DEVELOPMENT AND UTILIZATION OF VULNERABILITY MAPS FOR THE MONITORING AND MANAGEMENT OF GROUNDWATER RESOURCES IN THE ARCHIMED AREAS: PRESENTATION OF AN INTERREG III B PROJECT

Voudouris, K.[1*], Manos, B.[1], Adamidou, K.[2], Patrikaki, O.[2], Trikilidou, E.[2], Goutzios, B.[3], Arabatzis, S.[4] Papadopoulou, O[4]., Polemio, M.[5]

[1]Aristotle University, Thessaloniki, **Greece**, [2]Environmental Centre of Kozani (KEPE), [3]Region of Western **Macedonia**, [4]Tero Ltd, [5]IRPI, Bari, **Italy**

ABSTRACT

WATER-MAP is a 2-year project funded under the Community Initiative INTERREG III B ARCHIMED and implemented by nine partners from six countries (Greece, Italy, Malta, Cyprus, Turkey, and Palestinian Authority). The project looks at the topic of integrated groundwater resources management. The aim is to provide scientifically reliable information to the local authorities in order to develop optimal spatial development strategies. Within the framework of the project, vulnerability maps are generated in order to determine areas where aquifers are in high risk of pollution and thus, support the spatial development planning process. The method used to produce the vulnerability maps is the DRASTIC; the most widely used method. Regional assessment of groundwater vulnerability is a useful tool for groundwater resources management and protection zoning. In addition, a Decision Support System (DSS) with information on land uses, populations etc will also be developed and implemented so as to facilitate and optimize the decision-making process involving the problems of land use, water management and environmental protection. This paper presents the project's objectives, the general characteristics of the Archimed areas and the DRASTIC model in GIS environment including data required and initially encountered problems. Based on preliminary results, it is concluded that, regional assessment of groundwater vulnerability is a useful tool for groundwater resources management and protection zoning.

Keywords: groundwater vulnerability, water management, decision support system, European project

INTRODUCTION

In recent years, there has been an increase in demand for pure water in many countries. Groundwater, as a source of public water supply, presents significant advantages compared to surface water, due to its protection from surface pollutants. The new Directive 2006/118/EC on the protection of groundwater against pollution and deterioration, developed under the Water Framework Directive 2000/60/EC, sets out criteria to assess the chemical status of groundwater bodies. Furthermore, the aforementioned Directives have forced the committing member states to ensure good chemical and ecological status of groundwater (Cost Action, 2003; Gianneli et al., 2007).

Regional assessment of groundwater vulnerability is a useful tool for groundwater resources management and protection. The results provide important information and the vulnerability maps could be used by local authorities and decision makers. These maps are designed to indicate the areas of greatest potential for groundwater contamination on the basis of hydrogeological conditions and human impacts. Some countries use vulnerability maps as a basis for protection zoning (Diputacion de Alicante, 2004).

This paper presents the objectives of a project funded under the Community Initiative INTERREG III B ARCHIMED, the general characteristics of the Archimed areas and the DRASTIC model in GIS environment including data required and initially encountered problems. A Decision Support System with information on land uses, populations etc is also developed and implemented so as to facilitate and optimize the decision-making process relating to the problems of land use/water management/ environmental protection.

WATER-MAP PROJECT

WATER-MAP (www.watermap.eu) is a project designed to support the spatial development planning process. It is funded under the ARCHIMED Programme of the Community Initiative INTERREG III B that specializes in the interventions for improvement of the spatial planning integration of the South-eastern Mediterranean area. It involves 7 EU-partners from Greece, Italy, Cyprus and Malta (Fig. 1), as well as 2 non-EU partners from Turkey and Palestine Authority, including regional authorities, water management authorities, universities, a research center, a regional development agency and a NGO. The project is coordinated by the Region of Western Macedonia in Greece and will have a total duration of 2 years, ending in December 2007.

WATER-MAP will produce GIS-based groundwater vulnerability maps and a best practice guide with practical applications in selected issues that are critical for the participating regions, and, at the same time, can be transferred to a wider geographical context. The project territories will organize Regional Partnerships and set thematic focuses covering the respective key problem areas, mainly from the viewpoint of land use (e.g. agriculture, industrial development, housing development, etc).

