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CLIMATE CHANGE AND VULNERABILITY ASSESSMENT OF THE WATER RESOURCES

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ABSTRACT

The climate system of the earth, globally and locally, obviously has been changed from pre-industrial period to present. Some of the changes are due to natural phenomena and some due to human activities, where the crucial role has been played by the emission of so-called “green house gasses”. By 1990 the measured concentrations of GHG had reached their highest level. From the enlarged volume of observations we have come to the picture of world that is getting warmer. The observed climate changes and their impact on different sectors have to be quantified for the various regions. Regarding this, Republic of Macedonia has ratified the UN Framework Convention on Climate Change (Rio, 1992) and in 2002 has prepared the First National Communication on Climate Change for the sectors: energy, agriculture, forestry, biodiversity, hydrology and water resources and human health. The selection of vulnerable sectors was according to the IPCC methodology. This paper deals with some results that have been obtained for the climate change impact on hydrology and water resources and adaptation measures that have been proposed.

Key words: climate change, hydrology, water resources, water regime, adaptation measures, ecosystems, vunerability

1. INTRODUCTION

The Republic of Macedonia in September 2001 carried out a Strategic Environmental Policy Assessment (SEPA) within the United Nations Environment Program (UNEP). The main purpose of SEPA is to identify national needs in the environment sector and to identify corresponding strategic areas for support by the international community. Our country has ratified a number of international environmental agreements such as climate change, biodiversity and desertification. This part of the project titled National Capacity Self Assessment (NCSA) deals with the thematic area of Climate Change (CC).

From the enlarged volume of observations we have come to the picture of world that is getting warm. It is very probably that the nineties of the XX century have been the warmest decade, and the year 1998 the warmest year within the period of organized observations (1861-2000). The increase of the surface temperature in the north hemisphere in XX century was estimated to be greater than in any other century in the last thousand years. The duration of hot days has increased everywhere in the world, and the duration of cold days in continental regions has decreased. The precipitation has increased for (5-10) % in the north hemisphere, while in Africa and Mediterranean has decreased. The increase of storms has been observed in the middle and high lines of latitude. The frequency and violence of the droughts in parts of Africa and Asia have increased as well. The glaciers have rapidly shrunk in the last decades of the XX century and the snowdrift has decreased for 10%. The frontiers of the plant cover and insects’ appearance have been enlarged. These changes have influence on the human life and health, on the economic development of the societies and on the ecosystems as well. The observed climate changes and their impact in different sectors have to be quantified for the various regions in each country. This project has to have a small contribution to the global activities on climate change issues.

At the very beginning of XXI century, all around the world, some undesired consequences have appeared due to the variable meteorological and climatologically conditions. In 1999 in California has been registered rainfall world record. The same year in Canada has been observed snowdrift world record. In 2001 in Great Britain have appeared extreme flood in the last 400 years. In 2003 Europe has suffered mostly. Due to high temperatures in the summer period in France and Italy have died over 20000 people. During the summer period this year in the Balkan has been measured maximal temperature in the last 150 years. The regional projects in different sectors connected to climate and climate change have shown that the droughts and floods have become more frequent and more severe. In Macedonia have appeared also some extremes, such as desolation of about 3000ha of vineyards in the region of Tikveshko Pole due to intensive rainfalls, than 100% desolation of crops in the region of Strumichko Pole. The last decade in our country many forest fires happened due to high temperatures. Also the storms have become more frequent and more abrupt. The review of weather events globally and locally leads to the conclusion that the climate change has to be treated as a process, but not as an event. Therefore, the regional and national projects on climate change impact and capacity self assessment are necessary.

2. OBJECTIVES

Climate change impact on the water resources in Macedonia has not been carried out until now. The objectives of the performed analysis within the project on Vulnerability of Climate Change and Adaptation Measures were: (i) determination of water regime in main rivers, (ii) determination of water regime in natural lakes, (iii) determination of change in water regime, and (iv) adaptation measures and draft National Action Plan (NAP) with strategies and activities.

To achieve these goals the selection of hydrological stations has been made upon the following criteria: (i) hydrologic station should be representative for the basin with certain climatic meteorological conditions, (ii) hydrologic station should show results from several river basin areas, different by exposition, (iii) measured data should not be influenced by structures and reservoirs with flow regulation or this influence on the watercourse regime downstream should be minimum, (iv) hydrological station should be with longer period of observation and with qualitative information, (v) hydrological station should be on the watercourse that belongs to the representative basins on the territory of the country, (vi) near the hydrological station a meteorological station is required in order to register all climatic-meteorological parameters.

