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The Emerging Flood Risk on the Lower Part of Transboundary Meric/Maritsa River Basin

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Abstract
Meric (Maritsa, Evros) River is not only a transboundary river but also a border river among Turkey, Bulgaria and Greece. 65% of its catchment area is within the borders of Bulgaria. A portion of the lower part of Meric River constitutes the Turkey-Greece border, and the other portion of it flows in Turkey. The effects of global climate change are observed in the Meric River Basin. The changes on precipitation and temperature over the upper part of Meric River Basin situated in Bulgaria cause major problems in the lower part of the river basin in Turkey. Climate changes that have occurred in Bulgaria and projections on climate change over region, the Maritsa River water management approaches. Turkey has constructed a bay pass channel to protect Edirne city and surrounding agricultural lands from transboundary floods. This by pass channel is 7,8 km long 50 m width and 4 m depth has been almost completed. This channel capacity is about 1000 m3/s. This channel together with the original river bed will transmit flood discharge to Meric River bed about 7,5 km downstream of the Edirne City. Although it is completed recently, Lower Part of the Meric Basin is still under the flood risk and flood problems such as deterioration of water quality, ecosystem problems and socio-economic problems of the local population. Prevention and/or mitigation of these problems depend on the effective implementation of integrated transboundary watershed management strategies in the joint coordination among Turkey, Bulgaria and Greece. In this study we aim to investigate flood risk on the Lower Part of the Maritsa River Basin and necessary measures need to be taken in both side of the river. In this context, we also focused on hydrographic effect of Edirne By pass Channel, as well as run off from inter basin (Byala River-Greece) to the Lower Part of the Meric River and raising awareness on the importance of a basin wide flood management project. Altough Turkey implemented a by-pass channel to protect the Edirne city from transboundary floods of Meric River, additional measures such as basin wide flood management project , need to be taken to protect both side of the river bed in the lower part of the basin.

Keywords: Edirne by Pass Channel, Maritsa Floods, Maritsa Basin, Lower Maritsa Basin.

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1. Introduction

The Maritsa/Meric River is the largest river in the Balkan Peninsula. It originates in Bulgaria, and mark the border between Turkey and Greece. Intensive agriculture is widespread within the Maritsa basin. The basin is also highly industrialized and densely populated with the largest cities. Close to Edirne, the Maritsa's two largest tributaries, the Tunca and Arda, join the main flow of the Maritsa/Meriç. Throughout the Maritsa/Meric catchment area a significant number of reservoirs and weirs have been constructed for irrigation and hydroelectricity production purposes.
The Meric (Maritsa, Evros) River is one of the most important drainage systems of the Balkans. It has a

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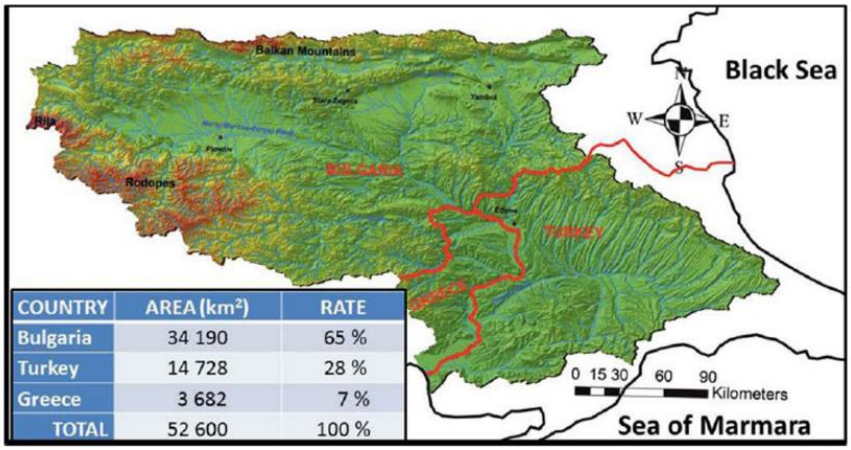
basin of 52.600 km^2 that stores water and its length is 550 km. The Meric River stems from the Rhodope Mountains (Rila, 2925m) in Bulgaria and Tunca River, Arda River and Ergene River form its sub-basin (Fig. 1a). The Meric River is fed by rain and snow melt. Climatic characteristics are important for the river's flow rate and regime. Although the river flows throughout the year, it is possible to observe flow rate shifts depending on the temperature and precipitation features of the river Basin.
Meric Basin lies within the territories of three different countries. It both flows beyond the borders and sets the borders. The flow rate and regime characteristics are controlled by multiple dams in Bulgaria, and weather conditions are other important features of the river. The river is also important for agricultural activities in all three countries. It is possible to observe hydrological drought and floods in the lower Meric River Basin in particular periods of a year.
Most of the Meric River basin is in the territory of Greece and Bulgaria. The biggest major branches of the river are the Arda and Tunca Rivers. Meric, Arda and Tunca Rivers being born in the territory of Bulgaria. The annual water potential in Edirne where the river enters Turkey, in Arda 1 085 hm^3, Tunca 673 hm^3. After combining these rivers the annual water potential of Meric River is 5 842 hm^3. The total length of the Meric River is 492 km. This length is 305 km long in Bulgaria, 12 km. The other 175 km marks the Turkish-Greek border.
Climate change and misoperated dams induced floods have occurred frequently in the Lower Meric Basin since last 20 years. It created serious flood problems in the parts of the Meric basin lies in Turkish and Greek territory (Fig. 1a).



