TEMPORAL COASTAL EROSION CHANGES ANALYSIS USING REMOTE SENSING IN NORTHERN TERKOS LAKE

by

İsmail Kaya

BS. in Geomatic E., Yildiz Teknik University, 2000

Submitted to the Institute of Environmental Sciences in partial fulfillment of the requirements for the degree of

Master of Science

in

Environmental Sciences

Boğaziçi University

2016

ACKNOWLEDGMENTS

Besides my advisors, I would like to thank ISKI Survey Engineering Department, IMP, my dear collegues Fatih Yentürk and Korcan Uçar for their insightful comments and encouragement, but also for the hard question which incented me to widen my research from various perspectives.

TEMPORAL COASTAL EROSION CHANGES ANALYSIS USING REMOTE SENSING IN NORTHERN TERKOS LAKE

Istanbul`s drinkable / useable water demand is provided by its nearby surface water resources (Yüzeysel Su Kaynakları Raporu, İMP 2005). The cities` exponentially increasing water need can not be satisfied with the existent water resources and new solutions should be provided to tackle the upcoming water shortness problem in the following decades.

Terkos Lake is one of the most crucial surface water resources of Istanbul city. Inevitably, as a result of increasing population, irregular urbanization over the Istanbul in the last 20 decades, qualities of the water basins have been reduced dramatically. All precautions taken and aggressive rules and regulations imposed did not prevent the water basins enough from environmental pollution (Çodur, 2004).

Remote sensing is a principle investigation method for large scale geographic locations. This method has been used for a lot research area (Gedik, 2006) like agricultural and geological branches. It is also a handy tool in environmental risk assessments. This study will initially focus on the satellite images which were converted into image vectors with the use of ArcMap and finally assess the status of Terkos Lake with the vector- time analysis.

TERKOS GÖLÜ KUZEYİNİN UZAKTAN ALGILAMA METODU İLE KIYI DEĞİŞİM ANALİZİ

İstanbul gibi nüfusu çoğu yabancı ülke nüfusundan büyük olan bir dünya kentinde, şehrin içme ve kullanma suyunun karşılanması, hayati önemde, temel problemlerden bir tanesidir. Ülke ve dünya açısından ekonomik, sosyal, kültürel ve tarihi bir cazibe merkezi olan İstanbul Metropoliten alanının içme ve kullanma suları yüzeysel su kaynaklarından elde edilmektedir (Yüzeysel Su Kaynakları Raporu, İMP 2005).

Terkos Gölü ve Havzası, İstanbul'un sahip olduğu sınırlı sayıdaki su kaynaklarının en önemlilerinden bir tanesidir. İstanbul İli'nin özellikle son yirmi yıl içerisinde maruz kaldığı yoğun göç ve buna bağlı nüfus artışı ve çarpık yapılaşma neticesinde, şehri besleyen su kaynakları kirlenme tehdidi altında kalmış ve su havzalarının su kaliteleri önemli mertebelerde düşüş göstermiştir. Su havzalarının korunması ile ilgili çıkarılan yönetmelikler ve alınan idari ve teknik tedbirlere rağmen su havzalarındaki illegal yapılaşmanın önüne geçilememiş ve su havzalarının maruz kaldığı çevre kirliliği etkisi artarak günümüze kadar gelmiştir (Çodur, 2004).

Uzaktan algılama büyük çaplı coğrafyalar için temel inceleme yöntemidir. Bu yöntem tarımdan (Gedik, 2006) çevreye birçok alanda uygulanma imkanı bulmuştur. Uzaktan algılama çevresel risk değerlendirme görevlerinde çok kullanışlı bir araçtır (Becker, 2000). Bu çalışma uydu görüntülerinin ArcMap programıyla işlenip vektör haline getirildikten sonra, zamana bağlı analizler sonucunda gölün durumunu yorumlayacaktır.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS/ABBREVIATIONS

Symbol	Explanation	Units used
İMP	İstanbul Metropolitan Planlama	-
İSKİ	İstanbul Su ve Kanalizasyon İdaresi	-
s	Particle surface area	m^2
ha	hectare	-

1. INTRODUCTION

Water is a natural resource and every human has the right to access to it. Water need is exponentially increasing accordingly with the increasing population and constant level of the water resources on earth. Today, 80 countries covering around %40 of the general population are suffering from the lack of water resources. Increasing population, faulty city management within the politics effect the existing water resources in a negative way and pollution is spreading over the resources in a very fast trend.

The importance of the water resources and the natural ecological properties has been confirmed in the conference of Stocholm in 1972 as well as in the assessment report of World Environment and Development commission in 1987. Enpowered by United Nations in 1992, World Environment and Development conference emphasised the fact that every human being needs to protect the environment from the birth. Thus, a new era called “environment sustainability” has been emerged and this idea has become the most important paradigm over the 20th century. At this point maintaining the basins and their protection has earned great importance.

Basin planning and management can be defined as recovering and managing the natural water, soil and other resources maximizing social welfare and economic aspects without endangering the maintainablity of the ecological systems (Küçükkaya ve Geray, 2007).

In paralel, within the aggressive urbanization, natural resources (forests, agriculture, stream beds, etc) is being exposed to heavy pressure of urban development. Consequences of these illegal urbanization have great impacts over the water basins. Basins in the Istanbul city has been suffering from threads coming from the structural development inside the city. In contraversion of the existing plans in environmental protection, the lack of audits, control and supervision is one of the main problems in the city.

Basin areas come up against major problems like illegal housing in the city walls, faulty terrain management and aggressive income investments of local managements and these has become vexed issues over time. Besides, increasing industrial structuring over the water collection areas in the basins is another thread to be considered. Steam beds over the basin areas are seen as tempting targets for the industrial companies as they are used for water resources for industrial production.

Not only housing contamination and pollution arised from industrial corporations, but also agricultural fertilization and disinfection, mining companies in the forests are the items in the contaminating list over the basins.

As with the growing size of the net of transportation structures like roads, railways or autobahns, settlements around the basins areas become a big target for relocation. Besides, industrial facilities inside or around the basins triggered the population increase in the area. All of these effects lead to new settlement areas with lack of urban planning and infrastructure system.

There is a big gap in the rules and regulations in the aspect of legal legislations related with preventing water basins and other natural resources. Especially ISKI legislations do not come up with solutions for preventing the basins, moreover they tend to ease the procedures for using the basin areas for industrial purposes.

1.1. Basin Concept

Concept of basin is being used by many disciplines and its definition varies dependent to its use. A basin is a collection small scale territories exhibiting similar characteristics of biopyhsical, social and economic attributes (Küçükkaya ve Geray, 2007). As explained in the Genc`s (2004) study, Water Pollution Control regualtion, defines a basin as the total of terrains of which the underground or surface water collections feeding the closeby rivers, lakes and dam reservoirs.

Basin has many definitions like “limited with mountains or hills, a land of whose water resources fall in the same sea”, “a coastal structure along with the side of sea”, “area, territory” in general terms. However as per hydrographical point of view it is defined as a closed water circuit which never ends up falling into the sea. Geomorphologically it is a natural topographical breakdown of a land in lenghts varying between several km and hundreds of km. Geologically, it is an area covered with sedimentary fillings collapsed in the median of which the layer slopes do not exceed 1-2 degrees. As per in minery terms, a basin is a wide land of mineral resources constituting a geographical and geological unity which is processed industrially by variaties of pits on it. In the oceanology basins are sedimental land units widened across the deep of the oceans which shows no difference in topographical meanings (Meydan Larousse, 1971).

Basin is a geomorphological, hydrological, topographical, biological and ecological unity surface land area that combines several sub-ecosystemic structures with their specific pysical, biological and ecological properties not changed and interacts with its neighbourhood ecosystems in macro and/or micro scales. Basin has geomorphologic, lithologic, limnologic, meteorologic and biologic attributes of the geographical system it is located inside in both macro and micro terms (Küçükali, 2005). As with these properties it forms an individual ecosystem in its own (Prasad ve diğ., 1994). Basin ecosystem is a natural combination of environmental elements like forest, water, river, vegetation flora, lakes, microorganisms, fauna, soil and climate (Çepel, 1995). Due to the nature of its very sophisticated structure, basin ecosystems have important physographical, climatic and agrarian items to be considered.

1.2. Drinking Water Basins

Water basins are the rally point of surface and underground water resources which are used for supply of drinking and domestic water. Factors like uncontrolled population, lack or even non-existing purification facilities, faulty industrial site selections, agricultural pesticides and waste dump areas cause erosion, sedimantation, pollution and a drastic change in regime and level of water in the environment. As per the need of maintaining the public health, these areas must be preserved against the pollution and water quality must be continiosly monitored.

Another important aspect of water basins is the green lands like forests or bushes they cover is this is vital in terms of city ecology and must be conserved precisely. These areas are effective in precipitation formation, rain that reaches to soil, water amount and quality, surface flow, water holding capacity of the terrain and base water level in the ecosystem.

The most important factor seeked in the water basins is the property of its structure that forms the maximum amount of water with the best biological quality. For this reason, it is critical to assess the ecological characteristics of the basins as well as the vegetation-soil-water interrelation of the ecosystem (Yönügül, 2007).

2. DRINKING WATER BASINS IN ISTANBUL AND TERKOS DRINKING WATER BASIN EXAMPLE

In this part of the thesis water basins in Istanbul will be assessed in general perspective and Terkos Drinking Water Basin will be evaluated along with the other basins in the city. After this analysis, Terkos Basin will be explained in terms of natural thresholds. Problems in the basin will be revealed and technical suggestions will be introduced.

2.1. Water Basins in Istanbul

There are a total of 7 basins supplying the drinking water demand in Istanbul. 4 of them reside in European side and the rest 3 of them are located in the Asian part of the Istanbul. Purposedly use for drinking water, basins in the European side are Alibeykoy, Terkos, Sazlidere and lastly Buyukcekmece dams. Terkos and Buyukcekmece are formationally lakes however as because of the dams built to hold the water over them, they are categorized as dams, as well. Sazlidere is located in Kucukcekmece Lake`s water accumulating basin which is not used for drinking water supply. Aforenamed basins supply an average of 665 million m^3 water per year and constitutes 70% of all water supplied to the city.

Moreover, along with the Istrance Streams Project: Duzdere, Kuzuludere, Buyukdere; in the part of Yildiz Streams Project: Sultanbahcedere, Kazandere, Elmalidere regulators, Yesilvadi and Sile Keson Wells are important sources of water in Istanbul.

Streams that are planned to supply water to the city are Yesilcay Regulator, Istrance 3rd and 4th level, Buyukmelen 1st, 2nd, 3rd, Goksu – Iznik, Yesilcay Dam and streams between Yesilcay and Sakarya (Table 2.2). The existing amount of drinking and domestic water distribution over the resources is depicted in the following graph (Figure 2.1).

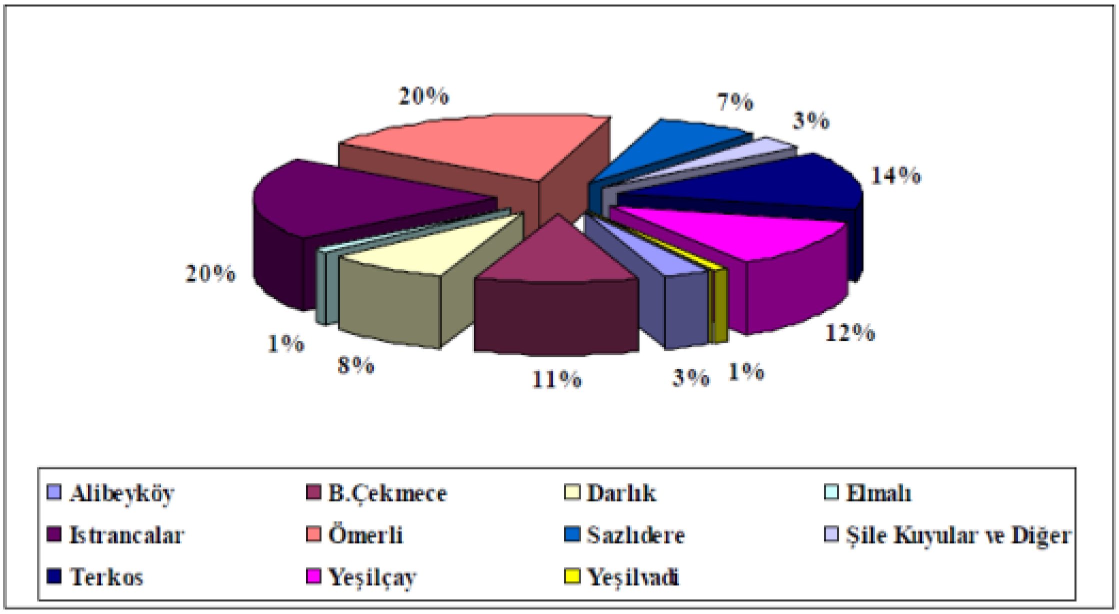

Figure 2.1. Drinking and domestic water amounts distributed over the resources (İSKİ, 2010).

In the following chart (Figure 2.2) total averages of monthly water contributory values (hm3) along with their ratios which belong to 7 big reservoirs (Terkos, Buyukcekmece, Sazlidere, Alibey, Omerli, Elmali and Darlik) can be observed.

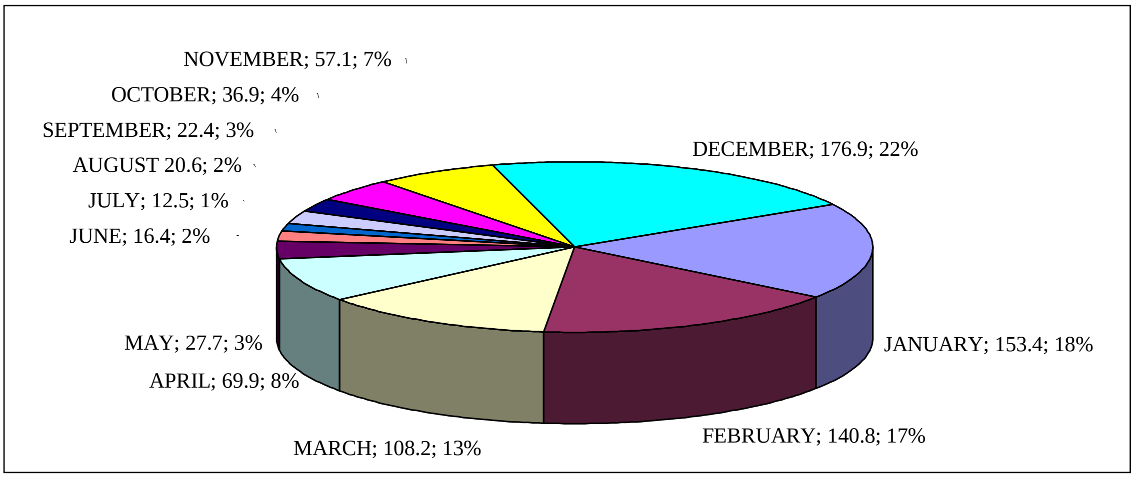

Figure 2.2. Total averages of monthly water contributory values (hm^3) along with their ratios (%) which belong to 7 big reservoirs (Terkos, Buyukcekmece, Sazlidere, Alibey, Omerli, Elmali and Darlik) (1994-2010) (İSKİ, 2010).

Terkos Dam is a dam built over Terkos lake in 1883. Terkos lake dam is located between province borders of Arnavutkoy and Catalca. Dam has an annual efficacy of 142 million m3 with a reserve capacity of 162.2 m^3 (Table 2.1 and Figure 2.3).

Table 2.1. Water resources of Istanbul (İSKİ, 2010).

Water Resource	**Service Begin Date**	**Annual efficiency (million m^3/year)**
Groundwater resources	1453-1893	10
Elmalı I veII	1893-1950	15
Terkos	1883	142
Alibey	1972	36
Ömerli	1972	220
Darlık	1989	97
Büyükçekmece	1989	70
Yeşilvadi	1992	10
Düzdere, Kuzuludere, Büyükdere	1995	44
Şile Keson Wells	1996	30
Elmalıdere, Kuzuludere, Büyükdere	1997	131
Pabuçdere	1998	60
Sazlıdere	1998	55
Cumulated annual average		**920**

Table 2.2. Water resources planned in Istanbul (İSKİ, 2010).

Water Resource	**Planned Service Date**	**Annual average efficiency(million m^3/year)**
Büyükmelen 3. Level	2020	461
Göksu - İznik	2025	500
Yeşilçay Barajı	2030	190
Yeşilçay - Sakarya arası dereler	2035	550
Cumulated annual average		**1701**

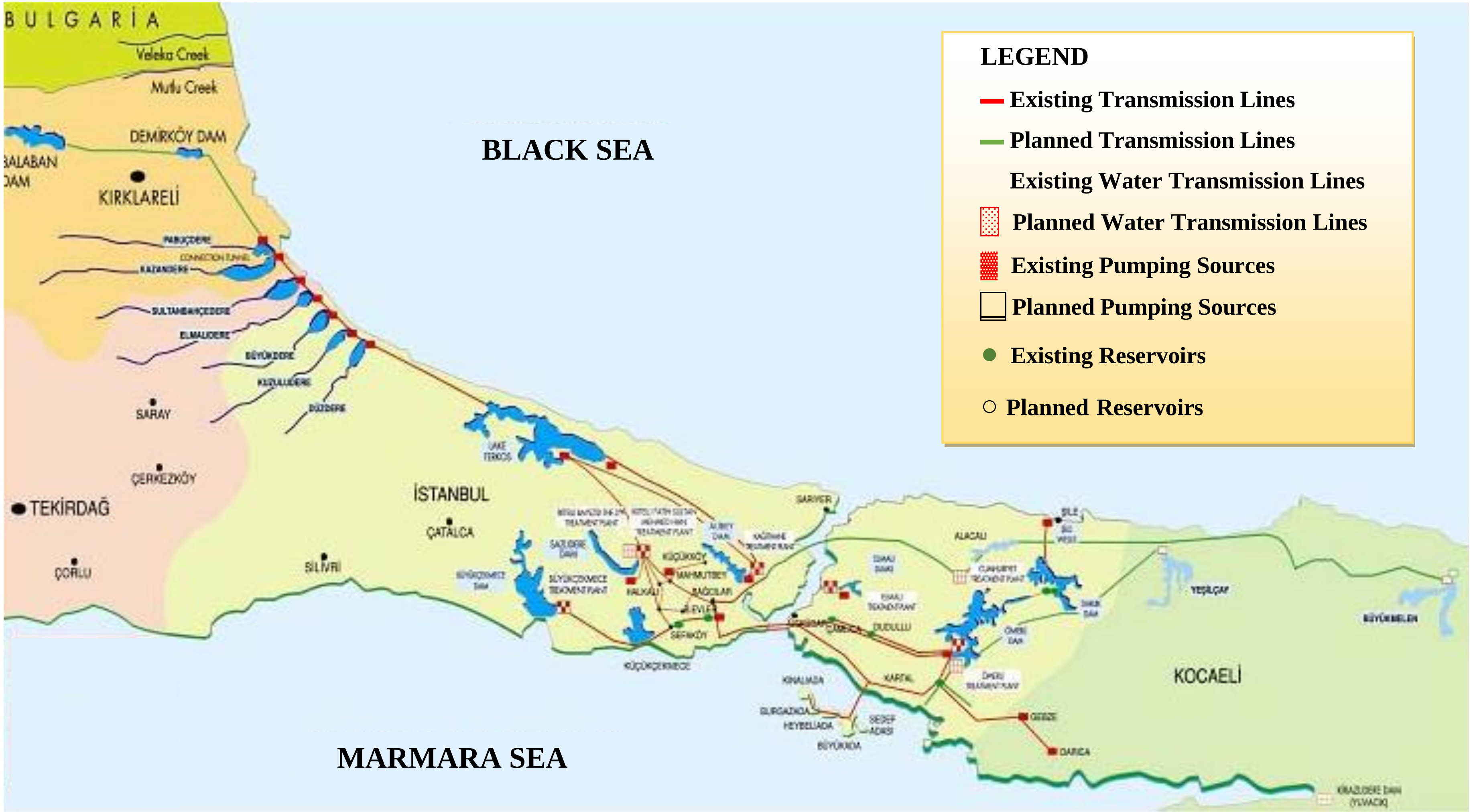

Figure 2.3. Existing and planned water resources that suplies water to Istanbul (İSKİ, 2010).

Total areas of drinking water basins in Istanbul is 24,718 ha. The biggest ratio in terms of occupied land area belongs to Terkos Basin and it is followed by Buyukcekmece, Omerli, Darlik, Sazlidere, Alibey and Elmali, respectively. Terkos has an area of 6,950 ha and out of the total area, 306 ha forms absolute secure zone, 543 ha forms short distance secure zone, 533 ha forms medium distance secure zone and remaining 5,568 ha forms long distance secure zone (Table 2.3).

Table 2.3. Secure Zones and areas in the water basins of Istanbul (İSKİ, 2010).

Drinkin Water Basin		Absolute SZA	Short DistanceS ZA	Medium Distance SZA	Long Distance-1 SZA	Long distance-2 SZA	Total (ha)	Total (ha)
West Side	Alibey	131	181	163	307	762	**1,544**	**16,124**
	Terkos	306	543	533	1047	4,521	**6,950**	
	B,Çekmece	189	351	454	1,314	3,736	**6,044**	
	Sazlıdere	138	287	314	539	308	**1,586**	
East Side	Ömerli	410	532	574	1,393	2,963	**5,872**	**8,594**
	Elmalı	59	106	12	322	217	**716**	
	Darlık	171	176	171	231	1,257	**2,006**	
Total		**1,404**	**2,176**	**2,221**	**5,153**	**13,764**	**24,718**	**24,718**

Another important point about the secure zones is about the number of municipalities located inside the secure zones. As it can be observed in the Figure 2.4, the number of settlement places in short distance secure zones comes second after he number of settlement places in long distance secure zones. 24% percent of municipalities are located in absolute secure zone, 20% in short distance secure zone, 22% in medium distance secure zone and lastly 34% reside in long distance secure zone (Turgut, 2000) (Table 2.4 and Table 2.5).

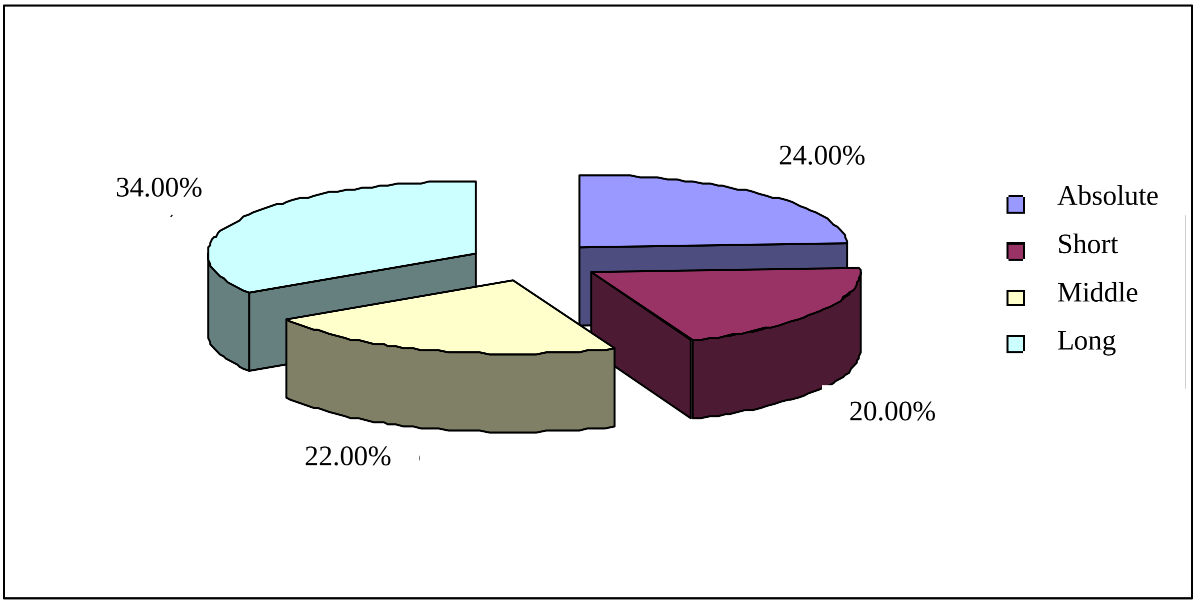

Figure 2.4. Distribution of settlements over the secure zones in the basins (İSKİ, 2010).

Forestry areas in the basins are another important component that needs to be considered. Forests are the most basic building block of Istanbul`s ecology. As covering 16,124 ha of areic size of basins in European side, 7,658 ha of area constitutes of foresty areas. Inside the Asian side, 5,302 ha of forest areas are located in a total areal size of 8,705 ha of all basins.

Totally forests form 12,880 ha in 24,718 ha of size of all basins in Istanbul. Shortly, 52% of drinking water basins are composed of forests. These numbers show the significance of forestry ecological properties over the city ecosystem and also over the quality of the water. Forest areas are not only important for the settlement areas in the basin borders, but also have a vital impact over all of the Istanbul`s ecological harmony.

Table 2.4. Forest areas in water accumulating basins (İSKİ, 2010).

Basin	Max Water elevation	Dam Area	Absolute Secure Zone Area(ha)			Short Distance Secure Zone Area ha)				Medium Distance Secure Zone Area (ha)			
			Foresrrt Area	Non-Forestry Area	Total Area	Foresrrt Area	Non-Forestry Area	Stream Absolute Area	Total Area	Foresrrt Area	Non-Forestry Area	Stream Absolute Area	Total Area
Alibey	30	430	1,290	27	1,317	1,360	423	30	1,813	930	592	112	1,634
Terkos	5	4,171	1,916	1,145	3,061	3,609	1,612	209	5,430	3,397	1,609	330	5,336
B.Çekmece	6	2,573	0	1,896	1,896	0	3,394	120	3,514	0	4,354	190	4,544
Sazlıdere	22	990	125	1,263	1,388	140	2,663	75	2,878	368	2,507	265	3,14
Ömerli	62	2,106	2,843	1,261	4,104	4,080	1,099	143	5,322	4,420	970	355	5,745
Elmalı	65	112	462	106	568	710	275	80	1,065	740	364	100	1,204
Darlık	52	627	1,692	18	1,710	1,410	128	230	1,768	1,000	275	440	1,715
Total	242	11,009	11,009	8,328	5,716	14,044	11,309	9,594	887	21,790	10,855	10,671	1,792

Table 2.5. (Continued) Forest areas in water accumulating basins (İSKİ, 2010).

Basin	Long distance – 1 secure zone area (ha)				Long distance – 2 secure zone area (ha)				Total (ha)			
	Foresrrt Area	Non-Forestry Area	Stream Absolute Area	Total Area	Foresrrt Area	Non-Forestry Area	Stream Absolute Area	Total Area	Foresrrt Area	Non-Forestry Area	Stream Absolute Area	Total Area
Alibey	2,330	538	210	3,078	5,140	1,618	862	7620	11,050	3,198	1,214	15,462
Terkos	5,860	3,617	1,000	10,477	36,347	3,820	5,046	45,213	51,129	11,803	6,585	69,517
B.Çekmece	0	12,641	500	13,141	11,420	23,722	2,220	37,362	11420	46,007	3,030	60,457
Sazlıdere	1,030	3,910	452	5,392	523	2,303	263	3,089	2,186	12,646	1,055	15,887
Ömerli	8,620	4,294	1,020	13,934	15,360	11,739	2,540	29,639	35,323	19,363	4,058	58,744
Elmalı	1,520	1,360	340	3,220	820	1,281	70	2,171	4,252	3,386	590	8,228
Darlık	1,400	564	347	2,311	7950	2,377	2,252	12,579	13,452	3,362	3,269	20,083
Total	20,760	26,924	3,869	51,553	77,560	46,860	13,253	137,673	128,812	99,765	19,801	248,378

2.2. Terkos Drinking Water Example

Terkos basin is one of the most important water resources of Istanbul. Being a naturally formed lake, Terkos has a varying level of water with minimum of -2 meter and a maximum of +4.5 meters. It first had been used for urban purposes in the Ottoman Empire times in 1883. Its use for being a water resource for the city, continues for at least one century. Terkos reservoir locates in the European side of the Bosporus, approximately 40 km northwest of the city and takes place in the coastal side of the Black Sea. With 12 km`s of extent and 5 km of latitude, this lake diverges from the Black Sea with a lip wall with a varying width between 0.25–3.7 km which is covered with sand dune. Lake has a total surface area of 39 km^2, and is slightly bigger than Omerli reservoir with respect to surface area coverage. However, Terkos has a safety capacity of 142 million m^3 / year which is approximately half of the reservoir of Omerli.