According to the stated criteria the following hydrological stations have been selected: Vardar - Skopje, Crna - Skochivir, Radika - Boshkov Most and Strumica - Sushevo. For natural lakes have been selected the following stations: Prespa Lake - Stenje, Dojran Lake - Nov Dojran and Ohrid Lake – Ohrid. Here will be discussed only Vardar at Skopje, Strumica at Sushevo and Dojran Lake at Nov Dojran.

3. NATIONAL CIRCUMSTENCES

Subject of examination of water resources is water and having into consideration its attributes as an elementary life product, it can be stated that quantity is natural process, and quality is process mostly under human influence. Therefore, water resources term is closely related to the water source areas that have utilization value. For long-term planning of the quantity and maintenance of the quality, systematic observations and measurements are required, as well as forecast and operation modeling where climate impact examination has significant contribution as well. Climate variety in Macedonia can be understood through a short description of the national circumstances, such as geographic, climatic and socio-economic characteristics.

Area of the Republic of Macedonia territory is 25.713 km^2. Territorial borders are: in north with Serbia and Montenegro (264 km), in east with Bulgaria (177,7 km), in south with Greece (262 km) and in west with Albania (192 km). The terrain of the country is mostly hilly-mountain with average elevation of 829 m. River valleys of Vardar, Treska, Lepenec, Topolka, Babuna, Pchinja, Bregalnica and Crna, then Crni Drim and Strumica, have been formed as a result of the tectonic processes and fluvial erosion influences. Composition of the valley is characterized with several cliffs. Cliffs of Dervenska (21,5 km), Taorska (31 km), and Demir Kapiska (16,6 km) are at river Vardar. Cliffs of Preglevo - Delvich (17,5 km), Devich - Zdunje (36,7 km), and Zdunje - Shishevo (29,5 km) are at river Treska. Cliffs of Skochivir - Chebren (19,7 km), and Vopsko - Brushani (34,7 km) are at river Crna Reka. Cliffs of Budinarci - Trabotivishte (19,1 km) and Todorovci - Istibanje (10,5 km) are at the river Bregalnica. Total area covered by karst is 2.400 km^2 or 9%. Western part of Macedonia is covered with limestone-dolomite rocks that enable complicated karst forms.

Temperature reduces from south towards north. The highest average annual temperature is 14,5°C in Gevgelija, and the lowest one is 7,3°C in Mavrovo. Rainfalls, through the moistening air masses arrive from northwest and west towards east. Average annual precipitation sum over 1.300 mm is in western part, in eastern part 800 mm (during the summer periods decreases to less then 200 mm), and in the central part is less then 500 mm.

The longest river in Macedonia is Vardar (302,6 km), with basin area of 22.456 km^2, with average rainfalls of 66 0mm, and with total annual discharging of 4,56·10^{9}m^3. The basic hydro-geographic characteristics of the largest river basins in Macedonia are shown in Table 1.

Table 1 Hydro-geographic characteristics of the basins in Macedonia

River	A (km^2)	H_{av} (m)	L_r (km)	S (‰)	Q (m^3/s)	V (m^3)·10^6
Vardar	22.456,0	793,0	301,6	2,12	144,9	4.564,35
Treska	2.068,0	1.010,0	138,3	10,54	24,2	762,30
Pchinja	2.840,7	758,0	136,4	10,62	12,6	396,90
Bregalnica	4.306,8	722,0	225,0	6,90	14,1	444,15
Crna	5.890,0	863,0	228,0	4,56	37,4	1.178,10
Strumica	1.520,0	638,0	75,1	18,03	4,2	132,30
Crn Drim	4.348,2	1.166,0	56,2	4,18	47,7	1.502,55

Source of data: Hydrometeorological Institute of the Republic of Macedonia, 2000

Water discharging in the Republic of Macedonia is performed through three watercourses: river Vardar at Gevgelija, Crn Drim in Debar and river Strumica in Novo Selo. The average annual runoff coefficient is highest in western part (0,48) and lowest in eastern part (0,18). The average annual evaporation is lowest for river Vardar basin (440 mm), and highest for river Strumica basin (649 mm). Inflow waters in Macedonia are the rivers: Lepenec, Pchinja and Eleshka. Output waters are the rivers: Vardar, Crn Drim, Strumica and Cironska. Available water quantities from the surface input waters are 1.014 millions m^3/annum, from output waters 6.360 millions m^3/annum, and domicile waters 5.346 millions m^3/annum. It can be stated that 84% of the available water quantities are domicile waters and only 16 % are outside waters.

