upstream/downstream, time series analysis).  *Figure 6.1. a - River network representation. b - image of the river network (light blue) in the Trento - Italy area*. The river can include water points which are spatial objects that can influence the stream flow (e.g. dam, water control construction).
Data source	River spatial data is provided by environmental or cartographic agencies. Other possible source of data are: ❖ DIVA-GIS (https://www.diva-gis.org/) ❖ HydroShed (https://www.hydrosheds.org/products/hydrosheds) ❖ HDMA (https://www.sciencebase.gov/catalog/item/5910def6e4b0e541a03ac98c) ❖ MERIT Hydro (https://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_Hydro/) ❖ AQUASTAT (FAO) https://data.apps.fao.org/catalog/iso/76e4aacc-b89e-4091-831f-63986fe029f9
Geometry	Line
Attributes	• **geographicalName**: a geographical name that is used to identify the river in the real world. It provides a 'key' to check the *freshwater fish farm* and *monitoring site* spatial location accuracy. *Other attributes/characteristics (e.g. river order, flow quantity, hydrological persistence value [e.g. perennial, seasonal]) can be offered by the data provider.*
Related features	Fish farm. In case the fish farm intake and/or outlet water to a river system, the farm is included in the river (the line contains the point). Monitoring site. In case a monitoring site is located within a water stream, the river contains the monitoring site (the line contains the point). Basin. A river is within a basin (the line is within the polygon).

	Water point. In case there is an hydraulic structure (e.g. dam, weirs) or more in general a natural or artificial artefact that may affect the aquatic ecosystem and the aquaculture animal health status, the water point is included in the river (the line contains the point). Lake. A lake can take in water from one or more rivers and can have one or more outlet rivers (the line touches the polygon). Transitional water. A river touches a transitional water area. A transitional water area is influenced by one or more rivers (the line touches the polygon).

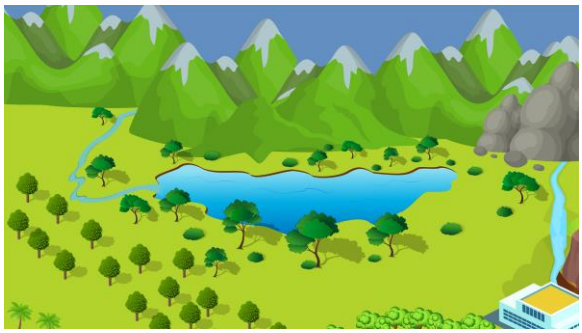
10) Water points

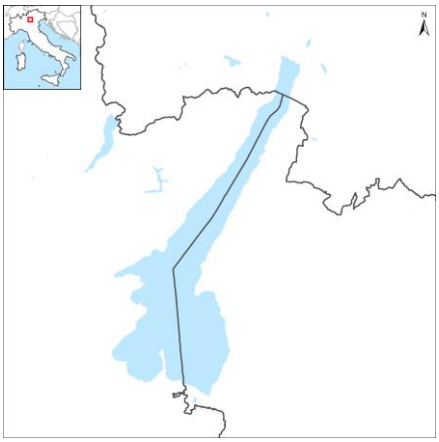
Name	**waterPoints**
Definition	Hydraulic structures that may affect the aquatic ecosystem and the aquaculture animal health status.
Description	This spatial object is used to represent natural or artificial artefacts located across rivers. This information is used for mapping purposes. Belonging to this spatial object class are artefacts such as dam, division headworks, canal regulation works, nets, closed conduits (e.g. pump, turbines) or barriers in general.  *Figure 7.1. Dam* This class of objects is used to include in the exploratory analysis the associated hydrodynamic effects that can affect the natural fish movement.
Data source	Water points are provided by environmental or cartographic agencies.
Geometry	Point

Attributes	• **waterPointType**: type of water point represented. The possible water point type can be:
	  ○ Dam
	  ○ Jump
	  ○ Net
	  ○ Pump
	• **geographicalName**: A geographical name that is used to identify the object.

Related features	River. A river contains the water point (the line contains the point).

