Control and Cybernetics

vol. **35** (2006) No. 1

TRANSCAT DSS architecture and modelling services

by

Jiri Horak, Jan Unucka, Josef Stromsky, Vladimir Marsik and Antonin Orlik

VSB - Technical University of Ostrava, Institute of Geoinformatics
17.listopadu 15, 70833 Ostrava-Poruba, Czech Republic
e-mail: jiri.horak@vsb.cz, jan.unucka@vsb.cz, josef.stromsky.hgf@vsb.cz, vladimir.marsik@vsb.cz, antonin.orlik.hgf@vsb.cz

Abstract: The main goal of the TRANSCAT project is to create an operational and integrated comprehensive Decision Support System (DSS) for optimal water management of catchments in borderland regions.

The analysis of system requirements was followed by the analysis of possible architecture of the complex system and its appropriate design. The core of the proposed system (ETRA GIS) contains gisToolkit, web server, DBS, database interface, web services application interface and remote components. The system utilises selected software tools of hydrological and hydrogeological modelling (HEC-HMS, ModFlow, GRASS GIS modules). The special wrappers for each of the model were developed, enabling communication among models. Decision-making is supported by integrated decision applications (mDSS, Mediator, ProDec, BarTend, ArgWar) facilitating mainly the process of evaluation of a wide spectrum of indicators and the process of decision-making. The core of the system utilises a database with special design. The object part of the database represents a data warehouse with multidimensional structure.

Implementation of TDSS was undertaken in Bela/Biała Głuchołaska (CZ/PL), Pasvik (NO/RUS), Sumava (CZ/D), Mesta/Nestos (BG/GR) and Guadiana (P/ESP) pilot areas, where also respective models were calibrated.

Keywords: GIS, DSS, water management, rainfall-runoff modelling, web services.

1. Introduction

The TRANSCAT project (see *TRANSCAT central server*) is concentrated on integrated water management by individual catchments, especially in transboundary conditions, where more problems usually occur.

The main goal of the project is to create an operational and integrated comprehensive Decision Support System (DSS) for optimal water management of catchments in borderland regions.

The proposed DSS is able to cope with the complexity of the water resource systems and the uncertainty of decision-making. The DSS will be built around modules that allow simulation of the range of different climatic, topographic, environmental and socio-economic conditions found in various EU and candidate countries transboundary catchment areas.

One of the important steps in the process of TDSS (TRANSCAT DSS) development was the concept and design of TDSS architecture. The appropriate proposal had to reflect the conditions of stakeholders (namely end-users) and also possibilities of up-to-date technologies. The analysis of formal system requirements was undertaken and the requirements were classified into primary and secondary categories. The UML (Unified Modelling Language – see *UML, Object Management Group*) models are used mainly for description of basic functionalities and business process model. The most promising solution is web distributed architecture with "core" application server and distributed mapping and modelling services.

One of the important features of the system is the realisation of a connection to hydrological and hydrogeological modelling software. The system is meant to provide services of numerical modelling in these areas for various tasks in water management. Solution of interfaces to such systems is not only a task for software engineering but above all the request for a conceptual solution, model development and calibration, data storing, definition of processes for deployment of these models and their integration to the uniform information system.

The utilisation of spatial data directly in the process of decision making process (e.g. visualisation of supporting maps) and indirectly in the pre-processing of data incoming to the modelling processes is connected with searching and development of appropriate forms for spatial data processing, modelling and visualisation. The distributed architecture for GIS offers a possibility to utilise a wide spectrum of tools independently of their platform and to develop highly tailored applications in a rapid way by chaining of existing spatial web services into the appropriate sequence.

2. System requirements and possible solutions

System requirements lead to a job description to be developed by the analyst. They are based on the management perspective of the future system's use.

The system requirements were divided into two main categories – primary and secondary (Fig. 1).

Primary requirements were identified on the basis of the system target and description of tasks. Secondary requirements were found during the analyses of stakeholder's requirements and conditions.

The UML diagrams were used for the representation of requirements.

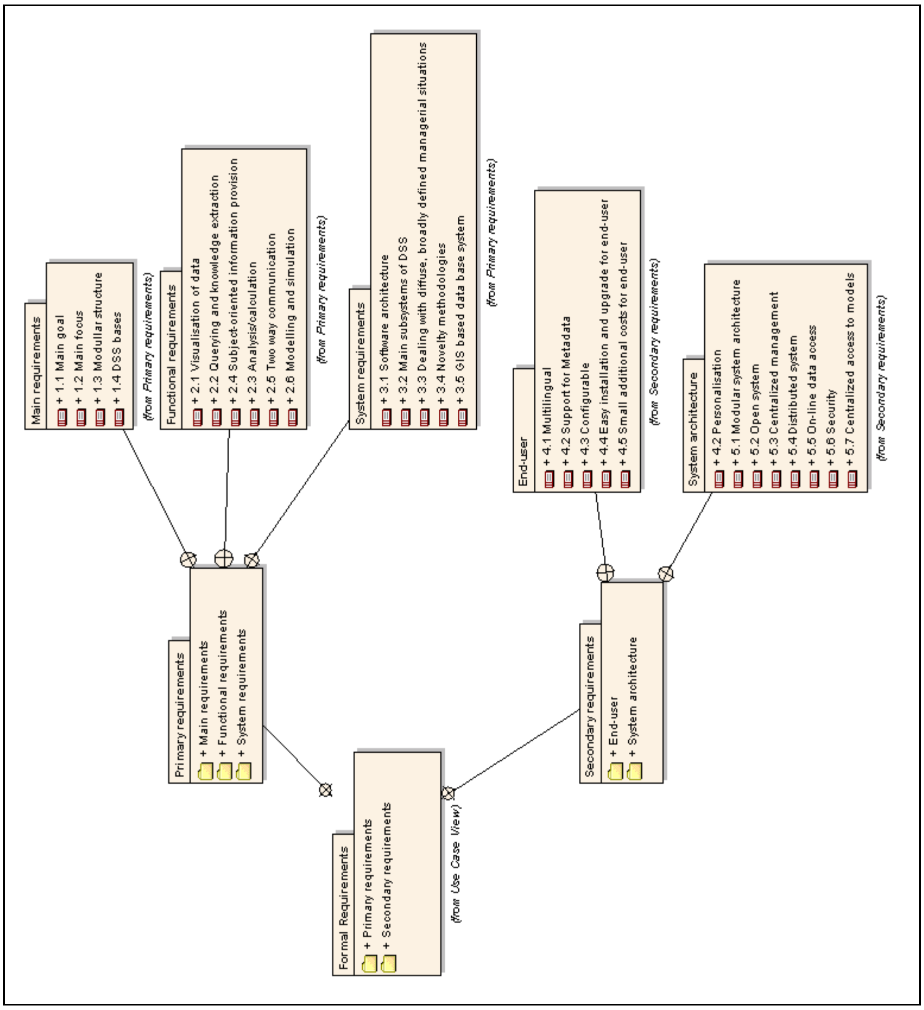

Figure 1. Classification of requirements in UML diagram

TDSS comprises four major subsystems concerned with data management, modelling, mapping and spatial analysis (geoprocessing) and DSS functionality.

Initial exploration of possible software architecture design included options like:

- Open source with PHP application server
- J2EE system architecture
- Commercial ESRI ArcGIS based architecture.

The first option with the use of UMN Map Server, MySQL, Apache, PHP and client site Java script was studied thoroughly and selected for pilot implementation of TDSS core subsystems.

The paradigm of service oriented architecture with infrastructure based on SOAP (Simple Object Access Protocol – see *World Wide Web Consortium*) web services comes in place also. Web services allow for the integration and mutual communication of apparently incompatible systems locally or in the frame of Internet/intranet. The utilization of standardized protocol SOAP, based on markup language XML, makes the communication platform independent.

