WATER AND WASTEWATER MANAGEMENT IN ISTANBUL

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THE GEOGRAPHICAL GEOLOGICAL STRUCTURE AND CLIMATE OF ISTANBUL

Istanbul is the only city in the world located on both the continents of Asia and Europe. The Bosphorus Strait cuts the city into two sides from the middle. As the city was founded on seven hills, locals have commonly named it as the City of Seven Hills. The main lakes within the city, namely Buyukcekmece, Kucukcekmece and Durusu are sea lagoons. The most significant forests of Istanbul are Belgrad, Aydos, and Kayisdagi. Forest territories of Istanbul cover approximately 44% of the city. The two tectonic plates, Eurasia and Africa, lined along the North Anatolian Fault Line, stretching below the Marmara Sea neighboring Istanbul push each other, causing a never ending movement of the fault line. Thus this fault line has caused severe earthquakes throughout history in the region.

The climate of Istanbul is a mild bearing transitory features of both the Mediterranean and Black Sea climates. Summers in Istanbul are hot and humid, while the winter time is cold, rainy and snowy at times. The average temperature in winter months is between 2 and 9°C on average. Snow can be seen for one to two weeks during the winter period. The average temperature in summer, on the other hand, varies between 18°C and 28°C.

The surface area of Istanbul equals ~5,500 km^2 and the population as of 2014 is ~14.5 million. (TUIK, 2015)

HISTORY OF ISTANBUL

The history of Istanbul extended further past to 8500 years ago with the excavations conducted on Yenikapi Theodosius Port area since 2010, where Neolithic Period settlements were found. Such these findings opened a new era about the cultural, artistic and geological changes, as well as the urban architecture in the city (Istanbul Archeological Museum, 2015). Founded as a tiny town in the proximity of Sarayburnu in 659 B.C., and expanding immensely later on, Istanbul is one of the oldest cities today. Its location on the meeting point of main trade routes and continents of Asia and Europe, its natural beauty, suitable climate, existence of natural harbors of the Bosphorus and the Golden Horn made the city a significant point for social, commercial and military grounds throughout history. Due to such aspects, the city often faced sieges, occupations and occasionally damages of various nations and communities (Demirkent, 2001). The city was captured by the Romans in 73 A.D., and became the capital of the Roman Empire, named as Byzantion. It then became the capital of the Eastern Roman Empire in 395 A.D., and was called Constantinopolis afterwards. It was ruled by the Byzantines for over 1000 years and became the capital of the Ottoman Empire upon the conquest of Mehmed II -the Conqueror- in 1453. Having served as the Ottoman capital until 1923, Istanbul has been the largest and the most developed city of Turkey since after the establishment of Republic of Turkey (ISKI, 1983).

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ECONOMIC STRUCTURE AND BASIC INDICATORS

Serving for centuries as the capital of three empires, and today as the financial and business center of the Republic, Istanbul is ahead of even various countries with its economic size worth of 200 billion $. The city is expected to increase with an annual average of 5% rate in the next decade. Istanbul is expected to rise up to the 27th ranking among large cities in the world by 2020 (Pricewaterhouse Coopers, 2007). The share of Istanbul within the national income of Turkey ranged between 20-25% since the 1960s. On the other hand, 33% of the consumption in Turkey takes place in Istanbul. 20% of the whole industrial employment in Turkey is in Istanbul. While 40 % of all industrial activities in Turkey occur here, 40-45 % of all import and export of the country is realized within Istanbul as well (Gokce, 2010).

The most significant subgroup of agriculture sectors in Istanbul is floristry. The most flower consuming city in Turkey, Istanbul meets this demand both from its own modern flower greenhouses and those in the nearby Yalova province. Animal breeding in Istanbul is not sufficient to meet the meat, and milk demands of the city. In terms of fisheries, Istanbul is the center of the country and of the Marmara region; while there are various fish species in the Marmara Sea. Parallel to the decrease in point and diffuse pollution loads discharged to the sea, water quality has improved in all sensitive aquatic areas in the Marmara Sea including the Golden Horn, İzmit and Gemlik Bays (TUBITAK MAM, 2010) Istanbul is rich with its greens with approximately 45 % of the city is covered in forests. There are limited mining options in the city. Nevertheless, clay, quartzite, and limestone are extracted within the province. Furthermore, marble, pearlite, and manganese is naturally available as well. The mining fields (for clay, lignite, and quartzite sand) are mostly in areas around Sile (Asian side), Catalca and Arnavutkoy (European side). The annual contribution of Istanbul to the central state budget is approximately 40%, while the share it receives from state expenditure is less than 10 %. The credit score of Istanbul Metropolitan Municipality is equivalent to the rating of the Government of the Republic of Turkey, and is the highest rating among all municipalities in the country. Approximately 45,000 people are currently working within Istanbul Metropolitan Municipality, Istanbul Electricity, Tramways and Tunnels General Management (IETT), Istanbul Water and Sewerage Administration, and their affiliate companies. ISKI responsible for all issues related with the management of water supply and wastewater in the city has share of nearly 20 % within these figures.

WATER RESOURCES AND MANAGEMENT IN ISTANBUL - FROM PAST TO PRESENT

The Roman Period: During the foundation of Istanbul (circa B.C. 659.), water requirement of the city was met through underground waters. The initial important water structures in the city were built in the Roman Period. The first of them was the transmission line built by Emperor Hadrian, providing water to the outskirts of the Golden Horn. The second one commenced during the reign of Emperor Constantine (A.D. 337-361), was improved by Valens (A.D. 364-378), Theodosius (A.D. 379-395), Arkadius (395-408), and several other Emperors, as the longest transmission line of the world at the time with a capacity of 90,000 m^3/day water supply, and a length of 242 km stretching from Istranca (Vize, Kirklareli) to Edirnekapi (Cecen, 1994). The third one was the transmission line built by Emperor Valens (A.D. 346-378) who supplied water from Halkali to Beyazit, and also constructed aqueducts and dams to bring water from the Belgrad Forest (Photograph 1). The most important structures within this system are the Bozdogan (Valens) Aqueduct. Emperor Theodosius (A.D. 379-395) built the fourth transmission line to bring water from the Belgrade Forest to Sultanahmet in order to meet the water requirements of the increasing population.

Photograph 1. Valens (Bozdogan) Aqueduct

The Byzantine Period: After the division of the Roman Empire into two in A.D. 395, water shortage became a critical issue in Istanbul, as the capital of the East Roman Empire. As no new transmission lines could be constructed due to political conflicts and wars; several tribes and armies besieging the city to conquer destroyed the existing aqueducts and transmission lines. Endeavoring to restore parts of the transmission lines and aqueducts, the Byzantine Empire faced another significant damage upon the Latin invasion in 1204 which destroyed the urban network once more, and focused this time in accelerating the construction of covered and open cisterns. The number of these cisterns was at one time more than 70, as they provided great benefits to the city during the hard times of drought and war. The most important covered cisterns known today are; Yerebatan (Basilica), Binbirdirek (Philoxenus) and Acimusluk cisterns (Photograph 2). The most important open cisterns known are Aetio (Vefa Stadium), Aspor (Cukurbostan) and Hagios Makios Cisterns. During the Byzantine Period, the capacity of the cisterns in the city reached up to ~900,000 m^3 (Crow et al., 2008; Bahadır, 2015).

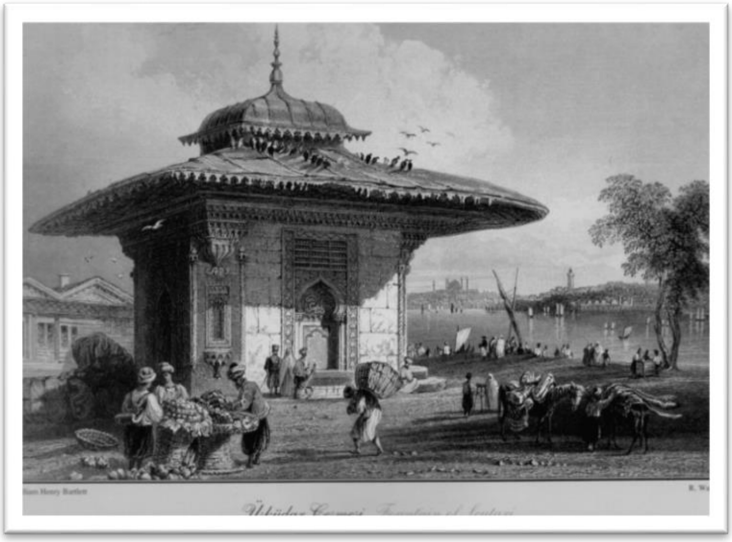
Photograph 2. Yerebatan (Basilica) Cistern