COUNTRY	AREA (km²)	RATE
Bulgaria	34 190	65 %
Turkey	14 728	28 %
Greece	3 682	7 %
TOTAL	52 600	100 %

Figure 1a. The Meric River drainage system and basin.

1.1 Extreme Flow Problems in the Lower Meric River Basin
Extreme flow rate problems have always been witnessed in the Lower Meric River Basin. Changes on the frequency and severity of floods were observed in the historical period. Ascending and descending extreme flow rate problems and their impacts have been felt in critical rates during the 2000s.
The Arda River and the Tunca River sub-basins connect to the Meric River in the vicinity of Edirne City. The water of these sub-basins forms a substantial water body on plain areas in times of extraordinary rain. Existing bed of the Meric River cannot carry this amount of water. The huge water body accumulated in the river channel overflow destroying the flood embankments along the river, flooding and ponding into the environment. Disasters caused by floods have frequently happened in Edirne since 2000's. These catastrophes in the lower river basin were caused by nature related reasons such as climate changes, drainage systems, and topographic characteristics. However, in the occurrence of the recent floods, dam operation factor plays an important role in addition to the natural reasons.

1.2 Turkey Built a by Pass Channel to Protect Edirne City and its Territories
Flood protection measures in Turkey have become an urgent matter and Turkey has decided to take its own measures. Turkey built a bypass channel to protect Edirne City and agricultural lands (Fig. 1 b)

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Figure 1b. Bypass Channel and Meric River.

Floods in the Maritsa River over the last 15 years have caused significant damages in Turkey and Greece. Total economic loss calculated at more than 300 million Euro.
Extreme precipitation, snowmelt and water released from Bulgarian dams are the most frequent causes of flooding in the downstream city of Edirne. But it is unfortunate that the three riparian state (two of which are currently members of the EU) have not taken any basin wide flood management measure to prevent the floods collaboratively. A basin-wide flood protection cooperation between the riparian states hasn't been achieved. So far, the three countries have only been able to establish a 'flood early warning system' in the basin through a recent EU project. This system has allowed the reduction of casualties but has not prevented very serious economic losses and social problems resulting from large floods.

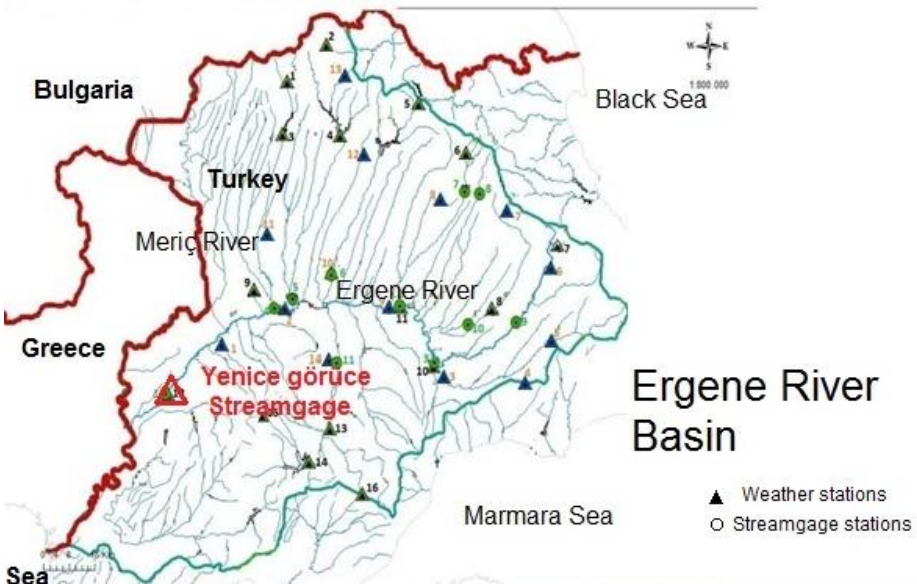

Figure 2. Ergene River Basin.

Scientific researches showed that floods might have been prevented with proper implementation and operation of Bulgarian dams. The same research also indicates that improper operation of the dams resulted in artificial floods or overflows. Therefore it is essential for Bulgaria, Greece and Turkey to cooperate in the planning of flood prevention and protection measures together. Dredging in the especially Lower Part of Maritsa River is also important. Basin wide preventive and protective measures

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are extremely needed. The Turkish and Greek reaches of the river basin are located almost at sea level, therefore they are not suitable for efficient engineering measures for flood prevention. Flood control measures in the lower basin may be insufficient.
Even Turkey has completed recently a bypass channel for a protective measure, Turkey and Greece still need basin wide preventive flood management not to be flooded in the lower part of the Meric Basin.