The pros and cons of distributed web architecture versus rich client solution were evaluated. But in the final proposed solution both types of applications co-operate.

3. TDSS architecture

The definition of the system architecture should establish the fundamental features of the system structure and operation. The architecture includes specifications for software solution, particularly for decomposition, communication, information interchange and solution for spatial processing and visualisation services (SW dimension); proposal of data structure and organising data exchange and processing (data dimension); actors in the system and organisational issues (personal dimension). The description of the whole architecture goes behind the extent and purpose of this paper. The main focus is here the description of software dimension.

3.1. Software dimension

TDSS system was build-up by an integration of distributed geographic information system and a set of powerful decision support systems, modelling servers (mainly hydrological and hydrogeological), data warehouses and relevant public information services.

The ground for TDSS developing is ETRA GIS system designed as special tool for rapid construction of this type of information systems. It is used as a central element integrating components distributed over the network. The basic parts of TDSS are shown in Fig. 2.

3.1.1. ETRA GIS server

ETRA GIS (Extensible gisToolkit with Remote Access) provides a possibility of:

- rapid development of service oriented geographic information systems, its simple management, extensibility and interoperability
- linkage of powerful (mainly GIS oriented) back-end systems and integration of their functionality
- system build-up without dependence on commercial solutions
- prompt deployment using the standard web application
- installation, management and configuration without deeper knowledge of relevant technologies or programming languages.

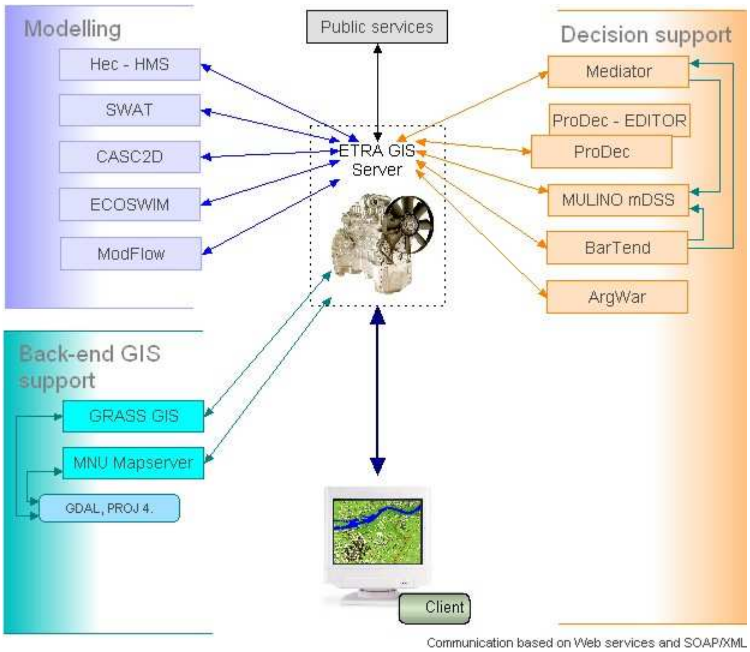

Figure 2. TDSS software architecture

ETRA GIS consists of the following basic server-side components:

- gisToolkit
- Web server
- Database management system
- EGDI – ETRA GIS Database Interface
- Web services application interface (WS-API)
- Remote components of distributed ETRA GIS system.

gisToolkit

gisToolkit represents a basic component of ETRA GIS, assuring a communication with the map server and linkage of other components. gisToolkit fundamentally extends map server possibilities, especially in the field of metadata, users definition and authorization, multilinguality etc.

gisToolkit methods are accessible through the web services application interface as well (WS-API). Thus, the system is not only consumer of remote software component functionalities, but it becomes a full-fledged component, which can be easily integrated within other systems (Fig. 3).

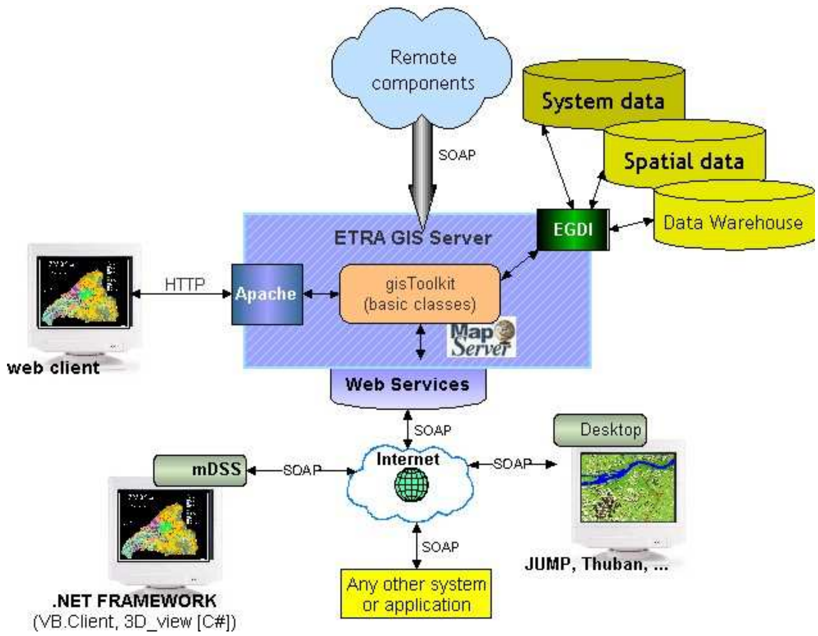

Figure 3. ETRA GIS solution scheme

gisToolkit provides to its clients the distribution of all basic map composition elements, usually through uniform interface WS-API. These elements (particularly map, legend, scalebar, copyright) are generated according to the requirements sent by client, access rights of a current user, selected language etc. Moreover, these map composition elements can be also stored and shared with other system users. The system supports the pre-arrangement of map compositions for groups of users, which is important in the situation of utilisation of large volumes of heterogeneous data. The compositions (organised according to themes like hydrology, topography) can be consequently shared and used by system end-users.

gisTolkit supports also the linkage of remote components and facilitates their integration to the system.

Except for connection of "common" components, gisToolkit enables the use and storage of information about servers providing web map services (see Web Map Services – specification). GisToolkit acts as a gateway for distant data, which can be used by the system.

The next important part of gisToolkit consists of classes enabling dynamic generation of client application and its behaviour. A client application is dynamically created according to the user currently logged in, his access rights, his role in the system (superadmin, admin, user, guest), selected language (gisToolkit requests data from data warehouse and remote components in appropriate language) and current time (system checks if requested data are up to date). Dynamic client application generation is important for full customisation meant for the expected usage by different groups of users. These groups are varying by interests, styles of geodata visualization etc.

These features are of great importance for assuring smooth transboundary communication. The way of geodata visualization, labelling or attribute selection reflects national lingual and cultural environment.

Web server

Web server in cooperation with PHP interpreter plays a role of application server for ETRA GIS system. Thus, the role of Web server can be understood as that of a certain mediator between client and server side applications. Currently, the system primarily utilises Apache web server, but it is possible to run alternative servers like IIS (Internet Information Services) or Netscape Enterprise Server.

DBMS

Database management system is the fundamental component intended to manage all system data and data warehouse. The data structure is described in Section 3.2.

Currently, MySQL is implemented in the position of DBMS. The system is distributed free and offers favourable speed, scalability and reliability. However, operating of ETRA GIS system is not limited to this product. Thanks to the implemented database abstraction layer there is a possibility to use such DBMS like FrontBase, Informix, FireBird, Microsoft SQL Server, mSQL, MySQL, Sybase, Oracle, and PostgreSQL. Further development will lead to systems, which directly support storing spatial data in relational databases like PostGIS, MySQL Spatial or Oracle spatial.

