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## Techniques for and consequences of using INSPIRE extensions: a case study with Swedish hydrological data\*

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### Abstract

The demand for easily available geographic information is increasing in society. Moreover, knowledge of spatial data infrastructures (SDIs) has increased in many European governmental agencies, in large part because of the implementation of the INSPIRE directive. Many countries, thus, recognise the need to provide more detailed geographic information as network services at the national level. One means of realising this goal is to create INSPIRE extensions, i.e., to extend the INSPIRE data specifications with more detailed and specific national information. This paper describes a study where a complex INSPIRE extension has been created to describe the national need of hydrography information in Sweden, based on the Swedish water system standard (SWSS). The study includes the creation of a UML application schema that extends the INSPIRE Hydrography (HY) theme, the transform from UML to an XSD schema, the creation of GML files, and finally, testing and evaluating the approach of using INSPIRE extensions. When evaluating the results, the consequences of replacing existing dataset/download services with one extended INSPIRE HY dataset/download service are evaluated from the perspectives of both users and data providers. The evaluation is carried out as quantitative tests of the resulting GML files, in a user-centric test where a

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user tests the applicability of the GML files in hydrological analyses, and by telephone interviews with personnel from Lantmäteriet, the Swedish mapping, cadastral and land registration authority. Beside these evaluations, the possible effects on the information modelling process when creating an INSPIRE extension are also examined. The study shows that it is possible to create complex INSPIRE extensions that include many object types, attributes and relations. From a user perspective, extended INSPIRE HY files do not differ substantially from SWSS files, and can be used in hydrological analyses. Data providers can relatively simply replace their current download services with one for the extended INSPIRE HY, but the specific economic consequences for this could not be drawn. It could be expected, though, that there can be both economic, administrative and maintenance advantages if today's separate INSPIRE and national download services are replaced with services exposing datasets based on an extended INSPIRE data model for all adequate themes.

**Keywords:** INSPIRE, INSPIRE extension, data harmonisation, GML, hydrological data

## 1. INTRODUCTION

The harmonisation of geographic data as part of the creation of spatial data infrastructures (SDIs) has become increasingly widespread in recent years at several geographic levels (European, national and municipal). The INSPIRE Directive (Directive 2007/2/EC, 2007) is one of the main drivers of this development. This directive is a primary motivator of the development of SDIs at the European level, but it also has a substantial influence on their development at other levels.

The data harmonisation part of the INSPIRE directive consists of data specifications and guidance documents for 34 defined INSPIRE themes. One of the prerequisites for the creation of the specifications was that member states should not have to collect new data to be able to fulfil the directive (Directive 2007/2/EC, 2007). For this reason, highly specialised or detailed feature types, attributes and relations are not included in the INSPIRE specifications, and only a few attributes are mandatory. This practise has resulted in data specifications that, in some cases, do not contain all the information that is needed to perform all the desired comparisons and analyses at the national level. In Sweden, for example, we use the Swedish water system standard (SS 637008:2015, 2015) at the national level, as it contains more detailed information than the INSPIRE Hydrography (HY) theme.

All the EU member states are legally required to provide the information specified by the themes in INSPIRE. This information should be harmonised according to

the requirements provided in the INSPIRE data specifications and should be provided through network services (discovery, view, download and coverage), following the requirements in the technical guidelines for network services.

In a European Spatial Data Research (EuroSDR) study, most of the 12 participating national mapping agencies noted that INSPIRE was the key activity with which they associated SDIs (de Vries and others, 2011). The study concluded that most countries began with a design-oriented approach of their INSPIRE implementation. That is, they followed a sequential and planned path that was determined by technological choices and steered by guidelines, milestones and rules; moreover, it was assumed that technological development would occur isolated from the social context. Four countries later developed a more cultivated approach that featured a more open and shared information infrastructure, in which experience, personal views and past technological choices could influence the implementation.

As seen above, the implementation of the INSPIRE directive has increased the knowledge of SDIs in many governmental agencies. At the same time, the demand for easily available geographic information is increasing in society; thus, many countries now recognise a need to also provide more detailed geographic information (for example, Fernández-Freire and others, 2013). One possible means of realising this goal involves extending the INSPIRE data specification to include more detailed and specific national information.

The INSPIRE Generic Conceptual Model (GCM, 2014) contains general requirements and examples of how the INSPIRE data specifications can be extended. Recommendations and design patterns that indicate how such extensions can be implemented have begun to appear, such as those by Wettransform (<http://inspire-extensions.wettransform.to/extension-methodology.html>). Such documents contain guidance for data providers in how to extend the INSPIRE specifications.

Network services that build on extended INSPIRE data specifications and that follow the INSPIRE extension rules are considered to be INSPIRE compliant; therefore, they will be treated as INSPIRE network services for this theme. To fulfil the extension, no new classes or attributes should be added within the INSPIRE base schema, and no constraints should be added to these parts of the schema (GCM, 2014). If new elements are added as “optional” in the extended schema (and constraints are used if there is the need to make them mandatory), the same web feature service (WFS) will be able to serve both the INSPIRE extended and the INSPIRE core GML files.

A first version of an INSPIRE validation service has been developed by the A Reusable INSPIRE Reference Platform (ARE3NA) project and is now available

(<http://inspire-sandbox.jrc.ec.europa.eu/validator/>). This web application assesses whether created datasets fulfil all the INSPIRE requirements for a given theme. However, to validate extensions to INSPIRE, additional tests are needed.

INSPIRE extensions can also be created in less formal ways. Examples include incorporating all the information from an INSPIRE theme into a national data specification or creating a national specification as a realisation of an INSPIRE specification. What these extensions have in common is that they do not reference any INSPIRE schemas. Because their content and structure are close to INSPIRE, the transformation of data from these data specifications to the corresponding INSPIRE specifications will be facilitated, although these extensions are not considered to be INSPIRE implementations.

The aim of this paper is to 1) study the techniques used to create formal extensions of the INSPIRE specifications and 2) evaluate the consequences of using an extended INSPIRE dataset or a network service that exposes datasets transformed according to an extended INSPIRE data model (instead of having separate INSPIRE and national datasets and services).

The paper is organised as follows. Section 2 presents previous studies on extending specifications and on evaluation methods. Section 3 describes the development of an extended INSPIRE HY specification, and Section 4 presents how the resulting datasets are tested using quantitative measures and by evaluations from the perspectives of both users and data providers. In Section 5, the results and evaluations are discussed, together with the future outlook. Finally, Section 6 concludes the paper.

## **2. PREVIOUS STUDIES**

The need for more easily-accessible geographic information is increasing in society. In many cases, INSPIRE can provide this information at the European level. However, in several countries, there is a growing need to also provide more detailed information at the national level. Extending a general data specification represents a means of providing more detailed information on individual fields while still supplying most of the information according to a standardised format. Another advantage of this approach is that the modelling does not have to start from scratch. These advantages have led to the creation of several extended INSPIRE data specifications, some of which are described below.

The European Location Framework (ELF) project has created ELF specifications that enable the provision of up-to-date, authoritative, interoperable, and cross-border geographic information with a European coverage from 29 national mapping and cadastral agencies in 25 countries (Pauknerova and others, 2016). The ELF specifications extend the INSPIRE data specifications with additional

features that are needed for cross-border and pan-European interoperability. Another extension example is described by Fernández-Freire and others (2013), who recognised a need for homogeneous cultural heritage information to increase the ease of sharing and linking this information with other geographic data. They decided to address this need through creating an extension of the INSPIRE theme Protected Sites. This extension also includes concepts from ISO 21127:2006 (2006) and the CIDOC Conceptual Reference Model, which is commonly used in the description of heritage features.

