HYDROGEOLOGICAL CHARACTERIZATION OF THE ALPU COAL MINE EXPLORATION SITE IN ESKISEHIR-TURKEY

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ABSTRACT

HYDROGEOLOGICAL CHARACTERIZATION OF THE ALPU COAL MINE EXPLORATION SITE IN ESKISEHIR-TURKEY

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May 2016, 272 pages

The purpose of the study is to characterize the hydrogeological conditions at the Alpu Coal Mine Exploration Site which is located in the Eskisehir Province in Turkey. This is required to provide baseline hydrogeological information before environmental impact assessment of the planned mining operations can be done. The characterization studies included hydrogeological and hydrochemical analysis of groundwater and surface water. The spatial and temporal variations in groundwater levels are determined by measuring the groundwater levels in drilled observation and pumping wells. The hydraulic parameters of the groundwater system are estimated by conducting aquifer tests in some of the wells. The hydrochemical characteristics of the waters are based upon measured field water quality parameters and chemical analyses of the samples taken at periodic intervals from both surface and groundwater.

Key Words: Alpu Coal Mine, Hydrogeological Characterization, Aquifer Tests

ÖZ

ALPU KÖMÜR MADENİ ARAMA SAHASININ HİDROJEOLOJİK KARAKTERİZASYONU, ESKİŞEHİR-TÜRKİYE

Çatak, Mert Onursal
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Bu çalışma Türkiye nin Eskişehir ilinde yer alan Alpu Kömür Madeni Arama Sahasının hidrojeolojik karakterizasyonunu ortaya koymayı amaçlamaktadır. Gerçekleştirilen çalışma, planlanan madencilik faaliyetleri için gereken Çevresel Etki Değerlendirme raporlarının hazırlanması için gerekli hidrojeolojik bilgilerin temelini oluşturmaktadır. Yapılan karakterizasyon çalışmaları bölgenin yüzey ve yeraltı sularının hidrojeolojik ve hidrokimyasal analizlerini içermektedir. Yeraltı su seviye değerlerindeki zamansal ve konumsal değişimler mevcut pompaj ve gözlem kuyularından yapılan ölçümlerle belirlenmiştir. Yeraltısuyu sisteminin hidrolik parametre değerleri mevcut kuyularda gerçekleştirilen akifer testleri ile saptanmıştır. Suların hidrokimyasal karakteristikleri sahada gerçekleştirilen su kalite parametre ölçümleri, yüzey ve yeraltı sularından periyodik olarak alınan örneklerin kimyasal analizlerinin yaptırılmasıyla belirlenmiştir.

Anahtar Kelimeler: Alpu Kömür Madeni, Hidrojeolojik Karakterizasyon, Akifer Testleri

TO MY BELOVED FAMILY AND FRIENDS...

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This master thesis had been conducted as part of the METU project no: 2014-03-09-2-00-29, entitled “Esan – Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu” supported by Eczacıbaşı Industrial Raw Materials Inc. Therefore, the support provided by Eczacıbaşı Industrial Raw Materials Inc. is greatly appreciated.

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER 1

INTRODUCTION

1.1. Purpose and Scope

The Eczacıbaşı Industrial Raw Materials Inc. (ESAN) has been conducting coal exploration activities in the vicinity of the Ağapınar, Cavlum and Kireç villages in Odunpazarı District in Eskişehir Province. The baseline studies had been conducted before the environmental impact assessment and feasibility studies. In order to investigate chemical, physical and hydraulic parameters of the watershed areas and hydrogeologically characterize the coal basin, hydrogeological studies had been conducted in this area. The scope of the study included a review of the existing topographical, hydrological, hydrogeological, geotechnical and water quality data. In order to make investigation of the hydrogeological data and physical, chemical and hydraulic characterization of the study area, pumping and observation wells were drilled in the study area. The aquifer tests were conducted in these wells and groundwater levels were monitored on monthly basis. The field water quality parameters such as temperature (T), pH, electrical conductivity (EC) and dissolved oxygen (DO) were measured on monthly basis from all pre-defined water monitoring points to make characterization of hydrochemistry and water quality. Some surface water monitoring points were also defined to establish the surface water runoff and evaluate the surface water flow potential in the study area. The water bearing units in the study area were identified. Spatial and temporal variations in groundwater levels as well as spatial and temporal variations in groundwater quality are determined. Finally, a conceptual groundwater budget of the study area was also calculated.

