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ECOLOGICAL AND HYDROLOGICAL STATE OF DOJRAN LAKE

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ABSTACT

In the Republic of Macedonia there are three natural lakes: Ohrid, Prespa and Dojran. Of these the Dojran Lake is the smallest, but not less significant as a water resource and as a scenic beauty. In the course of the last 15 years this site of natural heritage is threatened because the lake's water level decreased seriously. The watershed area of the lake and the lake itself are shared by Macedonia and Greece. Recharge of the lake comes from direct runoff, small tributaries and groundwater. Since 1988 the lake surface area decreased from 42 km^2 to 31 km^2, and more significantly, and the water volume dropped from 262 million m^3 to only 80 million m^3 in 2000.

The decline of water quantity together with the simultaneous deterioration of water quality resulted in serious ecological impacts. Biodiversity diminished and the reduction of plankton led to a reduction of fish portion. The number of birds also decreased dramatically. The attack on the ecosystem had a harmful impact on the economy in the region. Tourism that had been the most important economic sector almost completely stopped, and in 2000 barely attained one tenth of the level of the eighties.

Various efforts were initiated in Macedonia to improve the quantity and quality of this water resource. In order to reduce the inflow of polluted waters into the lake a sewage collector system was built along the lake shore. Also, formerly intensive groundwater extraction for irrigation has strongly been reduced, the irrigated areas being converted into rainfed farmland, provided with drip irrigation systems as appropriate.

Despite the efforts at the Macedonian side, the Dojran Lake did not recover. Therefore, water transfer from the neighboring watersheds in Macedonia has been considered, such as transfer of surface water from the river Konska and transfer of groundwater from wells in the Vardar River terraces. In spite of divergent experts' opinions about these one-sided actions, the second of the planned transfers was realized.

It is rather difficult to decide how much the present state of the lake was caused by hydrology and climate, or how much is it due to some other not clearly identified causes, including human activity. The paper presents hydrological and meteorological analyses of the Dojran Lake based on the data collected at the meteorological station of Novi Dojran, with a critical evaluation of their quantity and quality. The intention of the authors was to demonstrate the vulnerability of lake water and its biodiversity, and to invite support of the international community to launch joint projects and actions both in Macedonia and in Greece.

Key words: hydrology, water level, rainfall, temperature, evaporation

INTRODUCTION

Dojran Lake is a tectonic lake situated in the Balkan Peninsula in southeastern part of the Republic of Macedonia at an average altitude of 148 m a.s.l. The watershed of the lake belongs to the river basin of Vardar that gravitates towards Aegean See.

The lake was formed in a karstified basin created by combination of Tertiary volcanic and tectonic activity. The sediments of the lake watershed are composed of mineral-rich ancient alluvial and limnic sediments. Because of its geotectonic location and climate characteristics, Dojran Lake has a very rich biodiversity. Main economy in the region is tourism and fishery.

Today these activities are almost non-existent due to the environmental catastrophe that last over ten years. The lake and its biodiversity are influenced by uncontrolled human activities and climatic inconveniences as well. Due to these main causes the result is rapid and large water level decrease. Since 1988 the lake is facing the extreme water level and water volume decrease. From 262 million m^3 in 1988 the volume has decreased to only 80 million m^3 in 2000. According to the biologists over 140 species of flora and fauna have disappeared. Regarding that the watershed and the lake are shared by two countries, joint planning and decision-making is very poor although considerable efforts on problem definition have been made.

In 2000-2001 UNESCO and the Ministry of Environment and Physical Planning of the Republic of Macedonia have funded and realized the project titled: Feasibility Study on Dojran Lake Salvation. In 2002-2003 within the UNESCO Programe was executed a project titled: Sustainable Management in Dojran Lake Catchment - Campaign for Rehabilitating Dojran Lake. For the results of already undertaken activities has to be wait, but knowing that these activities were one sided, it is easy to understand that the ecosystem will not be save in near future. Up to now, the financial resources of the international institutions and Macedonian Government have been mobilized on monitoring and water recharge from the wells system in Gjavato.

