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Geographical informational resources for the protection of surface waters and groundwaters and INSPIRE initiative

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Abstract

The article presents the data model of geographical database, which structure corresponds with the requirements declared in Directive 2000/60 of the European Parliament and of the Council in the conditions of INSPIRE implementation. Besides, the article analyses the interoperability conditions of proposed data model with Fundamental Base of Geographical Information System (FBGIS) as the standard topographic template of state information system of Slovak Republic.

Key words: data model, geographical database, GIS, INSPIRE, interoperability, water protection

1. Introduction

Spatial data, geographical information and geographical information systems are the subjects of interest of important European activities. Slovak Republic observes this trend with big interest. The Geodesy, Cartography and Cadastre Authority (GCCA) introduced the conception of National Infrastructure of Spatial Information (NISI) and defined Automated Information System of Geodesy, Cartography and Cadastre (AISGCC) consisting of three subsystems – Cadastral Information System (CIS), Information System of Geodetic Control (ISGC), Fundamental Base of Geographical Information System (FBGIS). FBGIS presents reference spatial base of topographic objects of state information system of Slovak republic [3].

The conception of NISI presented by GCCA SR follows the European initiatives INSPIRE [2] focused on the creation of the European spatial information infrastructure (ESII) and their functions – serving integrated and user oriented services for spatial information processing. These services should allow users to identify and access spatial and geographical information from wide range of national and international sources by the form of their mutual and functional sharing. Implementation of INSPIRE is conditioned by use of many international standards and initiatives in the field of data models, technological tools and information communities (OpenGIS Consortium, World Wide Web Consortium – W3C, International Standardisation Organization – ISO, European Committee for Standardisation – CEN, Dublin Core Metadata Initiative, etc.) [2].

The European Commission issued Directive 2000/60/EC establishing a framework for Community action in the field of water policy oriented on the protection of surface waters and groundwaters. Implementation of this Directive on national and international level is a part of INSPIRE initiative.

This article presents the data model framework of geographical database of GIS, which structure corresponds with the requirements declared in Directive 2000/60 of the European Parliament and of the Council in the conditions of INSPIRE implementation. Besides, the article analyses the interoperability conditions of proposed data model with Fundamental Base of Geographical Information System (FBGIS) as the standard topographic template of state information system of Slovak republic. The article is a part of research project VEGA (1/0095/03).

2. Infrastructure for Spatial Information in Europe

Infrastructure for Spatial Information in Europe (ISPIRE) is initiative of European Commission. It intends to create a European spatial information infrastructure that delivers to the users integrated spatial information services. These services should allow the users to identify and access spatial and geographical information from a wide range of sources, from local level to global level, in an inter-operable way for a variety of uses [3]. The target users of INSPIRE include policy-makers, planners and managers at European, national and local level and the citizens and their organisations. Possible services are the visualisation of information layers, overlay of information from different sources, spatial and temporal analysis, etc. The spatial information infrastructure addresses both technical and non-technical issues, ranging from technical standards and protocols, organisational issues, data policy issues including data access policy and the creation and maintenance of geographical information for a wide range of themes.

Recent global advances in moving from paper to digital data and information has opened opportunities to revolutionise access to data, communication of information and for informed decision-making at all levels of society. This progress has brought new challenges. The data are often of unsatisfactory or undefined quality, based on proprietary geographic information systems and not accessible to the public or other users at local, regional, national and international level. Therefore, projects that combine data coming from various sources to provide policy-relevant information and tools are often time consuming and costly. Policies need to be put in place to reduce the duplication in collection, harmonisation efforts and to facilitate and promote wide dissemination of the data.

INSPIRE intends to improve the current situation by building the already mentioned European spatial information infrastructure based on the following principles:

- effective and one-off data collection,
- seamless combining spatial information from different sources and their mutual sharing,
- sharing data from different control levels,
- availability and extensive use of geographical information,

- easy assignment of availability and suitability of geographical information according to specific task groups,
- clarity and interpretability of geographical information for the purpose of cartographic interpretation and visualisation.

2.1 INSPIRE implementation

The INSPIRE implementation will follow a step-wise approach, starting from evaluation of potential of existing spatial data and spatial data infrastructures and then gradually harmonising data and information services allowing eventually the seamless integration of systems and datasets at different levels into a coherent European spatial data infrastructure. Achieving this objective will require the establishment of appropriate coordination mechanisms and common rules for data policies.

The first step will focus on harmonisation of documenting existing databases and on the necessary tools to make this documentation accessible. The second step will primarily aim at providing common ways to access the spatial data sets themselves allowing uncomplicated analysis of data on different themes coming from different sources. An example of such analysis is visual inspection of spatial relations between phenomena by overlay of datasets. The third step will target the establishment of common models of the objects in the environment for which spatial data is collected, such as transport networks, forests, etc. This will allow mapping existing datasets to a common set of models, the start of the creation of a really harmonised spatial data infrastructure that will facilitate the combination of information of various sources and more advanced analysis work. The fourth and last step will build upon the previous steps and concentrate on completing the common models and on providing the services to fully integrated data from various sources and various levels into coherent seamless datasets supporting the same standards and protocols. This step will allow real time access to up-to-date data across the whole of Europe.

These steps will partly be carried out in parallel, depending on user needs and degree of availability and harmonisation of existing information. All these steps involve actions of standardisation, of harmonisation and integration of data and services (Fig. 1).

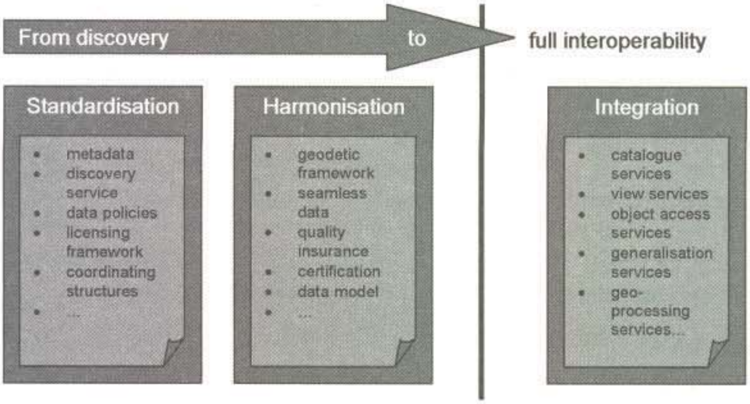

Fig. 1 Towards an Infrastructure for Spatial Information (according to [2])

3. Characterization of data model of geographical database for protection of surface waters and groundwaters

Data model of geographical database for protection of surface waters and groundwaters in accordance with Directive 2000/60 [6] is defined as an object-oriented system, which elements are created by features classes. The inheritance principle between the more specific classes and the more general classes is used for the specification of relations among features. All features in the feature class are geometrically expressed as points, lines or polygons. These geometric types cannot be mixed. It means, in each feature class can be only one geometric type. Every feature has a unique identifier in the database.

Figure 2 shows the object-oriented data model of geographical database for protection of surface waters and groundwaters in the form of oriented graph.

3.1 Feature classes of WaterBodies

All **WaterBodies** are subdivided into **SurfaceWaterBodies** and **GroundWaterBodies**. Surface water means inland waters, except groundwaters; transitional waters and coastal waters. The abstract class **SurfaceWaterBody** is classified on the first level into **FreshWaterBody** and **SalineWaterBody**.

Feature class **FreshWaterBody** is subdivided on the lower level into feature classes **RiverWaterBody** and **LakeWaterBody**. **RiverWaterBody** means 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. **LakeWaterBody** means a body of standing inland surface water. On the lowest classification level in accordance with Directive 2000/60 we differentiate **RiverSegments** and **LakeSegments**. They are in one-to-many (1 : N) relation with **RiverWaterBody** and **LakeWaterBody**. **RiverSegment** is a part of the river between confluences or point locations of monitoring network. **LakeSegment** is a polygon feature, which has nodes at inlets and outlets, thus providing connectivity to the **RiverSegments**.