1.2. Location of Study Area

The study area is located within the Eskişehir graben at the northwest of the central Anatolia. License area is located, approximately 14 km east of the Eskişehir, and 3 km northwest of Ankara-Eskişehir road. The study area is accessed via Eskişehir-Alpu road. Ağapınar, Çavlum, Sevinç and Kireçköy that belongs to the Odunpazarı Municipality are located within and/or in close vicinity of the study area. The license area which is located within the study area is approximately 24 km^2 and the longest distance from north to south is 5 km (UTM 4403000-4408000 North); from east to west is 6km (UTM 305000-311000 East) (Figure 1-1).

The Alpu plain, located 1.5–2 km from the north of the licence area, is drained by the Porsuk Stream which flows from west to east. The Porsuk Stream, which is the main tributary of the Sakarya River, starts from Kütahya, passes through Kütahya and Eskişehir plains and reaches to the Alpu plain.

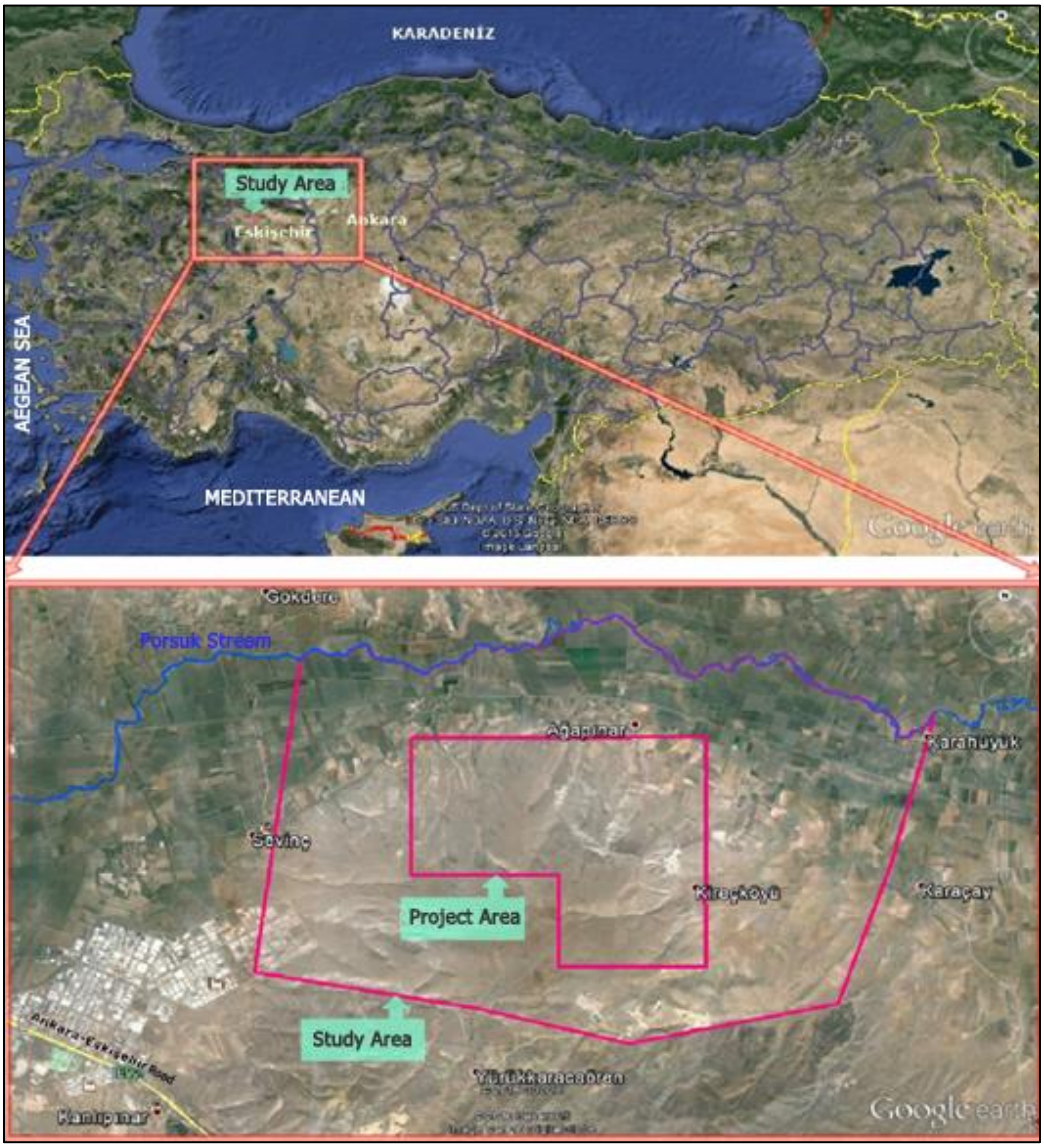


Figure 1-1: Location Map of the Study Area

1.3. Previous Studies

"Orta Sakarya ve Güneyinin Jeolojisi" report prepared by Gözler and others (1997) for MTA is one of the leading studies for the geological studies about the study area and its vicinity. The 1/100.000 scale geological maps of İ24, İ25, İ26 and İ27 sheets were prepared in this study. Şengüler (2013) prepared a report about the geology and stratigraphy of the Alpu Basin. Toprak and others (2015) investigated the petrographic and sedimentary environment of the same basin. The last report regarding the geology and the coal reserve of the study area was prepared by John Bambery in the behalf of Palaris (2016) prepared for Eczacıbaşı Industrial Raw Materials Inc. (ESAN). The coal exploration studies conducted from MTA continue in the north of the study area. In addition to all these studies 1/25.000 scale geological map of the study and its vicinity is prepared by MTA.