The Ottoman Period: After the conquest of Istanbul, the Ottoman Empire opened a new era and generated a unique water civilization for its time. After the conquest, the city population had increased to prove water facilities insufficient. Sultan Mehmet II ordered the rehabilitation of the water facilities within the Marmara region constructed by the Byzantine Emperor Valens. Various other Sultans and government dignitaries expanded the system onwards adding new lines to the Marmara region water facilities that were fed through various springs around Kucukcekmece which were called Halkalı Waters at the time (Map 1). These facilities' water potential was ~4,500 m^3/day, and they had the sufficient capacity to meet the requirements of the region. There are four large aqueducts on Halkalı Waters; these are Mazul, Black, Ali Pasa and Bozdogan (Valens) Aqueducts. Mazul and Bozdogan Aqueducts, dating from the Byzantines, were repaired to enable further use at the time. As water shortage became prevalent with increasing population over time, Suleiman I -the Magnificent- assigned famous Architecture Sinan to solve the problem, and so began the construction of Kirkcesme Water Facilities in 1555 (Map 1). Kirkcesme facilities enabled water supply from Alibey and Kagithane Streams to Eyup, and then its distribution to the city. As pressure-resistant pipes were not available at the time, water was flowing over aqueducts constructed in valleys. Completed in 1563, Kirkcesme Water Facilities included 4 aqueducts; Uzun, Kovuk, Guzelce and Maglova Aqueducts (Photograph 3). These water facilities had been feeding the 158 plants (94 fountains, 19 cisterns, 15 reservoirs, 13 baths and 7 palaces, etc.) with 4,200 m^3/day of water, even through driest seasons (Gravure 1). After Suleiman I, various charitable figures of the society commissioned constructions of fountains which naturally increased the quantity of water, and the number of the facilities within this network. After 4 dams called Kirkcesme dams in Belgrad Forest were put into use (Topuz Dam (Sultan Osman II, 1620), Greater Dam (Sultan Ahmet III, 1723), Ayvad Dam (Sultan Mustafa III, 1765) and Kirazli Dam (Sultan Mahmut II, 1818)), the total water supply capacity of Kirkcesme Waters raised to 10,000 m^3/day. Water problem of Beyoglu (Pera) region of Istanbul was solved by means of the Taksim Water Facilities constructed in 1732. Water collected into the Taksim Waters System (Map 1) from Bahcekoy (Sariyer) area had a water potential of 800 m^3/day, and was linked to the Taksim area with the 20 km-long transmission line into the main storage unit of 2,700 m^3 capacity called maksem, from where it would reach to 64 fountains and public fountains, and 3 water-tanks with a fountain (In addition, the name "Taksim" means "distribution" originating from distributing water at the time). Later, Topuzlu and Valide Dams, Bahcekoy (Sultan Mahmut) Aqueduct, and Sultan Mahmut II Dam constructions enabled an increase of the water potential capacity of Taksim Waters to accommodate for 3,000 m^3/day (Cecen, 1999), (İSKİ, 2014a).

Photograph 3. Maglova Aqueduct

Map 1. Istanbul waterways - as drawn by Mirliva İbrahim Edhem Pasha in 1894-95 (ISKI, 2014a)

1) Kırkcecme Waterway, 2) Taksim Waterway, 3) Terkos Waterway, 4) Halkalı Waterway, 5) a- Topuz Reservoir, b- Ayvad Reservoir, c- Greater Reservoir, d- Kirazli Reservoir, e-Topuzlu Reservoir, f- Valide Reservoir, g- Murat II Reservoir



Gravure 1. Uskudar Fountain (still in use)

Spring Waters Foundation Period: Until the Ottoman Empire, no transmission line had been constructed to Uskudar on the Asian side, where the water supply was limited to galleries, cisterns and wells built into hills during the Roman and Byzantine Periods. During the reign of the Ottoman Empire, a total number of 35 transmission lines were constructed in the region, including 18 large and 17 small transmission lines such as Mihrimah Foundation Waterway and Solak Sinan Waterway (commissioned by Sultan Suleiman I’s daughter Mihrimah Sultan), Atik Valide Waterway and Nevsehirli Damat İbrahim Pasa Waterway (commissioned by Sultan Murat III’s mother), and the whole water system was named as Uskudar Foundation Spring Waters. Waters collected from springs around the Camlıca Hill were sent to the fountains, mosques, baths, water-tanks with fountain, dervish convents and churches in city through the 3-15 km long transmission line (Borat, 2000), (ISKI, 2014a). To meet water requirements of the rising population, various spring waters were supplied through public fountains via smaller transmission networks. The most important of them is Hamidiye Waters, with a potential of 1,200 m^3/day, commissioned by Sultan Abdulhamit II in 1904 (Map 1). This water source was supplied from the springs in Kemerburgaz, and had been feeding palaces and barracks around Beyoglu as well as 50 fountains. Kanlıkavak and Sariyer Waters supplying water to Emirgan area were similar systems. Those located on the Asian Side were called Kayisdagi, Atik Valide, Kucuk Camlıca, Alemdag (Tasdelen) waters, as well as On Cesmeler, Karakulak and Ishakaga Foundation Waters in Beykoz. The water amount per capita becomes approximately 190 lt/day when the population is estimated to be around 200,000 (Cecen, 1999).

Privileged Water Companies Period: In order to meet the water demand of Istanbul and also to supply pressurized water to the modern buildings, French Company “Dersaadet Water Incorporated Company” (Terkos Company) was provided with the privilege to design-build-operate (DBO) water structures by Sultan Abdulaziz in 1868. This company provided water from the Terkos Lake to Beyoglu, Galata, west side of the Golden Horn, and European side of the Bosphorus. The first plant of the Terkos Company was a pumping station in Terkos Lakeside opened in 1883. Then, a regulator to elevate the water level had been constructed alongside. In 1926, the first water treatment plant in Kagithane was constructed, enabling water supply from the lake to the city upon treatment and chlorination. On the other side of the city, in order to meet the water requirements of Anatolian Side, “Uskudar-Kadikoy Water Company” was appointed as the privileged company in 1888, and the company constructed Elmalı I Dam and built up a water network between the Anatolian Fortress and Bostanci. The same company also constructed a treatment plant to treat the water taken from Elmalı I Dam, as well as a pumping station, transmission line between Baglarbasi and Baglarbasi Water Tank.

Istanbul Water Administration Period: Upon intensive complaints from the residents and failure in conducting the duties adequately, the Terkos Water Company was expropriated by the state in 1932 and Uskudar –Kadikoy Water Company in 1937, to be transferred over to Istanbul Water Administration (ISI). In the pre-transfer period, the quantity of water provided to Istanbul was approximately 35,000 m^3/day. Within the works conducted by ISI on the European side; the capacity of the Terkos Pumping Station and Kagithane Treatment Plant was increased, a second transmission line was added up to increase the system's capacity, and the number of pumping stations in the city was raised, while new electric pumps were put into service to replace the older steam pumps. Artesian wells opened in Cirpici area, and a new pumping station was also constructed there. A power transfer line was installed between Terkos and Silahtaraga, and the pumping stations at Terkos were reinforced with new electric pumps. The transmission lines and water distribution networks for Omerli Dam constructed by the Turkish State Hydraulic Works (DSI) were also completed at the time. On the Asian side, a second dam over Elmalı stream was constructed, the pumping station at Elmalı was equipped with electric water pumps, and the water treatment plant was rehabilitated. Five water ports on the Princes Islands at the Marmara Sea, as well as pumping stations, were installed. As the city continuously received immigration due to social and economic reasons, the need for a new administration to meet the water, sewerage and treatment needs of the city became apparent. In 1981, Istanbul Water Works (ISI) merged with the sewerage works, under the title of ISKI, Istanbul Water and Sewerage Administration.

ISKI Period: Abbreviated as ISKI, Istanbul Water and Sewerage Administration was founded in 1981 as a subsidiary of Istanbul Metropolitan Municipality (IBB) with a private budget under a specific law (Law no. 2560). The main duties and authorities of ISKI can be summarized as; (i) water supply (planning, construction, operation), (ii) wastewater and stormwater drainage (planning, construction, operation), (iii) protection of surface water such as seas, lakes and rivers, as well as groundwater sources against pollution and taking all necessary technical, administrative and legal measures to that end.

ISKI's general assembly is established by the IBB Council with the Mayor of Istanbul is also the chairman of the IBB Council. The Board of Management at ISKI includes six members, and the Mayor of Istanbul is the chairman of ISKI's Board of Management as well. The General Director of ISKI is a member and second chairman of the Board. Additionally, the most senior deputy general director is a natural member of the board. The other 3 members are selected amongst experts with at least 12 years of related service within or outside the administration. The hierarchy of ISKI's administrative organization includes the General Director, Deputy General Directors (5 of them), Heads of Departments, Directors and Supervisors. ISKI conducts investments mostly with its own equities and external loan, when deemed necessary. Certain large scale water supply projects (e.g. Melen, Yesilcay) are held by DSI through debiting of ISKI, to be handed over to ISKI onwards with a special protocol. ISKI operates all of the water supply system in Istanbul, and the operation of pumping stations and wastewater treatment plants is mostly handled through private sector companies via sub-contracting. ISKI investments have not yet been conducted via build-operate (transfer) BO (D) actions. This was partially due to the negative perceptions caused by certain implementations conducted in certain other water and sewerage administrations in Turkey where all metropolitan cities acquire one.

