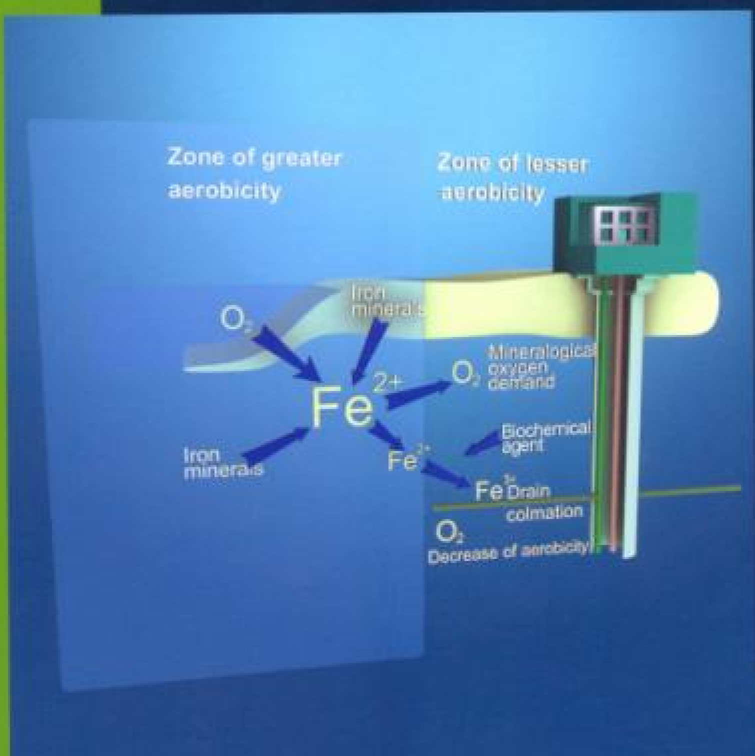
IWA SPECIALIST GROUNDWATER CONFERENCE



PROCEEDINGS

International Water Association

Jaroslav Černi Institute for the Development of Water Resources

Belgrade Water Supply and Sewerage Company

08-10 September 2011, Belgrade, Serbia

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INVITED PAPER

PROGRESS AND IMPROVEMENT OF THE STATUS OF GROUNDWATER IN SERBIA

Milan Dimkić[1], Zoran Stevanović[2] and Dušan Djurić[1]

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Abstract: The paper presents some recent data on hydrogeology and an overview of current groundwater utilisation and protection in Serbia. Over the past several years, national legislation in the water sector has been upgraded and adapted to the EU WFD, including several large projects for groundwater assessment and protection initiated or conducted in order to improve the status and standards of the national water sector. These activities included the establishment of a new national groundwater monitoring network, the study of aerobic-anaerobic conditions in the major alluvial aquifer systems, surveys for the opening of several new groundwater sources, the optimisation of artificial recharge for its wider application in practice, the management of major transboundary aquifers, and assessment of the possible impact of climate change. The approach is aimed to improving the status of groundwater and further contributing to its more sustainable use in the future.

Keywords: groundwater, water supply, protection, WFD, Serbia

INTRODUCTION

Serbia is relatively rich in groundwater reserves, deposited in different aquifer systems and unevenly distributed across the territory. The major groundwater reserves are accumulated in thick Quaternary and Neogene intergranular aquifers. Alluvial aquifers of large rivers (the Danube, Sava, Velika Morava and Drina) are particularly important and widely used for drinking water supply. Karstic aquifers dominate the southwestern and eastern regions of Serbia. These regions abound in springs which are generally vulnerable to considerable discharge fluctuations. Precipitation, watercourses, and groundwater provide Serbia with quite a favourable water regime: although Serbia is one of the largest food producers in the Balkans, only some 1-2% of its arable land is irrigated. Water deficiencies are found in the south of Serbia, as well as in a central region of Serbia (Šumadija).