Three natural lakes have also a great significance for the hydro-geography of the Republic of Macedonia and they are: Ohrid Lake (elevation 695 m) with total area of 358 km^2 (Macedonian part 229,9 km^2) and with maximum depth of 285 m, Prespa Lake (elevation 853 m) with total area of 274 km^2 (Macedonian part 176,8 km^2) and maximum depth of 54 m, and Dojran Lake with total area of 43 km^2 (Macedonian part 27,4 km^2) and maximum depth of 10m. In order to utilize the hydrological potential of the rivers, 20 large and over 100 small reservoirs/lakes have been constructed with total volume of 2400 millions m^3 of water. The largest are: Kozjak Lake on the river Treska with total volume of 550 millions m^3, then Spilje Lake on the rivers Crn Drim and Radika with 520 millions m^3, followed by Tikvesh Lake on the river Crna with 475 millions m^3. In Macedonia 4414 springs with total yield of 991,9 millions m^3/annum have been registered. Out of them only 58 have the yield over 100l/s, and out of them only three are located in the central part of the river Vardar basin and the others are in the west part of the country. The water treasure in Macedonia according to the Physical Plan of the Republic of Macedonia has been estimated as:18,8 billions m^3 from precipitation, 6,22 billions m^3 as discharging water from the watersheds, 0,52 billions m^3 as groundwater and 0,42 billions m^3 from the bigger springs.

Ground waters have also been noticed, but insufficient and no appropriate data for their yields and quantities exist. Observation and examination of the ground waters have not been performed systematical and continuously, except for the local demands for certain regions. More detailed examination has been carried out only within the period 1963-1975. With these examinations have been estimated static funds of ground waters and they are: in Polog plain 193 millions m^3, Skopje valley 925 millions m^3, Kumanovo valley 675 millions m^3, Ovche Pole 256 millions m^3, Strumica valley 850 millions m^3, and Gevgelija-Valandovo region 342 millions m^3.

Required water quantities in different economy sectors for the level 1996 and designed condition until 2010 and 2020 are presented in Table 2, with a remark that water demands for the energy/power produce are not completely developed in the existing and valid plan documents, as a result of the fact that most of the built and planned hydro-power systems release the installed discharges again in the water courses and are used as available water resources for other and/or same purposes.

Table 2 Water demands (m^3/annum)$\cdot 10^3$

	1996	2010	2020
Water supply ▪ population ▪ industry	 207.993,5 274.147,0	 285.602,2 280.580,5	 336.389,5 287.014,0
Tourism	7.254,0	9.295,4	11.871,8
Irrigation	899.335,0	907.376,0	1.806.711,0
Fishery	166.800,0	189.483,0	212.166,0
Total	1.555.529,5	1.672.337,1	2.654.152,3

Source of data: Physical Plan of the Republic of Macedonia, 1998

Socio-economic profile of Macedonia can be described with the following basic information. According to the last population census in Macedonia live something over 2 millions inhabitants. Population density is 80 inhabitants/km^2. Macedonia is characterized with 59% of population that are living in urban areas, out of which 23% are living in the capital Skopje and other 36% are living in other 29 cities. Present the Republic of Macedonia is divided into 123 municipalities and a new low for local self government is in procedure, according to which the communities will have larger competence and financial potential.

The last decade the economy of the Republic of Macedonia was confronted by the shocks caused by the transformation of political and economic systems. The result of this is a fall of GDP, a fall in employment rate and investments. The last decade due the new political and economic situation in Europe, Macedonia has lost the traditional market in East-European countries. This was the reason for rapid fall of industry production, from 46% of GDP in 1990 to 22% of GDP in 2000. Since 1996 the economy in our country has begun to improve.