ISKI operates in all 39 districts of IBB, and almost each district has one branch directorate in itself. The budget of ISKI for the year 2015 amounts to 3 billion 471 million $ (5 billion 762 million TL), and approximately 50% of this budget is allocated for investments.

One of the most important projects conducted by IBB and ISKI in the last 20 years is the Golden Horn Rehabilitation Project which has been completed in the period of 1997-2000. The total investment expenditure of this project is 365 million $ that enabled ~5 million m^3 partially contaminated seabed sediment has been dredged from Golden Horn. The project received the International Metropolis Organization award as the best environmental protection project among the 30 portfolios attended by 15 mega cities. The activities carried out by ISKI in the fields of water and wastewater management are given in detail in the following sections.

Photograph 4. Historical Peninsula view form the Asian Side

LEGAL FRAMEWORK FOR WATER AND WASTEWATER MANAGEMENT

Istanbul Water and Sewerage Administration (ISKI) has been conducting its water and wastewater management related duties within the framework of two types of legislation. The first of these is the general legislation framework at the level of central government (Ministries). In this context, Ministry of Environment and Urbanization (MoEU), Ministry of Forestry and Water Affairs (MoFWA), and Ministry of Health have issued related regulations and bylaws. These regulation provide general principles and standards, compatible with the EU Directives, regarding the management of water, wastewater, and treatment sludges in the country. The second type of legislation are special regulations developed by ISKI applicable to circumstances unique to Istanbul, and are therefore local and sometimes more strict, yet still in line with the general principles of the above mentioned national framework. Such general and specific regulations have been summarized briefly in Table 1.

Table 1. Fundamental regulation regarding water and wastewater management

Regulation	Responsible Authority
Water Pollution Control Regulation (OG: 31.12.2004- 25687)	MoEU
Urban Wastewater Treatment Regulation (OG: 08.01.2006- 26047)	MoEU
Regulations on the Use of Domestic Sewage Sludge on Soil (OG: 03.08.2010-27661)	MoEU
Regulation on Incineration of Waste (OG: 06.10.2010- 27721)	MoEU
Bathing Water Quality Directive (OG: 09.01.2006-26048)	MoEU
Regulation on Protection of Groundwater from Pollution and Deterioration (OG: 7.04.2012- 28257)	MoFWA
Surface Water Quality Management Regulation (OG: 30.11.2012- 28483)	MoFWA
Regulation on Water Intended for Human Consumption (OG: 17.02.2005-25730)	Ministry of Health
Tariffs Regulation (OG: 03.12.2014)	ISKI
Regulation on Watersheds Intended for Water Supply (OG: 03.12.2014)	ISKI
Regulation on Discharge of Wastewater in Sewer Systems (OG: 02.06.2014)	ISKI

* These regulations has already been harmonized with the relevant EU Directives.
** MoEU: Ministry of Environment and Urbanization
MoFWA: Ministry of Forestry and Water Affairs
OF: Official Gazette of Turkey

POPULATION AND WATER REQUIREMENT

During the Ottoman period, unplanned growth of the city was prevented though implementation of a certain kind of visa restriction. On the other hand, since the early years of the Turkish Republic (1923), unplanned settlements and rapid industrialization led to contamination of particularly surface waters, especially in the Golden Horn area, with intense waves of immigration from Anatolia and the Balkans. However this situation could only be effectively controlled during the 1990s. Lately, the construction and efficient operation of environmental infrastructure systems has been carried out by ISKI with the positive outcome that the water quality of the receiving water bodies has been significantly improved, and they can be used for several different purposes nowadays.

Istanbul is the most important industrial and commercial center of Turkey with population around 15 million in 2014. The annual population growth rate of Istanbul (~%2.09), as the average for the last 5 years, is approximately 1.5 times the overall population growth rate of Turkey (~%1.39). Such rapid increases bring with it the multitude of the problems. More than 150,000 people enter the city of Istanbul each year through migration only. Heavy migration, uncontrolled urbanization, and unhealthy industrial development cause the environmental infrastructure to become unsatisfactory. The latest large-scale projects, such as 3rd Bosphorus Bridge and the 3rd City Airport are expected to increase Istanbul's population even more in the upcoming decade.

The water demand of Istanbul calculated on the basis of 175~250 lt/capita-day equivalent (industrial usage, unaccounted usage and water losses included) are given in Table 2. Istanbul's water resources are made adequate to fulfill the demand -even in drought periods of 3 consecutive years- at year 2018 starting with the operation of the Greater Melen Dam.

Table 2. Water requirement projections (ISKI, 2014b)

Years	Population (million)	Total Demand (million m^3/year)
2015	14.58	951.19
2020	15.42	1,098.80
2025	16.18	1,233.80
2030	16.89	1,372.65
2035	17.6	1,517.92
2040	18.33	1,672.89

WATER RESOURCES

Water resources of Istanbul are mainly surface waters beyond provincial boundaries. Water is transported from Sakarya and Duzce provinces on the east, and Kirklareli province on the west (Figure 1). Following the severe drought in 1994, emphasis has been given to the development of water resources, and the total capacity has been increased from 590 million m^3/year in 1994 to 2,100 m^3/year in 2014. Table 3. presents the annual water potential of Istanbul's water resources, both readily available and soon to be commissioned.

ISKI has long before assigned Istanbul Master Plan Consortium (IMC) to prepare a Master Plan for planning of water supply, wastewater and storm water investments in the Istanbul Metropolitan Area. At present or in the near future, there is no deficiency in terms of water resources in Istanbul. As proposed in the Master Plan, additional water resources to be developed for the periods after 2040 in order to meet the future water needs, and their annual water potential are summarized in Table 4 (IMC, 1999).

Table 3. Development of water resources during the period of 1994-2014

Water Resources	Initial Service Year	Annual Water Potential (million m^3/year)
Asian Side		
Elmali I & II Dams	1893-1950	15
Omerli Dam	1972	220
Darlik Dam	1989	97
Yesilvadi Regulator	1992	10
Sile Caisson Wells	1996	30
Yeşilçay Regulator	2003	145
Greater Melen Regulator and Melen Stage I**	2007	268
Melen Stage II **	2014	450
Greater Melen Dam and Melen Stage III**	2017	359
Sakarya Water Intake Structure and Pumping Station	2014	315
Total		1,909 (%77)
European Side		
Terkos Dam	1883	142
Alibeykoy Dam	1972	36
Buyukcekmece Dam	1989	100
Istrancalar (Duzdere, Kuzuludere, Buyukdere, Sultanbahcedere, Elmalidere)	1995-1997	75
Kazandere Dam	1997	100
Sazlidere Dam	1998	55
Pabucdere Dam	2000	60
Total		568 (%23)
Grand Annual Total		2,477*

* Greater Melen Dam and Melen Stage III Transmission Line included (to be constructed in 2017)

** Water supply to Istanbul through the Greater Melen System is treated at the Cumhuriyet Water Treatment Plant and transferred to the European Side via the Bosphorus Transmission Tunnel.