LAKE BASIN CHARACTERISTICS

Dojran Lake is the smallest tectonic lake in Macedonia. The size and location of the lake is shown on the map in Figure 1. The geographic longitude of the lake is N41°23' and the latitude is E22°45'. On the north the lake is surrounded by the mountain Belasica which top is Dzami Kran (1198 m a.s.l.).On the west is Gevgelija-Valandovo valley disposed along the Vardar River on which west side is the mountain Kozuf with the top Dve Usi (1766 m a.s.l.). On the southeast part on Greek territory is mountain Disoro (860 m a.s.l.). The average altitude of the watershed is 148 m a.s.l. and only a small part, about 50 km^2 or 18% is located at altitude higher of 500 m a.s.l. Total watershed area is 271.8 km^2 out of which 92.1 km^2 or 32% belongs to Macedonia. Water surface area of the lake at normal level (147.34 m a.s.l.) is 42.2 km^2 out of which 27.1 km^2 or 63.6% belongs to Macedonia. The volume of the lake at normal level is 262 million m^3 with average depth of 6.5 m (maximum depth is 10.4 m). The maximum length of the lake is 8.9 km and the maximum width is 7.1 km.

Figure 1. Map of Dojran Lake and its watershed

Dojran Lake valley together with Gevgelija-Valandovo valley is one of the warmest in this part of the Balkan. The precipitation and temperature regime has been analyzed within the period 1961-1990 with data for the meteorological station at Nov Dojran. Precipitation and temperature regime mainly are under the Mediterranean influence from Aegean See. This influence causes the maximum precipitation in cold part of the year (28% of annual sum) and minimum precipitation in summer months (17% of annual sum). The average annual long-term precipitation sums for the meteorological station at Nov Dojran are presented in Figure 2. The average annual precipitation sum for the observed period is 623,4 mm.

Maximum temperatures appear usually in July and August and the minimum ones are in January and February. The average long-term monthly temperatures and the average long-term monthly rainfall sums for the period 1961-1990 are presented in Figure 3.

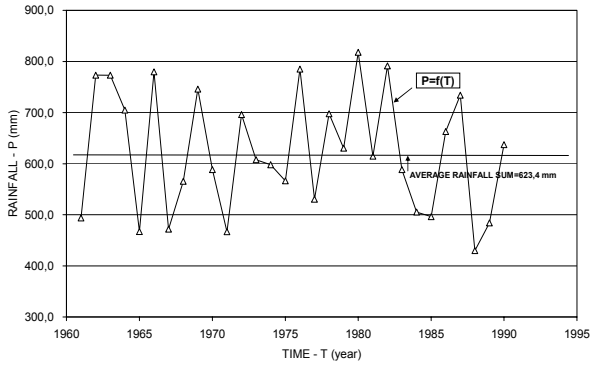

Figure 2. Average long-term annual precipitation sums

Relative humidity in Dojran Lake valley in summer period is 60% and in winter months up to 80%. The highest frequency of 319% has the wind from northwest direction, while the average annual calm is 525%. The average wind speed is 3.8 m/s. Basic wind characteristics obtained with data from meteorological station at Nov Dojran are presented in Table 1.

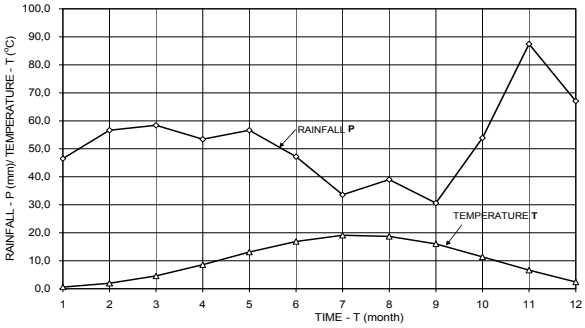

Figure 3. Average long-term monthly temperatures and rainfall sums

Table 1. Basic wind characteristics

Direction	N	NE	E	SE	S	SW	W	NW	C
Frequency [‰]	13	6	89	18	24	1	5	319	525
Wind speed [m/s]	3.2	2.1	2.6	2.0	2.1	1.4	2.0	3.8	-
Boffor scale	9	6	9	8	8	5	7	10	-

The average annual sunshine is 2440 hours or 6.6 hours daily. The maximum sunshine is in July with 330 hours or 10.6 hours daily and the minimum is in January with 90 hours or 3.0 hours daily. According to the very high annual sunshine and to a very small lake depth it can be expected a very high annual evaporation from lake water surface that is also disturbing the water balance of the lake. The computed evaporation from lake water surface by the formulas of Penman, Rohwer and Meyer are presented in Table 2. The average long-term monthly temperatures for the period 1961-1990 observed at the meteorological station Nov Dojran have been used. The computed evaporation *E* in (mm) varies from 907 mm (Penman) to 1179 mm (Rohwer).