INSPIRE extensions have also been created in less formal ways, i.e., without following the INSPIRE extension rules. Herman and Řezník (2013) recognised a need for improved visualisations of noise pollution data on the web. Their solution extends the INSPIRE Buildings3D profile through linking it with noise data from the European Noise Directive (2002/49/EC, 2002) and then presenting the information through X3D (Extensible 3D, an XML-based 3D graphics format) in a web application.

The iterative method used to create application schemas in INSPIRE has also been used in the development of other types of application schemas. Tóth and Kucas (2016) used this method when developing a domain model for the Integrated Administration and Control System (IACS) for the Common Agricultural Policy (CAP) in the EU. The domain model includes requirements from the CAP, use cases and a description of the spatial data needed, and these items are described in three different UML models. The use of shared semantics is important, and concepts from other agricultural policies, ISO standards, the INSPIRE data specifications and code lists have been used where possible.

In addition to providing data according to the INSPIRE directive, there are also many other e-reporting obligations within the European Union. As an example, this statement applies to air quality data. Kotsev and others (2015) described the problems that occur when different e-reporting obligations and the INSPIRE directive require data in different formats and delivered in different ways, and when the same terms are used with different meanings. This situation complicates both the reporting and the reuse of air quality data. The benefits could, thus, be large if the e-reporting obligations, including INSPIRE, could be streamlined with regards to their legal, semantic, technological and organisational interoperability.

The European project HUMBOLDT studied various data harmonisation solutions, especially concerning structural and semantic heterogeneities between different conceptual schemas. On this basis, they developed their own data harmonisation process that also includes a set of tools (Fichtinger and others, 2011). One of the tools developed within the project, the Humboldt Alignment Editor, has been further developed and is now renamed to Hale Studio and is widely used (<https://www.wetransform.to/products/halestudio/>).

The extensions that have been created for the OGC standard CityGML provide another example of the need to extend existing data specifications. CityGML also includes rules describing how it can be extended, either by using generic city objects and attributes or by creating Application Domain Extensions (ADE). The CityGML schema has been extended with various types of information. For example, Tegtmeier and others (2014) created 3D-GEM (Geotechnical Extension Model), a CityGML ADE that incorporates features that are needed in geotechnical work at construction sites. 3D-GEM builds on concepts from GeoSciML (an XML-based data transfer standard for the exchange of digital geoscientific information), Observations and Measurements (O&M, ISO 19156:2011) and user requirements captured in an earlier study. Li and others (2016) created an ADE extension that incorporates the ability to describe the ownership of condominiums in a detailed manner. It is called CityGML-LADM ADM and extends the CityGML model using inheritance and associations. CityGML-LADM ADM also includes links to another standard, ISO 19152, the Land Administration Domain Model (LADM), to facilitate cadastral management. Another example of an extended CityGML schema is the Energy ADE, in which the CityGML schema has been extended with information needed in the calculation of the building energy flows (Nouvel and others, 2015).

All INSPIRE data specifications are compliant with the recommendations described in the GCM (2014). This implies, among others, that ISO 19101:2005 Geographic Information – Reference Model (ISO 19101, 2005) should be used as the reference model when creating the INSPIRE data specifications. It also implies that the INSPIRE application schemas should be specified in UML conforming to ISO 19109:2006 Geographic information – Rules for application schema (ISO 19109, 2006) and ISO 19103:2005 Geographic information – Conceptual schema language (ISO 19103, 2005) with some minor exceptions. Tóth and others (2012) describe how a generic conceptual model can be used when developing specifications for an SDI. The report includes a description of a data modelling process and describes some rules for application schemas. The INSPIRE application schemas are all developed in the same information modelling software and the same software is also used for modelling all ISO 191xx application schemas. Provided that this software is used, an existing INSPIRE UML model can be imported and used as a starting point when developing a new formal INSPIRE extension.

This study also involves the evaluation of an extended INSPIRE data specification using both quantitative and qualitative measures, and where the applicability of the data is an important aspect. Here, different testing methods are required. The quantitative test is straightforward and follows a list of predefined parameters that can be computed, but the testing of applicability and usefulness can be performed using a variety of methods, some of which are described below.

According to Nielsen (2003), usability can be defined in terms of five quality components: learnability, efficiency, memorability, errors and satisfaction. These components must all be considered together with utility (i.e., whether the application has the functionality that the user requires) in order for the user to consider the application to be useful. The ISO standard 9241-11 (1998) includes a very similar definition of usability: According to this standard, usability is the “[e]xtent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.”

Both Preece and others (2002) and Demšar (2007) suggest that the use of a combination of different testing methods during the development cycle may be the best testing practise. This practise is often called ‘triangulation’ and is used because a single method may be more or less suitable during different design phases. Moreover, different methods may complement each other, giving a more complete picture of the process, and can, thus, often be ideal for evaluations. For example, Demšar found that a combination of formal and exploratory evaluation methods gave satisfactory results in a test of geovisualisation tools.

Interviews can be conducted in different ways concerning both time and place. Opdenakker (2006) conducted a study in which different interview techniques were compared from both temporal and spatial perspectives. The interviews were conducted face-to-face and by telephone, MSN Messenger and e-mail. The study concluded that all techniques can be used in research, but different circumstances require different techniques. For example, face-to-face or telephone interviews are preferable if social cues must be noted. Irvine and others (2013) performed a study in which they compared face-to-face interviews with telephone interviews. The authors noted that the respondents in telephone interviews needed more clarifications and repetitions of the questions, and that these interviews were slightly shorter than those conducted face-to-face. Regardless of the technique used, an interview may be unstructured, very structured, or somewhere in between. The questions used in an unstructured interview are open-ended, and unstructured interviews are often conducted when the interviewer has relatively little knowledge of the subject; on the other hand, structured, closed-ended questions are used in structured interviews in which the answers to very specific questions are needed (Leech, 2002). In a study performed by Leech, she determined that interviews must often be somewhere in between (i.e., semi-structured). In semi-structured interviews, open-ended questions are posed in which the respondents are asked to describe a situation, and follow-up questions or prompts are also used to elicit more detailed responses.



### 3. EXTENDING THE INSPIRE HYDROGRAPHY DATA SPECIFICATION

#### 3.1. Background

Four official hydrographic specifications currently exist in Sweden. Specifically, these specifications are the INSPIRE HY specification (2014), the Swedish water system standard (SWSS; SS 637008:2015, 2015), the ELF HY specification (which is an extension of INSPIRE HY; European Location Framework, 2016) and the data specification for water from the Svensk geoprocess (2017), a governmental and municipal cooperative that serves municipal needs and is used at the regional level.

The SWSS covers the geographic representation of water systems and defines concepts relating to water systems with their associated terms, definitions and inter-relationships. The standard encompasses surface water, coastal water, soil water and groundwater, as well as areas and sites relating to these objects. It does not cover the classification of water according to its biological or limnological properties or according to any administrative subdivision. The aims of SWSS are to facilitate the exchange of geodata concerning the objects described, and to form part of national and international initiatives for the harmonisation of geodata, such as the EU Water Framework Directive and the INSPIRE HY specification.