4. BASIC WATER BALANCE COMPONENTS

Useful water demands, not only in Macedonia, but also globally are increasing. Therefore, assuming that in near future socio-economical development will escalate in characteristic pressure for solving out the water economy problems, especially because these problems cannot be solved irascible and incidentally, but organized and in long-term bases. Climate change can only increase this pressure having into consideration that hydrological parameters are especially sensitive on the climate change. Change of the intensity and time distribution of the rainfalls, dictates the frequency and intensity of the floods and droughty seasons, while the change of temperature will cause changes in evaporation, infiltration and water capacity. Hydrology in one region is also under human activities impact, as it is woodcutting, urbanization, and water resources utilization. Hydrological investigations have been directed lately, towards the effect of global warmth. But, having into consideration they are still in development stage, final answers for causes and consequences do not exist. Therefore, it is very important to support the regional projects and to establish regional hydrological and water resource management. The basic hydrological components having a direct influence on the surface and ground water balance will be discussed in addition.

Precipitation. The amount of precipitation is closely related to the physical-geographical, orographical, geological, pedological, and climatic factors. Physical distribution of the precipitation is no uniform as a result of complex orography. This causes variable pluviometric regime during the year, seasons and months. Factors that have influence on this non-uniformity are: (i) frequent movement of the cyclones from the Mediterranean during winter seasons, (ii) separation of the moist air masses from the Mediterranean from the dry and cold air masses from the north that result from the orographical characteristics, (iii) frequent anti-cyclonic movements during the summer periods, (iv) influence of the

Atlantic Ocean air masses, through the Western and Central Europe in the beginning of summer that causes unstable air masses from the continent. The annual amount of precipitation for the selected meteorological stations are presented in Table 3.

Temperature. Air temperature regime is one of the main climatic factor. Average annual temperatures in Macedonia for the period 1961-1990 are between 14^{o}C in the southern part (Gevgelija - Valandovo region), 10-12^{o}C in the central part (Skopje region and Pelagonija) and from –2^{o}C to 2^{o}C in the highest mountains (Shara, Pelister, Solunska Glava). Annual air temperature amplitudes are highest in the central region and they are over 22^{o}C. The average annual air temperatures and the annual temperature amplitudes ($\Delta T = T_{max} - T_{min}$) for the selected meteorological stations are presented in Table 3.

Table 3. Temperatures, temperature amplitudes and rainfalls

	Measurement point	Tav (^{o}C)	ΔT (^{o}C)	P (mm)
1	Skopje-Petrovec	12,0	23,0	504,4
2	Veles	13,3	22,8	442,6
3	Strumica	12,7	22,7	567,4
4	Bitola	11,0	22,5	599,8
5	Ohrid	11,1	19,0	698,3
6	Resen	9,5	18,8	715,2
7	Shtip	12,6	22,7	475,6
8	Lazaropole	6,8	17,8	1.065,9
9	Nov Dojran	14,1	21,2	625,4
10	Gevgelija	14,0	21,6	675,5
11	Popova Shapka	4,7	16,8	991,0
12	Solunska Glava	-0,4	16,0	817,6

Source of data: Hydrometeorological Service of the Republic of Macedonia, 2000

Evaporation. The evaporation measurements in Macedonia started in 1957. Evaporation measurements (evaporation pan Class A) are performed at the meteorological stations: Skopje - Zajchev Rid, Shtip, Gevgelija, Strumica, Bitola, Ohrid, and Mavrovo. Also, evaporimeter GGI3000, evaporation pool 20m^2, as well as Garnier evaporation pan for soil evaporation have been installed at Skopje - Zajchev Rid. Using direct measured data and empiric calculations for potential evaporation based on turbulent diffusion estimation for average annual evaporation from surface water has the following distribution: over 1000 mm in Tikvesh valley, Veles, Ovche Pole, and Prilepsko Pole, (1000-900) mm in Gevgelija -Valandovo region, Dojran, Skopje, and Radovishko Pole, (900-800) mm in Kochani, Ohrid, Bitolsko and Kriva Palanka, (800-700) mm in Strumichko Pole, (700-600) mm in Polog valley and less than 600 mm in Berovo region and higher mountain regions. The average annual evaporation is higher than the average annual precipitation amounts on the entire territory of the country, with the exception of the Polog and Berovo and the mountain regions.