1.3 Ergene River Basin
Meric-Ergene basin is one of the 25 main river basins of Turkey. Ergene basin, located in Meric-Ergene basin, has 7 sub-basins and has a precipitation area of 11.000 km^2. (Fig. 2). Total streamflow of the basin has been measured in Yenicegörüce Stremgage station (Fig. 2). Daily flows measured in this station is given in Fig. 3 and Fig. 4.

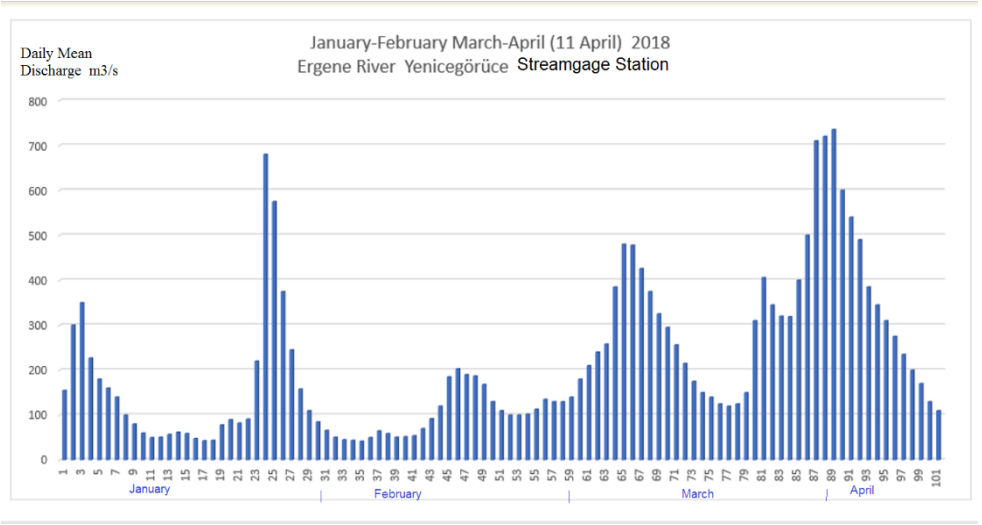

Figure 3. Daily mean discharge in Ergene River (2018).
Source : http://edirnenehir.dsi.gov.tr/

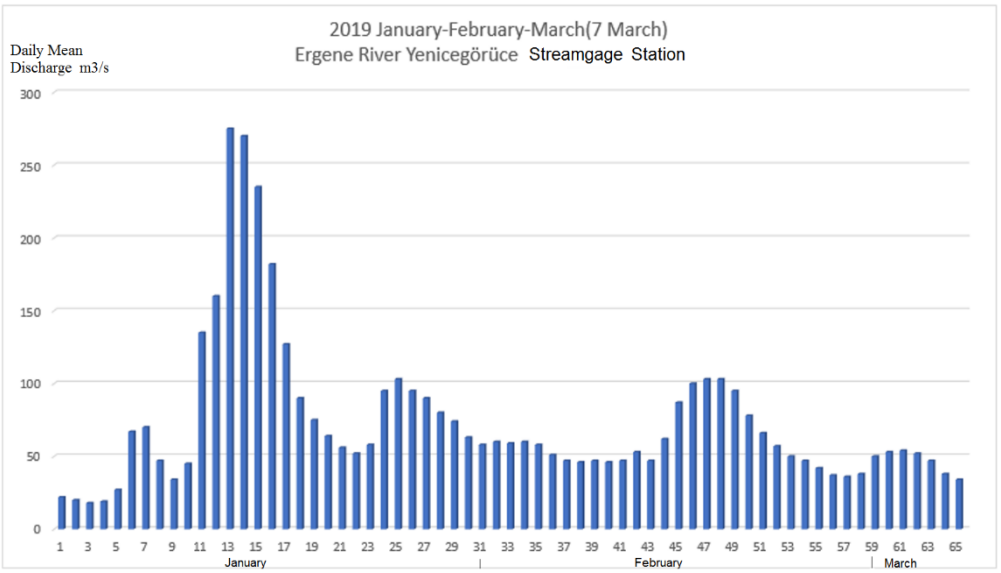

Figure 4. Daily mean discharge in Ergene River (2019).
Source: http://edirnenehir.dsi.gov.tr/

As shown In Fig.3 , in January 2018 and March 2018 discharge in Ergene river has been measured between 500 m^3/s and 720 m^3/s in eight times. This shows us the Ergene River could bring more than 500 m^3/s discharge potential to Main Meriç River during one week in a year.