Terkos Lake began to be used for the city by cutting the connection between lake and Black Sea by means of building a regulator upon the mouth of Istranca Stream towards the Black Sea in 1883. Lake water elevation was thereby amped up to 3.25 meters and with setting the French made water purification facilities into the operation, lake was then started to be used for drinking water resource. In 1962, a capped regulator was built in order to increase the operational water level up to 4.5 meters and hence the efficiency of the lake has significantly been enhanced. At the lowest level of operational water elevation of -2 meters, lake volume (dead volume) is 24.551 million m^3 with an area of 16 km^2. At the highest operational water elevation of +4.5 meters, lake volume is 186.8 million m^3 with an area of 31 km^2. The capacity of water retention has been enhanced to 162 million m^3 by a dam built by DSI in 1972. The extension characteristics of Terkos Lake have been shown in Table 2.6, general attributes are summarized in Table 2.7 and positional characteristics are depicted in the map in Figure 2.5.

Coşkun et al. (2006) have studied Terkos Drinking Water reservoir, monitoring the protected bands using satellite data. A similar study was conducted for the Ömerli Basin using remote sensing, GIS, and regression analysis regarding water quality (Coşkun et al., 2008; Coşkun and Alparslan, 2009).

Table 2.6. The extension characteristics of Terkos Lake (DSİ, 2010).

Terkos Lake Extension	Lake Location	Arnavutköy -İSTANBUL
	Stream	Over Terkos Lake
	Purpose	Drinking and usage water
	**Construction end year**	Ended in1971
	Body filling type	Steel Covered Concrete
	Body Volume	-
	Height (thalweg)	8.80 m
	Volume at normal water level	186.80 hm^3
	Area at normal water level	$30.4x10^6$ m^2
	Irrigation Zone	-
	Power	-
	Yearly Production	-

Table 2.7. Terkos Lake properties (DSİ, 2010).

Lake/Reservoir/Schooner Name		Terkos Lake (Natural)
Basin		Marmara
Sub Basin		Terkos
Surface area (m^2)	**Lake Area**	32 km^2
	Rainfall Area	619 km^2
Altitude (m)		-1.0 m
Protected Status		Drinking Water Natural Resource (according to ISKI)
Purpose of use		Drinking Water
Depth	**Maximal Depth (m)**	5.0 m
	Average Depth (m)	4.45 m
Average Water Temperature (ºC)		16.6 º C
Volume (m^3)		186,610,000 m^3 /year
Sources of pollution over the lake (Urban, Industrial, Agricultural)		Agricultural, Urban
Geology		Permeable Zone; running sand, low clayey sand, silty sand, sansstone and its destructed variaties, Impermeable Zone; Mostly clay, marl, low silty clay and partly sandy ground
Lake Flora		No Available Flora Study
Lake Fauna		No Available Fauna Study
Lake Type (oligotrophic, mesotrophic, eutrophic)		eutrophic (phosphor level)
Location	**Coordinates**	630^{025} - 4580^{900}
Distance from river mouth *(km)		7.5 km

(*) If located in side walls, distance to the intersection point.

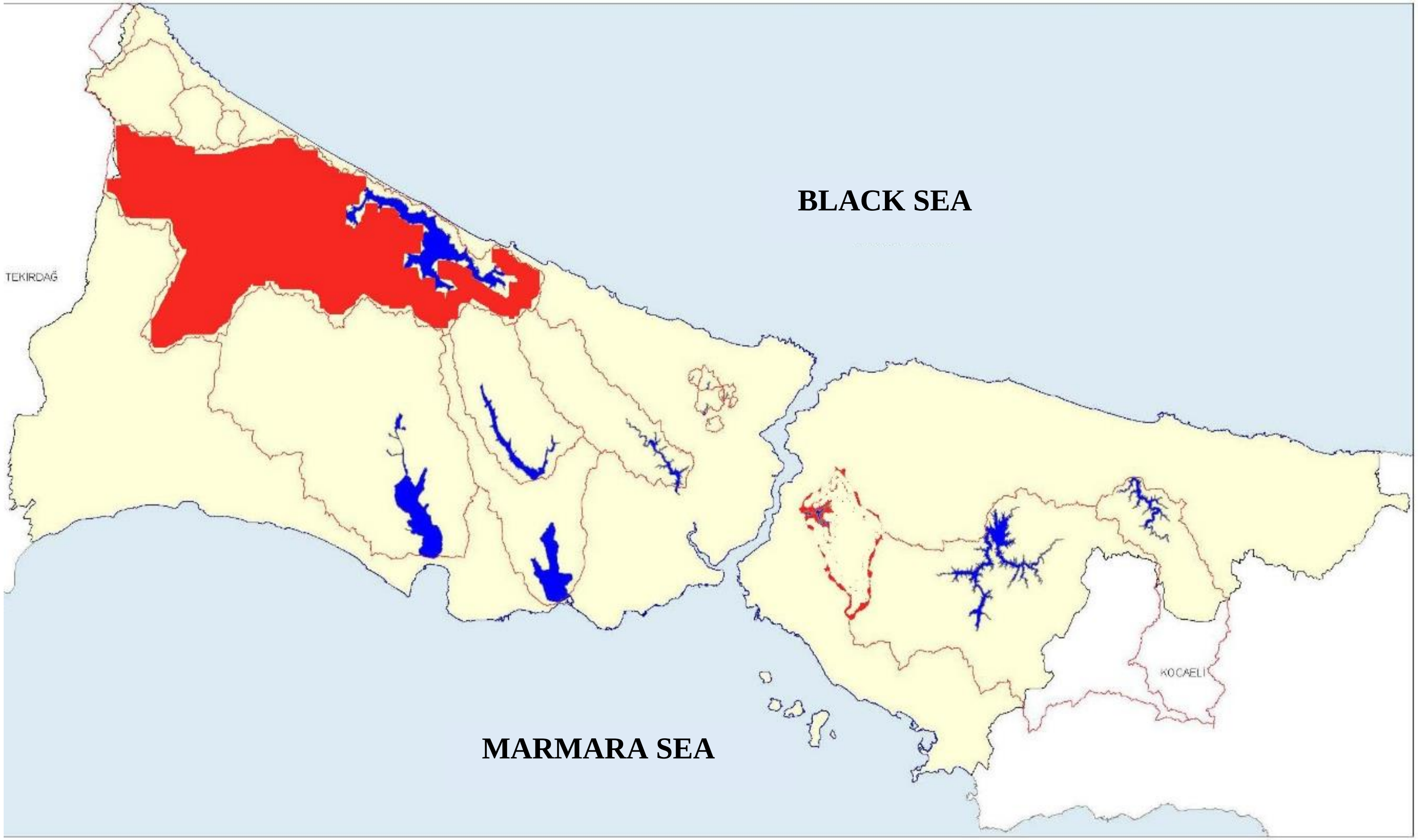

Figure 2.5. Istanbul city water resources and Terkos Basin geographical location (İMP, 2006).

Lake water is now being used with the help of transmission pipes connecting through the lake of Alibey Dam. Aqueducts in the basin are presented in the Table 2.8. Terkos Lake Basin contains a low level of population and is oftenly used as an agricultural land. There is no big industrial facility in the blister area of the basin. However, occasionally, sand withdrawn from the coastal area has a destructive effect over the band that separates the Black Sea and the basin itself. There have been preemptive measures employed at this point.

Table 2.8. Influent streams sourcing the lake of Terkos (İSKİ, 2010).

Ana Stream	Derin Stream	Kısa Stream	Sinanköprü Taşlıbayır Stream
Arı Stream	Dışbudaklık Stream	Koca Stream	Sinir Stream
Ayazma Stream	Dingil Stream	Kumarlı Stream	Sivas köy Stream
Balçık Stream	Eğrek Stream	Kurt Stream	Sukarışığı Stream
Belgrad Stream	Fitirgan Stream	Kuru Stream	Suluklu Stream
Binkılıç Stream	Gümüşparası Stream	Kürek Stream	Şeytan Stream
BüyükStream	Istranca Stream	Kürk Stream	Şişkafa Stream tributaries
Ceviz Stream	Kaci Stream	Kütüklü Stream	Taşlıgeçit Stream
Çatalcakaya Stream	Kanlıyazma Stream	Malakçı Stream	Tayakadın Stream
Çatalkaya Stream	Kaptan Çayırı Stream	Mandıra Stream	Tuğlapınarı
Çavuşoğlu Stream	Karacaköy Stream	Mekan Stream	Tumba Stream
Çeko Streams tributaries	Karamandıra Stream	Molla Hüseyin Stream	Ustuluk Stream
Çeşme Stream	Karasu Stream (and 3 tributaries)	Mürverçeşme Stream	Yeniköy Stream
Çiftlik Köy Stream	Karatina Stream	Pınar Stream	

Water inlet values through the Terkos Dam has been depicted in the Figure 2.6. Terkos Lake is mainly fed from the precipitational water over the winter periods (December-February). 54.2% (91 million m^3) of the annual water inlet occurs in winter, rest are in descending order as spring (45.8%), autumn (15.7 %) and summer (5.2%) (İMP, 2006 Yüzeysel Su Kaynakları Araştırma Raporları).

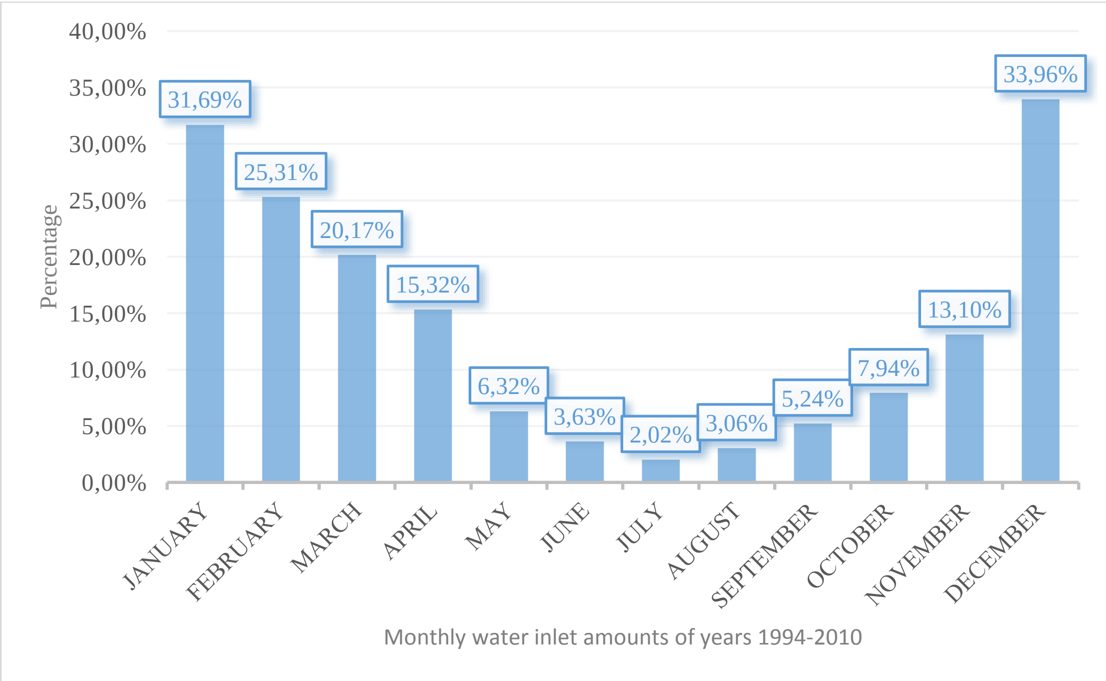

Figure 2.6. Monthly water inlet amounts (hm^3) and respective ratios (%) for Terkos Lake resorvoir (1994-2010) (İSKİ, 2010).

2.3. Physical Ecosystemic Properties and Natural Thresholds of the Terkos Basin

In this section, natural thresholds related with the Terkos Drinking Water Basin and associated ecosystemic properties (geomorphology, geology, hydrology, seismicity, erosion, etc) will be revealed according to the results obtained from the ground determination studies and also from some variaty of related institutions` work.

Terkos Drinking Water Basin`s physical ecosystemic attributes are based on the natural thresholds. These properties are geomorphological status, agricultural, forestry, mine and erosion areas, lastly hydrological and hydrogeological conditions.

2.3.1. Terkos Lake Geomorphology

Topographic Structure: Terkos Lake Basin is located in Çatalca domain residing in between Çatalca-Kocaeli at northwestern side of Marmara Region in Turkey (Darkot ve Tuncel, 1981) (Figure 2.7). The basin has boundaries with coastal region between Kasatura

Körfezi-Yalıköy at north, coastal region between Karaburun-Rumelifeneri at east, Alibeyköy Dam Lake Basin, Sazlıdere Dam Lake Basin, Küçükçekmece Dam Lake Basin, Büyükçekmece Dam Lake Basin and coastal region between Silivri-Büyükçekmece at south, Boyacı Stream Basin and Tekirdag at west sides. The boundaries have actually been formed with the lines undergone through the inlet streams towards the basin itself. Terkos Basin has an area of 736 km² and is located between 41º 14' – 41º 27' Northern latitudes and 28º 08' – 28º 43' Eastern longitudes.

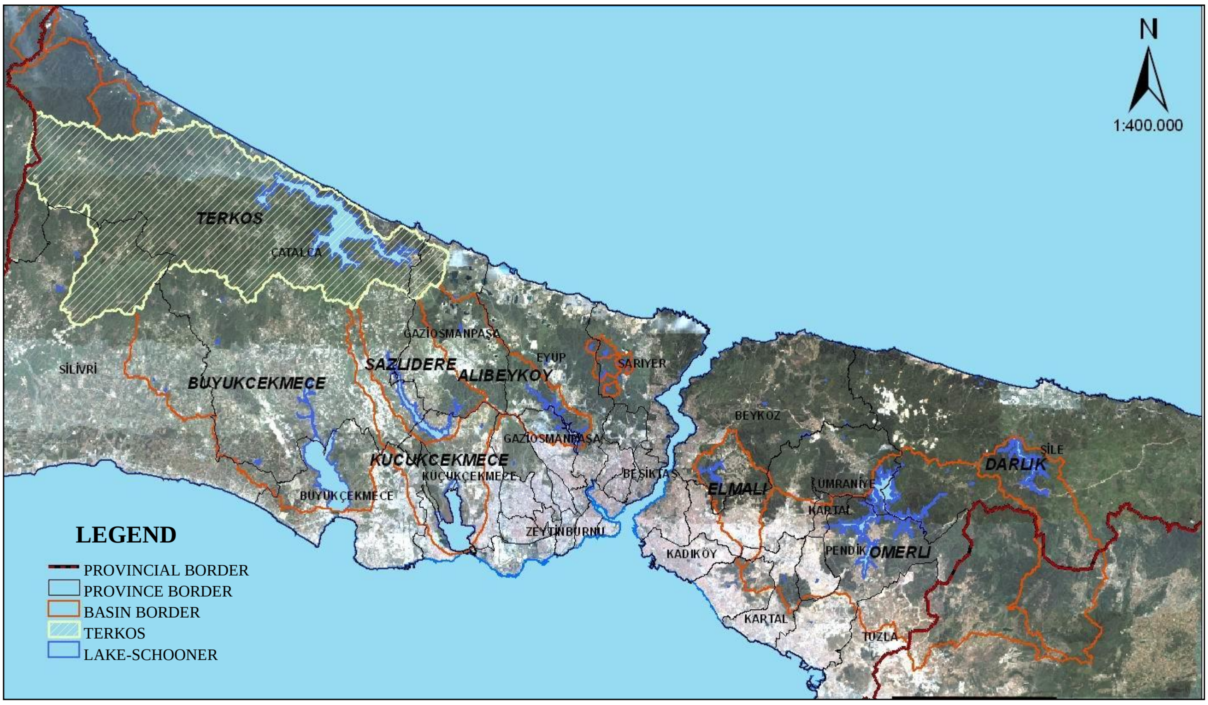

Figure 2.7. Location of Terkos Drinking Water Basin in Istanbul (İMP, 2006).

Inside the area of the basin, typical settlement places are forest villages which count up to 28. These villages are; Karacaköy (Karamandere, Ormanlı, Belgrat, Gümüşpınar, Hisarbeyli, Celepköy), Binkılıç (Binkılıç, Aydınlar, Yaylacık), Silivri (Danamandra, Küçük Sinekli, Sayalar), Büyükçavuşlu (Çayırdere), Çiftlikköy (Çiftlikköy, Başakköy, Örencik, Kalfaköy, Dağyenice), Hadımköy (Yazlık, Yassıören), Durusu (Balaban, Karaburun, Durusu, Boyalık, Baklalı), Yalıköy ve Taşoluk (Tayakadın, Yeniköy) forest villages (Figure 2.8) (Turgut, S., 2000).

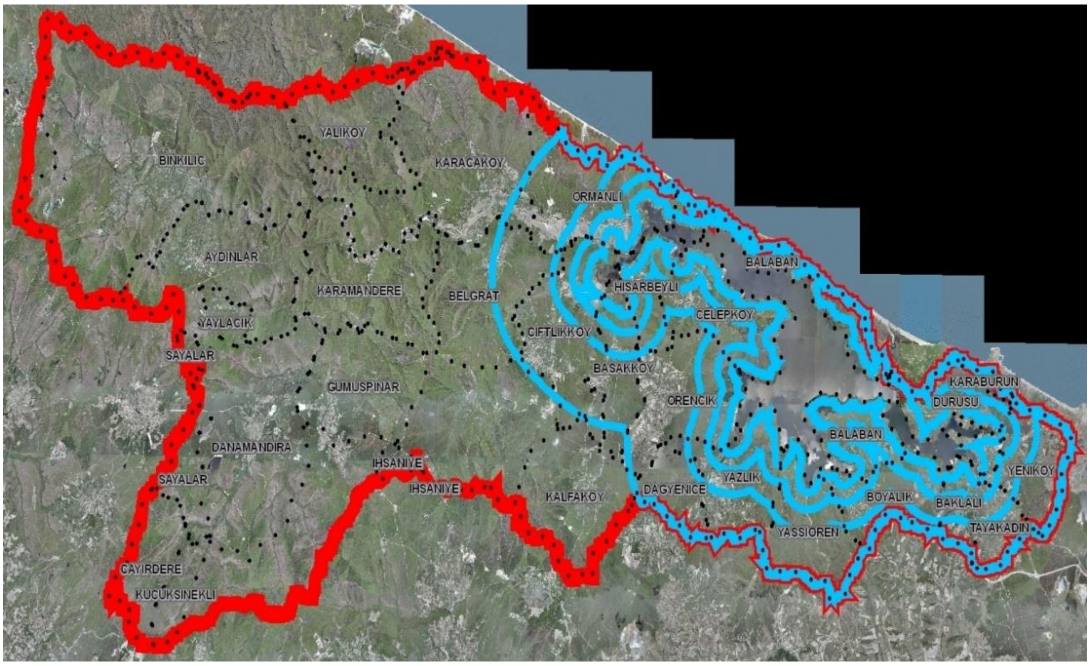

Figure 2.8. Settlement places located in Terkos Lake (İMP, 2006).

Contour Map Analysis: All examples of mountains, plateaus and plains with their structural geomorphological unities can be seen in the Terkos Basin. (Table 2.9, Figure 2.9 and Figure 2.10) The broadest distribution among these geomorphological modalities belongs to the plateau platforms and their hillside landings. Plateau platforms cover 20% of the total area of the basin. Mountains follow plateaus with 10%, plains and basal planes come after with 5%. Hillside areas should also be considered in addition to the main morphological units. Hillside areas cover 65% of the total basin area. This ratio is almost the double of the sum of other geomorphological units` ratios in the basin. This fact also suggests the fast rate of corrosion, cleavage and disruption in the land.

When the hillside areas are considered together with the plateu platforms, the total coverage of plateaus increases up to 85% and this is almost the entire of the basin itself. The mountains forming the foothills of the Istranca (Yıldız) mountains cover 1/10 of the basin. Plains and basal planes are found in trace quantities, forming only 5% of the basin (Figure 2.13) (İstanbul Metropoliten Planlama ve Kentsel Tasarım Merkezi, 2006. Doğal Yapı Grubu Araştırma Raporları).

Table 2.9. Terkos Lake main geomorphological unities analysis (İMP, 2006).

Terkos Basin	**Area (km^2)**	**Percentage (%)**
MOUNTAINS	73	10
PLATEAUS	141	20
PLAINS	38	5
HILLSIDES	442	65
TOTAL	**694**	**100**
TERKOS LAKE AREA	42	
TOTAL BASIN AREA	**736**	

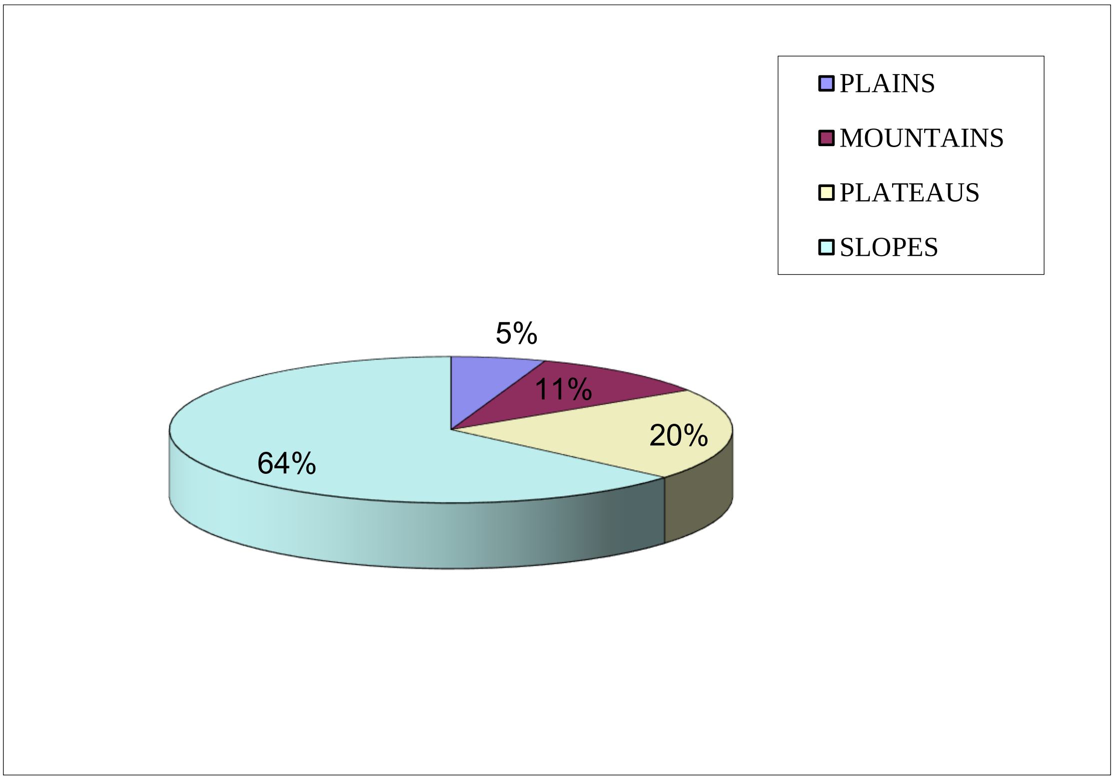

Figure 2.9. Terkos Lake main geomorphological unities analysis graphic (İMP, 2006).

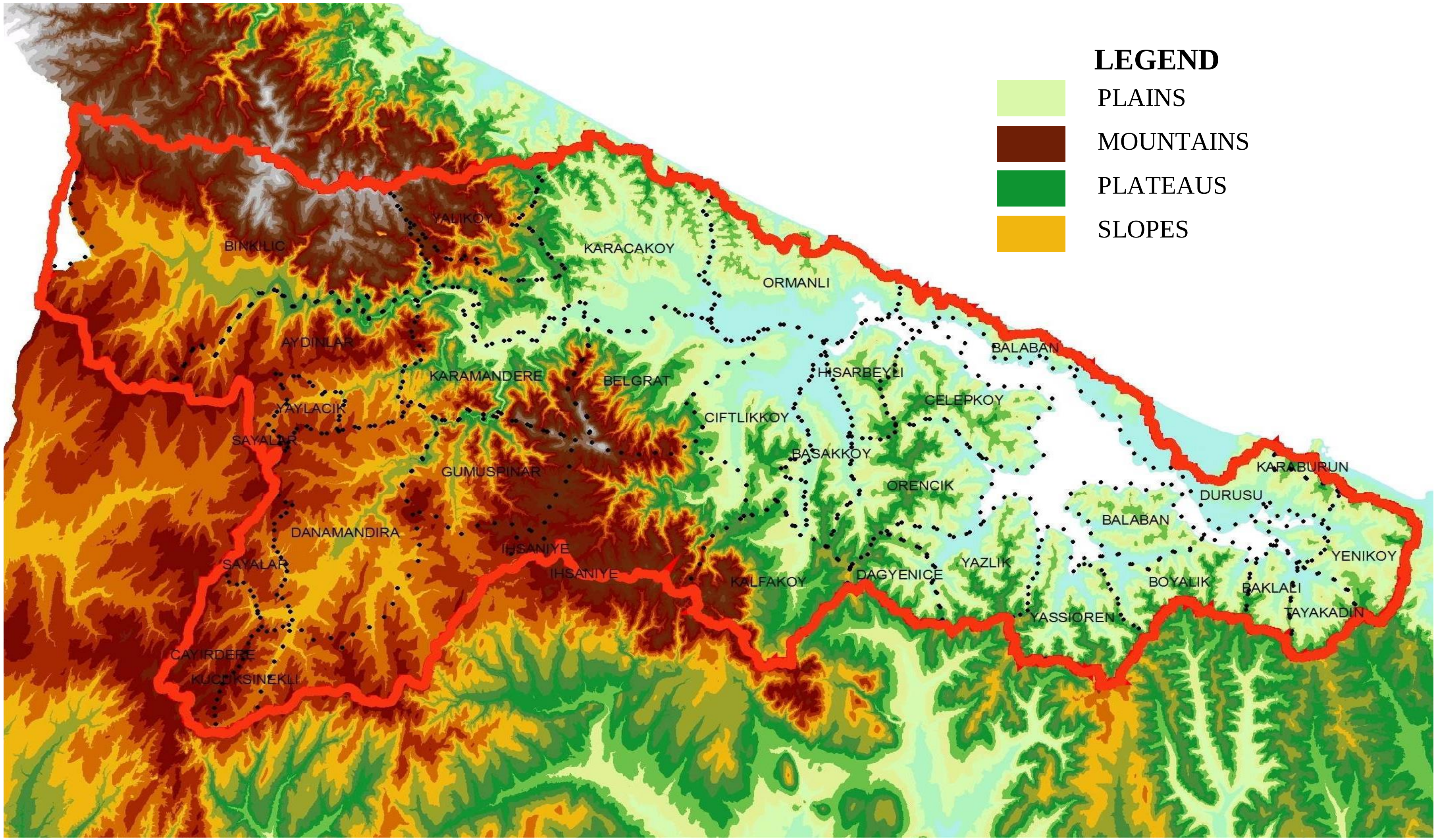

Table 2.10. Terkos Drinking Water Basin contour map analysis (İMP, 2006).

