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Working group on Hydrology RA VI (Europe)
Dr. Josef FÜRST
Rapporteur on "Application of GIS in operational hydrology"

c/o University of Agricultural Sciences Vienna
Department of Water Management,
Hydrology and Hydraulic Engineering
Muthgasse18
A-1190 Vienna, Austria
Fax: +43 1 36006 5549
Tel: +43 1 36006 5511
e-mail: fuerst@boku.ac.at

Application of Geographical Information Systems (GIS) in Operational Hydrology

Report to WMO RA VI

J. Fürst

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CONTENTS

1 INTRODUCTION

1.1 Background and objectives

In its twelfth session, the Working Group on Hydrology (WGH), Regional Association (RA) VI (Europe) of the World Meteorological Organisation (WMO) decided to elaborate a report on the "Application of Geographical Information Systems (GIS) in operational hydrology" in its member countries. The chairman of the Working Group in Hydrology RA VI, Prof. Dr. F. Nobilis, Austria, nominated Dr. Josef Fürst, Department of Water Management, Hydrology and Hydraulic Engineering, University of Agricultural Sciences, Austria, to be the rapporteur on "GIS application in hydrology".

According to resolution 11 (XII-RA VI) the tasks of the rapporteur on "GIS application in hydrology" are to

- report on recent developments in RA VI countries on the use of GIS in operational hydrology; and
- to investigate the needs and possibilities of producing European, consistent maps of the principal water balance elements.

1.2 Procedure

To achieve the specified objectives, given the constraints in financial capacity and available time of a rapporteur, the following procedure was pursued:

1. Questionnaire based survey among members and the hydrological advisers.
2. Literature and public database research
3. Further individual inquiries as necessary
4. Compilation of draft report
5. Circulation of draft report among WGH members
6. Final draft for submission to the WGH meeting

2 STATE OF GIS APPLICATIONS IN OPERATIONAL HYDROLOGY

2.1 Introduction

The majority of information in this section is derived from a questionnaire (see Appendix) based survey, which was performed from November 2000 to June 2001 in all WMO RA VI member countries.

The questionnaire had two main parts. The first part asked for the users of GIS, from public authorities to private consultants, and for which purposes they apply GIS. The second part asked for the available spatial datasets, their scale and resolution and accessibility for users.

2.2 Organisation of the survey

The WMO-WGH in RA VI (Europe) has 50 members, of which 30 (60%) returned the completed questionnaire. The map in Figure 1 displays the member states of RA VI and indicates whether the questionnaire was completed. Although several attempts were made to contact representatives in all countries, there was either no response at all or at least a completed questionnaire was never received from 20 countries as indicated in the map. However, the 50 member states have together a surface area of 26.7 million km^2, of which 24.1 million km^2 (90%) are covered by the evaluated questionnaires.

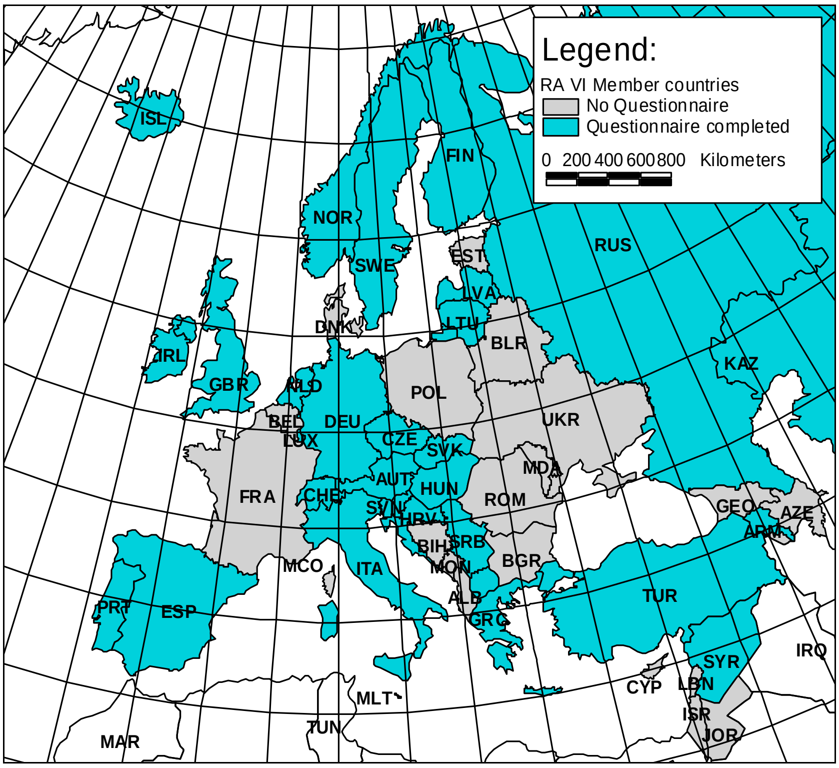

Figure 1: RA VI member countries and overview of returned questionnaires (The countries are labeled with 3-digit codes as used by the Worldbank. See table A-1 in the appendix for a list of associated full names.)

2.3 Results

A complete listing of the replies to the questionnaire is given in the appendix, with an indication of the relative frequency of "Yes" answers. A discussion of the most significant results is given below, in the outline of the questionnaire.

2.3.1 GIS users and uses

2.3.1.1 Public authorities

A slight majority of the countries has hydrology and water management geographically organised by administrative units (province, district, ...). 40 percent of the countries have an organisation by river basins and catchments, as intended by the new water framework directive of the EU. Interestingly, even 9 of the current EU member countries still have an organisation by administrative units, 3 reported an organisation by river basins (no response from France, Belgium and Denmark).

Responsibility for water affairs is rather scattered in most of the countries, only in 43% of the countries water affairs are united under a single supreme national authority. The ministry of environment is involved in hydrology and water management in 87% of the countries, but frequently the ministries of agriculture and forestry, health, economy and others are involved.

Use of GIS by the national hydrological services is quite popular, with a frequency of 77%, while only 53% of the meteorological and climatological services routinely use GIS. The purposes of GIS usage are illustrated in Figure 2. The fact that 63% of the hydrological services are using GIS for the acquisition and management of spatial data raises some optimism for improved and more efficient hydrological mapping in the future. A significant number of 30% of the hydrological services already makes hydrological information available by GIS based public information systems.

Use of GIS by Hydrological services	%	0 100
Acquisition and management of spatial data	63	
Hydrological analysis and modelling	50	
Hydrological mapping	60	
in-house information and decision support system	47	
public information system	30	
Other:	3	

Use of GIS by Meteorological Services	%	0 100
Acquisition and management of spatial data	30	
Meteorological analysis and modelling	30	
Meteorological and climatological mapping	37	
in-house information and decision support system	27	
public information system	13	
Other:	7	

Figure 2: Use of GIS by hydrological and meteorological services

It has to be mentioned that in 87% of the countries, additionally to the hydrological and meteorological services, other national organisations were mentioned to be collecting water related information. In many cases, the national geological service was explicitly mentioned.

2.3.1.2 Consultants

In most countries, a significant proportion of water related planning (e.g. water supply facilities, river engineering, waste water treatment plants, sewers) is performed by private consultants, 70% of which are estimated to use GIS. They are generally provided with available digital datasets by the contracting public authorities. From 47% of the countries it was reported that these data are provided at no cost, 27% can get the data for "additional cost" of providing the datasets, and 13% can buy the data at a regular commercial prize.

When plans and studies are elaborated with GIS support, in 20% of the questionnaires it is assumed that the results are reported only as hardcopies. But in most cases obviously such results are already transferred to the public contractors in a digital format. 53% reported even the use of a standard format for integration into an information system.

2.3.1.3 Research and education

In all countries, education and training in the use of GIS is currently available at the institutions of higher education (universities, colleges). (The "No" answers in the questionnaires are from Luxembourg and Monaco, simply because there are no universities in these countries.) However, only in 13% of the countries, GIS education is a basic course in all curricula of science and engineering. In 60% of the countries, GIS education is offered in post-graduate and/or external training courses. With regard to plans for future education in GIS, the focus seems to be on post-graduate and/or external training courses.

In 73% of the countries, institutions of higher education are using GIS in water related planning. The areas of application are similar as in Figure 2, except that an additional focus is on the development of applications and - naturally - on the training of students.

2.3.2 Available spatial datasets

2.3.2.1 Digital datasets of topography

2.3.2.1.1 Topographic RASTER maps

Topographic maps in a geo-referenced raster format are widely available in the responding countries. Availability of the layers of rivers and lakes, roads and railways, and elevation contours is reported by approximately 70% of the countries. The dominant scale (63%) is 50 000 or better and the surface coverage is 100% in 57% of the countries. See the appendix for details.