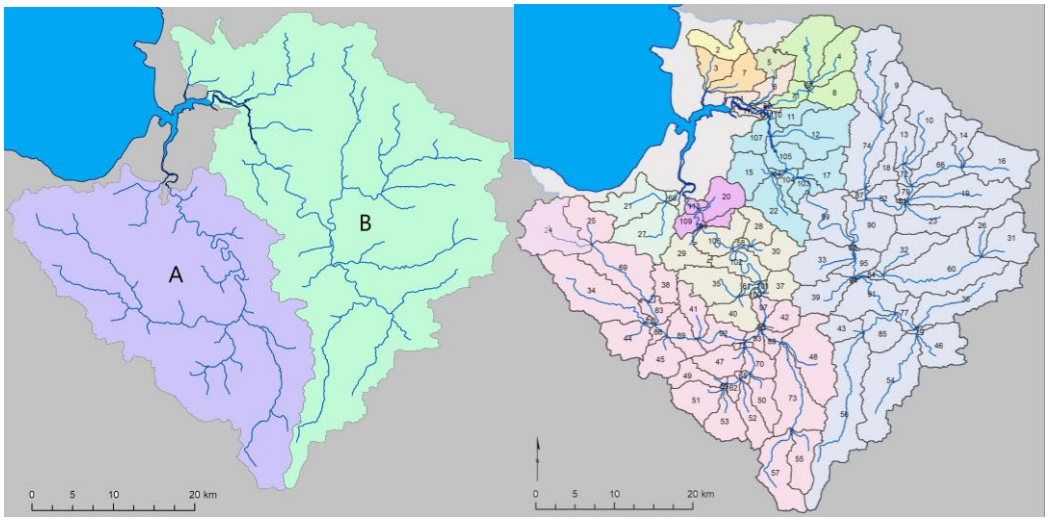
11) Lake

Name	**lake**
Definition	Representation of natural or artificial standing inland surface water bodies.
Description	This spatial object is used to represent lakes, ponds, and reservoirs for mapping purposes. It provides the map background and the geographical name to support the spatial consistency of *freshwater fish farms* and *monitoring site* spatial objects. No indication is provided about the minimum water surface size to identify a body of water as a lake. However, as a rule of thumb, a water body can be considered as a lake if it should have been a 'discrete and significant' element of surface water. Significant could mean in terms of size or epidemiological interest.  *Figure 8.1. a - Pond (source: Shutterstock). b - Natural lake - Cornino lake (Source: personal picture)* If the lake is connected to the river network, then the inlet and/or outlet point should be explicit; while if the lake is not connected to the river network (i.e. isolated lake) then only the relation with the basin should be explicit.  *Figure 8.2. Example of a lake tributary*
Data source	Lake spatial data is provided by environmental or cartographic agencies. Other possible source of data are: ❖ DIVA-GIS (https://www.diva-gis.org/) ❖ Natural Earth https://www.naturalearthdata.com/downloads/10m-physical-vectors/10m-lakes/
Geometry	Two types of representation are possible:

	12) Single polygon: a single polygon that describes the lake's edge.  *Figure 8.2. Garda lake - Italy represented as a polygon (Source: personal picture, source: PCN layer).* 13) Single point: this representation can be used in case of a small lake.  *Figure 8.3. Lake represented as point*
Attributes	• **geographicalName**: a geographical name that is used to identify the lake in the real world. It provides a 'key' to check the *freshwater fish farm* and *monitoring site* spatial location accuracy. **Other attributes/characteristics (e.g. origin [e.g. natural, artificial], average depth, hydrological persistence value [e.g. perennial, seasonal]) can be offered by the data provider.*
Related features	Fish farm. The farm is within the lake (the polygon contains the point). River basin. The lake is within the basin (the polygon contains the polygon). Water point. The water point touches the lake (the point touches the polygon).

14) River basin

Name	**riverBasin**
Definition	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.

Description	A river basin is a drainage area defined based on the digital terrain model and the river network. Starting from these two pieces of information, a software GIS, by calculating the drainage directions, accumulated flow, and stream segments is able to define the basin areas. An important characteristic of any basin delineation is the sub-basin breakdown: larger basins are subdivided into multiple tributary sub-basins. A second critical feature of basin delineations is the way the sub-basins are grouped to allow for the breakout of nested sub-basins at different scales, or to navigate within the sub-basin network from up-to downstream. The two above mentioned characteristics allow the use of the river basin to aggregate events or data that are located within the basins area. The result is a lattice map that represents the aggregated values.  *Figure 9.1. Example map showing river basins A & B and a lattice map showing sub-basins of A & B. (source: ArcGIS with source data generated using SWAT)*
Data source	River basins are provided by environmental or cartographic agencies. Other possible source of data are: ❖ HydroBASINS (https://www.hydrosheds.org/products/hydrobasins) ❖ Ecrins (https://www.eea.europa.eu/en/datahub/datahubitem-view/a9844d0c-6dfb-4c0c-a693-7d991cc82e6e)
Geometry	Polygon
Attributes	• **geographicalName [M]**: a geographical name that is used to identify the basin within the real world. It provides a 'key' for implicitly associating with other datasets.