Slope Analysis: Terkos Drinking Water Basin mostly constitutes of hilly terrains. Hence, the number of flatwise and smooth terrains is significantly low.

Basin is found to have varying slopes ranging from too steep to mild steep points. Regions with 12-20% of downslopes cover most of the basin with 21,207.70 ha of area. (Table 2.10, Figure 2.11 and Figure 2.12). Steep regions are commonly covered with forests in the basin and the steepness had a restrictive effect of determining landuse capability among the region terrains (İstanbul Metropoliten Planlama ve Kentsel Tasarım Merkezi, 2006. Doğal Yapı Grubu Araştırma Raporları).

Table 2.11. Area distribution among the slope groups (İMP, 2006).

Slope	**Area(ha)**	**Percentage(%)**
0-2	3,317.90	4.91%
2-6	12,789.70	18.93%
6-12	15,700.70	23.24%
12-20	21,207.70	31.40%
20+	14,529.90	21.51%
Total	67,545.90	100.00%

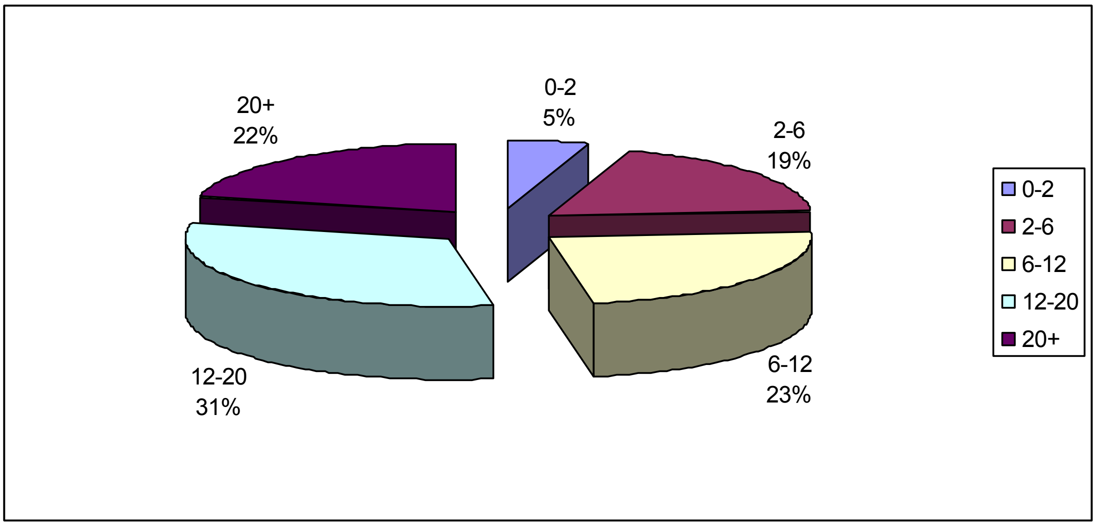

Figure 2.10. Area distribution among the slope groups (İMP, 2006).

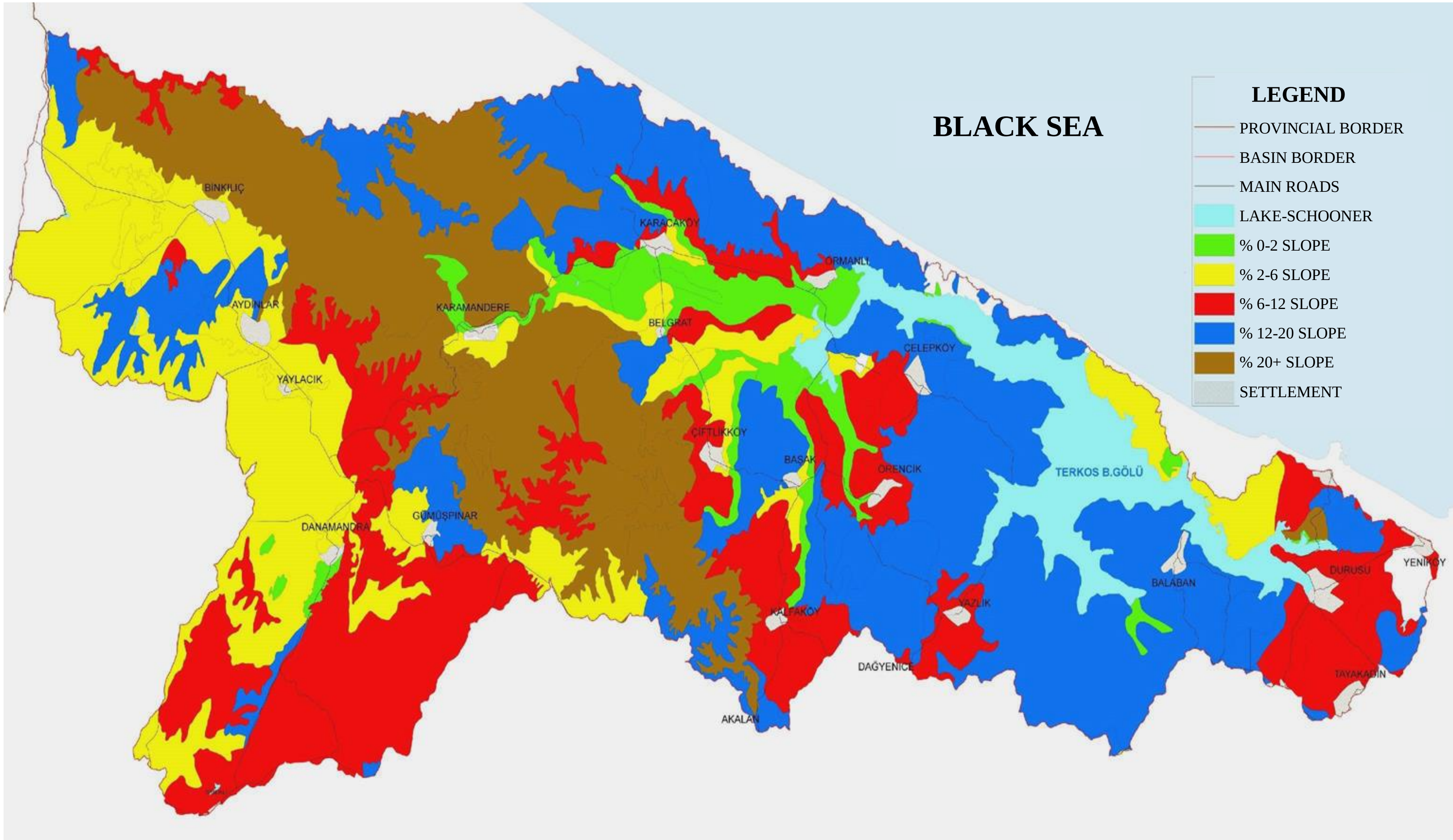

Figure 2.11. Terkos Drinking Water Basin slope analysis (İMP, 2006).

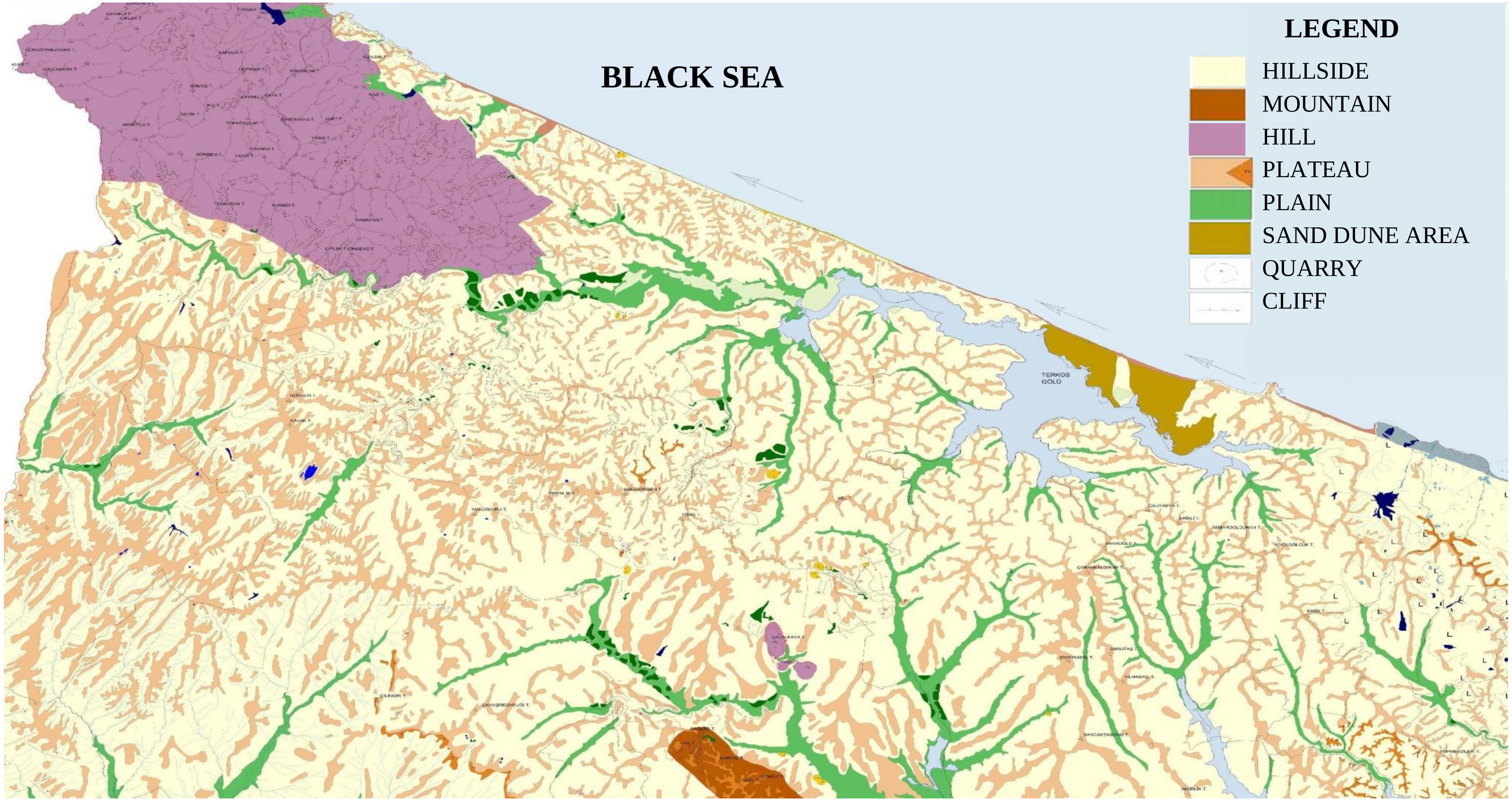

Figure 2.12. Terkos Drinking Water Basin geomorphologic analysis (İMP, 2006).

2.3.2. Terkos Basin Geology

The oldest structures in the basin are high mountainside areas located in northwestern side of the basin. They were typically formed by Paleozoic schist, metaquartzites and granites that have changed morphologically with the hard and resistive metamorphites over the Istranca Massifs. Over this massif region, high Eosen-Oligosen formation argillaceous limestone- chalky claystone and sandstone became discordant (Figure 2.16). In general terms Terkos Basin plateaus were mainly formed by the rocky structures which represent the high flat and high corrosion surfaces in the basin (Figure 2.14).

Figure 2.13. Overlook towards Terkos Lake cliffs and coastal cordon in norteastern side (İMP, 2006).

Quaternary old aluvions can be seen in the bottoms of valleys in Belgrad Stream, Binkılıç (Istranca) Stream, Kurt Stream, Çiftlik Stream, Karaağaç Stream, Örencik Stream, Yiğitler Stream, Sinanköprü Stream, Kapaklı Stream, Tayakadın Stream, Yeniköy Stream and Mandıra Stream. These areas are considered as plains and basal planes in the context (Figure 2.15) (İMP, 2006., Tarım Alanları ve Toprak Araştırma Grubu Tarafından Yapılan Arazi Çalışmaları Sonuçları)

Figure 2.14. An overlook from Ormanli Village towards the swampy and reedy basal terrain in the west of Terkos Lake (İMP, 2006).

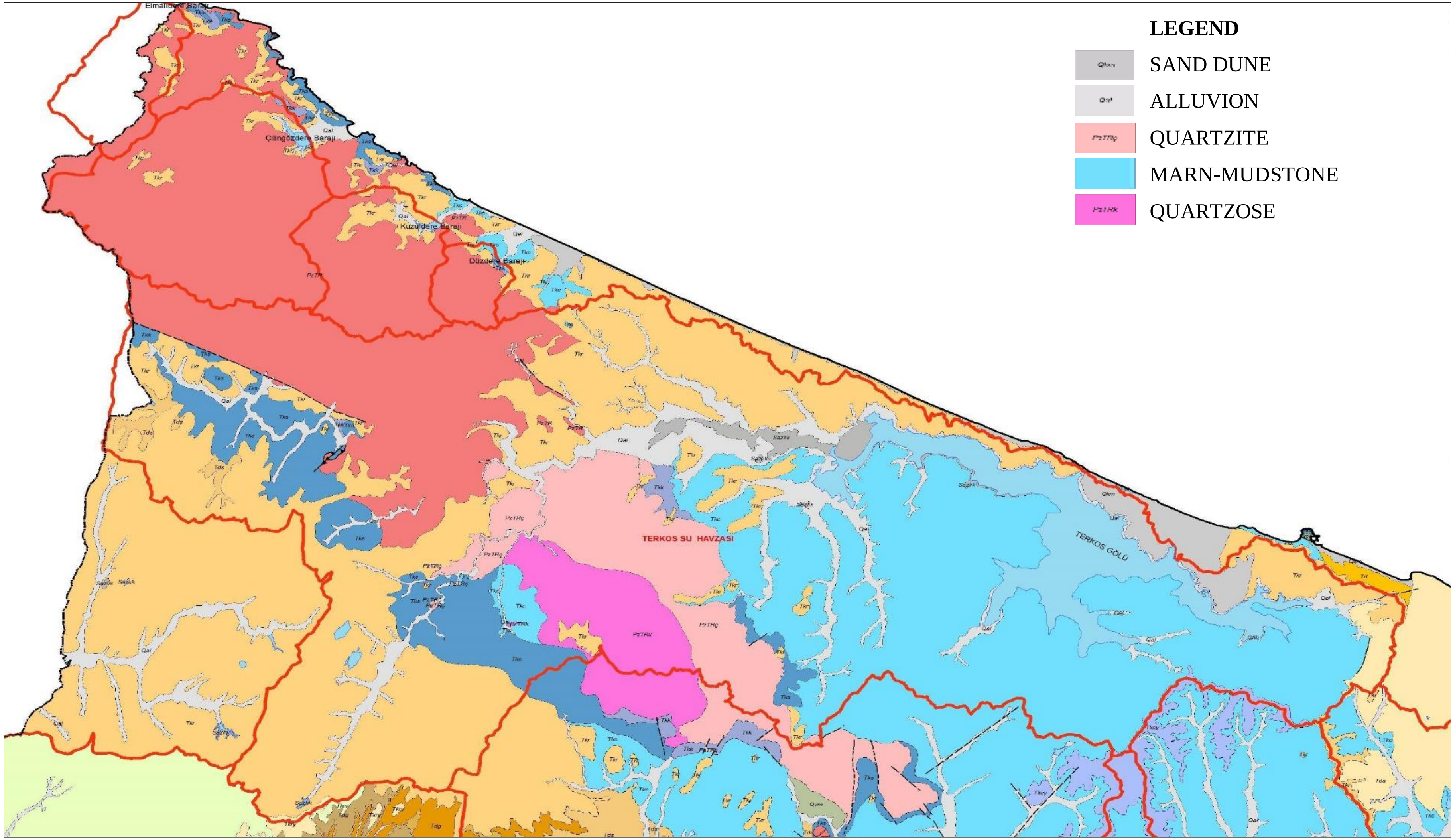

Figure 2.15. Geological situation analysis map (İMP, 2006).

2.3.3. Hydrological Structure in the Terkos Basin

Topography in the Terkos Lake Basin and the nearby water resources have a direct impact over the climate conditions in the environment. The region mostly takes place in the coastal side with an altitude of almost sea level. Due to this fact, Black Sea climatic conditions are clearly observed in the basin ecosystem. The lake climate is rainy in the winter, arid and warm in the summer terms. Water temperature of the lake is 4–6°C in winter and is around 24°C in summer periods. Warmest month of the year is July and on the contrary the coolest is January. The most dominant breeze in the region comes from North and NorthEast. However, winds blowing from the South have clear dominancy between November and April. The ratio of humidity varies between 50% and 85% with a mean value of 73% (İstanbul Metropoliten Planlama, 2006., Çevre Sorunları Araştırma Grubu Araştırma Raporları).

The relation between Terkos and other neighbour basins and regional underground water flow are closely associated with the impermeable fundament litology which functions as a natural barrier in the basin. Terkos Lake main axis is 12 km in length and 5 km in width in East – West direction. The lake elevation from the sea level changes between -2 m and +4.5 m. Spring waters are generally drained away from Kırklareli, Ergene and Belgrat formations (İstanbul Metropoliten Planlama, 2006., İstanbul Geneli Jeolojik Yapı raporları).

A stream station was built in 1966 by DSI nearby Karamandere Village over Istranca Stream which feeds the Terkos Lake. During the observations performed in the station, the average flow rate of Istranca was found to be 2.17 m^3/sn. The least and the most values for flow rates were found to be 0.01 m^3/sn and 380 m^3/sn, respectively. Figure 2.17 illustrates the monthly average changes of the superficial flows towards the Terkos Lake. The graphic clearly suggests that the superficial flows especially in July, August and September have a significant degredation in 85% rate when compared to the flows occurred in winter.

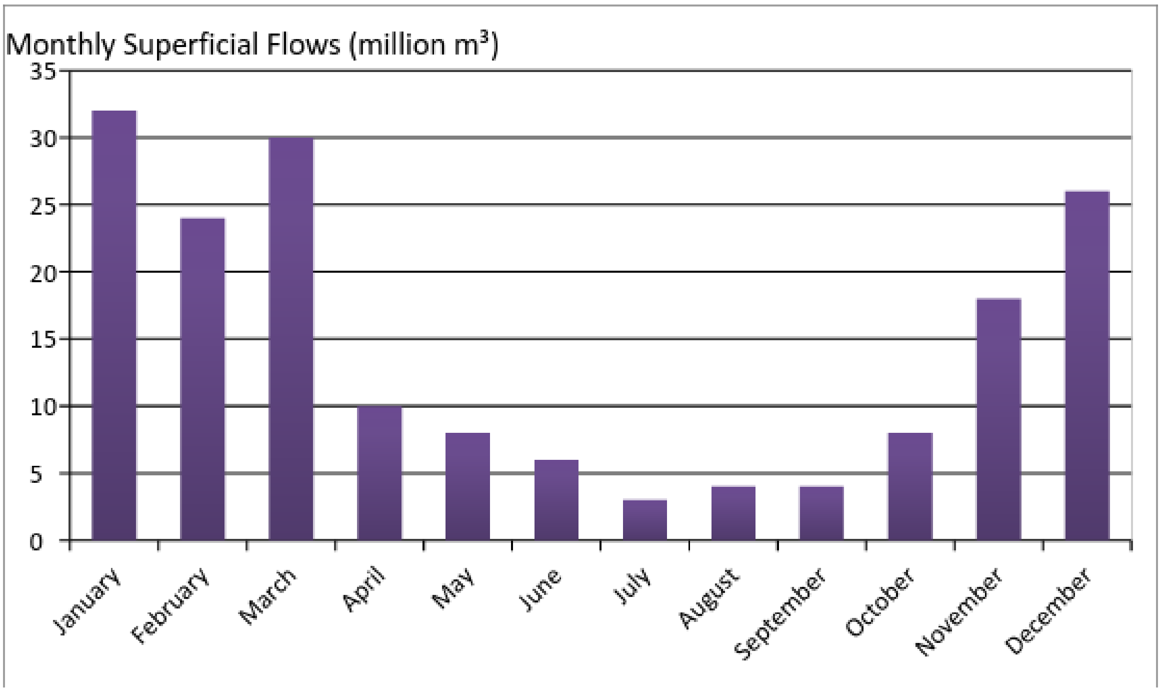

Figure 2.16. Monthly average changes of the superficial flows towards the Terkos Lake (İSKİ, 2010).

The main drainage behaviour of the basin exhibits dendritic drainage characteristics. However, especially in the southern side of the lake, sporadic drainage corruptions and spring fractures can be observed which actually indicates that the basin environment has a potential of disturbed drainage characteristics as well. Moreover, due to the fact that the springs located in the borders of weak contact zones and formations, basin shows lattice drainage behaviours occasionally.

The streams feeding Terkos Basin and performing the water conduction in the basin are under protection by ISKI. Streams are fall out to Terkos from east, west and south junction points. When the existing superficial ground flows are considered, streams are observed to be more commonly located in the western side of the lake. Being one of the main streams feeding the lake, Istranca Stream is located in the west of the basin and carry the water load in 3 main branches. Istranca and other streams fall out to the Terkos in an interconnected manner. In the east and southern sides, streams are not as dense as it is seen in the western side of the basin.

Streams feeding Terkos Lake in the east inlet are Ayazma, Tayakadın, Kanlıyazma, Yeniköy, İstilik, Ceko; In the south inlet Malakçı,_Sinanköprü, Taşlıbayır, Kaptançayırı, Ayna, Derin; In the west inlet Koca, Fıtırgan Sivasköy, Bıyık, Kumalı, Kürk I, Tuğlapınar, Çiftklikköy, Eğrek, Sülüklü, Keçierme, Belgrad, Ceviz I, II, Sınır, Çavuşoğlu, Karasu, Karacaköy, Balçık, Istranca I, II, III, Çatalkaya, Karamandıra, Keçi, Şeytan I, II, Binkılıç, Büyük, Kısa, Çeşme, Kürk II, Taşlıgeçit, Kürek, Dingil, Gümüşparası, Şişkafa, Dişbudak, Kütüklü, Münverçeşme, Mandıra. (Figure 2.18 and Figure 2.19) (İstanbul Metropoliten Planlama ve Kentsel Tasarım Merkezi, 2006. Doğal Yapı Grubu Araştırma Raporları).

According to the stream order system developed by Horton (1945) and Strahler (1952), drinking water basins` stream ordering is performed with the flow directions which start from 3rd degree courses in the drainage network (Figure 2.20). This model states that courses collecting water only from superficial resources are called 1st degree courses. One other condition for being 1st degree course is not to have any branch over any stream basins. Same model also identifies 2nd degree courses as combination of one or more 1st degree courses. Similary 3rd degree courses are considered as combination of 2nd degree courses. Numbering goes the same way for the upper degree courses. Once the degree of the course increases, the basin area, total course length and superficial ground flow rate increases.

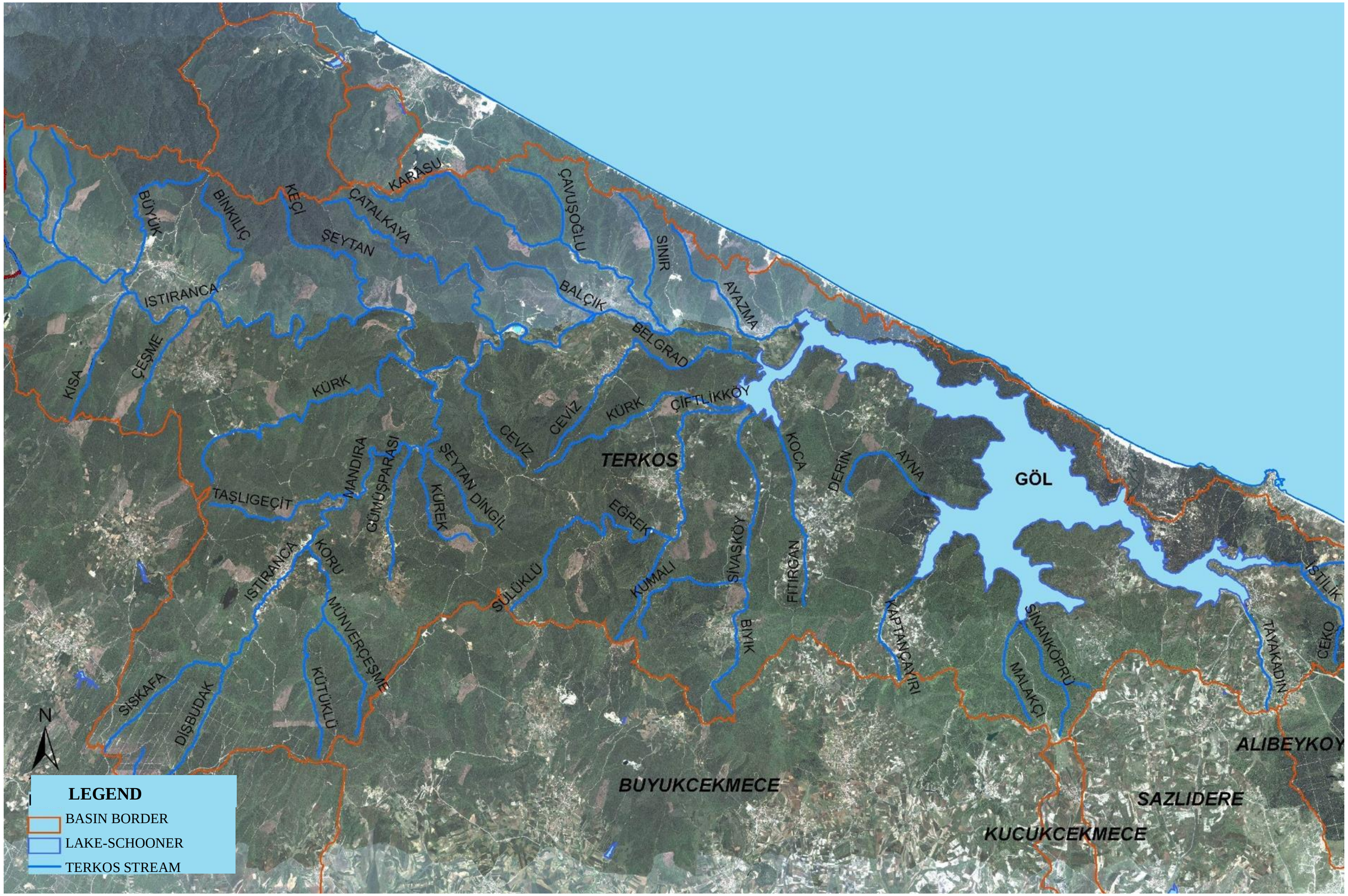

Figure 2.17. Streams feeding the Terkos Lake (İMP, 2006).

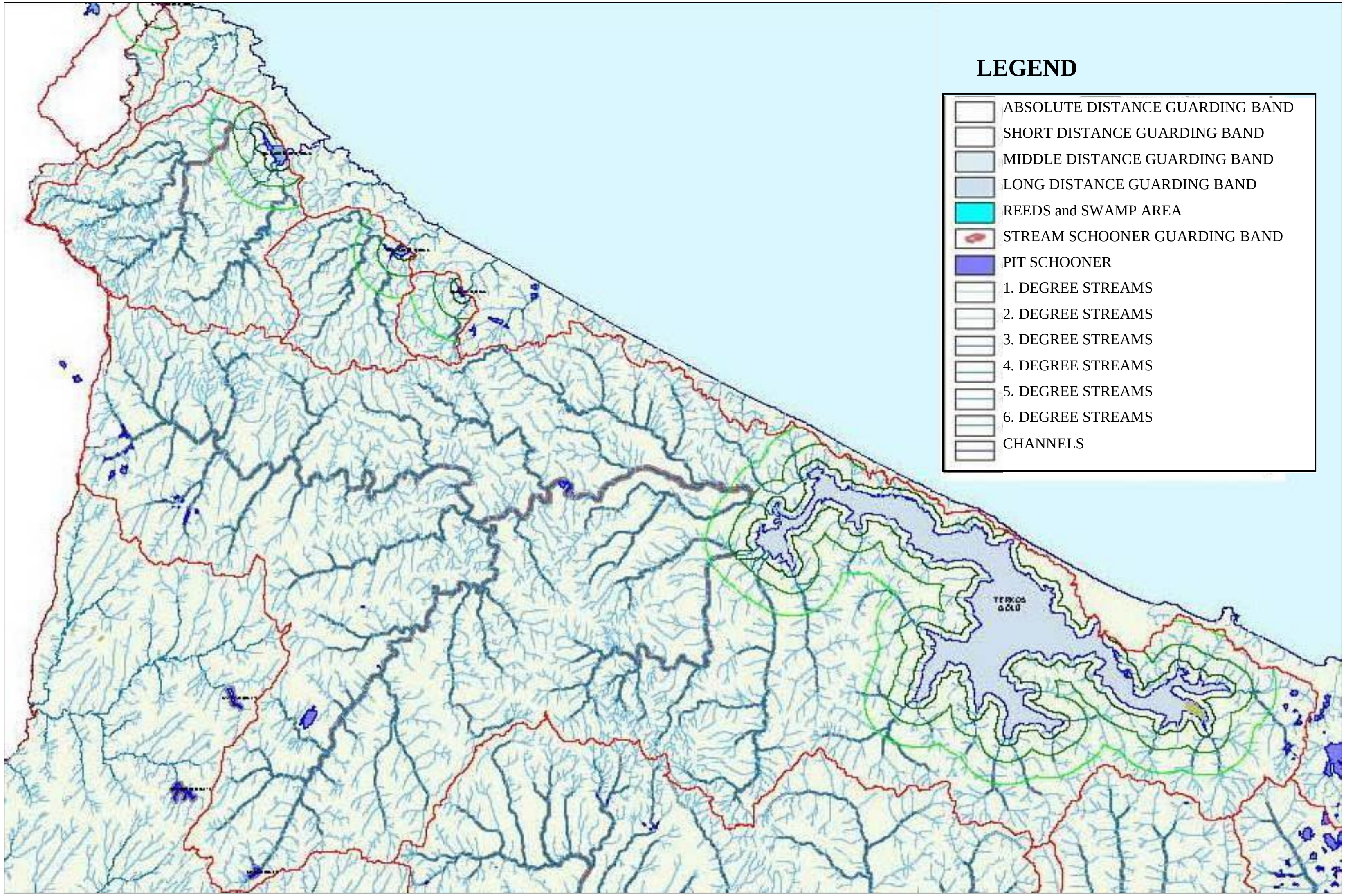

Figure 2.18. Hydrological structure analysis map (İMP, 2006).

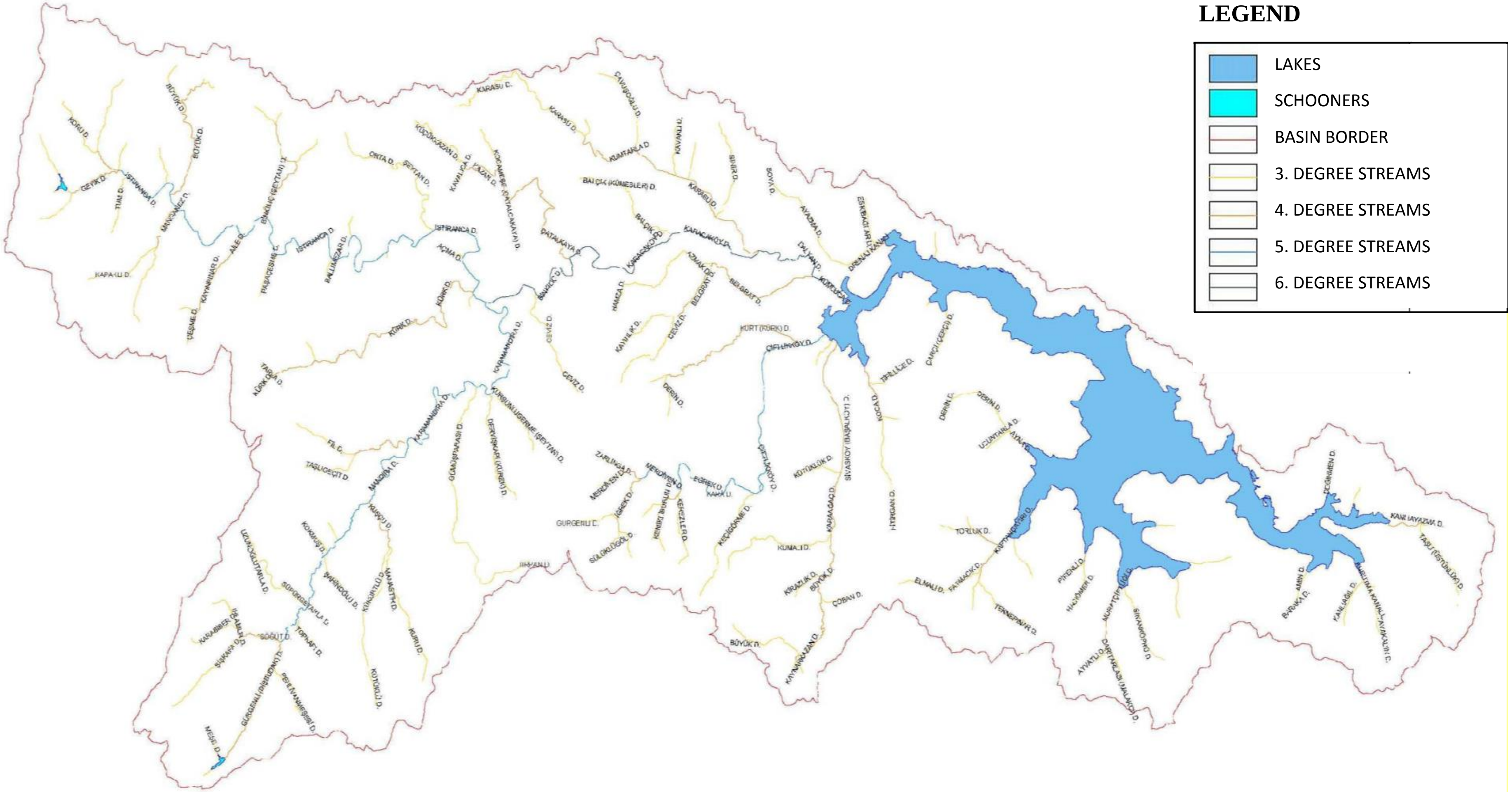

Figure 2.19. Terkos (Durusu) basin schema depicting streams according to ordering and flow directions (İMP, 2006).

2.3.4. Hydrogeological Situation in Terkos Basin

Geohydrological environments and water spots constitutes the hydrogeological environments. Water springs formed by natural leakages of surface water from very small indents on the ground they can be called in various ways like faunts, corpuscules, springs etc.. These springs can be classified under 3 main groups in Istanbul: “springs which preserve their natural outlook”, “springs which were converted to fountain or watering hole”, “springs converted into springwater facilities”.

Water spots are high in number in the Terkos Basin, formed of faunts/ corpuscules (total of 253), fountains (total of 91), springwater facilities (total of 13) and water wells (total of 131). These areas should be preserved with great care (Figure 2.22, Figure 2.23, Figure 2.24, Figure 2.25, Figure 2.26).

Geohydrological environments are also classified as impermeable, semi-permeable semi-impermeable and permeable environments (Figure 2.21). Impermeable environments collect the water underground and they possess an underground collector role. Likewise, semi – impermeable environments help to hold the water underground. Semi- permeable and permeable types are low efficient water collectors.

Hydrogeological environments are constituted from aquifers and aquitards. (İstanbul Metropoliten Planlama ve Kentsel Tasarım Merkezi**,** 2006, Yeraltı Suyu Araştırma Raporları)

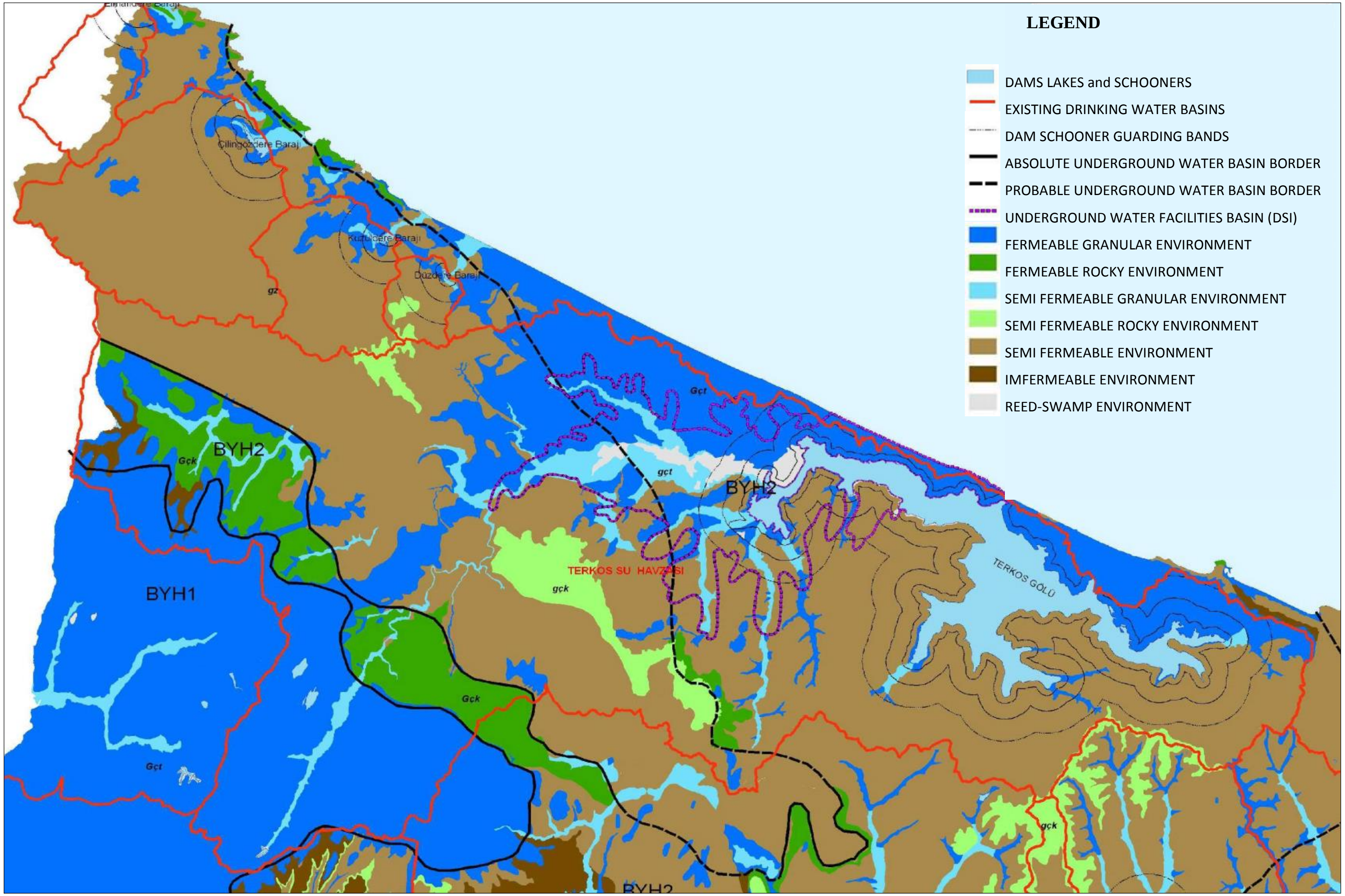

Figure 2.20. Terkos Drinking Water Basin hydrogeological structure analysis map (İMP, 2006).

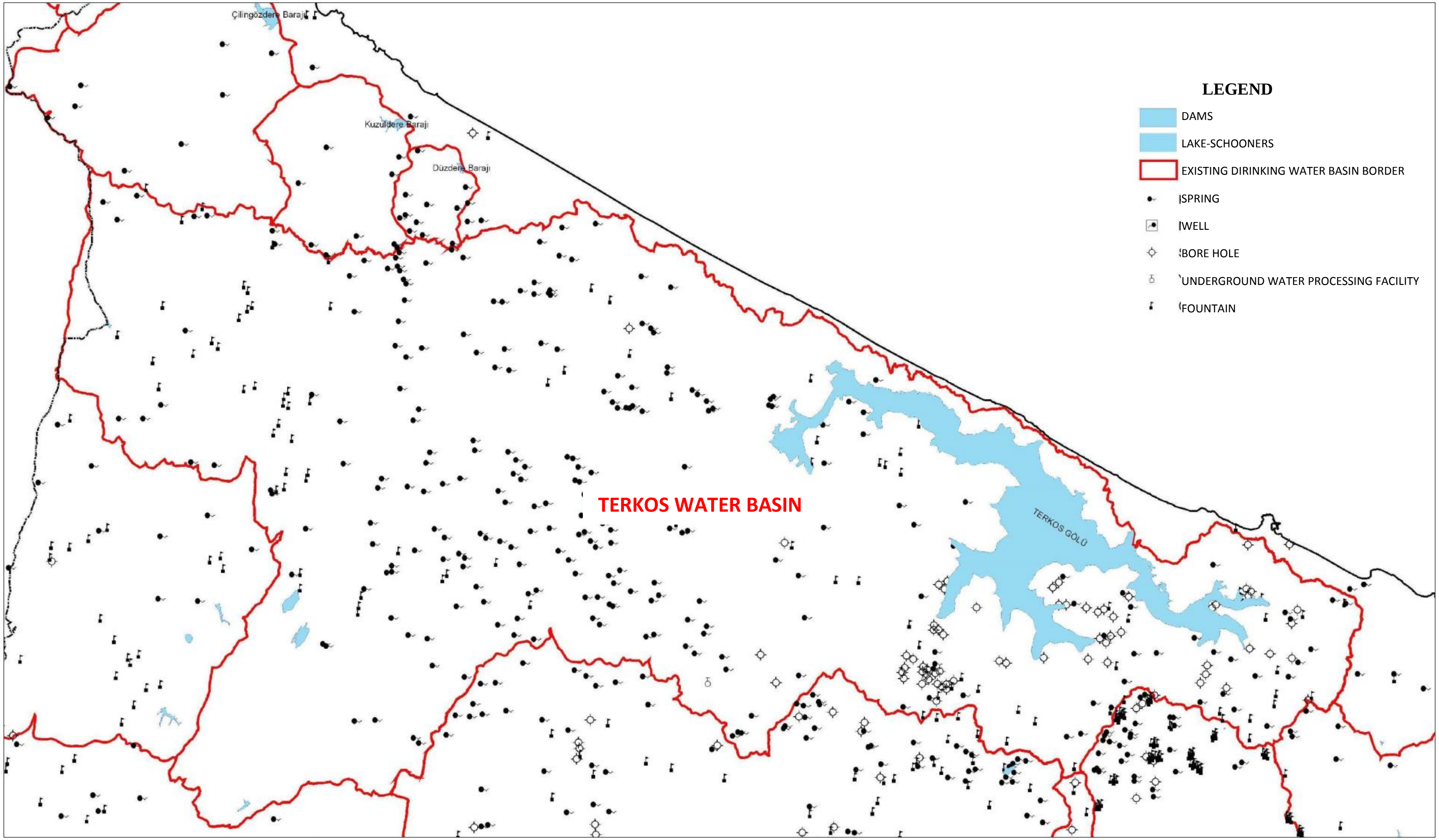

Figure 2.21. Terkos Drinking Water Basin water spots map (İMP, 2006).

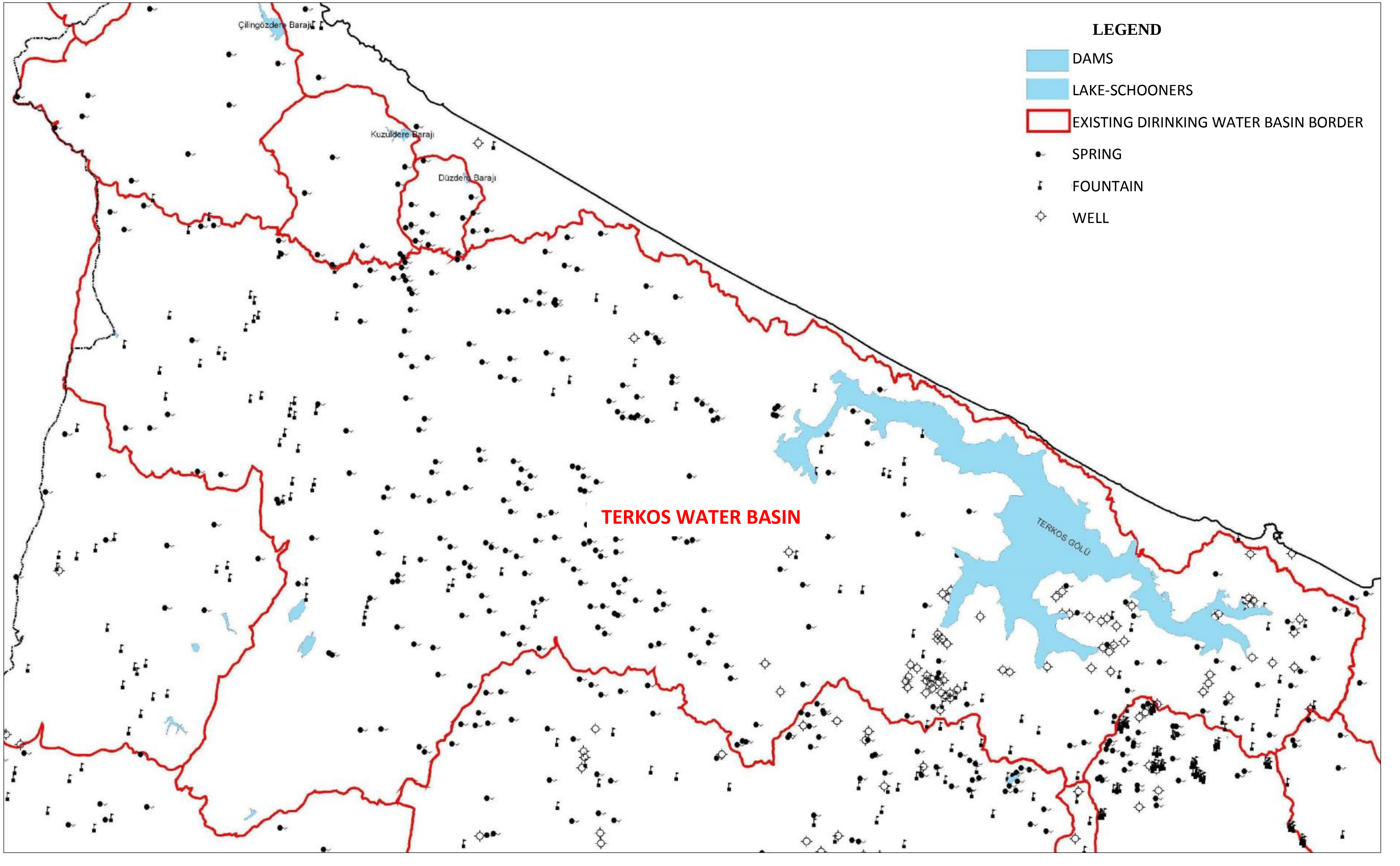

Figure 2.22. Terkos Drinking Water Basin spring, fauntain and water well map (İMP, 2006).

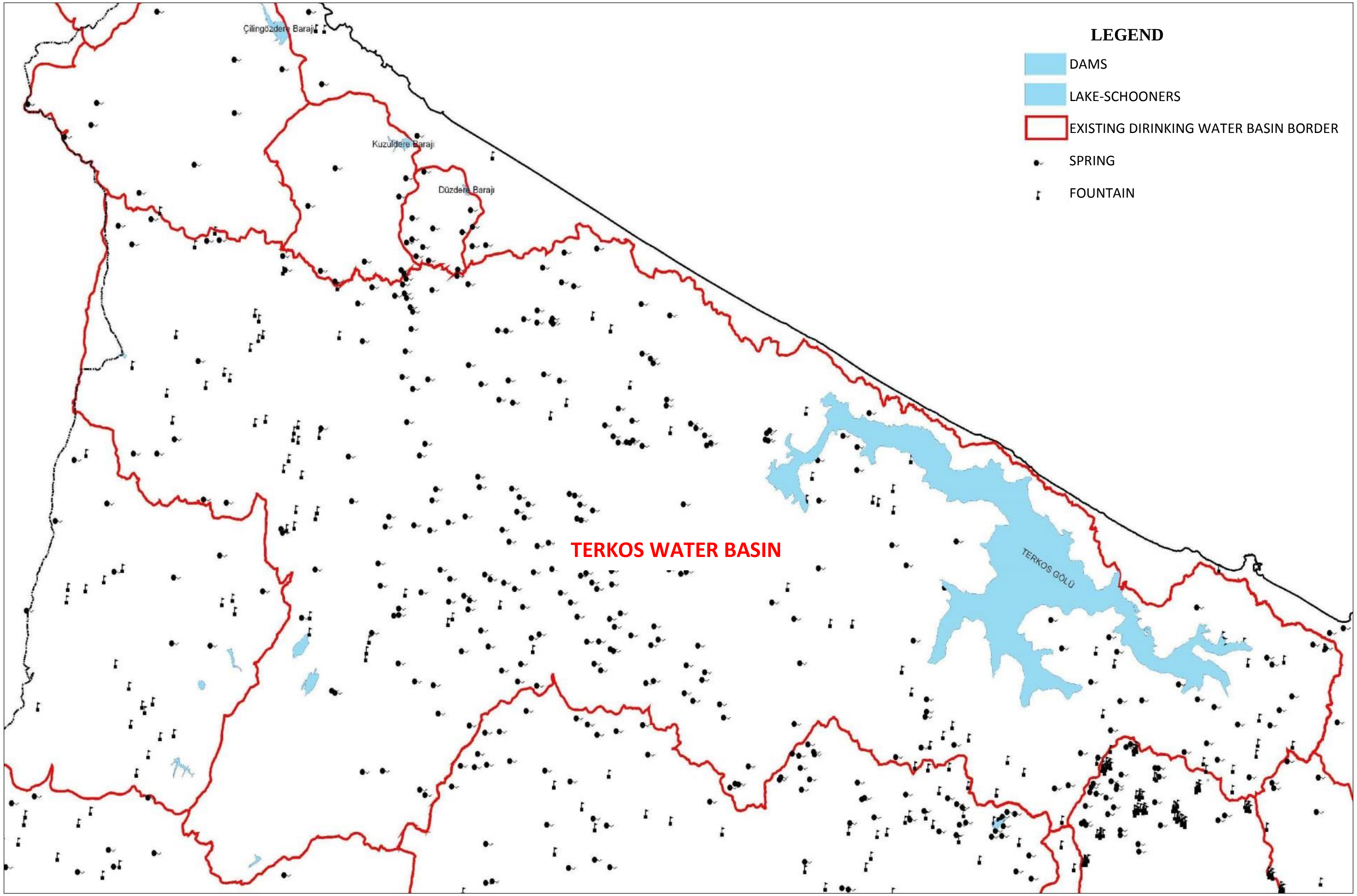

Figure 2.23. Terkos Drinking Water Basin springwater facilities map (İMP, 2006).

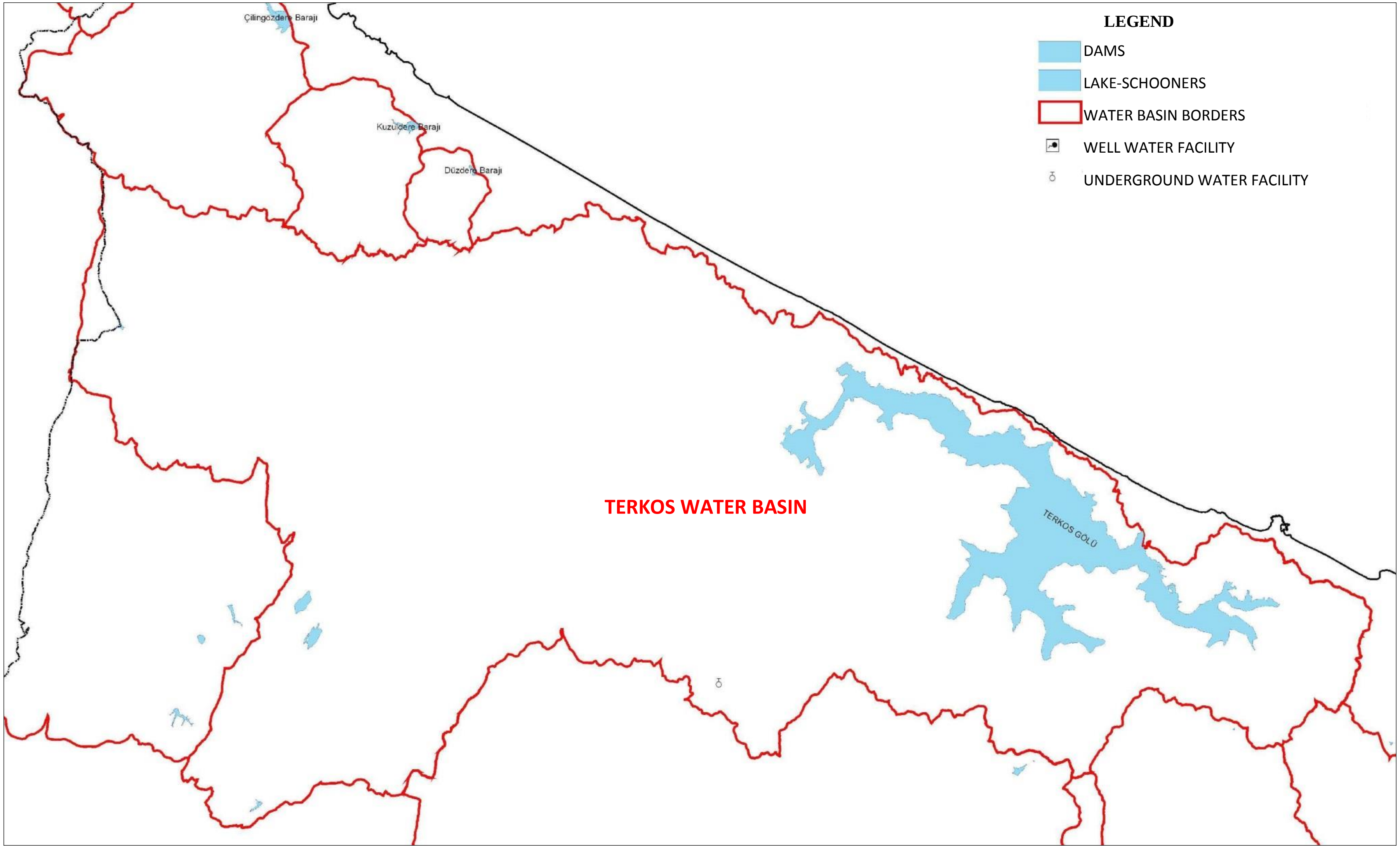

Figure 2.24. Terkos Drinking Water Basin underground water facilities map (İMP, 2006).

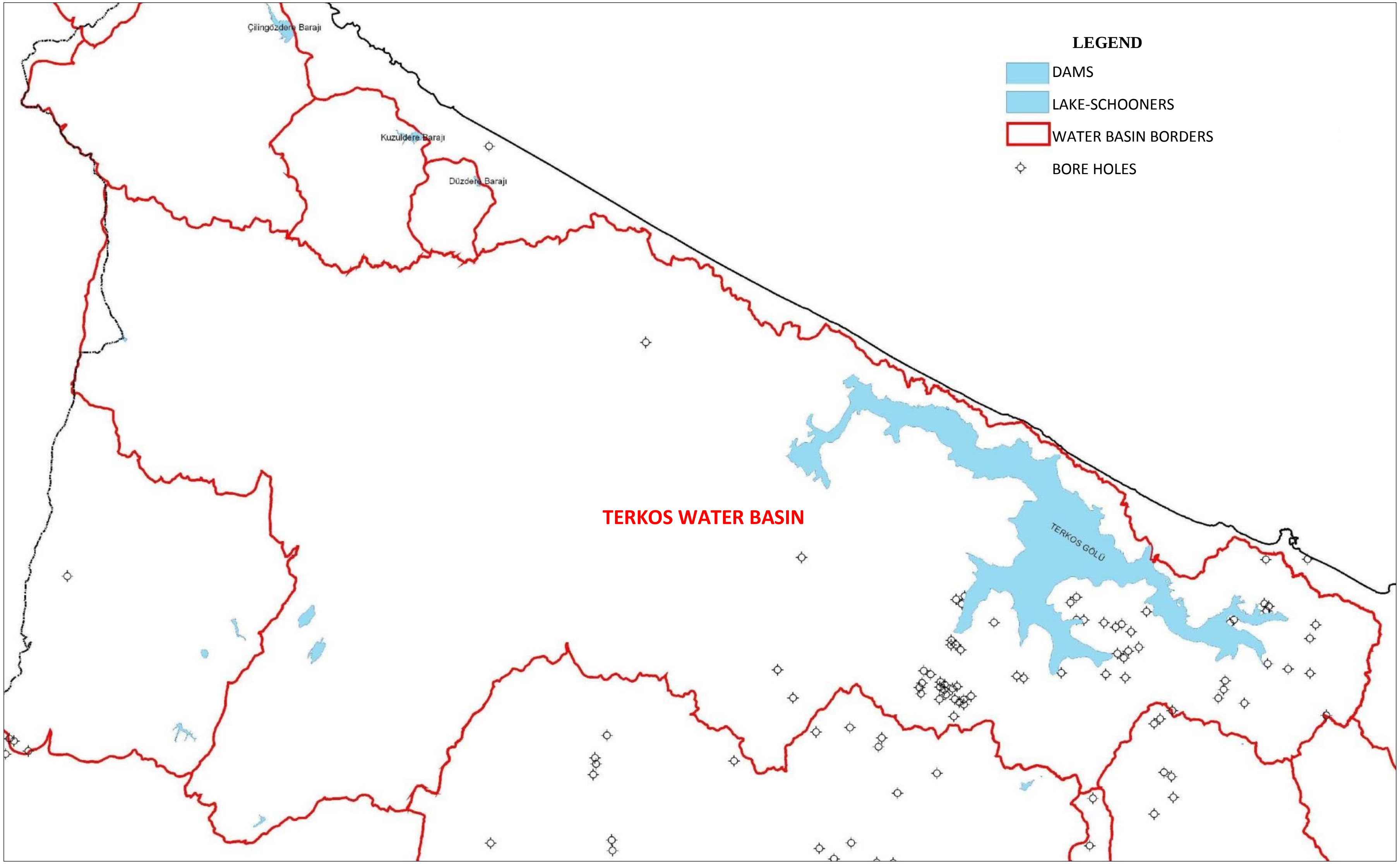

Figure 2.25. Terkos Drinking Water Basin boreholes map (İMP, 2006).

2.3.5. Forest Areas in Terkos Basin

67% (49,178.90 ha) of the working area in Terkos Basin are covered with forests (Table 2.11, Figure 2. 27).

Table 2.12. Terkos Basin forestry areas (Forest Regional Directorate, 2003).

Forest Areas in Terkos Basin	**Area (ha)**
Forest Area	49,178.90
Non-Forest Area	24,443.74
TOTAL	73,622.64

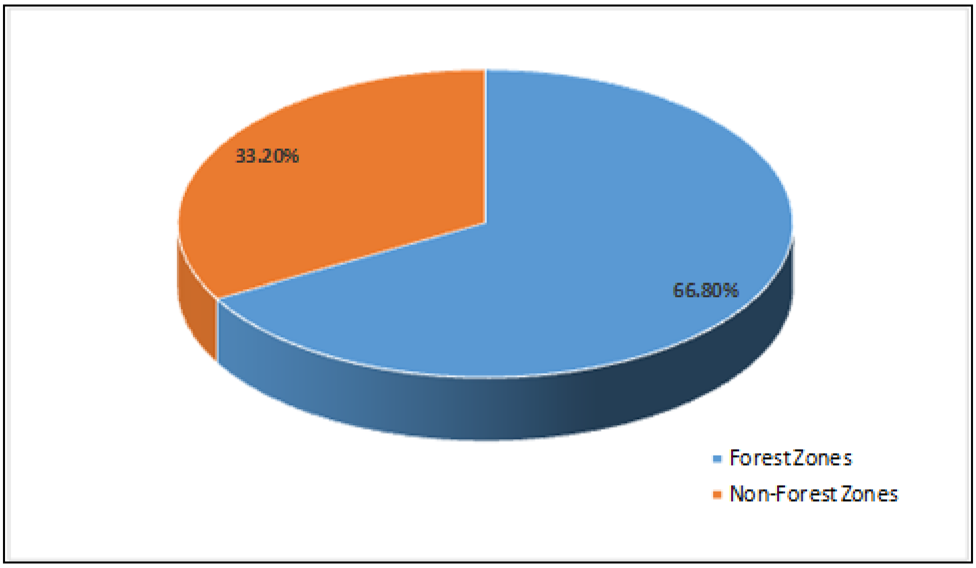

Figure 2.26. Forestry areas in Terkos Basin (Forest Regional Directorate, 2003).

Analysing the functional distribution of the forestry areas in the Terkos Basin, the area can be classified into two functions. In this manner, 61.6% of the forest area functions as forest goods production, 5% functions as preventing erosion, 0.4% functions as hydrological units, 0.1% functions as aesthetical purposes, 11.2% functions as national defense and 0.3% functions as maintaining public health. Lands that do not belong to the forestry zones in the basin are considered as non-forest (housing, agriculture, mine pits) areas (Table 2.12, Figure 2.28).

Table 2.13. Functional distribution of forest areas in Terkos Basin (FRT, 2003).

	Function Type	Function Name	Area (ha)
Terkos Basin	Economic Function	Forest Goods Production	43,684.27
	Ecologic Function	Erosion Prevention	3,566.15
	Ecologic Function	Hydrological	298.71
	Social Function	Aesthetics	68.55
	Social Function	National Defense	7,938.70
	Social Function	Public Health	210.13
	Other Areas	Other Areas	15,167.56

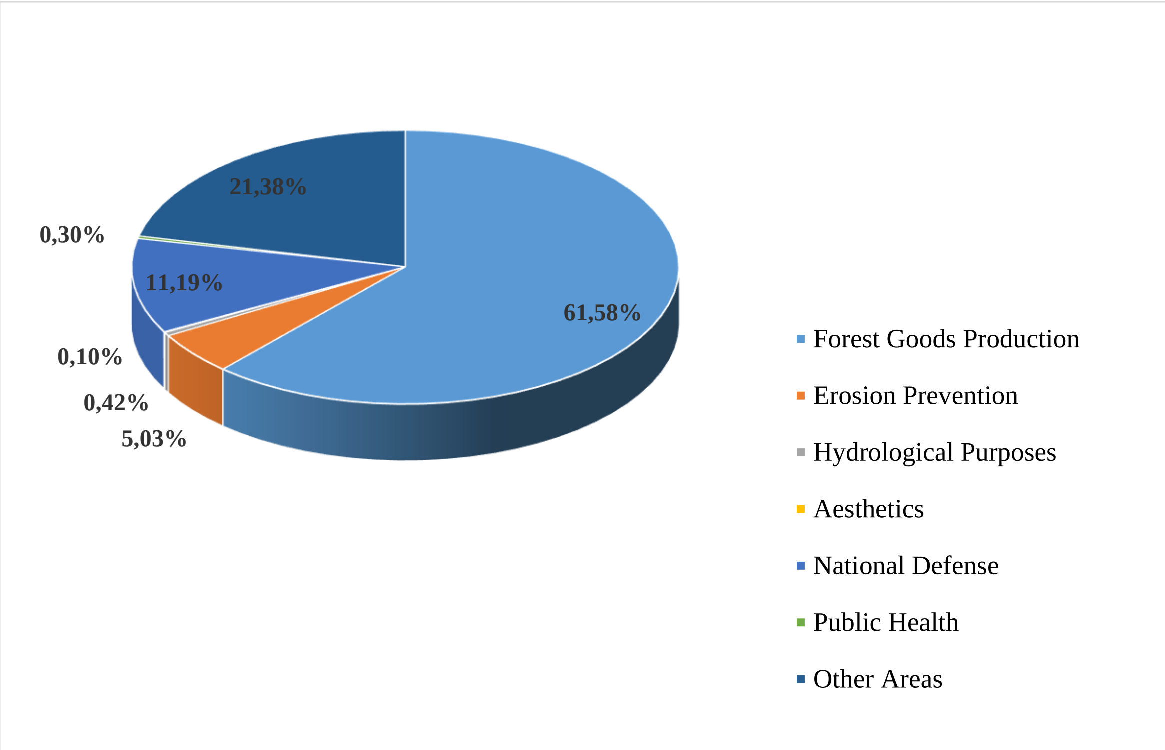

Figure 2.27. Functional distribution of forest areas in Terkos Basin (FRT, 2003).

Forestry lands can also be classified according to their operational types. Among all forestry zones, 68.7% proportion is swamp and 31.3% proportion is high forest. Among the high forest lands, 4.7% are needle-leaved and 0.3% are forests (Table 2.13, Figure 2.29)

Table 2.14. Terkos Basin forestry operation types (FRT, 2003).

Terkos Basin	Operational Type	Operation Name	Area (ha)
	Swamp	Swamp	38,201.43
	High Forest	Needle –leaved	2,608.02
		Leaved	14,594.99
		Mixed	183.73

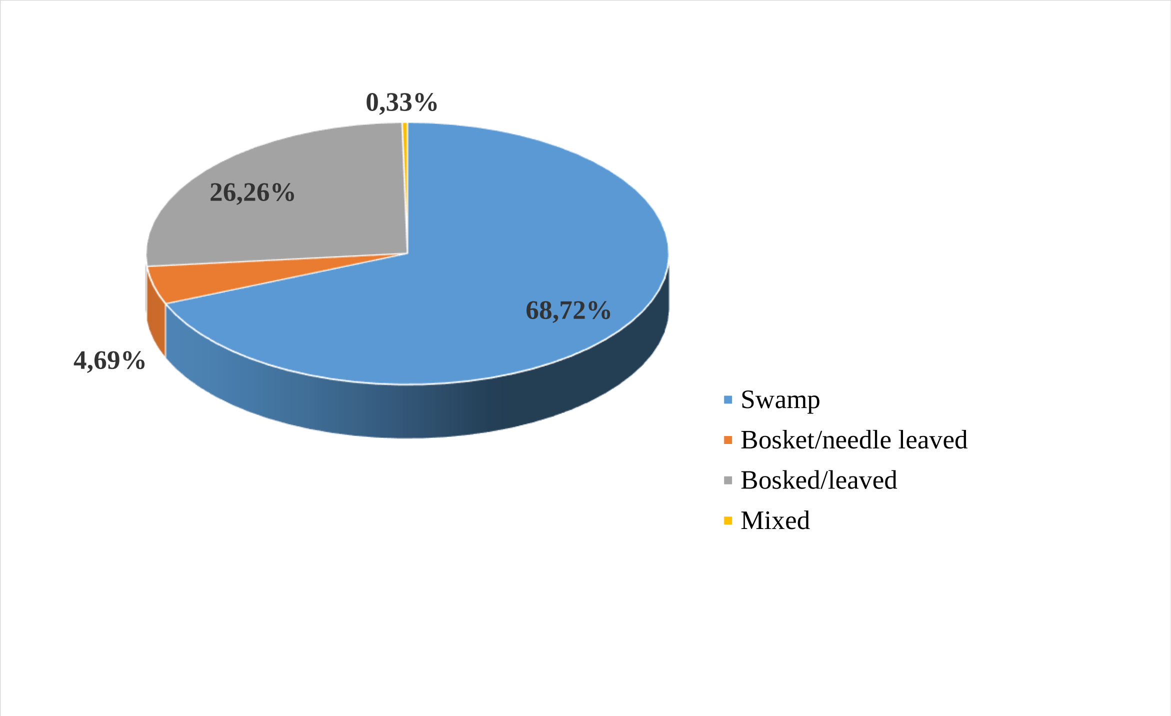

Figure 2.28. Terkos forest areas operating types (FRT, 2003).

2/B Areas: As per the measures defined in Forest Code 2nd specification B column; for various reasons the land zones lost their forest property are shifted to non-forest zones by Forest Cadastre Comissions with respect to the legal process and procedures.

67% (49,178.90 ha) of the Terkos Basin is covered by forests. However, due to the pressure of increasing population in the basin, unplanned and illegal urbanization like shantyhouses and uncontrolled agricultural work, there are many 2/B zones that were moved to non-forest areas. Recently 2% (3,499.9 ha) of the working land areas are moved to the non-forest zone as per Forest Code 2nd specification B column (Table 2.14, Figure 2.30).

Table 2.15. Terkos Basin 2/B zones (FRT, 2003).

Terkos Basin 2/B Zones	**Area (ha)**
Terkos Basin Total Area	73,622.64
Terkos Basin Total Forestry Area	49,178.90
Terkos Basin Total 2/B Area	1,518.77

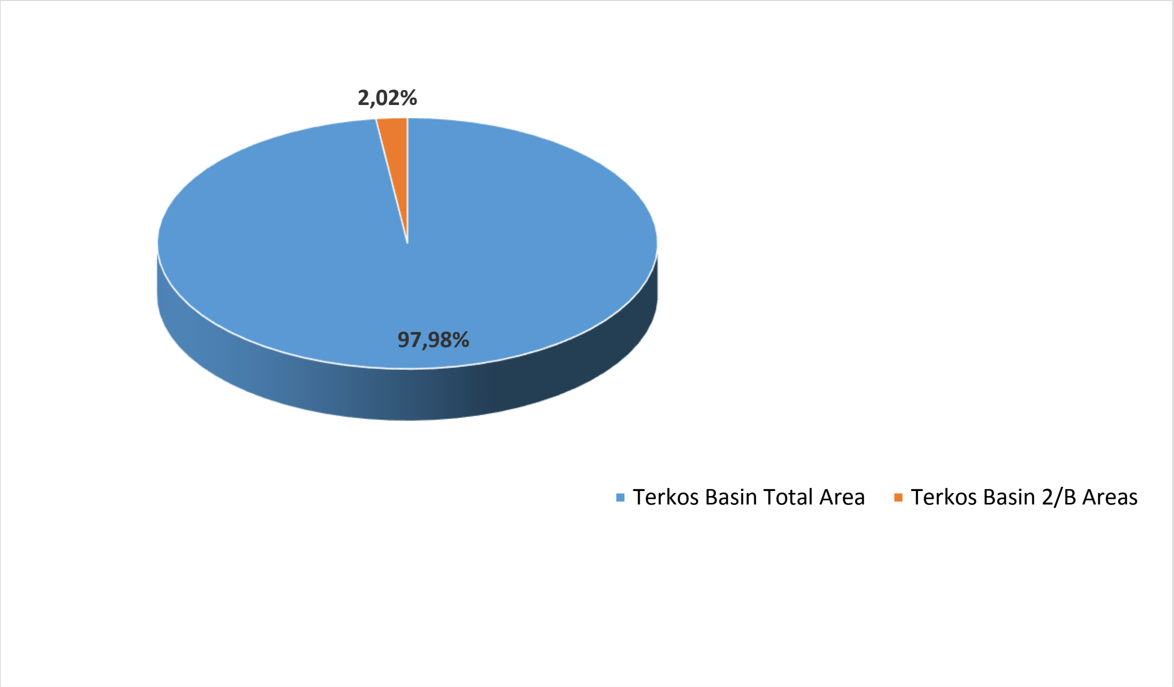

Figure 2.29. Terkos Basin 2/B areas (FRT, 2003).

2/B zones are depicted in the Terkos Basin Forestry and 2/B areas usage sheet (Figure 2.32)

Satellite images of IKONOS taken in June 2005 are combined with the 2/B zone maps taken from Forest Regional Directorate and a total of 6 categories of 2/B areas were defined with respect to their locational distribution. These categories are; Urbanization (areas exposed to serious urbanization), Farming (areas to be used for agricultural purposes), Urbanization+Farming (areas under both urban and agricultural effect), Forest (natural forestry zones), Forest+Urbanization (areas with forestry zones and urbanization alltogether) and lastly Forest+Farming (areas of Forests and agricultural work).

2/B zones cover a total of 1,518.77 ha area which is composed of 71.3% of farms, 20.1% of farms+urbanization, 8.2 % of forests+farms, 0.4% of forests. In line with this work, most of the Terkos Basin coverage belongs to the Farming categorie (Table 2.15, Figure 2.31, Figure 2.32) (İMP, 2006 Doğal Yapı Orman Alanları ve Ekoloji Araştırma Grubu Raporları).

Table 2.16. Terkos Basin 2/B zone structure situation (FRT, 2003).

Terkos Basin 2/B Zones Structure Situation	
Type of Structures	Area (ha)
Forest	6.80
Forest+Farms	124.07
Farms	1,083.22
Farms+ Urbanizations	304.68
TOTAL	1,518.77

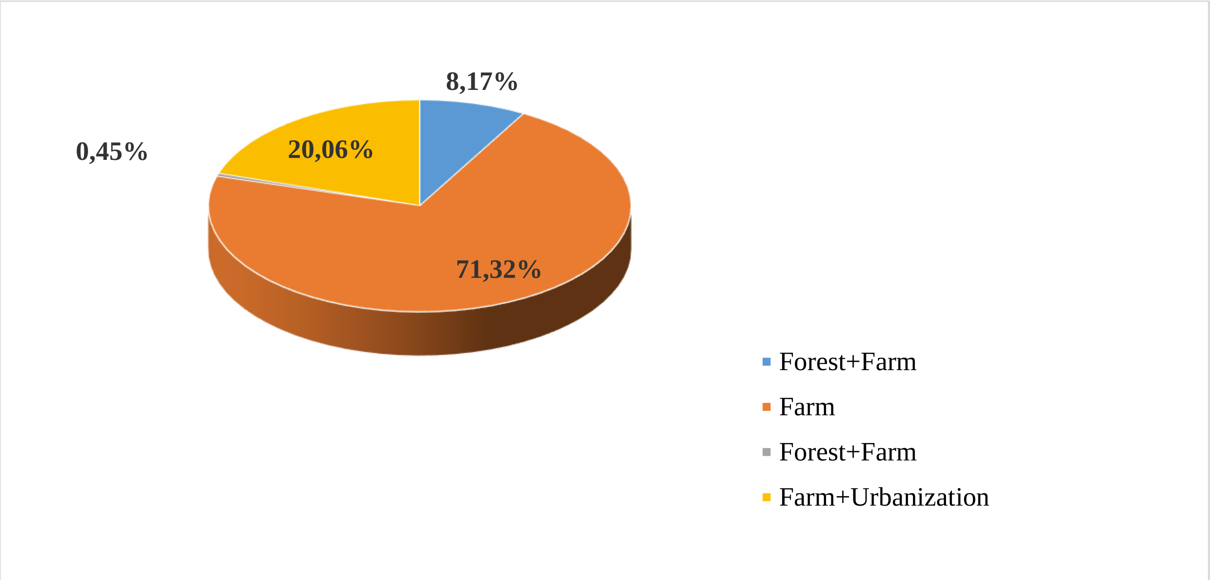

Figure 2.30. Terkos Basin 2/B zone structure situation (FRT, 2003).

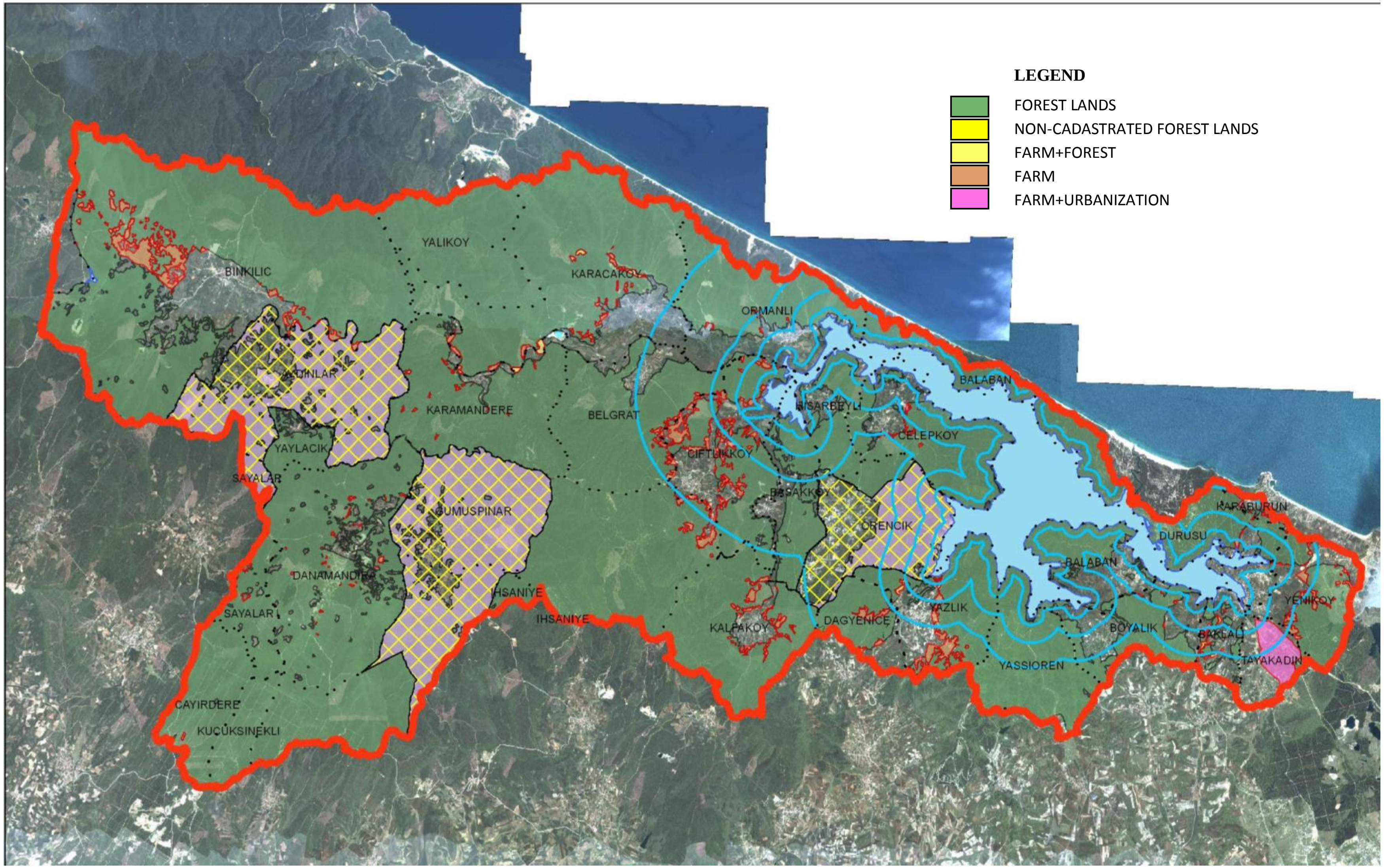

Figure 2.31. Terkos Basin forest and 2B areas usage analysis map (FRT, 2003).

2.3.6. Terkos Basin Farming Areas

In analysis of Terkos Basin Farming areas, an initial classification for the soil capability needs to be performed. It is found that the basin is composed of I, II, III, IV, VI, VII. and VIII. Degree soil types (Table 2.16 and Figure 2.33). The areal distiribution of the usage areas of these types are more or less the same with each other. Among those types, the most frequent type is IV. Degree with 18.337,2 ha (27%) area. It is followed by III. Degree with 14,637.6 ha (22%) area and II. degree with 13,969.9 ha (21%) area and VII. Degree with 11,539.1 ha (17%) area (Figure 2.34).

Table 2.17. Areal analysis of the soil capability degrees (İMP, 2006).

Soil Capability Degrees	**Area (ha)**
I	682.4
II	13,969.9
III	14,637.6
IV	18,337.2
VI	8,284.0
VII	11,539.1
VIII	95.5

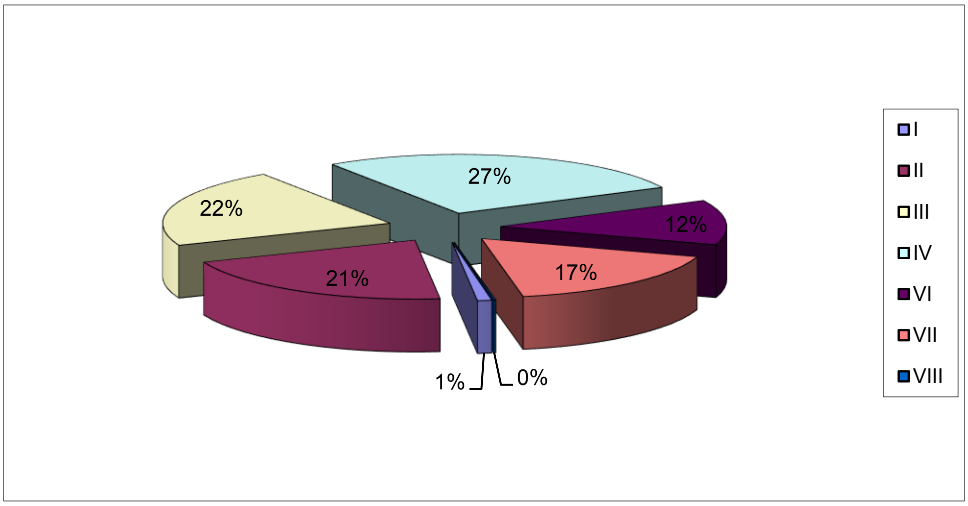

Figure 2.32. Rational areal analysis of the soil capability degrees (İMP, 2006).