2.3.2.1.2 Topographic maps in a graphical VECTOR format

The availabilty and spatial coverage of topographic maps in a graphical vector format (mostly DXF) is similar to that of the raster maps. Rivers and lakes are available at 77% of the countries and the dominating scale is also 1 : 50 000.

2.3.2.1.3 Topographic maps in topological (GIS) VECTOR format

In the context of this report the most important and valuable data are in a topological, GIS-oriented vector format. Surprisingly, although the investment to generate this type of datasets is higher than for raster or graphical formats, the coverage is even better. 83% of the countries reported availability of the layer rivers and lakes, in a scale of 50 000 or better by 63%. In 57% of the countries, 100% of the surface area are covered. Other layers are less frequently available. Figure 3 illustrates the availability of maps of rivers and lakes at scale 1 : 200 000 or better in GIS format.

2.3.2.1.4 Digital elevation models (DEM)

DEM are fundamental for almost all hydrological applications, since elevation is the main driving force of water movement. DEM are available in 90% of the countries, with coverage of the whole country in 60% and more than 50% coverage in 17% of the reporting countries. The spatial resolution is better than 50 x 50 m in 47% of the countries, and another 27% have DEM with a resolution of better than 100 x 100 m. The origin of the DEM data is in its majority (50%) from digitised contour lines from topographic maps.

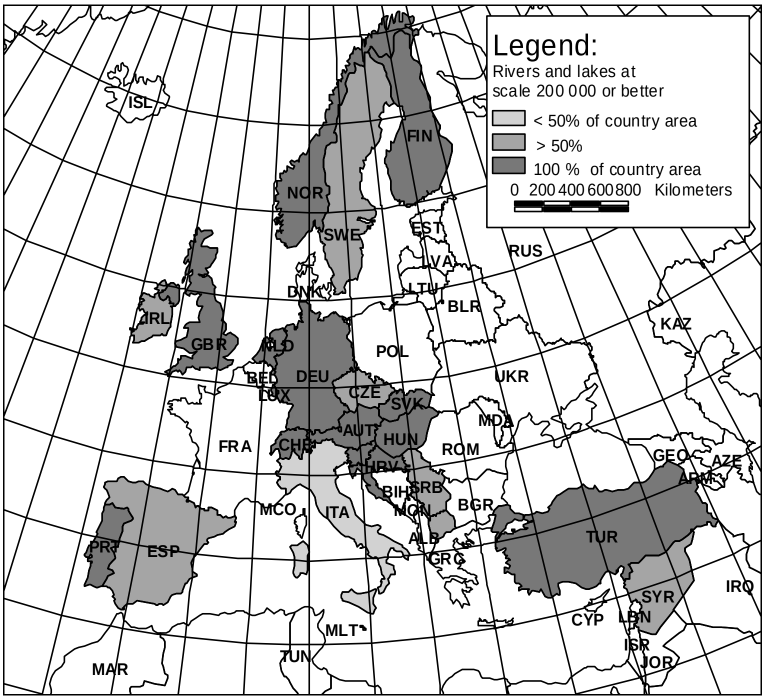

Figure 3: Availability of maps of rivers and lakes at scale 1 : 200 000 or better in GIS format

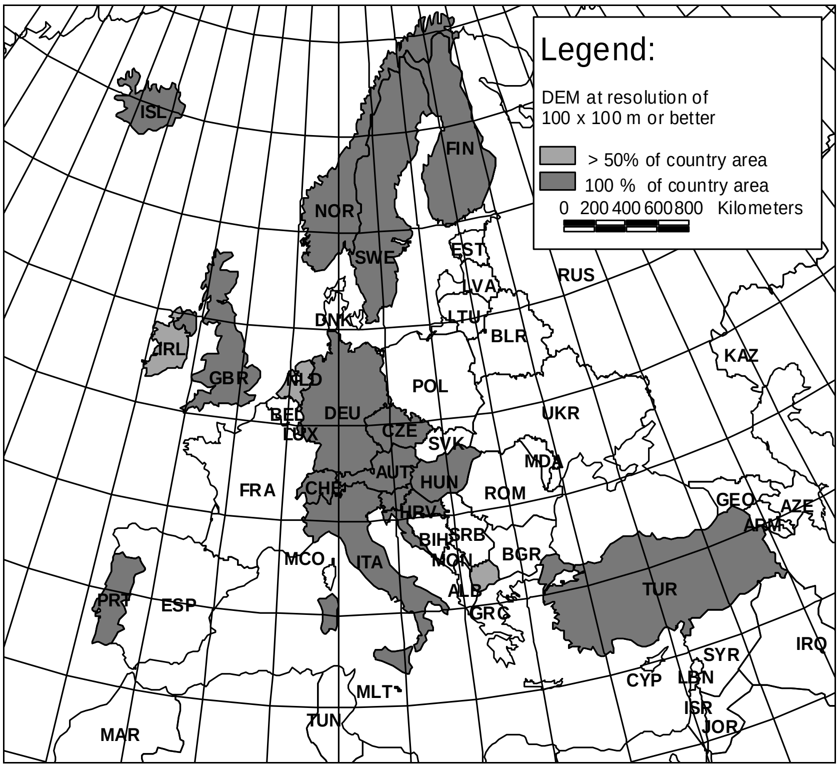

Figure 4: Availability of DEM at a spatial resolution of 100 x 100 m or better

2.3.2.2 Hydrological and hydrometeorological information

2.3.2.2.1 Background

In most countries (67%), only a national hydrological and hydrometeorological agency exists, while 37% have both, national and regional organisations. Where a national service of hydrology exists, the responsibilities for the various elements of the water cycle vary significantly as illustrated in Figure 5.

Responsibility of national hydrological service	%	0..........100
Surface water quantity	90	IIIIIIIIIIIIIIIIII
Groundwater quantity	67	IIIIIIIIIIIII
Precipitation, air temperature and evapotranspiration	47	IIIIIIIII
Water quality	67	IIIIIIIIIIIII

Figure 5: Responsibility of national hydrological services for elements of the water cycle

Information about the locations of monitoring stations (coordinates, maps) is publicly accessible) in 70% of the countries, while 20% only provide this information for the authorities. The observed time series data are publicly available in 67%, and only for the authorities in 27% of the reporting countries.

The usual mode of publication of hydrological information is characterised in Figure 6. The most popular format is still the classical yearbook (70%). Digital publication formats of processed data are surprisingly rare. On the other hand, real-time public information of online stations is already available in 27% of the countries. In 17%, data are not published but only available on request.

Publication of hydrological information	%	0.... 100
Annual yearbook of hydrology with selected data and hydrological characterisation	70	IIIIIIIIIIIIII
Digital publication on CD-ROM	10	II
Open access to processed data via public information system (Internet)	27	IIIII
Real-time public information for online stations	27	IIIII
No, publication data are only available on request	17	III

Figure 6: Mode of publication of hydrological information

2.3.2.2.2 Hydrological mapping

Spatially consistent, map-based presentations of the elements of the hydrological cycle are available in 70% of the reporting countries. 30% have homogeneous, consistent collections of maps (e.g. Hydrological Atlas), while 43% have only individual, independent map sheets from different authors.

The available topics are illustrated in Figure 7. Maps of precipitation are most frequently available (73%).

Available thematic maps	%	0....... 100
Precipitation	73	
Evapotranspiration	57	
Discharge	57	
Water quality	37	
Soil- and Groundwater	53	
Water management	17	

Figure 7: Availability of thematic maps

For maps of statistical evaluations (e.g. " annual mean precipitation"), a common time period would be important for comparison between different maps within and between different countries. In 40% of the reporting countries, these maps are based on the WMO standard period of 1961-1990, 13% use a different, but common time period, but 40% report different reference time periods for their maps.

40% of the countries have these thematic maps with common scale and base maps, so that direct comparisons are possible. The scales, however, are generally small, with 1 : 500 000 and even smaller than 1 : 1 000 000 dominating.

Only 17% of the countries have all their hydrological maps available in digital format, at least 47% have some of them digitally. Hydrological maps are routinely processed with GIS support, for all or at least for some of them, by 60% of the reporting countries.

2.4 Summary

Based on a return of questionnaires from 60% of the WMO RA VI member countries, it can be concluded that GIS are widely used in operational hydrology. 77% of the national hydrological services use GIS in their routine work. In 87% of the countries, additionally to the hydrological and meteorological services, other national organisations are reported to collect water related information. Digital availability of geo-referenced hydrological information in most countries should facilitate consistent, Europe-wide processing of hydrological maps in the future.