	• **Basin identifier [O]:** unique basin identifier. A code used to identify the basin and related sub-basin. It also allows to define the hierarchical structure of the basin system. **Other attributes/characteristics (e.g. origin [e.g. natural, artificial], average depth, hydrological persistence value [e.g. perennial, seasonal]) can be offered by the data provider.*
Related features	Fish farm. The farm is within the river (the polygon contains the point/polygon). Lake. The river is within the basin (the polygon contains the polygon). River. The river is within the basin (the polygon contains the line).

15) Sea region

Name	**seaRegion**
Definition	The area that is covered by an ocean, sea or similar salt water body is identified by a specific name. A sea region is typically represented as a polygon with a name (e.g. Adriatic sea, Black sea).
Description	It is possible to identify a sea with its name. The sea region theme is therefore both an important theme in its own right, but may act as a background theme, or reference data, for visualisation in a GIS project or map. Sea regions may also act as a framework to aggregate information of spatial objects and events occurring within an area (e.g. number of fish farms, number of outbreaks).  *Figure 10.1. European regional seas - European Environment Agency (source: EEA)*
Data source	Sea region spatial data are provided by environmental or cartographic agencies. Other possible source of data are: ❖ Marine Region (https://www.marineregions.org/about.php)
Geometry	Polygon

Attributes	• **geographicalName**: a geographical name that is used to identify the sea within the real world. It provides a 'key' for implicitly associating with other datasets. **Other attributes/characteristics (e.g. number of outbreaks, number of fish farms) can be associated by a joint operation or by extending the attributes list.*
Related features	Fish farm. The farm is within the sea region (the polygon contains the point/polygon). AquacultureArea. The area is within the sea region (the polygon contains the polygon). Zone. The zone is within the sea region (the polygon contains the polygon).

16) Transitional water body

Name	transitionalWaterBody
Definition	Bodies of surface water localised in proximity to coastal waters and influenced by river flow or the ice melting.
Description	Transitional waters are partly saline in character (i.e. the salinity is generally lower than in the adjacent coastal water) and substantially influenced by sweet water flow (by means of a river flow or the ice melting). Transitional water body includes marine lagoons, wetlands, coastal inlets or fjords, delta, and estuaries. Transitional water body can **not** share the whole or part of its surface with a sea water body. The boundaries between transitional waters, freshwaters and coastal waters are usually established by a competent authority according to a series of ecological evaluations (e.g. salinity gradient, physiographic features). Transitional water body can be assigned to the nearest or most appropriate river basin area(s) or areas. No indication about the minimum water surface size to identify a water of body as a transitional water is provided. However, as a rule of thumb, a water body can be considered as a transitional area if it should be as a 'discrete and significant' element of surface water. Significant could mean in terms of size or epidemiological interest. 

	Figure 11.1. Salmon aquaculture, Lofoten islands - Norway (source: Shutterstock).  *Figure 11.2. Estuaries, Ko Lanta Island - Thailand (source: Shutterstock).*  *Figure 11.3. River delta - Mozambique (source: Shutterstock).*
Data source	Transitional water body spatial data is provided by environmental or cartographic agencies.
Geometry	**Polygon**: a transitional water body can be designed with just a single polygon that represents the water body's edge.

	 *Figure 11.4. Example of lagoon as polygon - Venice lagoon (source: wikipedia)*
Attributes	● **geographicalName**: a geographical name that is used to identify the transitional water body in the real world. It provides a 'key' for implicitly associating different representations of the object. **Other attributes/characteristics (e.g. type of water body [e.g. lagoon, estuary], mean salinity, tidal range) can be associated with a joint join operation or by extending the attributes list.*
Related features	Fish farm. The farm is within the transitional water (the polygon contains the point/polygon). Sea region. Transitional water is within the sea region (the polygon contains the polygon). Basin. Basin touches the sea region (the polygon touches the polygon). Aquaculture area. Transitional water intersects aquaculture areas (the polygon intersects the polygon).