Surrounding systems have access to data through EGDI interface. Thereby, safe access to DBMS is ensured, because user (client) does not dispose of direct access to data. This is handled by the interface mentioned.

EGDI

EGDI (ETRA GIS Data Interface) is the component providing the database related services for other TDSS components. Also external third party application can use EGDI services.

Services are provided in the form of SOAP web service, as a part of the mentioned WS-API. They supply data queries (select request), data manipulation (save, update and delete requests) and data model metadata access (class metadata and collections metadata request). The usage of EGDI service is secured by user authentication and authorization united in the context of ETRA GIS Server.

The EGDI component works on the basis of object-relational mapping. The service client is accessing logical object oriented database model, which is virtually constructed on the top of relational data representation. The physical data model (tables, columns) is hidden. The dependence on concrete (relational) database management system is eliminated.

Querying is pursued with object oriented query language. The result of "select" query is XML serialization of resulting objects and their associations. Also the insert or update requests pass on XML serialization of objects in demanded state. The access and manipulation of spatial data in the form of OpenGIS defined GML and Well-Know Text (WKT) (see *Open GIS consortium*) format is in further development.

Application interface for Web Services (WS-API)

The application interface generally provides access to methods and functionalities of previously developed systems. The main reason is to provide all services independently in a distributed system – not only for local invoking, but also for remote invoking.

ETRA GIS system provides an entrance to access all functions through web services application interface (WS-API). It offers the possibility to utilise all functions in the frame of other systems. In the final phase of WS-API development it is assumed that ETRA GIS system will become a client of its own application interface. This step will bring new cooperation possibilities for all distributed information systems developed on the basis of ETRA GIS.

3.1.2. ETRA GIS client

ETRA GIS provides an own web application, which was developed in the frame of TRANSCAT project as a default client. The client is a dynamically generated interpreted application and implements the entire functionality of ETRA GIS Server in the form of plugins (Fig. 4).

ETRA GIS Web client is an application written in JavaScript, interpretable by common web browsers such as Mozilla, Firefox, Internet Explorer. Such solution is broadly available, no installation of desktop client and optional of

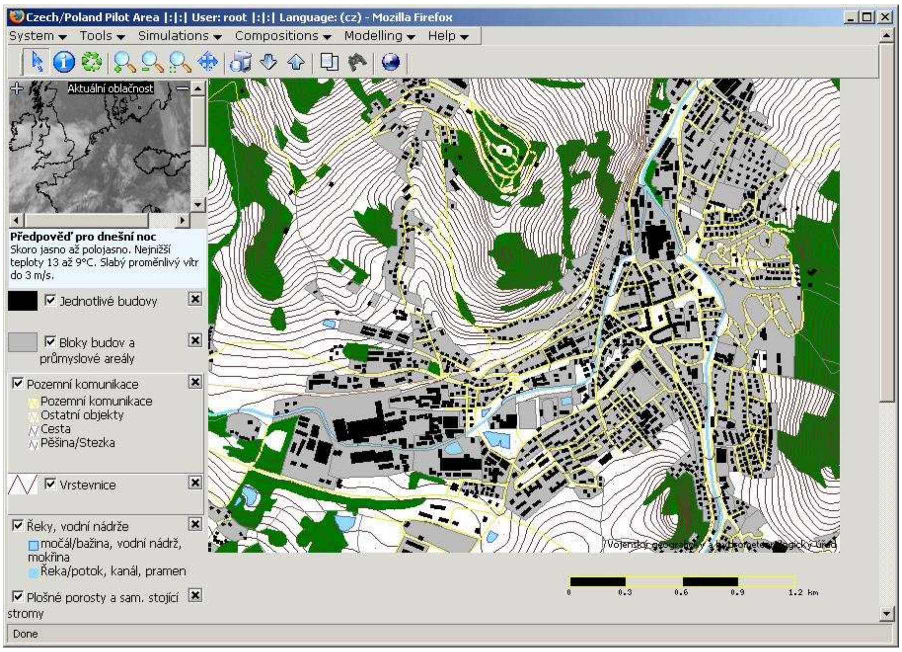

Figure 4. ETRA GIS Web client

some software platforms (Java Runtime Environment, .NET Framework or Perl interpreter) is required. The web client user works always with the latest version of application and he/she is not charged with managing and upgrading the version.

Major part of data used and processed by this system has a spatial character. The basic client function is spatial data visualization and common functions for manipulation with interactive digital map (documented, e.g., in Horak and Owsinski, 2004).

Moreover, the client is equipped with more advanced functions like layer labelling (on the basis of attribute selection and buffer definition). The map settings in the web client can be stored as map compositions (Fig. 5).

Two basic tools for querying attribute data are available. A cursor tool is intended to show instantly the specified attributes for a selected object in the interactive map. A search tool organises querying in the opposite way and the user is able to construct the query from the list of available attributes and SQL operators. The query result is presented in a table form and selected object can be marked and zoomed in the map. Both tools utilise the customised form of attribute selection – only permitted attributes and selected language variants are listed for querying (Fig. 6).

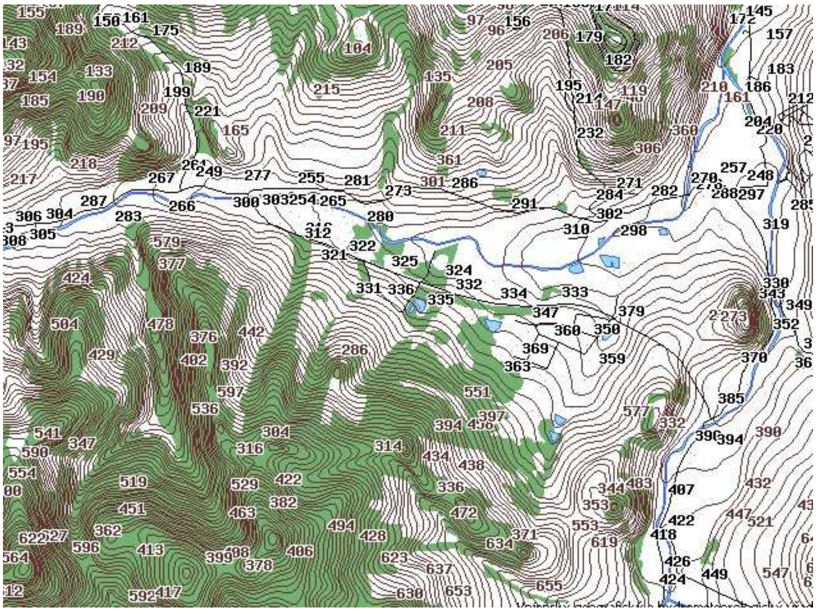

Figure 5. Layer labelling

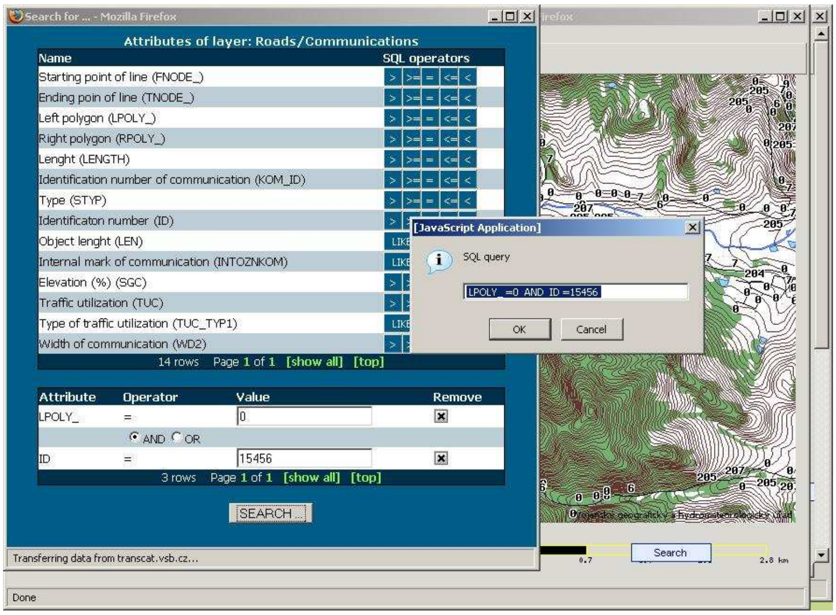

Figure 6. Data querying

Web client enables also opening an information window and displaying selected relevant information (e.g. weather forecast, cloudiness over current area).

In the development phase, special attention was given to preparation of simulations, which demonstrate application of the complex system (ETRA GIS) in contamination transport modelling, calculation of peak flow times, snow melting, changes in groundwater withdrawal, events with groundwater contamination, evaluation of area vulnerability, evaluation of ecological quality in the frame of Water Framework Directive etc. Currently, a part of these functions is in operational status. They utilise the prepared rainfall-runoff model and offer flow prediction for several days, permission of water withdrawal in this time period and complementary displaying of information about the selected profile on a water course and radar precipitation estimation (Fig. 7).

3.1.3. Modelling systems

As one of the fundamental requirements the utilisation of numerical modelling tools was identified in the analytical phase of the project. In spite of the fact that a plenty of various modelling systems exist, there is a great lack of systems providing such interface, which will enable a remote invocation of their methods. The preferable situation is when modelling system plays the role of server and provide to its clients simulation possibilities of different phenomena defined by accepted parameters in a pre-arranged and calibrated model. For each modelling system in TDSS, the special wrapper (interface) must be prepared. The wrapper cooperates with database and this allows to manage model computations. Requirements accepted by this interface in the form of web services are consequently passed and translated to a particular modelling system. The calculated result is then delivered back through web services and SOAP protocol (Fig. 8).

Some models require continuous stream of current and updated data and they are periodically recalculated. A special engine downloads and/or receives data from accessible sources, writes them to the integrated database, updates all models with new data and runs models in an appropriate order. Also, every model wrapper performs storing of output data to the integrated database.

This kind of wrappers is presently prepared for modelling systems HEC-HMS, Modflow (see *MODFLOW Guidelines*) and GRASS GIS system, which were selected from the analysis of selected DSS for water management (Tylcer et al., 2004).

An interface specification that proposes a unification in modelling systems linkage, is designed in the frame of European project HarmonIT. The interface OMI (Open Modelling Interface) (Gijsbers et al., 2004) allows (in case of successful introduction) to integrate modelling systems and combine their functions in order to improve final results. One of main project outputs is, side by side with interface specification, also the development of an environment for implementation support. It is presently under development. The design of modelling

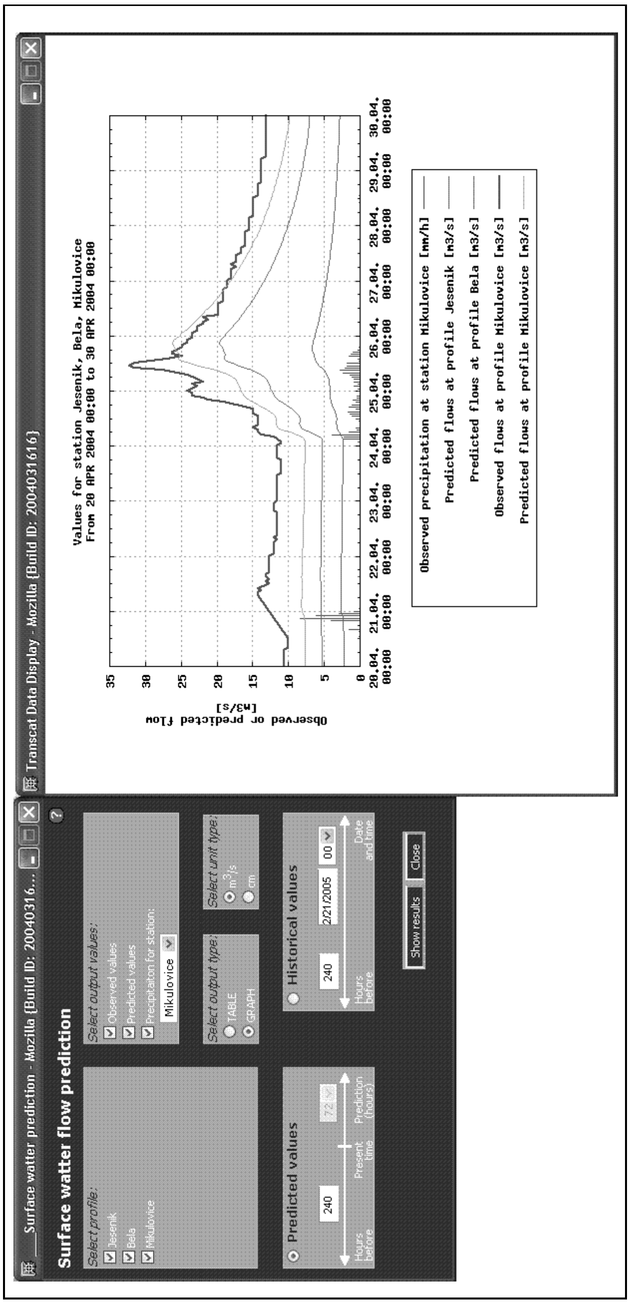

Figure 7. Surface water flow prediction – selection and graphical output

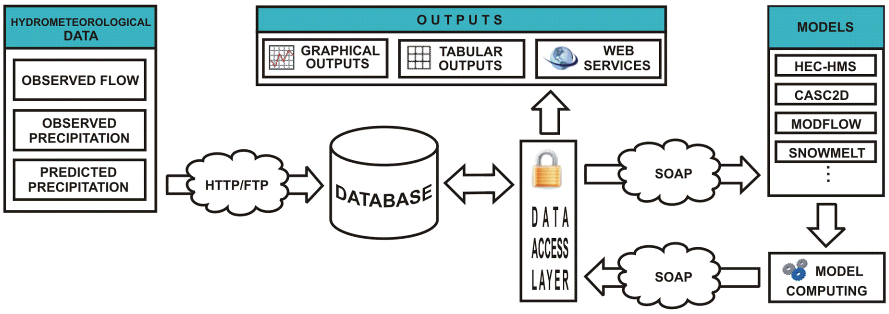

Figure 8. Data sharing in hydrological and hydrogeological modelling

system wrappers and their further development follows a basic direction established by HarmonIT project in order to enable a possible implementation of project results in the future.

3.1.4. Decision applications

The DSS system cannot be fully developed without integration of specific decision applications (DAs) supporting directly decision making mainly for strategic level. Connecting and technique of communication for decision applications is analogous to the solution of modelling systems. These applications will be equipped by appropriate interfaces, currently under development, and the uni-directional or bi-directional communication will be assured. The implementation seems to be easier due to the fact that most of DAs already implement an interface in the form of web services.

Decision applications prepared for integration into distributed architecture of TDSS include:

mDSS. The mDSS is a Decision Support System aimed at supporting the choice from a set of discrete policy options. The DSS bases on a set of multicriteria decision methods (MCA) to chose from according to the specific characteristics of the problem at hand and according to the background of the policy makers. The MCA methods are complemented by sensitivity (robustness) analysis and by analysis of sustainability of the management regime. Group decision making (i.e. decision involved a group of policy makers and stakeholders) is supported (see *MULINO project*).

Mediator represents a tool for group decision-making support. Participants provide their classifications of explicitly formulated options in terms of preferences. These preference expressions are then aggregated according to a number of rules. The mediator of the process sees the results of the aggregation according to various rules and communicates accordingly with the participants (see *Mediator project*, and also, for this and the following DAS, *TRANSCAT PL*.

ProDec provides assistance in the design of decision-making procedures based on decision tree with the possibility of introducing linguistically interpretable fuzzy values in the individual conditional rules.

BarTend represents a simple bargaining / tender application for situations, in which it is possible to ask the question about payment for realisation/non-realisation of certain options.

ArgWar is a simple instrument for voting YES / NO to a given question with indication of definite explicit arguments (pro or con), which motivate to vote YES or NO. It is also possible that a user introduce new pro or con arguments into the application.

3.2. Data dimension

The database represents a crucial part of the system. ETRA GIS is driven by the data stored in the database. The design and composition of the client is generated on the fly from the specification stored in database.

The database consists of two main parts – the system part and the object part.

The system part is intended to manage the application. It contains parameter values, definition of users, groups, their rights to other objects; specification of geographical themes, layers, map compositions, classification schemes for individual layers, definition and setting of attributes, datasets, functions, metadata for spatial data (Fig. 9). The system part is organised as a classical relational scheme with a set of database relations, where each database relation (usually called table) represents an individual type of entity, described by a set of fixed defined attributes.

Another approach was used for the object part of the database. This part is oriented to "classical" (facts) data. It includes measurements (e.g. water stage level, groundwater head elevation, results of chemical/biological analysis, coordinates of wells), but also description of documents, contact data of persons and organisations, and others. These data can be classified according to their value – e.g. the cost of laboratory testing of water sample can vary from x0 to x00 Euros. It is understandable that the cost connected with data acquisition has to be fully utilised. But the value of information thus obtained is determined by a sufficient knowledge of all circumstances relevant for a range of possible applications. Thus, this knowledge has to be recorded in the form of metadata. Moreover, the metadata should be specified directly for each value, not for the whole row (set of various attributes). We decided not to force users to skip a lot of various conditions and push them to save their data into classical tables because it is connected with obvious interpretation and simplification.

Instead of it we store data in the multidimensional structure and create a data warehouse (Fig. 10).

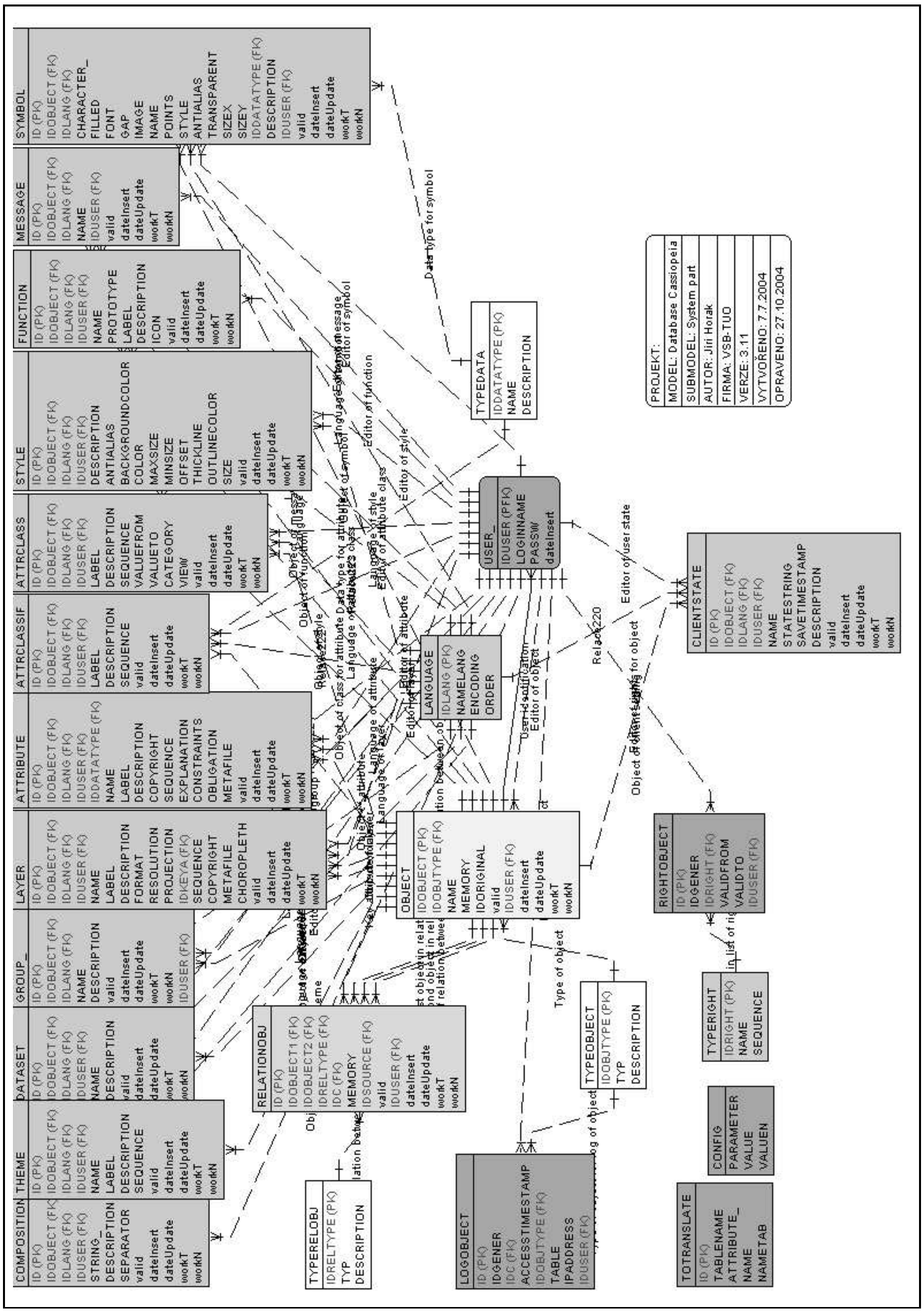

Figure 9. ERA diagram for the system part of the database

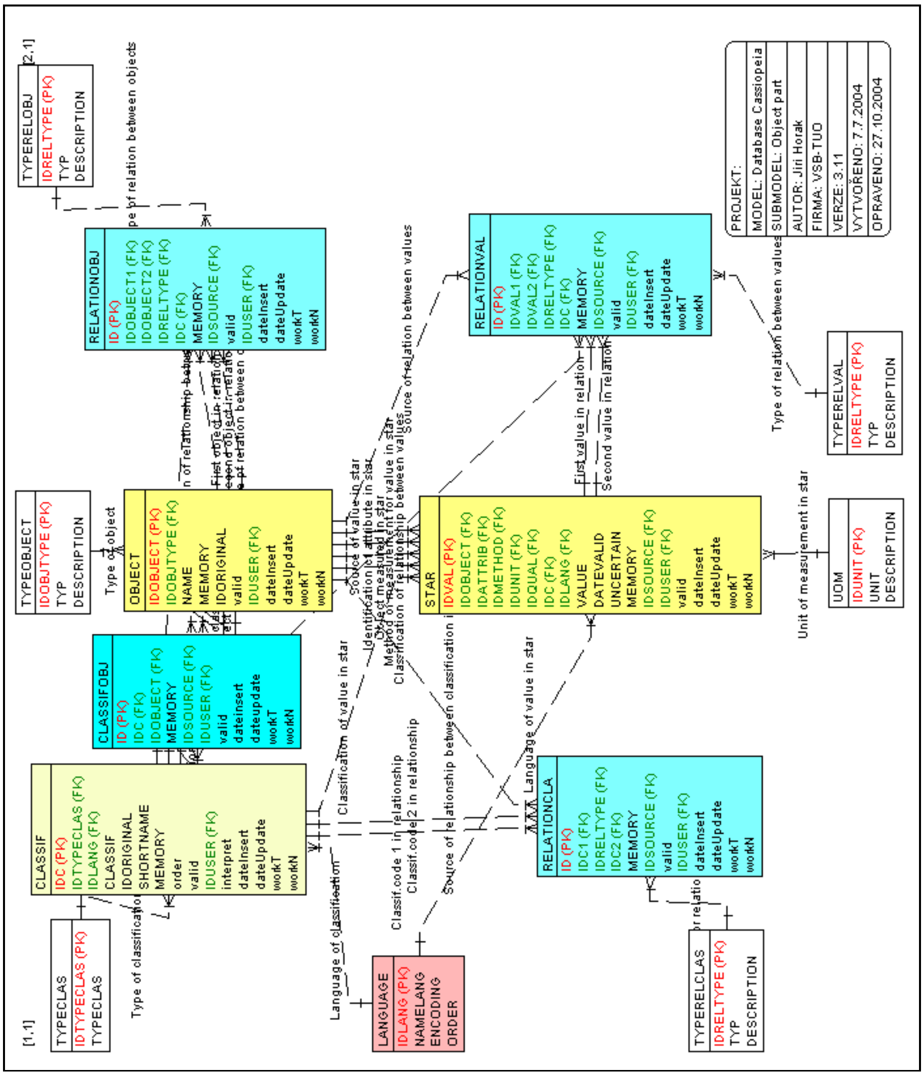

Figure 10. ERA diagram for the object part of the database

Dimensional modeling begins by dividing the world into measurements and context. Measurements are usually numeric and taken repeatedly. Facts are always surrounded by mostly textual context true at the moment the fact is recorded. If the facts are truly measures taken repeatedly, you find that fact tables always create a characteristic many-to-many relationship among the dimensions. This approach creates the concept of multidimensional structure consisting in a fact table surrounded by dimension tables (Kimball, 2003).

Also the report of HarmoniRiB (Moore, Tindall and Bech, 2003) contains similar recommendation with a lot of arguments. They suggest using three main axes for the multidimensional cube, which represent features (WHERE observations were made), attributes (which record WHAT the observation was a measure of) and occasions (WHEN the observations were made). Thus, each cell in the cube records the value of an attribute at a particular feature for a particular point in time. Additional dimensions are qualifier, method, uncertainty information, and dataset.

The main dimensions in ETRA GIS warehouse are:

- Date (date&time)
- Method (e.g. what analytical method)
- Dataset (used for link to full metadata, copyrights, etc.)
- Units (units of measurement)
- Object (ID of sample, well etc.)
- Attribute (what attribute is measured)
- Qualificator (=,<, >,traces,etc.)
- Uncertainty evaluation
- Classification scheme (for codes like type of rock, kind of layer, kind of soil, type of vegetable, the level of satisfaction)
- Source
- Language.

The input of data to the data warehouse is then more complicated due to the need of full specification of any measured value – from where we know the value, how it was measured, in what units, date and time of measurement, membership to certain dataset, evaluation of uncertainty, etc.

The multidimensional structure is not appropriate for common requested outputs (having the form of classical tables). The secondary tables will be used for storing data derived from the primary data. The process between primary and secondary data may contain various forms of interpretation, simplification, regularisation etc. The database can contain an empty structure for secondary tables or these tables can be generated on the fly.

These two parts (system and object) cannot be easily separated. To the contrary, we would like to utilise the joined and integrated database. One of the reasons is a need to specify relationships between objects from both sides, e.g. Addresses (object part) for Users (system part), Rights (system part) for Measurements.

As it was possible to recognise yet, one of the cube axis (dimension) is language. The multilingual feature of TDSS is very important. For facilitation it is needed to store a lot of attributes in different language versions (and respective character set coding).

Each language will have only one setting of names, copyrights, metadata description etc. Thus, the database contains more records than one for any object, because it is needed to store more language/character set coding variants.

The English language record in any multilingual table has the highest privilege – it means that if no language variant of the value for requested languages exists, the English one is used. The same rule is applied to controlling of programme procedures.

A part of data will not be transformed and stored locally. The system is able to process distant geographical data (stored in external server) using WMS and WFS specifications (Fig. 11).

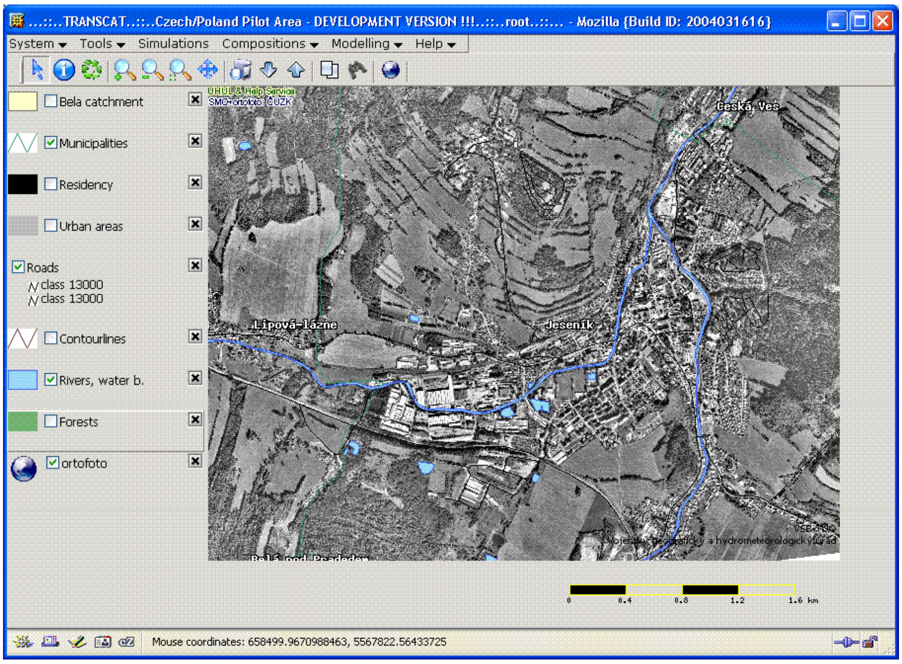

Figure 11. Ortophoto as a WMS layer

The data structure is complicated and it can cause problems to end-users. To facilitate the process of data manipulation, the application interface has to be developed. The second reason for application development in independent environment is the possibility to prepare data locally, then import them into the joined database (usually MySQL server). The interface is under the development in MS Access 2000 environment.

3.3. Personal dimension

Users accessing the ETRA GIS system through application interface can take on four different roles. ”Guest“ is a user account that provides access into the system. Higher access rights to public sources can be set up depending on the current implementation of ETRA GIS system. Next type of user can be called common ”user“. He must be a member of any defined group and adopt all its settings and access rights. By analogy to this type of user we can define ”administrator“. This user is a member of some group as well, but simultaneously he is the administrator of one group. The respective account is then used exclusively to change settings, access rights, etc. of the related group. All settings are taken over by all members and subgroups recursively. Last type of user is ”super-administrator“ (root). This user works according to the same principles as the previous one. The super-administrator manages the top level group and has access to special methods and plugins made for remote management of the entire system.

New users are placed into the hierarchical structure (Fig. 12), in which they take over all the default settings of the respective groups. In case of absence of default values, the settings take the values from the superior group.

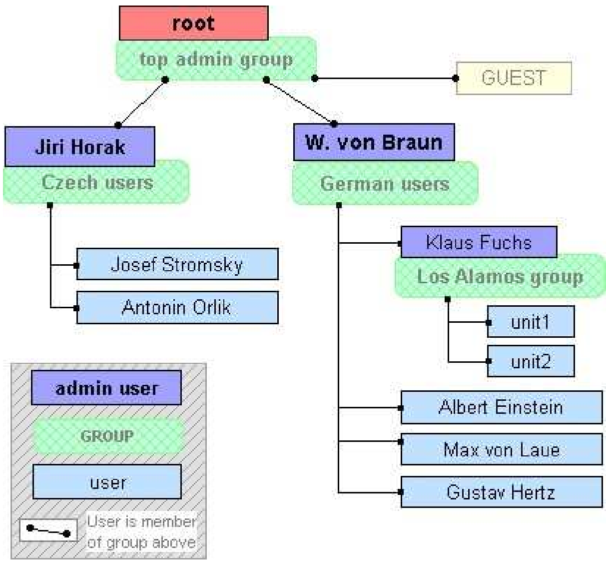

Figure 12. User hierarchy

4. Water flow modelling and connection with GIS

In the framework of the project, in particular, the rainfall-runoff model prototype of the Bela (the Czech part) catchment was prepared. Initial catchment schematisation was accomplished with the support of ArcGIS, ArcView GIS and GRASS GIS systems.

SCS method (CN-curves according to Beven, 2001) was used for the infiltration solution, Clark's unit hydrograph (Bedient and Hubber, 2002) was the method utilized for the rainfall-runoff transformation in semi-distributed sense (not grid, but small, relatively homogenous subbasins), kinematic wave approximation was used for the channel (1D) and for the overland (2D) flow.

HEC-HMS software permits using the various types of the unit hydrographs (for example Clark, Snyder and SCS unit hydrograph). Although this method has some limitations, the presumption of linearity of the hydrologic system above all, it permits easy catchment schematisation and with the use of semi- or distributed model provides acceptable results. Non-linear systems and methodology have not been commonly used worldwide to the present days.

For the channel routing (1D) and overland flow we have used kinematic wave approximation and Saint Venant equations. Relative low sensitivity to the channel geometry (bottom width, cross-sections) is one of the advantages of this solution. Kinematic wave velocity can be thought of as the speed with which a particular storage or depth value is moving downslope. Both steady and unsteady flow can be simulated with these methods, although some limitations of hydraulic extremes exist (Beven, 2001).

Base flow (groundwater outflow) was handled by the recession method, for which the fact that the method is not data demanding can be considered as the main advantage. These methods brought conceptual solution into the "real life" and operational running of the model will show their potential disadvantages. Because HEC-HMS does not include snowmelt module up to the version 2.2.x, additional snow module was developed. The module takes advantage of the degree/day and Anderson methods, which are relatively data undemanding (especially the former) and they can substitute one another.

Final computations can be visualised as raster (grid or TIN) in ArcGIS (Djokic and Maidment, 2000) or GRASS environment (Neteler and Mitasova, 2002), thus these GIS platforms are used for pre-processing, post-processing and specific hydrological computations (topographic index map according to Beven, 2001, flowline density, flowline path and flowline length etc.).

We are at the stage of hydrogeological model preparation in the version fully collaborating within TDSS. The model will be used for groundwater flow in the saturated zone, and it will take advantage of the simulation of the connection with the surface water flow. Interaction with hydrological models allows better calibration of both hydrological and hydrogeological models.

In many cases output from one model is used as input for another model - for example groundwater level estimated from hydrogeological model can be applied as parameter for hydrological model, predicted river flow from one hydrological model may be utilised as input for another (downstream) model etc. The concept of integrated database enables models to share their input and output data, including parameters. When any principal parameter common for more models is changed, it is not necessary to change it in all these models but just once in the integrated database – all models read its parameters from the database before actual model computations. The Bělá (Jeseníky mountains) and Upper Vltava (Šumava mountains) catchment models have been created with support of methods described above (Figs. 13 and 14). Initial calibration was done both for extreme (floods in 2002) and "normal" (peak discharge at the level of approximately annual maximum) rainfall-runoff episodes. The results of modelling are offered through the default web client. They are incorporated in functions facilitating operational management.

5. System application

TDSS represents the system useful for a large spectrum of end users with various requests for system operation. Primarily, the system is intended for decision support in water management. It can be applied both for operational and strategic decision making.

For the operational support TDSS provides current information useful for decision making like maps, graphs, tabular data, hyperlinks, information panels etc. One of the important features is connection to modelling tools, particularly from the domain of water management (currently HEC-HMS, ModFlow and individual modules of GRASS GIS).

The following applications of modelling are assumed:

1. modelling of water balance (simulation of runoff and precipitation, evaluation of changes of water resource according the requests); assumed tasks: e.g. permission of water withdrawal both from surface and groundwater;
2. modelling of groundwater flow in saturated and unsaturated zones including communication with surface water; assumed tasks: e.g. evaluation of quantitative status of water resources, evaluation of quantitative impacts of land use changes, permission of groundwater withdrawal;
3. modelling of contaminant transport in groundwater; assumed tasks: e.g. evaluation of sources of contamination, setting and modification of water disposal, evaluation of quantitative impacts of land use changes, permission of groundwater withdrawal;
4. modelling of surface water flow; assumed tasks: e.g. permission of water intake, waste water disposal;
5. modelling of contaminant transport in surface water; assumed tasks: e.g. evaluation of sources of contamination, setting and modification of water disposal, permission of surface water intake, permission of waste water disposal, evaluation of extraordinary ecological events.