5. CLIMATE CHANGE SCENARIOS

For preparation of the vulnerability assessment and adaptation measures as part of the Macedonia's First National Communication under the UNFCCC several climate change scenarios were examined using estimated average values and different values for climate sensitivity. Climatic models used were the software package MAGIC SCENGEN (Hulme at all. 1995) as well as MAGIC (version 2.4 dated 2000) published by IPCC (Second Assessment, 1996

The simulating scenarios were performed for the basic parameters (air temperature and precipitation) for the projected periods in XXI century: 2025, 2050, 2075 and 2100, assuming that the current policy of increasing the concentration of GHG emission would be kept. Two projections of social-economic development IS92a and IS92c were chosen: emission scenario IS92a as a scenario of "the best estimation" of climatic sensibility and IS92c as scenario of "low" climatic sensibility. The obtained results are shown in Table 4.

According to the six mentioned models of the climate change scenarios during the XXI century the precipitation decreasing will appear in spring, summer and autumn, while in winter it will increase. The most significant changes will appear during the summer periods according to the scenario IS92a (decreasing from −11,8 % to −15% related to the period 1961-1990).

Table 4 Annual air temperature and precipitation change in XXI century

Year	IS92a						IS92c					
	Temperature[°C]			Precipitation [%]			Temperature [°C]			Precipitation [%]		
	L	M	H	L	M	H	L	M	H	L	M	H
2025	0,7	1,0	1,4	-1,0	-1,4	-1,9	0,6	0,8	1,2	-0,8	-1,2	-1,6
2050	1,2	1,7	2,4	-1,7	-2,4	-3,4	0,9	1,3	1,8	-1,2	-1,8	-2,5
2075	1,7	2,5	3,5	-2,3	-3,4	-4,9	1,0	1,6	2,3	-1,5	-2,2	-3,2
2100	2,2	3,2	4,6	-3,0	-4,4	-6,3	1,1	1,7	2,5	-1,6	-2,4	-3,5

Source of data: Hydrometeorological Service of the Republic of Macedonia, 2000

6. HYDROLOGICAL ANALYSES

The analysis of available water resources and estimation of their change in the future have been performed with determination of flow trends for the surface watercourses and with trends of water levels for the natural lakes for the period 1951-2000.

Average flow for river Vardar-Skopje, Figure 1, for the period 1971-1980 is 64,56 m^3/s, for 1981-1990 it is 53,61 m^3/s, and for 1991-2000 it is 46 m^3/s. Presented in percentage average ten years flows have reduced for 14%-17%. The analysis of maximum annual flows also has shown the explicit reduction. For example, within the decade 1961-1970 the maximum occurred flow is 1.080 m^3/s in 1962, while in the following decade 1971-1980 maximum occurred flow is 983 m^3/s in 1979, and in the next decade 1981-1990 it is 404 m^3/s. In the last decade, maximum occurred flow is only 226 m^3/s. Presented in percentage, maximum flows in river Vardar within the period 1961-2000 have reduced for 79%. If presented trends continue in the future, the following conditions can be forecasted: in 2050 average flows will be reduced to 20 m^3/s, and maximum to only 85 m^3/s. Regarding the low water periods, that is minimum flows, small oscillations are noticed and trend lines are with small gradients. Registered minimum flows in the observed period are within the range (5,20-8,50) m^3/s.

For river Strumica - Sushevo, Figure 2, a very bad hydrological condition can be stated. Minimum flows are within (0-0,5) m^3/s limits for the observed period. Average flows are: 2,11 m^3/s for 1961-1970, then 1,84 m^3/s for 1971-1980, for 1981-1990 it is 1,42 m^3/s and for the last decade 1991-2000 is 1,00 m^3/s. With this descending trend, it is expected the river Strumica to be classified as a non-permanent watercourse. Taking into consideration time distribution of hydrological and meteorological parameters in the eastern part of country, similar situations can be assessed for the other watercourses in this region.

For Dojran Lake - Nov Dojran, Figure 3, are shown the characteristic water levels for the period 1951-2000. Small amplitudes of the water levels with continuous descending trend have been noticed for the period 1955-1985. The amplitude for 1956-1980 (24 years) is 219 cm, and for 1984-1995 (11 years) the amplitude increases to 411 cm. It can be concluded that the amplitude increases proportionally almost twice, with double reduction of the time period. Average and minimum water levels have same descending trend that continues in the last five years too. Alarming descending of the level of this natural lake causes ecological catastrophe with largest consequences on the rare species of flora and fauna. Life quality of the people in the region is significantly reduced, and society damages are also presented trough the impact of the tourism which is almost completely shut down.