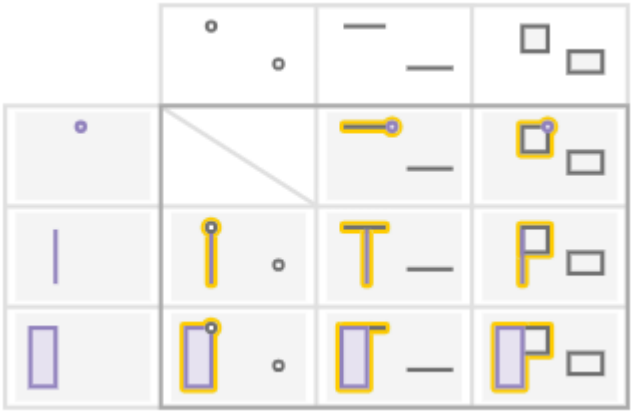
Annex 1. Spatial relationship predicates

A spatial relationship predicate represents the set of acceptable values between two geometric objects. If the spatial relationship between the two geometric objects corresponds to one of the acceptable values, then the two objects are correct.

The documents used as reference are:

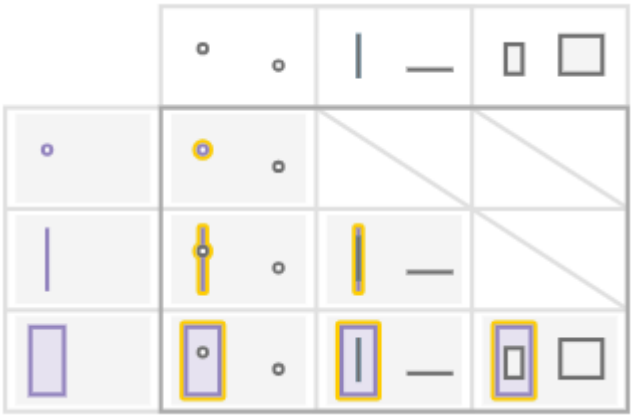
1. OpenGIS Implementation Specification for Geographic information - Simple feature access - Part 1:Common architecture, 2005, OGC 05-126, version 1.1.0
2. Spatial relationships, ESRI. accessed 09/02/2024 https://developers.arcgis.com/documentation/mapping-apis-and-services/spatial-analysis/geometry-analysis/spatial-relationship/

Touches. A part of the feature from feature class 1 comes into contact with the boundary of a feature from feature class 2. The interiors of the features do not intersect.



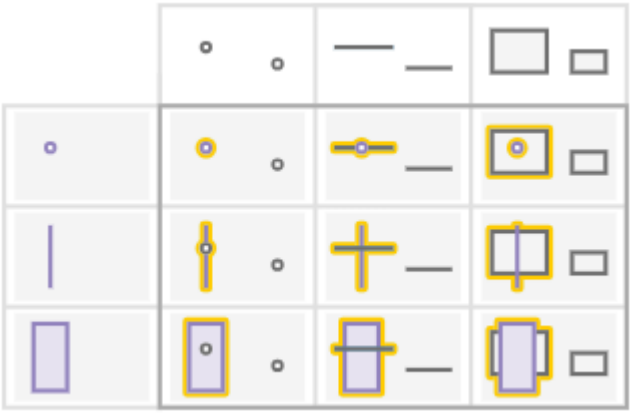
The left geometry **touches** the top geometry.

Contains. A feature from feature class 1 completely encloses a feature from feature class 2.



The left geometry **contains** the top geometry.

Intersects. Any part of a feature from feature class 1 comes into contact with any part of a feature from feature class 2.



The left geometry **intersects** the top geometry.

Related. A custom spatial relationship is defined based on the interior, boundary, and exterior of features from both feature classes.

Within. A feature from feature class 2 completely encloses a feature from feature class 1.

Crosses. The interior of a feature from feature class 1 comes into contact with the interior or boundary (if a polygon) of a feature from feature class 2 at a point.

Overlaps. The interior of a feature from feature class 1 partly covers a feature from feature class 2. Only features of the same geometry can be compared.

Reference

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