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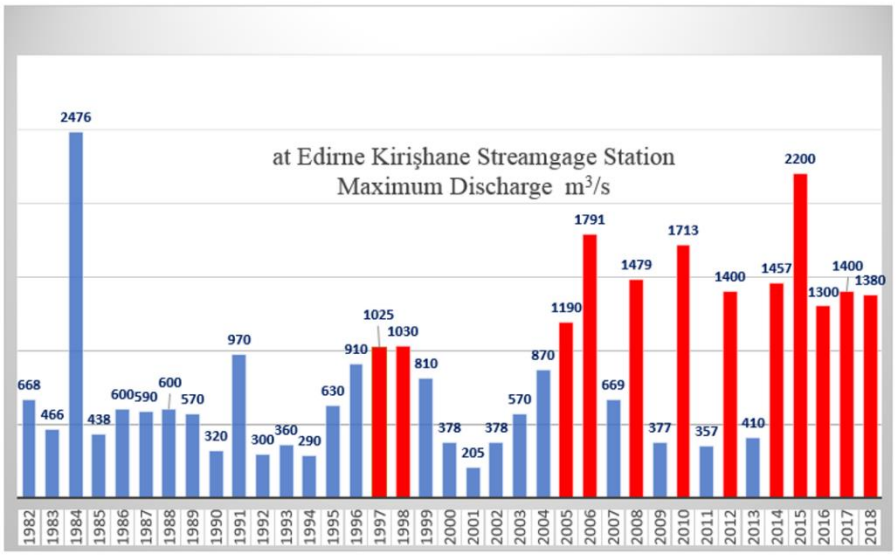

Figure 5a. Maximum discharge measured at the Edirne Kirişhane Streamgage Station.

Fig 5a shows us flood discharges measured at the Edirne City has increased dramatically. They were mostly more than 1200 m^3/s since last 13 years. This figure indicates us in each year as of 1500 m^3/s as a maximum average discharge in Meric River at Edirne, is highly probable. In general, the flood comes in February and March as it is seen in the same period in Ergene River.

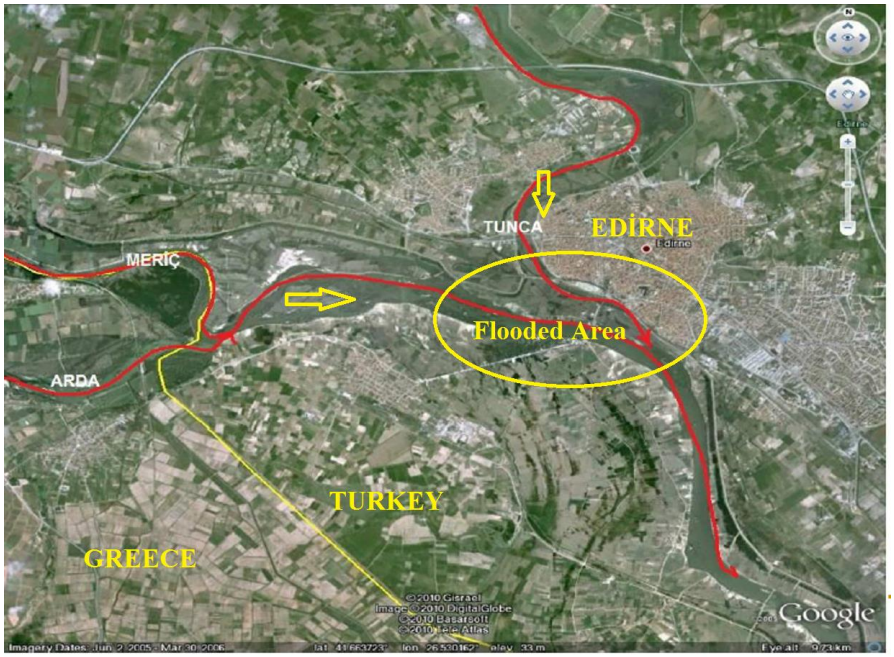

Figure 5b. Meric, Arda and Tunca Rivers crossroad and Edirne City.

2. Study Area

In this study, the area to be focused is given in Fig. 6. This area is selected after the Ergene River entrance point to the Meric River. After this point flood risk is getting higher with the accumulation flash floods comes from Ergene river basin as well as the basin between Edirne and İpsala both in Turkey and Greece.

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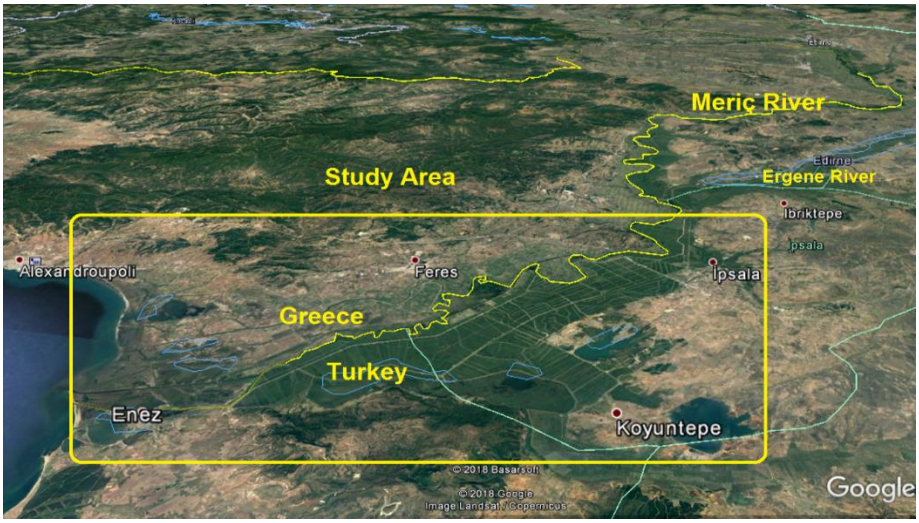