The hydrogeological studies of the study area and its vicinity are limited. The hydrogeological survey of the Alpu Basin conducted by by General Directorate of State Hydraulic Works (DSİ) in 1977 investigated the potential, depth, amount and quality of the groundwater in the plain.. A revised report was also prepared by DSİ in 2010 to re-estimate the groundwater potential in the basin..

CHAPTER 2

DESCRIPTION OF THE STUDY AREA

2.1. Morphology

Digital Elevation Model (DEM) of the study area is produced from the 1/25000 scale topographical maps (Figure 2-1). According to the model, the elevation ranges between 760-1000m. The lowest elevation within the regionis formed by the alluvial units of the Porsuk Stream to the north of the license area. The average elevation around this region is in between 760-790 m. The highest elevations are at the southern part of the study area where average elevation is 1000 m.

Hill tops that are forming the high elevations within and in the close vicinity of the study area are shown in Figure 2-1. The highest elevation in the region is Kireç Tepe, lies within the license area, with 1027m. Remaining hills with respect to their elevations are Menevşeli Tepe (1012 m), nameless hill (1006 m), Aktepe (1004 m), Çüruksu Tepe (977 m), Maslak Tepe (976 m), Gavurpınar Tepe (952 m), nameless hills 938 m, 936 m and 924 m, Köyarkası Tepe (910 m), Aktoprak Tepe (843 m), nameless hill (831 m), Tekkehöyük Tepe (805 m) and nameless hills 799 m, 797 m, 784 m and 769 m.