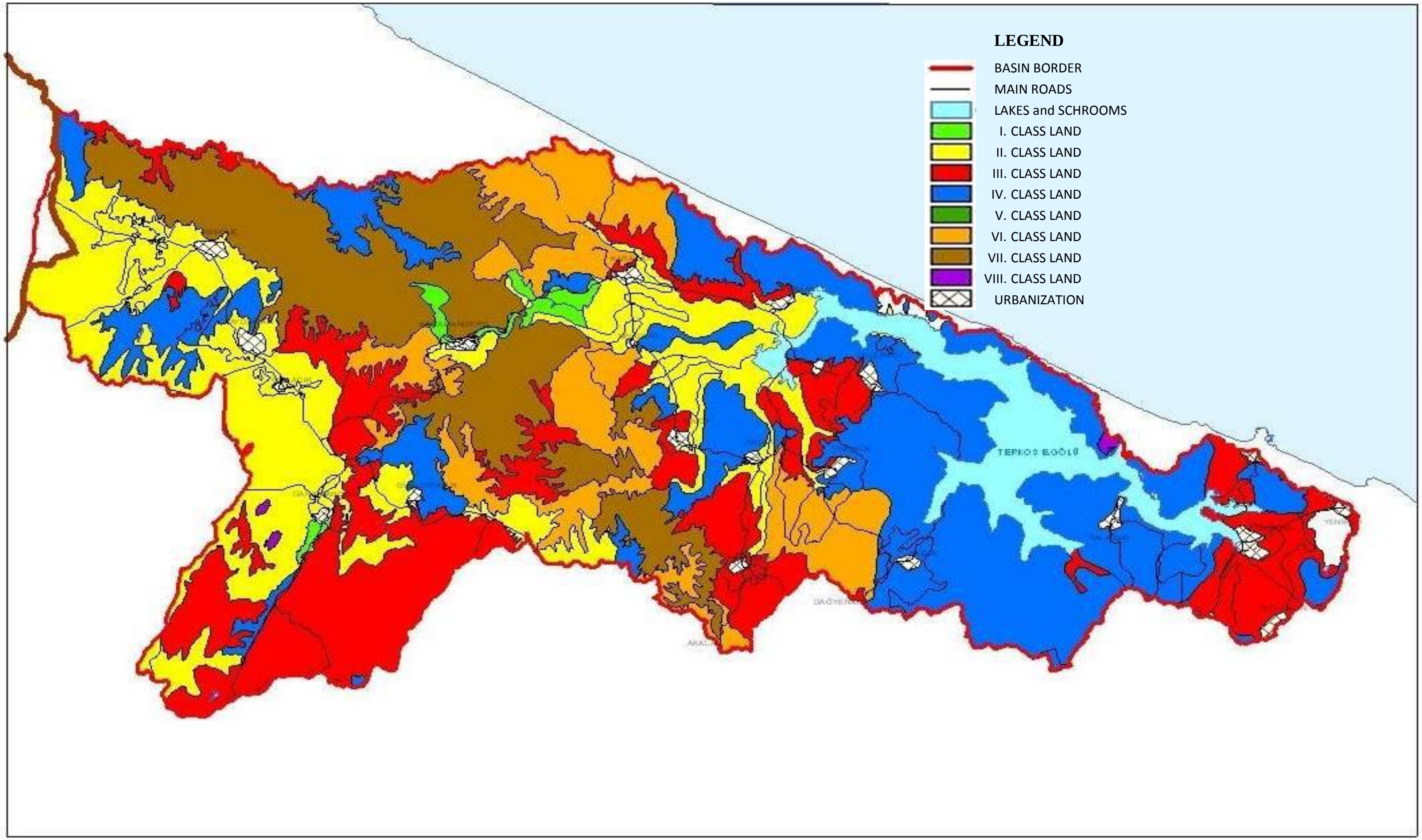

Figure 2.33. Terkos Basin soil capability analysis map (İMP, 2006).

Non-agricultural lands overwhelm other type of lands with a ratio of 89% and most of these non-agricultural terrain belongs to forestry zones in the basin. This is followed by 6% of dry farming lands, 4% of heaths and 3% of inadequately irragated farming lands. Inadequately irragated farming is mostly processed in alluvial soils (Table 2.17, Figure 2.35).

Table 2.18. Land usage types and their areal & proportional distribution (İMP, 2006).

Land Usage Type	**Area**	
	(ha)	**(%)**
Dry Farming	4,477.1	6
Irrigated Farming	137.5	0
Inadequately Irrigated Farming	2,226.4	3
Yard	185.2	0
Meadow	95.1	0
Forage	1,625.4	2
Heaths	3,258.8	4
Urbanization	1,129.3	2
Non-farming area	59,735.2	83

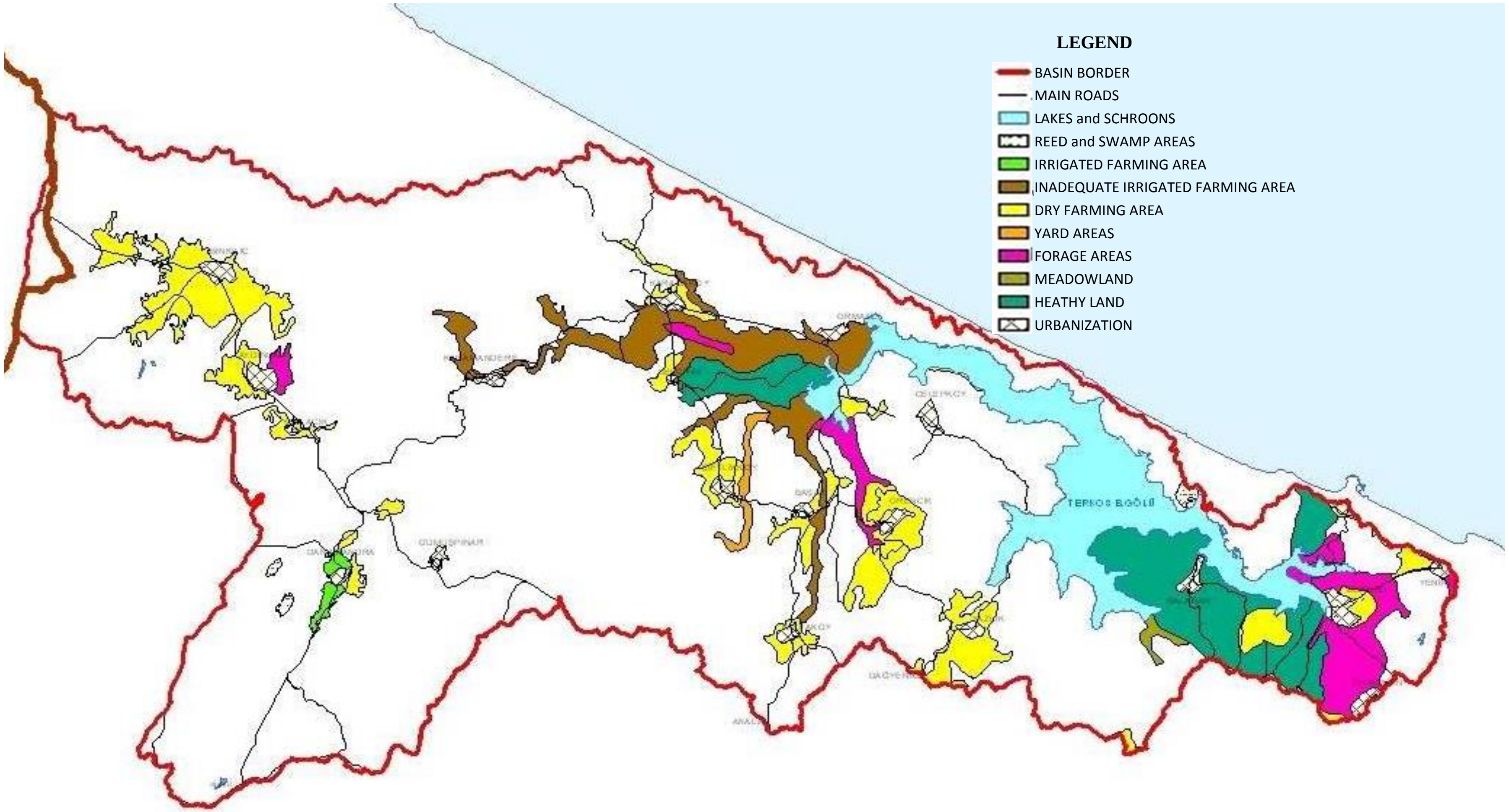

Figure 2.34. Terkos Basin agricultural land usage analysis map (İMP, 2006).

With the help of these data, a synthesis work has been performed with respect to the agricultural lands. According to this study, I and II degree dry farming lands, I, II, III, IV degree irrigated farming lands, I, II, III, IV, V and VI degree yard lands and all degrees pasture lands are considered to be "Lands Require Absolute Protection" (Table 2.18).

Table 2.19. Terkos Basin agricultural areas and items used for soil investigation. syntehesis (İMP, 2006).

Protection-Usage Groups	**Layer**	**Land Degree**	**Land Usage**
Lands Require Absolute Protection	PL_1	1+2	Dry Farming
		1+2+3+4	Irrigated Farming+ Public Irrigation
		1+2+3+4+5+6	Yard Areas
		1+2+3+4+5+6+7	Meadow+pasture
Lands Require preferential Protection	PL_2	3	Dry Farming
		7	Yard
Land with limited agricaltural quality	PL_3	4+5+6	Dry Farming
Non agricultural areas	PL_4	7	Dry Farming
		8	Shore Sand+mine+reeds bed

Based on the calculations performed over the Protection-Usage groups, 8.5 % of the lands (6.237,5 ha) in the entire basin were considered to be the "Lands Require Absolute Protection" (Table 2.19, Figure 2.36). These areas are prohibited to be used for any purposes except for specific issues defined in 5403 numbered soil protection act and in 4342 numbered pasture law (İMP, 2006, Tarım Alanları ve Toprak Araştırma Grubu Tarafından Yapılan Arazi Çalışmaları Sonuçları).

Table 2.20. Areal distribution of the lands in terms of protection – usage groups in Terkos Basin (İMP, 2006).

Protection – Usage Groups	**Area (ha)**	**%**
Lands Require Absolute Protection	6,237.5	8.5
Lands Require preferential Protection	849.9	1.1
Land with limited agricaltural quality	1,659.5	2.2
Non – agricultural basin	95.5	0

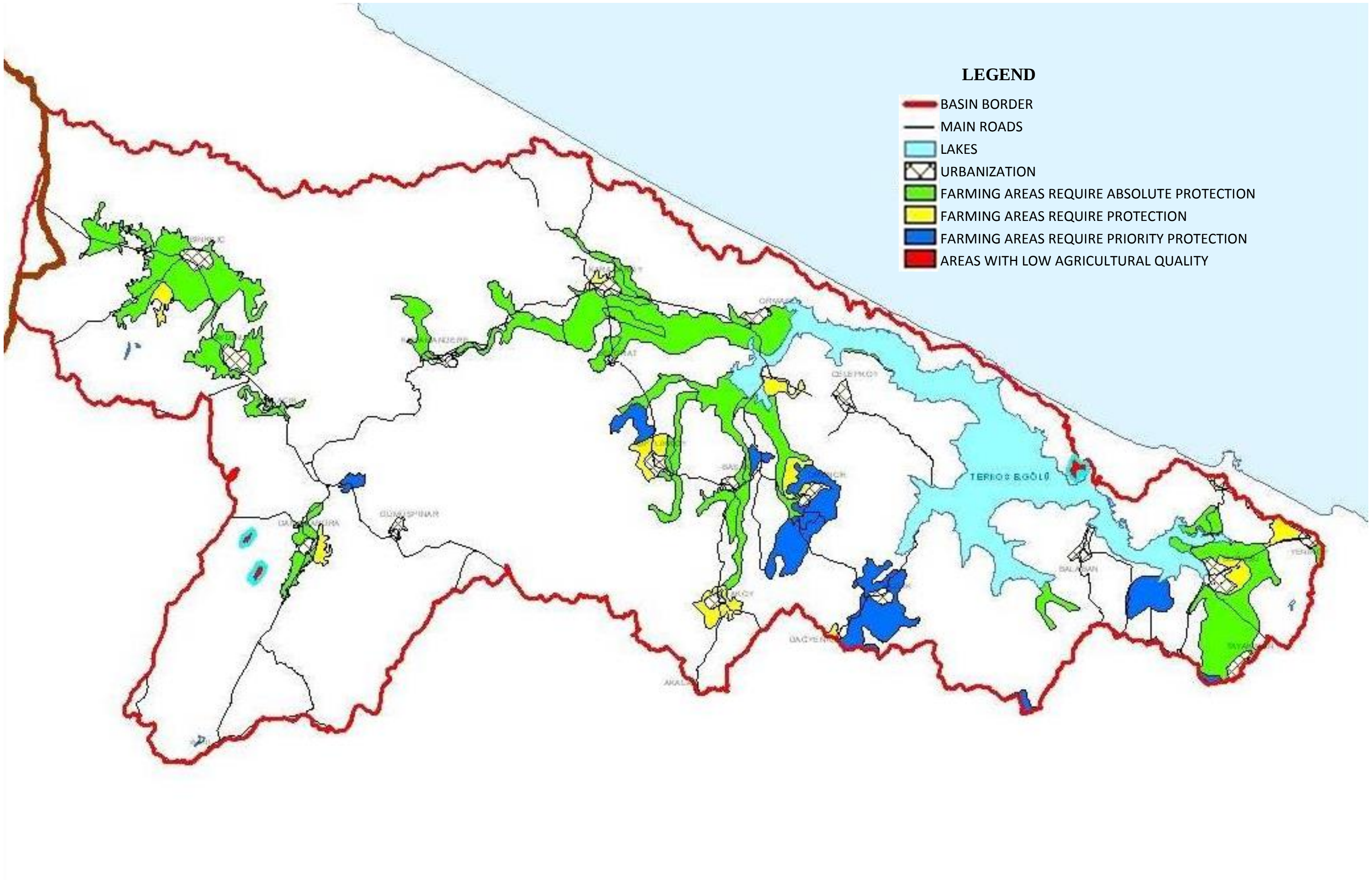

Figure 2.35. Terkos Basin agricultural lands synthesis analysis map (İMP, 2006).

2.3.7. Mining Fields and Quarries in Terkos Basin

Terkos Lake Basin does not host any mining or raw material pits to be used for industrial purposes. As there is not any mining facility taking place inside the basin borders, there cannot be any economic contribution originated from mining operations. However, inside the borders of basin feeding ground there are various abandoned pits which were once used for mining but vacated after some period of time. These pits did not have any regulation or recreation work and thus, they generate siltation problem as the nature of the basin is highly sensitive to precipitation and floods.

Between the lines of the dam lake drenaige band and the distant protecting band, there is a sand- gravel pit which is still operational. Being located in Ergene formation, one of these pits is over the Karacakoy Stream located at the northeast of Karaman Stream. Other pit is located in the north east of Ameylibag. Both of the pits have washing, elimination and shattering facilities. Their products like sand and gravel are used by the construction industry (Figure 2.37, Figure 2.38, Figure 2.39).

Figure 2.36. Sand- gravel facility over Karamandere – Karacakoy (İMP, 2006).

Figure 2.37. Sand – gravel pit at Karacakoy – Ameylibag (İMP, 2006).

Figure 2.38. Washing and elimination sub facilities in the sand-gravel pit located in Karacakoy-Ameylibag (İMP, 2006).

A total of 38 people are working in Karacakoy Stream and Ameylibag pits. This number does not include the headcount responsible in transportation part of the business. The production capacity of the pits is around 800,000 m^3 of sand and gravel.These are used in construction industry as structure materials.

Sand – Gravel pits do have washing and elimination facilities. Post-washing products of clay and fine meterials at the dimensions of silt are fedback to the system after conditioning in sedimentation ponds. Sedimented silty material are collected in the pit holes. As an obvious and inevitable result of open cast mining vagetation cover is eliminated, these lands are becoming susceptive to the erosion and thus siltation risk.

In the east region of the Terkos Drinking Water Basin, there are some formations of coal structures in the land. Moreover, upon the past years there had been lignite mining works between the basin border and the distant guarding band (Figure 2.40 and Figure 2.41). Nowadays these lignite mining facilities are not existing (İstanbul Metropoliten Planlama ve Kentsel Tasarım Merkezi, 2006. Sanayi Grubu Araştırma Raporları).

Figure 2.39. Formerly operating coal pits in Terkos distant guarding band (İMP, 2006).

Figure 2.40. Formerly operating coal mining pickling areas (İMP, 2006).

2.3.8. Terkos Basin Erosion Areas

Inside the basin, generally medium and high magnitudes of erosion is observed. According to the calculation, 44,751.9 ha of area is exposed to medium magnitudes of erosion, 19,280.8 ha area suffers from high magnitudes and 3,463.9 ha of area experiences low levels of magnitudes of erosion (Table 2.20 and Figure 2.42). Shallow lands suffer from erosion at medium levels and too shallow lands suffers from higher magnitudes of erosion (İMP.,2006 Tarım Alanları ve Toprak Araştırma Grubu Tarafından Yapılan Arazi Çalışmaları Sonuçları).

Table 2.21. Erosion land distributions (ha) (İMP, 2006).

Erosion Degree	Area (Ha)	%
High	19,280.8	28.6
Medium	44,751.9	66.3
Low	3,463.9	5.1
Total	67,496.6	100

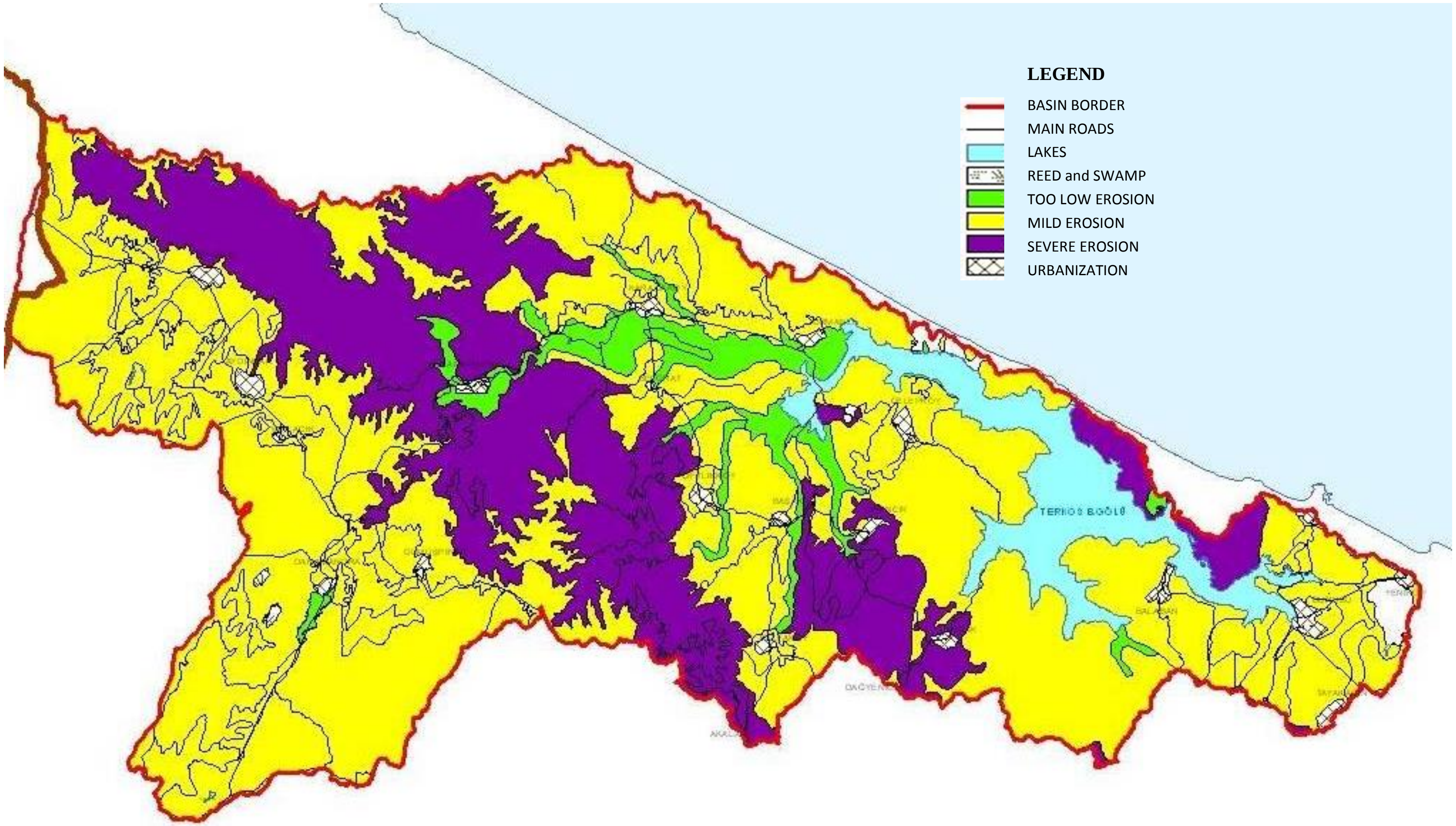

Figure 2.41. Terkos Basin erosion analysis map (İMP, 2006).

2.3.9. Terkos Basin Natural Threshold Analysis

Classification was determined according to the items that create the basis of natural threshold analysis. These items are mainly slope, contour lines and drift of the terrain, distribution of agricultural lands, forest lands, mining sites and land properties like geology, erosion, hydrology, hydrogeology.

One of the main principles of the natural threshold analysis states lands having 40% - 60% of magnitudes of slope values are considered to be partially available for people habitation.

Areas having slopes greater than 60% are considered to be not available for habitation. Forest and 2B zones are also considered to be not available for settlement. Non operational mining fields can be regarded as partially available for people settlement. However, operational mining fields can not be count as settlement areas. Important geologic areas and lands that do require detailed geologic surveys can be considered as people settlement areas.

Medium and high risk of erosion lands including medium-long distance water basin protection zones are also considered to be partially available settlement areas. Absolute or short distance protection lands are not allowed for settlements. In the respect of hydrology or hydrogeology; lands having swamps, wells, water channels, boreholes and underground water resources are not counted as areas for people settlement.

In terms of environmental issues; wasteyards and disposal sites are not regarded as settlement areas. As depicted in the natural threshold analysis map (Figure 2.43), red zones are the lands not available for settlement, yellow zones are the partially available lands for settlements (İstanbul Metropoliten Planlama, 2006., Doğal Yapı ve Sentez Önerileri Raporu).

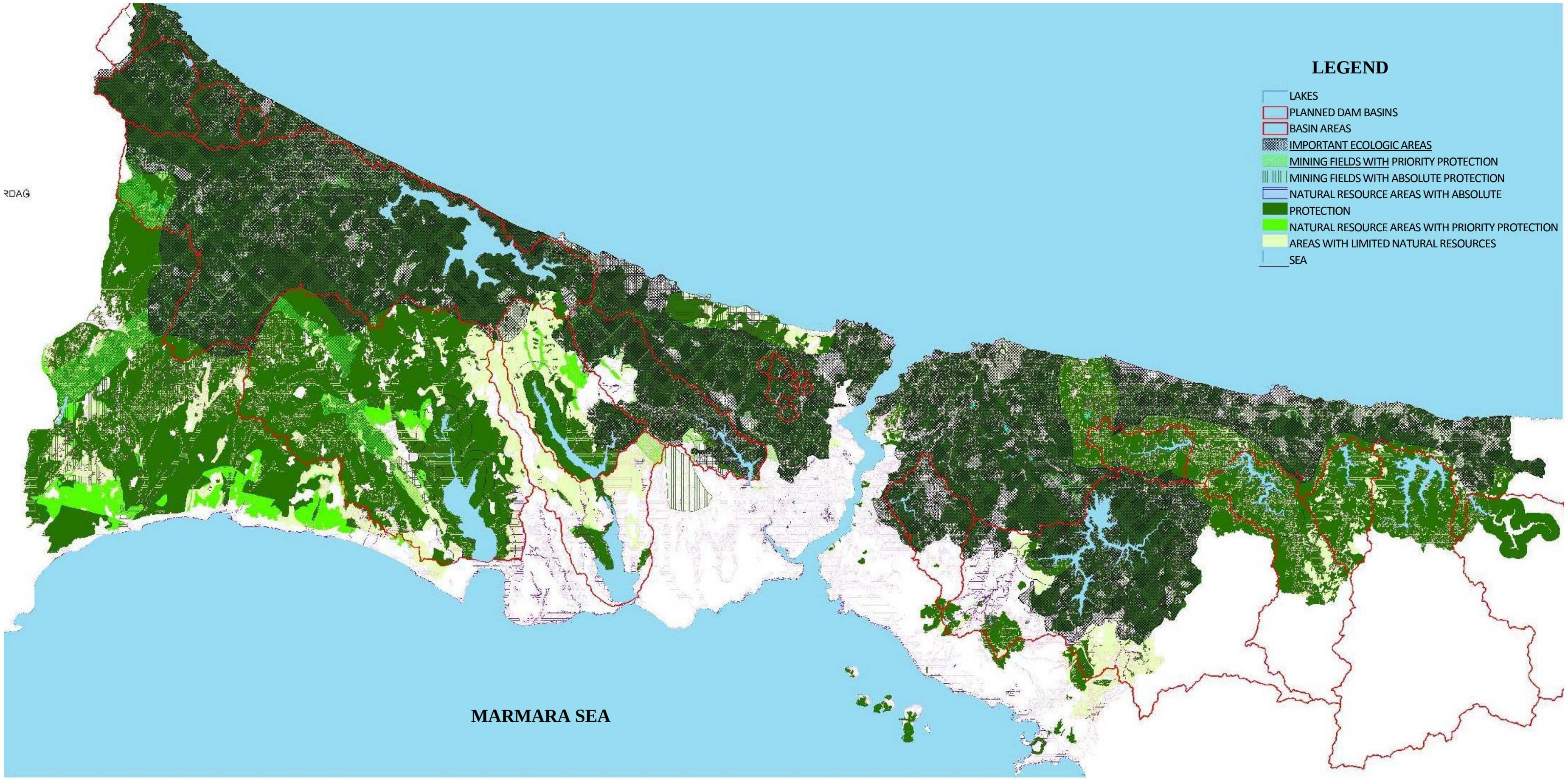

Figure 2.42. Terkos Basin natural threshold analysis map (İMP, 2006).

3. METHODOLOGY

Satellite images provided from ISKI are digitally vectorized with the help of ArcMap software and these vectorized images were then assessed with water attributes to achieve annual based comparisons (Figure 3.1).

Grading the values associated with water attributes:

- Water inlet from Istranca,
- Amount of precipitation,
- Amount of evaporation,
- Existing amount of lake water,
- Amount of water withdrawn from lake,
- Processed images are then assessed with the annual amount of water in the basin,
- Several comparisons were studied with annual values cross check.

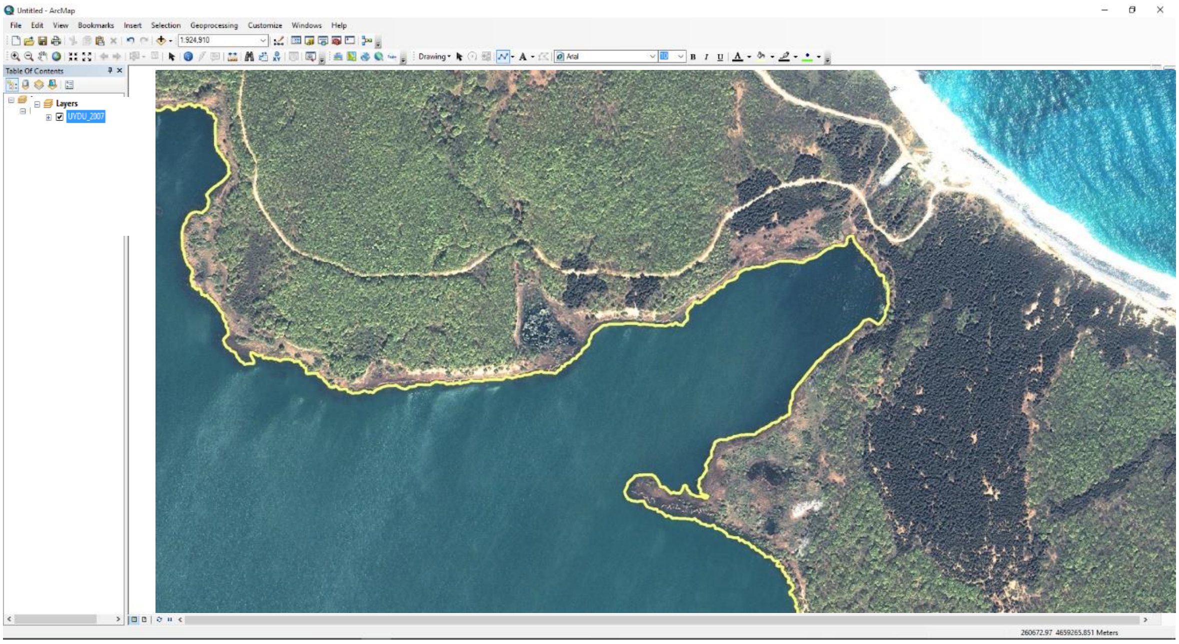

Figure 3.1. Digitilized satellite image sample.