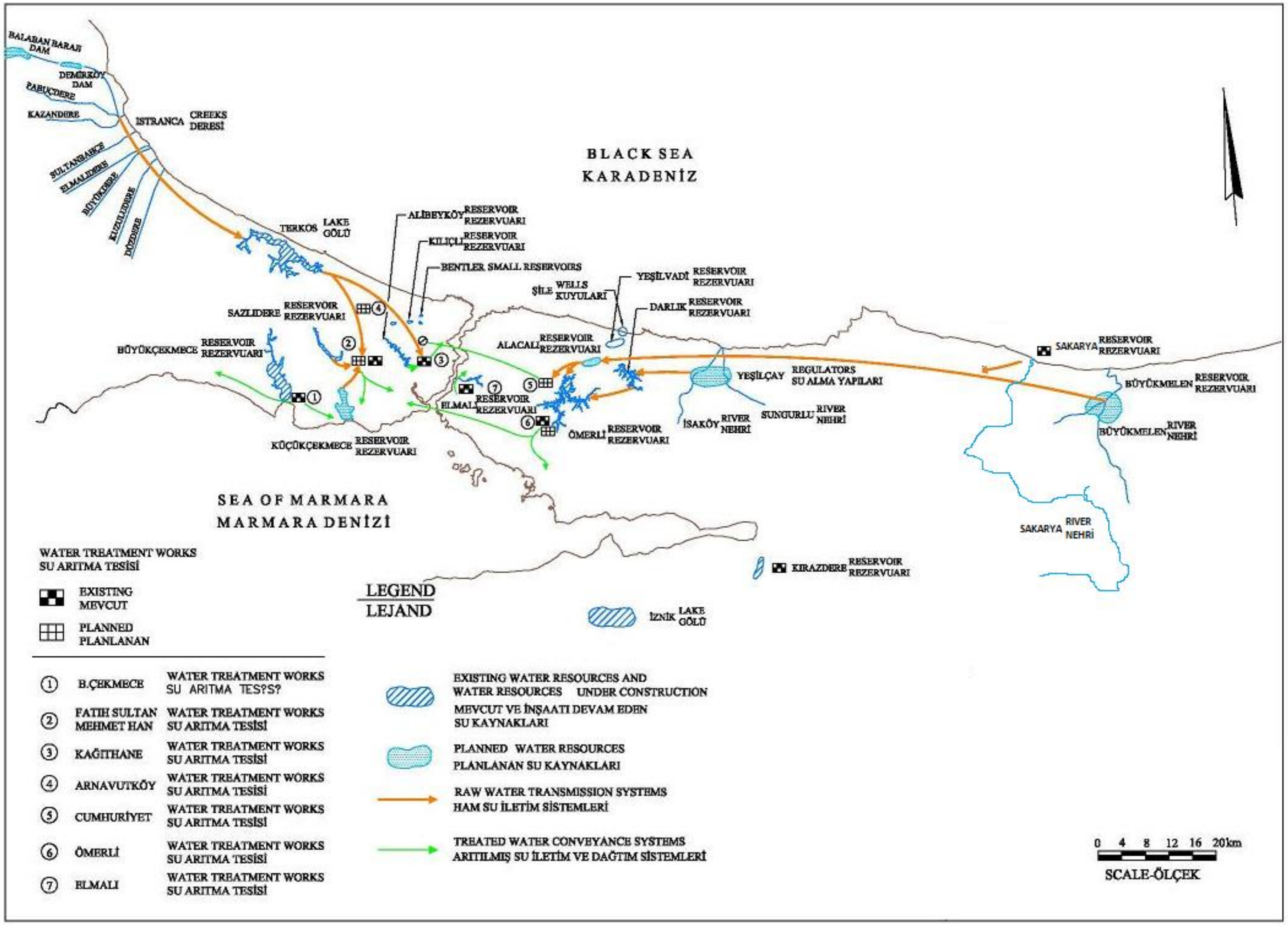


Figure 1. Water resources of Istanbul

Table 4. Planned water resources and their potentials

Water Resources	Initial Service Year	Annual Water Potential Capacity (million m^3/year)
Isakoy Dam	2040-	195
Sungurlu Dam	2040-	115
Hisarbeyli Dam	2040-	194
Kabakoz Dam	2040-	25
Istranca 4 (Rezve)	2040-	117
Annual Total		646

Istanbul presents an asymmetrical case in terms of its water resources and population distributed non-homogeneously between the European and Asian sides. The Asian side, where ~35% of the population lives in, has ~77% of the total water resources including Greater Melen. Therefore, in the Water Supply Master Plan of ISKI, the Melen System is indeed developed to accommodate for the water deficit of the European Side. The water supply/demand curve for the high demand scenario in the Master Plan has been updated in this study as given in Figure 2.

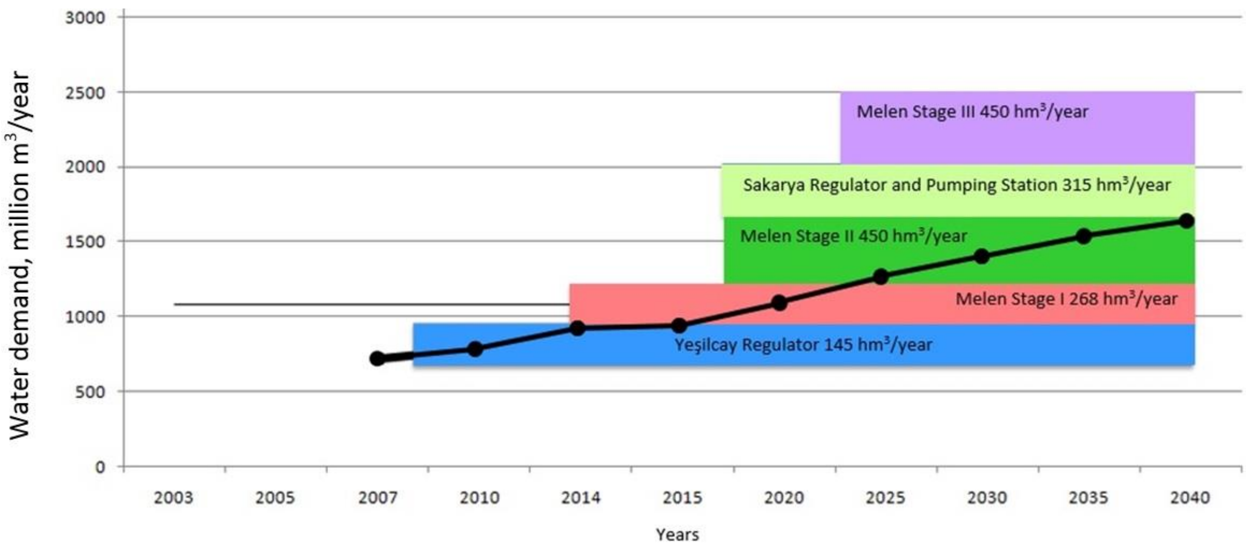


Figure 2. ISKI's water supply/demand curves for updated population projection scenarios (ISKI, 2014b)

PROTECTION OF WATER CATCHMENT BASINS

Some of the water resources of Istanbul are within the provincial borders, such as Elmali, Omerli, Darlik, Sazlıdere, Alibeykoy, while most of them are beyond, such as aquifers Istranca, Sakarya, and Duzce (Greater Melen). It has been long since recognized that water resources of the city are scarce, and catchment basins must be protected for sustainable water supply in the future. ISKI's basic approach to watershed protection against pollution is expropriation of the absolute protection zone regarded as the first 300 meters of the boundary line of the reservoir (max. water level), and not to allow any settlement within this zone, as also provided by the national framework legislation of Water Pollution Control Regulation. ISKI has expropriated and forested ~65% of absolute protection zones in all related watersheds, except for Greater Melen only. In the remaining part between the protection zone boundary and the water dividing line, industrial activities where manufacturing is directly engaged with water is prohibited, and only low-density and controlled settlements are permitted. On both sides of the rivers, just outside the regulated cross-section of the streams, 10 m wide strip have been expropriated where wastewater and stormwater channels and service roads are being contoured. ISKI has been implementing this strategy since the 1990s; even tough it is based on a prohibitive and strict approach, it has been accepted by the community based on the gains in watershed quality. In order to protect the Melen resource, ISKI has taken over the construction and operation of the WWTPs in Duzce Province that encompasses majority of the watershed.

WATER TREATMENT PLANTS

Total capacity of the existing water treatment plants that supply drinking water to Istanbul is nearly ~4.4 million m3/day (Table 5). As seen from the table, the majority of these plants (~75% of total capacity) are built in the last 20 years. Some older facilities, such as Elmali, Kagithane, and Omerli water treatment plants, have gone through significant maintenance and repair, along with upgrading through addition of ozonation and activated carbon units. ISKI maintains a high treatment capacity to supply the city from the alternative treatment plants and to supply water to the city in case of major mechanical breakdowns. Hence, the resistance of the city of Istanbul to drought has been provided. Therefore, the high treatment capacities of the WTPs are due to the strategy to minimize the risk of any interruption in the water services.

Table 5. Existing water treatment plants of Istanbul (ISKI, 2014b)

Water Resource	Water Treatment Plant	Initial Service Year	Situation	Capacity (m^3/day)
Asian Side				
Omerli, Darlık and Yesilcay	Orhaniye	1972	Existing	300,000
	Orhaniye	1995	Capacity increase	200,000
	Muradiye	1995	New	320,000
	Osmaniye	1997	Renewal	220,000
	Emirli	2001	New	500,000
Greater Melen and Sakarya	Cumhuriyet	2012	New	720,000
European Side				
Istiranca, Durusu (Terkos) and Alibeykoy	Celebi Mehmet	1972	Existing	378,000
	Yıldırım Bayezid	1996	Renewal	280,000
	Yıldırım Bayezid	1996	Capacity increase	70,000
	Tasoluk	2006	New	50,000
Buyukcekmece Dam	Buyukcekmece	1989	Existing	400,000
Elmalı I and II Dams	Elmali	1994	Renewal	50,000
Sazlidere and Terkos Dams	Fatih Sultan Mehmet	1998	New	420,000
	II. Bayezid	2004	New	420,000
Package (Modular) Water Treatment Plants (#6)				67,600
Total				4,395,600

The water requirement of Istanbul is supplied 98% from surface waters, with the remaining portion from groundwater and historic wells and small reservoirs. The processes applied for treatment of surface waters are usually: aeration + pre-oxidation (chlorination or ozonation) + coagulation, flocculation, sedimentation + rapid sand filtration and final disinfection. Powdered activated carbon adsorption is applied whenever required in water treatment facilities, especially in times of algae explosion. Alum, $FeCl_3$, polyelectrolyte, and lime are the main treatment chemicals that are used. Treated water quality is monitored regularly every day in terms of bacteriological and chemical parameters on 300-350 samples taken from various points of the city's water supply by Istanbul Metropolitan Municipality and Provincial Directorate of Ministry of Health. ISKI laboratories are equipped with analyzing the water quality parameters of Turkish Standards (TS-266) and World Health Organization (WHO, 2011). More than 98% of the samples taken in 2014 were compatible with the drinking water standards of both Turkey and World Health Organization. ISKI's water quality reports are examined and cross-checked routinely by the Istanbul Provincial Health Board every month, and the water quality analyses are published on ISKI's websites. Urban drinking water quality has increased significantly in the last 20 years through important improvements in water treatment plants and renewal of the pipes in the water distribution network.