7. ADAPTATION MEASURES

Until now, change of the climate and its influence on the hydrology and water resources has not been investigated in the Republic of Macedonia. Performed analyses, conclusions and opinions in this project, do not have an ambition either cannot give definite answer to this complex question. Taking into consideration the fact that our meteorological data series are very short or inhomogeneous, that is not complete/reduced, then it is more than obvious that acceptable answers and appropriate solutions for this problem will still be waited for quite a long time.

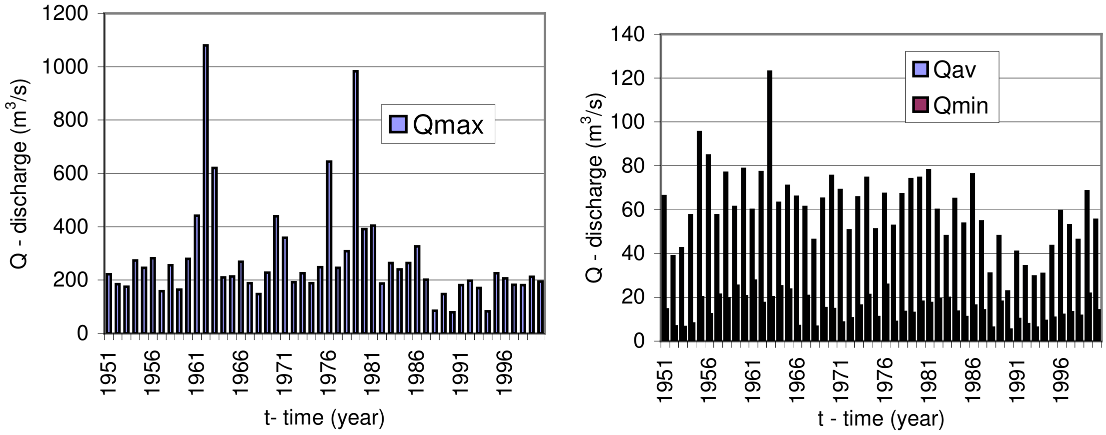

Figure 1. Characteristic discharges for river Vardar in Skopje

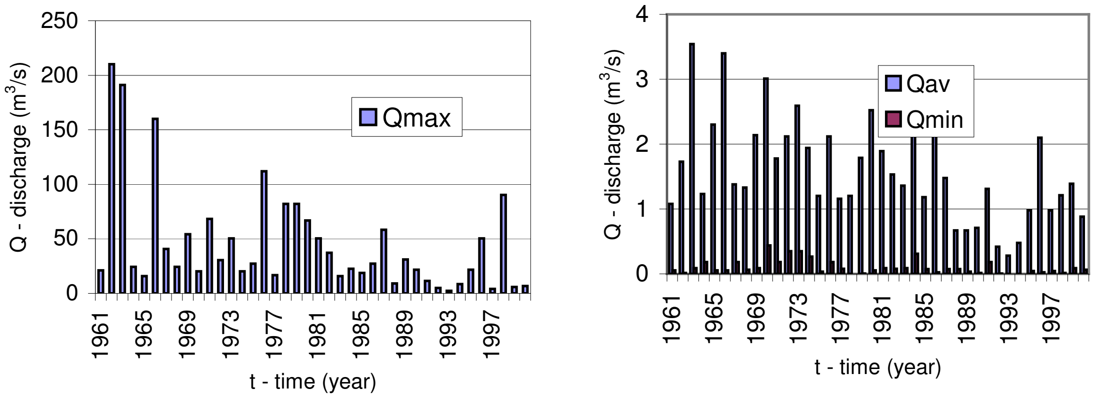

Figure 2. Characteristic discharges for river Strumica in Sushevo

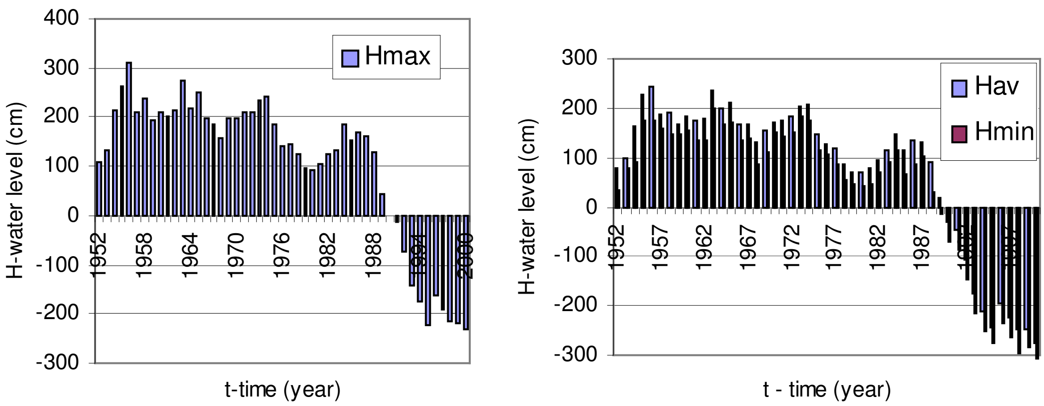

Figure 3. Characteristic water levels for Dojran Lake in Nov Dojran

Recently, different hydrological simulative models that are base for global warmth or so-called “conservatory” scenario have been offered. But it is common impression that all those models are in development stage, and process of calibration and verification is long-term process and requires a lot of information which collecting needs additional investigations, engagement of different funds, and of course new organizational establishment of the authorized institutions. In this sense, investigation initiatives and capacities on national level should be supported by priority. Special attention should be given to more detailed investigation on droughts and floods. In the Republic of Macedonia evidently droughts are more frequent and with longer duration, and floods are with rare re-appearance.

National Action Plan (NAP) for GHG emission abatement has to be elaborated and accepted by the Government of the Republic of Macedonia. The objectives of this plan are: (i) to generate positive effects on national economy, (ii) to minimize the costs of reduction of GHG emissions, (iii) to provide the economy with international competitiveness, (iv) to act appropriately with financial capacities, (v) to achieve reliability and competitiveness in energy supply, food and other strategic resources, (vi) to exercise social fairness and acceptability, (vii) to achieve flexibility and viability of solutions and (viii) to develop medium and long-term solutions. This plan should also present the knowledge in investigation methodologies, measurement techniques, data processing etc. Achievement of those goals of the NAP will help the long-term planning in water resources utilization. Providing of information flow and stable information exchange will be of high significance, as well as the providing of public, professional and open discussion of all partners at stage of different levels such as systemic, institutional and individual.