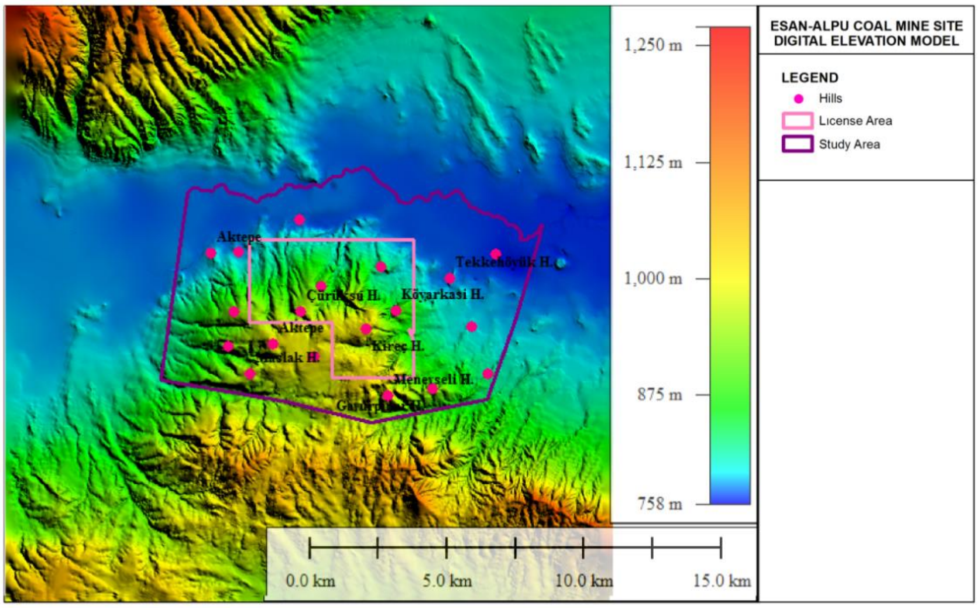


Figure 2-1: Digital elevation model of the study area

2.2. Population and Settlement Areas

The most populated settlement that could be affected socio-culturally by mining activities within the study area is Odunpazarı Municipality with 383,523 people. Ağapınar, Çavlum, Sevinç and Kireçköy of the Odunpazarı Municipality that lie within the license area and its close vicinity could be considered within the area of influence of the mining activities. Population statistics of the settlements and villages were obtained from Address Based Population Registration System of TUİK (Turkish Statistical Institute) 2015 data. The total population of these villages listed above is 2739. The most populated settlement among them is Sevinç settlement, located west of the study area, with 1300 population and the least populated settlement, north of the study are, is Çavlum with 130 people. The population distributions of the settlement areas are shown in Figure 2-2.

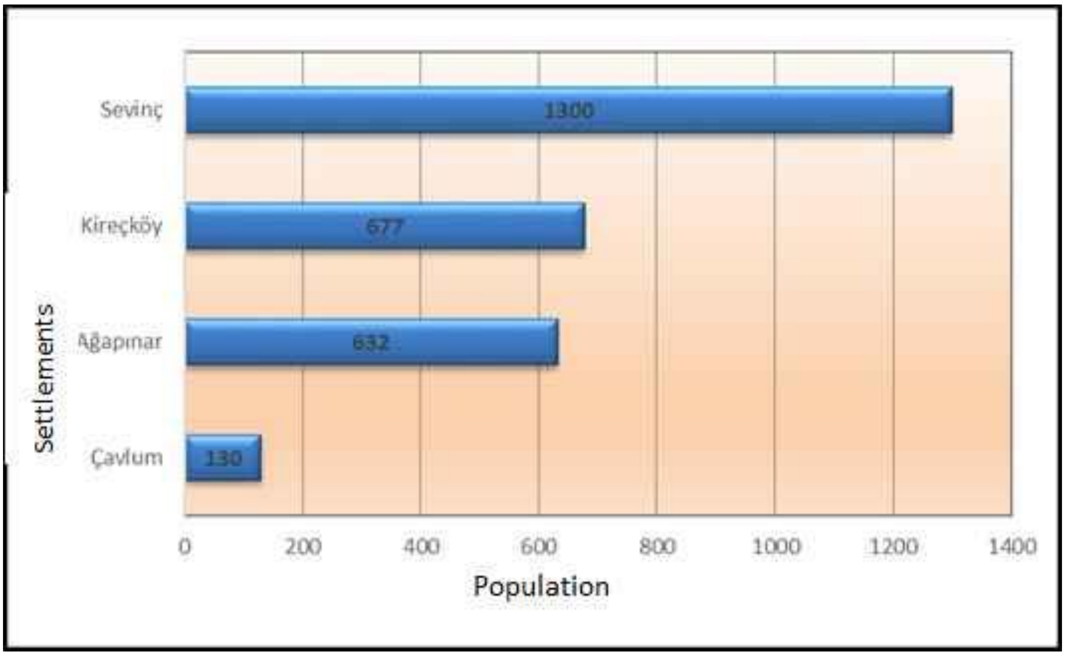


Figure 2-2: Population distributions in the settlements

2.3. Climate and Meteorology

The region covering the study area has a typical continental climate having hot and dry summers and cold and snowy winters. In order to define climatic properties within the license area, data from meteorological stations that were operated or being operated, that are within the study area or in its vicinity have been examined (Table 2-1, Figure 2-3).

Table 2-1: Detailed information about meteorological stations

Station No.	Station Name	UTM longitude	UTM latitude	Elevation (m)	Distance to Project Location (km)	Data Period
17126	Eskişehir Met. Blg Md.	290146	4404721	801	15	1929-1978, 1981-1990, 2007-2014
17124	Eskişehir Askeri Myd. Met. Blg. Md.	293045	4406434	785	12	1978-1981
17123	Eskişehir Anadolu Sivil Myd. Met. Blg. Md.	287460	4410374	789	17	1990-2012
3343	Alpu	325815	4403788	765	15	1984-2002

Among the meteorological stations listed above, station 17126 named Eskişehir Met. Blg. Md. has the longest observation period. This station is being operated from 1929 to date and there are data losses between 1978-1981 and 1990-2006. Since the stations 17124 Eskişehir Askeri Myd. Met. Blg. Md. and 17123 Eskişehir Anadolu Sivil Myd. Met. Blg. Md. were operated when 17126 was not operational, an almost complete data set for downtown Eskişehir could be generated. In addition to these stations, station 3343 located at Alpu was operated by MGM between 1984 and 2002. For the stations listed in Table 2.1, the total monthly precipitation, monthly average, minimum and maximum temperature, monthly average relative humidity and total monthly open surface evaporation values are discussed below, respectively.