Table 2. Evaporation from surface water

Months	Temperature T (^oC)	Penman E (mm)	Rohwer E (mm)	Meyer E (mm)
Jan.	0.6	33.03	74.52	61.92
Feb.	1.9	27.86	39.91	34.97
Mar.	4.6	46.84	49.01	43.47
Apr.	8.6	74.64	71.20	66.95
May	13.1	110.23	96.71	91.90
Jun.	16.9	139.18	152.47	143.37
Jul.	19.1	161.76	217.19	195.07
Aug.	18.7	136.27	178.45	169.58
Sep.	16.0	88.22	127.45	125.15
Oct.	11.4	48.52	77.44	72.76
Nov.	6.7	24.28	52.06	46.10
Dec.	2.4	16.40	42.85	35.61
Sum		907.22	1179.56	1086.85

Penman $$E = (\frac{\Delta}{\gamma} H + E_a)/(\frac{\Delta}{\gamma} + 1)$$

Penman equation defines the evaporation E with the following parameters: E_a - aerodynamic parameter that includes wind speed and air humidity deficit, Δ-constant parameter computed with air temperature T, H - total heat, and γ - constant (γ = 0.485 mmHg/^{o}C). The total heat H is a function of the reflection r, of sun radiation R_i and earth radiation R_o, $H=R_i(1-r)-R_o$.

Rohwer $$E = 0.484(1 + 0.6w)(e_w - e_a)$$

The parameters in Rohwer formula are: w - wind speed, e_w - maximum vapor pressure at temperature T, and e_a - real vapor pressure.

Meyer $$E = 15F(1 - \frac{U}{100})(1 + 0.225w)$$

The Meyer formula computes the evaporation with the following parameters: F - maximum vapor pressure that depends on temperature T, U - relative humidity, and w - wind speed.

WATER LEVEL ANALYSES

The analyses of water levels in Dojran Lake is carried out with the observed data at water gauge station at Nov Dojran. The average monthly data on maximum, average and minimum water levels in (m a.s.l.) for the period 1952-2002 are presented in Figure 4. It is obvious that very strong water level decreasing trend of Dojran Lake has started in 1988. Therefore, the total data series can be divided into the following two time sub-sets: 1) 1952-1987 and 2) 1988-2002. The amplitude of maximum water level for the first time sub-set is 148.06-145.85=2.21 m which defines the average water level decrease of 6.31 cm annually. For the first time sub-set it can be noted pretty regular water level oscillations which maximum and minimum appear every 5 year.