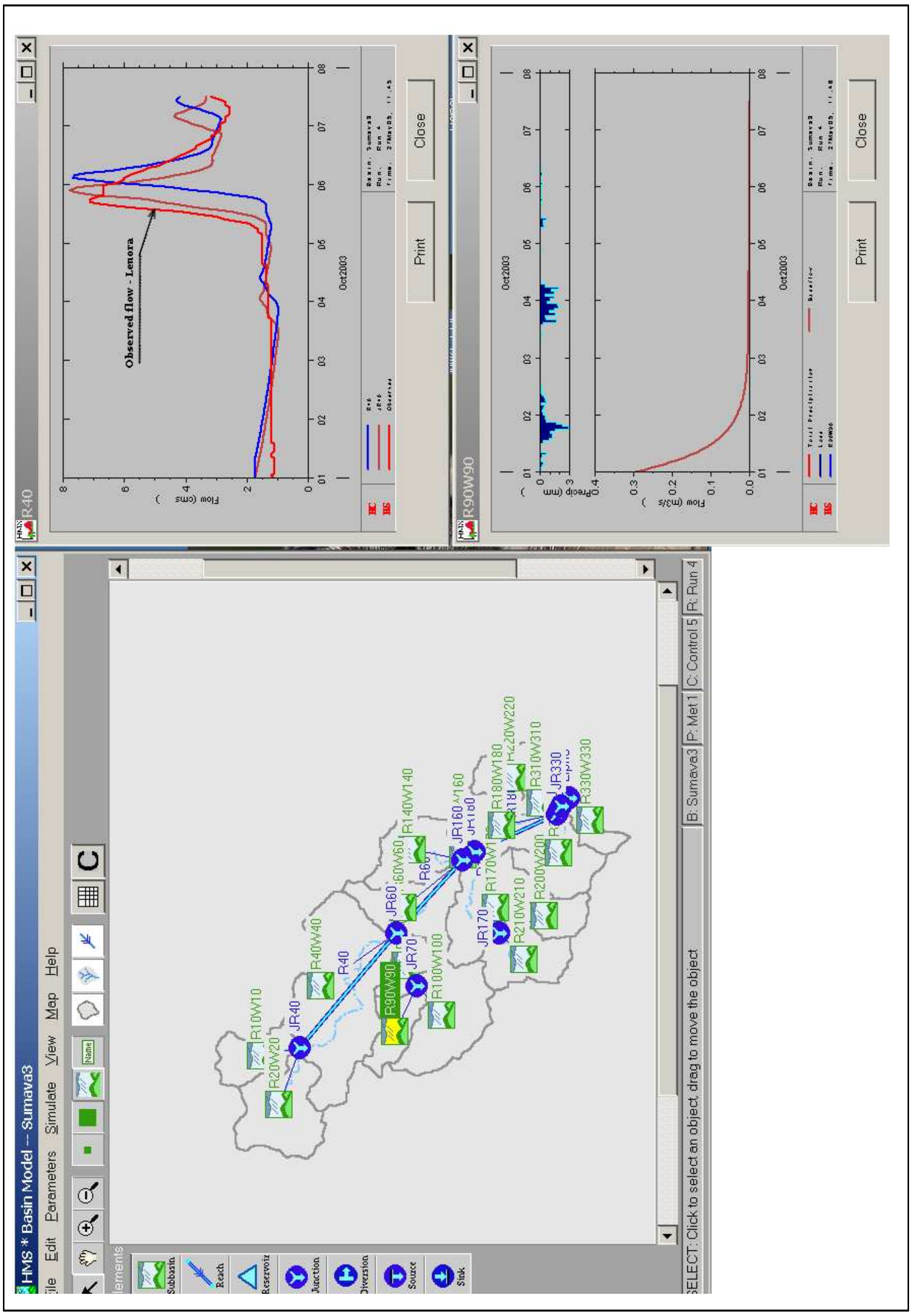

Figure 13. Upper Vltava catchment model scheme and output hydrographs

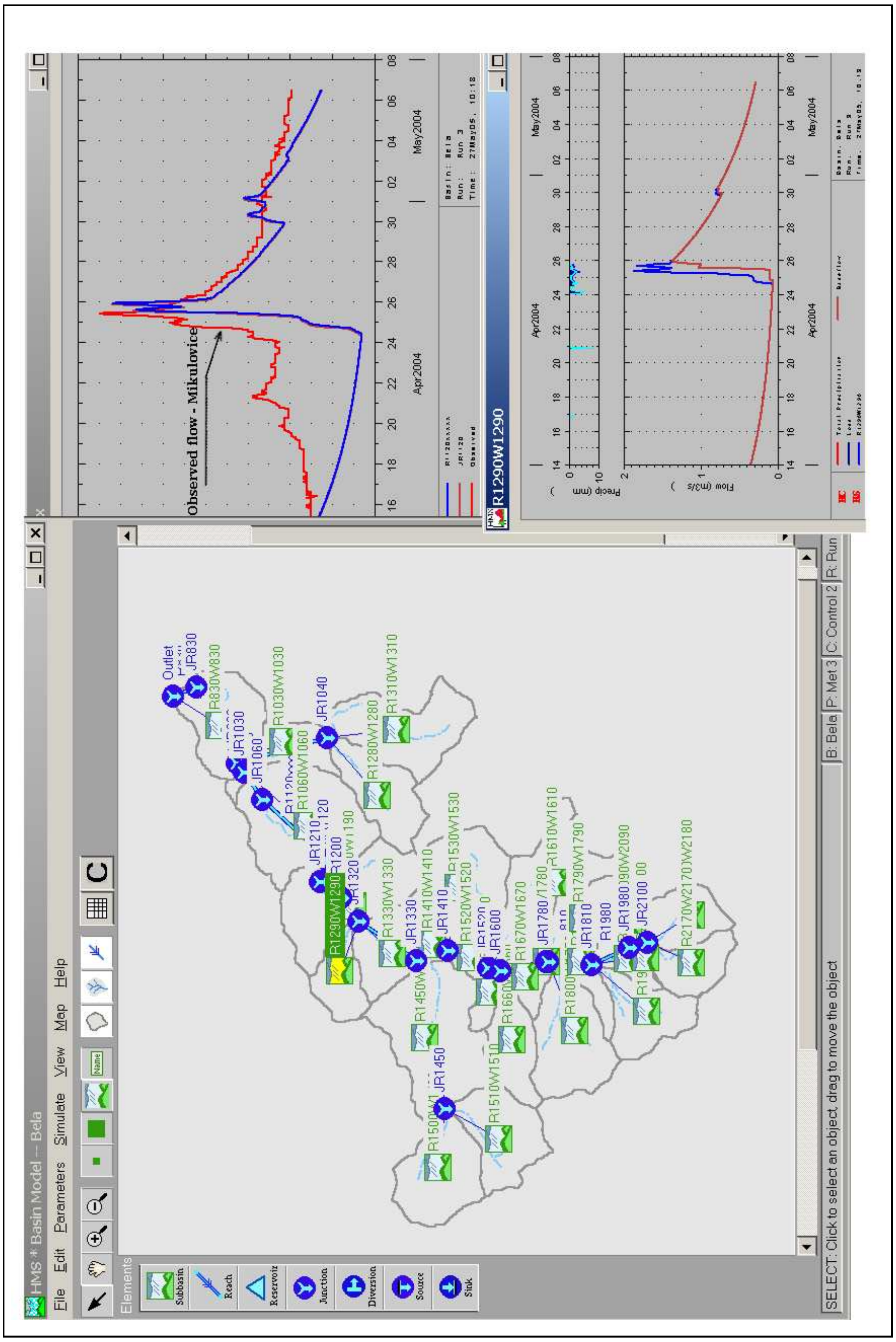

Figure 14. Bělá catchment model scheme and output hydrographs

The decision procedures of operational character can be designed for particular kinds of events with ProDec application, and then run according to current data, whenever deemed necessary.

The strategic decision making will be supported by standalone decision applications (mDSS, Mediator, BarTend, ArgWar) addressing the selected issues of decision making, particularly group decision making. Main tasks refer to ranking and evaluation of certain alternatives of activities in managed area and taking decision as to which variant is more appropriate from the point of view of comprehensive evaluation and possible impacts.

TDSS is currently implemented for Bela/Biała Głuchołaska catchment (Jeseniky mountains) for both Czech and Polish sides, for the National Park of Sumava, for the Pasvik catchment (the border region of Finland, Norway and Russia), for Guadiana catchment (Spain – Portugal) and Mesta/Nestos river (Bulgaria – Greece).

TDSS is still under development, but the pilot implementations are in or close to the operating status.

The address of the prototype is: http://transcat.vsb.cz. Login: guest; password: guest.

6. Conclusion

Web mapping and web services are of great importance for the up-to-date geographical information systems. Movement from standalone to a client-server and then to distributed systems influences also the architecture of geographical information systems. Improvement of spatial data availability and enhancement of their utilisation is one of the goals of the INSPIRE programme (Dufourmont, Annoni and Groof, 2004) and it is also one of the main aspects of Spatial Infrastructure development on various levels – from regional, through country level to European and Global SDI.

The system called TDSS was developed to address specific transboundary conditions for integrated water management as well as common requests on full integration of numerical modelling tools. The architecture of TDSS is open and fully distributed with utilisation of web services for various requests. The system provides, e.g., multilingual environment, full control of data/services access, data warehouse features and dynamically generated client application. Connections to selected modelling systems were developed, especially for modelling of water balance, groundwater flow and surface water flow (HEC-HMS, ModFlow, GRASS GIS modules). The interfaces with other modelling systems (SWAT, ECOSWIM) are under development as well as interfaces for communication with DSS tools like mDSS, Mediator, BarTend etc.

Application of such systems should facilitate the process of Water Framework Directive implementation.

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