Figure 6. Study Area.

The evaluation of Ergene Basin on line discharge data accessible from the DSİ web site shows an emerging flood risk in the lower part of the Meriç Basin. In addition to the flood discharge that will be transmitted with bypass channel in a shorter period of time, serious amount of extra flood discharge could also come from these two sub basins.

New bypass channel will transmit the flood discharge safely up to 1000 m^3/s to the downstream. It can rise up to 2000 m^3/s together with the original river bed of the Meriç. Analysis of on line discharge data obtained from the İpsala, Kirişhane and Yenicegörüce (Ergene basin) streamgage stations showed that area flooded in 2006 with 2632 m^3/s is still under the risk. In this context the Lower part of the Meriç Basin was studied by Sönmez at all (2013). Sönmez at all (2013) made a very comprehensive and valuable study to explore possible area that will be flooded by different flood discharges in the lower part of the Meriç River Basin

In this study, the model which was created by using HEC-RAS program was calibrated with the data obtained from the flood occured in the year of 2006.Using this model they explore the **inundation maps** that shows where flooding would occur for 1000, 2000, 3000, 4000, 5000 and 6000 m^3/s. Stream condition in the lower part of the Meriç Basin.

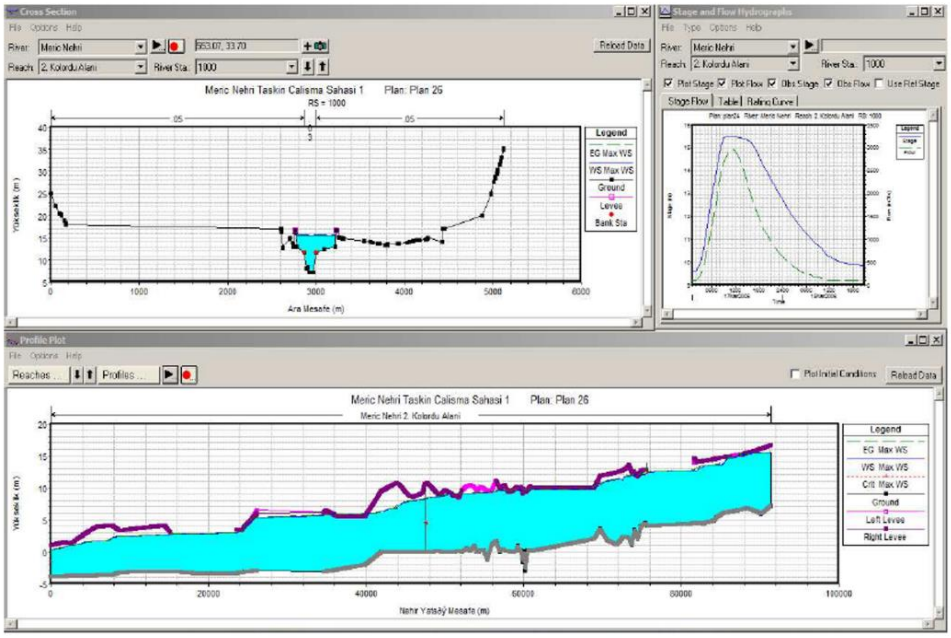

Figure 7. Maximum water elevation during the flood in Meric River (Sönmez at all 2013).