EXTENDED ABSTRACT

KARST AQUIFER AS A "BUFFER" FOR CLIMATE VARIATIONS AND CHANGES

Zoran Stevanović, Vesna Ristić Vakanjac and Saša Milanović

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Keywords: karst, aquifer, storativity, climate change, buffer

INTRODUCTION

According to some estimates, around 20-25% of the world's population consumes groundwater originating from karstic aquifers. A similar situation exists in SE Europe and in Balkan countries (Stevanović, 2009). In terms of the proportion of karst waters in its water supply systems, Austria, with over 50%, is a leader. In other countries, due to the lesser extent of rich aquifers, the percentage is lower. However, the population of six capitals in the SEE region consumes water exclusively or dominantly from the karst (Vienna, Rome, Sarajevo, Tirana, Podgorica, Skopje). In Serbia, about 20% of the population also uses karst waters for drinking; this percentage increases towards eastern and western areas where carbonate rocks prevail in lithological composition. From the standpoint of water quality these are mainly waters of high natural quality that do not require expensive treatment if they are not artificially polluted.

Although important, these water resources are the least studied of water resources in Serbia (surface and underground); systematic research and monitoring is, therefore, required. Better understanding of karst and assessment of stored groundwater reserves are particularly important where the negative impact of climate changes is concerned. Some preliminary calculations which indicate abundant reserves in karst massifs (e.g. Beljanica, Kučaj, Vidlič, Pešter) have to be verified and these areas protected and preserved as an alternative source for the future water supply of Serbia.

The Earth's climate changes regularly over geological time. However, human impact is likely also to contribute progressively to global warming. In Europe, the mean annual temperature is higher by 1.4 oC than in the pre-industrial period with the warmest decade (last 10 years) in the last 150 years All existing scenarios and all utilized climate models foresee a temperature increase on

Paper for IWA Conference 2011, Belgrade

CLIMATE CHANGES AND WATER SUPPLY IN SOUTHEASTERN EUROPE –

- THE PROJECT CC-WATERS

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ABSTRACT

"Climate Changes and Impacts on Water Supply" is a large 3-year project under implementation since 2009. The project is being carried out by 18 project partners from 9 countries from southeastern Europe. The main objective is to maintain for several decades water availability and safety for a sustainable water supply for citizens in different regions under the influence of climate changes also causing land-use changes. The project consists of seven working packages. Five of them are purely technical and closely linked. In total, 25 test areas with different climate, morphological, hydrological and geological settings are selected for the application of a defined methodology. Estimated climate changes and, consequently, water availability and future land use patterns will provide a base for the proposal of adequate responses in the water management sector and to mitigate negative impacts on water supply.

Key words: climate change, water resources, groundwater, water supply, land use, southeastern Europe

INTRODUCTION

CC-WaterS is an acronym of the 3-year project "Climate Changes and Impacts on Water Supply" under implementation since May, 2009. It is being implemented under the Southeast Europe programme (European Territorial Cooperation, ETC-SEE), funded by the European Regional Development Fund (ERDF) and the Instrument for Pre-Accession Assistance (IPA). The SEE programme supports projects within four Priority Axes: Innovation, Environment, Accessibility, and Sustainable Growth Areas - in line with the *Lisbon and Gothenburg strategies* - and is contributing to the integration process of non-EU member states.

There are 18 project partners from 9 countries involved in this project (Austria, Italy, Slovenia, Hungary, Romania, Bulgaria, Greece, Croatia and Serbia). The leading partner is the Municipality of the City of Vienna - Waterworks, Austria. The partners are from different sectors: governmental bodies, water suppliers and research institutions. They are working together and their complementary knowledge and findings should be implemented jointly in the water/land use practice. Project activities are supported and supervised by the Steering Committee and the Scientific Advisory Board (one representative from each country).