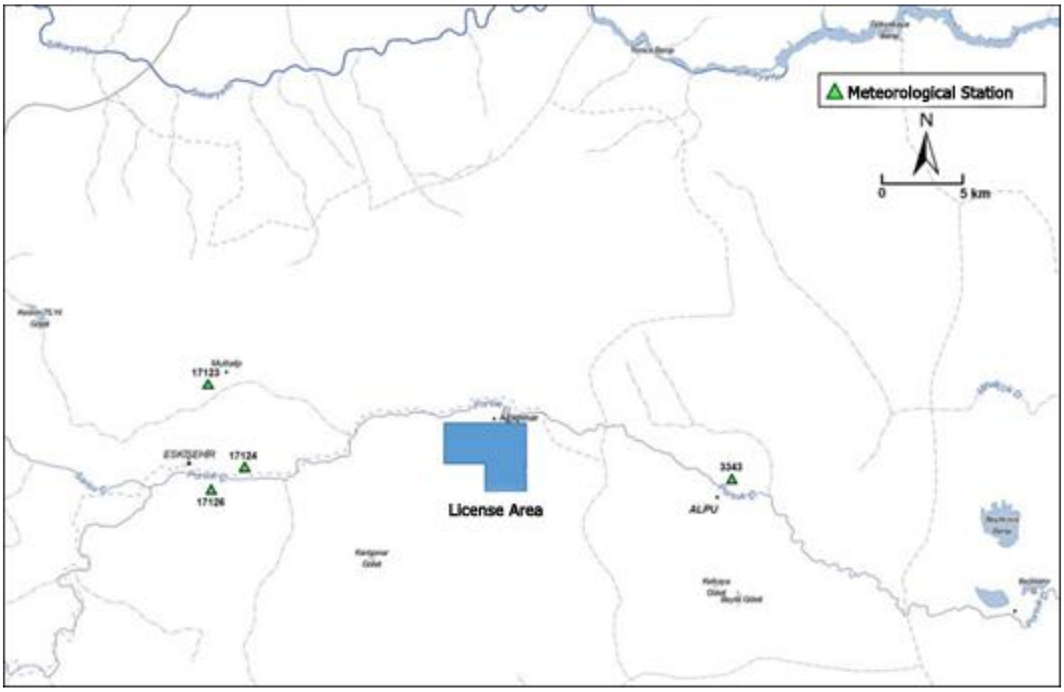


Figure 2-3: The meteorological stations in the vicinity of Study area

2.3.1. Precipitation

In order to evaluate the long-term precipitation regime in the study area, the yearly total precipitation and cumulative deviation from the average annual graph generated from precipitation data obtained from the station 17126 Eskişehir Met. Blg. Md. between 1929 and 2015 are shown in Figure 2-4. For the periods of 1978-1981 and 1990-2006, when the meteorological data of station 17126 were missing, the data from stations 17124 and 17123 were used. Additionally, the precipitation data obtained from the station 17126 during the period of 2007-2012 was found low compared to the data obtained from the other meteorological stations; therefore, the precipitation data of the station 17126 considered as misleading and the data from the station 17123 were used instead. As shown in Figure 2-4 the driest year is 1932 (194 mm) and the wettest year is 1963 (518 mm) between 1929 and 2015. The year 2013 is the second driest year with 209 mm total precipitation. The long-term average yearly precipitation of Eskişehir province is 366 mm. In year 2015, when this study was conducted, the total precipitation was 423.8 mm, 15% more than the long-term average yearly precipitation. When the yearly total precipitation and cumulative deviation from the average annual graph examined, 1929-1937, 1951-1956, 1982-1997 and 2002-2008 coonstitute the dry periods, while 1938-1950, 1957-1981, and 2009-2012 are the wet periods. When the general trends are considered, it is seen that the period between 1957 and 1981 is a significant wet period and the period between 1982 and 2014 is generally a dry period.