The reported figures of spatial coverage with a variety of digital datasets gives a very optimistic impression at first sight. However, there is a large heterogeneity of scales and spatial resolution. The basic data layers (Topography, DEM, rivers) for individual national maps of water balance elements are widely available which allows efficient processing (and updating) of national maps. However, even basic data layers are incompatible between different countries because there are no common geographic reference systems, no consistent observation data and no common methods.

3 NEEDS AND POSSIBILITIES OF PRODUCING EUROPEAN, CONSISTENT MAPS OF THE PRINCIPAL WATER BALANCE ELEMENTS

3.1 Hydrological maps in the context of a European Spatial Data Infrastructure

The term "Europe" is frequently used with different spatial meaning. In the context of WMO RA VI we have to consider the 15 members of the European Union, the accession countries who will be EU members in the near future, countries with close relationships (e.g. Switzerland, Norway, Iceland, ...) to the EU and other countries in geographical Europe and the rest of WMO RA VI countries in the middle east and central Asia. For the purpose of this report, the EU and accession countries are viewed as one group with a rather unified GI policy (in the near future) while for the other countries such a unified policy is not expected. Table A 1 in the appendix indicates also EU membership and accession status.

3.1.1 EU, accession countries and countries with close EU relationships

Although this part of the report does not explicitly refer to maps of the water balance elements as part of GIS based data infrastructures (not even digital maps), it is concluded from the general scope of the report, that the possible development of such maps should be seen from the perspective of a European Spatial Data Infrastructure.

National governments in Europe as well as EU institutions are increasingly aware of the need for harmonised and interoperable layers of relevant, spatial information and methods for reproducible spatial analyses to support cross-sectoral integrated and inter-national assessment to facilitate more balanced, effective and responsible land-use and management of the natural, human and technological resources in Europe. This awareness is documented by an EC GI&GIS Web portal at the JRC in Ispra, Italy, which lists the following GI & GIS related activities within the European Commission Services:

Acronym	**Name**
COGI	Interservice Committee for Geographical Information within the Commission
EC-GI&GIS	EC GI&GIS Web Portal
EUROSTAT-GIS	GI&GIS in Eurostat
GI-INFSO	GI in the Information Society Programmes (IST, eContent...)
GISCO	Geographical Information Systems for the COmmission of European Community
I&CLC2000	Image and CORINE Landcover 2000
JRC GI&GIS	GI & GIS : harmonisation and interoperability
LUCAS	Land Use / Cover Area Frame Statistical Survey
Natura2000	Natura2000

On the EU level, the DG "Information Society" of the European Commission (EC) is primarily responsible for information policies, including a European Spatial Data Infrastructure (ESDI). EUROGI is the European Umbrella Organisation for Geographic Information and, as one of its objectives, encourages greater use of GI in Europe through improved availability and access to GI.

In the framework of the INFO2000 programme (1996 to 1999), the need for a European policy framework for geographic information (GI) has been recognised and documented by the European Commission (EC) in a Communication entitled *Towards a European Policy Framework for Geographic Information - GI2000.* Although this communication was never adopted as a separate document, it illustrated the specific importance of Geographic Information. It highlighted the following:

- The importance of creating a pan-European set of base data, for which national mapping agencies would be key data holders. It was recognised that it might cost as much as 300 million € to harmonise existing nationally held data.
- The development of a single European standard for collecting and classifying GIS data was essential.
- Although base data collection was the responsibility of public sector agencies (and only they had the ability to do it) it was recognised that by involving the private sector as well, a stronger market for the outputs of the work would be created
- The processes could be transferred to Accession countries, which were having to start their data collection and mapping activities from scratch.

Although economical opportunities and necessities account for the majority of arguments promoting a GI infrastructure for Europe, the GI2000 communication also underlines the need for geographic environmental information to support decision-making of governments and businesses.

Despite all these initiatives, still in September 2000, a position paper from COGI ("Towards a GI policy for the EC") pinpoints that "an explicit and coherent data policy for the EC is urgently needed" (COGI 2000). According to this, *the object of an EC geographic information policy should include the terms and conditions for the acquisition, use, maintenance, and dissemination within the Commission and to third parties of all the geographically referenced data that is necessary to formulate, implement, and monitor EU policies.*

The **EU Water Framework Directive** (WFD), issued in October 2000, regulates a unified water policy for the EU, which is based on catchments and river basins instead of administrative and national boundaries. Although not explicitly required by the WFD, consistent European maps of the principal water balance elements are a prerequisite for fulfillment of the reporting duties imposed by the WFD.

In the context of WMO, one of the WHYCOS (World Hydrological Cycle Observing System) objectives is to **"promote and facilitate the dissemination and use of water-related information, using modern information technology** such as the World Wide Web and CD-ROMs".

European, consistent maps of the principal water balance elements are therefore fully in the line of Europe's GI policy as well as a necessity for improved European decision making in environmental protection and natural resource management.

Concluding, at this time there exists a pronounced intention and demand for an EU spatial data infrastructure (including the principal water balance elements), but an explicitly formulated policy has not yet been adopted.

3.1.2 Additional WMO RA VI countries

Within a few years, after the currently ongoing extension of the EU, practically all continental European countries will contribute to "European" river basins with part of their territories. It is evident that a water policy oriented at river basins needs consistent information on the principal water balance elements also from these countries.

The WMO RA VI countries in the middle east and central Asia are hydrologically quite different from Europe. While some water balance elements (e.g. annual mean precipitation) can still be mapped consistently with a European definition of the mapped themes, other themes would definitely require a modified definition. E.g., the definition of seasons would have to be specific to produce meaningful information.

3.2 Possibilities for "European" maps

European, consistent maps of the principal water balance elements require that at least the following conditions are met:

- Use of a **common geographic reference** and common base maps: map projection, country and administrative boundaries, drainage network, boundaries of basins and catchments, digital elevation model.
- Use of **consistent observation data**, adhering to standards of observation, data collection and data processing.
- Use of **common methods** to interpolate and regionalise observations to produce continuous maps.

The conditions above are required to achieve spatial consistency within and thematic consistency between the maps at European scale. Spatial **consistency within a map** means that the indicated values of a theme (e.g. annual mean precipitation) represent the natural phenomenon only and are not biased by the local practice of observation and data processing. Thematic **consistency between maps** means that the methods used are compatible and that any existing hydrological relationships between the presented themes (e.g. that runoff is the difference of precipitation and evapotranspiration) are respected within a certain accuracy.

It is further desirable that this set of maps is not only consistent in itself, but that **consistency** is maintained also **at different scales**. National or local maps of a theme should not be in contradiction to the map at European scale. E.g., the mean annual precipitation of the Enns catchment in Austria should be the same if derived from the detailed Austrian maps or from the European map. Obviously, we have to be aware that this expectation is only a very long term wish.

3.2.1 Common geographic reference and common base maps

3.2.1.1 European Spatial Reference System

A common European Spatial Reference System is necessary to seamlessly integrate spatial information from all over Europe, including EU15 as well as the accession countries. Currently, the Space Applications Institute (SAI) of the Joint Research Centre (JRC) has defined and is now implementing a project called "GI/GIS: Harmonisation and Interoperability", the objectives of which support the policy, data related, and technical initiatives necessary for the integrated assessment of EU policies. The activities of MEGRIN (now EUROGEOGRAPHICS) which represents the interests of the European National Mapping Agencies are complementary to those of SAI. According to Annoni & Luzet (2000), a suitable candidate as European Spatial Reference System already exists: ETRS89. There is consensus amongst the experts that this is the system to adopt at the European level, and several countries have already done so. The Danubian countries in the context of ICPDR made a commitment to use ETRS89. It is not realistic to require all existing data in the Member States to be transformed into this new system - not even in the medium term. However, it could be required for all new data collected and for updates to existing data. In addition there is also a need for Mapping Agencies to make public the transformation algorithms and parameters for converting the data between national systems and ETRS89.

Mapping of the principal water balance elements on a European scale does not require geodetic precision of coordinates. Producing point-, line- and area-based vector datasets in geographical coordinates would generally satisfy the conditions for a common geographic reference and allow non-ambiguous, loss-free conversion to and from other common projections and coordinate systems. However, for raster-based themes, projections and conversions are generally irreversible and cause loss of information. Raster based maps should therefore be processed in the target reference system.

3.2.1.2 Common base maps

Base maps are needed for at least two purposes:

1. To carry the background information so that the reader of a map can visually get oriented. Depending on the scale, this can include selected country and administrative boundaries, major cities, main traffic connections and rivers and major waterbodies.
2. To provide elementary spatial units to associate thematic information.