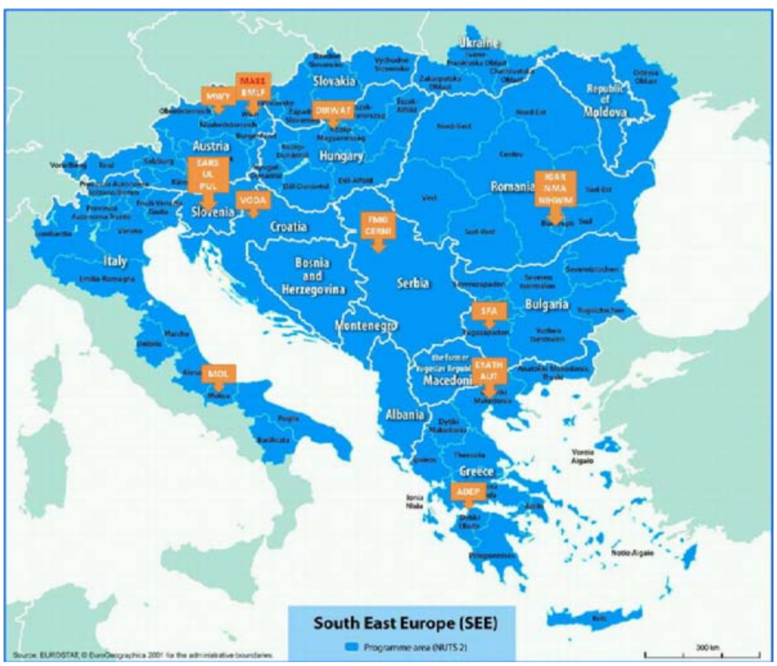

Fig. 1 Study area and countries and institutions involved (acronyms)

The project consists of seven working packages (WP). Mmong them five deal with technical issues: *Climate Change, Water Resources Availability, Land Uses and Water Safety, Socio-economic Evaluation*, and *Water Supply Management Measures*; the remaining two, *Management and Coordination*, and *Communication and Dissemination*, are more organizational.

The five technical WPs are strongly linked. *Climate Change* provides input for the next parallely operating packages: *Water Resources Availability* and *Land Uses*. The results of the work of all three are the basis for *Socio-economic Analyses*: any changes in the water availability and safety of the public water supply result in economic losses or benefits. Therefore, climate change with its impact on water resources and land use may also have impact on the technical requirements and the organization of public water supply. Finally, *Management Measures* should be a logical consequence of findings and conclusions from previously completed WPs.

In addition to preparation of the jointly developed Monograph, wider promotion of the project results is planned through numerous scientific and popular articles, brochures, and movies. This comprehensive document would cover the background problems of the project, the challenges, methodology and achievements regarding climate change, and the mitigation of its impacts on water supply.

During the preparation of this paper the CCWaterS project continues; some of its results are completed, others are still under evaluation and reporting. Thus a complete presentation of the project’s achievements is not possible at this stage: more emphasis has put on climate change and methodology of water resources assessment, while the parts related to socio-economic analyses, management principles and proposed measures are still incomplete (recently started).

PROJECT OBJECTIVES

Climate change (CC) affects fresh water resources and may have significant influence on the ability to provide safe and sustainable drinking water. The region of southeast Europe is also facing the challenge of ensuring water supply in a changing climate. Under these circumstances the policy makers and water suppliers are required to develop sustainable management practices for water resources. Land use activities will also change and it is crucial to assess their impact on water resources. In order to mitigate possible negative impacts of CC and implement alternative solutions in the most efficient way, joint transnational action with a multisectoral and multilevel approach is required. This goal oriented the CC-WaterS project and its activities directly, aiming:

- to assess the possible range of impact of CC on the water resources used for drinking water supply;
- to identify and evaluate the resulting impact on the availability and safety of public drinking water supply for several future decades;
- to delineate critical areas where measures are needed.

The main objective of CC-WaterS is to safeguard water availability and safety for a sustainable water supply for several decades for citizens in different European regions under the influence of CC provoking land-use changes.

One of the main project targets is to develop methods and instruments to predict the magnitude and effects of land use changes and their impacts on water supply. Measures to adapt water supply management to these changes will be proposed in the final stage of the project. These measures would focus on optimization of water extraction, land use restrictions, and socio-economic consequences in three geographical units shared by the SEE countries: the Alps, Danube Middle and Lower Plains, and coastal areas, representing different climates and topography characteristics.

TEST AREAS

Each of the countries involved identified test areas where established methodology is going to be applied: Estimated climate changes (at the end of 21 Ct.) → Water and land use situation about one century from now: Water resources availability ↔ Land use changes.