WATER TRANSMISSION AND DISTRIBUTION SYSTEMS

ISKI operates Istanbul's water transmission and distribution system which is currently over 20,000 km. Greater Melen transmission line (~35 m^3/s capacity) carrying drinking water to Istanbul from ~190 km, is almost the contemporary version of the ~240 km long waterway connecting Vize (Kirklareli) - Istanbul in the Roman ages. In 2014, the length of the water distribution system has reached over 18,000 km and ~98% of the network consists of ductile iron pipes. According to ISKI's distribution system rehabilitation program, the rest of the PVC, asbestos cement (<%0.5), and cast iron pipes will be changed in the short term. The ratio of unaccounted water has decreased from 65% (1994) to 24% (2014) as a result of effective pressure control and renewal of the pipes in the water network. The amount of treated water given to the distribution system is currently 924,448,500 m^3/year (~2.53 million m^3/day). This corresponds to an accounted household water consumption of 194 m^3/year (0.38 m^3/day). Average accounted net water consumption equals to ~133 lt/cap-day with the assumption of average household size of 4 people in Istanbul (ISKI, 2014b).

MUNICIPAL WASTEWATER MANAGEMENT IN ISTANBUL

Istanbul, located along the shores of the Marmara Sea and Istanbul Strait (Bosphorus), is the largest potential point-source pollution contributor in the Marmara Basin with a ratio of 65%. However the prevention of pollution has largely been achieved in the last 20 years by ISKI's large wastewater treatment plant (WWTP) investments, through application of advanced biological treatment with nutrient (N, P) removal on Istanbul discharges made to the Sea of Marmara.

EXISTING SITUATION OF WASTEWATER AND STORMWATER COLLECTION SYSTEMS

Municipal infrastructure of wastewater in Istanbul is not as well developed as its water supply system. Especially municipal wastewater treatment could not have been improved sufficiently yet. A sanitary sewer system serving 98% of population with a length of ~14,000 km exists in Istanbul (ISKI, 2014b). On the other hand, existing stormwater collection system of Istanbul has a length of ~4,250 km. A part of the existing sewer system is a combined system, and mainly bears significant amounts of stormwater. The sewer system overflows time to time during intense precipitation and results in surface water pollution at local level with health risk for the community. Remediation projects have already been accelerated regarding the streams within residential areas of Istanbul with priority on densely populated watersheds. Current projects for building coastal collectors and major treatment plants are affected to a certain extent by the stormwater carried by wastewater collection systems. The sewer network system is now planned according to ISKI's policy on making separate systems for wastewater and stormwater. ISKI is responsible for 106 streams among which ~85 of them has dense urban development. Rehabilitation projects still continue in order to decrease overflows through remediation of hydraulic profiles of rivers and binding flows.

The Wastewater Management Master Plan (IMC, 1999) foresees that, the secondary stage biological treatment should be applied at the first phase, and tertiary biological treatment (with N & P removal) should be implemented at the second phase for the wastewater discharges into the Marmara Sea. In addition, physical (mechanical and/or primary) pre-treatment is required for the first stage, and chemically enhanced settling or high-load activated sludge system (secondary treatment) is proposed for the second stage regarding all wastewaters discharged directly into the Bosphorus. These Master Plan suggestions are developed through a modeling study conducted by Danish Hydraulic Institute (DHI) regarding improving the water quality of the Marmara Sea and Bosphorus System (IMC, 1999). The current (up-to-date) situation of the existing and planned wastewater treatment and marine outfall facilities first set by the Master Plan is summarized in Table 6.

Accordingly, ~%60 of the domestic and industrial wastewaters generated within the Istanbul Metropolitan Area are currently connected to pre-treatment and marine outfall systems, with the remaining ~%40 connected to biological and advanced biological treatment plants. When all the planned and under construction treatment plants as listed in Table 6. are put into operation, the ratio of wastewaters in Istanbul sent to pre-treatment and marine outfall systems will be reduced to less than ~%10. Even under current conditions, 72% of discharges made to the Marmara Sea, and directly 88% of discharges made to the neighboring Black Sea are resulting from advanced biological WWTPs.

Table 6. Current situation of WWTPs as proposed by Istanbul Master Plan (ISKI, 2015)

WWTP	Discharge Medium	Situation E, U, I	Treatment Level	Capacity (m^3/day)
Asian Side				
Baltalimani	Bosphorus	E	PT+DSD	625,000
Atakoy Stage I	Marmara Sea	E	ABT	390,000
Kucukcekmece	Marmara Sea	E	PT+DSD	354,000
Bahcesehir	Haramidere Stream	E	BT	7,400
Ambarli Stage I	Haramidere Stream	E	ABT	400,000
Buyukcekmece	Marmara Sea	E	PT+DSD	155,120
Canta	Canta Stream	E	BT	1,600
Gumusyaka	Damlaca Stream	E	BT	1,700
Terkos - Durusu	Terkos Lake	E	ABT	1,730
Yenikapi	Bosphorus	E	PT+DSD	864,000
Buyukcekmece Stage I	Marmara Sea	U	ABT	130,000
Selimpasa Stage I	Marmara Sea	U	ABT+DSD	70,000
Silivri Stage I	Marmara Sea	U	ABT+DSD	52,000
Canta Stage I	Marmara Sea	U	ABT+DSD	36,500
Gumusdere	Black Sea	I	ABT	30,000
Baltalimani	Bosphorus	I	ABT	750,000
Atakoy Stage II	Ayamama Stream	I	ABT	210,000
Kucukcekmece	Marmara Sea	I	ABT+DSD	400,000
Ambarlı Stage II and III	Haramidere Stream	I	ABT	600,000
Buyukcekmece Stage II and III	Marmara Sea	I	ABT	260,000
Selimpasa Stage I and III	Marmara Sea	I	ABT	330,000
Silivri Stage II and III	Marmara Sea	I	ABT+DSD	146,000
Canta Stage II and III	Marmara Sea	I	ABT+DSD	156,000
Yenikapi	Bosphorus	I	BT+DSD	925,000
Silahtaraga	Bosphorus	I	ABT	475,000
European Side				
Pasakoy Stage I	Riva Stream	E	ABT	100,000
Pasakoy Stage II	Riva Stream	E	ABT	100,000
Kucuksu	Bosphorus	E	PT+DSD	640,000
Uskudar	Bosphorus	E	PT+DSD	77,760
Kadikoy	Bosphorus	E	PT+DSD	833,000
Pasabahce	Bosphorus	E	PT+DSD	575,000
Tuzla Stage I	Marmara Sea	E	BT+DSD	150,000
Tuzla Stage II	Marmara Sea	E	ABT+DSD	100,000
Pasakoy Stage III	Riva Stream	I	ABT	100,000
Kadikoy	Bosphorus	I	BT+DSD	1,000,000
Pasabahce	Bosphorus	I	BT+DSD	300,000
Rural Treatment Plants (villages)	71 plants	E	182,500 PE	
	70 plants	E	105,000 PE	

E: Existing (in operation)
U: Under construction
I: Planned
PE: Population Equivalent
PT: Preliminary Treatment
DSD: Deep Sea Discharge (Marine Outfall)
ABT: Advance Biological Treatment
BT: Biological Treatment

MARMARA SEA AND THE TURKISH STRAITS SYSTEM

The most significant characteristic of the Turkish Straits System that consists of Dardanelle and Bosphorus is the two-layered flow separated by the terminating pycnocline. Less saline upper layer waters of the Black Sea flow through the Straits System down to the Aegean Sea, while more saline Mediterranean Sea waters flow back (re-circulate) via lower layers. With the assumption of the two-layered Straits System, the average water transfer between top and bottom layers could be estimated with a model that takes into account both the water and salinity budgets. Water transfers obtained on the basis of average annual salinity values are presented in Figure 3. The ratio of upper flows to lower flows of Bosphorus is accepted to be 2/1 on the average.