Common base maps are important for the visual appearance of a set of maps, so that different thematic maps become visually compatible and comparable.

More important for the GIS versions of the maps is the use of common digital base maps, so that spatial relationships and overlays can be easily defined. E.g. if water balance elements are defined for catchments, all the relevant themes (e.g. discharge, precipitation, evapotranspiration, ...) should use identical catchment boundaries, so that water balance computations for catchments can be performed in the attribute space of the catchments, without the need for geometric intersection of the involved map layers.

It is desirable for economic and practical reasons, to use already existing databases at EU level as far as possible, with the GISCO database being a possible candidate. GISCO (Geographical Information Systems for the COmmission of European Community) is the main service of GI for the EC. Its mandate is described in the GISCO Database Manual at http://www.aris.sai.jrc.it/data-dist/search-tools/metadata/p1ch1.htm. The datasets are primarily for use by the EC, but most of them can be made available for other users and purposes.

Within the framework of the GISCO project, a large geo-referenced database has been developed. The datasets offered by GISCO include:

Topographical data on:

- hydrography
- altimetry
- infrastructure
- administrative entities

Thematic data (with relevance for hydrology) on:

- land resources (land cover, soil data, vegetation, climatic conditions, ...)
- environmental data (coastal erosion, soil erosion, ...)

The spatial coverage is currently restricted to the EU 15 countries, but extension for at least the accession countries has already started. The datasets refer to different nominal scales between 200 000 and 1 000 000 (3 000 000). More severe is the fact that topological and geometrical consistency between these datasets is not validated. As an example, if the course of a river defines a political border, the corresponding lines in the dataset of administrative boundaries are not necessarily the same as in the drainage dataset.

3.2.1.2.1 Drainage network and catchment boundaries

One of the most important basic datasets for hydrological applications is a digital map of the drainage network (rivers and lakes) and an associated map of catchment boundaries. The main challenges for a digital drainage network are the representation of the hierarchical tree-like structure and a topological relation between the river network and the catchment boundaries. Complementing the topological consistency of river network and catchment structure, a unique coding system for rivers and catchments is desired, which incorporates the network hierarchy. A suitable coding system would conveniently support the consistent use of catchment-related information at different levels of spatial aggregation (scale).

At this time, there are versions of digital drainage networks available for Europe at different scales (e.g. ERICA1M), but they lack spatial and topological consistency. Coding systems that represent the hierarchical structure of a river network and the associated catchments have been established at national levels or for large international basins (e.g. Rhine, Danube), but the rapporteur is not aware of a common system for whole Europe. The EU WFD (Water Framework Directive) - GIS working group has a task referring to a "unique coding system for rivers.

3.2.1.2.2 Digital elevation model (DEM)

Terrain elevation is the driving force for the flow of water and therefore DEM provide essential information for GIS-based hydrological modelling and mapping. It depends on the concept of a model how accurate the DEM has to be and what spatial resolution is required. On the national level, most countries have raster-based DEM with a spatial resolution down to less than 50m. However, in most instances the elevation in the grid points is not the result of an original measurement, but frequently derived from digitised contour lines on topographic maps. Also, most of these DEMs are not freely available.

Publicly available world wide datasets with a spatial resolution of approximately 1 km (30") include the USGS GTOPO30 (USGS 1997) and the GLOBE dataset developed and provided by the National Geophysical Data Center (GLOBE Task Team and others 1999). These datasets are appropriate for generating shaded reliefs and for modelling with moderate expectations of horizontal and vertical accuracy. This accuracy is sufficient for the development of maps of the water balance elements. As an example, a statistical correlation between elevation and precipitation depth is frequently used for spatial interpolation of precipitation.

3.2.2 Common standards for observation and data processing

Observations of the water balance elements are generally based on point-related samples of a variable, which is more or less related to the desired phenomenon. E.g. we want to know (and map) with spatial continuity the areal precipitation falling on the ground surface, but we measure the amount of precipitation falling into the funnels of a few raingauges, 1 meter above the ground. With the available technology, the observed value is influenced by instrument type, instrument location, observation practice and data processing. Being aware that we do not observe "true" values, it is important to use standardised instruments and to adhere to standards of observation and data processing in order to collect at least comparable data.

For observation of meteorological variables (precipitation, etc.), most national hydrological services adhere to WMO guidelines (WMO 1996). WMO also published a comprehensive guide to hydrological practices (WMO 1994), but neither observation nor processing of hydrological data is free of individual, institutional and national preferences. Before using hydrological data from different countries for the production of European maps it is therefore important to carefully verify the compatibility.

3.2.3 Common methods

The survey on available spatial datasets (section 2.3.2) revealed that many hydrological maps of water balance elements are existing in the RA VI countries. They differ, however, in their exact definition as well as in the methods used for regionalisation, scale, and time period used. It is therefore impossible to produce European maps by "mosaicking" existing maps of the member countries together. As an example, the recently developed hydrological atlasses of the neighbouring countries Switzerland, Germany and Austria exhibit significant differences of annual mean precipitation depth at the common borders due to different methods of interpolation and different methods of correcting systematic measurement errors.

If spatially and methodically consistent maps of any water balance element are desired for whole Europe, these maps have to be newly developed. This requires

- careful data collection to ensure homogeneity and consistency of the data, and
- agreement on the methods to be used for data processing and regionalisation.

4 CONCLUSIONS

The survey on the **current state of GIS application** in operational hydrology revealed that

- GIS technology has become a widely accepted tool in operational hydrology at national hydrological services, private consultants and education.
- Use of and access to GIS technology is not restricted to the "rich" EU-15 countries but is affordable and available in all countries.
- Basic spatial datasets, such as topography, DEM and drainage networks, are available in most countries, although in different scales and resolution.
- Hydrological maps in GIS format are rather rare and in small nominal scales.

The **need** for European, consistent maps of the principal water balance elements can be clearly concluded from the EU's GI policy in the context of Europe's unification process and is a prerequisite for the implementation of the Water Framework Directive.

The **possibilities** to develop European, consistent maps of the principal water balance elements are conditioned by the use of a common geographic reference and common base maps, consistent observation data and common methods. These conditions are not yet fully met.

While the common geographic reference is not a critical issue for hydrological maps, there is a deficit of common base maps which provide the elementary spatial units to associate thematic information. Efforts should be undertaken to develop a digital drainage network that represents the hierarchical tree-like structure and the topological relation between the river network and the catchment boundaries and includes also a unique coding system for river sections and catchments. Alternatively, raster based maps can be considered.

The main obstacles are probably the consistent observation data and common methods of data processing and regionalisation. To ensure spatial and methodical consistency within and between maps, a project should be formulated with all WMO RA VI countries as contributing partners, but with rigorous coordination and final processing being the responsibility of a single institution.

5 ACKNOWLEDGEMENTS

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APPENDIX

Table A 1: Countries in WMO RA VI (3-Digit Code, Country Name, Area)

CODE	Country	Area (km^2)	Questionnaire	EU/Accession
ALB	Albania	28 755	N	
ARM	Armenia	29 872	Y	
AUT	Austria	83 739	Y	EU
AZE	Azerbaijan	85 808	N	
BEL	Belgium	30 480	N	EU
BGR	Bulgaria	110 802	N	AC
BIH	Bosnia and Herzegovina	51 403	N	
BLR	Byelarus	206 681	N	
CHE	Switzerland	41 178	Y	
CYP	Cyprus	9 227	N	AC
CZE	Czech Republic	78 495	Y	AC
DEU	Germany	356 109	Y	EU
DNK	Denmark	42 671	N	EU
ESP	Spain	505 674	Y	EU
EST	Estonia	45 545	N	AC
FIN	Finland	333 797	Y	EU
FRA	France	546 729	N	EU
GBR	United Kingdom	243 137	Y	EU
GEO	Georgia	69 943	N	
GRC	Greece	131 852	Y	EU
HRV	Croatia	56 288	Y	
HUN	Hungary	93 030	Y	AC
IRL	Ireland	69 384	Y	EU
ISL	Iceland	101 805	Y	
ISR	Israel	20 774	N	
ITA	Italy	300 980	Y	EU
JOR	Jordan	89 275	N	
KAZ	Kazakhstan	2 715 976	Y	
LBN	Lebanon	10 240	N	
LTU	Lithuania	64 849	Y	AC
LUX	Luxembourg	2 594	Y	EU
LVA	Latvia	64 299	Y	AC
MCO	Monaco	12	Y	
MDA	Moldova	33 567	N	
MKD	Macedonia	25 321	Y	
MLT	Malta	332	N	AC
MON	Montenegro	13 743	N	
NLD	Netherlands	35 493	Y	EU
NOR	Norway	316 962	Y	
POL	Poland	310 715	N	AC
PRT	Portugal	92 098	Y	EU
ROM	Romania	236 654	N	AC
RUS	Russia	16 851 940	Y	
SRB	Serbia	88 202	Y	
SVK	Slovakia	48 648	Y	AC
SVN	Slovenia	20 246	Y	AC
SWE	Sweden	443 800	Y	EU
SYR	Syria	187 937	Y	
TUR	Turkey	779 986	Y	AC
UKR	Ukraine	596 041	N	