In total, there are 25 test areas (from 1 to 5 per country); different climates, morphologies, geological settings and water availability are well represented. In some of the areas water is already scarce and these areas are facing different problems such as water shortage due to limited recharge, inappropriate land use, water pollution, and salt water intrusion. Some other partners proposed test areas which are rich in water, representing current or very promising sources for future water supply.

A majority of the sites includes groundwater sources utilized by local waterworks. This is quite logical given the prevalence of groundwater supply for drinking purposes over surface water use in SEE. In the entire region, 65-70% of the population drinks groundwater.

Test areas also represent well different aquifer systems and variable recharge-discharge conditions. For instance, the karstic aquifer systems are being evaluated within the Eastern Alps (Rax-Schneeberg Mts.), the Apennines (Matese Mt.), the Horst-mountains of the Pannonian basin (Bükk Mt.), the Carpathian Mountains (Stara Planina), the Peloponnesus (Panachaiko) or coastal Dinaric system as in the case of Croatian islands (Cres, Korčula). Alluvial aquifer systems are being studied along the Struma, Sava, Nišava, and Pek Rivers. Sub-artesian aquifers of deeper structure are selected in the Pannonian depression (Banat) or in Oltenia. Specific hydrogeological structures such as terrace and aeolian hills are also considered as in the case of Nyirseg (near Nyíregyháza). The size of waterworks has also been chosen to represent large and, for management, more complex systems, such as those of Vienna, Thessaloniki, Ljubljana or Belgrade, along with numerous smaller operational utilities.

CLIMATE CHANGE

This basic WP consists of three sub-packages:

- Establishment of transnational climate data base,
- Development, calibration and validation of an intra-project-downscaling methodology,
- Generation of future climate data and estimation of associated uncertainties.

Global Circulation Models (GCMs) are the primary tool used to simulate the global climate system and provide reliable projections of future climate change in the climate perturbed by various greenhouse gas emission scenarios. The most comprehensive overview of state of the art GCMs is presented in the last IPCC report (IPCC, 2007).

The first task of the partners was to agree on one or several climate models and scenarios to be further applied for the entire region and for each test area (Fig. 2). Meteorological data from observations and simulations are merged in a transnational climate data base. Common understanding of the methods of correction of the raw model data was an important part of this task.

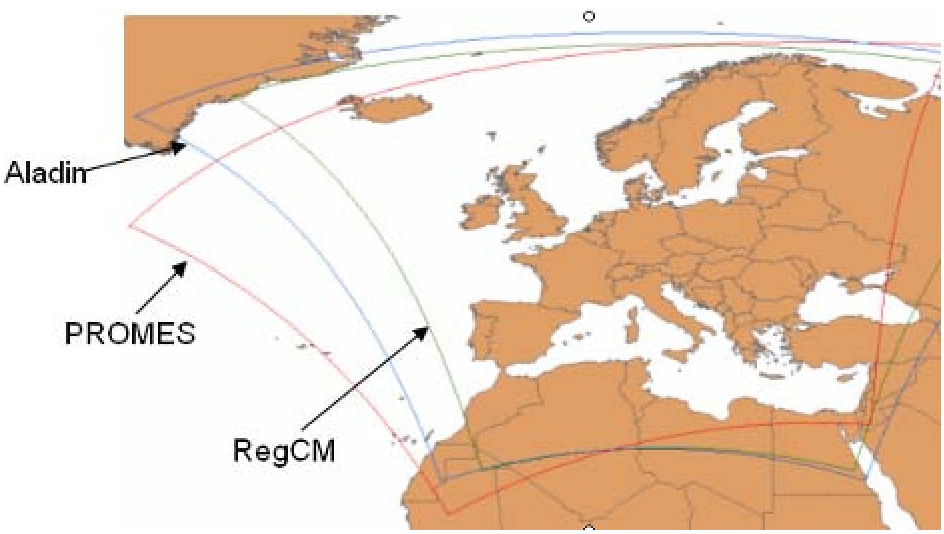

Fig. 2 Spatial extent of the selected models Aladin, PROMES i RegCM used in CCWaterS

Regarding the green house emission scenario, the A1B scenario was selected as the common scenario for all analyses (IPCC, 2007). The most important reason for using just one scenario was that data by several RCM using this scenario are available from the ENSEMBLES project. As the driving GCM was considered to have a larger influence than the emission scenario, especially in the first decades of the 21st century, it was decided to use three RCMs with three different driving GCMs. The three selected RCMs from ENSEMBLES were RCM Aladin driven by GCM ARPEGE, RCM PROMES driven by GCM HadCM3Q0, and RCM RegCM driven by GCM ECHAM5-r3 (Fig. 2).