The main beneficiaries of WATER-MAP are the policy makers that are involved in spatial development. This group encompasses policy makers in all sectors and geographical levels. Other beneficiaries include the controlling authorities, the citizens of the project territories, the economic actors of the project territories (farmers, industry, services), and the tourists that visit the project territories.

WATER-MAP has the following specific objectives:

- To establish a network of the Archimed areas that face similar risks of groundwater pollution.
- To exchange information on the existing level of knowledge on the state of groundwater resources and their vulnerability in the participating regions, as well as on existing policies and legislation.

- To apply the DRASTIC and SINTACS methods in order to produce detailed maps for assessing groundwater vulnerability.
- To incorporate the produced results in a spatial monitoring system for the identification of environmental risks.
- To assess alternative land-use and spatial development practices in relation to groundwater pollution risks.
- To develop a Decision Support System that will use all information and offer water management guidance.
- To identify similarities and differences in the regional contexts and showcase examples of best practice.
- To jointly develop a best practice handbook reacting to the different interests and expectations of the actors involved.
- To train staff of the participating regions in implementing best practices.
- To disseminate all information and consult with the public through the organization of special events and through the establishment of a public dialogue mechanism.
- To present the network's results to regional policy makers.
- To incorporate groundwater management considerations in regional and spatial development policies.
- To improve and rationalize the utilization of Structural Funds in the regions.
- To consider the question of transferability of regional experiences to a wider level.
- To extent the network to additional local and regional authorities, industry, NGOs, educational and research institutions, etc.

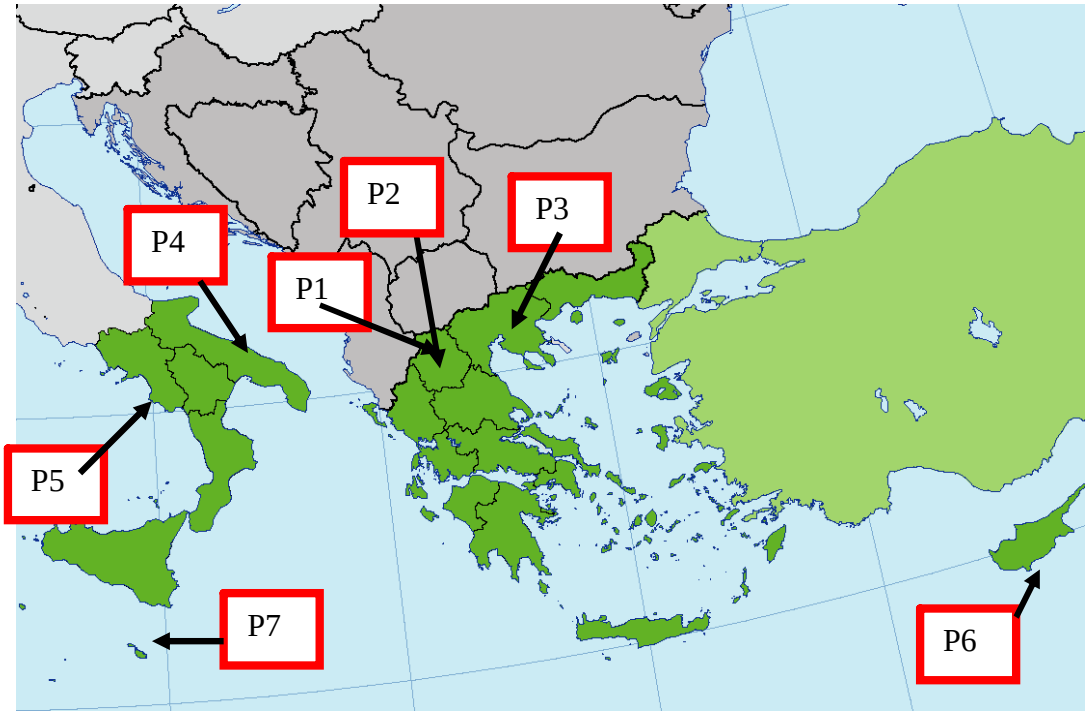

Figure 1. Project leader (P1) Region of Western Macedonia, (P2) Environmental Centre of Kozani, (P3) Aristotle University of Thessaloniki, (P4) CNR-IRPI or Research institute for geo-hydrological protection, (P5) Liri-Garigliano & Volturno Rivers Basin Authority, (P6) Development Agency of Larnaca, (P7) Malta Resources Authority.