Question		%	Country:	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
Questionnaire response		60			1	1						1		1			1			1	1	1	1	1		1		1	1		1	1	1			1		1	1		1		1	1	1	1	1	1	1	1	1		1
2.3 GIS Users and uses																																																					
2.3.1 Public authorities																																																					
Background: Structure of public water authorities																																																					
How is hydrology and water management geographically organised in your country?	by administrative units (province, district, ...)	53				1											1			1	1		1	1				1				1						1	1					1		1	1	1	1		1		
	by river basins and catchments	40			1							1		1								1				1		1	1				1								1				1					1			1
Is there a single supreme national authority (e.g. a ministry) responsible for all water affairs (hydrology, water quantity, quality, environmental issues)?	Yes/No	43			1	1						0		1			0			1	0	0	0	0		1		1	1			1	0			0		0	0		1		0	1	0	1	1	0	0	1	0		0
Which of the listed sectors are involved in public water management and hydrology?	Agriculture and forestry	40				1								1			1				1	1										1						1			1				1		1				1		1
	Environment	87			1	1						1					1			1	1	1	1	1		1		1	1			1	1			1		1	1		1		1		1	1	1	1	1		1		1
	Health	20										1					1					1																	1						1			1					
	Economy	7															1																																1				
	Other:	40										1									1	1	1	1								1						1	1				1		1					1	1		
GIS uses																																																					
Is your national hydrological service using GIS?	Yes/No	77			0	1						0		1			1			1	0	1	1	1		1		0	1		0	1	1			0		1	1		1		0	1	1	1	1	1	1	1	1		1
If yes, for which purposes?	Acquisition and management of spatial data	63												1			1			1		1	1			1						1						1	1		1			1	1	1	1	1	1	1	1		1
	Hydrological analysis and modelling	50												1			1			1			1			1												1	1						1	1	1	1	1	1	1		1
	Hydrological mapping	60				1								1			1			1			1			1												1	1		1			1	1	1	1	1	1	1	1		1
	in-house information and decision support system	47				1								1			1			1			1						1										1		1			1	1	1		1	1				1
	public information system	30												1			1			1			1	1								1													1				1				1
	Other:	3																														1																					
Is your national meteorological and climatological service using GIS?	Yes/No	53			0	1						1		1			1			0	0	1	1	0		1			1			0				0		1	1		1		0	0	1	1	0	1	0	1	0		1

Question		%	Country:	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
If yes, for which purposes?	Acquisition and management of spatial data	30	IIIIII											1			1									1													1						1	1		1		1			1
	Meteorological analysis and modelling	30	IIIIII											1			1									1												1	1							1		1		1			1
	Meteorological and climatological mapping	37	IIIIIII			1						1		1			1																					1	1		1				1	1		1		1			
	in-house information and decision support system	27	IIIII														1												1										1		1				1	1		1					1
	public information system	13	III																																			1	1		1				1								
	Other:	7	I																				1															1															
Are there other national services collecting water related information? (e.g. geological service)	Yes/No	87	IIIIIIIIIIIIIIIII		1	1						1		1			1			1	1	1	1	1		1		1	1			1	1			0		1	1				1	1		1	1	1	1	1	1		1
2.3.2 Consultants																																																					
Background:																																																					
What proportion of water related planning (e.g. water supply facilities, river engineering, waste water treatment plants, sewers) is performed by private consultants?	none - everything is done by public authorities	17	III		1																1												1											1			1						
	less than 50%	60	IIIIIIIIIIII									1		1						1		1	1			1		1				1				1		1	1				1		1	1		1	1	1	1		
	100 %	7	I			1																																														1
GIS uses																																																					
Are private consultants using GIS in water related planning?	Yes/No	70	IIIIIIIIIIIIII		0	1						1		1			1			1	1	1	1	1		1						1				0		1	1		1		1		1	1	0	1	1	0	1		1
If yes, for which purposes?	Acquisition and management of spatial data	47	IIIIIIIII											1			1			1	1	1	1	1		1												1							1	1		1	1				1
	Hydrological analysis and modelling	47	IIIIIIIII			1								1			1			1	1					1						1						1	1						1	1		1			1		1
	Hydrological mapping	47	IIIIIIIII			1						1		1			1			1	1	1																	1	1		1				1			1			1		1
	in-house information and decision support system	20	IIII			1																																							1		1	1		1		1
	public information systems	13	III														1																								1		1										1
	Other:	10	II														1					1		1																												
Do public authorities provide their consultants with available digital data sets for the contracted plans or studies?	Never	7	I																																1														1			
	Yes, at additional costs	27	IIIII									1					1															1	1								1				1	1					1		
	Yes, at no cost	47	IIIIIIIII		1	1						1		1			1			1		1	1									1						1	1								1		1				1
	No, consultants can buy data at regular prize	13	III																	1					1																	1					1					

Question		%	**Country:**	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
If results of plans and studies are produced in GIS format, are they transferred to public contractors in a digital format?	No, only hardcopy reports.	20	IIII									1									1												1										1							1			1
	Yes, in consultant's working format for archive purposes only	23	IIIII			1											1					1		1														1													1		1
	Yes, in a standard format for archive	17	III											1			1							1																	1													1
	Yes, in a standard format for integration into an information system	53	IIIIIIIIIII			1								1			1			1		1	1			1						1							1		1				1	1	1	1	1				1
2.3.3 Research and education																																																					
Background:																																																					
Is education and training in the use of GIS currently available at the institutions of higher education (universities, colleges) in your country?	No	10	II		1																											1				1																	
	Yes, in curricula of geography	57	IIIIIIIIIII			1						1					1			1		1	1	1					1									1	1		1		1		1	1		1	1				1
	Yes, in curricula of surveying, remote sensing and land information	57	IIIIIIIIIII			1						1					1			1	1	1		1		1							1					1	1				1		1	1		1	1				1
	Yes, in curricula of civil engineering	57	IIIIIIIIIII			1						1					1			1	1	1	1	1		1												1	1				1	1	1	1		1	1				
	Yes, as a basic course in all curricula of science and engineering	13	III									1		1								1																	1														
	Yes, in post-graduate and/or external training courses	60	IIIIIIIIIIII			1						1					1			1		1		1					1				1						1		1			1	1	1	1		1	1	1		1
Are there any attempts or existing programs to establish GIS education?	No	13	III																		1		1													1			1						0								
	Yes, in curricula of geography	17	III									1					1			1									1																									1
	Yes, in curricula of surveying, remote sensing and land information	17	III									1					1			1						1																											1
	Yes, in curricula of civil engineering	17	III									1					1			1						1																		1									
	Yes, as a basic course in all curricula of science and engineering	13	III		1							1																												1		1											
	Yes, in post-graduate and/or external training courses	37	IIIIIII			1														1									1												1			1		1	1	1		1	1		1
GIS uses in institutions of higher education																																																					
Are institutions of higher education using GIS in water related planning?	Yes/No	73	IIIIIIIIIIIIIII		0	1						1		1			1			1	1	1	1	1		1			0				1			0		1	1		1		1	0	1	1	0	1	1	1	1		1