The models have a 25x25 km resolution and their A1B scenario runs are available for the entire 21st century (2000-2100) with the exception of PROMES, which is available only for 2000-2050. A comparison of three models for the period 2021-2050 and of two models for 2071-2100 was considered sufficient for an estimation of the uncertainties related to the choice of the climate model.

As RCM simulations for control runs still show considerable errors when compared with observations, the raw model data was bias corrected with a quantile mapping approach. The observational datasets used as the base of the bias correction were the E-OBS dataset developed in ENSEMBLES, which provided daily temperature and precipitation fields on a 0.25°x0.25° grid for the whole of Europe and the period 1950 – 2009. Within the Alpine region a gridded precipitation data-set by Frei and Schär was used, which has a higher spatial resolution (10') and includes many more observation stations.

For the provision of climate data with a higher resolution than 25km and for the investigation of uncertainties related to the choice of the downscaling method, three statistical downscaling approaches were applied in three areas of different climatic influences. In an Alpine test area in Austria, an SDM based on weather classification was tested, in Romanian areas with Continental influence a Canonical Correlation Analysis (CCA) was applied and in Mediterranean Greece an Artificial Neural Network (ANN) approach was adopted.

The two characteristic examples of the outputs of the climate model, are as follows:

1. For Austrian test sites in Eastern Alps, the RCMs showed no apparent changes in temperature seasonality and variance but did show a clear increase in the mean of between 1.1 to 2.2 °C in the reference period 1961-1990 and 2021-2050 and of approximately 3.3 °C until 2071-2100. In the late period, the summer extreme temperature increased more than the mean. As the increase in temperature plays a major role in impacts on the hydrological cycle in Alpine areas, this clear signal will lead to clear trends in subsequent impact modeling despite high uncertainties regarding precipitation.

2. In the Serbian Carpathians, over the entire 2001-2100 period the most intense increase in air temperature and the most significant decrease in precipitation will be during summer. Compared to the period of 1961-1990, the air temperatures will successively rise, while the precipitation amount will fall in the periods 2021-2050 and 2071-2100 (Aladin) or rise in the period 2021-2050 and then fall in period of 2071-2100 (RegCM).

However, the results of WP Climate Change show the various uncertainties associated with the generation of climate change information for impact assessment studies. Especially for precipitation, but to a lesser degree also for temperature, there are large biases in the RCM data as well as in observational data sets used for bias correction. Future scenarios for precipitation also show no clear trend in many areas, as in Austria, Hungary, Romania and Croatia. In Romania only for summer, in Croatia for spring and summer, consistent results predict decreasing precipitation. In Greece, consistent trends of decreasing precipitation in all seasons were detected. For temperature, there are rather consistent predictions of an increase of between 3 and 3.6°C in the annual mean towards the end of the 21st century. Especially in the countries in the south of the region, the highest temperature increase is expected for summer periods.

The data provided from this WP have facilitated impact modeling in the subsequent work packages and contributed to the understanding of climate change in the SEE region.

WATER RESOURCES AVAILABILITY

The three sub-packages of this WP are as follows:

- Establishment of a transnational hydrological and water management database,
- Assessment of the present conditions of water resources,
- Evaluation of climate change-induced changes in available water resources.

The expected main negative impacts of climate changes on water availability are: (i) decreasing runoff or recharge due to the negative change of the difference between precipitation and potential evapotranspiration, and (ii) increasing frequency of droughts due to the more frequent extreme events. The extent and importance of these impacts will vary by region and by type of resources. The water availability is assessed in the test areas in order to give a general picture and to highlight the sensitive regions. A common methodology has been set up for determining available water resources, based on the principle of the EU Water Framework Directive: to promote sustainable water use, the abstraction can not exceed the renewable water resources minus the water demand of the ecosystems (Fig. 3).