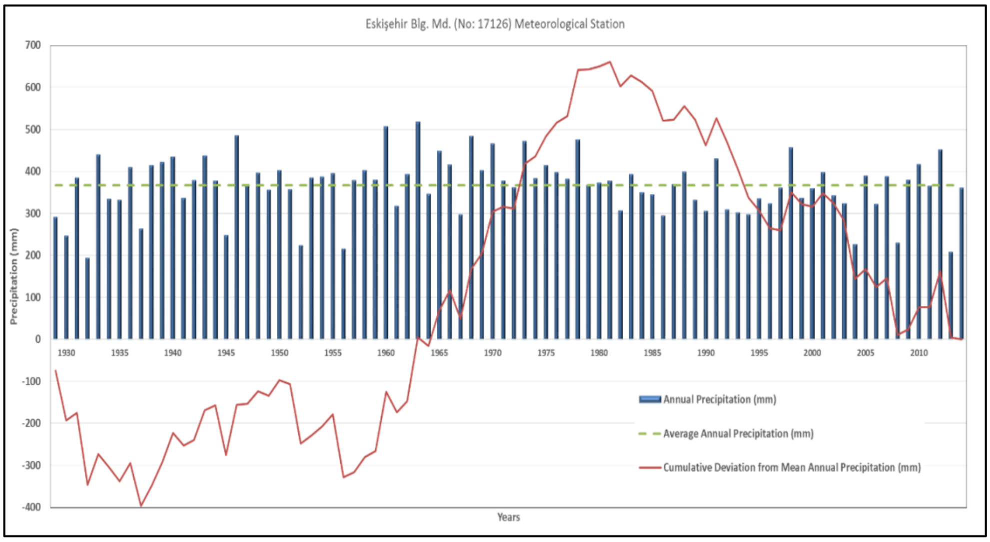


Figure 2-4: Eskişehir Blg. Mdr. Meteorological Station Annual Precipitation (mm) and Cumulative Deviation from Mean Annual Precipitation (mm) Graph (1929-2014)

The station 3343 Alpu meteorological station was operated continuously between 1985 and 2001 and long term precipitation data and cumulative deviation from the average annual precipitation for this meteorological station are given in Figure 2-5. According to this figure, 1992 (288 mm) is the driest year and 1997 (535 mm) is the wettest year. The average yearly precipitation measured is 388 mm, which is 22 mm higher than the Eskişehir city center. The driest period is between 1985 and 1996 and wettest period is between 1997 and 2001 which is consistent with the data of the station 17126 Eskişehir Met. Blg. Md.

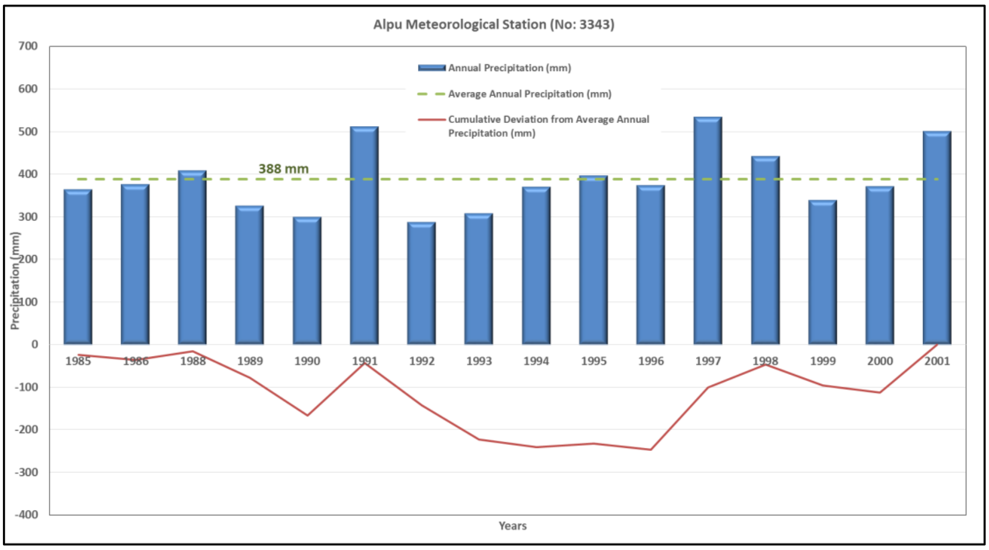


Figure 2-5: Alpu Meteorological Station Annual Precipitation (mm) and Cumulative Deviation from Mean Annual Precipitation (mm) Graph (1985-2001)

Long term average monthly precipitation data of Alpu (3343) and Eskişehir Anadolu Sivil Myd. Met. Blg. Md (17123) meteorological stations for the time period 1991-2001 when both stations were operational are given in Figure 2-6. As seen from this figure, more precipitation were observed at Alpu station compared to Eskişehir Anadolu Sivil Myd. Met. Blg. Md. Since the study area is located in between Eskişehir city center and Alpu, it is expected that the total precipitation would be in between the precipitation values observed at those two stations.

