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SUSTAINABLE MANAGEMENT OF WATER RESOURCES BASED ON WEB SERVICES AND DISTRIBUTED DATA WAREHOUSES

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Abstract. Sustainable management of water resources is multidimensional and complex process often requires the incorporation of efforts of many impacts and responsibilities of concerning institutions. This research work is devoted for developing of web service based Water Resource Management Information System (WRMIS). The WRMIS has been developed in accordance with the European Union Water Framework Directive and EIONET ReportNet infrastructure requirements to environmental water sector reporting by EU member states. It is realised as a web portal where users can receive information on environmental water sector, combining data from the participating data warehouses and giving an opportunity to extract useful information by the available functions and tools. The WRMIS portal allows the access to information of data warehouses on the surface water quality in rivers and lakes, ground water, and point sources (emissions). A detailed description of the main components of the Water Resource Management Information System is given, the advantages of Web Service-based solution are presented, and the direction of a further WRMIS development in the future is shown.
Keywords: environmental information system, water resource management, sustainable water recourse usage.

1. Introduction

The proper selection of information technologies and up-to-date methods of their control as well as the skills of their mastering allow us to realise the sustainable development problems of organizations more efficiently and to organise the interstate of inter-departmental and interregional cooperation in a new way for water management.

The water management and water quality treatment is one of important problems related with environment and implies many requirements for sustainable management (Rajasekaram,

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Nandatal 2005; Richter *et al.* 2003; Dzemydienė 2001). Water has relation with all cycles of biological life. This research is devoted for the multi-component, web service based approach allowing us to create the interdependent structure of information for recognition of situation for water treatment and evaluation. The Water Resource Management Information System (WRMIS) is developed under the project "Transposition of the EU Water Framework Directive in Lithuania" (DANCEE... 2003; Jacobsen, Maskeliūnas 2003). The EU Water Framework Directive (WFD) (Directive... 2000) and the future European environmental data reports repository ReportNet (Saarenmaa 2002) imply.

The current situation recognised on data management and reporting in the water sector resulted in the following findings. The water types have strong division between groundwater, marine water and fresh (surface) water (Rajasekaram, Nandalal 2005; Mysiak *et al.* 2005). A lot of data are available at many different locations, in different types of databases, with a high degree of dedication and specialisation (Karnegy, Filion 2005; Richter *et al.* 2003; Shen 2003; Zavadskas, Ustinovichus 2003)). The amount of data to be stored and analysed will dramatically increase in near future. This caries out some difficulties to share data: no strong tradition for coordination and sharing of data and knowledge.

Reuse of the existing databases is preferable, but the future administration of water bodies and reporting is foreseen to be complex. It will be necessary to combine information from different institutions and sectors. It is required to encode information, based on geographical borders and locations.

Most of the existing environmental information systems have evolved during a long period of the time (Bolloju *et al.* 2002; Zavadskas *et al.* 2007; Liebowitz, Megholughe 2003). Also, they stem from different traditions. Therefore most of the systems are found to be both heterogeneous and scattered – without much possibility of using data and information in an integrated manner. In the years to come it will be a necessity to combine data from many sources to better understand the environmental processes and to be able to make the required reporting. It is possible to overcome these barriers by creating an environmental portal.

The aim of this research is the development of the framework for integration of main components of water management portal work. Also it has been cleared up that the main general challenges to be met in developing such an environmental portal are as follows: ownership of data; telecommunication/digital infrastructure (allowing sufficient internet throughput); maintenance and development (ie involvement of more institutions, regional departments of the Ministry of environment; integration with external data warehouses and web services – for reporting the EU etc): institutional set-up, manpower; openness and a proper public participation.

2. Principles and requirements of developing the water resource management system

Decision-making aimed at the evaluation of the water management processes deals with:

- Complexity of structures of processes;
- Multiple subsystems with complex mechanism interacting as internal or external parts;
- Time and space/geographical dependencies;
- Great volume of data acquired from the processes;
- Multi–criteria decision–making;

- Causal, temporal relationships and interaction of processes;
- Complexity of legal information.

The Water Resource Management Information System (WRMIS) developed corresponding to following principles:

- The techniques and architecture selected should be in compliance with the development trends (ie with the guidelines and requirements identified by the European Environmental Agency (EEA) on future architecture of European environmental reporting (Saarenmaa 2002);
- Users should have access to data by means of the Internet; establishing a WRMIS portal with proper links to the participating data warehouses;
- The information generated by the system always be based on the best data available;
- The various types of data providers to the system require that some special software should be available for them. It can be achieved by implementing a Client/Server system based on services at the participating data warehouses;
- The databases and allocated tools have to be secured by restricted access.

The architecture of the WRMIS is presented in Fig. 1.

A distributed database system, based on data warehouses (DW) and web services, was chosen because it improves both the quality of data and the value of the reports. It allows us to eliminate some boring and time consuming work associated with collection of data from different sources and bringing it on a format so that it could be used in the common context.

The main components of the WRMIS include:

- A web portal that combines data sources and provides the users with information and tools for interpretation;
- A surface fresh water data warehouse (DW1) and a point source data warehouse (DW2), both hosted in Environmental Protection Agency (EPA). This system works on Windows platform, developed with Delphi 6 (and later upgraded to Delphi 7);
- A ground water data warehouse (DW3), hosted in Geological Survey of Lithuania (GS), on the Linux platform, developed with Java;
- Online map tools (ie two Web map servers), and a meta database on maps;
- A client application that can be used for maintaining the surface water database on a decentralised level.

Though the two data warehouses are placed at the same server in EPD, it is important to stress that the system can be easily reconfigured by moving the participating DWs to other servers (locations), or to gather all DWs in one place.

The system has been based on the existing databases, and the XML technology has been used for combining the data warehouses with the WRMIS Web portal. The Web portal is produced by a combination of XML technologies and ASP programming.

The system is scalable in the sense that it has been prepared for extensions in the form of adopting additional data warehouses, for developing and implementating new functionalities, and for using external Web Services.

Digital maps are included in the graphical user interface (GUI) both for presentation and administration purposes. Online map tools are implemented in the WRMIS, where the users can compose their own maps by using of the available digital layers as well as, on request, get information on specific map objects.

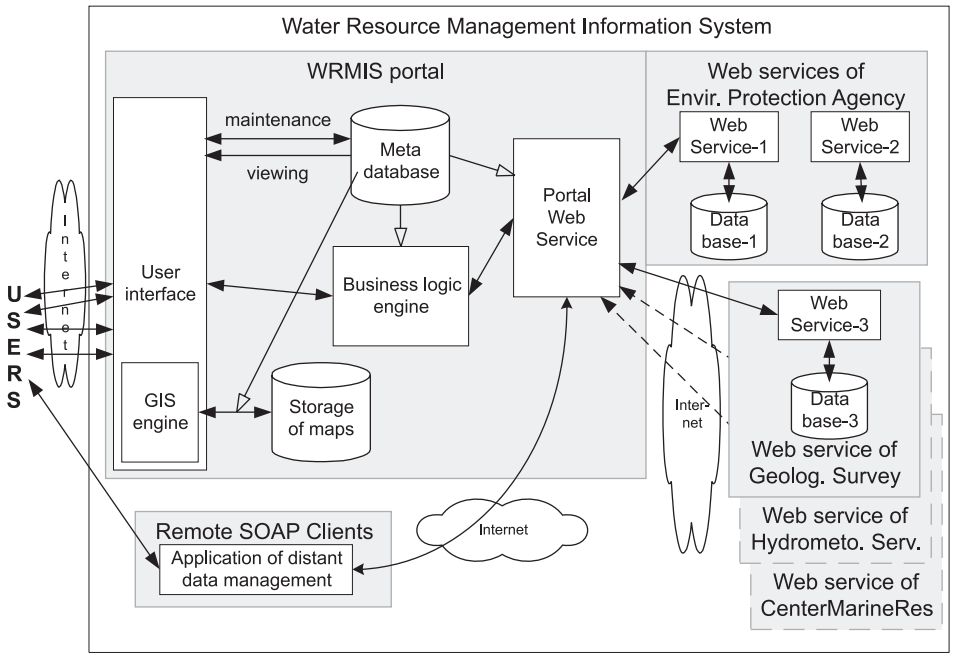


Fig. 1. Architecture of the water resource management information system (WRMIS)

The portal includes services where the users can have useful information related to the WFD and the WRMIS, including links, documents, and news.

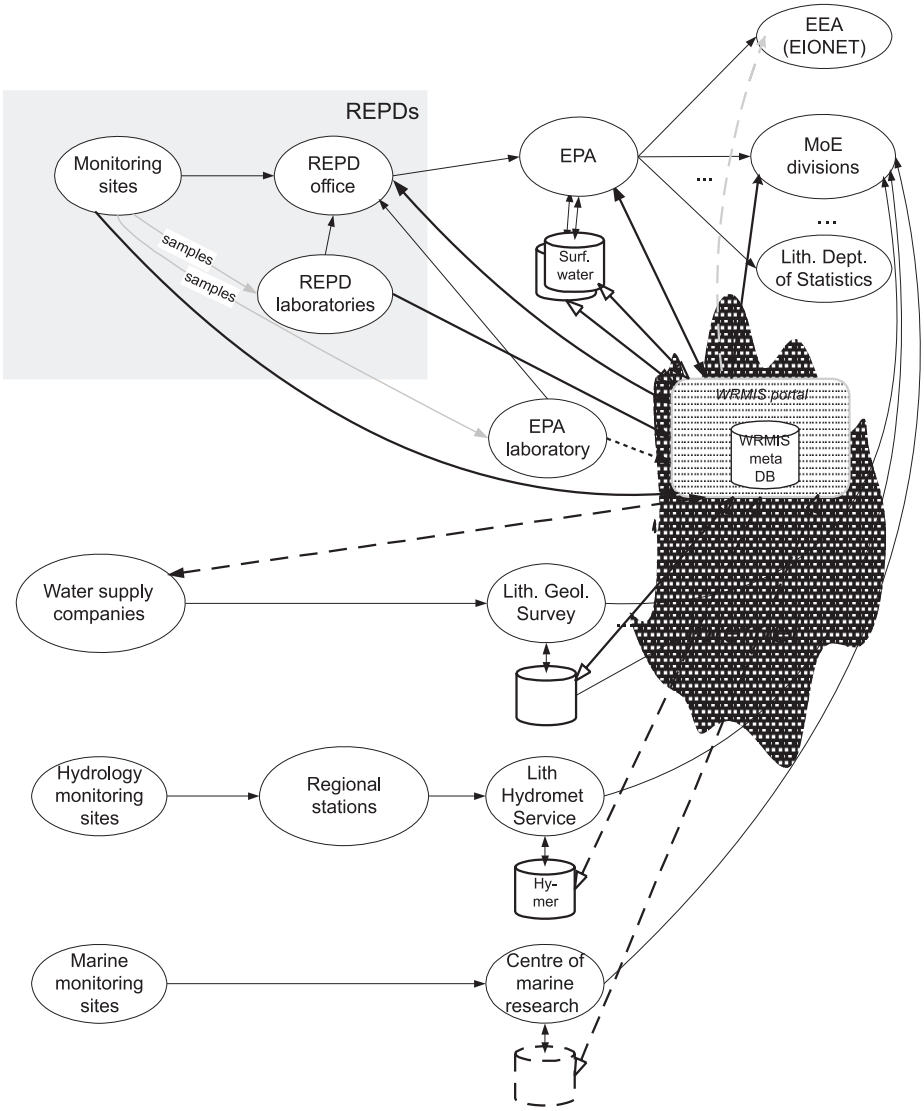
A logic procedure has been established on the WRMIS portal to secure that only registered users can have access to the available information. The WRMIS system administrator has special rights to the system, that give access to maintain the system by updating the news, links, documents, meta database, and the system administrator is responsible for granting rights to the users of the system.

On the other hand, talking in terms of Service-Oriented Architecture (Brown *et al.* 2002), the portal Web Service is a service broker: it passes on service requests to service providers (Fig. 2). The list of portal Web Service operations is presented.

The UDDI registry of WRMIS Web Services is developed for internal purposes only having in mind that exposing it freely on the Internet increases the security risks (Web Services... 2002).

3. The component-based structure of data warehouses for surface water evaluation

A data warehouse has been established based on data from the "Water monitoring in rivers and lakes (VANMON)" database (Jacobsen, Maskeliūnas 2003). Database structures similar to the VANMON database have been created in Oracle, and an interface by use of a database SOAP server has been established on top of the database. The database server provides SOAP-based Web Services with basic functions for using and maintaining the database, eg: selection from, update of, and appending to the WRMIS VANMON database.



Abbreviations:

EEA – European Environmental Agency,

EIONET – European Environment Information and Observation Network,

EPA – Environmental Protection Agency,

MoE – Ministry of Environment,

REPD – Regional Environment Protection Department,

dashed lines indicate what will be available in the near future.

Fig. 2. Environmental Water sector data flows enhanced by the WRMIS

A deep representation of knowledge provided by the semantic model allows an explicit representation of domain specificity (Dzemydienė 2000). This is a structural conceptual scheme of information system. The structure of concepts ties the characteristics of the concept together. It is based on the relationship of intentional containment. The representation of surface water topology is shown in Fig. 3.

Consequently, information systems have been developed, leading to recognition of a field of activity called environment protection analysis, which has been described as the identification of and the provision of insight into the relationship between data and other potentially relevant data with a view to control and management practice.

By connecting to the WRMIS portal and selecting a Surface Water item in the menu, the user is able to retrieve data from a specific river monitoring station. The possibilities to select a site and get all the analysis results stored in warehouses are introduced.

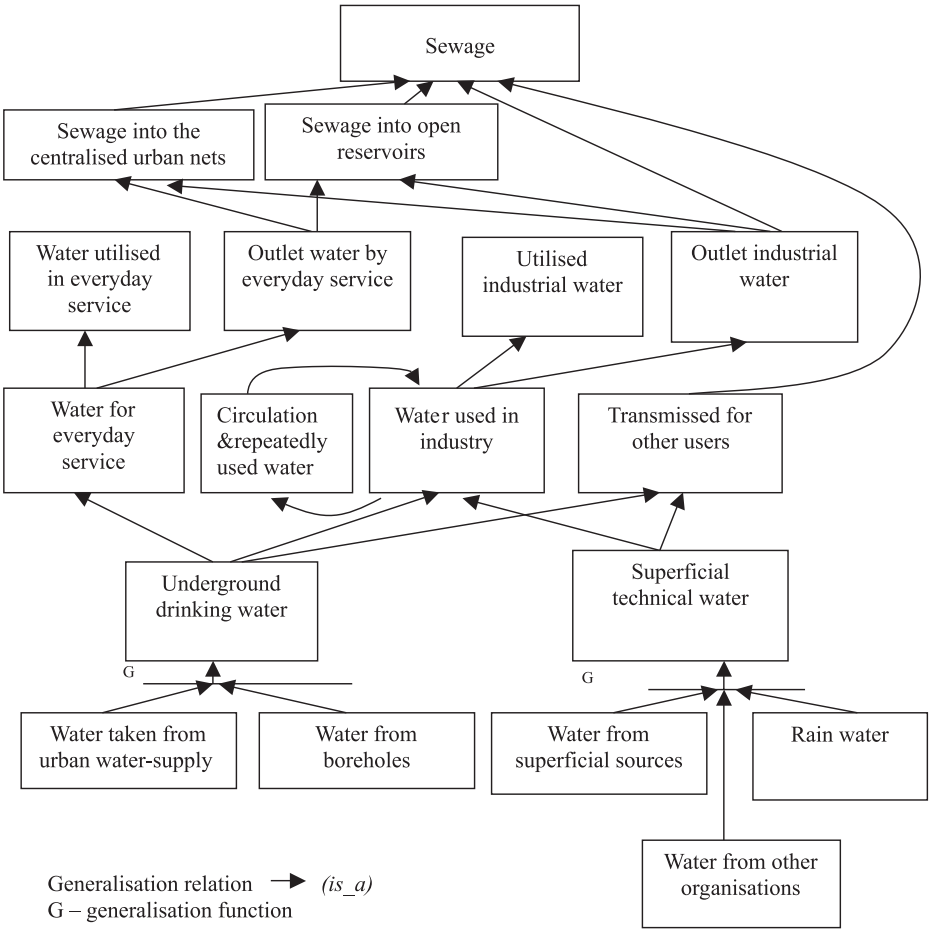


Fig. 3. An example of semantic representation of water distribution in a contamination object

The MapServer assuming that the site is selected in two steps: first, selecting a region, and afterwards selecting a particular site in the region.

When the function is activated, a map showing all the 8 regions of Lithuania (corresponding to 8 Regional Environmental Protection Departments of the Ministry of Environment) appears in the "Presentation area". The map includes a clickable layer of the regions. Similarly, a dropdown box with a list of the regions appears. The dropdown box with regions is the result of a SOAP call to the Surface water data warehouse.

When the user selects a region in the dropdown box, or when the user clicks on a region in the map, a new map and an additional drop down box with sites appears. This map can be zoomed to the selected region. In the map the site and river layers are visible, and the site layer is clickable.

3.1. DW1 client application

For the WRMIS VANMON database a special client application has been developed, that enables the users to update the central WRMIS VANMON database by the Internet. The application makes it possible to the staffs both in the Regional departments and in offices of EPD to work with the common data.

3.2. Point source database (DW2)

A second data warehouse similar to the surface water data warehouse was established on top of the point source database. The system gives access to information on outlets from point sources. The functionality of the Point Source database and the corresponding Web Service is the same as that of the Surface Water database.

3.3. Ground water database (DW3)

The third data warehouse has been found in the Geological Survey of Lithuania (GS). The WRMIS staff in GS has elaborated this data warehouse in the Java environment. Web Services that give access to information stored in the GS Oracle Ground water database have been developed and made available on the Internet.

The technology used:

- Programming language (lgt.* classes), Java JSDK 1.4 API;
- SOAP server (SOAP Servlet), Apache SOAP v2.3.1;
- Servlet Container (Web server), Apache Tomcat 4.04;
- Database (geological dataset), Oracle8 Enterprise Edition Release 8.0.6.2.0;
- Link to Database, Oracle JDBC Thin JDBC Driver;
- Server Operating System, SunOS 5.8 (Solaris 8) Generic_108528-17 sun4u sparc SUNW, UltraAX-i2;
- Server Platform (hardware), Sun Fire V120 Server, 650 MHz UltraSPARC-Iii.

The package and class diagrams of the Ground water Web Service are presented in Figs. 4, 5.

Available Ground water Web Service operations at the GS are:

- WRMIS_waterfields, retrieves the list of waterfields with the main parameters;

- WRMIS_waterhorizons, retrieves the list of water horizons with the main parameters in a given water field;
- WRMIS_WH_extracted_water, retrieves the amount of extracted underground water in m^3 in a given water horizon.

4. Geographical Map tools and server integration

The WRMIS prototype uses a wide by digital maps in the GUI both for presentation and administration purposes. All these maps are stored either in ArcSDE, or in shape files. The system uses maps for selecting data. Two map servers have been developed, making it possible for the users to receive information in a map and to compose their own maps on request. The first solution has been developed by means of the MapServer (hosted in EPA) and shape files. The MapServer is an open source development environment[1] ; MapServer functionality is easy to integrate in Internet-based GIS applications. Another solution has been achieved by use of ArcIMS and ArcSDE (hosted in the Ministry of Environment).

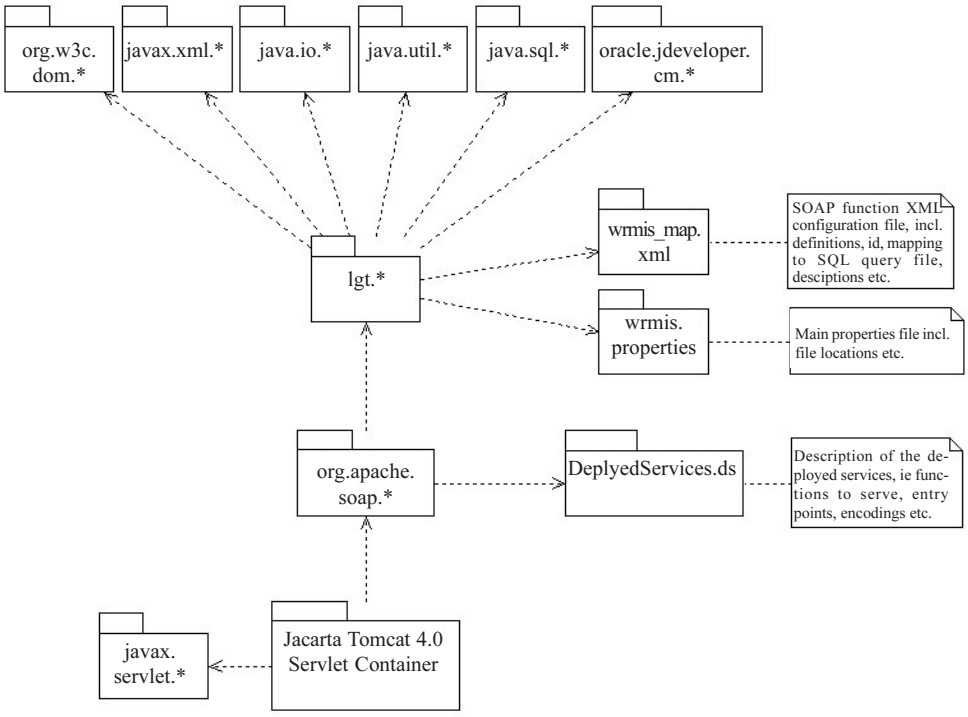


Fig. 4. Inner packages of Ground Water Web Service

[1] http://mapserver.gis.umn.edu/

A meta-database with information on the digital maps used in the Map tools has been formed. It holds information described as mandatory in the ISO 19115 standard[2] .

The sample of screenshots of the WRMIS prototype is given in Fig. 6.

More in details we consider the example of analysis of water resources and the pollution of

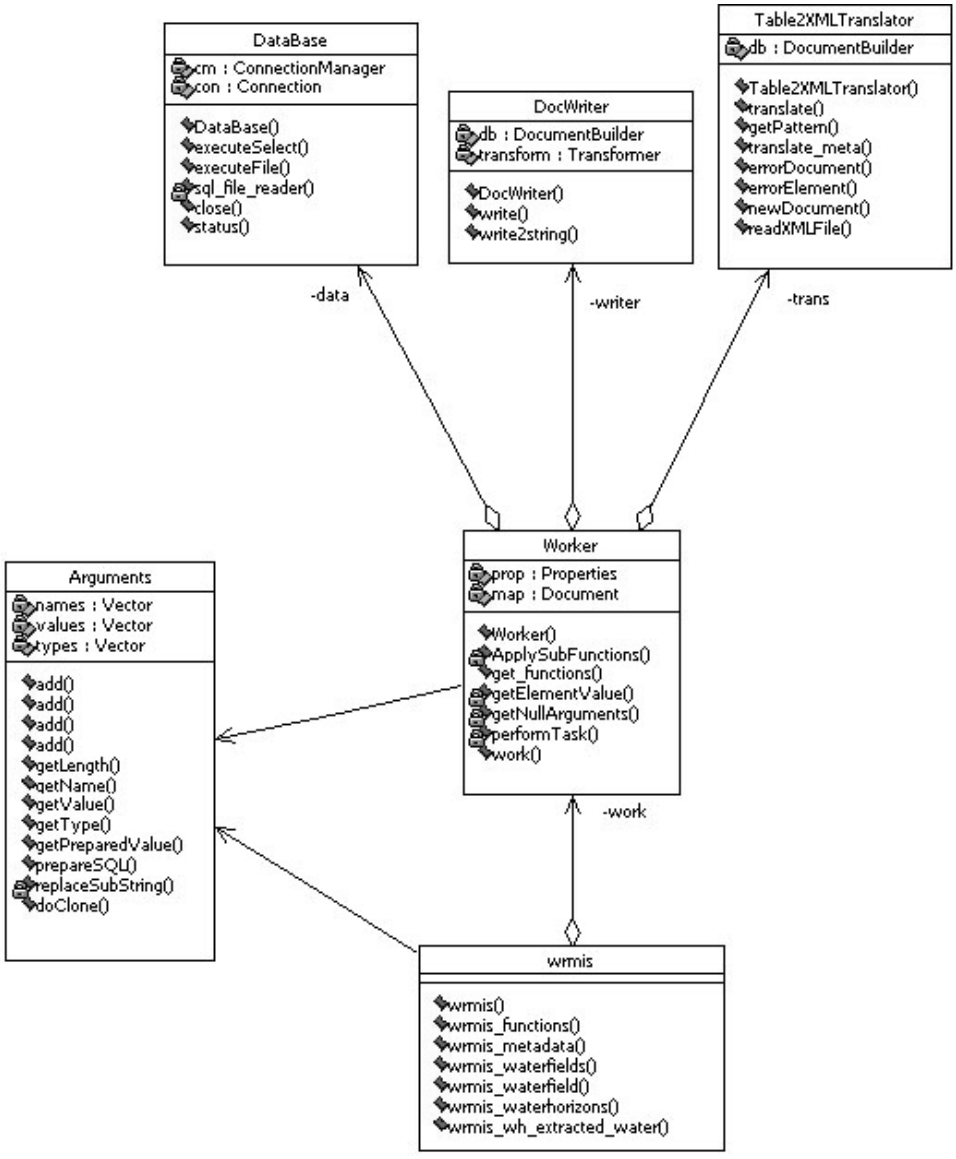


Fig. 5. Class diagram of lgt.* package in Ground Water Web Service

[2] http://www.isotc211.org/scope.htm#19115 , http://www.isotc211.org/publications.htm

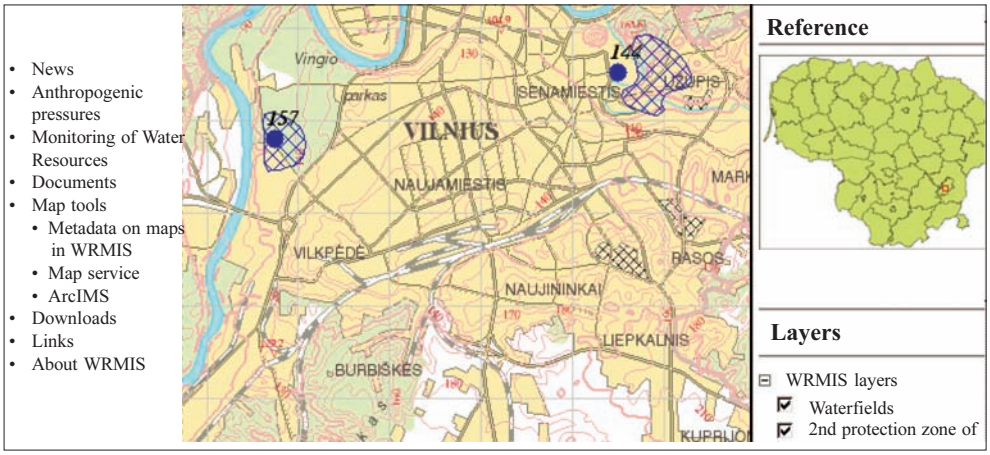


Fig. 6. WRMIS sample screenshot with ground water GIS information

sewage of the enterprise. The pollutants from the production enter the water in some cases. The initial task is always data gathering, resulting in a set of observed findings.

The main steps of diagnosis are suggesting a fault and undesirable performance of functioning enterprise on the basis of problem description. Such task is highly complex, since solving a problem often involves iterative loops, backtracking, shortcuts etc.

The system is ready for data interchange with external Web Services. Also, the system can be easily improved to share information on digital maps with external systems by implementing, using and supporting the OpenGIS in Web Map Server (WMS) and Web Feature Service (WFS). Both Mapserver and ArcIMS can be configured to support WMS.

5. Conclusions

The main contribution of WRMIS is a possibility to establish a Web portal service with information, on request, in a system based on centralised and decentralised data sources.

The future success of the WRMIS portal is closely connected with information the system is able to provide for users. Therefore it is essential that the system be maintained continuously to secure that basic data were up-to-date. Furthermore, it is planned that the system should develop according to increasing needs and demands. A centralised solution with all the servers placed in one centre can be maintained by a highly. The solution can be based on decentralised data warehouses, where different topic centres are responsible for the maintenance of their own data warehouse. This is required by a competent manpower able to have the servers running as well as to administrate and maintain the software and databases at each data warehouse.

The next phase of the development will include improvement of reporting tools as well as integration of two additional data warehouses. It is expected to include into the WRMIS the data warehouse of Marine water (located at the Centre of Marine Research, Klaipėda), and DW of hydro-meteorological data (located at the Lithuanian Hydro-Meteorological Service), to extend the functionality of the WRMIS prototype, and finally to deliver in the middle of

2004. If the WRMIS prototype proves to be successful, the same solutions will be applied in other Environmental sectors, too.

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DARNUS VANDENS IŠTEKLIŲ VALDYMAS TINKLO PASLAUGŲ IR IŠSKIRSTYTŲ DUOMENŲ SAUGYKLŲ PAGRINDU

D. Dzemydienė, S. Maskeliūnas, K. Jacobsen

S a n t r a u k a

Vandens išteklių valdymas reikalauja daugiakriterinių, kompleksinių šio sudėtingo proceso darnaus valdymo uždavinių sprendimo, pasitelkiant daugelio institucijų darbo pastangas ir atsakomybę. Mokslinio tiriamojo darbo tikslas – sukurti tinklo paslaugomis grindžiamą vandens išteklių valdymo infrastruktūrą, kuria remiantis būtų integruota bendra vandens išteklių valdymo informacinė sistema. Straipsnyje aprašoma vandens išteklių valdymo sistema, kuriama pagal Europos Sąjungos Vandens išteklių valdymo direktyvos ir *EIONET ReportNet* tinklo valdymo infrastruktūros reikalavimus, vykdant Europos Sąjungos šalių narių aplinkos apsaugos įsipareigojimus vandens sektoriuje. Sistema yra realizuojama kaip interneto portalas, integruojantis dalyvaujančių šalių duomenų saugyklas ir dinamiškai valdomus atitinkamus įrankius ir funkcijas. Šios tinklo paslaugos leidžia vartotojams gauti informaciją apie aplinkos vandens išteklių valdymą, vandens sudėtį, išgaunamus ir išleidžiamus vandens kiekius. Portale realizuojamos paslaugos, leidžiančios gauti informaciją apie paviršinio vandens kokybę upėse ir ežeruose, giluminio vandens ir atskirų taškų išteklius, jų emisijas. Straipsnyje pateikiamas detalus pagrindinių vandens išteklių valdymo sistemos komponentų aprašas ir numatomos šios sistemos plėtros perspektyvos.

Reikšminiai žodžiai: aplinkos apsaugos informacinė sistema, vandens išteklių valdymas, darnus vandens išteklių naudojimas, duomenų saugyklos, tinklo paslaugos.

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Research interests: Web services, information management, enterprise architecture.