Project: Sustainable Hydro Assessments and Groundwater Recharge Projects
Project acronym: SHARP

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APPENDIX: Long version of good practices to be adapted report

GPA 9	Use of DSS for strategies of groundwater resources management

Involved Project Partners:
Institute of Meteorology and Water Management (IMGW)
Regional Agency for Rural Development of Friuli Venezia Giulia (ERSA)

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1. Concise description of the adapted good practice

Improvement of techniques that are used to sustainable management and protection of groundwater resources is one of the main objectives of the SHARP project. Currently, one of the most advanced techniques for water resource management are decision support systems. Earlier, the interest of specialists was directed for the exploration and documentation of groundwater resources, but now attitude is changing and the main emphasis is turned to the resources management to protect the quality and quantity. For this purpose, the water management systems are created, that include a wide variety of issues and processes, involving many techniques used in hydrogeology.

The primary objective of the informatics system, which is a decision support system, is to provide information that is necessary to decide on a specific management level. DSS allows the user, by changing the parameters, to study the impact of decisions on the conditions of the modeled object (system) to choose the most optimal action scenario. The main aim of works done within the SHARP project was the good practice transfer by providing a common model of creation of DSS and guideline which could be adopted in PP4 and other partners institutions and regions.

IMGW-PIB deals with many aspects of water resources management. At the Institute, there are many studies, expert opinions and reports on water management issues in relation to surface water and groundwater.

Methodology has also been developed to create decision support systems for water resources management, delivered in the form of a manual, entitled "Decision support systems in water management" (Polish title: “Systemy wspomagania decyzji w gospodarce wodnej”, [Gromiec et all, 2006]. In one part of the manual the problems of DSS concerned the groundwater resources management are discussed.

Both partners have experience in the field of decision support systems.

The example of DSS carried out in the IMGW-PIB concerned a closed and reclaimed municipal landfill, where a network of measurement-observational points were established. Decision Support System is the system designed for use in the protection of groundwater and soil at closed (rehabilitated) municipal landfill.

System allows a combined use of visualization tools with database files is a useful tool for project management of environmental protection of groundwater.

The objective of the study is to develop and implement the decision support system so as to support the decision-making process concerning protection of groundwater and soil.

DSS is based on a combination of:

- CADD (Computer Aided Design and Drafting) software – to create 3D drawings and modeling of surfaces and solids.
- 3D authors models of flow and pollution transport in groundwater
- Spatial information system – GIS

The developed system enables to perform an analysis of: hydrological flow, migration of contamination and environmental risks associated with the source of pollution [Gromiec et all, 2006].

Gathering and analyzing data (in particular information concerning the type and extent of contamination and forecasting spread of these pollutants) provides the basis for creation of the concept to take protective activities.

Presented by Italian Partner a simple DSS is a web-based tool aimed to disseminate codes of good agriculture practices to the farmers, with special emphasis on the reduction of nitrates of agricultural sources as well as on sustainable farming.

The web tool has been projected to comprise three different sections:

a) farm self evaluation section which enables the users (farmers, technicians, advisory services) to evaluate the sustainability degree of the farm under test, on the basis of farming and breeding techniques applied with respect to a given set of sustainability reference standards;
b) estimation of N and P balances at the barn level, vessel capacity for storing the animal effluents, simulation of the animal effluents utilization and of the fertilization plan in the farm used agricultural area;
c) evaluation of farm economic sustainability and profitability.

The developed DSS becomes a useful tool in the management of groundwater resources thanks to the collaboration between visualization tools and database file.