APPROACH AND KEY ISSUES

The work plan of the project includes the major activities presented below (Fig. 2):

- management and coordination of the international consortium,
- network development among the partners and the regional stakeholders through the setting up of regional and interregional partnerships,
- application of DRASTIC method to assess vulnerability of groundwater to pollutants, development of vulnerability maps in selected application areas,
- spatial integration of all collected information into the Decision Support System,
- exchange of know-how and experiences through staff exchange in relation to the application of the models and joint workshops to assess the application of the models and compare advantages/disadvantages of applying the methods in different areas,
- dissemination of information.

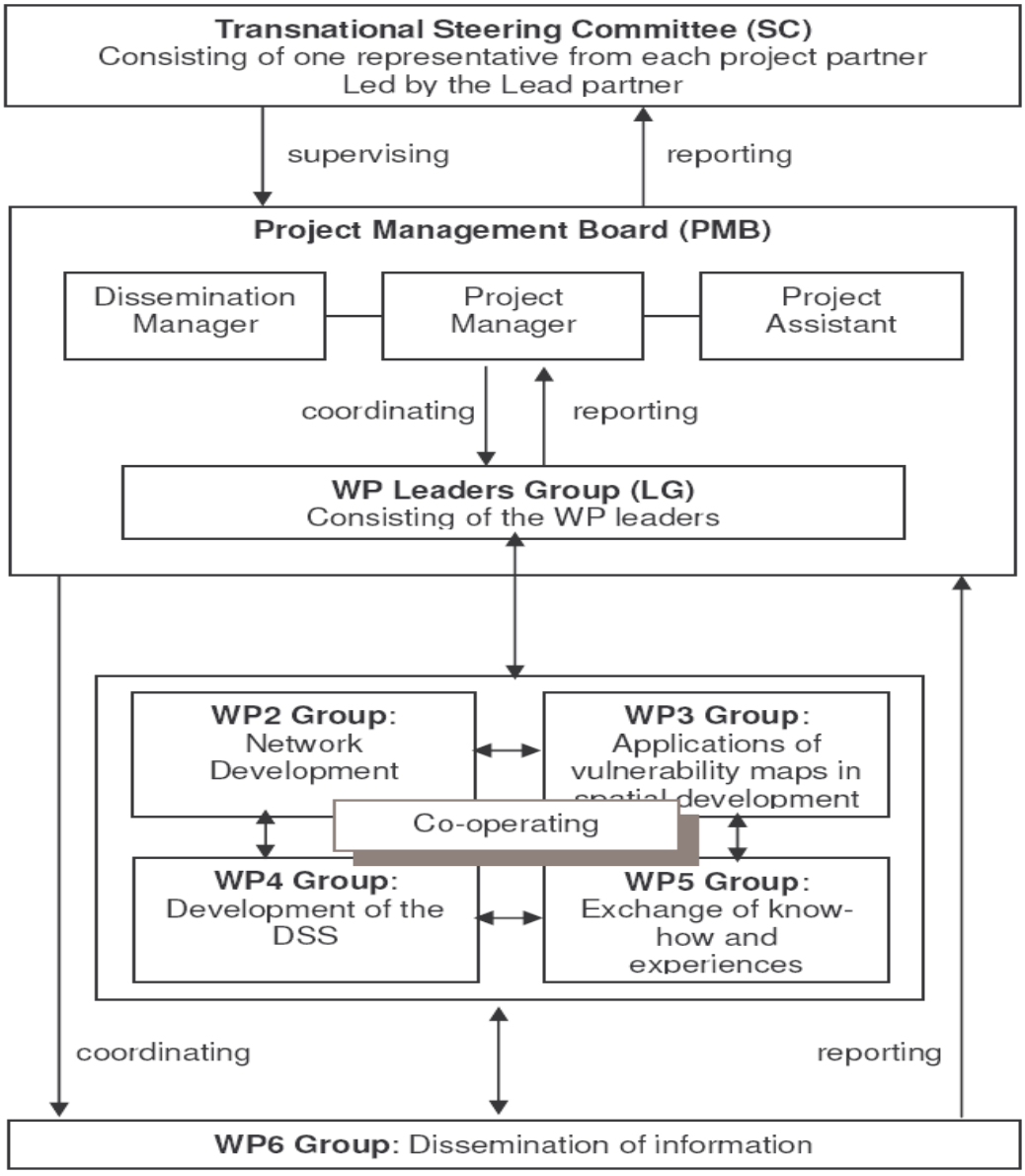

Figure 2. Organization of the WATER-MAP work plan.