The deviation of average monthly precipitation throughout the year was examined for the stations 3343 Alpu (1984-2002) and 17126 Eskişehir Met. Blg. Md. (1929-2015). According to the data of the station 17126 the wettest month is December (46.4 mm/month) and August is the driest month (8.3 mm/month). Rainfall is generally observed in winter and spring (December – May), July, Augusts and September are the months with least rainfall. The deviation of average monthly precipitation throughout the year graph generated from the data obtained from the station 3343 shows similar distribution with the station 17126. Average precipitation during the months October, November, December, April and August is significantly more than the station 17126. While December is the month that has the most average precipitation (51.8 mm/month), July, August and September are the driest months.

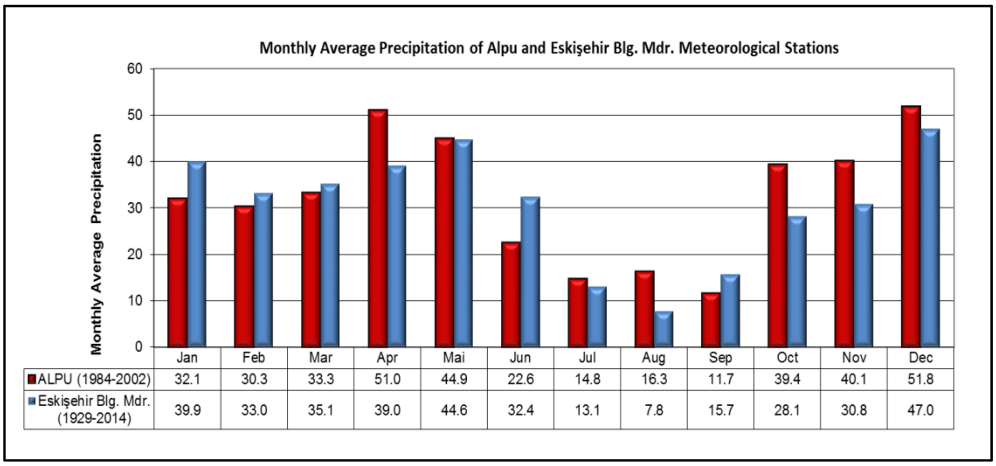
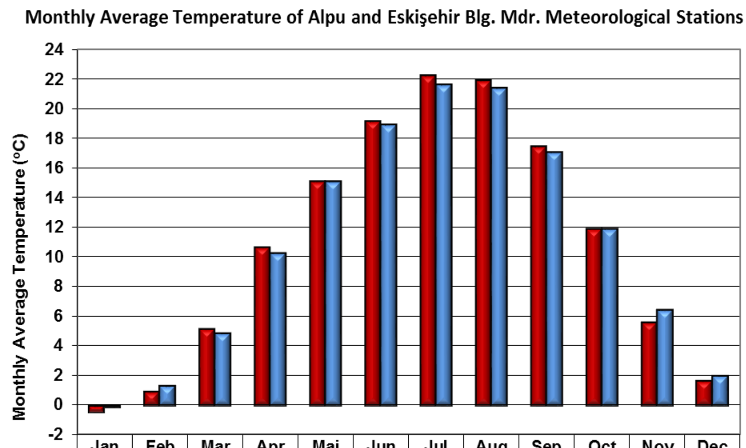


Figure 2-6: Monthly Average Precipitation of Alpu (No:3343) and Eskişehir Blg. Mdr. Meteorological Station (No:17126)