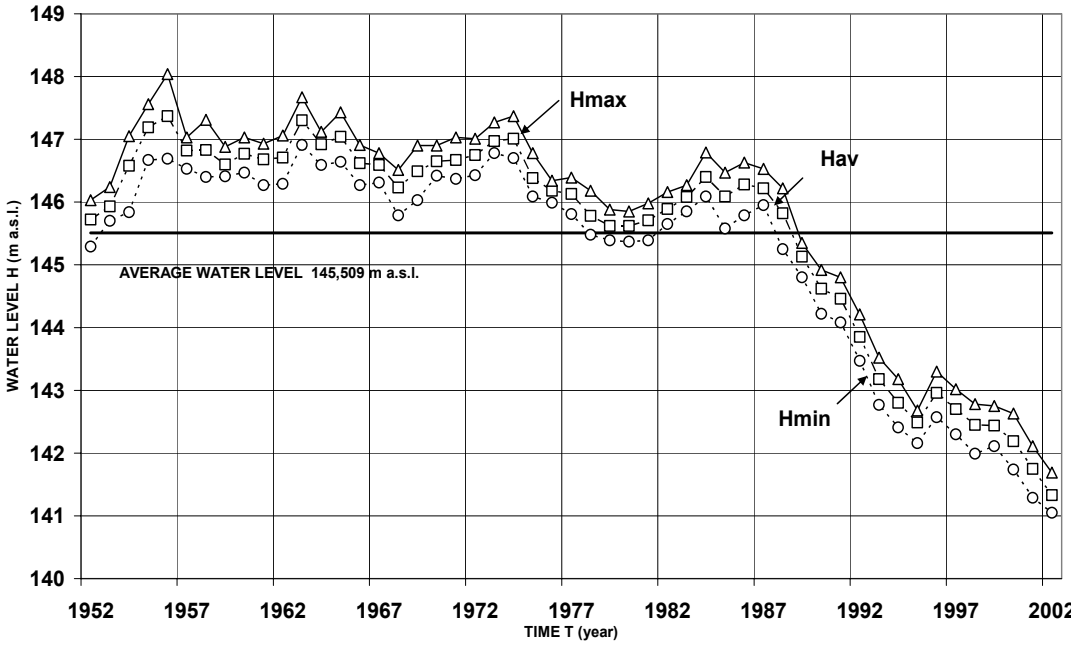

Figure 4. Minimum, average and maximum water levels for Dojran Lake at Nov Dojran

For the second time sub-sets the amplitude of maximum water level is 146.79-141.69=5.10 m which results the average water level decrease of 34.0 cm annually. This decreasing trend is alarming most of all because the causes have not been recognized clearly yet. It is most probable that drastic water level decrease within the period 1988-2002 might be a result of uncontrolled anthropogenic activities and partly due to the long draught period. The anthropogenic activities are mainly connected with water use in irrigation sector.

The water level trend in Dojran Lake can be discussed and with the average monthly water level oscillation within one year. Unfortunately it was not possible to obtain long-term monthly data. Therefore, this analysis is carried out with monthly water level data only for three years: 2000, 2001 and 2002. The observed average water levels are presented in Figure 5. The amplitude of water level oscillation in 2000 is 142.59-141.75=0.84 m, in 2001 is 142.08-141.32=0.76 m and in 2002 is 141.56-141.08=0.48 m. From the presented graphs it is obvious that the maximum average water level appears usually in May and the minimum usually in November and December. The exception is 2002 when the maximum water level appears in December. This is most probably due to the additional inter-basin water transfer from Gjavato wells into the lake and partly due to the rainfall increase. The increase of rainfall can be referred to the start of wet period in 2002 that last even today. Another word, this effect is not a natural regime and can not be taken as a normal long-term monthly water level oscillation.

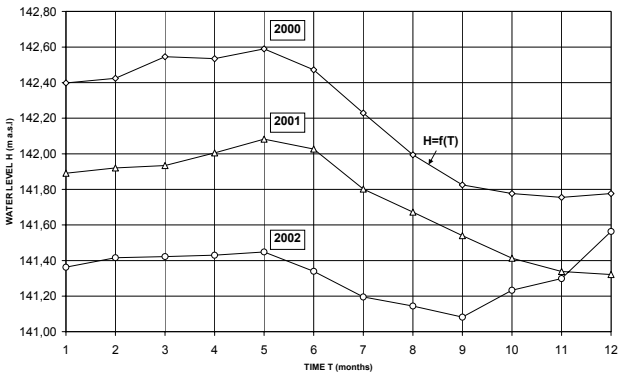

Figure 5. Average monthly water level at Nov Dojran

CONCLUSIONS

Dojran Lake is one of the three tectonic lakes in the Republic of Macedonia. According to the size this lake is the smallest one but no less significant by natural beauty and rear species of flora and fauna. Last decade Dojran Lake is facing the ecological catastrophe due to a rapid water level and volume decrease. The basic economy in the region, tourism and fishery, has stopped almost completely. Since 1988 the observed water levels in the lake are in permanent decreasing trend. In 2002 the registered decrease was over 5 m that is over 34 cm annually. This water level decrease resulted with water withdraw from the shore of over 200 m and volume lost from 260 million m^3 to only 80 million m^3.

The climatic characteristics also have impact on hydrology of Dojran Lake. In this region the average long-term precipitation sum is something over 600 mm annually that is less then in the other regions of the country (for example in Prespa region is over 700 mm, in west part over 1000 mm etc.). The temperature regime is the warmest in the country that results with very high evaporation from free surface. The evaporation is almost two times greater of precipitation. This is due the temperature regime and due to the very small depth in the lake.