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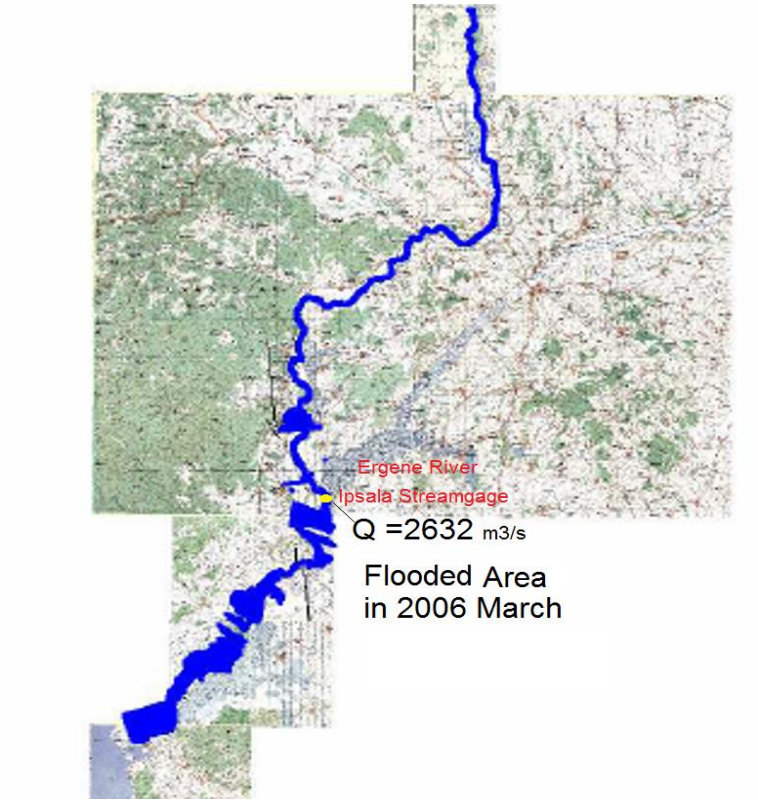

Figure 8. Flooded Area in 2006 March (Sönmez at all 2013).

3. Expected Challenges in the Lower Meric Basin

The climatic characteristics of the Meric River Basin vary due to variation in temperature and precipitation from year to year. This change becomes apparent because of temperature rise and variation in precipitation regime, and causes changes in the flow and regime characteristics of Meric River in a negative way.

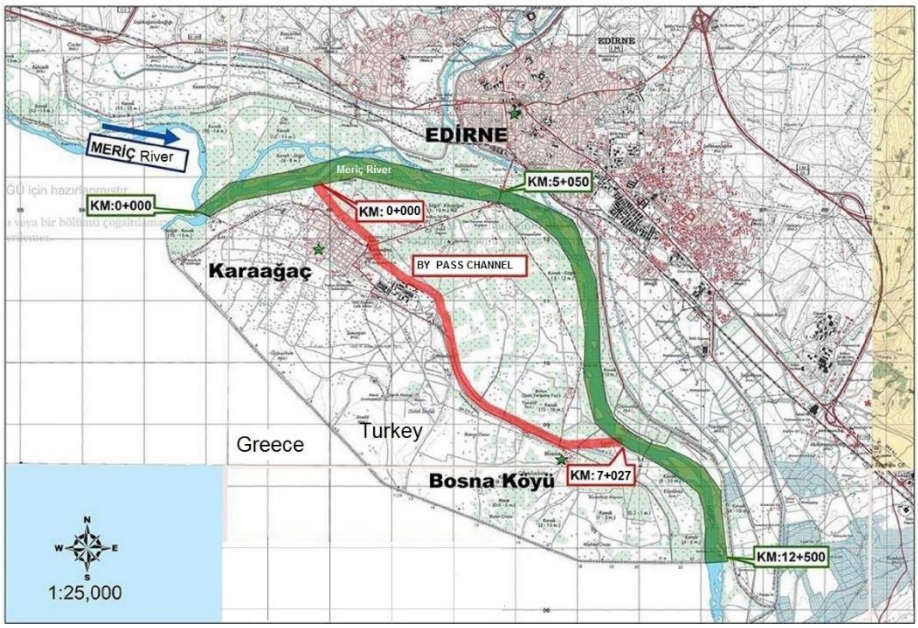

Figure 9. Completed Bypass Channel and Meriç River bed in the vicinity of Edirne City.

The effects of temperature and precipitation variations in the Upper and Lower Meric Basin requires

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more attention to prevent floods. The more frequent and sever floods have created deterioration of the water and soil quality, ecosystem problems, and changes in the channel properties of the Lower Meric River.

A part of Lower Meric River flows in a large alluvial flood plain within the Turkish borders. The other part of Lower Meric River forms the border between Greece and Turkey. Underground water in this region is commonly used agriculturally by farmers. Deteriorated quality or polluted water prevents utilization of ground water. It is clear that groundwater level goes deeper and the water quality becomes worse from year to year in Edirne-Enez (Turkey) part of Meric River.

4. Discharge comes from the Inter Basin between Edirne and İpsala city

Taking into account the flood retention time in the vicinity of Edirne (Fig. 10). and travel time between two streamgage stations, cross check analysis were carried out with the daily on line discharge data obtained from the Edirne-Kirişhane, İpsala and Ergene-Yenicegörüce streamgage stations.

Figure 10. Flood accumulation area before the bypass channel construction in the vicinity of Edirne City. (Sönmez at all.2013)

Figure 11. Edirne flood in 2006.

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No online discharge data was available from the Kızıl River originated and flows 57 km in Bulgaria, pass through the Greece with 33 km and enter the Meric River at this inter basin. (Fig. 11). Annual water potential of the river at the entrance point is assumed as of 1158 hm^3 by DSİ (State Hydraulic Works).

Figure 12. Lower Part of the Meric Basin and used streamgage stations in this study

Figure 13. Inter basin of Meric River between Edirne and İpsala city.