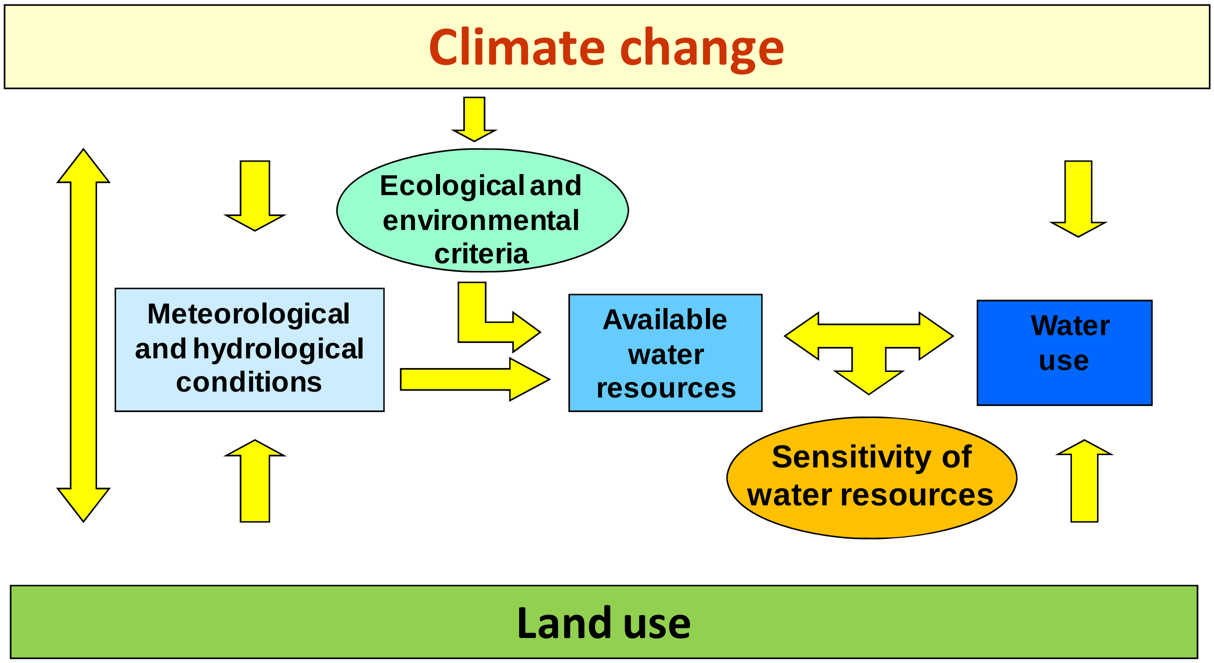

Fig. 3 The main elements of the methodology for available water resources assessment

The methodology has a modular structure, including (i) setup of meteorological input (precipitation and temperature) based on datasets of climate modeling, (ii) water balance modeling, (iii) additional groundwater flow modeling if needed, (iv) consideration of ecological criteria, (v) impact of the changing land use on water availability, (vi) evaluation as determination of available water resources and comparison with actual water use. The modular methodology aims to ensure similar results allowing comparative evaluation, rather than using uniform models. The applied methodology is general and can be proposed for similar assessments as well.

The water balance models are the essential part of the methodology providing the renewable water resources. Its form depends on the type of resources and the results can be daily or monthly time series (in the case of surface water resources and springs) or long-term averages (in the case of groundwater resources from porous intergranular aquifers). In certain test areas redistribution of the recharge among baseflow, spring flow and outflow to neighbouring aquifers needs additional – usually steady state – groundwater flow models. The ecological criteria can be expressed as minimum flow to be left in the creeks or rivers, minimum water levels in reservoirs, groundwater levels or minimum baseflow and evapotranspiration from groundwater. All these options occur in the test areas.

Results of the assessment of the climate-induced changes in land use are incorporated in the models through the parameters depending on the land use (e.g. evapotranspiration, run-off coefficient etc.). The models are calibrated and validated for different periods according to the available data, but the simulation for the comparative evaluation is carried out for the same periods: 1961-90 as baseline and 2021-2050 and 2071-2100 for assessing the variation of water reserves under climate changes. The impact of the climate is going to be finally presented as changes in the available water resources between the baseline period and future periods for all test areas. Besides the test areas with considerable changes, areas sensitive to water shortages will also be selected by comparing the calculated available water resources with the present water use.