The Ministry of Agriculture, Forestry and Water Economy, the Ministry of Environment and Physical Planning of the Republic of Macedonia together with the non-governmental ecological organizations have animated the domestic and international professionals by informing on the problem and undertaken some one-sided activities through preparation and realization of projects on lake salvation. Most of the projects were focused on biodiversity issue and only one deal with technical measures for delivering additional water quantities from Gjavato wells that are located in the direct river basin of Vardar. Realization of this project together with a convenient hydrological condition in 2004 resulted with partly increase of water level for the first time within the past period of 15 years.

The authors would like to stress out the necessity of more intensive cooperation between the authorized institutions in both countries that share the lake basin and the lake itself. The international community and the financial mechanism should help the both countries in improvement of hydrological, water quality, water use and meteorological monitoring in the lake basin that will lead to better environment. If this will not be done in a very near future no doubt Dojran Lake will reach the point of no return.

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EKOLOŠKO I HIDROLOŠKO STANJE DOJRANSKOG JEZERA

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Rezime

Republika Makedonija ima tri prirodna jezera: Ohridsko, Prespansko i Dojransko. Najmanje je Dojransko, ali nije malo ni kao vodni resurs, ni kao prirodni raritet. U poslednjih 15 godina to prirodno bogatstvo je ugroženo zbog veoma značajnog opadanja nivoa vode. Sliv i jezero su podeljeni između Makedonije i Grčke. Dotok u jezero nastaje od padavina, od dotoka malim vodotocima, i od podzemnih voda. Od 1988. godine vodena površina jezera smanjila se sa 42 km^2, na 31 km^2, dok se zapremina smanjila sa 262 miliona m^3 na samo 80 miliona m^3 (u 2000 godini).

Tako veliko obarenje nivoa jezera, zajedno sa narušavanjem kvaliteta vode u njemu, izazvali su veoma ozbiljne ekološke posledice. Smanjeni su biodiverziteti, a smanjenje planktonskih organizama dovelo je do osiromešenja ribljeg fonda. Iščezao je i veliki broj pričjih vrsta. Uništenje ekosistema jezera ima teške posledice i na celokupnu ekonomiju regiona. Turizam, koji je bio primarna privredna grana, danas je sasvim zamro, tako da je u 2000 godini bio samo deseti deo od onog iz osamdesetih godina prošlog veka.

Makedonija je uložila značajne napore da poboljša količinu i kvalitet tog vodnog blaga. Da bi se smanjilo zagađenje jezera izgrađen je kanalizacioni sistem duž obale jezera. Takođe, značajno su smanjene količine vode koja se troši na navodnjavanje u slivu, na taj način što se prešlo na navodnjavanje metodom "kap po kap". Međutim, i pored uloženih napora sa strane Makedonije - jezero još uvek nije spaseno. Zbog toga se čine dodatni napori, uz razmatranje alternativa - dovođenje dopunske količine površinskih voda sa Konjske reke, ili dovođenje zahvaćene podzemne vode iz jednog aluviona podzemnih voda kraj reke Vardar. Bilo je oprečnih mišljenja eksperata o tim jednostranim rešenjima, ali se resorno ministarstvo opredelilo za drugu soluciju, koja je i realizovana.

Sada je dosta teško razgraničiti koliko na sadašnje loše stanje jezera utiču hidrološka stanja i klimatske karakteristike u regionu, a koliko utiču drugi nedovoljno jasno determinisani razlozi (među njima i uticaj ljudskih aktivnosti). Članak razmatra hidrološke i meteorološke analize ponašanja Dojranskog jezera, na bazi podataka meteorološke stanice u Novom Dojranu. Daje se kritički osvrt na obim i kvalitet raspoloživih podataka. Osnovna namera autora je bila da ukažu na veliku ranjivost tog prirodnog jezera, njegovih biodiverziteta, i da inicira hitnu i snažnu podršku međunarodne zajednice za izradu odgovarajućih projekata i preduzimanje zajedničke akcije obe strane - Makedonije i Grčke.

Ključne reči: hidrologija, padavine, vodostaji, temperature, isparavanja, biodiverziteti

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