Raster values gathered from ISKI archives, were processed with ArcMap. 1996 6th month, 2003 6th month, 2004 9th month, 2005 6th – 12th month, 2006 3rd, 6th, 9th, 12th month, 2007 3rd, 6th, 9th, 12th months, 2008 3rd, 6th, 12th months, 2009 6th month, 2010 6th months values are digitilized with the software assistance.

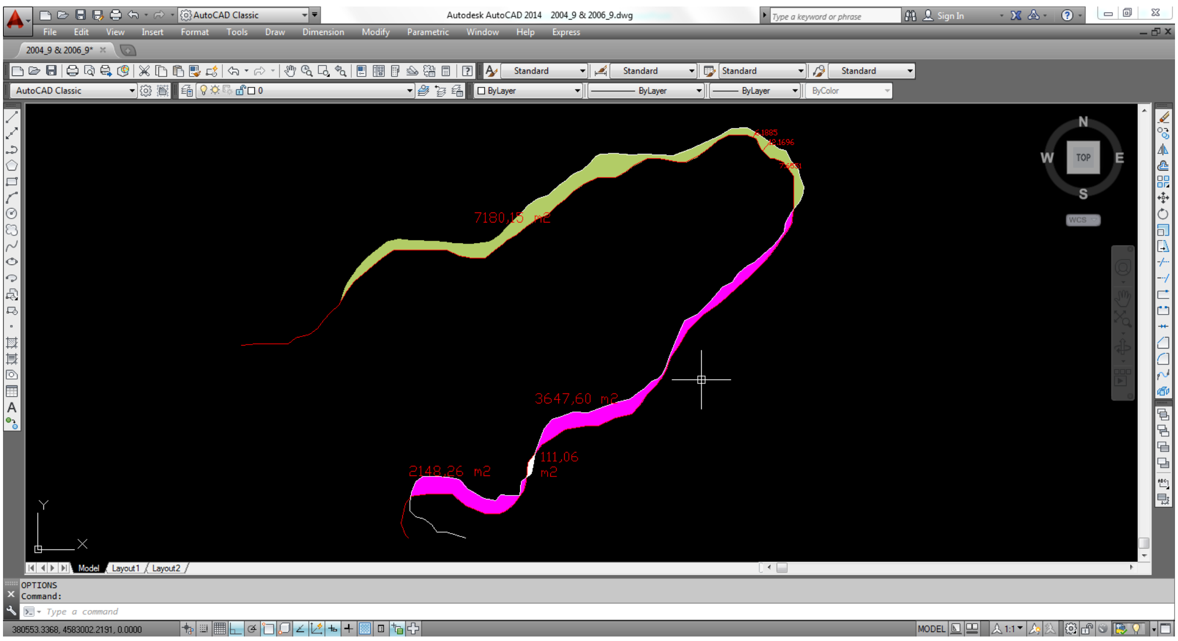

Figure 3.2. Exported autocad satellite image sample.

Digitilized data were exported as dxf format. Then comparisons were made with autocad software as taking the data of several months of different years to account (Figure 3.2).

Water values taken from ISKI were analysed.

First group of data are the values of Evaporation levels upon the Terkos Dam, which actually show the evaporation levels in mm terms between 1995 and 2012 (Given in Appendix A).

Second data show the change of water levels in the Terkos Dam. Changes of Water inlet from Istrance and changes of water inlets except from Istranca are shown in m3 units (Given in Appendix B).

Third and last group of data shows the precipitation levels in the dam between years 1993 and 2012 (Given in Appendix C).

Table 3.1. Comparison of water values among years.

Compared Values	**Quantity (m)**	**Lake Of Area (m²)**	**Quantitative Amount of Change (m³)**
1996 6th month existing lake water			134,990,600 m³
1996-2008 amount of water wıthdrawn from Lake			-740,000,000 m³
Between months 1996 6th and 2008 6th amount of water withdrawn from Istrancalar			665,358,639 m³
Between months 1996 6th and 2008 6th amount of precipitation	9.48718 m	30,400,000 m²	288,410,272 m³
Between months 1996 6th and 2008. 6th amount of evaporation	7.38071 m	30,400,000 m²	-224,373,584 m³
2008 6th month existing lake water			124,862,000 m³

Water levels are assessed and compared according to the annual values. In this comparison, units are equalized beforehand. Precipitation and evaporation values are first converted from mm to m then converted to m3 by multiplying with Terkos Lake surface area (Table 3.1).

4. RESULTS AND DISCUSSION

4.1. Change of The Northern Side Borders of Terkos Drinking Water Basin Through Years

In this section the change in the boundaries in the northern side of Terkos Drinking Water basin will be analysed and assessed. In terms of the gathered scientific data, the amount of change with its direction (uptrend or withdrawal) will be revealed.

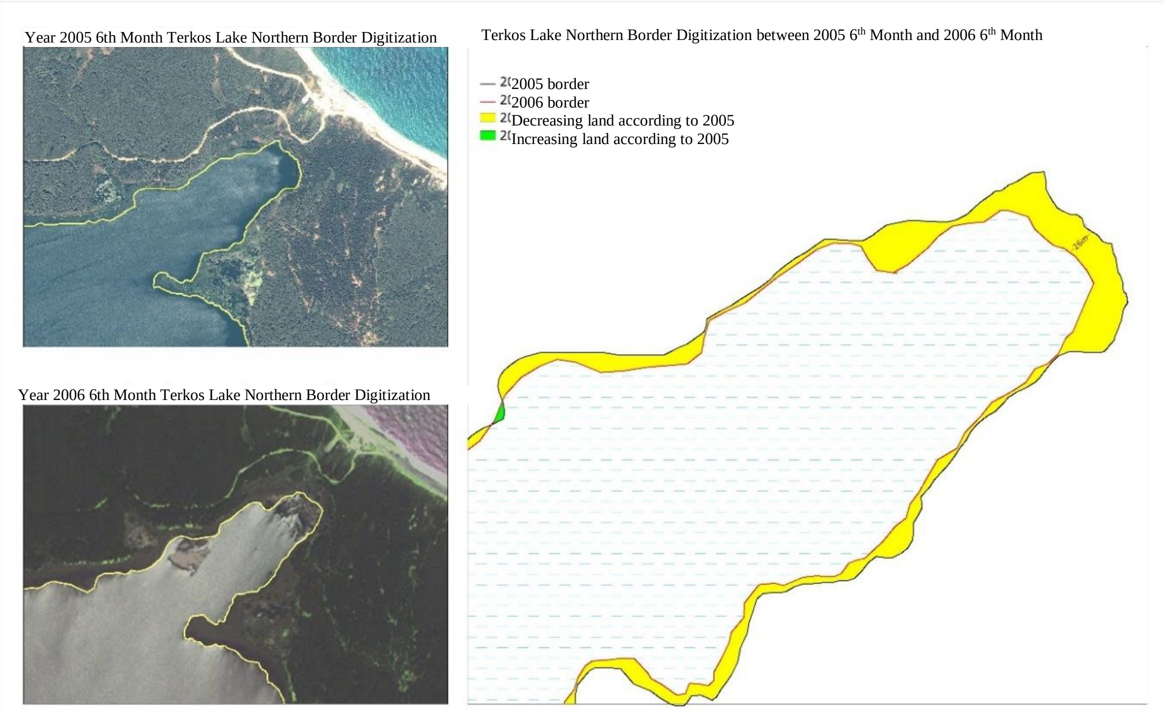

Figure 4.1. Section the change in the boundaries in the northern side of Terkos Drinking Water basin (2005- 2006).

Table 4.1. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2005-2006).

Compared Values	**Quantity (m)**	**Lake Of Area (m^2)**	**Quantitative Amount of Change (m^3)**
2005 6th month existing lake water			157,176,000 m^3
2005-2006 amount of water withdrawn from lake			-58,000,000 m^3
Between months 2005 6th and 2006 6th amount of water withdrawn from Istrancalar			40,755,199 m^3
Between months 2005 6th and 2006 6th amount of precipitation	0.67933 m	30,400,000 m^2	20,651,632 m^3
Between months: 2005 6th and 2006 6th amount of evaporation	0.65730 m	30,400,000 m^2	-19,981,920 m^3
2006 6th month existing lake water			140,138,000 m^3

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 26 m of withdrawal has been occurred in between 2005 6th month and 2006 6th month.

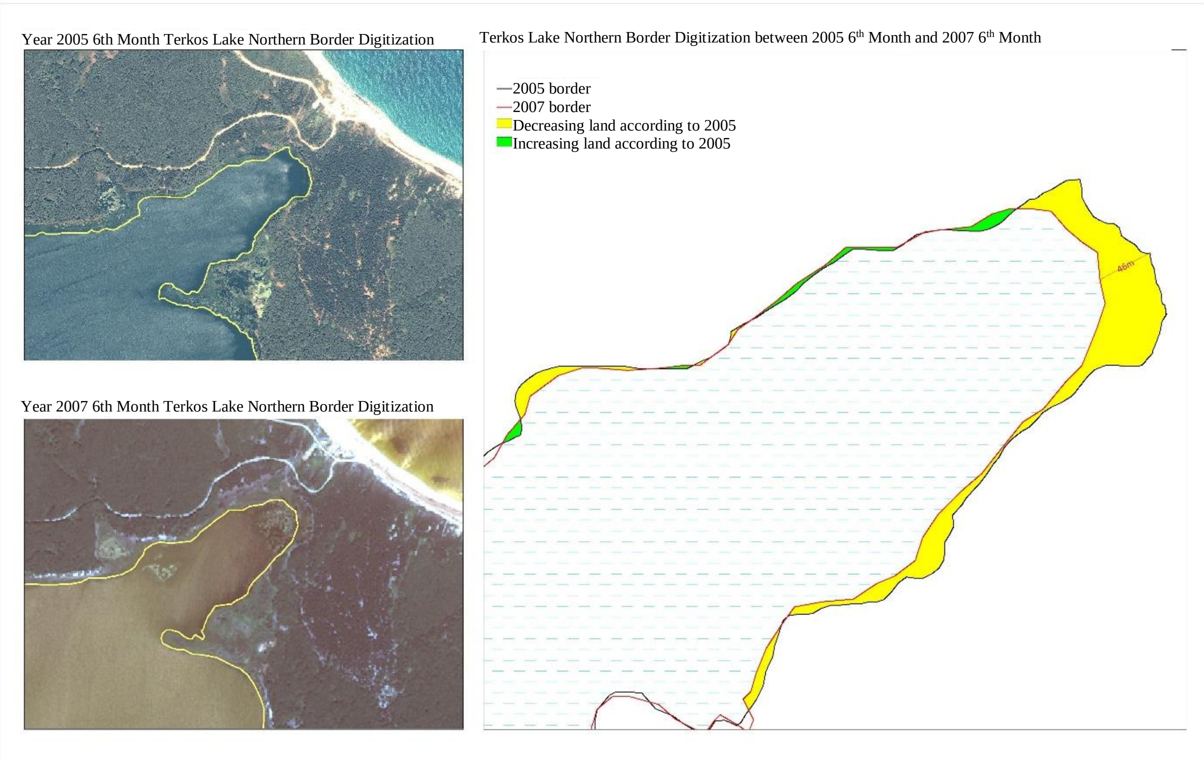

Figure 4.2. Terkos Drinking Water Basin north borders change (2005-2007).

Table 4.2. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2005-2007).

Compared Values	**Quantity (m)**	**Lake Of Area (m²)**	**Quantitative Amount of Change (m³)**
2005 6th month existing lake water			157,176,000 m³
2005-2007 amount of water withdrawn from Lake			-210,000,000 m³
Between months 2005 6th and 2007 6th amount of water withdrawn from Istrancalar			160,875,716 m³
Between months 2005 6th and 2007 6th amount of precipitation	1.33908 m	30,400,000 m²	40,708,032 m
Between months: 2005 6th and 2007. 6th amount of evaporation	1.25971 m	30,400,000 m²	-38,295,184 m³
2007 6th month existing lake water			109,805,000 m³

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 46 m of withdrawal has been occurred in between 2005 6th month and 2007 6th month.

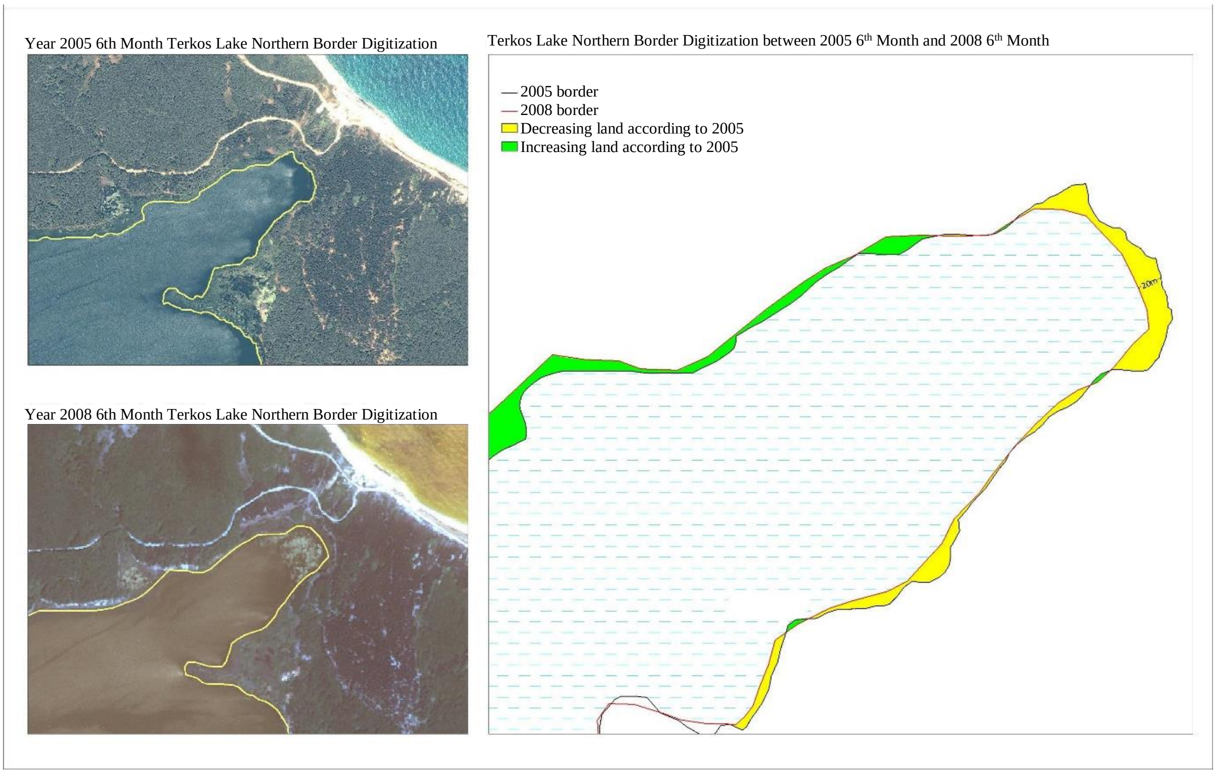

Figure 4.3. Terkos Drinking Water Basin north borders change (2005-2008).

Table 4.3. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2005-2008).

Compared Values	**Quantity (m)**	**Lake Of Area (m²)**	**Quantitative Amount of Change (m³)**
2005 6th month existing lake water			157,176,000 m³
2005-2008 amount of water withdrawn from lake			-310,000,000 m³
Between months 2005 6th and 2008 6th amount of water withdrawn from Istrancalar			160,875,716 m³
Between months 2005 6th and 2008 6th amount of precipitation	2.01403 m	30,400,000 m²	61,226,512 m³
Between months: 2005 6th and 2008. 6th amount of evaporation	1.91032 m	30,400,000 m²	-58,073,728 m³
2008 6th month existing lake water			124,862,000 m³

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 20 m of withdrawal has been occurred in between 2005 6th month and 2008 6th month.

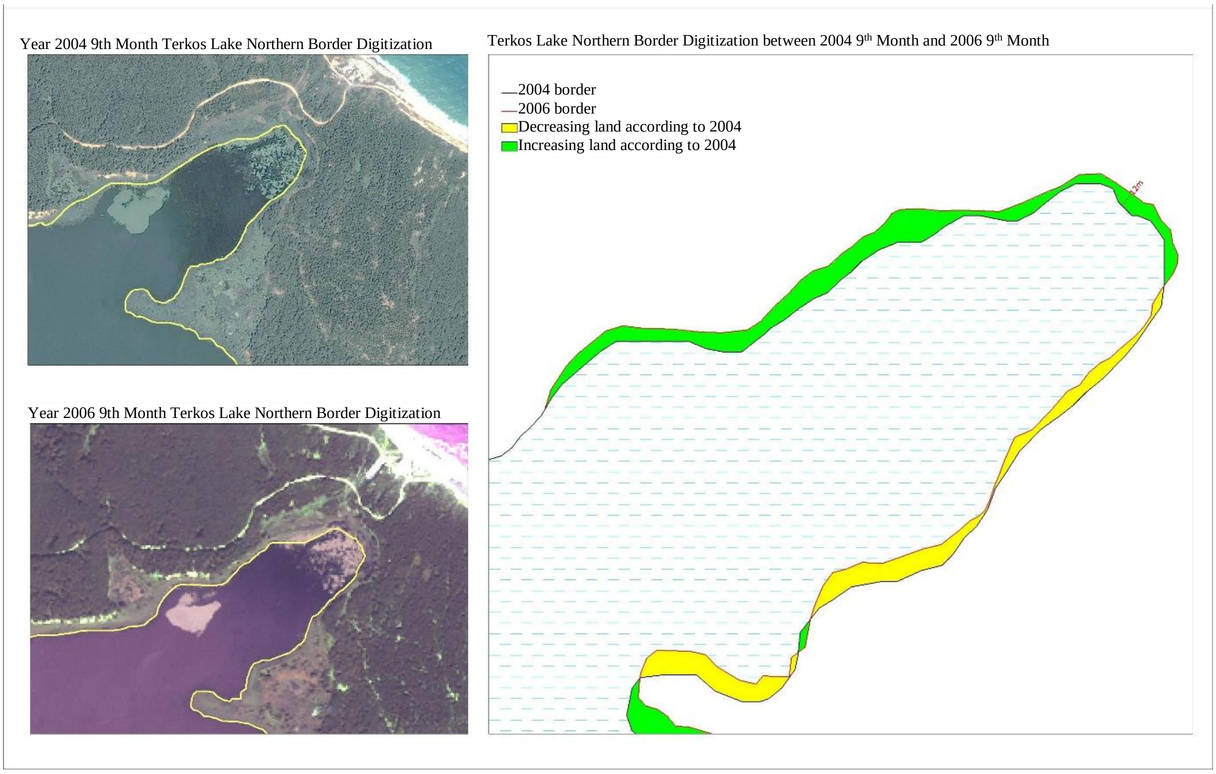

Figure 4.4. Terkos Drinking Water Basin north borders change (2004-2006).

Table 4.4. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2004-2006).

Compared Values	**Quantity (m)**	**Lake Of Area (m²)**	**Quantitative Amount of Change (m³)**
2004 9th month existing lake water			96,093,000 m³
2004-2006 Amount of water withdrawn from lake			-143,000,000 m³
Between months 2004 9th and 2006 9th amount of water withdrawn from Istrancalar			136,565,455 m³
Between months 2004 9th and 2006 9th amount of precipitation	1.54488 m	30,400,000 m²	46,964,352 m³
Between months: 2004 9th and 2006 9th amount of evaporation	1.11880 m	30,400,000 m²	-34,011,520 m³
2006 9th month existing lake water			102,750,000 m³

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 12 m of progress has been occurred in between 2004 9th month and 2006 9th month.

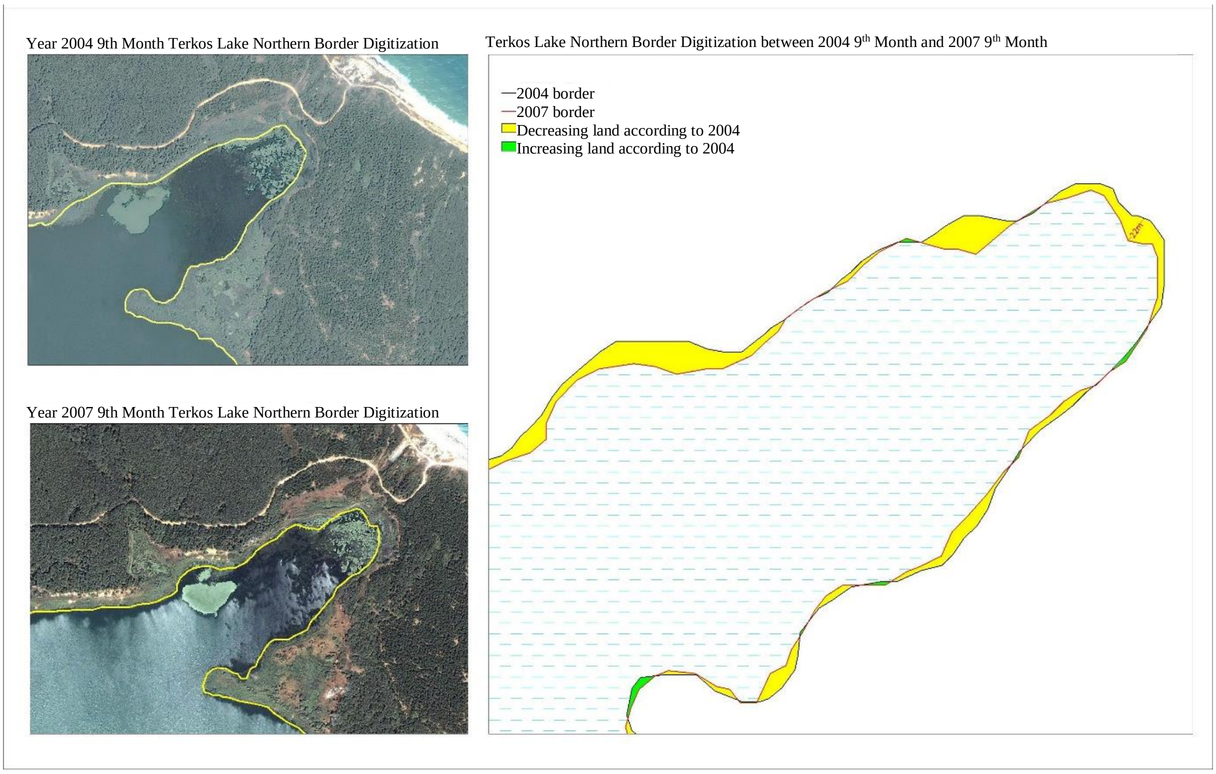

Figure 4.5. Terkos Drinking Water Basin north borders change (2004-2007).

Table 4.5. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2004-2007).

Compared Values	**Quantity (m)**	**Lake Of Area (m^2)**	**Quantitative Amount of Change (m^3)**
2004 9th month existing lake water			96,093,000 m^3
2004-2007 amount of water withdrawn from lake			-310,000,000 m^3
Between months 2004 9th and 2007 9th amount of water withdrawn from Istrancalar			262,855,956 m^3
Between months 2004 9th and 2007 9th amount of precipitation	2.30093 m	30,400,000 m^2	69,948,272 m^3
Between months 2004 9th and 2007 9th amount of evaporation	1.76856 m	30,400,000 m^2	-53,764,224 m^3
2007 9th month existing lake water			65,482,000 m^3

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 22 m of withdrawal has been occurred in between 2004 9th month and 2007 9th month.

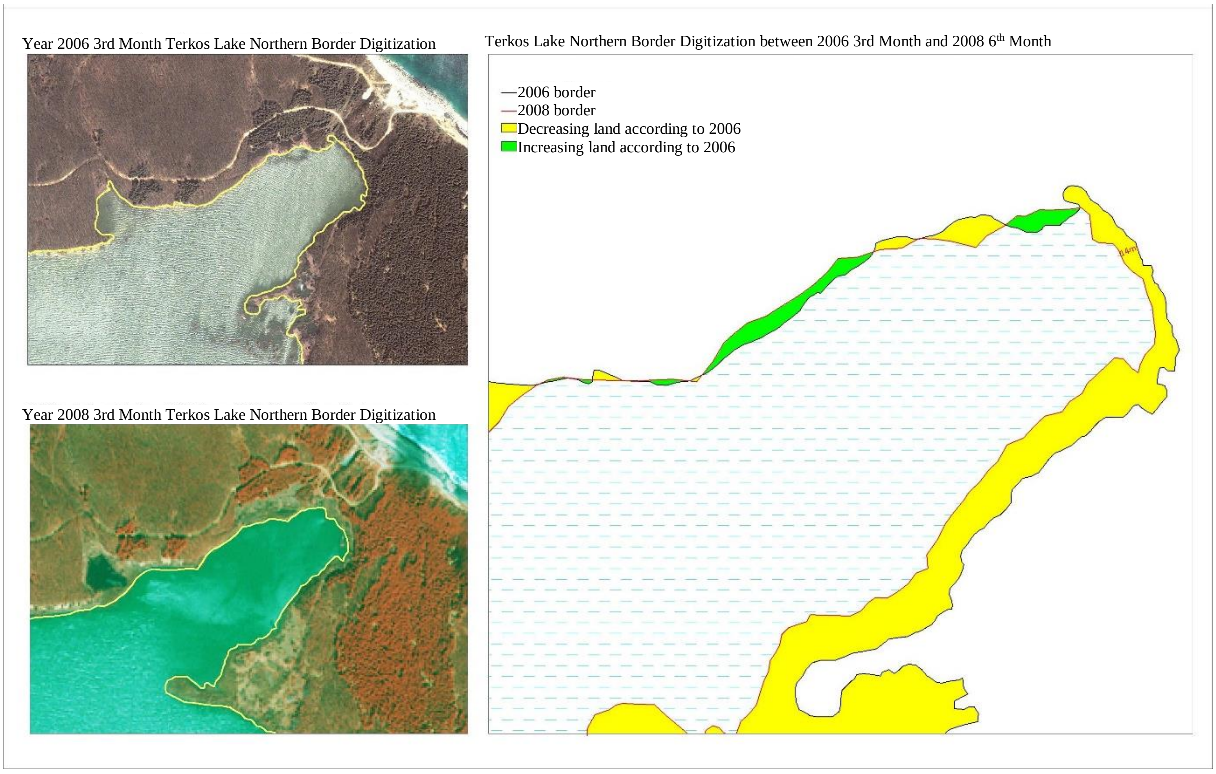

Figure 4.6. Terkos Drinking Water Basin north borders change (2006-2008).

Table 4.6. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2006-2008).

Compared Values	**Quantity (m)**	**Lake Of Area (m^2)**	**Quantitative Amount of Change (m^3)**
2006 3rd month existing lake water			161,606,000 m^3
2006-2008 amount of water withdrawn from lake			-263,000,000 m^3
Between months 2006 3rd and 2008 3rd amount of water withdrawn from Istrancalar			204,095,010 m^3
Between months 2006 3rd and 2008 3rd amount of precipitation	1.48047 m	30,400,000 m^2	45,006,288 m^3
Between months: 2006 3rd and 2008. 3rd amount of evaporation	1.27950 m	30,400,000 m^2	-38,896,800 m^3
2008 3rd month existing lake water			108,952,000 m^3

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 14 m of withdrawal has been occurred in between 2006 3rd month and 2008 3rd month.