GROUNDWATER VULNERABILITY ASSESSMENT

The concept of the groundwater vulnerability is based on the assumption that the physical environment may provide some degree of protection to groundwater against human activities. The DRASTIC method will be applied to evaluate aquifer vulnerability. The acronym DRASTIC corresponds to the initial of the included seven (7) parameters: **D**epth, **R**echarge, **A**quifer media, **S**oil media, **T**opography, **I**mpact of the vadose zone media, hydraulic **C**onductivity of the aquifer.

The method was developed by the United States Environmental Protection Agency (EPA) as a technique for assessing groundwater pollution potential (Aller et al., 1987). Determination of the DRASTIC index involves multiplying each parameter weight by its site rating and summing the total (Al-Zabet, 2002). The equation for the DRASTIC Index (DI) is: DI=DrDw + RrRw + ArAw + SrSw + TrTw + IrIw + CrCw

where: D, R, A, S, T, I, C were defined earlier, **r** is the rating for the study area and **w** is the importance weight for the parameter.

For each parameter there are two weights. The first is for the application of DRASTIC to generic municipal and industrial pollutants (typical), whereas the second is for agricultural pesticides (specific). Each parameter has a rating scale between 1 and 10. The higher sum values represent greater potential for groundwater pollution, or greater aquifer vulnerability.

The steps for implementing the DRASTIC method include: Definition of the study area, Collecting data relating to the required parameters, Digitizing source data, Apply the DRASTIC method to assess vulnerability of groundwater to pollutants, Creation of thematic maps and Production of the final map using the international colour code. The thematic maps and the final map of the DRASTIC groundwater vulnerability, all in 1:150.000 scale will be developed in a Geographical Information System (GIS) (Al-Adamat et al., 2003; Corniello et al., 1997; Secunda et al., 1998). The DRASTIC method will be tested, using data from hydrochemical analyses (NO_3^-) of groundwater samples. Furthermore, the SINTACS method (Civita, 1994), including seven parameters will be applied in order to compare the results. Both DRASTIC and SINTACS methods belong to rating methods for assessing groundwater vulnerability.

Finally, a Decision Support System (DSS) will be developed in order to support the spatial development planning process (Uricchio et al., 2004; Manos et al., 2004). It will be based on vulnerability maps and facilitates and optimizes the decision-making process relating to the problems of land use, water management and environmental protection. The integration of the vulnerability maps in the decision support system will enable the regional authorities to design optimal spatial development policies.

REQUIRED DATA

The following data will be used (Voudouris et al., 2004):

- Hydrogeological, hydrometeorologic and geological data
- Drilling and geophysical data, including geological and hydrogeological information (depth and type of geological formations, aquifer, depth of unsaturated zone, geometry of the aquifer etc)

- Piezometric measurements in static conditions (using boreholes not discharging or piezometers) and
- Pumping test data to calculate the hydraulic parameters.

The variable D (Depth to the water table) will be extracted from the piezometric maps and in situ measurements of groundwater level; the variable T (Topography) will be obtained from elevation points, using the triangulation method in ARC/INFO system; the variable R (net Recharge) will be calculated from rainfall data and coefficients of infiltration (Panagopoulos et al., 2005). The evaluation of variables A (Aquifer material), I (Impact of the vadose zone) will be based on data reports from the geological map, and drilling data. It is difficult to collect many soil samples for laboratory analysis and the variable S (Soil media) will be obtained from soil classification maps. The variable C (Conductivity) will be based on data from pumping test analyses.

The distribution of the parameters in space in order to create thematic maps will be constructed using the kriging method, which is a special geostatistical method of making estimates of spatially distributed values from point values. Data for land use could be taken from Corine Land Cover program (Bossard et al. (2000). The land use map will be overlaid on the groundwater vulnerability map. This is an essential step in order to find out whether any possible pollution sources (farms, settlement) lay within the low or moderate vulnerability zones. The first difficulties relate to: data availability, distribution of data (homogenous or not) and accuracy of data. It should be pointed out that the vulnerability methods must not replace the field studies. The “rapid assessment” using unreliable data can lead to serious mistakes.