As an example, the stochastic model applied in the case of karst springs in the Carpathian Mts. of Serbia shows that as a result of climate variations the annual average discharge of some springs will decrease from 6-23% by the end of 21Ct. Moreover, seasonal variation shows a strong depletion of the reserves during the dry period of the year (even 40% less), while an increase during winter months is expected (up to +25%). The exceptions are ascending siphonal springs with accumulated large geological groundwater reserves and they would not be seriously affected by reduced rainfalls during the summer/autumn periods (longer residence time).

LAND USES AND WATER RESOURCES SAFETY

The three sub-packages are as follows:

- Impact of existing land uses on water quantity and quality under climate change conditions,
- Evaluation of climate-change induced land use changes,
- Evaluation of the climate change impact and other pressures on future water quality.

Works of this WP mostly focus on the analyses of actual land use in test areas, current and forecasted water quality data, and expected changes in the environment as a result of climate changes.

One of the main tools used for these analyses was DPSIR (Driving Force – Presure – State – Impact – – Response) (Fig. 4), which was proposed by the European Environmental Agency (EEA, http://ec.europa.eu/environment/water/water-framework/groundwater/brochure/en.pdf) The essential question that would have to be responded to for each test area is: Does climate change drive towards land use change in a test area? In the case of a positive answer the following question is to be responded to: Are these changes compatible with sustainable development of groundwater and various hydrogeological and water extraction scenarios? Analysis of relationships between actual land uses and future climate scenarios is therefore one of the essential steps towards preparation of mitigation measures ("responses") in case of their incompatibility.

The three main land uses were studied, such as forestry and pasture in mountanous areas and agriculture in alluvial plains and karst poljes. In case of forestry, forest management practices should be changed in the water protection zones. In case of agriculture increased average temperature leads to higher mineralization of organic matter. Besides, increased rainfall will increase leaching, which extent for wetter areas is much higher than in drier areas.

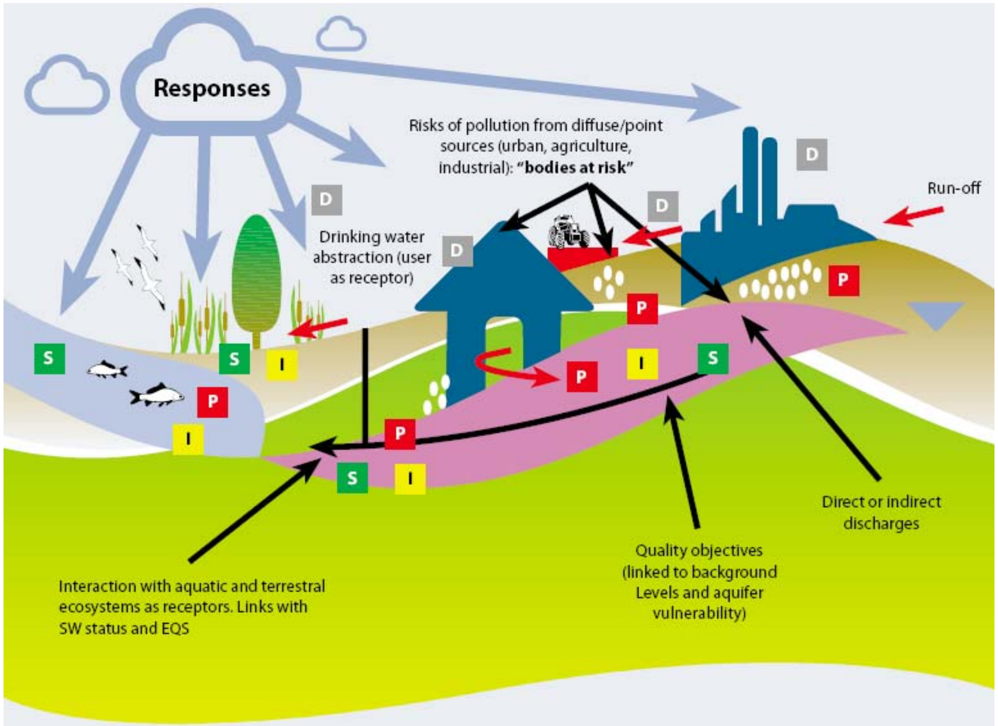

Fig. 4 Scheme of DPSIR mechanism (source: http://ec.europa.eu/environment/water/water-framework/groundwater/brochure/en.pdf)