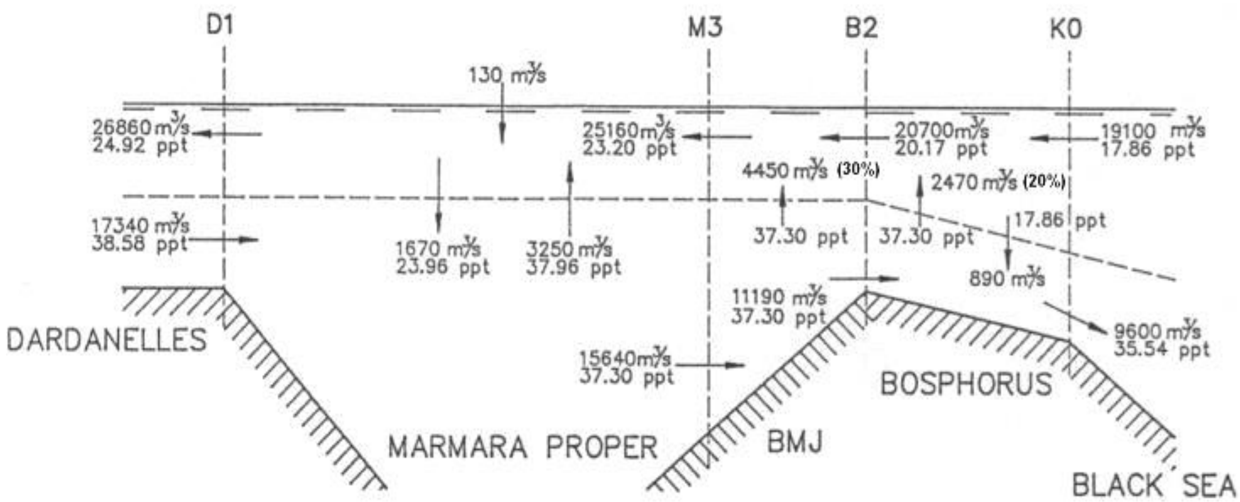


Figure 3. Turkish Straits System Flow Structure (long term average) IMC(1999).

LEVELS OF POLLUTION IN THE MARMARA SEA

Significant amount of nutrients reach the Black Sea through rivers and the pollution load of the wastewaters are discharged throughout the western and northern cost of the Black Sea. From there, it is transported through the Strait via the dominant natural geostrophic currents. Black Sea has been exposed to high pollution loads from the Danube and Dnieper rivers. As a result, a significant portion of the pollution feeds the Sea of Marmara through the upper flows of the Bosporus. The dissolved oxygen concentration at 10 cm beneath the sea surface is near to the saturation limit in the Marmara Sea. Chronic lack of oxygen (20-30% of the saturation level) is observed at 50 m beneath the surface layer. However, the average dissolved oxygen concentration in the Marmara Sea is 2 mg/L and this value does not fall below 1 mg/L at any point. Dissolved oxygen levels in the transition zone (in the pycnocline layer between 20-30 meters) gradually decreases. Oxygen consumption by the biochemical decomposition of the N and P containing organic residues decreases the level of dissolved oxygen in the lower layers.

Across the Marmara, the primary production is equivalent to 1.2 million tons of carbon; 70-80% of it is consumed in the production in the upper layer, and 85% of the rest is consumed in levels under the halocline. (IMC, 1999). These are typical results for the summer months when oxygen concentrations are 1 ~ 2 mg/L. In winter concentrations are over 1.5 mg/L.

As proposed in the ISKI Wastewater Management Master Plan (IMC, 1999) the wastewater treatment and discharge strategies are as follows:

Short Term (2000-2015): Current data in the DHI model indicates that in the short term, deep sea discharges of the wastewater is possible for Istanbul. Modeling studies foresees that it will be sufficient for large-scale (Yenikapi, Baltalimani, Kadikoy) plants to use preliminary treatment (initial screening + aerated grid removal) and for the small-scale (Uskudar, Kucuksu, Pasabahce) plants to use physical treatment (coarse / fine screen or sieve). Biological treatment should be applied prior to the discharges to the lower layers of Marmara in order to control the eutrophication.

Long-term (post 2015): The third stage biological treatment is required to reduce the preliminary treated wastewater's oxygen consumption and to prevent eutrophication in the Marmara, which is considered as a sensitive area. Regarding the wastewaters to be discharged into the Bosporus, by taking into account the space constrains for the WWTP installation, hydrodynamic structure and the assimilative capacity of the Strait (gray area), pretreatment with chemically enhanced settling and high-load activated sludge system is considered mandatory.

IMPLEMENTATION OF THE MASTER PLAN

Wastewater treatment and marine outfall systems as proposed in the Istanbul Wastewater Master Plan are given in Figure 4. Prior to discharges into the lower layers of Bosphorus, preliminary treatment (initial screening + aerated grid removal) at Kadikoy, Yenikapi, and Baltalimani WWTPs is recommended for convenience in application of the short and medium term strategies. According to the modeling results, almost 33% of discharged wastewater returns to Marmara therefore, it is also recommended to apply primary treatment (primary settling tanks + sludge thickening + anaerobic sludge digestion + mechanical sludge dewatering) especially to Kadikoy and Yenikapi WWTPs located at the Marmara Sea inlet of the Strait (IMC, 1999).

Secondary stage biological treatment (activated sludge systems) prior to discharging into the bottom of the Marmara Sea is recommended for Tuzla, Kucukcekmece, Atakoy, Ambarli and Buyukcekmece WWTPs for the medium term. According to the environmental impact assessment, these facilities will be converted into tertiary biological treatment plants, where nutrient removal will be achieved in the long run. Secondary stage biological treatment is suggested for Pasakoy WWTP in the medium term, and tertiary treatment in long term. All of these WWTPs have been designed as activated sludge systems with C, N and P removal, and are still in operation. By the end of 2014, 98% of the domestic (municipal) wastewater has been connected to wastewater treatment and disposal system, and ~100% of the wastewater from population connected to the sanitary sewer system has already been treated.

Industrial wastewaters from urban areas are discharged into central sewer networks after pre-treatment compatible with ISKI's Regulation on Discharge of Wastewater in Sewer Systems. Industrial wastewater not connected to central sewerage is treated to be discharged into receiving water bodies, with respect to discharge standards for industrial wastewaters into receiving water bodies as defined by the Water Pollution Control Regulation of MoEU.