Within the UNDP activities in Macedonia the project on Vulnerability of the Climate Change and Adaptation Measures has been performed on which base the First National Communication under the United Nations Framework Convention on Climate Change has been prepared. According to this Communication the most vulnerable sectors in the country are: agriculture, forestry, biodiversity, water resources and human health. In water resources sector the adaptation measures have been proposed for the following sub-sectors: hydrometeorology, water supply, sewage, irrigation and hydropower. In Table 5 are listed the proposed measures with estimation of difficulties in implementation marked with **H**, **M** and **L** (standing for High, Medium and Low). Stakeholders with priorities in relevance are listed as well.

8. CONCLUSIONS

The Republic of Macedonia covers only a tiny part of the Globe (only 0,005% of total surface area), its population is neglected small ($2{\cdot}10^6$ as compared with $6{\cdot}10^9$ or 0,03% of the World’s population), and due to its low industrial and other activities (expressed by a GDP of only US$ 800) is a rather small contributor into the global GHG emissions and climate changes. Regardless of its small contribution in changing the global climate, the population of the Republic of Macedonia experiences the full extent of the climate worsening consequences. This fact pinpoints why Macedonia should undertake measures against climate changes: as a member of the international community it is its duty to contribute in preventing further climate deterioration.

Present status of the vulnerable sectors in the country is different according to the organizational establishment, management and funding. Basically, the most important for the future activities in implementation, research and management in different sectors related to climate change is the reorganisation and modernisation of the hydrometeorological service the status of which is far from being satisfactory. Modernisation and reconstruction of the hydrometeorological network is essential for all other activities. As an addition to this is the fact that out of 110 established hydrological stations on the surface watercourses, only 60% are in function and among them only one on the river Vardar in Skopje is automatic. For groundwater observation 115 hydrological stations have been established, but only 40% are in function and none is automatic. Achieving these goals will lead to the increase of data quantity and quality and further more will improve the human health, the sate of ecosystems and the design and construction of water economy systems. The main constraints are lack of domestic and international funding, lack of inter-ministerial and inter-institutional cooperation and low awareness of hydrometeorological data collection importance. The type of constraints has been estimated on systemic, institutional and individual level. The Government of Macedonia together with the International institutions has to undertake immediately the proposed measures.