The SWSS is quite complex and includes many more object types, attributes and relations than the INSPIRE HY specification. To extend the INSPIRE HY specification with all the additional information from the SWSS is, therefore, a suitable test to determine whether it is possible to extend the INSPIRE data specifications (following the extension rules given by INSPIRE) when the detailed information needed at the national level is very complex.

#### 3.2. Methodology

The extension design patterns *Inheritance* and *Association* from the extension methodology described by Wettransform are used in the test (<http://inspire-extensions.wettransform.to/patterns/>). These design patterns are chosen as they describe the way the information from the SWSS will be added to the INSPIRE HY application schema.

The test includes the following steps that are described in detail in the sections below:

- Compare the INSPIRE HY and the SWSS application schemas to determine which object types, attributes and relations exist only in the SWSS.
- Create a UML application schema that extends the INSPIRE HY data specification with all additional information from the SWSS. This is done

following the requirements stated in both the INSPIRE GCM and the extension design patterns developed by Wetransform.

- Transform the UML application schema to an XSD schema file.
- Map data to the created XSD file, transform it to GML files and, finally, validate the GML files.

The study also evaluates the consequences of using one extended INSPIRE HY dataset/download service instead of having separate download services and datasets for INSPIRE HY and the national SWSS. Here, data users and data providers evaluate these consequences from their different perspectives. The GML files are evaluated in quantitative tests. Thereafter, a user evaluates the usefulness of the data by using the GML files in hydrological analyses. Semi-structured telephone interviews are performed with personnel from the IT and marketing departments at Lantmäteriet, the Swedish mapping, cadastral and land registration authority, to also evaluate the technical and economic aspects of using extended INSPIRE services.

### 3.2.1. *Comparison of the INSPIRE HY and the SWSS application schemas*

A manual comparison between the INSPIRE HY and the SWSS application schemas is performed, and all object types, attributes and relations that only exist in the SWSS application schema are marked. The SWSS application schema includes 62 object types; whereas INSPIRE HY includes 24. Eighteen of these object types occur in both application schemas. The INSPIRE HY application schema also includes four object types that are used to represent geometric networks, where the SWSS instead uses logical networks. Additionally, the Shore and Shoreline Construction object types found in INSPIRE HY are not included in the SWSS.

The results of the comparison suggest that 44 object types, together with their attributes and relations, should be added to the INSPIRE HY application schema in order to make it compatible with the SWSS.

### 3.2.2. *Create a UML application schema that extends the INSPIRE HY data specification*

The extended INSPIRE HY application schema follows the rules given in the INSPIRE GCM. To adhere to these rules, the following are not permitted in creating an extension:

- Adding, changing or deleting feature types, attributes or relations in the INSPIRE application schema; the schema can only be referenced.
- Adding requirements that break any of the requirements of the INSPIRE data specification.

However, it is permissible to create a new application schema, to import the desired INSPIRE schemas into it, and then to create new object types, associations, constraints, and so forth there. New values can also be added to the INSPIRE code lists, which are extensible.

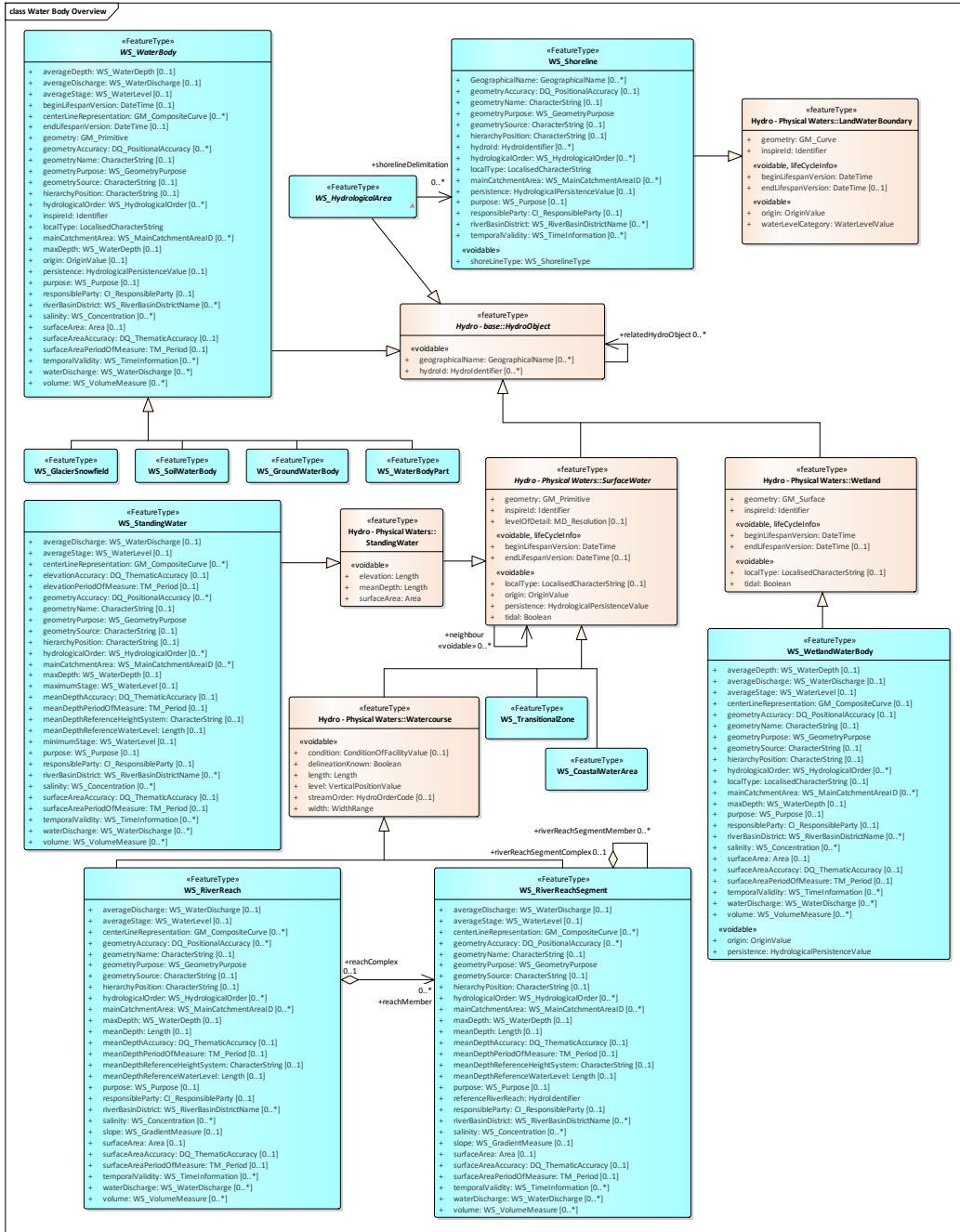
In the study, a new Enterprise Architect (EA) project is created with its own namespace, and the INSPIRE consolidated UML model (<http://inspire.ec.europa.eu/Data-Models/Data-Specifications/2892>) is imported into the project. A package for the extension model is created, together with a package for each application schema.

Diagrams are created, and the appropriate INSPIRE HY object types are inserted from the INSPIRE consolidated UML model. Thereafter, the new object types from the SWSS are added manually. This process is repeated until all 44 object types and their attributes, data types, code lists and relations have been added.

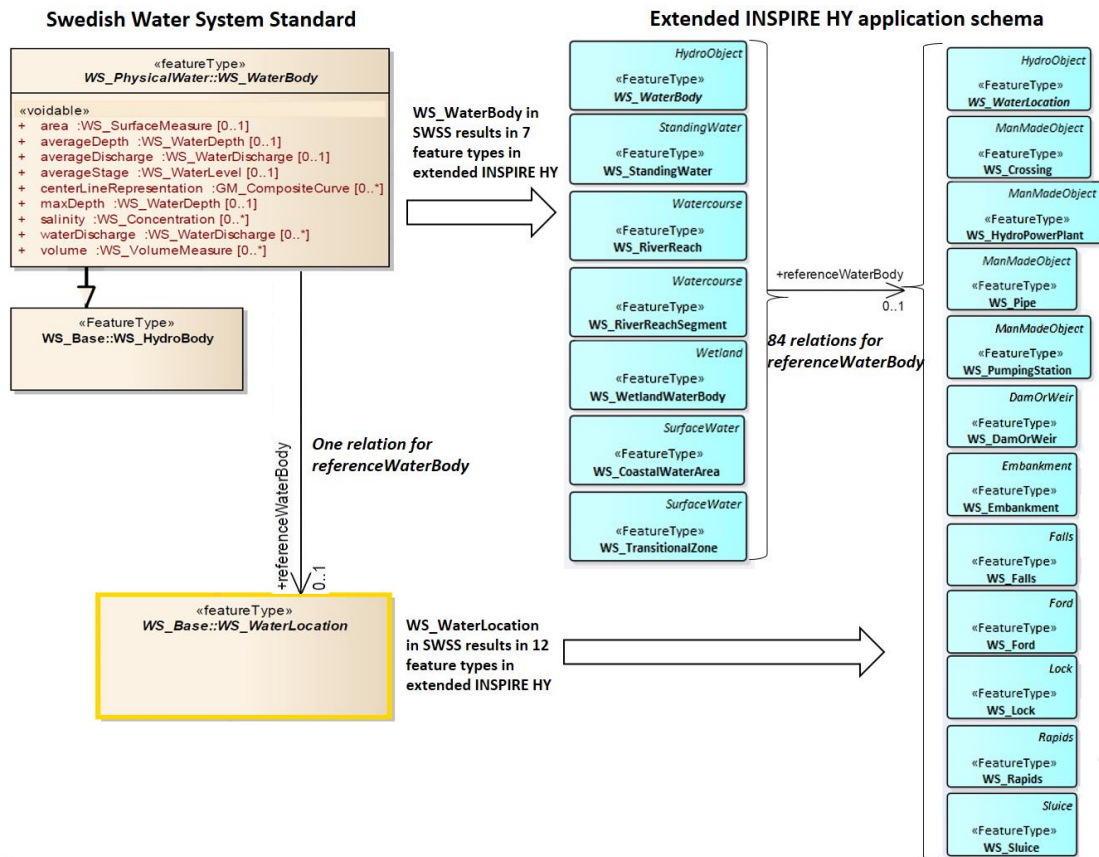
Besides having many more object types, the SWSS application schema also includes more attributes. The application schema is structured so that attributes that are common to many object types are included in abstract object types high up in the hierarchy. As changes to the INSPIRE structure are not permitted in an extension, all of these attributes must be added further down in the structure. The same is true for relations; instead of one relation between two object types high in the hierarchy (as is the case in the SWSS), many relations between object types at a lower level are added.

Figure 1 shows a selected part of the created application schema. INSPIRE HY object types are light grey and have the prefix Hydro (e.g., *Hydro – base::HydroObject*), whereas the added object types are light blue, are named according to the SWSS and have the prefix WS\_ (e.g., *WS\_ StandingWater*). The figure gives a good example of how common SWSS attributes must be added at a lower hierarchical level. Figure 2 shows how the feature types *WS\_ WaterBody* and *WS\_ WaterLocation* in SWSS result in seven and twelve feature types, respectively, in the extended INSPIRE HY model. The consequence of this is that one relation for *referenceWaterBody* in SWSS results in 84 relations in the extended model.

**Figure 1: The addition of water bodies from the SWSS to the INSPIRE HY application schema**



**Figure 2: Relationships between water bodies and water locations in the SWSS (left, one relation) and in the extended INSPIRE HY (right, 84 relations)**



### 3.2.3. Transform the UML application schema to an XSD schema file

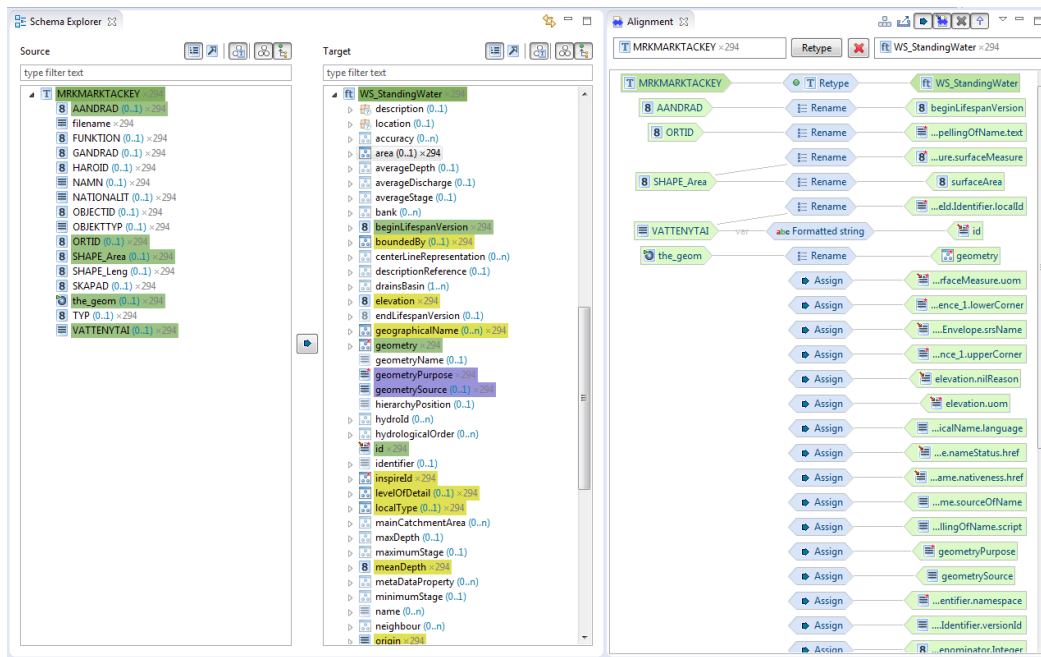
ShapeChange 2.1.0 (<https://shapechange.net/>), an open-source Java tool, is used to transform the UML application schema to an XSD file. Before the transformation can be performed, GML tags must be added to objects in the EA application schemas, and variables in the ShapeChange configuration files need to be modified to conform to the test environment.

### 3.2.4. Map the data to the created XSD file; transform and validate the GML files

The open-source application Humboldt Hale is used to map the data to the generated XSD file. Figure 3 shows how a shapefile that follows the structure of the source database for standing water at Lantmäteriet is used to map data to the WS\_StandingWater object type in the generated XSD file. Such mappings are

performed for all object types in the extended INSPIRE HY for which Lantmäteriet or the Swedish Meteorological and Hydrological Institute (SMHI) have provided data.

**Figure 3: Mapping the source data to the extended INSPIRE HY using Hale**



The mapped data is transformed to GML files in Hale, and the generated GML files are then validated in an XML editor (Altova XMLSpy).

## 4. EVALUATING THE EXTENDED INSPIRE HY GML FILES

### 4.1. Evaluation methodology

The evaluation studies the consequences of using one extended INSPIRE HY dataset/download service (as described in Section 3) instead of having separate download services and datasets for INSPIRE HY and the national SWSS. These consequences are evaluated from the perspectives of both users and data providers. To capture these different perspectives, the evaluation is divided into three parts.

The first part of the evaluation is purely quantitative and concentrates mainly on the size and structure of the GML files, as these parameters can affect the applicability as perceived by the users. The second part of the evaluation is a user-centric study that focuses on the applicability of the data. This evaluation is based

on common usages of hydrological data in hydrological analyses that require national data that are included in the national model (in this case, the SWSS). The third and final part of the evaluation is a data provider-centric study, where we evaluate information modelling, technical and economic aspects of using extended INSPIRE services.

According to the INSPIRE Directive, the GML files should be provided using network services. If network services are implemented, a download service, exposing datasets transformed according to the extended INSPIRE HY data model, would replace the two current (INSPIRE HY and SWSS) download services. This type of download service is, hereafter, named *extended INSPIRE service* in this paper. The implementation of download services is not included in the study, but the means by which the files are distributed has important implications, especially for data providers. Therefore, it is assumed here that the GML files are provided using network services.

#### **4.2. Data and study area**

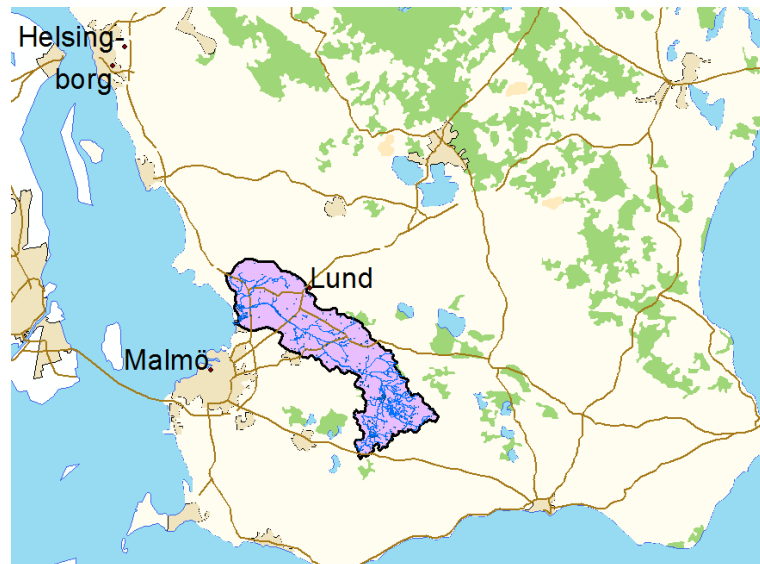
The same test data are used in both the first and second parts of the evaluation. The following datasets are used:

- INSPIRE HY data provided by Lantmäteriet
- Data according to the Swedish Water System Standard provided by Lantmäteriet and SMHI

Based on these datasets, an extended INSPIRE HY dataset is created, following the procedures described in Section 3.

The study area is the Hölje å drainage basin (Figure 4).

**Figure 4: The study area, Høje å drainage basin in the southern part of Sweden (map source: Lantmäteriet)**



#### 4.3. Quantitative evaluation

The quantitative evaluation compares the size and structure of the GML files, as these parameters can affect the applicability of the files for the users. GML files from the INSPIRE HY, the SWSS and the extended INSPIRE HY are analysed. As an example, a more detailed comparison of the standing water object type (WS\_StandingWater) is described below. The parameters that are evaluated are the file size, the number of attributes that contain values, the number of empty attributes with void reason and the maximum number of hierarchical levels for an attribute (Table 1).

**Table 1: Results of the quantitative evaluation for standing water**

Data Specification	File size in kB	No. of attributes with values	No. of empty attributes with void reason	Max no. of hierarchical levels for an attribute
INSPIRE HY	1137	20	5	9
SWSS	1166	23	3	11
Extended INSPIRE HY	1599	27	5	8

The INSPIRE HY GML file has the smallest file size and contains fewer attributes than the others, whereas the extended INSPIRE HY file has the largest file size and contains the largest number of attributes. The SWSS GML file has more



hierarchical levels than the others, due to the greater complexity of its geometry model.

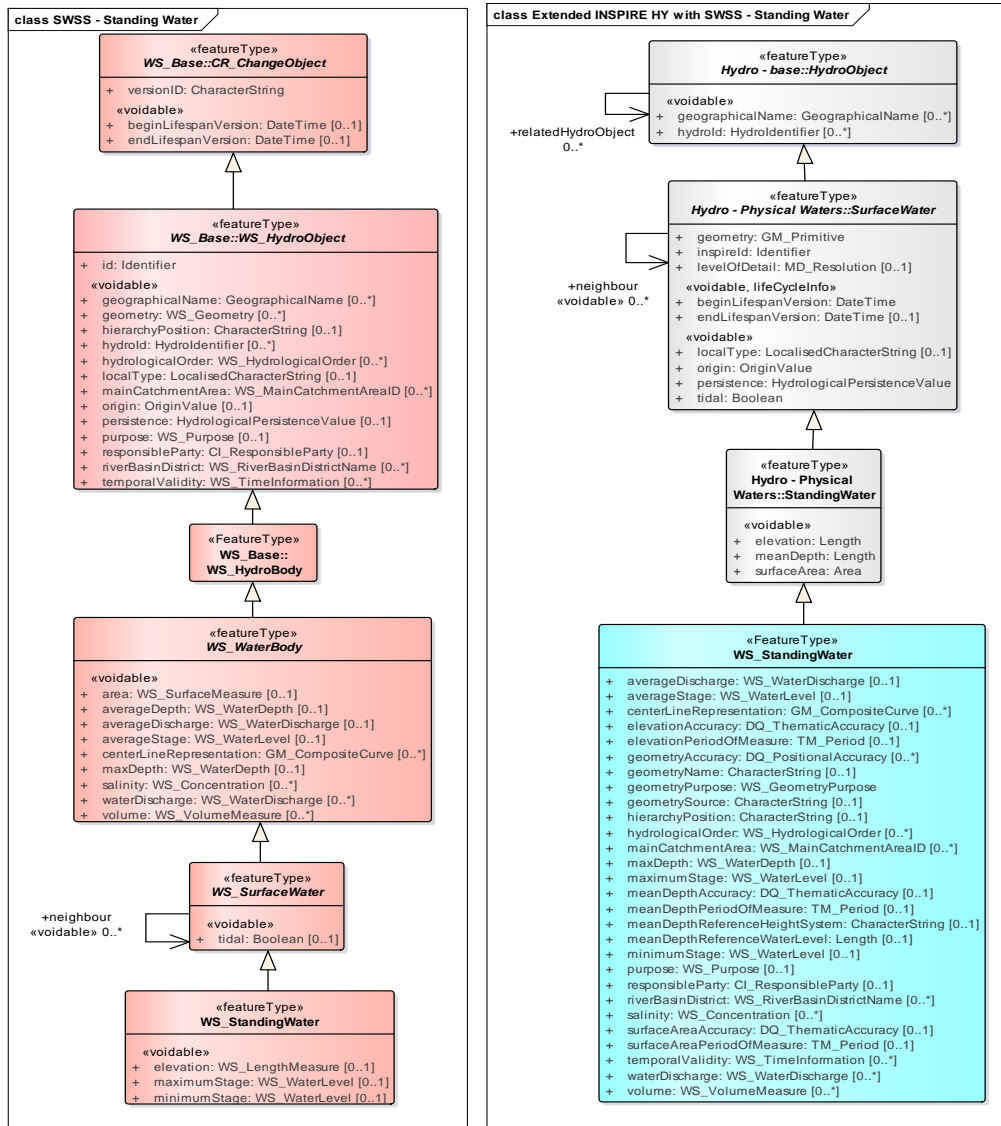
Comparison of all the object types that the three GML files have in common shows that the average file size and number of attributes for INSPIRE HY are 60 percent (60%) and 52 percent (52%) of the corresponding values of the extended INSPIRE HY, whereas the average file size and number of attributes for the SWSS are 85 percent (85%) and 88 percent (88%) of the corresponding values of the extended INSPIRE HY, respectively. That is, there is a strong correlation between the number of attributes included and the file size.

When comparing the UML application schemas for the SWSS and the extended INSPIRE HY, it is obvious that the hierarchical structures differ. The abstract feature types that contain attributes that many other feature types have in common occur higher in the hierarchy (e.g., *WS\_HydroObject* and *WS\_WaterBody*) within the SWSS. Because INSPIRE HY does not include these attributes, the attributes from the SWSS must be added to the new feature types that are created (i.e., to *WS\_StandingWater*); see Figure 5.

Despite the differences between the application schemas, the structural differences in the GML files are not as prominent. The location within the UML structure, where an attribute is defined, does not affect the hierarchical structure in the GML file. However, the complexity and structure of the data types used does have an effect. In Figure 5, the attribute *purpose* is second from the top in the hierarchical structure of the SWSS UML schema, and it occurs at the lowest level in the extended INSPIRE HY UML schema; however, in the corresponding GML files, they occupy the same level (see Figure 6). On the other hand, the *geometry* attribute is at the same level in both UML schemas, but the data type for *ws\_base:geometry* in the SWSS is more complex than that of *hy-p:geometry* in the extended INSPIRE HY. This difference results in seven levels and two metadata elements in the GML file for the SWSS, whereas the simpler data type in the extended INSPIRE HY results in three levels.

A conclusion of the above is that, as the GML files for the SWSS and the extended INSPIRE HY have similar structures, it will probably not have any major impact on the data applicability – whether a user uses the SWSS or the extended INSPIRE HY GML file.