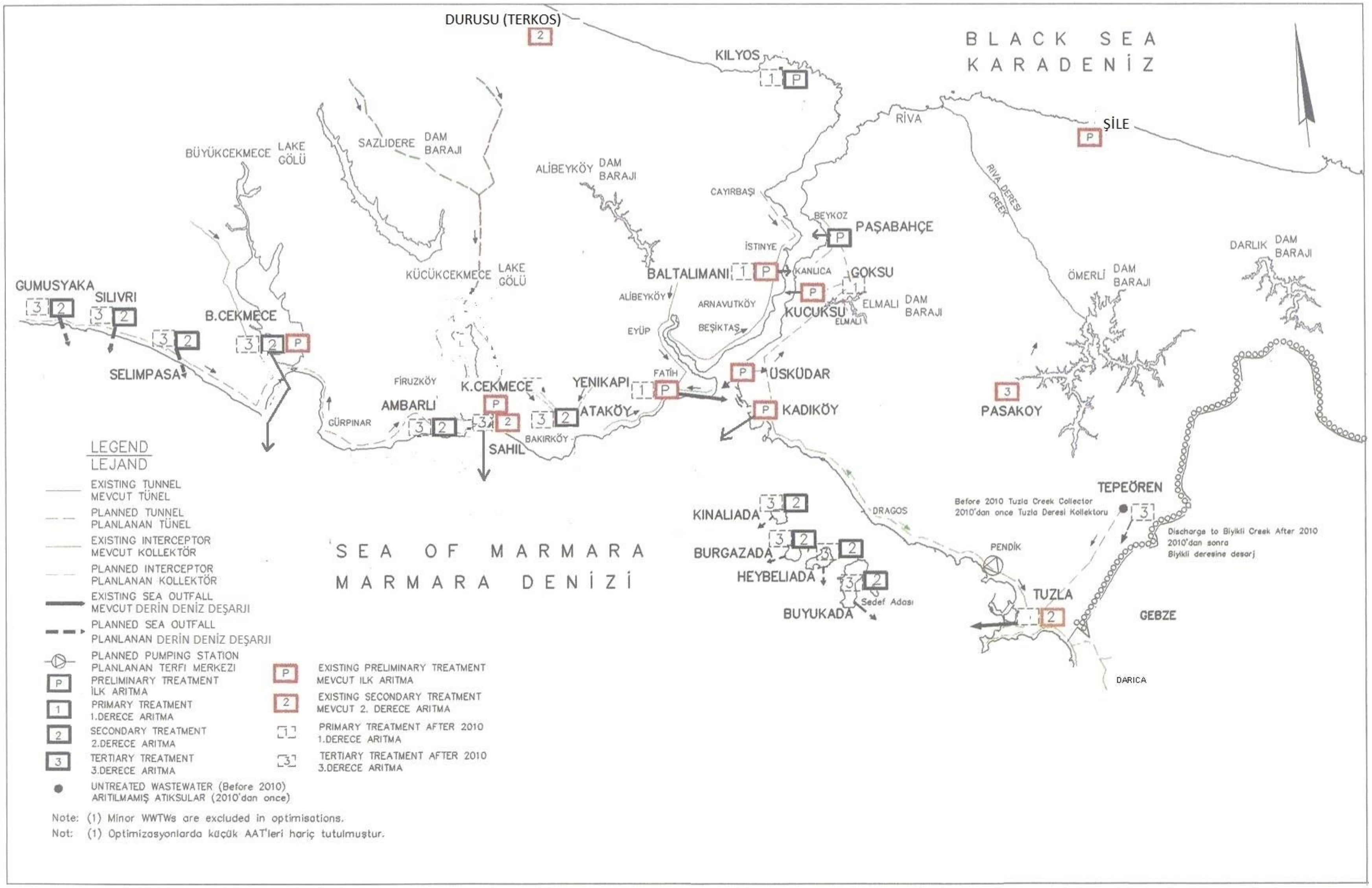


Figure 4. WWTPs and marine outfall facilities of Istanbul

Industrial discharge monitoring and control in Istanbul is executed by ISKI. Monitoring and control of urban WWTP discharges is executed by the Provincial Directorates of MoEU within the scope of Urban Wastewater Treatment Regulation. The current practice of ISKI for management of WWTP sludges is applying mechanical dewatering for such aerobically/anaerobically stabilized bio-solids until >%30 solids ratio is reached, followed by disposal at municipal solid waste (MSW) landfills. In management of biological treatment sludges, ISKI takes into consideration the usage of sludges as supplementary fuel in licensed cement factories nearby following thermal drying. Meanwhile, bio-solids composting and incineration alternatives in special facility is also being evaluated for the upcoming 5-year period (after 2015). In addition, two incineration plants in the Asian and European sides of Istanbul are planned for the disposal of WWTP sludges in the long run. Non-hazardous industrial treatment sludges are stored in separate cells of the sanitary MSW landfills. Hazardous treatment sludges, on the other hand, are transferred to the neighboring Kocaeli Izaydas Hazardous Waste Disposal Plant with licensed hazardous waste transportation vehicles.

Wastewaters from the rural population between 500~5,000 inhabitants are treated with package biological treatment systems or low-cost stabilization ponds on-site. Systems such as oxidation ditches are predominantly applied for residential areas with population more than 5,000 inhabitants. Wetland treatment after sealed septic tank or percolating ditch systems is offered for villages with population less than 500 people. Supports for vacuum truck services are prolonged in such regions.

WATER QUALITY MONITORING STUDY IN THE RECEIVING WATER BODY

Starting from 1996, ISKI has initiated a water quality monitoring program for guiding the ISKI Wastewater Master Plan through evaluation of environmental effects regarding WWTPs and marine outfall facilities on the receiving water bodies, namely the wastewaters discharged into the Istanbul Strait and the Marmara Sea. In the monitoring program, the variation of oceanographic, biological, ecological, bacteriological and water quality parameters with water column, together with the upper and lower layer current flow velocity profiles of the Bosphorus were investigated in monthly samples at a total of 28 stations.

Significant improvement of bacteriological and physical/ aesthetics quality of coastal water in Marmara and Golden Horn waters were observed with preliminary treatment and marine outfall facilities in Istanbul. Analysis results show that bacteriological quality is provided within the required limits of the Water Pollution Control Regulation and EU Bathing Water Quality Directive in wide coastal areas, except for the close impact zone of some surface discharges (ISKI, 2014b). Transboundary pollution from the Black Sea down to the Marmara Sea has not increased in the past ten years, however it still has significance on the marine ecosystem (Okus et. al., 2006), (Öztürk & Tanik, 2013), (Polat Beken et. al., 2013). Pollution from the Black Sea source has great impact on the tropic situation of Marmara basin.

Strategies and application schedule of ISKI's Wastewater Management Master Plan has been re-evaluated with scientific findings of the current water quality monitoring program. It is concluded that the pre-treatment level in Yenikapi, Baltalimanı and Kadikoy WWTPs will be increased to chemically enhanced primary treatment and/or high-load activated sludge system (Process A) during the 2015-2018 period.

INVESTMENT REQUIREMENTS

In the Master Plan of ISKI, total investment requirement for Water Supply, Wastewater Management, Stormwater Collection and Stream Reclamation Systems is over 9.7 billion $ in 2000-2020 (Table 7). If stream reclamation is excluded, ~3.3 billion $ of the ~8.5 billion $ total investment could be taken on with loans, and it could be paid back through a water consumption tariff of ~1.1 $/m^3 (excluding expropriation, soil improvement, and flood control costs). Existing tariff conducted by ISKI for water supply and wastewater disposal is ~1.75 $/m^3. The activities envisaged in the Master Plan have already been performed by ISKI to more than 80%.

ISKI has increasingly preferred subcontracting operation and maintenance services of sewer and wastewater treatment systems to the private sector. Applications of build-operate or build-operate-transfer systems have yet not been exercised by ISKI.

Table 7. Investment requirement estimations of ISKI Master Plan (IMC, 1999)

Investments of Master Plan	Cost (Million $) Phase 1 2000-2010 (2000-2015)	Phase2 2011-2020 (2016-2025)	Phase 1 + 2 (%)
Water Supply Projects	2,985	543	3,528(37)
Wastewater Collection, Treatment and Marine Outfall Projects	2,350	1,390	3,740(39)
Stormwater Collection System Projects	575	608	1,183(13)
Stream Reclamation Projects	1,123	87	1,210(13)
Total	7,033	2,628	9,661(100)

ACTIVITIES TO DECREASE IMPACTS OF AND INCREASE RESILIENCE AGAINST CLIMATE CHANGE IN ISTANBUL

The impact of climate change on water resources that are mentioned in the Turkey's Climate Change Adaptation Strategy and Action Plan (2012) can be summarized as follows (OECD, 2013):

- Increase in the annual ambient temperature for Turkey is 2~3 °C for the 2071-2100 period relative to the 1961-1990 reference period.
- During the summer seasons, the increase in the average temperature is up to 6°C in western half of Turkey (especially in the Aegean Region).
- The transformation of snowfalls to rainfalls due to increasing overall temperatures.
- Significant amount of reduction in the precipitation along the Aegean, Mediterranean and specifically in the Southeast Anatolia Regions.
- Net loss of surface flow (blue water) rate of up to 30%, particularly in the Aegean, East Mediterranean, Central Anatolian, and Southeast Anatolian Regions.
- Significant increase in eutrophication and toxic algae explosions in the shallow lakes and potable water reservoirs, water quality deterioration, and inadequacy of current water treatment plants.

The critical vulnerability of the water resources and water supply systems; significant changes in the flow rates of the streams and quality of the water within the river basins, adverse impacts on potable and industrial water and agriculture and ecosystem services due to drought and reduction in the amount of water potential, increase in the intensity, frequency and duration of the extreme weather events (such as droughts, floods, forest fires, etc.) and their impact on the critical economic sectors and their development can be cited as the adverse effects of the climate change (Brown and Ward, 2013).

On the basis of the Intergovernmental Panel on Climate Change (IPCC) fifth assessment report (IPCC, 2013), using the Regional Climate Model (RegCM4.3.4.), Turkish State Metrological Service applied HadGEM2_ES Global Climate Models running with the RCP 4.5 and 8.5 representative concentrations, and the study of "Climate Change Projections According to New Scenario in Turkey" depicted the condition of the Western Black Sea and Marmara Watersheds, where Istanbul's main water sources are present, and the condition of the basin could be stated as follows (MGM, 2013).

According to the RCP 4.5 scenario (the optimistic scenario), with reference to the 1971-2000 period, the expected increase in the average summer time temperature in the Marmara and Black Sea Region is 2~3 °C for the 2013-2040 period, and 3~4 °C for the 2041-2100 period.

The autumn rainfall precipitation is expected to decline by 20% within the same period. As for the RCP 8.5 scenario (the pessimistic scenario), the effects are expected to be more devastating. Due to the increase in the temperature, evaporation, and evapotranspiration related to the impact of climate change on the region, (although a significant reduction in the precipitation is not expected) at least 20% level decrease in the surface and ground waters are expected in the surface and ground waters (blue and green water) in the Western Black Sea and Marmara Basements, where Istanbul's main water sources are located (Öztürk et al., 2013).

In the Final Report of the "Climate Change Impacts on the Future of the Water Sources for Istanbul and Turkey Project "conducted by Turkish Water Foundation on behalf of ISKI, it is stated that due to the temperature change between 2015 and 2040, heavy rainfall, drought, and temperature rise are expected along with the increase in the frequency and duration of these events, and a series of measures are recommended to be taken including the inter-basin water transfer (to secure water supply, water demand management, aquifer restoration, etc.) (Turkish Water Foundation, 2010).