5. The Erythropotamos River (Red River, Mad River, Kızıldelisu)

The Erythropotamos River is tle largest river which flows into the Meric River in the Inter Basin between Edirne and İpsala excluding Ergene River (Fig. 13). It is born in Bulgaria and after running for about 10 km on and alongside with the Greek Bulgaria border. It enters Greece and flows into the Meric River at the level of the town of Didyomitichon.

In the area where the river enters Greece 300 ha cultivated land are often flooded. Greek and Bulgaria sides agreed on the necessity to construct flood control Works to make Greek Bulgarian border stable along 11250 m. This study has been approved by both sides in 1994.

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The source of the river is in the eastern Rhodope Mountains in the western Meric regional unit, Greece, near the village Mikro Dereio. Its largest tributary is the Byala reka ("white river") in Bulgaria. Considering name of the river we can predict the river flows often with flood discharge.

Figure 14. The Erythropotamos River (Red River, Mad River, Kızıldelisu).

Amount of streamflow's enters to Meric River along the inter basin between Edirne and İpsala is not available (Fig. 13). Therefore, we calculated it using daily average online data and considering travel time between two streamgage stations given in the article (1), due to focusing on flood risk assumption in the lower part of the Meric Basin we used data of flood period of time (Jan-April). Used data for this calculation was also compared to each other's for the similarity .Correlation coefficient was obtained as of 0,96 (Fig. 14).

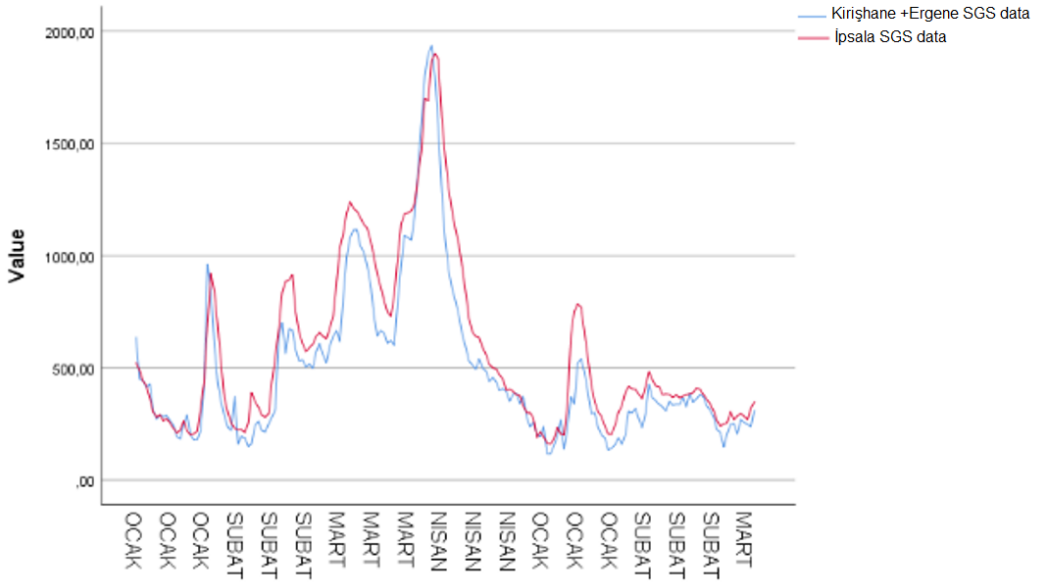

Figure 15. Daily discharge data comparison considering flow travel time.

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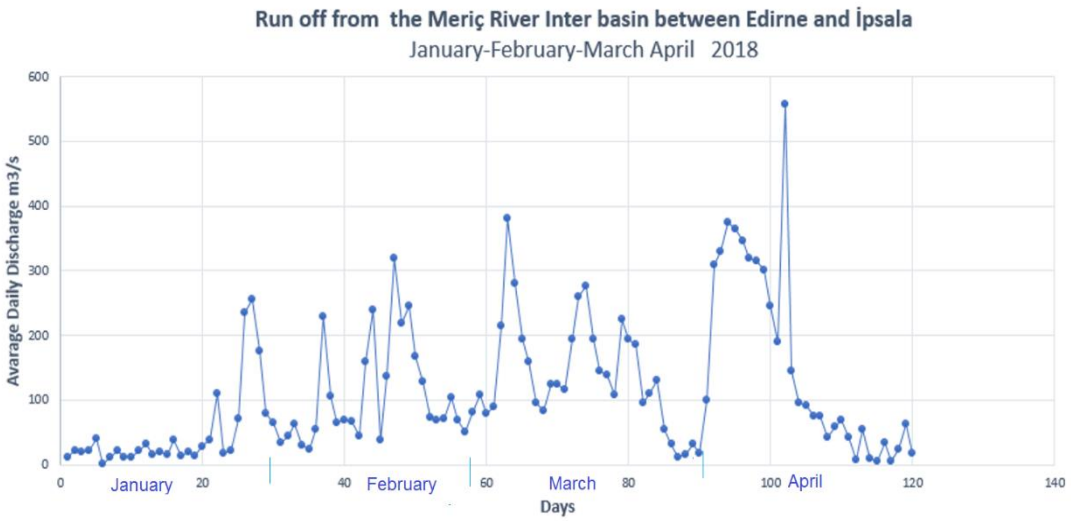

Figure 16. Run off from the inter basin (Excluding Ergene River's Run off, 2018).