The feature class **SalineWaterBody** is analogously on the lower level classified into the feature classes **TransitionalWater** and **CoastalWaters**. **TransitionalWaters** are bodies of surface 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. **CoastalWaters** means surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters.

There can be added other feature classes among **FreshWaterBodies** and **SalineWaterBodies** – **ArtificialWaterBody** and **HeavilyModifiedWaterBody** – depending on whether it is artificial or heavily modified river, lake, transitional water or coastal water.

GroundWater means all water, which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil. The question is, how such bodies should be delineated, and subsequently represented. For the purposes of the present model, it is assumed that groundwater bodies will be 2-dimensional polygon features. Unlike surface water bodies, the delineated boundaries of groundwater bodies will rarely coincide exactly with river basins.

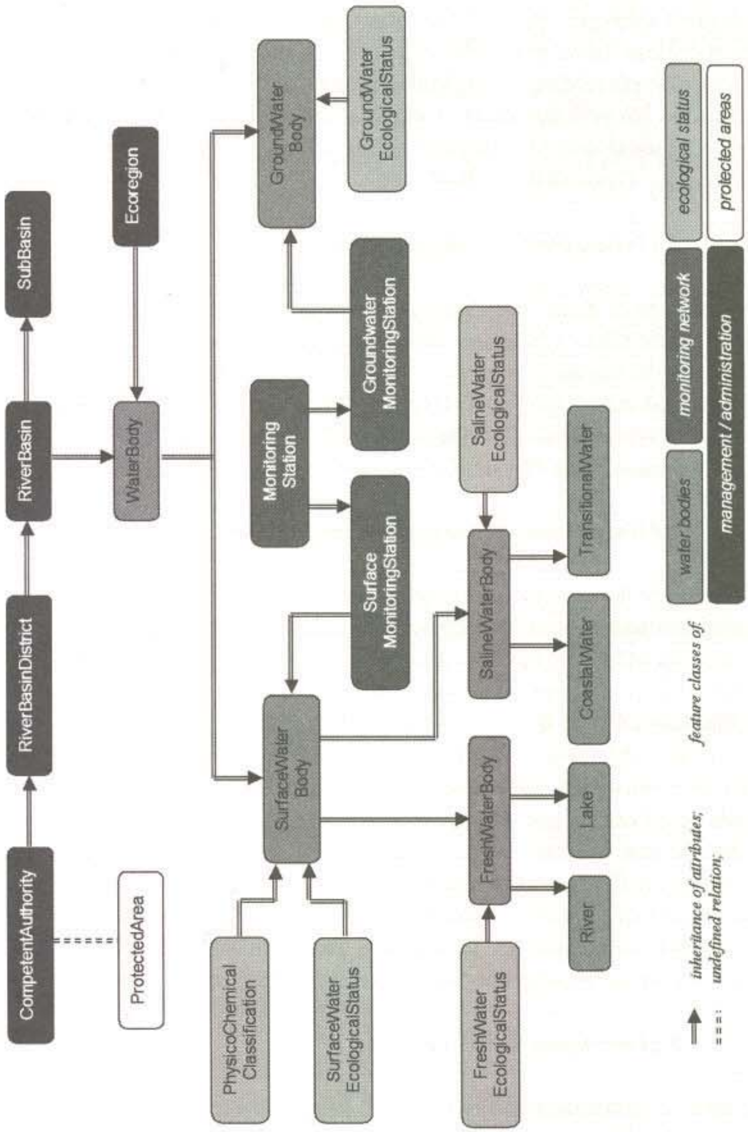

Fig. 2 Object-oriented data model of geographical database for protection of surface waters and groundwaters.

3.2 Feature classes of monitoring network

Monitoring stations form the basis of the assessment of water ecological status. Abstract class **MonitorigStation** can be on the lower level subdivided into **SurfaceMonitoringStation** and **GroundwaterMonitoringStation**. Monitoring stations are point features. Since a station may serve multiple functions, it is not appropriate to define distinct subtypes. Besides, they may monitor multiple water bodies. Monitoring stations therefore have many-to-many (M : N) relationship with water bodies. The feature class **SurfaceMonitoringStation** participates in the M : N relationships with feature classes **RiverWaterBody**, **LakeWaterBody** and **TransitionalWater**. The feature class **GroundwaterMonitoringStation** participates in the M : N relationship with the feature class **GroundWaterBody**.

3.3 Feature classes of ecological status

For each type of water body, parameters of its ecological status can be defined, thus form the feature classes **EcologicalStatus** of relevant water bodies, with which they are linked via the unique *EuropeanCode*. Thus there exist feature classes **GroundWaterEcologicalStatus**, **SurfaceWaterEcologicalStatus**, **FreshWaterEcologicalStatus** and **SalineWaterEcologicalStatus**. Besides, to all feature classes of surface waters belongs the feature class **PhysicoChemicalClassification**.

3.4 Feature classes of management / administration

This group of feature classes includes **SubBasin**, **RiverBasin**, **WaterBasinDistrict**, **CompetentAuthority** and **Ecoregion**. **Subbasin** means the area of land from which all surface run-off flows through a series of streams, rivers and, possibly, lakes to a particular point in a watercourse (normally a lake or a river confluence). **RiverBasin** means 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. River basins shall not overlap. **RiverBasinDistrict** means the area of land and sea, made up of one or more neighbouring river basins together with their associated groundwaters and coastal waters. It is the main unit for management. There should be established a **CompetentAuthority** for each river basin district, responsible for implementation of Directive 2000/60. In accordance with this Directive, the area of Europe is subdivided into 25 **Ecoregions** for fresh water bodies (rivers, lakes), or 6 Ecoregions for saline water bodies (transitional and coastal waters).

3.5 Feature class of protected areas

The term **ProtectedArea** has not been precisely defined in Directive 2000/60 so far. Protected areas are modelled as polygon features, each with a name and unique *EuropeanCode*.

4. Interoperability of geographical database for protection of surface waters and groundwaters

Interoperability of geographical database is evaluated in relation to FBGIS, because the structure of its database accepts international standards DIGEST [4] and INSPIRE [3]. Thematic attributes of selected feature class are analysed, mainly those which may be defined as the primary keys necessary for sharing the data warehouse of FBGIS and of geographical database for protection of surface waters and groundwaters. The evaluating approach is documented on one feature class.

The feature class **RiverWaterBody** was chosen from the proposed data model for analysing the ability of sharing. Its specification is documented in Tab. 1.

Other feature classes, such as **RiverSegment**, **LakeSegment**, **LakeWaterBody**, could be analysed in detail as well, because their corresponding feature classes are parts of other departmental monitoring systems of water management. This analysis will be subject of separate work.

Feature class **RiverWaterBody** is defined by 34 thematic attributes. In Tab. 1, the thematic attributes *ID, EcoRegionCode, RiverBasinCode* are highlighted. They contain standard codes – *EuropeanCodes* and will create relations of proposed data model of geographical database. The attribute MSCode is not highlighted, but it has a key importance for assignment of sharing of proposed data model in the conditions of National Infrastructure of Spatial Information (NISI).

Tab. 1 Feature class **RiverWaterBody**

Attribute	**Value**
Shape	lines
ID	European code
Name	
MSCode	national ID
EcoRegionCode	1–25
InsertedWhen	DDMMRRRR
InsertedBy	
RiverBasinCode	European code
StatusYear	YYYY
HeavilyModified	Y/N
Artificial	Y/N
System	A/B
AltitudeTypology	high: > 800 m; mid-altitude: 200–800 m; lowland: < 200 m
GeologyTypology	C – calcareous; S – siliceous; O – organic
SizeTypology	small: 10–100 km^2; medium: 100–1,000 km^2; large: 1,000–10,000 km^2; very large: > 10,000 km^2
Latitude	
Longitude	

Attribute	Value
Geology	?
SizeMeasurement	?
DistRiverSource	?
FlowEnergy	?
MeanWidth	?
MeanDepth	?
MeanSlope	?
RiverMorphology	?
DistRiverSource	?
ValleyMorphology	?
SolidsTransport	?
AcidNeutCapacity	?
MeanSubstratComp	?
Chloride	?
AirTempRange	?
MeanAirTemp	?
Precipitation	?

Note: ? means, that the value is not defined in Directive 2000/60

The set of elements of geographical database – the feature catalogue of FBGIS [3] – defines relative feature class **Watercourse**, as a part of feature category **Waters**, and has three thematic attributes – *Name*, *Nomenclature* and *Character of Watercourse*. There are not defined value domains for these thematic attributes. It can be assumed implicitly, that corresponding intent and also the same value domain is valid for the pair *Name* (from the table **RiverWaterBody**) and *Name of Watercourse* (from the feature catalogue of FBGIS), and similarly for the pair *MSCode* and *Nomenclature of Watercourse*. Compatibility with the feature catalogue of FBGIS with international exchange standard DIGEST is assigned by the coding of feature classes of catalogue. The feature class *Watercourse* is labelled with code ***BH140***.

The feature catalogue of FBGIS is being created in co-operation with Topographic institute of Slovak republic. The relation between feature catalogue of FBGIS and feature catalogue of Military Information System about Teritory (MIST) [5] is being defined. Figure 3 presents definition of relative feature class ***BH140*** **River**, **Creek** and the list of compulsory attributes with facultative values. Also in this case, there is not explicitly defined value domain – type of coding system for river identification, for thematic attribute *NAM (Identifier)*.

BH140 River, Creek
Permanent water flow running on the bottom of valley

Compulsory attributes and their facultative values:
EXS (Category of actual state of feature)
0 *Unknown*
32 *Navigable*
48 *Controlled*
339 *Impassable*
999 *Other*
HYC (Hydrological characteristics /according to seasonal water incidence/)
0 *Unknown*
3 *Dry*
6 *Non-Perennial/Intermittent/Fluctuating*
8 *Perennial/Permanent*
999 *Other*
LOC (Relative location of feature)
0 *Unknown*
4 *Below Surface/Submerged/Underground*
8 *On Ground Surface*
999 *Other*
NAM (Identifier, code)
0 *Actual Value*
TXT (Text, note, label)
0 *Actual Value*

Fig. 3 Feature class **River, Creek** of feature catalogue MIST

6. Conclusion

The ability of sharing the data model of geographical database for protection of surface waters and groundwaters on international and national level can be defined from the viewpoint of content and form. The content viewpoint defines semantic compatibility of potentially shared data warehouses on national and international level. The formal viewpoint defines exchange standard and hierarchical structure (category, subcategory, feature, attribute, attribute value) of data model elements of sharable warehouses.

The content compatibility condition [7] of proposed data model under NISI is compatibility with FBGIS. To reach this compatibility, besides formal definition of corresponding feature classes and their thematic domains, it is necessary to specify the value domains of those thematic attributes, which will represent primary keys of shared relational data warehouses. In this case, it means the need for clear specification of type of coding identifier system – system of value domain of thematic attribute *Nomenclature of Watercourse* in the feature catalogue of FBGIS; and adoption of such defined value domain to the proposed data model. Generally, it can be required:

- the need for clear definition of national (departmental) identification systems of those feature classes, which should be implemented as a part of European infrastructure of spatial information in accordance with valid directives of European Union and equally are part of FBGIS as the unified topographic base of NISI of Slovak Republic,

- to open up these identification systems beyond the area of departmental information systems,
- to implement valid identification systems to the conception of FBGIS and to its feature catalogue,
- to launch general duty of their use for identical feature classes under NISI of Slovak Republic.

Formal compatibility of shared data warehouses can be secured by unified coding system of feature catalogue for individual elements – subsystems of NISI. DIGEST can be such standard. Although implementation of DIGEST is not one of conditions of INSPIRE building, formal coding system FACC (Feature and Attribute Coding System) of DIGEST, which was partly implemented in proposal of feature catalogue of FBGIS and fully implemented in proposal of feature catalogue of MIST, presents a proper form for definition of hierarchical structure of data model elements of NISI and its subsystems in accordance with INSPIRE initiative.

A clear feature catalogue definition of individual subsystems of NISI of Slovak Republic is essential in near future and requires complex analysis of all types of identification systems as well as their formal and content integration on national and international level.

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