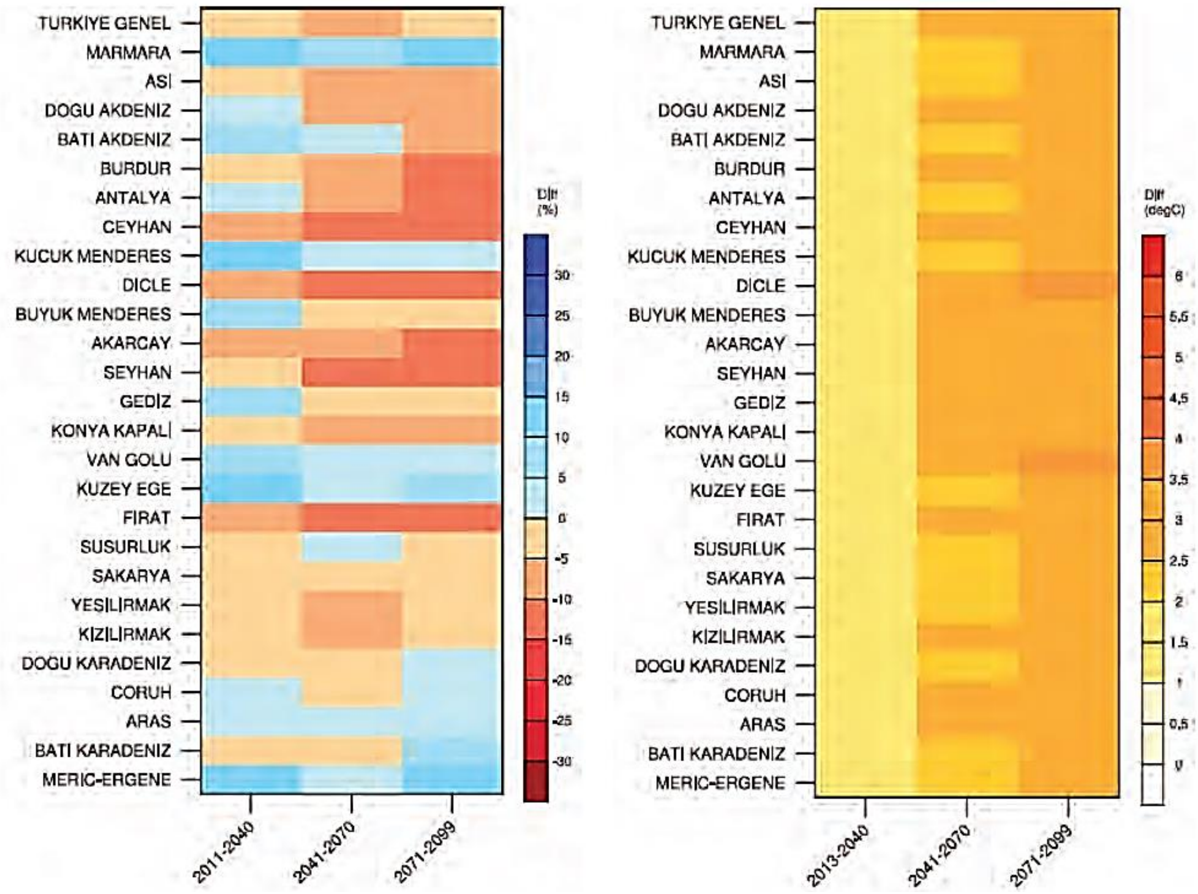


Figure 5. According to the RCP4.5, temperature and rainfall precipitation projections based on water basin (MGM, 2013)

Taking the IPPC's Fifth Assessment Report into account, another project that examines the effect of climate change on the water resources, water potential of the river basins and selected pilot river basin's sectoral impact analysis methodology is ongoing in detail (MoEU-SYGM, 2014-2016). The scientific references mentioned above are used to the fullest extent to increase the resilience against climate change in Istanbul.

Planned and Conducted Works by ISKI

The works conducted by ISKI to increase the climate change adaptation capacity has been emphatically included initially in the Master Plan (IMC 1999), thereafter in the strategic plan (ISKI 2011-15) and in the latest strategic plan (2016-2020). In this context, the planned and already conducted works are summarized as follows:

- ***Measures taken to mitigate the risk of drought and to secure the supply of water in water abstraction systems:***
  Water transfer between water basins. As foreseen in ISKI's Water Supply Master Plan (IMC, 1999), the construction of Greater Melen Dam and water distribution systems. The project's first two stages were completed in the period of 2007-2015 and transfer through the inter-basin water transfer from the Greater Melen River Basin's ~180 km from Istanbul (1Φ2500 mm + 1Φ3000 mm steel pipeline) ~ 400x106 m3 / year water supply is provided. With the completion of the Greater Melen Dam by the end of the 2016, the water to be transferred from Greater Melen System to Istanbul will reach ~ 1,05 x109 m3 / year. Consequently, Istanbul will endure three consecutive years of drought.

Aquifer restoration. Due to the fact that groundwater reserves (aquifer areas) in Istanbul are very limited, over 95% of the water demand is met from surface sources. As a result of excessive water withdrawal from the known aquifers of Istanbul for the industrial use, the static water levels were decreased excessively and partial increase in the water salinity was encountered. After the relocation of industrial facilities to outside Istanbul, specifically the restoration of Bakırkoy and Yenibosna aquifers is on the agenda. After the restoration of such degraded aquifers, ISKI is planning to create a strategic groundwater reserve to provide ~5-10 % of the annual water demand.

Reduction of the non-revenue (unbilled) water. One of the important and primary goals of the ISKI's Strategic Plan is to reduce the rate of non-revenue (unbilled) water to 15-17% by 2023, which currently stands at ~25%. In this context, the SCADA assisted pressure control integrated with the hydraulic modeling are being used for rendering more effective "isolated sub-networks" enabling more micro scale water loss analysis applications. The reduction of the unbilled water rate across the country is directed by the "Regulation on the Control of Potable Water Losses in Water Supply and Distribution System" which was published by the MoEU in 2014. Throughout Istanbul, a better performance was achieved (30%) compared to the targeted rate in the aforementioned regulation. A 1 % reduction in the unbilled water in ISKI water supply corresponds to ~30,000 m^3/day (~11x10^6 m^3/year) which is equivalent to additional resources.

The use of reclaimed wastewater. Studies are conducted for the use of reclaimed wastewater from the effluents of the ISKI's advanced WWTPs after treated with Sand Filtration + UV disinfection to be used for the landscape irrigation, toilet flushing, and industrial process water (commercial applications). Within this context, at Paşaköy WTTP a rapid sand filtration and UV system was installed to the effluent line that has a capacity of 150,000 m^3/day. The water produced was used in toilet flushing and landscape irrigation at the nearby Teknopark Istanbul Campus, and as process water in Tuzla Organized Industrial Zone. The excess water from this system is used for the irrigation of urban areas around Tuzla's shores. ISKI is planning to extend the same application to other large WWTPs during the new strategic plan period (2016-2020). In this way, within the ISKI's service area, ISKI foresees a potential to recover a minimum of 200~250,000 m^3/day of water (ISKI, 2014c).

- ***Ensuring an effective and efficient use of water.*** To promote an effective and efficient use of mains water, ISKI applies a gradual tariff. With this application, consumers consuming water more efficiently (<10 m3/house. month) pay less. The same principle applies to commercial and industrial subscribers. Effective use of such economic tool makes the use of treated/gray water more attractive to many industrial and commercial sectors. For the ordinary ISKI subscribers, awareness campaigns on expanding the use of water saving equipment like water conservation faucets, shower heads, boilers, flush systems, etc. are carried out. Ministry of Science, Industry and Technology also provides significant incentives for the production of domestic water-saving devices and equipment.
- ***Increasing Renewable Energy Use in ISKI's property.*** In order to ensure a reduction in energy consumption and carbon foot print in the activities conducted by ISKI, increase in the use of renewable resources such as, primarily the wind power, solar energy and biogas / biomass energy is planned. In particular, the targeted objective in the new Strategic Plan (2016-2020) includes special Wind Power Plants to be set up in Water Treatment Plants on the Asian side. The feasibility and site selection studies have been completed. Pilot-scale projects in some ISKI's shallow water reservoirs

(specifically Buyukcekmece and Terkos) such as energy production with floating solar systems, evaporation and algae growth control (reduction) have been launched. A pilot project has planned by the Istanbul Metropolitan Municipality's Urban Planning Department to launch whereby the urban planning will incorporate 'acting sensitively on water or to a water-reconciled planning concept' (such as permeable pavements, urban artificial wetlands, rainwater harvesting, green buildings, etc.).

Pilot scale R & D activities are carried out for the joint treatment of organic wastes from restaurants and/or separately collected wastes in the sludge digesters in ISKI's large WWTPs. In the medium term, at least one full-scale application is planned in this regard.

- ***Flood Control and Stream Rehabilitation.*** It is a common knowledge that one of the most evident effects of climate change is the significant increase in the number and frequency of devastating floods in cities as a result of very heavy rains (Brown and Ward, 2013). In this context, ISKI prepared maps for flood risk management for all the creeks with historic flood records and with future flood risks, thereby identifying all the areas under risk. In line with the project outcomes, the rehabilitation of the creeks that flow and carry the risk of flooding in the urban areas as well as the expropriation of buildings in the risky areas has been completed to a great extent (Turkish Water Foundation, 2010), (ISKI, 2014c).

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