Question		%	Country:	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
If yes, for which purposes?	Acquisition and management of spatial data	47				1						1		1						1			1	1		1													1	1		1				1			1	1				1
	Hydrological analysis and modelling	57				1						1		1			1			1	1	1				1													1	1		1				1	1		1		1	1		1
	Hydrological mapping	50				1						1		1						1	1	1				1													1	1		1		1					1		1	1		1
	in-house information and decision support system	27										1								1																				1						1	1		1			1		1
	public information systems	23										1								1		1																		1		1		1										1
	development of applications	57				1						1		1						1	1	1				1							1					1	1				1		1	1		1	1		1		1
	training of students	63				1						1		1			1			1	1	1	1										1					1	1		1		1		1	1		1	1		1		1
	Other:	7																						1									1																				
2.4 Available spatial data sets																																																					
2.4.1 Digital data sets of topography																																																					
Topographic RASTER maps																																																					
Which of the following layers of information are available in a geo-referenced raster format?	Rivers and lakes	70				1						1					1			1	1	1	1			1			1			1	1						1		1		1	1		1	1		1	1	1		1
	Roads and railways	67				1						1					1			1	1	1	1			1						1	1			1			1				1	1		1	1		1	1	1		1
	Elevation contours	73				1						1					1			1	1	1	1			1			1			1	1			1		1	1		1		1	1		1			1	1	1		1
	Land use	63				1						1					1			1	1		1			1			1			1	1						1		1					1	1	1	1	1	1		1
	Settlements	57				1						1					1			1	1		1	1		1						1	1						1					1		1			1	1	1		1
	Orthophotos	40				1						1					1			1	1	1	1										1								1					1			1				1
	Other:	13															1			1												1																	1				
What is the scale of the topographic maps available in raster format?	50 000 or better	63				1											1			1	1	1	1	1		1						1	1			1			1					1		1	1	1	1		1		1
	200 000	23				1						1								1						1			1															1						1	1			
	500 000	17				1														1	1					1																							1				
	1 000 000 or worse	10																		1																					1		1										
Are these data sets published by the national institution of surveying?	Yes	63				1											1			1		1	1	1		1						1	1						1		1			1		1	1	1	1	1	1		1
	No, by private, third party distributor	10										1									1																					1									
What percentage of the surface area of your country is covered by these data sets?	Only small parts	3																			1																														
	less than 50%	0																																																		
	more than 50%	17																					1		1																		1			1			1			
	100 %	57				1						1					1			1		1	1									1	1			1			1		1		1			1		1	1		1		1

Question		%	Country:	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
Topographic maps (non-topological VECTOR)																																																					
Which of the following layers of information are available in a graphical, non-topological vector format (e.g., DXF)?	Rivers and lakes	77				1						1					1			1	1	1	1	1		1						1	1						1		1		1	1	1	1	1	1	1	1	1		1
	Roads and railways	67				1						1					1			1	1	1	1	1		1						1	1			1			1				1		1		1	1	1		1		1
	Elevation contours	53										1					1			1	1		1	1		1						1	1						1		1		1					1	1		1		1
	Land use	47				1						1					1			1	1		1									1	1						1		1						1		1		1		1
	Settlements	57				1						1					1			1	1	1	1	1		1						1	1						1						1			1	1		1		1
	Other:	13															1							1								1													1								
What is the scale of the topographic maps available in graphical, non-topological vector format?	50 000 or better	57				1											1			1	1			1		1						1	1			1			1						1	1	1	1	1		1		1
	200 000	23										1								1		1											1																1	1	1		
	500 000	20																		1	1		1	1																				1					1				
	1 000 000 or worse	17																		1																							1						1	1	1		
Are these data sets published by the national institution of surveying?	Yes	43				1														1			1	1		1						1							1							1	1	1	1	1			1
	No, by private, third party distributor	20										1					1				1	1																					1										1
What percentage of the surface area of your country is covered by these data sets?	Only small parts	3																			1																																
	less than 50%	7																																										1	1								
	more than 50%	20																						1		1							1														1			1			1
	100 %	50				1						1					1			1		1	1	1												1			1		1		1			1		1	1		1		
Topographic maps (topological VECTOR format)																																																					
Which of the following layers of information are available in a topological (GIS) vector format?	Rivers and lakes	83				1						1		1			1			1	1	1		1		1			1			1	1					1	1		1		1	1	1	1	1	1	1	1	1		1
	Roads and railways	67				1						1		1			1			1	1			1		1			1			1				1		1	1				1		1	1	1		1		1		1
	Elevation contours	57										1					1			1	1			1		1			1			1				1			1		1		1		1	1			1		1		1
	Land use	67				1						1		1			1			1	1	1				1			1			1	1			1		1	1		1					1	1		1		1		1
	Settlements	53				1						1		1			1			1	1	1		1					1			1						1	1						1				1		1		1
	Other:	17												1			1							1								1													1								
What is the scale of the topographic maps available in a topological (GIS) vector format?	50 000 or better	63				1								1			1			1	1			1								1	1			1		1	1					1	1	1	1	1	1		1		1
	200 000	33										1		1						1		1				1			1				1								1								1	1			
	500 000	17																		1	1			1																					1				1				
	1 000 000 or worse	17																		1																							1		1				1		1		
Are these data sets published by the national institution of surveying?	Yes	67				1								1			1			1		1		1		1						1				1		1	1		1				1	1	1	1	1	1	1		1
	No, by private, third party distributor	20										1									1												1										1	1									1

Question		%	**Country:**	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
What percentage of the surface area of your country is covered by these data sets?	Only small parts	3																			1																																
	less than 50%	3																								1																											
	more than 50%	23												1										1									1											1			1	1		1			
	100 %	57				1						1		1			1			1		1		1								1						1	1		1		1		1	1			1		1		1
Digital elevation model																																																					
Are digital elevation models available for your country?	No	10			1																																1							1										
	only for small parts	3																			1																																
	less than 50%	0																																																			
	more than 50%	17																						1									1					1							1		1						
	100 %	60				1						1		1			1			1		1	1			1						1							1		1			1		1		1	1	1	1		1
What is the spatial resolution of country-wide available DEM?	500 x 500 m or worse	13																		1																								1			1			1			
	250 x 250 m	13				1															1					1																			1								
	100 x 100 m	27										1		1									1															1	1		1					1			1				
	50 x 50 m or better	47				1											1			1		1		1		1						1	1					1			1							1	1		1		1
What is the source of original DEM data?	Terrestric survey	17										1																													1			1			1			1			
	Photogrammetric survey	33				1						1		1						1				1								1															1	1		1			1
	Digitized contour lines from topographic map	50										1		1			1			1	1	1				1							1						1						1	1			1	1	1		1
	Other:	13																					1	1		1												1															
2.4.2 Hydrological and hydrometeorological information																																																					
Background																																																					
How are the hydrological services organized in your country?	National hydrological or hydrometeorological agency only	57										1									1	1	1	1		1			1			1	1						1		1				1	1		1		1	1		1
	Regional (provincial) hydrological or hydrometeorological agencies only	0																																																				
	Both national and regional (provincial) hydrological or hydrometeorological agencies	37			1	1								1			1			1								1										1					1	1			1		1				
	Neither national nor regional (provincial) hydrological or hydrometeorological agencies	0																																																			
	Other:	10																				1														1		1															

Question		%	Country:	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
If a national service of hydrology exists, for which of the enumerated elements of the water cycle is it responsible?	Surface water quantity	90	IIIIIIIIIIIIIIIIII		1	1						1		1			1			1		1	1	1		1		1	1			1	1					1	1		1		1	1	1	1	1	1	1	1	1		1
	Groundwater quantity	67	IIIIIIIIIIIII		1	1						1		1			1					1	1	1								1	1						1		1			1	1	1	1		1	1	1		1
	Precipitation, air temperature and evapotranspiration	47	IIIIIIIII		1	1						1		1							1					1		1	1															1	1	1	1			1	1		
	Water quality	67	IIIIIIIIIIIII			1								1			1			1		1						1	1			1	1					1	1		1		1	1	1	1	1		1		1		1
Is information about the locations of monitoring stations publicly accessible (co-ordinates, maps)?	Yes, for all data	70	IIIIIIIIIIIIII		1	1						1					1			1		1	1	1				1	1			1	1					1	1		1			1	1	1	1		1				1
	Yes, but not for quality data	3	I																																																	1		
	Yes, but only rounded values	3	I																							1																											
	No, only for authorities	20	IIII											1							1															1							1					1		1			
Are the observed time series data publicly available?	Yes, for all data	67	IIIIIIIIIIIII		1	1						1					1				1	1	1	1		1							1					1	1		1		1	1	1	1	1		1				1
	Yes, but not for quality data	0																																																			
	No, only for authorities	27	IIIII											1						1								1	1			1				1												1		1			
Does your national service of hydrology regularly publish the collected data?	Yes, annual yearbook of hydrology with selected data and hydrological characterisation	70	IIIIIIIIIIIIII		1	1						1		1			1			1	1	1		1		1		1	1			1						1					1	1	1	1	1		1		1		
	Yes, digital publication on CD-ROM	10	II									1										1																											1				
	Yes, open access to processed data via public information system (Internet)	27	IIIII														1			1			1			1													1		1								1				1
	Yes, real-time public information for online stations	27	IIIII																				1			1												1	1					1		1			1				1
	No, data are only available on request	17	III									1																					1			1												1		1			
Hydrological mapping																																																					
Are there spatially consistent, map-based presentations of the elements of the hydrological cycle existing for your country?	Yes/No	70	IIIIIIIIIIIIII		1	1						1		1			1			1	0	1	1	0		1		1	0			0	1			0		1	1		1		1	0	1	1	1	1	1	0	0		1
If yes, how are these maps organized?	Homogeneous, consistent collection of maps (e.g. Hydrological Atlas)	30	IIIIII			1														1								1											1				1			1	1	1	1				
	Individual, independent map sheets from different authors	43	IIIIIIIII			1						1		1			1					1	1			1							1					1			1		1		1								1