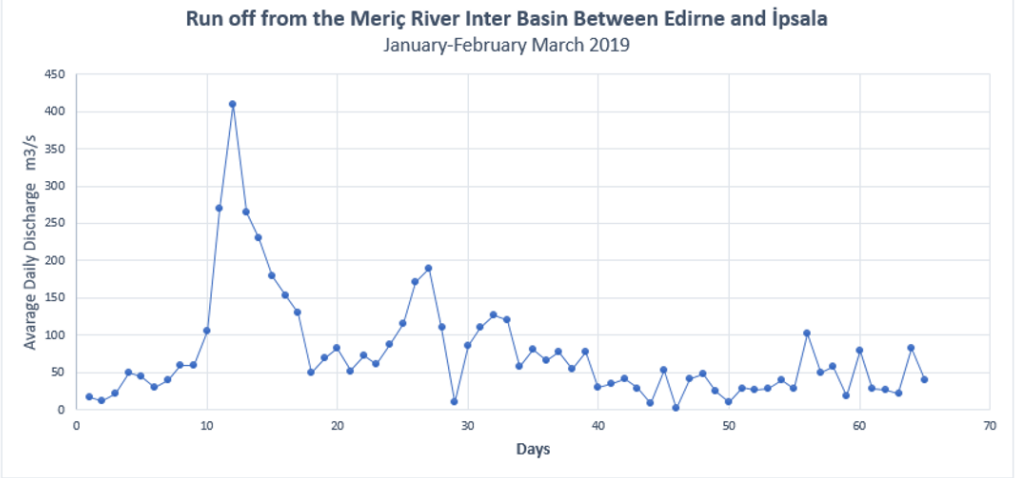

Figure 17. Run off from the inter basin (Excluding Ergene River's Run off, 2019)

If Meric River flows with 1500 m^3/s, Ergene River flows with 700 m^3/s and run off from the inter basin enters to Meric River as 400 m^3/s, at the same period of time, total flood discharge can reach in the lower part of the Meric River as of 2600 m^3/s. The river bed section won't be able to pass through flood discharge as it occurred in 2006 (Fig. 8).

6. Discussion: Evaluation and Recommendation

The Meric River is an international water qualified stream whose basin is within the Bulgarian, Turkish and Greek borders and at the same time forming the border between Greece and Turkey. In addition, it is one of the biggest rivers in the Balkans. Change in the climate characteristics of the river basin occurs year by year. This change becomes particularly apparent due to temperature rise and variation in precipitation regime. It is recognized by all scientists that this situation becomes intensified gradually.

The variation in the temperature and precipitation characteristics, which is observed in the Upper Meric River Basin and becomes gradually intensified, will provide a basis for flow and regime characteristics disorder, increase in hydrological drought, degradation of water quality, ecosystem problems, and changes on river channel, making social life difficult due to local and regional socio-economic problems. It is crucial for rivers that form borders to have changes in their flow and regime characteristics. Flow and regime variation will also have an effect on the erosional and depositional characteristics of Meric River in the flood plain. It is required to show sensitivity to the fluvial geomorphology developments, specifically possible streambed shifts that occur naturally.

Despite all the agreements and cooperation, it is apparent that an effective "Transboundary Water Management" strategy cannot be put into practice without the participation of riparian states. Floods, flash floods etc. problems occurred in the past are the most tangible evidences of this situation in the Lower Meric River Basin within Turkish and Greece territory. The effects of climate change also make the problems more serious as the years go by.

The Meric River is both a transboundary and border forming river. In this context, it is necessary for each of three countries to share the same goal and same vision to implement a basin wide Project for flood preventive measures. it is not an engineering solution to implement expensive protective measures in Grece and Turkey separately.

Collaboration among the riparian states should start to take some urgent but easy measures at the first stage. The Meric River forms the 175 km border between Greece and Turkey. Because of that, 1/1000 scale river bed and flood plain maps couldn't be taken. In order to carry out a flood management model study this map need to be urgently provided with a joint study. Following this, river bed arrangement work is extremely needed for elimination of artificially constructed Sand Island and sediment accumulation in the river bed.

This study showed that floods can accumulate at the same period of time in the lower part of the Meric River. This means the lower part of the Meric Basin is still under the risk of flood as it occurred in 2006. Therefore apart from other basin wide protective measures, the early warning system in operation need to be extended to cover the lower part of the Meric Basin in soon.

Conflict of Interest

All of the authors declare that there is no conflict of interest.

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