Table 5 Vulnerable sectors and adaptation measures

PROPOSED MEASURES	DIFFICULTIES IN IMPLEMENTATION	STAKEHOLDERS
Hydrometeorology ▪ Modernization of hydro - meteorological network ▪ Data monitoring establishment of hydro meteorological and water quality parameters ▪ Implementation of real-time predictive models	**M**	Republic Hydro-meteorological Institute (RHI) Ministry of Agriculture, Forestry and Water Economy (MAFWE) Ministry of Environment and Physical Planning (MEPP)
Water supply ▪ Implementation of dual supply systems for potable and non-potable water ▪ Reduction of water losses especially in urban areas ▪ Rain water collection for non-potable uses	**H**	Communal Enterprises Local Self-Government Ministry of Agriculture, Forestry and Water Economy (MAFWE) Ministry of Transport and Communication (MTC)
Sewage ▪ Construction of waste water treatment plant for waste water purification and their re-use ▪ Water efficient appliances ▪ Use of recycled waters especially in urban areas for street and car washing	**M**	Communal Enterprises Local Self-Government Ministry of Environment and Physical Planning (MEPP) Ministry of Agriculture, Forestry and water Economy (MAFWE) Ministry of Transport and Communication (MTC)
Irrigation ▪ Covering-lining of the open canals ▪ Introduction of drip, micro-spray and other low energy irrigation systems ▪ Night time irrigation ▪ Implementation of the management with the systems ▪ Rehabilitation and completion of the systems ▪ Implementation of new technologies	**H**	Public Water Economy Enterprises (PWEE) Water management Organizations (WMO) Ministry of Agriculture, Forestry and Water Economy (MAFWE)
Hydropower ▪ Construction of additional reservoirs ▪ Introduction of more efficient turbines ▪ Implementation of management with the systems	**M**	Electric Power Company Ministry of Economy (ME) Ministry of Agriculture, Forestry and Water Economy (MAFWE)

Main purpose of the proposed measures for water resources adaptation with the constructed and/or required infrastructure in the Republic of Macedonia is to reduce the water losses in conditions of climate changes, various in time and space. Studies for evaluation of the river basin's sensitivity and water balance components under different scenarios of unfavorable climate impacts are necessary. For measures implementation, previous identification of the endangered regions is required as well as carrying out of the law regulation for utilization and maintenance of the structures and systems for water resources utilization under conditions defined in the National Action Plan. Beside this education public awareness is required.

In the sector of water resources some constraints have been identified and mainly their type is address to institutional level. The need for quick and almost general implementation of the management with the water economy systems will lead to lower the water losses, energy consumption and air and water pollution. This sector has to improve the regional cooperation, the income of foreign investments and the fee collection rate.

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KLIMATSKE PROMENE I NJIHOV UTICAJ NA VODNE RESURSE

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R e z i m e

Klimatski sistem zemlje, globalno i lokalno, očevidno je promenjen od pre-industrijskog perioda do danas. Neke od nastalih promena su rezultat prirodnih fenomena, a neke ljudskih aktivnosti gde krucijalni udeo ima emisija takozvanih "stakleni gasovi". Najveća koncentracija ovih gasova je izmerena 1990 godine. Od dosadašnjih observacija došli smo do slike sveta koji se globalno zagreva. Observacija klimatskih promena i njihov uticaj na različite sektore trebaju se kvantificirati za različite regione. Saglasno ovome, Republika Makedonija je ratifikovala Konvenciju za klimatske promene (Rio, 1992) i 2002 pripremila prvu nacionalnu komunikaciju za klimatske promene za sektore: energija, poljoprivreda, šumarstvo, biodiverzitet, hidrologija i vodni resursi i zdravstvo. U ovom radu su prezentirani neki rezultati od analiziranih klimatskih promena u sektoru hidrologija i vodni resursi sa predloženim merama za adaptaciju.

Ključne reči: klimatske promene, hidrologija, vodoprivreda, vodni režimi, mere za adaptaciju, ekosistem, osetljivost

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