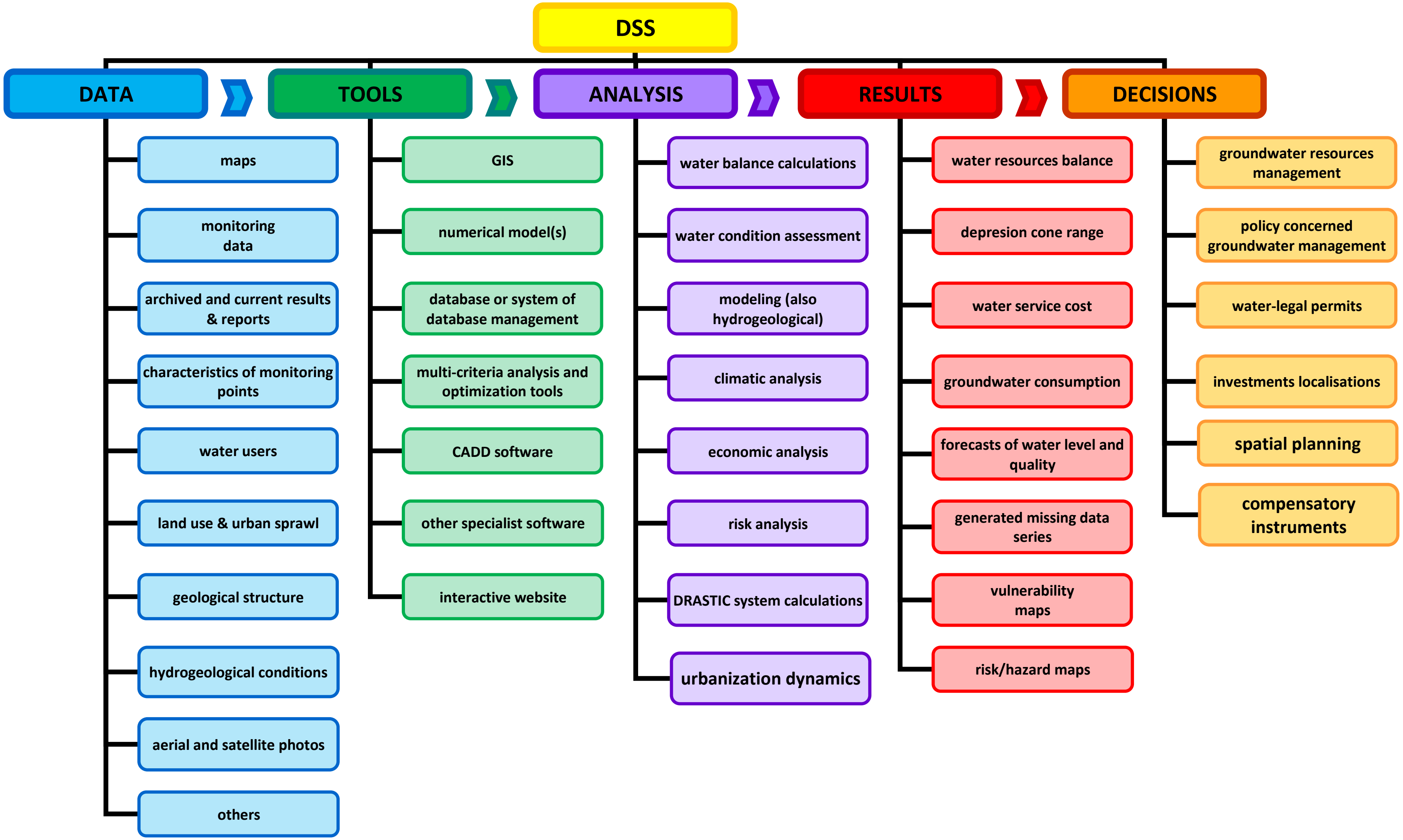

Fig. 1: The scheme of jointly elaborated decision support system model.

The system allows for using various combinations of tabular and graphic data and conducting spatial analysis and simulations for different scenarios.

Providing a common model of creation of DSS (Fig. 1) and guideline include the steps of the DSS creating, which could be adopted in PP4 and other partners institutions and regions.

The use of DSS enables more effective management of groundwater resources, which will allow a faster achievement of environmental objectives and possible benefits in economic terms.

Using the tool that is Decision Support System by facilitating decision-making process in the management of groundwater resources allows for better protection of groundwater, both in terms of quantity and quality.