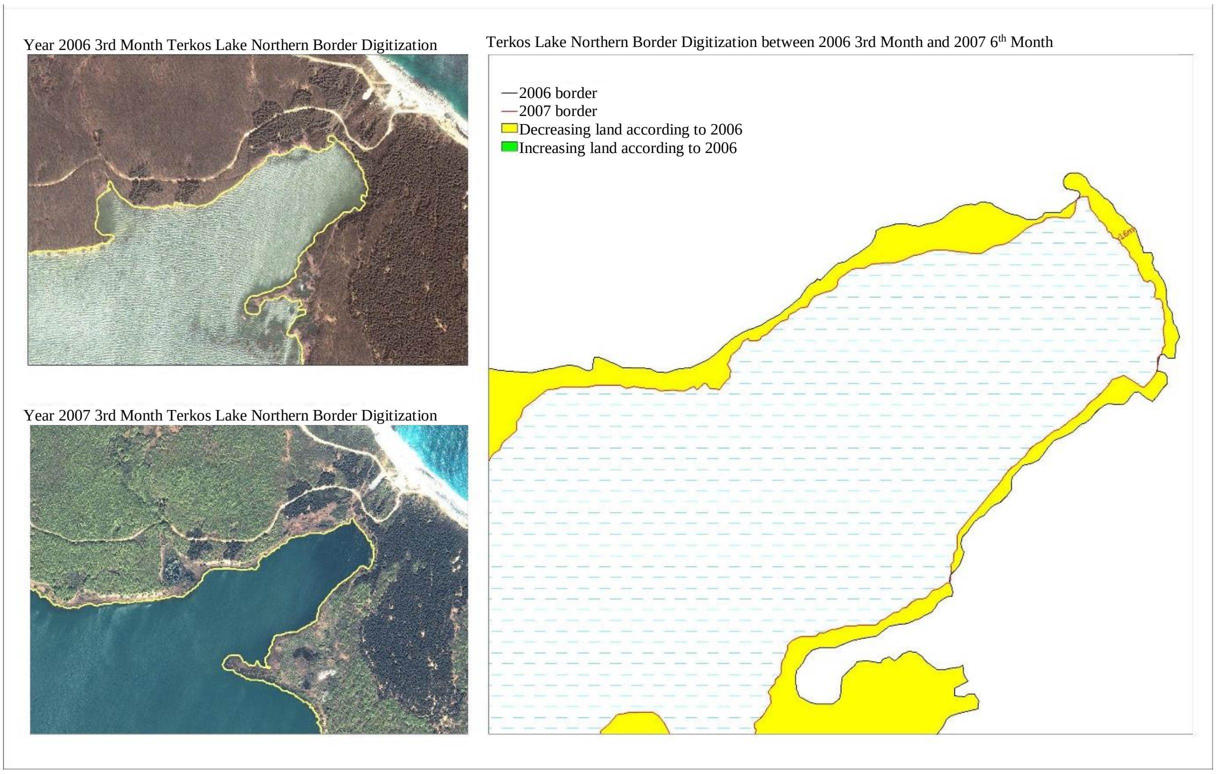

Figure 4.7. Terkos Drinking Water Basin north borders change (2006-2007).

Table 4.7. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2006-2007).

Compared Values	**Quantity (m)**	**Lake Of Area (m²)**	**Quantitative Amount of Change (m³)**
2006 3rd month existing lake water			161,606,000 m³
2006-2007 amount of water withdrawn from lake			-125,000,000 m³
Between months 2006 3rd and 2007 3rd amount of water withdrawn from Istrancalar			71,246,289 m³
Between months 2006 3rd and 2007 3rd amount of precipitation	0.70438 m	30,400,000 m²	21,413,152 m³
Between months: 2006 3rd and 2007 3rd amount of evaporation	0.63860 m	30,400,000 m²	-19,413,440 m³
2007 3rd month existing lake water			109,805,000 m³

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 16 m of withdrawal has been occurred in between 2006 3rd month and 2007 3rd month.

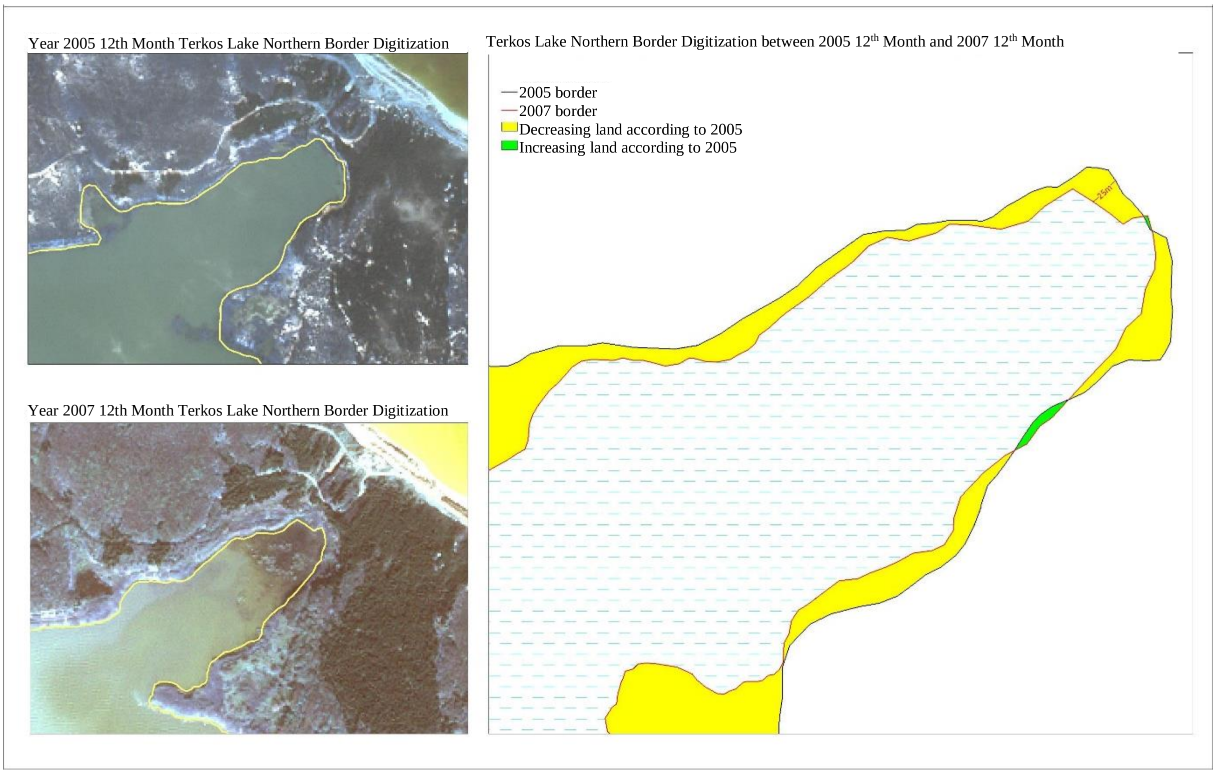

Figure 4.8. Terkos Drinking Water Basin north borders change (2005-2007).

Table 4.8. Change in the amount of water in the northern side of Terkos Drinking Water Basin (2005-2007).

Compared Values	**Quantity (m)**	**Lake Of Area (m^2)**	**Quantitative Amount of Change (m^3)**
2005 12th month existing lake water			87,659,000 m^3
2005-2007 amount of water withdrawn from lake			-194,000,000 m^3
Between months 2005 12th and 2007 12th amount of water withdrawn from Istrancalar			172,518,077 m^3
Between months 2005 12th and 2007 12th amount of precipitation	1.18267 m	30,400,000 m^2	35,953,168 m
Between months: 2005 12th and 2007 12th amount of evaporation	1.27950 m	30,400,000 m^2	-38,896,800 m^3
2007 12th month existing lake water			63,720,000 m^3

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 25 m of withdrawal has been occurred in between 2005 12th month and 2007 12th month.

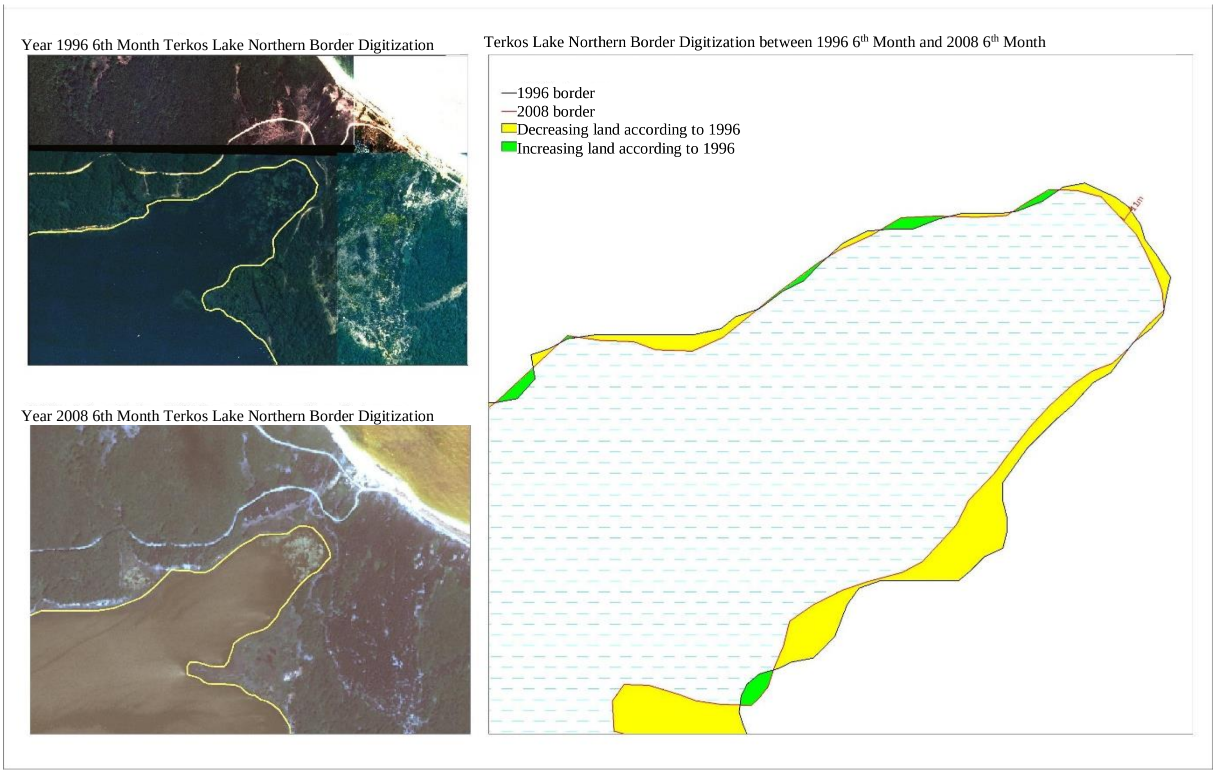

Figure 4.9. Terkos Drinking Water Basin north borders change (1996-2008).

Table 4.9. Change in the amount of water in the northern side of Terkos Drinking Water Basin (1996-2008).

Compared Values	**Quantity (m)**	**Lake Of Area (m^2)**	**Quantitative Amount of Change (m^3)**
1996 6th month existing lake water			134,990,600 m^3
1996-2008 amount of water withdrawn from lake			-740,000,000 m^3
Between months 1996 6th and 2008 6th amount of water withdrawn from Istrancalar			665,358,639 m^3
Between months 1996 6th and 2008 6th amount of precipitation	9.48718 m	30,400,000 m^2	288,410,272 m^3
Between months: 1996 6th and 2008. 6th amount of evaporation	7.38071 m	30,400,000 m^2	-224,373,584 m^3
2008 6th month existing lake water			124,862,000 m^3

According to the comparison of the location of northern face of Terkos Drinking Water Basin, it is observed that 11 m of withdrawal has been occurred in between 1996 6th month and 2008 6th month.

4.2. Assesment and Results

4.2.1. Terkos Drinking Water Basin North Border Change Summary

Table 4.10. Terkos Drinking Water Basin north border change summary table.

Months	**Comparison Years**		**Change amount (m)**
June	2005	2006	-26 m
	2005	2007	-46 m
	2005	2008	-20 m
	1996	2008	-11 m
September	2004	2006	12 m
	2004	2007	-22 m
March	2006	2008	-14 m
	2006	2007	-16 m
December	2005	2007	-25 m

Based on the results of the comparisons, a significant amount of withdrawal was observed in months June, March and December. In September, the border seems to be changing in both trends.

5. CONCLUSIONS

As being one of the most crucial water resources and a natural life zone, Terkos Lake Basin constitutes a great importance for the city of Istanbul. Terkos Lake has been used as a drinking water supply since late 19th century. Terkos Lake is also a unique ecosystem providing habitat for thousands of plant and animal species. Thus, a preventative plan to maintain the water quality and keep the lake`s ecological balance and protect its boundries from artificial amendments is required.

Based on the results of the study, a significant amount of water withdrawal was observed in months June, March and December over and entire year. Also in September months the border seems to be changing in both directions. The reasons for these changes are not entirely clear and may be a result of multiple actions such as excess water withdrawal for the city of Istanbul; illegal sand removal between Black Sea and the Lake; and possible water withdrawal for nearby agricultural fields.

Mining facilities over the area of Terkos Basin do not cause a significant environmental problem. The areas between the distant protection line and the basin`s feeding ground border which contains decoupage zones of former coal pits, were not afforested suitable to todays` norms. As the time passed away through years, some vegetation cover has grown up over the terrain, however degradation and siltation problems still exist due to superficial rain flow. As for the currently operational sand and gravel units, the associated environmental impact is not scientifically significant.

6. RECOMMENDATIONS

Terkos Lake possesses very crucial role as being one of the major water resources of Istanbul. In accordance with this purpose, a sequence of suggestions that might form a base for environmental protection for Terkos Lake are listed below.

Forestry areas taking place inside and peripheral of Terkos Basin Lake must be protected with strict policies and rules. Those areas must be protected under “protection forest status”. Protection areas must be publicised and 0-300 m protection band must be vegetated. Agricultural facilities such like green-housing or tree-nursering must be restricted so that there would be no pesticides, chemicals or fertilizers allowed in these agricultural operations.

Existing or planned in-forest recreation zones would be strictly controlled for preventative measure with respect to water pollution. Water pollution caused by the structures inside the forest must be eliminated with preventative operations.

Existing master development plans violating the borders of forestry zones inside the basin must be cancelled and revised. Future plans should be carefully designed not to run down through forest areas in the basin. Forest areas should be completely freed from human made structures. Master developement plans must be prepared in accordance with the Regional Directorate of Forestry.

2% of the total basin area is 2/B zone and this zone is mainly classified as farming territory. All 2/B practices should be must be banned in the basin with no exceptions. All previously 2/B structured territories should be relocated outside of the basin area and zones belonging to the 2/B must be unified with the forest areas in the basin. Construction of roads, energy lines, water pipelines around the basin should be minimized so that the forest area can be isolated from negative impacts like erosion and etc. In order to prevent the water streams feeding the lake from effects of erosion and agricultural facilities, vegetation must be preserved or established especially in the river sides with higher slope.

REFERENCES

Becker, F., 2000. Fundamentals of Remote Sensing for Risks Assessment, Surveys in Geophysics, Kluwer Academic Publishers, Netherlands, 127–131.

Budak C., Tüzün K., 1993. İstanbul'da İçme Suyu Havzaları, Planlama Dergisi TMMOB Şehir Plancıları Odası Yay., 93/1-4, Ankara, 46-51.

Coşkun H. G., Gülergün O., Yilmaz L., 2006. Monitoring of protected bands of Terkos drinking water resorvoir of metropolitan Istanbul near the Black Sea coast using satellite data. International Journal of Applied Earth Observation and Geoinformation 8, 49

Coşkun H. G, Tanik A., Alganci U., Cigizoğlu H. K., 2008. Determination of Environmental Quality of a Drinking Water Resorvoir by Remote Sensing, GIS and Regression Analysis.Water Air Soil Pollut, 275

Çepel, N., 1995. Orman Ekolojisi, İstanbul Üniversitesi Orman Fakültesi Yayını., İstanbul.

Çodur A. D., 2004. İstanbul'un Mevcut Su Kaynakları, Su Kalitesi ve İçme Suyu Havzalarının Korunması' 04, İstanbul, 8-9 Ocak 2004, 2, 3-8.

Darkot, B., 1938. Boğazların Menşei ve Coğrafi Araştırmalar. İ.Ü. Edb. Fak. Coğr. Enst. Yay, İstanbul.

Gedik, İ., 2006. Uzaktan Algılamanın Tarımda Uygulamaları, DSİ Teknik Bülteni, 103, 30

Genç, G., 2004. Havzaların Genel Durumu ve Peyzaj Açısından Değerlendirilmesi, İstanbul ve Su Sempozyumu, TMOOB Mimarlar Odası İstanbul Büyükkent Şubesi' 04, İstanbul , 8-9 Ocak 2004, 133.

Geray, U., Küçükkaya, L., 2007. "Havza Yönetim Modeli Üzerine Düşünceler" http://kelkit.gop.edu.tr/txt/havzayonetimmodeli.doc.

Horton, R. E., (1945), Erosional Development of Streams and Their Drainage Basins: Hydrophysical Approach to Quantitative Morphology, Bull. Geol. Soc. Am., Vol. 56, pp. 275-370.

İMP, 2006. Doğal Yapı Orman Alanları ve Ekoloji Araştırma Grubu Raporları, 4-11.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Tarım Alanları ve Toprak Araştırma Grubu Tarafından Yapılan Arazi Çalışmaları Sonuçları, 13-14.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Tarım Alanları ve Toprak Araştırma Grubu Tarafından Yapılan Arazi Çalışmaları Sonuçları, 15-28.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Tarım Alanları ve Toprak Araştırma Grubu Tarafından Yapılan Arazi Çalışmaları Sonuçları, 19-20.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Yüzeysel Su Kaynakları Araştırma Raporları, 161-162.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Çevre Sorunları Araştırma Grubu Araştırma Raporları, 6-9.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. İstanbul Geneli Jeolojik Yapı raporları, 42-51.

İMP, 2005. Yüzeysel Su Kaynakları Raporu, 2-5.

İMP, 2006, Yeraltı Suyu Araştırma Raporları, 33-35.

İMP, 2006. Doğal Yapı Grubu Araştırma Raporları, 42-51.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Doğal Yapı Grubu Araştırma Raporları, 44-45.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Doğal Yapı Grubu Araştırma Raporları, 47-48.

İstanbul Metropolitan Planlama ve Kentsel Tasarım Merkezi, 2006. Sanayi Grubu Araştırma Raporları, 1-6.

Küçükali, U.F., 2005. Havza Tanımı ve Doğal Kaynak Yönetimi, Yüksek Lisans Tezi, Yıldız Teknik Üniversitesi, 6.

Prasad, T., Kumar, S., Verdhen, A., Prakash. N., Gyawali, D., Dixit, A., Lali, N.K., Regmi, B.R., 1994. Co-opretaion for intenational river basin development: the Kosi basin, Integrated River Basin Development, Ed. By Celia Kirby and W.R. White, John Wiley & Sons, HR Wallingford Ltd and Institute of Hydrology,18, 5.

Strahler, A. N., 1952. Hypsometric (area-altitude) Analysis of Erosional Topography, Bull. Geol. Soc. Am., Vol. 63, pp. 1117-1142.

Su Kirliliği Kontrolü Yönetmeliği., 1988. Bölüm 1. Madde3 Meydan Larousse, 1971. Cilt 5, MEYDAN Gazetecilik ve Neşriyat Ltd. Şti.

Turgut, S., 2000. Metropoliten Alanlarda Planlama – Kent Yönetimi İlişkileri ve İstanbul Metropoliten Alanı'nda Planlama Yönetimine İlişkin Bir Model Denemesi, Doktora Tezi, Yıldız Teknik Üniversitesi, İstanbul, 120-122.

Uysal, Y., 1997. İçme Suyu Havzalarında Yeni Gelişmeler, Su Kongresi ve Sergisi'97, İstanbul, 70-85.

Yönügül, Y., 2007. İstanbul'daki İçmesuyu Havzalarının Önemi, İçme Suyu Koruma Havzaları' nda Yaşanan Sorunlar Ve Çözüm Önerileri, Yüksek Lisans Tezi, Gazi Üniversitesi.

APPENDIX A: Terkos barajının buharlaşma miktarları

TERKOS BARAJININ BUHARLAŞMA MİKTARLARI (mm)												
	A Y L A R											
Yıllar	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
	ocak	şubat	mart	nisan	mayıs	haziran	temmuz	ağustos	eylül	ekim	kasım	aralık
1995	.	.	.	80.20	146.00	168.00	166.20	138.60	70.80	40.10	6.00	.
1996	.	.	108.00	40.70	125.20	154.50	166.70	115.00	63.90	38.30	21.20	.
1997	.	.	.	Ölç.Yok	114.00	124.00	154.00	90.00	66.00	34.00	.	.
1998	.	.	.	Ölç.Yok	Ölç.Yok	139.00	132.00	146.00	69.00	51.00	.	.
1999	.	.	.	Ölç.Yok	86.00	138.00	156.00	129.00	63.00	22.00	.	.
2000	.	.	.	30.00	136.00	165.00	187.00	116.00	56.00	14.00	18.00	.
2001	.	.	.	32.00	90.00	133.00	130.00	110.00	100.00	49.00	.	.
2002	.	.	.	22.00	85.00	119.50	142.50	99.10	44.40	44.80	.	.
2003	.	.	.	20.70	122.80	161.70	177.30	165.80	69.80	26.00	.	.
2004	.	.	.	61.40	73.50	91.90	123.60	101.00	90.70	32.10	.	.
2005	.	.	.	14.80	54.80	76.60	112.00	82.40	76.60	42.30	.	.
2006	.	.	.	51.90	95.40	120.10	130.80	138.30	62.20	39.90	.	.
2007	.	.	.	44.30	73.50	117.10	169.70	129.50	75.76	31.04	.	.
2008	.	.	.	40.70	86.81	121.99	126.04	135.27	65.71	38.00	.	.
2009	.	.	.	57.94	75.20	106.40	129.70	118.78	43.10	30.60	.	.
2010	.	.	.	64.31	90.13	85.15	110.40	143.57	99.38	22.42	4.85	.
2011	.	.	.	22.93	115.48	124.68	199.27	165.48	140.80	42.52	.	.
2012	.	.	.	52.52	103.99	184.02	229.07	181.68	127.83	61.68	.	.

APPENDIX B: Terkos barajındaki su değişimleri

Yıllar	Terkos Barajındaki Değişim	Istrancalar'dan Alınan Sular	Istrancalar Hariç Değişim	Istrancalar'dan Alınan Sular	Terkos Barajı Maksimum Rezerv
Oca 96	49,709,000	4,703,470	49,709,000		162,241,000
Şub 96	54,797,400	3,307,667	50,093,930		162,241,000
Mar 96	86,583,800	5,838,797	78,572,663		162,241,000
Nis 96	114,670,600	4,984,949	100,820,666		162,241,000
May 96	139,227,200	4,282,446	120,392,317		162,241,000
Haz 96	134,990,600	1,686,096	111,873,271		162,241,000
Tem 96	122,804,100	0	98,000,675		162,241,000
Ağu 96	108,952,200	0	84,148,775		162,241,000
Eyl 96	96,093,900	0	71,290,475		162,241,000
Eki 96	86,583,800	0	61,780,375		162,241,000
Kas 96	77,572,600	0	52,769,175		162,241,000
Ara 96	70,574,400	1,565,567	45,770,975	26,368,992	162,241,000
Oca 97	77,311,400	4,478,649	50,942,408		162,241,000
Şub 97	92,807,000	3,335,764	61,959,359		162,241,000
Mar 97	95,544,500	3,691,365	61,361,095		162,241,000
Nis 97	108,099,000	5,859,577	70,224,230		162,241,000
May 97	145,958,000	4,412,692	102,223,653		162,241,000
Haz 97	140,138,300	1,004,576	91,991,261		162,241,000
Tem 97	130,495,300	39,977	81,343,685		162,241,000
Ağu 97	118,138,500	1,749,560	68,946,908		162,241,000
Eyl 97	111,229,300	142,944	60,288,148		162,241,000
Eki 97	98,854,200	3,791,884	47,770,104		162,241,000
Kas 97	100,798,400	2,176,140	45,922,420		162,241,000
Ara 97	96,918,000	371,866	39,865,880	31,054,994	162,241,000
Oca 98	154,349,000	10,004	96,925,014		162,241,000
Şub 98	160,019,900	18,984	102,585,910		162,241,000
Mar 98	158,437,600	0	100,984,626		162,241,000
Nis 98	159,702,600	0	102,249,626		162,241,000

APPENDIX C: Terkos barajının yağış miktarları

TERKOS BARAJI SU YILI YAĞIŞ MİKTARLARI (mm)												
	A Y L A R											
Yıllar	1	2	3	4	5	6	7	8	9	10	11	12
	ocak	şubat	mart	nisan	mayıs	haziran	temmuz	ağustos	eylül	ekim	kasım	aralık
1993-94	29.70	25.00	35.70	20.30	45.30	73.90	220.10	4.43	0.00	170.60	103.20	130.20
1994-95	173.76	26.40	62.52	26.24	14.42	8.18	89.67	43.39	58.22	19.28	59.70	29.30
1995-96	46.99	97.32	63.60	42.83	26.00	7.30	2.95	14.80	48.93	75.04	36.27	132.73
1996-97	23.88	66.46	46.07	92.72	15.35	25.63	46.16	103.09	11.78	164.10	26.58	166.77
1997-98	21.94	66.29	137.84	51.61	75.79	12.45	21.78	0.00	61.57	98.58	119.28	117.19
1998-99	49.39	119.38	67.37	11.07	16.90	42.42	34.63	42.61	56.94	28.88	106.75	117.67
1999-00	72.59	68.09	57.45	60.08	61.23	17.13	36.95	9.15	91.21	107.28	5.46	47.30
2000-01	92.60	71.20	44.00	48.05	20.40	23.80	0.00	6.80	59.12	19.20	161.40	254.20
2001-02	8.10	24.30	56.60	42.10	9.30	9.20	41.90	35.41	184.28	64.60	93.00	83.78
2002-03	160.80	108.30	50.60	79.00	0.00	0.00	2.20	0.00	65.30	213.95	137.02	105.10
2003-04	166.46	50.02	123.96	20.60	58.20	143.80	7.20	49.70	12.00	102.20	39.70	90.70
2004-05	109.70	82.60	80.70	13.60	74.25	11.90	55.10	36.90	86.80	86.30	138.00	189.80
2005-06	105.80	97.50	121.25	19.10	4.00	51.20	6.70	21.60	129.70	145.70	91.00	44.50
2006-07	25.50	41.40	40.68	6.20	59.95	15.20	1.50	15.50	34.10	93.60	233.75	106.20
2007-08	37.90	59.80	64.20	11.00	2.20	4.40	20.30	3.90	118.80	64.00	78.09	102.00
2008-09	125.20	182.00	152.67	66.20	20.73	1.71	5.92	40.11	310.48	187.87	88.80	172.44
2009-10	138.40	110.35	87.21	34.24	6.80	52.76	66.95	4.49	47.23	242.40	51.87	134.17
2010-11	105.49	50.17	38.41	99.75	18.48	12.91	20.29	26.58	13.33	253.39	23.98	120.82
2011-12	68.15	101.24	47.74	94.54	39.01	6.26	23.52	38.75	34.11	143.31	73.44	173.97