GENERAL CHARACTERISTICS OF THE STUDY AREAS

Western Macedonia is located in NWestern part of Greece, covering an area of 9,450 km^2 and is divided into four (4) prefectures: Kozani, Grevena, Kastoria, Florina (Fig. 2). In a large part of the area irrigated agriculture is practiced. The land is used mainly for cultivation of cereals and cows and sheep graze the area. The study area is covered by a geological map at a scale of 1:50,000; this map has been surveyed by Institute of Geological and Mineral Researches (IGME).

The main aquifer systems are developed in Quaternary deposits and carbonate rocks (karst aquifers). The major water use is in irrigation for agriculture; 82% of the total consumption. Groundwater is the main source of water supply in the study area and is taken from a numerous boreholes and partly by the discharge of the rivers. Regional environment is subject to numerous pressures, most important of which are the changes of land uses and of groundwater quality and availability. Based on hydrogeological data, the alluvial aquifer systems are showing signs of depletion due to overexploitation and contamination due to the existence of sources pollutants.

Water resources quality deterioration is exhibited as a result of anthropogenic activities. Untreated waste effluent from industrial and livestock units, waste water treatment plant shortage and the lack of proper landfill sites consist major pollution sources of surface water bodies that in conjunction with the agricultural activities are

responsible for the groundwater quality degradation. Central municipal sewage-treatment systems do not exist in small towns. Fertilizers and agricultural chemical compounds are being used intensively to maintain the productivity of the soil. In the frame of this project the DRASTIC method will be applied in three representative basins of western Macedonia: Sarigkhiol, Florina and Mouriki.

Apulia region (Puglia), the south eastern part of Italy, is characterized by extreme scarceness of surface water due to its karstic geological nature (Polemio, 2005). Despite the massive water import, at the moment the Apulian groundwater satisfies more than 20% of the local demand for drinking water. Furthermore, groundwater is the only resource available for diffuse water utilization, as an effect of the very low incidence of stream flow. Groundwater is so the main regional water source. The remarkable and rapid socio-economic development over the past few decades has further stressed the Apulian hydrogeological system as it has originated different sources of risk for the groundwater quality. Salt contamination due to seawater intrusion is one of two main problems. At the same time, the aquifers are increasingly becoming a kind of ultimate "receptacle" for domestic and industrial waste waters and of chemicals used on excess or without scruples on the ground surfaces. Groundwater of adequate quality is diminishing; chemical-physical and biological pollution is gaining importance. The quality degradation effects of a multitude of pollution sources are dramatically observed, as a total, to the outflow, constituted by many springs located along the coasts, above and below the sea level. The importance of injured natural resources and the special severity of the situation require a rigorous approach based on all available scientific knowledge to define aquifer vulnerability assessment methods able to be applied in the simplest way to the whole region obtaining “robust” results, useful to contribute to the reduction of quality degradation risks of Apulian region.

The area of application for the Water-Map project in Malta will be the catchment area of the mean sea level aquifer in the island. The mean sea level aquifer is by far the most important body of groundwater in the country, sustaining around 70% of the total groundwater abstracted in the country. The protection of the integrity of such an important natural resource assumes therefore important proportions. The project will be also extended to the catchment area of the sea level aquifer of the island of Gozo. This body of groundwater is practically the sole source of water for the island, and so is of high regional importance. The application area in Cyprus is the Basin of Tremithos River, close to the sea and the Community Board of Kiti. It is a tourist, agricultural and residential area, with serious groundwater contamination potential.

CONCLUSIONS

The WATER-MAP project, funded by European Community, is presented in this paper. Within the framework of the project, vulnerability maps are generated in order to determine areas where aquifers are in high risk of pollution and to support the spatial development planning process. Furthermore, DSS provides a valuable basis for land use planning and sustainable groundwater management and can be used to find a balance between human activities and environment. The proposed methodology will be delivered to the European Commission and will be a useful tool for groundwater resources management and protection zoning in other areas with similar characteristics.

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