**Figure 5: WS\_StandingWater in the SWSS (left) and in the extended INSPIRE HY (right)**



**Figure 6: GML files with WS\_StandingWater in the SWSS (left) and the extended INSPIRE HY (right)**

```

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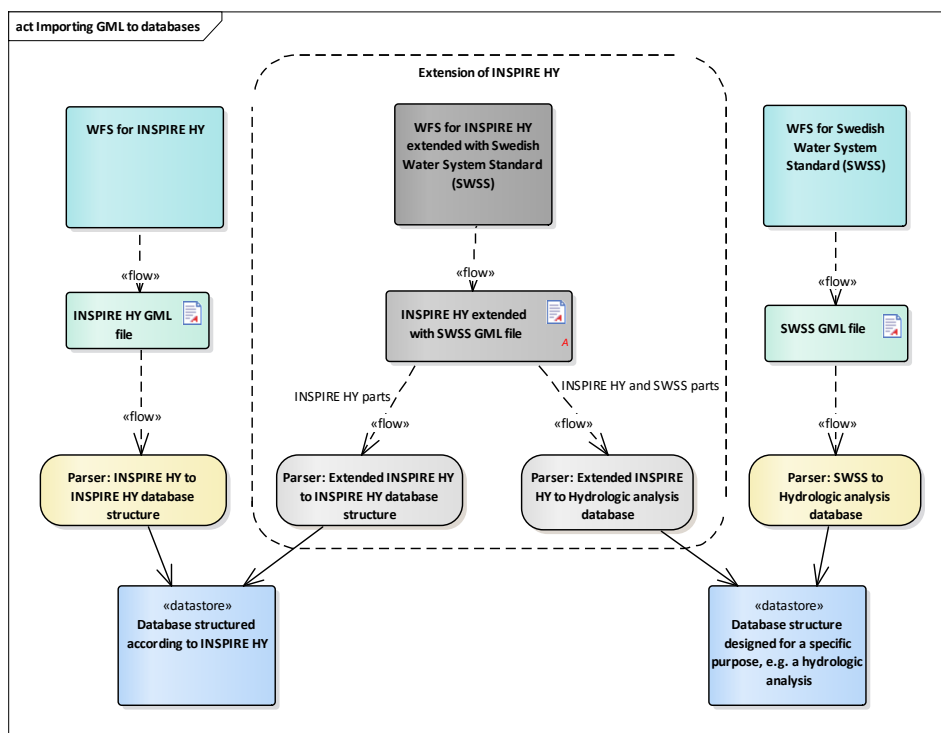
#### 4.4. Evaluation of the data applicability from a user perspective

Figure 7 illustrates two use cases for hydrological data. The first use case (on left hand side) illustrates an example where an INSPIRE HY model is wanted. This could, for example, be a cross-border hydrological study. To perform this study today in Sweden, an INSPIRE service is used. The second use case (on right-hand in Figure 7) requires more hydrological data than is contained in the INSPIRE HY

model. For these types of applications, the SWSS data are currently used in Sweden. The main focus in this part of the evaluation is to study the effect of replacing the INSPIRE data and the SWSS data with an extended INSPIRE HY model for the two use cases (the grey part in the middle of Figure 7).

From a practical point of view, we encountered a problem with the structure of the geometric element in the SWSS file. This structure cannot be read directly by some GML-readers, as, for example, with the FME Data Inspector included in FME (probably due to descriptions in the XSD file or a more complex geometry representation).

**Figure 7: The process of importing GML files into databases**



#### 4.4.1. Use case one: INSPIRE data

To obtain INSPIRE HY data from an extended INSPIRE HY model is a straightforward selection process. If the extended INSPIRE HY data is distributed as a download service of WFS type, a query that conforms to the Filter Encoding standard (OGC 09-026r1 and ISO 19143, 2010) can be used to obtain the INSPIRE HY data. Also, in case we have access to the complete GML file for the extended INSPIRE HY data, it is straightforward to use an ETL-tool to extract the sought INSPIRE HY data.

#### 4.4.2. Use case two: Hydrological analyses of detailed hydrological data

This use case is performed by Andreas Persson, a researcher in hydrology and GIS at Lund University, who has not been involved in any other parts of the study. In this use case, he examines whether the differences in the structures of the INSPIRE HY, the extended INSPIRE HY and the SWSS GML files have any effect on the usage in hydrological analyses. In order to perform analyses with the data, the user must first map the GML files to internal database structures. Here, INSPIRE HY, SWSS and extended INSPIRE HY GML files are mapped to a database to evaluate whether the different file structures have any impact on the complexity of the mapping (using the process described in Figure 7). Note that WFSs are not included in the test case; thus, the process begins with the GML files.

The use case is performed as a part of setting up a number of hydrological analyses. This includes data preparation for spatially-distributed hydrological modelling with GIS tools, as well as river flooding analysis in stand-alone hydrological models. Spatial data covering watercourses and connected characteristics are prerequisites to carry out each of the modelling procedures.

##### Data import

The information included in the three GML files is both textual information and geometries of the objects. The textual information can be divided into attributes that are associated with the hydrology (e.g., *meanDepth*, *elevation*, *surfaceArea*, *tidal* and *persistence*), and metadata at the object level (e.g., *levelOfDetail*, *purpose* and *responsibleParty*).

The data is investigated via spatial data explorer tools before the import – both to access the textual information and to preview the spatial information. The content in the metadata fields does not differ between the three GML files. Some conversion parameters are included as attribute data in the extended INSPIRE HY file which makes it larger than the corresponding INSPIRE HY and in SWSS files. The spatial extent of the datasets can be acquired and compared, as well as the attribute fields. No differences between the three GML files are observed during the data import.

##### Data observations

In the SWSS, the *WS\_RiverReach* layer covers the whole river in a vector line format. The *WS\_RiverReachSegment\_Line* layer contains the vector lines of the water course that, together with the layer *WS\_RiverReachSegment\_polygon*, creates a full cover of the rivers with wider parts digitised as polygons. Corresponding layers are also included both in the INSPIRE HY and in the extended INSPIRE HY. For overview purposes, the *WS\_RiverReach* layers are useful, but for setting up the hydrological model, full polygon coverage of the rivers

would be beneficial. Other layers that the three datasets have in common are shoreline and standing water (lakes). Here, the SWSS and the extended INSPIRE HY differ to a small extent, having a few more polygons of waterbodies than INSPIRE HY. The geometric data do not differ between the compared files. All the geometric data can be used the same way for setting up a hydrological modelling scheme in a GIS environment.

It is cumbersome to work with the textual information in the databases since a large part of the information is metadata. As most of the metadata is the same for all objects, it should rather be saved in metadata structures on the dataset level than as attributes on the object level. Attributes associated with the actual hydrology tend to be less accessible when working in a GIS environment. In this test case, the river reach characteristics are most important (e.g., lengths, areas and depths). Here, the depths information is missing for the layers where the attribute is present. Many attributes that are listed in the datasets would be useful in a modelling setup, but have null-values. However, this is because the data providers do not have this information in their databases.

#### **4.5. Evaluation from a data provider perspective**

From a data provider perspective, three types of evaluations are performed: information modelling aspects, technical aspects and economical aspects of using extended INSPIRE models. The first aspect builds on experiences from the information modelling performed in this study (cf. Section 3) and from other information modelling projects. The second aspect of the evaluation is performed using telephone interviews with technical personnel at Lantmäteriet. Finally, the third aspect is evaluated based on telephone interviews with two persons at the marketing department at Lantmäteriet. Semi-structured interviews with pre-defined questions were used in all interviews.

##### *4.5.1. Information modelling aspects*

Usually, the information modelling starts from scratch – that is, with an empty UML model. When developing an extended INSPIRE HY UML application schema, the INSPIRE consolidated UML model is imported and the additional national information is added to this model. This is a less time-consuming task than to start the UML modelling process from nothing. On the other hand, this could make the UML application schema more complicated to maintain, as all new object types, attributes and relations need to be added further down in the UML structure as child elements to the INSPIRE object types. The imported INSPIRE parts can also cause the extended UML application schema to appear to be more complex, as all INSPIRE types might not be needed in the national context.

Using INSPIRE application schemas ensures that these parts of the schema will be standardised and harmonised with INSPIRE. But, if there are changes made to

the INSPIRE application schemas, the national schemas will also be affected. We do not see any substantial risk for frequent updates of the INSPIRE application schemas though, as some correctional updates already have been implemented and also because such updates would affect many existing INSPIRE implementations.

All INSPIRE application schemas are written in English. This will make an extended INSPIRE application schema more easily understood in other countries. But, the English language could also cause a problem for countries that want to have national schemas in their own languages. For some national mapping agencies, including Lantmäteriet, there are decisions that their national databases should be based on an information model with object types and attributes in their own national languages; a consequence of that is that an extended INSPIRE model will be defined in mixed languages.

#### 4.5.2. *Technical aspects*

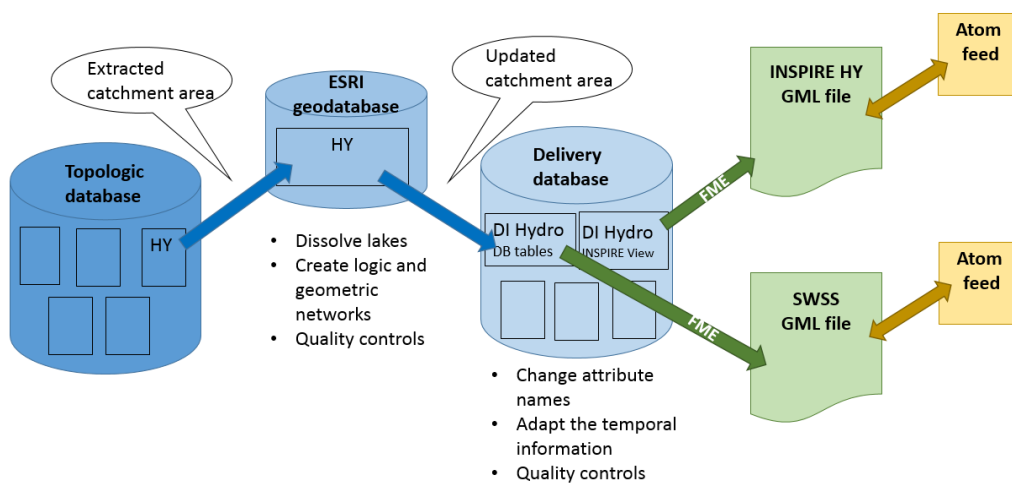
The technical aspects are based on interviews with two technicians at Lantmäteriet and were carried out to determine the technical consequences of replacing the current download services for INSPIRE HY and the SWSS with one download service for the extended INSPIRE HY. The technicians were asked to describe the transformation and delivery process and to answer the following questions:

- Is the transformation and delivery of hydrographic data performed from a production database or from a delivery database?
- Does the transformation include any complex calculations?
- Are there any differences in the complexity of the transformations to INSPIRE HY and SWSS?
- In the case of a delivery database:
  - Does the structure differ greatly between the delivery and the production databases?
  - What kind of restructuring or changes are made?
  - How frequently is the delivery database updated?
- What would need to be done if the current INSPIRE HY and the SWSS download services were to be replaced with an extended INSPIRE HY service?

The technicians described that hydrographic data for INSPIRE HY and the SWSS are provided from a delivery database as GML files using Atom feeds. Many differences exist in the structures of the production database and the delivery database. The most complex transformations are those that dissolve all of the lakes (which are stored as parts of lakes in the production database) and create logical and geometric networks. There are very few differences in the complexity of the transformations to INSPIRE HY and SWSS. The delivery database is updated twice a year. Figure 8 describes the transformation and delivery process.