2. Description of adaption process

To potentially successful transfer of the selected approach, we have to follow the given below guideline:

The elaboration procedure to create and implement a decision support system for groundwater management shall include the following stages:

a) data collection process;
b) selection of tools that will be useful to achieve the objective;
c) analysis;
d) evaluation of results;
e) decision concerning the management of groundwater resources (Fig. 2).

Fig. 2: The stages of creating a decision support system.

Input data for decision support system

The data necessary for the realization of the topic should be grouped by their type. For the purposes of the implementation issues are necessary maps, in this case can be useful: topographic maps, soil and agricultural map, hydrographic map, geological maps, geoenvironmental maps, orthophotomaps, DTM. There should be collected data for the characteristics of the measuring points located in the areas of research, including the location of points and a description and observations or measurements range: water gauge stations, groundwater monitoring points (wells and piezometers), precipitation and climate stations (located in the area of research and its nearest surroundings, enabling the description of climatic conditions in the area of research). In addition to the characteristic of measurement points, the gathering of measurement data from these points and evaluation of the measurement points quantity and measurement data for selection of analysis, which can be used. It is also necessary to collect data about groundwater users (water abstractions), and in case of the decision support system for aspects of groundwater quality should be considered a source of pollution, both point and non-point. In order to know the exact geological and hydrogeological structure of the area, the profiles and data of the geological drilling and geological sections should be also collected. To facilitate the establishment of the system and the subsequent interpretation of the results obtained after completion of the analysis, it is necessary to collect all the archival studies, reports and results.

Tools and analysis useful in decision making process

The tools that may be useful in achieving tasks can be:

a) spatial information programs (GIS);
b) numerical models;
c) database programs – e.g. MS Access;
d) tools to performance multicriteria analysis and optimization;
e) other specialist software, performed for DSS or part of it;
f) tools used for visualization of the results other than maps – for example, AutoCAD, Adobe After Effect;
g) Interactive websites that enable to make analyzes;
h) risk analyses and hazard indexes to be incorporated in the DSS analyses tool in order to asses potential pollution of the groundwater resources. In this context the following issues should be taken into consideration:
   - source of possible pollutants to be taken into account (civil, industrial, agriculture);
   - the pollutant and rank danger risk;
   - assessment of the index or likelihood of possible danger to the water bodies occurring because of the settlement of industrial or other economic activities in certain areas;
i) vulnerability maps

After the stage of the data and tools selection, the analysis stage could be started.

The basic processes that can support water management include: water balance, the assessment of water conditions, numerical modeling (including modeling of the hydrogeological conditions, the pollution transport and the water balance), climate analysis, economic analysis, system DRASTIC, and risk assessment. The above-mentioned analyzes are examples that can be performed depending on the aim of groundwater management, used tools and performed analysis must be adapted to the purpose of the system, and depending on expected results.

In the case of using a decision support system in the investment (or planning) process, the rational approach should result in decisions at the beginning of the investment process. A necessary stage in the planning process is to identify the initial ("zero"), water conditions, which will provide a comparative level, which is used to solve the current problems and any disputes relating to the impact of the investment (or the plan) on the environment. If there is no possibility of assessing initial water conditions, current state should be defined. In order to analyze the hydrological situation in the basin long measurement time series (accepted standard is the 30-year measurement period) should be prepared. The normal year should be selected , to which all analysis should be referred. It is also necessary to assess whether the monitoring point amount is sufficient. The Water Framework Directive does not specify the quantity of groundwater observation points – number of observation points should allow a reliable assessment of groundwater state, including an assessment of available groundwater resources, as well as their quality.

For most of the analyzes it is necessary to identify of groundwater users, as well as point and diffuse sources of groundwater pollution, and indication of pollutants, or those substances whose concentrations result in recognition of water as not-meeting environmental standards.

To accomplish some of the DSS, the key element will be to create hydrodynamic hydrogeological model. As a part of works on the hydrogeological model, an analysis of maps, cross sections, geological profiles and archival records should be made in order to construct a conceptual model of water circulation and the preparation of inputs to the model. It is essential to conduct schematization of hydrogeological conditions involving the generalization of the real hydrogeological system. In order to generalize, partial aggregation of lithological divisions within the aquifers can be performed as well as interpolation and extrapolation of data concerning capacity and filtration parameters of the aquifers in the area. The number of modeled layers should be determined on the basis of available archival materials and there should be prepared spatial maps of the structural features that will be introduced into the model as the boundaries of individual layers of the model. Data referring to filtration coefficient of all model layers are also necessary. The next step is to develop and implement into the model input data of measurements of water level and precipitation totals, and for qualitative models the pollution sources and pollutant concentrations at the measuring points are needed. Then the calibration of hydrogeological model is performed.

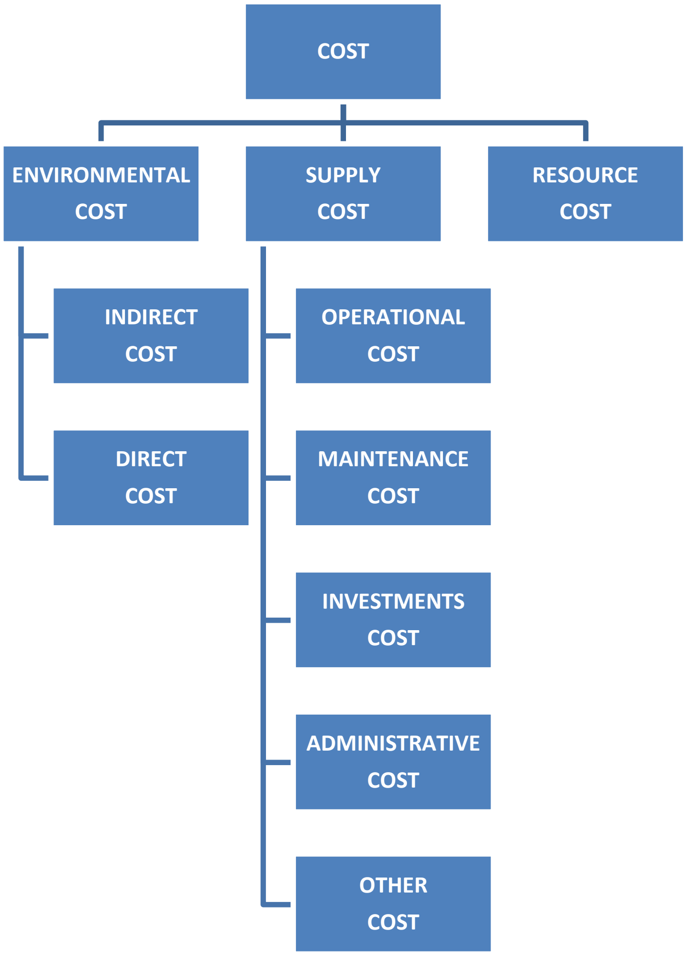

Fig. 3: Components of the costs of water services.

As a result of modeling, depending on the model and its objectives, the value of hydrogeological parameters, water balance, groundwater circulation system, existence and size of the depression cone, pollutant dispersion pattern and substance concentration in each layer and point of modeled system are obtained. Above the use of the hydrogeological model is described, which may be part of the DSS. However, the whole decision support system can be a model, or a set of models, as well as almost any of the performed analyzes can be carried out with numerical modeling methods.

Currently in the field of water protection it is necessary to pay attention to the economic efficiency of planned projects, so it is necessary to perform economic analyzes, according to recommendation of the Water Framework Directive there should be guarantee repayment of costs of water services [WFD, Article 9].

For this purpose is possible to use decision-making methods based on common mathematical programming methods. When creating decision-making models it is possible to make use of methods of assessing the effectiveness of the investment:

- Costs-Benefits Analysis;
- Cost-Effective Analysis, [Mikłaszewski, 1993].
- To cover the total costs of water services should be considered (Fig. 3), [Deliverable, 2004]:
- costs of water supply, represented by the cost of setting up the investment, exploitation and maintenance, labor, administrative costs and other direct costs;
- costs of resources, namely the loss of profits caused by limitations in the availability of water resources;
- environmental costs, i.e. costs of environmental damage caused by water users.

Beside the Cost-Benefits Analysis and the Cost-Effective Analysis other interesting issues can be considered when it comes to set up the what if and scenarios tools for the DSS simulations, such as urbanization and mitigation measures, degree of water abstraction, possible intervention to restore the primitive conditions of groundwater bodies to counteract pollution events.

Useful analysis, that can be used in the DSS and are fulfilling the requirements of the WFD and the Nitrates Directive, are the analysis used to create maps of groundwater vulnerability to pollution. There are many methods to measure groundwater vulnerability to pollution, which can be divided into those which take as a basis for evaluation for example: time of contaminant migration from the surface to the aquifer, insulating layer thickness or value of hydrogeochemical indicators, as well as those that are based on a rank system, assigning the specific weight to the designated crucial parameters [Duda, Witczak, Żurek, 2011, ANPA 2001].

One of the most popular methods of determining the areas vulnerable to pollution is the ranked DRASTIC analysis (developed by U.S. Environmental Protection Agency), used in many European countries, including SHARP project partners countries (PP2, PP4, PP6). It is a simple evaluation system of the potential risk of groundwater quality from the objects and activities harmful to the environment. DRASTIC is based on an analysis of indicators: hydrogeological, soil, geological and climatic, and is therefore useful to assess the environmental impact of planned investments and the existing objects as well as is suitable to create maps of groundwater vulnerability to contamination. The main purpose of these maps is to assess groundwater vulnerability to pollution, conditioned only by natural factors: geological structure and hydrogeological conditions [Duda, Witczak, Żurek, 2011]. These maps are used as an element of decision support in the field of planning the groundwater quality monitoring networks location, land use planning, as well as decision making in the field of MGB (major groundwater basin) protection action [Kajewski 2008].

Results and decisions

At the end of the analysis process, it is crucial that the DSS should be able to show the decision makers or the spatial planners and therefore simulate the following scenarios:

- how the different withdrawals from groundwater affect the size of the groundwater bodies;
- how and to which extent the urbanization can negatively affect the supply of water to the groundwater and eventually what are the most suitable mitigation and compensatory measures to be put into action or considered;
- possible plans or measures of intervention to recover the original situation when a pollution event occurs.

This kind of results should be as much as possible easily understandable for decision makers and spatial planners, so that they can choose useful policies, adopt effective mitigation measures and management strategies.

Identified and described above guidelines have been starting to create a common framework (basis) for decision support system, which was the main objective of the jointly elaborated adaptation.

Partner 4 added to the jointly developed guidelines and scheme aspects, in which PP6 is not involved, namely risk analyses and hazard indexes in order to asses potential pollution of the groundwater resources.

PP4 also paid an attention for interesting issues which can be considered when it comes to set up the what if and scenarios tools for the DSS simulations, such as vulnerability maps, urbanization and mitigation measures, degree of water abstraction, possible intervention to restore the primitive conditions of groundwater bodies to counteract pollution events.

Obstacles in the transfer of the described methodology may be:

- a significant technological advancement of decision support systems, which require the use of very sophisticated tools, which involves the participation of highly qualified staff;
- high costs of applying the DSS - the use of complicated tools require to buy expensive commercial software or order of execution software, specifically tailored to the requirements of developed DSS;
- different know-how;
- too high expectations of end users, to the results obtained by the use of DSS;
- lack of or difficulty in obtaining data, maps and other input elements to DSS;
- significant labor consumption applied solutions.

The easiest way is to simplify the implemented model, which both reduce the costs, labor consumption, and the number of input data that will be needed for the planned solution implementation.

A thorough market survey should be carried out with respect to price and possibilities of software available in the market. And then choose a cheaper solution, with the same technological capabilities or use free software such as the use of GRASS GIS instead of commercial software, such as ArcGIS and MapInfo.

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