Question		%	**Country:**	ALB	ARM	AUT	AZE	BEL	BIH	BGR	BLR	HRV	CYP	CZE	DNK	EST	FIN	FRA	GEO	DEU	GRC	HUN	ISL	IRL	ISR	ITA	JOR	KAZ
For which topics do such maps exist?	Precipitation	73	IIIIIIIIIIIIIII		1	1						1		1			1			1		1	1			1		1
	Evapotranspiration	57	IIIIIIIIIII		1	1						1					1			1		1	1			1		
	Discharge	57	IIIIIIIIIII		1							1		1			1			1		1	1					1
	Water quality	37	IIIIIII		1	1								1			1			1		1						
	Soil- and Groundwater	53	IIIIIIIIIII		1	1						1		1			1			1		1	1					1
	Water management	17	III									1								1		1						
For maps of statistical evaluations (e.g. "mean annual precipitation", are these maps based on a common time period?	Yes, WMO standard period of 1961-1990	40	IIIIIIII		1															1		1						
	Yes:	13	III											1												1		
	No, different time periods possible	40	IIIIIIII			1						1		1			1					1	1					1
Are these maps using a common scale and base map?	Yes/No	40	IIIIIIII		1	0						0		1			0			1		0	0			1		0
If Yes, what scale?	50 000 or better	7	I																									
	200 000	10	II											1														
	500 000	20	IIII		1															1						1		
	1 000 000 or worse	20	IIII																	1			1					
Are any of these maps available in digital format?	Yes, all of them	17	III																	1								
	Yes, some	47	IIIIIIIII			1						1					1					1	1			1		
	None	13	III		1									1														1
Are hydrological maps routinely processed with GIS support?	Yes, all of them	10	II											1														
	Yes, some	50	IIIIIIIIII			1						1					1			1		1		1		1		
	None	17	III		1																		1					1

Question		%	**Country:**	LVA	LBN	LTU	LUX	MKD	MLT	MDA	MCO	MON	NLD	NOR	POL	PRT	ROM	RUS	SRB	SVK	SVN	ESP	SWE	CHE	SYR	TUR	UKR	GBR
For which topics do such maps exist?	Precipitation	73	IIIIIIIIIIIIIII					1					1	1		1		1		1	1	1	1	1	1			1
	Evapotranspiration	57	IIIIIIIIIII										1	1		1		1			1	1	1	1				1
	Discharge	57	IIIIIIIIIII											1		1		1		1	1	1	1	1				1
	Water quality	37	IIIIIII													1				1		1		1				1
	Soil- and Groundwater	53	IIIIIIIIIII										1			1				1		1		1	1			1
	Water management	17	III																						1			1
For maps of statistical evaluations (e.g. "mean annual precipitation", are these maps based on a common time period?	Yes, WMO standard period of 1961-1990	40	IIIIIIII					1					1	1		1					1	1	1	1				1
	Yes:	13	III										1							1								
	No, different time periods possible	40	IIIIIIII											1				1						1	1	1		
Are these maps using a common scale and base map?	Yes/No	40	IIIIIIII					1					1	1		1		0		0	1		1	1	0	1		0
If Yes, what scale?	50 000 or better	7	I					1														1						
	200 000	10	II											1							1							
	500 000	20	IIII											1						1				1				
	1 000 000 or worse	20	IIII										1	1		1										1		
Are any of these maps available in digital format?	Yes, all of them	17	III					1					1	1							1							
	Yes, some	47	IIIIIIIII													1				1		1	1	1	1	1		1
	None	13	III															1										
Are hydrological maps routinely processed with GIS support?	Yes, all of them	10	II					1						1														
	Yes, some	50	IIIIIIIIII													1				1		1	1	1	1	1		1
	None	17	III															1			1							

WORLD METEOROLOGICAL ORGANIZATION
ORGANISATION MÉTÉOROLOGIQUE MONDIALE

Dr. Josef FÜRST
Rapporteur on "GIS applications in hydrology"

c/o University of Agricultural Sciences
Vienna
Department of Water Management,
Hydrology and Hydraulic Engineering
Muthgasse18
A-1190 Vienna, Austria
Fax: +43 1 36006 5549
Tel: +43 1 36006 5511

GIS applications in hydrology

Report for WMO RA VI
QUESTIONNAIRE

J. Fürst

November 2000

1 REPORT ON THE APPLICATION OF GIS IN OPERATIONAL HYDROLOGY

1.1 Background and objectives

In its twelfth session, the Working Group on Hydrology (WGH), Regional Association (RA) VI (Europe) of the World Meteorological Organisation (WMO) decided to elaborate a report on the "Application of Geographical Information Systems (GIS) in operational hydrology" in its member countries. The chairman of the Working Group in Hydrology RA VI, Prof. Dr. F. Nobilis, Austria, nominated Dr. Josef Fürst, Department of Water Management, Hydrology and Hydraulic Engineering, University of Agricultural Sciences, Austria, to be the rapporteur on "GIS application in hydrology".

According to resolution 11 (XII-RA VI) the tasks of the rapporteur on "GIS application in hydrology" are to

- report on recent developments in RA VI countries on the use of GIS in operational hydrology; and
- to investigate the needs and possibilities of producing European, consistent maps of the principal water balance elements.

1.2 Procedure

To achieve the specified objectives, given the constraints in financial capacity and available time of a rapporteur, the following procedure is planned:

1. Questionnaire based survey among members and the hydrological advisers.
2. Literature and public database research
3. Further individual inquiries as necessary
4. Compilation of draft report
5. Circulation of draft report among WGH members
6. Final draft for submission to WGH meeting

To meet the deadlines specified by WGH, it is important to pursue the following scheme:

30 November 2000	Distribution of questionnaires by mail and e-mail
31 December 2000	Return of completed questionnaires
December 2000 - March 2001	Evaluation of questionnaires, literature and public database research, individual complementary inquiries
15 April 2001	compilation of draft report
15 May 2001	Circulation of draft report among WGH members
1 September 2001	comments returned
1 October 2001	final draft report ready for submission to WGH

Please, co-operate with and support the rapporteur in order to achieve a comprehensive report in time and to avoid unnecessary work. A complete and up-to-date report on the current state of GIS application, especially on the availability of datasets, will be of significant value for deciding on future directions of WGH's activities.

1.3 How to use this questionnaire

This questionnaire is distributed in conventional printed format as well as electronically by e-mail. The preferred way of communication is by e-mail.

If you prefer to process this questionnaire in conventional printed format, please use the provided copy or print the provided MS Word document. Most of the questions are answered by ticking the appropriate boxes. If you want to provide additional information, please make a note in the questionnaire and add your text on extra pages. When completed, please mail or fax the questionnaire to the rapporteur at the address given on the cover page.

For both sides the most convenient method to process the questionnaire would be to fill out and send it electronically. The questionnaire is prepared as an online form in MS Word 97. It is provided as a MS Word document template (`GISquest.dot`) file. To fill out the questionnaire, please proceed as follows:

1. save the GISquest.dot file in the directory where MS Word stores all templates (usually `C:\Program Files\Microsoft Office\Templates\Other Documents`; the exact names of the directories depend on the language version of your MS Office! You can find the correct path in Menu `Tools->Options->File locations->User templates`)
2. Start Word 97; in Menu `File -> New`, tab to the document template `GISquest.dot`. I.e. you create a new document of type GISquest. You should now see the text of the questionnaire, with the tick boxes and text entry fields shaded in grey. Clicking with the mouse in a tick box should mark it. If already marked, a click should unmark it. You should not be able to change the text of the questions. If clicking does not mark tick boxes and if you can change the questionnaire's text, you must set the form as "protected". To do this, turn on the toolbar "Forms" (Menu `View->Toolbars->Forms`) and click the button "`Protect Form`" ( ).
3. Fill out the form. Text entry fields are of adjustable size and can accept multiple lines of text also. For extensive additional text, please create a new, freely formatted document. After completing the questionnaire, save the document as a word document file (.doc) under a name that identifies the contact person, e.g. `yourname.doc`.
4. Send the filled questionnaire document and any additional documents by e-mail attachment to the rapporteur at fuerst@edv2.boku.ac.at . Alternatively, print the documents and send by mail or fax.