SOCIO-ECONOMIC EVALUATION

The following aspects (sub-packages) are considered in this WP:

- Future water availability for public water supply,
- Estimation of economic consequences of future water availability and safety,
- Estimation of emerging imbalances between different demands,
- Environmental aspects in water pricing.

Many of the research and assessment activities to date have focused on the climatological, physical and biological aspects of climate change impacts. A better understanding of the socio-economic and institutional aspects of vulnerability and adaptation, including costs and benefits, is therefore found to be one of the very important demands of the project.

Regional development leads to conflicts between competing sectors and demands for safe water resources. The main target of this WP is merging demographic forecast data and water demands with future water availability and estimation of the emerging consequences and costs of water supply. An economic analysis of water management and land use changes for different scenarios should provide better information to the water managers and help to orient their decisions towards more sustainable solutions in water utilization.

WATER SUPPLY MANAGEMENT MEASURES

This WP includes work on the following subjects:

- Proposal of strategy change in spatial planning,
- Promotion of (new) legislative rules and guidelines,
- Adaptation of water supply management system,
- Feedback cycle.

The objective of current and future water supply management adaptation measures is managing the risks associated with future climate change impacts. Adaptation measures occur primarily at transnational (e.g. river catchments), sub-national and local levels and therefore involve many levels of decision making. It is a cross-sectoral issue requiring comprehensive integrated approaches. Objectives of this WP are:

- development of appropriate technical measures, and
- preparation of a legislative basis to mitigate possible negative effects of climate and land use changes on water supply management.

Applying well-prepared adaptation measures will serve to solve conflicts between competing sectors and demands. Measures should be integrated in the water supply management system (WSMS) of the region.

The following water supply management options under different climate conditions would be considered and evaluated in WSMS:

- land use: managing supply and possible loads,
- legislation: changing environmental standards, restriction of land uses, enlargement of protected areas,
- managing the demand: water pricing and prioritization and competitiveness (management of imbalances) by using impact of WP *Socio-economic evaluation,*
- alternative supplies: identification of new resources, alternative recharge, regulate-managing the flow (including ranking criteria for evaluation of alternatives),
- managing water supply.

A sound feedback cycle is followed to compare the resulting system with the project objectives.

CONCLUSION

Transnational action is needed to prepare SEE for the challenge of ensuring water supply for society for several decades. Policy makers and water suppliers must develop sustainable management practices for safe drinking water supply, considering existing and future CC influences of the changing climate. Therefore the on-going project CC-WaterS is identifying and evaluating impacts on the availability and safety of public drinking water supply for several future decades. Elaborated adaptation measures build the ground for an optimization a WSMS regarding water extraction, land use restrictions, and socio-economic consequences under climate change scenarios for water suppliers in SEE. The joint actions to produce WSMS on a transnational level in the different areas with specific characteristics of the climate, topography and water resources availability would be the result of performed analyses.

In CC-WaterS, SEE governmental bodies, water suppliers and research institutions work together and implement jointly developed solutions, to be applied on a regional or local level. Capitalizing on already existing knowledge and data from EU-funded scientific projects and eliminating parallel investigations, CC-WaterS will make information applicable for concrete solutions, develop tools and instruments for public water supply and implement safeguarding measures. An accessory dissemination strategy will ensure that durable results of the CC-WaterS are transferred to the relevant users.

Links:

http://ec.europa.eu/environment/water/water-framework/groundwater/brochure/en.pdf (European Commission, Directorate-General for the Environment 2008: Groundwater Protection in Europe the new Groundwater directive – consolidating the EU regulatory framework).

www.ccwaters.eu

www.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf