ENVIRONMENTAL PROBLEMS OF SULTANSAZLIGI WETLAND AND DETERMINATION OF SURFACE WATER AND GROUNDWATER RELATION AT SULTANSAZLIGI WETLAND BY USING ENVIRONMENTAL ISOTOPES

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Abstract: Sultansazligi Wetland is found in the middle of Develi Plain and Develi Plain is located in the Central Anatolia of Turkey. This wetland area is a conservation area protected by International Ramsar Agreement. According to the biological studies 35 species of Hymenoptera, 6 species of Odonata, 19 species of Mollusca, 3 species of Amphibia, 10 species of Reptilia and 21 species of Mammals have been determined. A total of 301 bird species live within this wetland which is placed on the way of the migrant birds. There is Yay Lake, Northern (Kepir) and Southern (Ortuluakar) Marshland area comprised by the Sultansazligi Wetland area. The Yay Lake water is salty and there is fresh water in the marshlands. The water level of Sultansazligi Wetland has dropped considerably in the recent years and there is an irrigation water supply problem concerning the agriculture plots within the basin. In order to find out the effects of water scarcity of Sultansazligi Wetland environmental isotopes are used to determine surface water of wetland intrusion into groundwater. Tritium (^{3}H), deuterium (^{2}H), oxygen18 (^{18}O), carbon 14 (^{14}C) and carbon 13 (^{13}C) are utilized as environmental isotopes for this purpose. Groundwater samples and surface water samples have been taken for the environmental isotope analysis. According to the isotope analysis, it is concluded that there is no direct relationship between the surface water of Sultansazligi Wetland and the groundwater under the wetland and that groundwater can feed the surface water of Sultansazligi Wetland on long time period, but global warming increases the water scarcity at Sultansazligi Wetland.

Keywords: isotope analysis, Sultansazligi Wetland, surface water-groundwater interaction, water scarcity.

Introduction:

Develi Plain is located in the Central Anatolia in Kayseri City. Its average elevation varies between 1070-1150 m above the mean sea level, the total area of the plain is approximately 800 km^2 and its drainage area is 3190 km^2. Develi Plain has an average slope of 2 %. It is surrounded by Erciyes Mountain (3916 m), Develi Mountain (2074 m), Aladaglar Mountain (3373 m) (part of Taurus Mountains) and Hodul Mountain (1937 m) to the north, east, south and west directions respectively.

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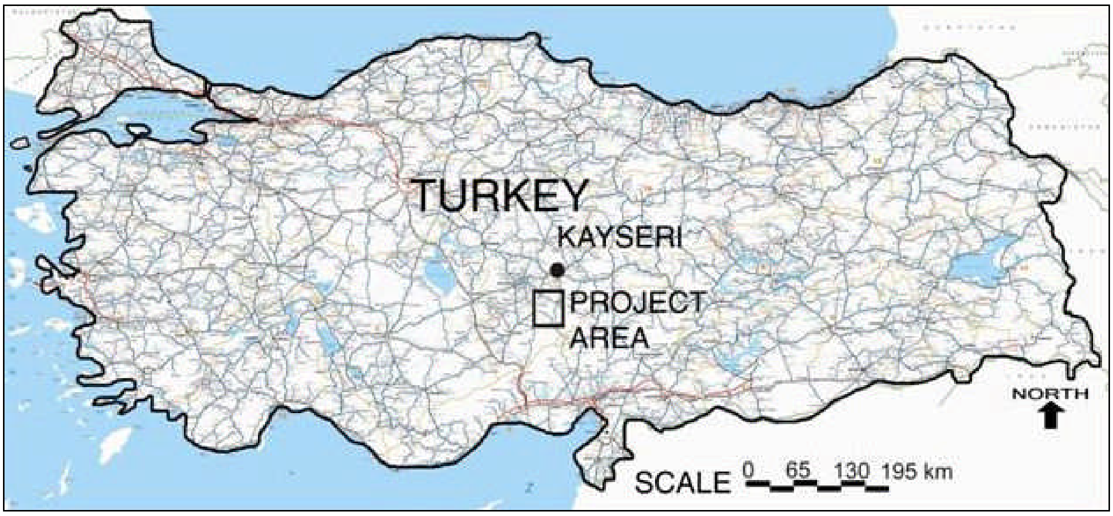
Sultansazligi Wetland is one of the seven important wetland of Turkey. Sultansazligi is located in the center of Develi, Yesilhisar and Yahyali Districts. Yay Lake, Cöl Lake, Southern (Ortuluakar) and Northern (Kepir) Marshlands are found in Sultansazligi Wetland Region. Develi Closed Basin is located at the northern end of Ecemis tectonic trench (fault) (Somuncu 1988; Erol 1999). Location of Develi Closed Basin can be seen in Figure 1.

Figure no. 1 Location of Develi Closed Basin

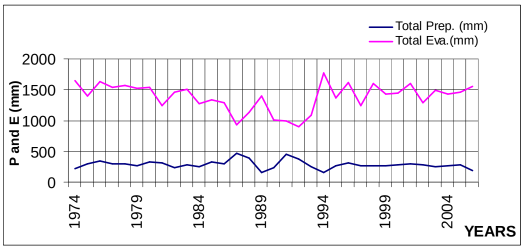


The ornithological importance of Sultansazligi Wetland can be summarized as the population of Flamingo reaches 50,000, Shelduck 10,000 and ducks of various species 600,000 during the migration season. Fresh and saltwater ecosystems are found side by side within this wetland area. Main Breeding Species are: Flamingo, Spoonbill, White Pelican, Glossy Ibis, Grey Heron, Little Egret, Great White Egret, Cattle Egret, Squacco Heron, Night Heron, Great Crested Grebe, Redthroated Diver, Pygmy Cormorant, Little Bittern, White Stork, Greylag Goose, Shelduck, Ruddy Shelduck, Gadwall, Teal Mallard, Pintail Duck, Garganey, Red-crested Pochard, Pochard, Ferruginous Duck, Water Rail, Little Crake, Corn Crake, Moorhen, Coot, Crane, Oystercatcher, Black–Winged Stilt, Avocet, Stone Curlew, Collared Pratincole, Woodcock, Redshank, Blackheaded Gull, Slender-billed Gull, Gull-billed Tern, Common Tern, Whiskered Tern, Little Tern, White-winged Black Tern and, in the barren areas, Sandgrouse. Migratory and wintering species are: Little Grebe, Great Crested Grebe, Red-throated Diver, Black-throated Diver, Cormorant, Pygmy Cormorant, Dalmatian Pelican, Bittern, Great White Egret, Little Egret, Grey Heron, Black Stock, Flamingo, Mute Swan, Greylag Goose, White-fronted Goose, Shelduck, Ruddy Shelduck, Wigeon, Gadwall, Teal, Mallard, Pintail Duck, Garganey, Shoveler, Marbled Duck, Red-crested Pochard, Pochard, Ferruginous Duck, Tufted Duck, Smew, White-headed Duck, Coot, Moorhen, Black-Winged Stilt, Avocet, Little Ringed Plover, Ringed Plover, Dotterel, Golden Plover, Grey Plover, Lapwing, Greenshank, Spurwing Plover, Ruff, Black-tailed Godwit, Curlew, Woodcock, Mediterranean Gull, Little Gull, Lesser Blackbacked Gull and Herring Gull (Habitat of Turkiye 2014).

The total irrigation area covers 97 % of the total area of Develi Plain and generally the flood irrigation system is used for the basin (the water loss is about 60 % - 65 %) (Yildiz 2007) so the irrigation water requirement is very high. There are three dams at Develi Closed Basin for irrigation purpose but the water allocated for irrigation is not sufficient so many deep wells had been drilled to use groundwater for the irrigation requirement. So there are many legally and illegally opened deep wells in Develi Closed Basin.

The aim of this study is to investigate the effect of the groundwater abstraction over the water scarcity of Sultansazligi Wetland by using isotopic analysis. Because if there is any relationship between the groundwater and the surface water of the wetland then excess groundwater abstraction can cause surface water level drop throughout Sultansazligi Wetland. During the field studies it was observed that Northern Örtülüakar and Southern Kepir Marshlands, Yay Lake and Çöl Lake are entirely dry during the irrigation period because there is no required water to feed the reed field. Additionally the evaporation from free water surface and evapotranspiration from the reed field area which is covered by *Phragmites*, are very high. The evaporation is higher than the precipitation as it can be seen in Figure 2.

Figure no. 2 The relationship between evaporation and precipitations



According to the field studies in the project area it has been determined that only precipitation and drainage water feed Sultansazligi Wetland. There are many springs in Develi Closed Basin, some of them are feeding dams but other springs can only feed Sultansazligi during winter because they are being used as an irrigation water during the irrigation period. According to the DSI (Turkish State Hydraulic Works) report (DSI 1970, 1995), 15 % of the total irrigation water is feeding Sultansazligi as drainage water but during field investigations it was observed that the drainage water was being used by the farmers as an irrigation water.

Electrical resistivity tests were made at Sultansazligi in 2003 according to the electrical resistivity tests, it was determined that there is a thick clay layer under Sultansazligi Wetland. According to the water chemistry analysis and electrical resistivity tests it was determined that there is no direct relationship between the surface water of Sultansazligi and the groundwater (Gurer and Yildiz 2007; Yildiz 2007).

In order to define the complete scope of the former studies about the project area, a detailed literature review has been made. There are many studies about Develi Closed Basin.

For example the Turkish State Hydraulic Works prepared a series of investigation reports about the water quality, hydrology and hydrogeology of Develi Closed Basin (DSI 1970, 1995).

Additionally there is a paper about the water budget of Develi Closed Basin (Gurer and Yildiz 2007).

The Turkish Ministry of Environment and Forestry asked ENCON Company to prepare a hydrogeology report about Develi Closed Basin (ENCON 1999).

Gurer (2004) prepared an integrated water resources management report for Sultansazligi Wetland in 2004, within the scope of GEFII World Bank project for the General Directorate of Turkish National Parks.

Erol (1999) wrote a research paper about the geomorphology of Develi Closed Basin, Goncuoglu and his colleagues prepared a geology report of this basin (Goncuoglu et al. 1991) and Yildiz (2007) prepared a PhD thesis about the hydrology of Develi Closed Basin.

Dadaser-Celik et al. (2006) carried aut a research paper about the dynamic hydrologic model of the Örtülüakar Marshland (Northern Marshland) at Sultansazligi Wetland.

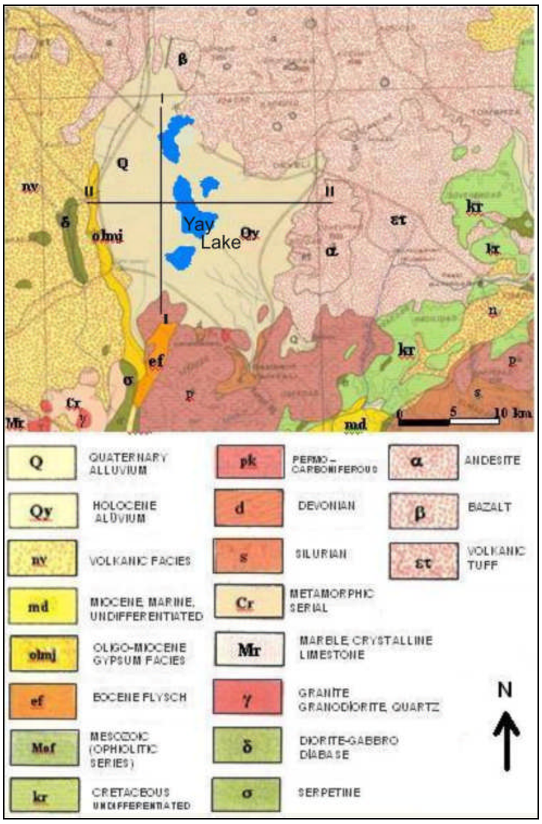
Also Dadaser-Celik et al. (2008) have designed another research paper about the ecosystem changes of Sultansazligi Wetland in satellite images.

Finally Bayari and Yildiz (2011) wrote a paper about the effects of the North Atlantic Oscillation and groundwater use on the contraction of Sultansazliği Wetland. There is no former study to analyse the surface water-groundwater interaction at Sultansazligi Wetland but these research papers and reports are used for this paper in order to purvey information about the hydrogeology, hydrology and geology of Develi Closed Basin.

There are basically three factors affecting the geomorphology of the Develi Closed Basin. These are Ecemis tectonic trench, Erciyes volcanic cone and rivers carrying sediment to the basin. Erciyes Mount is a volcanic cone, this mount developed in the large collapsing tectonic basin at the northern end of Ecemis Fault starting in the late Miocene (Erol 1999). Develi Closed Basin is located at the end of the elongated tectonic depression (Ecemis tectonic trench) along the northern part of the Taurus Mountains. Rivers carried sediments to this tectonic depression basin and Quaternary alluvium formed in the middle of the basin, this alluvium plate is called Develi Plain whose volcanic and magmatic rocks formed from the lava of the Erciyes Volcanic Cone.

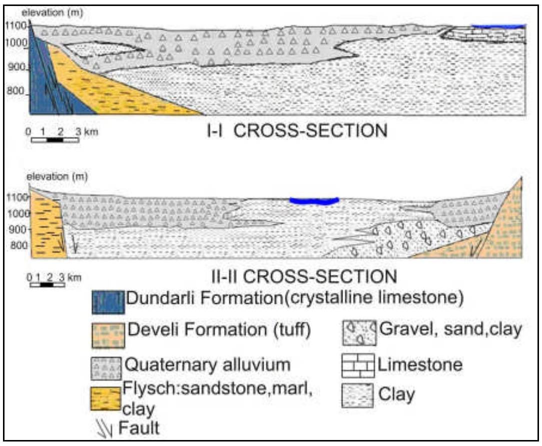
The geological ages of the formations at Develi Closed Basin vary from Paleozoic to Quaternary. Figure 3 shows the geological map of Develi Closed Basin. I-I and II-II cross sections are given in Figure 4. To the south of Develi Closed Basin, there are metamorphic rocks such as limestone, schist and gneiss (Dundarlı formation). To the northern side (nearby the volcanic Erciyes Mountain), there are volcanic and magmatic rocks such as tuff, andesite and basalt (Develi tuff formation, Kulpak formation). To the eastern and western parts, there are volcano-sedimentary formations (Yesilhisar formation, Sarica formation). The sediment formation contains sand, gravel, clayey silt and silty clay within Develi Plain. The sediment particle size reaches from gravel and sand size to carbonate clay and silty clay size while going from the northern side to the middle part of Develi Plain. There is crystallized limestone, schist and gnays in the southern part of Develi Plain (Yildiz 2007).

Figure no. 3 The geological map of Develi Closed Basin



There is an unconfined aquifer under Develi Plain, its thickness being of about 100-150 m. There is only one confined aquifer between Develi and Ilyasli village which is covering a small area (DSI 1995). The sediment particle size of the aquifer decreases around Sultansazligi Wetland (DSI 1970, 1995). There are flysch formations on the western part of the basin near Yesilhisar. Additionally there are many illegally opened wells within Develi Plain so excess groundwater abstraction is an important problem (Gurer and Yildiz 2007; Yildiz 2007). Sustainable aquifer abstraction is computed as $65*10*10^6$ m^3/year by the Turkish State of Hydraulic Works (DSI 1995).

Figure no. 4 The geological sections I-I and II-II of Develi Closed Basin (see Fig. 3)



In the content of this study, tritium (^{3}H), deuterium (^{2}H), oxygen 18 (^{18}O), carbon 14 (^{14}C) and carbon 13 (^{13}C) are used in order to investigate the surface water and groundwater relationship proper to Sultansazligi Wetland. Environmental isotopes are used to define the groundwater-surface water intrusion and the groundwater velocity so as to determine the origin and the age of the groundwater. Environmental isotopes are also used to trace the water pollution and water leakage. The environmental isotopes occur naturally and they are found in abundance in the environment. Oxygen-18 (^{18}O), deuterium (^{2}H) and tritium (^{3}H) are commonly used isotopes. Isotope hydrology studies started in the world in the 1960s (Craig 1961). The isotopic composition of the natural water was discovered by Craig in 1961. Then Ericksson, Payne and Dincer used deuterium, oxygen 18 and tritium as isotopic tracers. Friedman has used environmental isotopes for the water balance of the lakes (Eriksson 1965; Payne and Dincer 1965; Friedman et al. 1964; Dincer 1968; Clark and Fritz 2011).

Is the groundwater under Sultansazligi Wetland feeding the surface water of this wetland? This is the main question of this study.

Materials and methods:

During the investigation of water scarcity in Sultansazligi Wetland; a numerical model of groundwater flow could be established to test the effects of climate change and water use. Unfortunately, the present data on the three dimensional distribution of effective porosity, storage coefficient, hydraulic conductivity is not sufficient to prepare a reliable 3D groundwater flow model. Besides, the total number of illegally opened wells is unknown regarding Develi Closed Basin, therefore the total real groundwater abstraction is unknown.

Accounting for this study groundwater samples have been collected from 27 deep wells and 18 springs. Some springs and deep wells located around Sultansazligi Wetland were selected to represent the entire groundwater quality of the basin. Additionally surface water samples have been collected from 4 locations (surface water samples were collected from lakes of Sultansazligi Wetland and irrigation water pump station). Water samples were collected in 2003-2005 time period, two times in each year. Water sampling was made in November (dry season) and April (wet season) throughout three years. 1 lt plastic bottles were used for the sampling. In situ measurements were made for the water temperature, EC and pH in the groundwater at the sampling locations and plastic water sample bottles were carried to the laboratory immediately for the isotope analysis. The isotope laboratory of State of Hydraulic

Works (DSI) carried out tritium, deuterium, oxygen 18 analysis of the water samples. The water samples were sent to Isotope laboratory of Groningen University for Carbon 13 and Carbon 14 isotope analysis.

Isotope laboratory of Groningen University is a certified laboratory undertaking data analysis, quality checks and calibration "The centre is specialized in making highly accurate measurements of (the variations in) the natural abundances of rare isotopes. This laboratory has a wide range of modern instrumentation (mass spectrometers, including a 2,5 MV accelerator mass spectrometer for C-14, as well as laser-based spectrometers), and carries out research that aims to improve existing techniques or develop new measurement methods" (Groningen University 2013).

The Isotope laboratory of State of Hydraulic Works (DSI) is a certified laboratory using; Turkish Quality Standards and international quality standards (TS EN ISO 170025 standart). The international standard water references: VSMOW, SLAP, GISP are employed, the local standards (Edremit, Ucpinar and Kazdagi) are prepared by using VSMOW, SLAP and GISP in this laboratory. Furthermore, QA/QC protocol is used for the isotope analysis in this laboratory. Local standards are controlled by the content of QA/QC protocol. Concerning drift correction, Grubb's test are applied for the measured water samples in order to control the accuracy of the isotope results of the water samples.

Figure 5 (Annexes) shows the locations of the water samples for the isotope analysis.

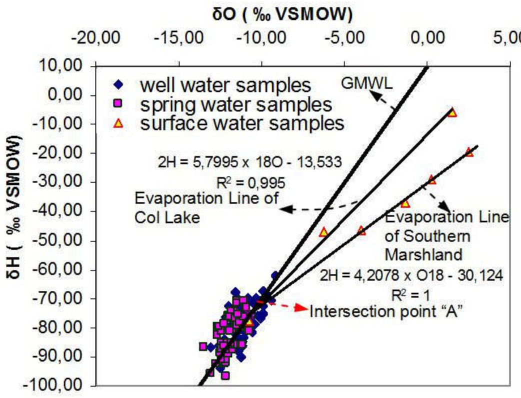
Deuterium, oxygen 18, tritium, carbon 13 and carbon 14 analysis results of the groundwater samples taken from wells and springs and surface water samples can be seen at Table 1 (Annexes).

Isotope laboratory of Groningen University (Netherlands) has undertaken carbon 13 and carbon 14 analysis of the water samples of this study. Isotope laboratory of Groningen University is a certified one making data analysis, quality checks and calibration. Isotope laboratory of Groningen University is specialized in making highly accurate measurements of the natural abundances of rare isotopes. This laboratory has a wide range of modern instrumentation (mass spectrometers, accelerator mass spectrometers and laser-based spectrometers) and carries out research that aims to improve existing techniques or develop new measurement methods.

Results and discussion:

Deuterium and oxygen 18 values of the water samples are plotted on "Global Meteoric Water Line" and this graph is given in Figure 6. This figure shows that oxygen 18 and deuterium concentrations of the groundwater samples are different from oxygen 18 and deuterium concentrations of the surface water samples of Sultansazligi Wetland.

Figure no. 6 Deuterium and oxygen 18 values of the water samples



The intersection point of the evaporation lines and Global Meteoric Water Line shows the original oxygen 18 and deuterium concentrations of surface water samples before the evaporation. Point "A" shows this intersection point in Figure 6. According to Figure 6, it can be said that the isotopic concentrations of some groundwater samples

SK2, SK6, SK7, SK8, SK23, SK 25 and SK 26 are close to the isotopic concentrations of the intersection point “A”. This means that there can be any relationship between the surface water of Sultansazligi Wetland and the groundwater samples SK2, SK6, SK7, SK8, SK23, SK 25 and SK 26. In order to investigate the relationship between the surface water of Sultansazigi Wetland and the groundwater samples: SK2, SK6, SK7, SK8, SK23 and SK 25; well logs are investigated, additionally tritium and water chemistry analysis were made to these water samples. Deep wells, where SK2, SK 23 and SK 26 samples had been taken, are close to Calbalma Pumping Station (see Fig. 4). These wells are polluted by the drainage water of Calbalma Pumping Station (electrical conductivity of SK 2 and SK 23 are very high 8015 and 3010 µS/cm respectively). Oxygen 18 and deuterium concentrations of SK2, SK23 and SK26 are close to oxygen 18 and deuterium concentrations of the intersection point “A” because of the drainage water pollution. SK 25 had been taken from the shallow well which had been located at the southern of Örtülüakar Marshland (see Fig. 5). Water of Southern Marshland is infiltrating and feeding this shallow well so isotropic concentration of SK 25 sample is close to the isotropic concentrations of the intersection point “A”. As a result there is a relationship between the water of this shallow well (SK25) and the surface water of Sultansazligi Wetland.

Conceptual groundwater flow model for the deep wells, where SK6, SK7 and SK8 groundwater samples had been taken, is shown in Figure 7. Oxygen 18 and deuterium concentrations of SK6, SK7 and SK8 are close to oxygen 18 and deuterium concentrations of the intersection point “A”. Tritium analyses were made to these water samples in order to determine if there is any relationship between SK6, SK7 and SK8 and the surface water of Sultansazligi Wetland. According to the tritium analyses surface water of Sultansazligi Wetland is modern water. Two water samples from the well SK6 are modern water, five water samples from the well SK7 are the mixture of modern and submodern water and two water samples from the well SK8 are submodern water (old water). Deep well SK8 is the closest well to Yay Lake but water of this well is submodern so there is no direct relationship between the groundwater of this well and the surface water of Sultansazligi Wetland. Deep well SK6 is being fed by the precipitation and deep well SK7 is being fed by the precipitation and submodern groundwater. It is determined that there is not direct relationship between the water of these wells (where SK6, SK7 and SK8 had been taken) and the surface water of Sultansazligi Wetland (Yildiz 2007).

Figure no. 7 The conceptual groundwater flow model for the deep wells

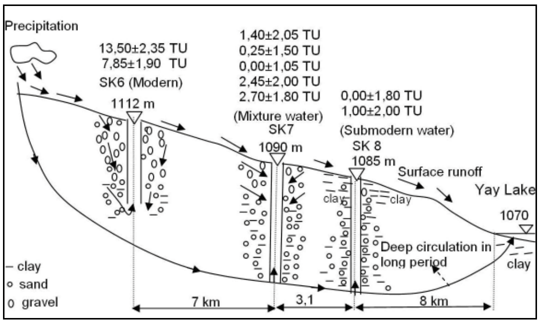


Figure 8 shows tritium and oxygen 18 concentrations of the groundwater samples at Develi Closed Basin. According to Figure 8, oxygen 18 isotopic concentration of the spring water samples are more negative than oxygen 18 isotopic concentration of the well water samples so it can be stated that precipitation water falling on the high elevations (and/or cold regions) feed the springs at Develi Closed Basin. Also, spring water samples are modern water, their tritium contents are more than 6 TU.

Figure 9 shows chloride concentrations (in meq/lt unit) and tritium isotope concentrations of the groundwater samples which have been collected from Develi Closed Basin.

Figure no. 8 The tritium and oxygen 18 concentrations of the groundwater samples at Develi Closed Basin

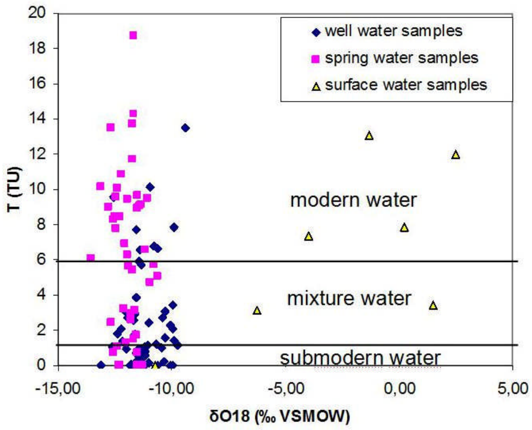
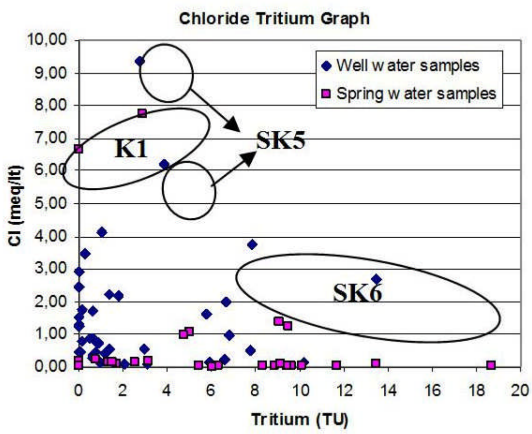


Figure no. 9 The chloride concentrations (in meq/lt unit) and tritium isotope concentrations of the groundwater samples



Retention time (rock-water interaction time) of the deep groundwater flow is more than the retention time of the shallow groundwater flow, so chloride concentration at the deep groundwater is more than the chloride concentration at the shallow groundwater. In addition tritium concentration is low regarding the deep water (submodern water), generally deep submodern groundwater has high chloride concentration and low tritium concentration. When Figure 9 is examined, it can be said that submodern groundwater samples which have tritium concentration of about 0-1 TU, comprise high chloride concentrations. But Ilipinar Spring (K1) and deep well water samples (SK5 and SK6) have higher chloride concentrations than the other groundwater samples. The deep well where SK5 samples have been taken from, has been drilled into basalt, hence according to the water chemistry analysis of SK 5 samples; sodium and chloride concentrations are higher than the other ion concentrations. According to the field investigations and well logs, it is determined that the deep well, where SK6 samples have been collected from, has been polluted by the salty drainage water, so the chloride concentration is high in this well. Ilipinar Spring (K1) is located within the fault zone, thus, according to the water chemistry analysis concentrations of chloride, bromide and other ions are high in this spring.

Tritium contents of the groundwater samples: SK 8, SK 15, SK 21 and K 17 are shown in Table 1. As it can be seen in Figure 5, SK 8, SK 15, SK 21 and K17 are the close to the Sultansazligi Wetland. According to the tritium values of these deep wells, the surface water of Sultansazligi Wetland water does not feed these wells because the ages of the water of these wells are sub-modern.

Carbon 13 and carbon 14 values of the water samples are given in Table 1. When Tab. 1 is examined, it is determined that the K16 spring water sample and deep well water samples SK15, SK21 and SK23 have lower carbon 14 activity than the surface water sample Y1 and deep well water sample SK24. According to the tritium (^{3}H) contents of SK24, it is determined that this well is recharged by the precipitation in wet seasons. The ^{3}H and ^{14}C activities of the groundwater samples SK21 (^{3}H = 0.25 +/- 0.20 TU, ^{14}C =14.24 +/- 0.12 pmc), K16 (^{3}H = 0.74 +/- 0.13 TU, ^{14}C = 14.98 +/- 0.13 pmc) and SK23 (^{3}H = 1.12 +/- 0.31 TU, ^{14}C =18.01 +/- 0.15 pmc) reveal the presence of old groundwater underneath the Sultansazligi Wetland.

The absence of detailed information on the flow system (for example: the aquifer mineralogy, exact distribution of aquifer characteristics etc.) does not allow determination of the absolute radiocarbon ages for these samples. However, apparent radiocarbon ages ranging from 5,000 to 10,000 years before present may be inferred if an initial ^{14}C activity of 50 pmc is assumed for the annual recharge at the water table

Conclusions:

According to the isotope analyses it is concluded that there is not direct relationship between the surface water of Sultansazligi and the groundwater under the wetland. But groundwater can infiltrate into the clay and feed the wetland in the very long time period (clay thickness is about 400 m (DSI 1970) (DSI 1995) under Sultansazligi Wetland. Also, the surface water of Sultansazligi can infiltrate into clay in the very long time.

Obviously, the problem of water scarcity in Sultansazligi Wetland has occurred because of the wrong water management policies since 1940. The irrigation water requirement is very high and the surface water supplied from the reservoirs is not sufficient at Develi Closed Basin. So there are many illegaly opened wells at Develi Closed Basin. Illegaly opened wells cause the excess groundwater abstraction at the basin. As a result there is a water scarcity at Sultansazigi Wetland due to insufficient surface water inflow (precipitation, drainage water etc.) and high evaporation.

Rezumat:

PROBLEME DE MEDIU ÎN ZONA UMEDĂ SULTANSAZLIGI ȘI DETERMINAREA RELAȚIEI DINTRE APA DE SUPRAFAȚĂ ȘI CEA FREATICĂ PRIN FOLOSIREA IZOTOPILOR DE MEDIU

Zona umedă Sultansazligi se găsește în mijlocul câmpiei Develi, iar câmpia Develi este localizată în Anatolia Centrală, Turcia. Această zonă umedă este arie protejată Ramsar. Conform studiilor biologice au fost determinate un număr de 35 specii de hymenoptere, 6 specii de odonate, 19 specii de moluște, 3 specii de amfibieni, 10 specii de reptile și 21 specii de mamifere. Un număr total de 301 specii de păsări sunt prezente în această zonă umedă, care este plasată pe culoarul de migrație al păsărilor. În aria umedă Sultansazligi sunt cuprinse mai multe zone acvatice: Lacul Yay, Mlaștinile Nordice (Kepir) și Mlaștinile Sudice (Ortuluakar). Apa din Lacul Yay este sărată, iar mlaștinile au apă dulce. Nivelul apei din zona umedă Sultansazligi a scăzut considerabil în ultimii ani și apare problema alimentării cu apă de irigație pentru terenurile agricole. În scopul de a afla efectele deficitului de apă din zona umedă Sultansazligi, au fost utilizați izotopi de mediu pentru a determina intruziunile din apa de suprafață în cea freatică. Au fost folosiți în acest scop următorii izotopi de mediu: Tritium (^{3}H), deuterium (^{2}H), oxigen 18 (^{18}O), carbon 14 (^{14}C) și carbon 13 (^{13}C). Pentru analizele izotopilor de mediu au fost recoltate probe atât din apa de suprafață, cât și din cea freatică. Potrivit cu analizele izotopilor de mediu, nu există o relație directă între apa de suprafață din zona umedă Sultansazligi și cea freatică, iar apa freatică poate alimenta zona umedă Sultansazligi pe o perioadă lungă de timp, dar încălzirea globală mărește deficitul de apă din zona umedă Sultansazligi.

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Annexes:

Figure no. 5 The locations of the water samples for the isotope analysis.

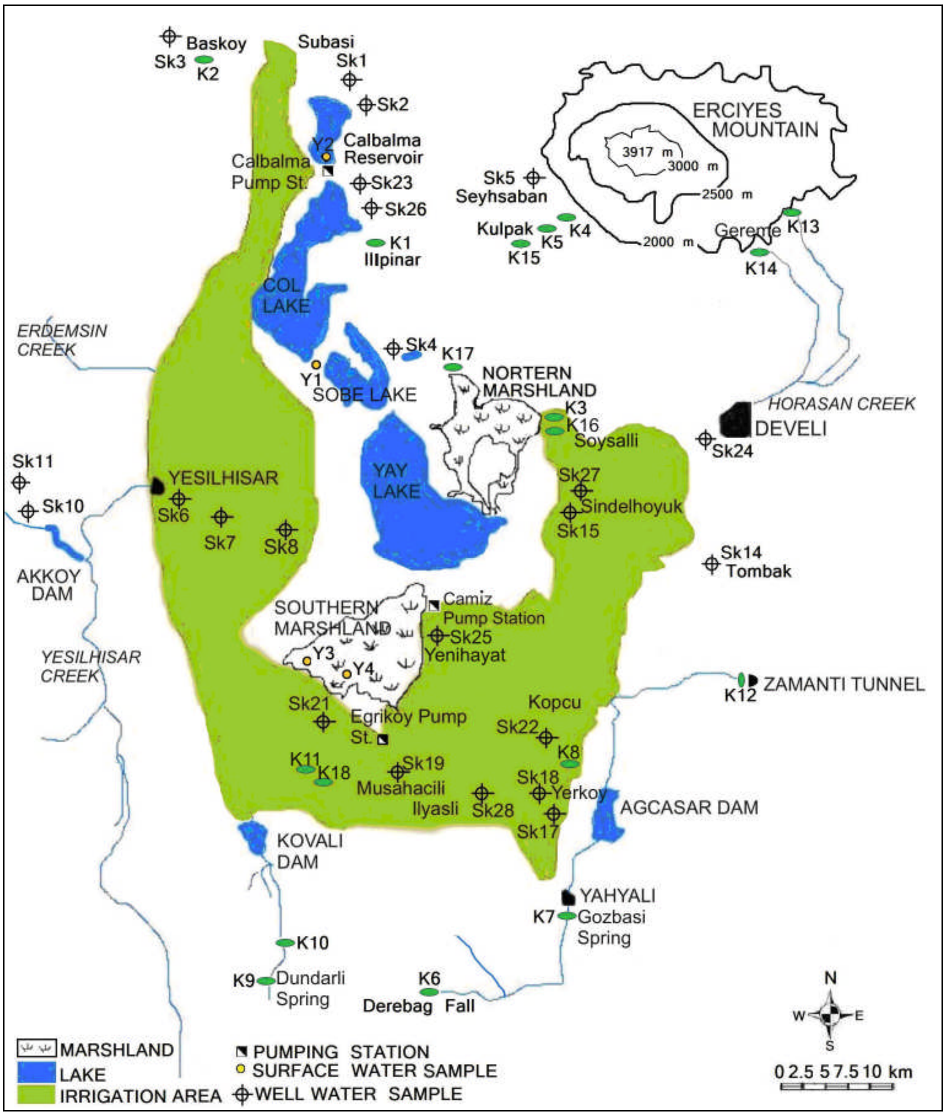

Table no. 1 Isotope concentrations of the water samples.

a.

No.	Sample Location	Elev.(m)	^{18}O (‰)	D(‰)	T (TU)	^{13}C	^{14}C
1	K1 Ilipinar Spring	1075	-11.48	-79.51	0.0±2.00		
2	K1 Ilipinar Spring		-11.78	-75.94	2.9±2.05		
3	K2 Baskoy Spring	1277	-11.28	-80.29	0.0±1.95		
4	K2 Baskoy Spring		-11.66	-76.70	3.15±2.00		
5	K3 Soysalli Spring	1096	-12.52	-88.63	8.45±1.95		
6	K3 Soysalli Spring		-12.65	-82.48	2.45±2.00		
7	K3 Soysalli Spring		-12.12	-85.28	3.25±2.00		
8	K4 Kulpak Erikli Spring	1867	-11.74	-80.48	5.40±2.05		
9	K4 Kulpak Erikli Spring		-11.97	-75.82	9.45±2.15		
10	K4 Kulpak Erikli Spring		-11.81	-74.29		-10,64	
11	K5 Kulpak Bahçe Spring	1611	-11.19	-85.56	6.55±1.95		
12	K5 Kulpak Bahçe Spring		-12.43	-87.09	7.80±2.25		
13	K6 Derebag Spring	1410	-11.51	-79.11	8.90±2.10		
14	K6 Derebag Spring		-13.54	-86.65	6.05±1.65		
15	K7 Gözbasi Spring	1170	-11.32	-78.15	9.12±2.10		
16	K7 Gözbasi Spring		-12.59	-79.59	8.30±1.70		
17	K8 Karaboga Spring	1090	-11.07	-76.16	9.50±2.05		
18	K8 Karaboga Spring		-11.40	-75.57	9.05±2.15		
19	K8 Karaboga Spring		-11.10	-70.54		-9,53	
20	K9 Dündarlı Spring upper elevation	1354	-12.21	-78.79	10.85±2.15		
21	K10 Dündarlı Spring	1342	-11.72	-80.50	11.70±2.10		
22	K10 Dündarlı Spring		-12.39	-81.09	10.10±2.10		
23	K11 Kücük Kurbagali Spring	1077	-10.62	-75.57	5.05±1.95		
24	K11 Kücük Kurbagali Spring		-10.94	-72.99	4.75±1.35		
25	K12 Zamanti Spring	1251	-11.49	-77.67	0.00±1.90		
26	K12 Zamanti Spring		-11.66	-74.23	1.50±2.00		
27	K13 Erciyes Spring	1994	-12.66	-79.67	13.5±2.30		
28	K14 Gereme Spring	1823	-11.66	-75.67	18.7±2.20		
29	K15 Kulpak Spring	1154	-13.10	-95.62	10.15±1.90		
30	K16 Karapinar Spring		-12.59	-80.41	0.70±2.05		
31	K17 Çayirözü Spring	1086	-12.29	-92.52	0.00±1.70		
32	K17 Çayirözü Spring		-12.36	-87.39	0.00±2.00		
33	K18 Büyük Kurbagali Spring	1086	-12.04	-89.28	6.90±1.85		
34	K18 Büyük Kurbagali Spring		-11.90	-81.05	5.65±2.05		

b.

No.	Sample Location	Elev. (m)	^{18}O (‰)	D (‰)	T (TU)	^{13}C	^{14}C
1	SK1 Deep well 1 at Subasi	1124	-11.61	-77.68	2.95±2.00		
2	SK1 Deep well 1 at Subasi		-12.16	-76.30	1.35±2.00		
3	SK2 Deep well 2 at Subasi	1086	-9.94	-72.35	3.45±1.95		
4	SK2 Deep well 2 at Subasi		-10.32	-71.33	3.05±1.95		
5	SK3 Deep well at Basköy	1132	-10.69	-76.47	1.20±1.85		
6	SK3 Deep well at Basköy		-11.20	-75.55	0.6±1.95		
7	SK4 Deep well at Cayirözü	1086	-11.57	-77.94	7.75±2.10		
8	SK4 Deep well at Cayirözü		-11.78	-73.59	0.0±1.85		
9	SK5 Deep well at Seyhsaban	1099	-11.54	-77.33	3.85±2.00		
10	SK5 Deep well at Seyhsaban		-11.98	-72.51	2.75±1.80		
11	SK6 Deep well 1 at Yesilhisar	1112	-9.43	-70.64	13.50±2.35		
12	SK6 Deep well 1 at Yesilhisar		-9.88	-67.47	7.85±1.90		
13	SK7 deep well 2 at Yeşilhisar	1090	-11.02	-81.64	2.45±2.00		
14	SK7 deep well 2 at Yeşilhisar		-10.38	-78.47	2.70±1.80		
15	SK8 deep well 3 at Yeşilhisar	1085	-9.99	-75.93	0.00±1.80		
16	SK10 Deep well at Güzelöz	1368	-11,06	-83,39	1,15±2,00		
17	SK10 Deep well at Güzelöz		-11.46	-78.95	0.65±1.90		
18	SK11 Deep well at Devretbasi	1504	-12.01	-87.73	0,95±2,00		
19	SK11 Deep well at Devretbasi		-12.24	-83.84	2.05±1.90		
20	SK14 Deep well at Tombak	1119	-11.19	-78.52	0.60±2.02		
21	SK14 Deep well at Tombak		-11.65	-74.18	1.80±1.95		
22	SK15 deep well 1 at Sindelhöyük	1082	-13.10	-86.84	0.00±2.00		
23	SK15 Deep well at Sindelhöyük	1082	-11.65	-81.51	0,00±2.00		
24	SK15 Deep well at Sindelhöyük		-11.53	-74.18	0.12±0.24	-3.17	24.77±0.17
25	SK17 Deep well 1 at Yerköy	1082	-11.48	-78.71	5.90±2.00		
26	SK17 Deep well 1 at Yerköy		-12.05	-76.41	3.10±2.00		
27	SK18 Deep well 2 at Yerköy	1098	-10.94	-77.21	10.15±2.20		
28	SK18 Deep well 2 at Yerköy		-11.38	-71.92	6.60±1.70		
29	SK19 Deep well at Musahacili	1078	-11.04	-78.55	0.15±1.95		
30	SK19 Deep well at Musahacili		-10.82	-69.69	6.80±2.05		
31	SK20 Deep well at Egriköy	1086	-10.64	-76.33	6.65±2.14		
32	SK20 Deep well at Egriköy		-11.33	-73.33	5.75±2.00		
33	SK21 Deep well at Ovaciftlik	1081	-11.34	-84.04	0.30±1.80		
34	SK21 Deep well at Ovaciftlik		-11.87	-79.06	0.0±2.00		
35	SK21 Deep well at Ovaciftlik		-11.47	-81.51	0.90±2.05		
36	SK21 Deep well at Ovaciftlik		-11.54	-69.59	0.25±0.20	-9.91	14.24±0.12
37	SK22 Deep well at Kopcu	1087	-11.41	-74.95	0.65 ±1.00		
38	SK 23 Deep well 2 at Calbalma	1081	-9.71	-68.11	1.12±0.31	-1.01	18.01±0.15
39	SK 24 Deep well at Develi	1092	-11.57	-67.76	0.75±0.30	-8.57	62.49±0.30
40	SK 24 Deep well at Develi	1092	-12.54	-93.72	9.60±2.05		
41	SK 24 Deep well at Develi		-11.16	-84.70	0.00±2.15		
42	SK 25 Shallow well at Yenihayat	1080	-9.14	-62.22		-11.56	
43	SK 26 deep well at Calbalma	1071	-10.60	-81.38	0.00±1.70		
44	SK 26 deep well at Calbalma		-9.94	-74.93	2.10±2.00		
45	SK 27 deep well 2 at Sindelhöyük	1084	-12.38	-91.21	1.80±1.85		

c.

No.	Sample Location	Elev.(m)	^{18}O (‰)	D(‰)	T (TU)	^{13}C	^{14}C
1	Y1 Cöl Lake Canal 2	1073	-6,22	-46,68	3,15±0,36	-4,07	80,65±0,35
2	Y1 Cöl Lake Canal 2	1073	-10,76	-77,78	0,00±1,95		
3	Y2 Calbalma Pump Station	1074	1,53	-5,74	3,45±1,90		
4	Y3 Sap Lake	1070	-1,34	-36,76	13,05±2,30		
5	Y4 Egri Lake	1065	-4	-46,27	7,35±2,05		
6	Y4 Egri Lake		2,51	-19,56	12,00±2,25		
7	Y4 Egri Lake		0,26	-28,73	7,85±2,2		