2 QUESTIONNAIRE ON GIS APPLICATIONS

2.1 Introduction

This questionnaire has two main parts. The first part asks for the users of GIS, from public authorities to private consultants, and for which purposes they apply GIS. The second part asks for the available spatial data sets, their scale and resolution and accessibility for users.

As far as possible, the answer to the questions should be given by ticking the appropriate boxes near the answers. If you feel that the given choices are not sufficient or not applicable, please use extra pages and give freely formulated answers there. You can also refer to published reports or other sources of information, if these are accessible by the rapporteur.

2.2 Contact information

First name (given name):	
Family name:	
Affiliation (Authority, Institution):	
Job function:	
WMO function:	
Street address:	
Postal code, City:	
Country:	
Telephone:	
Fax:	
e-mail:	

2.3 GIS Users and uses

2.3.1 Public authorities

Background: Structure of public water authorities	
How is hydrology and water management geographically organised in your country?	☐by administrative units (province, district, ...) ☐by river basins and catchments
Is there a single supreme national authority (e.g. a ministry) responsible for all water affairs (hydrology, water quantity, quality, environmental issues)?	☐Yes ☐No
Which of the listed sectors are involved in public water management and hydrology? Tick one, if the answer to the previous question was Yes, otherwise tick more than one.	☐Agriculture and forestry ☐Environment ☐Health ☐Economy ☐Other:

GIS uses	
Is your national hydrological service using GIS?	☐Yes ☐No
If yes, for which purposes?	☐Acquisition and management of spatial data ☐Hydrological analysis and modelling ☐Hydrological mapping ☐in-house information and decision support system ☐public information system ☐Other:
Is your national meteorological and climatological service using GIS?	☐Yes ☐No
If yes, for which purposes?	☐Acquisition and management of spatial data ☐Meteorological analysis and modelling ☐Meteorological and climatological mapping ☐in-house information and decision support system ☐public information system ☐Other:
Are there other national services collecting water related information? (e.g. geological service)	☐Yes ☐No

2.3.2 Consultants

Background:	
What proportion of water related planning (e.g. water supply facilities, river engineering, waste water treatment plants, sewers) is performed by private consultants?	☐none - everything is done by public authorities ☐less than 50% ☐100 %
GIS uses	
Are private consultants using GIS in water related planning?	☐Yes ☐No
If yes, for which purposes?	☐Acquisition and management of spatial data ☐Hydrological analysis and modelling ☐Hydrological mapping ☐in-house information and decision support system ☐public information systems ☐Other:
Do public authorities provide their consultants with available digital data sets for the contracted plans or studies?	☐Never ☐Yes, at additional costs ☐Yes, at no cost ☐No, consultants can buy data at regular prize
If results of plans and studies are produced in GIS format, are they transferred to public contractors in a digital format?	☐No, only hardcopy reports. ☐Yes, in consultant's working format for archive purposes only ☐Yes, in a standard format for archive ☐Yes, in a standard format for integration into an information system

2.3.3 Research and education

Background:	
Is education and training in the use of GIS currently available at the institutions of higher education (universities, colleges) in your country?	☐No ☐Yes, in curricula of geography ☐Yes, in curricula of surveying, remote sensing and land information ☐Yes, in curricula of civil engineering ☐Yes, as a basic course in all curricula of science and engineering ☐Yes, in post-graduate and/or external training courses
Are there any attempts or existing programs to establish GIS education?	☐No ☐Yes, in curricula of geography ☐Yes, in curricula of surveying, remote sensing and land information ☐Yes, in curricula of civil engineering ☐Yes, as a basic course in all curricula of science and engineering ☐Yes, in post-graduate and/or external training courses
GIS uses in institutions of higher education	
Are institutions of higher education using GIS in water related planning?	☐Yes ☐No
If yes, for which purposes?	☐Acquisition and management of spatial data ☐Hydrological analysis and modelling ☐Hydrological mapping ☐in-house information and decision support system ☐public information systems ☐development of applications ☐training of students ☐Other:

2.4 Available spatial data sets

2.4.1 Digital data sets of topography

Topographic RASTER maps	
Which of the following layers of information are available in a geo-referenced raster format?	☐Rivers and lakes ☐Roads and railways ☐Elevation contours ☐Land use ☐Settlements ☐Orthophotos ☐Other:
What is the scale of the topographic maps available in *raster format*?	☐50 000 or better ☐200 000 ☐500 000 ☐1 000 000 or worse
Are these data sets published by the national institution of surveying?	☐Yes ☐No, by private, third party distributor
What percentage of the surface area of your country is covered by these data sets?	☐Only small parts ☐ess than 50% ☐more than 50% ☐100 %
Topographic maps (non-topological VECTOR)	
Which of the following layers of information are available *in a graphical, non-topological vector format (e.g., DXF)?*	☐Rivers and lakes ☐Roads and railways ☐Elevation contours ☐Land use ☐Settlements ☐Other:
What is the scale of the topographic maps available *in graphical, non-topological vector format*?	☐50 000 or better ☐200 000 ☐500 000 ☐1 000 000 or worse
Are these data sets published by the national institution of surveying?	☐Yes ☐No, by private, third party distributor
What percentage of the surface area of your country is covered by these data sets?	☐Only small parts ☐less than 50% ☐more than 50% ☐100 %
Topographic maps (topological VECTOR format)	
Which of the following layers of information are available *in a topological (GIS) vector format?*	☐Rivers and lakes ☐Roads and railways ☐Elevation contours ☐Land use ☐Settlements ☐Other:
What is the scale of the topographic maps available *in a topological (GIS) vector format?*	☐50 000 or better ☐200 000 ☐500 000 ☐1 000 000 or worse
Are these data sets published by the national institution of surveying?	☐Yes ☐No, by private, third party distributor

What percentage of the surface area of your country is covered by these data sets?	☐Only small parts ☐less than 50% ☐more than 50% ☐100 %
Digital elevation model	
Are digital elevation models available for your country?	☐No ☐only for small parts ☐less than 50% ☐more than 50% ☐100 %
What is the spatial resolution of country-wide available DEM?	☐500 x 500 m or worse ☐250 x 250 m ☐100 x 100 m ☐50 x 50 m or better
What is the source of original DEM data?	☐Terrestric survey ☐Photogrammetric survey ☐Digitized contour lines from topographic map ☐Other:

2.4.2 Hydrological and hydrometeorological information

Background	
How are the hydrological services organized in your country?	☐National hydrological or hydrometeorological agency only ☐Regional (provincial) hydrological or hydrometeorological agencies only ☐Both national and regional (provincial) hydrological or hydrometeorological agencies ☐Neither national nor regional (provincial) hydrological or hydrometeorological agencies ☐Other:
If a national service of hydrology exists, for which of the enumerated elements of the water cycle is it responsible?	☐Surface water quantity ☐Groundwater quantity ☐Precipitation, air temperature and evapotranspiration ☐Water quality
Is information about the locations of monitoring stations publicly accessible (co-ordinates, maps)?	☐Yes, for all data ☐Yes, but not for quality data ☐Yes, but only rounded values ☐No, only for authorities
Are the observed time series data publicly available?	☐Yes, for all data ☐Yes, but not for quality data ☐No, only for authorities
Does your national service of hydrology regularly publish the collected data?	☐Yes, annual yearbook of hydrology with selected data and hydrological characterisation ☐Yes, digital publication on CD-ROM ☐Yes, open access to processed data via public information system (Internet) ☐Yes, real-time public information for online stations ☐No, data are only available on request

Hydrological mapping	
Are there spatially consistent, map-based presentations of the elements of the hydrological cycle existing for your country?	☐Yes ☐No
If yes, how are these maps organized?	☐Homogeneous, consistent collection of maps (e.g. Hydrological Atlas) ☐Individual, independent map sheets from different authors
For which topics do such maps exist?	☐Precipitation ☐Evapotranspiration ☐Discharge ☐Water quality ☐Soil- and Groundwater ☐Water management
For maps of statistical evaluations (e.g. "mean annual precipitation", are these maps based on a common time period?	☐Yes, WMO standard period of 1961-1990 ☐Yes: ☐No, different time periods possible
Are these maps using a common scale and base map?	☐Yes ☐No
If Yes, what scale?	☐50 000 or better ☐200 000 ☐500 000 ☐1 000 000 or worse
Are any of these maps available in digital format?	☐Yes, all of them ☐Yes, some ☐None
Are hydrological maps routinely processed with GIS support?	☐Yes, all of them ☐Yes, some ☐None