To replace the current INSPIRE HY and the SWSS download services with one for the extended INSPIRE HY would be relatively simple. This process would require the development of new scripts (written in FME by Safe Software) to create GML files, together with new Atom feed descriptions. From a maintenance perspective, there are advantages in having one download service instead of two; however, as updates are only performed twice a year, the difference in the workload between one or two services is not large.

**Figure 8: The current process of transformation and delivery of hydrographic data at Lantmäteriet**



#### 4.5.3. Economical aspects

For the evaluation of the economic aspects, we interviewed two persons at the marketing department at Lantmäteriet. The aim was to determine what the economic consequences of providing the hydrographic data from one instead of two download services would be. The following questions were asked:

- How much would it cost to develop an INSPIRE-compatible download service?
- What would be the yearly maintenance cost of such a download service?
- How much time and money would be saved if a data provider must provide only one download service per geographic theme, instead of two?
- Do you see any other consequences of providing the data from one download service, instead of two?

There is one budget for the maintenance of all network services at Lantmäteriet, and, therefore, it is not possible to know how much money would be saved if one download service were used, instead of two. It is also difficult to obtain any exact figures for the development costs. In regard to other consequences of the service



replacement, it could be an advantage to have a combined service if the user group is well defined and has homogeneous requirements, whereas separate services might be better if the user group is more diverse.

A conclusion that could be drawn is that one download service less would not make a substantial difference; however, Lantmäteriet is responsible for providing information for nine additional INSPIRE themes. As an example, if half the number of network services could be created as extended INSPIRE services (instead of having two services per theme), a corresponding decrease in the development and maintenance costs could be expected.

## 5. DISCUSSION AND OUTLOOK

The quantitative part of the evaluation did not provide any significant differences between the INSPIRE HY, SWSS and extended INSPIRE data that will substantially affect the applicability of the data. The main disadvantage with the extended INSPIRE data is the increased file sizes, which mainly is due to the fact that it also includes more attributes. On the other hand, the extended INSPIRE data also has advantages to the national SWSS model. Since the extended INSPIRE model uses a more standardised GML structure, it can be read by most GML-readers, while we have encountered interoperability problems to read geometric elements in the national SWSS data in some GML-readers.

The user-centric study focuses on the applicability of the data. The test showed that the extended INSPIRE HY data supported the tested applications, i.e., the data was applicable. It should be noted that we have not performed a complete usability test of the three GML files (INSPIRE HY, SWSS, and extended INSPIRE HY), for example by evaluating the quality components described by Nielsen (2003) and answering questions such as:

- How easy is it to *learn* how to transform the three GML files to databases?
- Is it equally *efficient* to use all three datasets for hydrological analyses?
- Was it easy to *remember* the data structures and how to use the datasets the next time you were using the data?
- What affects the *satisfaction* of using the GML files?

The number of *errors* that were made and how to recover from these was not included in the test case.

The data provider evaluation has three parts. In the information modelling part, it is shown that creating an extended model will probably be faster than starting from scratch, but could be more complicated to maintain. Using INSPIRE application schemas will ensure standardisation of these parts, but changes here will also affect the national schemas. The second part concerns the technical aspects. Here,

we see that the transformation of data from the delivery database to SWSS and extended INSPIRE HY data are very similar, as all data needed is included in the database. In this case, the extended INSPIRE HY download service will be of the same type as the current SWSS download service, as SWSS uses standardised OGC network services. In other cases where another type of network service is used, a change to an extended INSPIRE service could result in a new type of service provision and that information will no longer be provided in the way to which the users are accustomed. Finally, the third part studies the economic aspects, but here the evaluation could not conclude if the development and maintenance costs are reduced if one extended INSPIRE download service is used, instead of one INSPIRE and one national service, due to how these costs are described in the budget. But, generally speaking, a lower number of download services to develop and maintain would probably result in reduced costs.

Whether one extended INSPIRE service or two separate services is the best solution will vary from case to case. If a national dataset does not fit into any INSPIRE theme at all, it should be kept as a separate national dataset and service. Otherwise, it is suggested that the possibility of creating an extension of an INSPIRE theme, instead of having two separate datasets and services, should always be considered and investigated.

Another advantage of using extended INSPIRE download services is that there will be less division between the INSPIRE services and other services within a national SDI. The INSPIRE services are sometimes seen as something that will not be used, but that still needs to be provided to satisfy legal requirements. If these INSPIRE services can be extended with detailed information that is needed at the national level, they will be able to both satisfy the legal requirements at the European level and the more detailed and specific requirements at the national level. Thus, such extensions can lead to both a reduction in the number of services and an increase in the frequency with which these services are being used.

## **6. CONCLUSION**

This study shows that it is possible to create complex INSPIRE extensions that include many object types, attributes and relations. The general parts are still compliant with INSPIRE, but new attributes must be added at the lowest level in the UML application schema to conform to the INSPIRE extension rules. Such additions can make the UML models more difficult to maintain. When comparing the resulting GML files from the Swedish Water System Standard and the extended INSPIRE HY, the structural differences between the UML models are not especially prominent any more.

The quantitative evaluation compares the sizes and structures of the GML files, as this can influence the applicability of the files for the users. The evaluated

parameters are the file size, the number of attributes that contain values, the number of empty attributes with a void reason and the maximum number of hierarchical levels for an attribute. The results show a strong correlation between the number of attributes included in a GML file and the size of the file. Both the SWSS and the extended INSPIRE HY include more attributes than INSPIRE HY; therefore, their file sizes are also larger. This difference in file size could have an effect for the users if the GML files cover large geographic areas.

The user-centric part of the evaluation shows that setting up the data for the hydrological analyses and acquiring data from the three different GML files (INSPIRE HY, SWSS and extended INSPIRE HY) did not differ in input of labour or time. A large part of the textual information in the files is metadata presented at the object level. Most of the metadata is the same for all objects and should, therefore, rather be saved in metadata structures on the dataset level. This would facilitate the access to the attributes associated with the actual hydrology and also reduce the size of the GML files.

The information modelling will probably be faster when creating an extended INSPIRE application schema, than creating a new national application schema. The modelling does not need to start from scratch, as it builds on an existing INSPIRE schema, but if there are changes made to the INSPIRE application schemas, the national schemas will also be affected.

From a data provider perspective, it would be relatively simple to replace the current INSPIRE HY and the SWSS download services with one for the extended INSPIRE HY, as all the information needed is included in the current delivery database. New scripts to create GML files and new Atom feed descriptions would need to be developed.

How much money that would be saved if one download service were used for hydrographic data, instead of two, is not possible to say. The assessment of the development and maintenance costs are not structured in such a way that the cost of individual services can be determined. One download server less would not make an especially large difference for a data provider; however, there are 34 INSPIRE themes, and having three download services per theme (INSPIRE, national and regional) results in 102 services. If extended INSPIRE download services were used wherever possible, reductions in the number of services and costs (in terms of both time and hardware) would result. Such changes might also benefit users, as they would only need to use one network service or dataset per geographic theme.

## 7. ACKNOWLEDGEMENTS

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