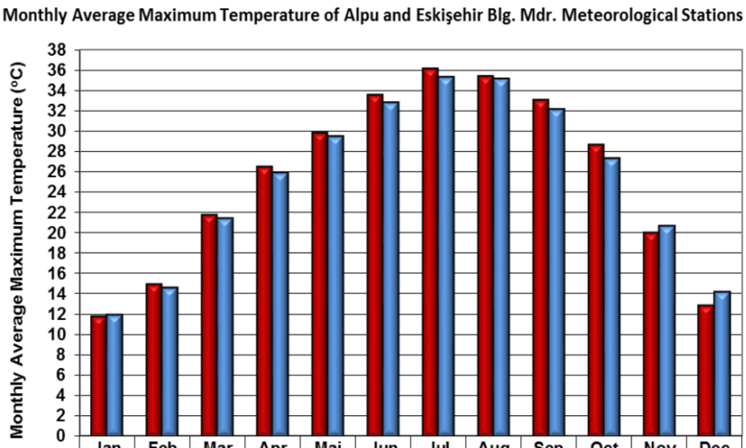
2.3.2. Temperature

The monthly average, average minimum and average maximum temperature values of the stations 3343 Alpu (1984-2002) and 17126 Eskişehir Met. Blg. Md. (1929-2015) are shown in Figures 2-7 through 2-9, respectively. When monthly average temperature values are examined (Figure 2-7), it is seen that January is the coldest month with subfreezing temperature and July is the hottest month with 21^{o}C-22^{o}C average temperature values. Since temperature values at Alpu and Eskişehir shows strong correlation, the study area is expected to have similar temperature values. However, the topographically elevated parts of the study area is expected to have 1-2^{o}C lower temperature values. When monthly average minimum temperature values are examined (Figure 2-8), icing is observed between October and April within the region. Especially during December, January and February temperatures could go below -10^{o}C. According to monthly average maximum temperature values, July and August are the hottest months for study area having a temperature value above 35^{o}C-36^{o}C (Figure 2-9). Between December-February the average maximum temperature values could reach up to 12^{o}C-15^{o}C.



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alpu (1984-2002)	-0.5	1.0	5.2	10.7	15.1	19.2	22.3	22.0	17.5	11.9	5.6	1.7
Eskişehir Blg. Mdr. (1929-2014)	-0.1	1.3	4.9	10.3	15.1	18.9	21.6	21.4	17.1	11.9	6.4	2.0

Figure 2-7: Monthly Average Temperature of Alpu (No:3343) and Eskişehir Blg. Mdr. (No:17126) Meteorological Stations



	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alpu (1984-2002)	11.9	15.0	21.8	26.6	29.9	33.7	36.2	35.5	33.1	28.8	20.0	12.9
Eskişehir Blg. Mdr. (1929-2014)	12.0	14.6	21.5	26.0	29.6	32.8	35.4	35.2	32.2	27.4	20.7	14.2

Figure 2-8: Monthly Average Maximum Temperature of Alpu (No:3343) and Eskişehir Blg. Mdr. (No:17126) Meteorological Stations

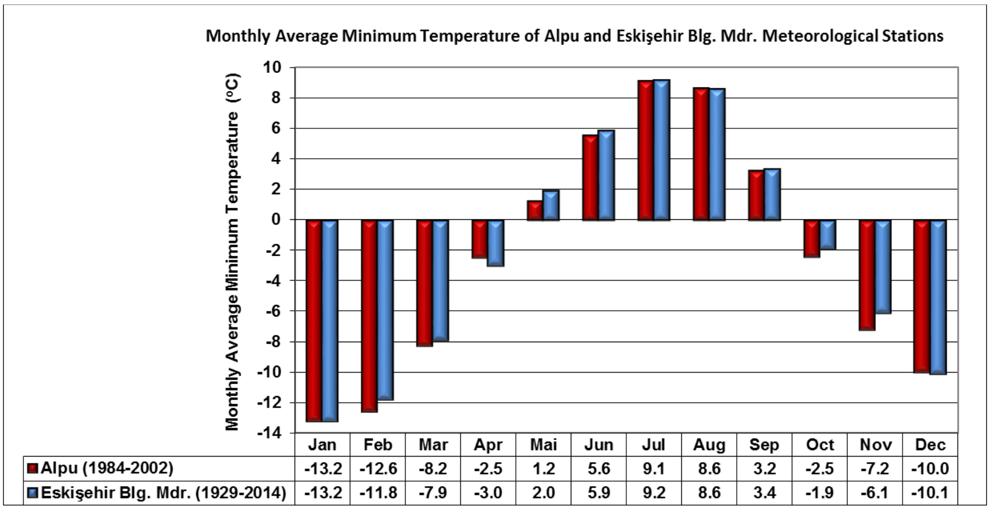


Figure 2-9: Monthly Average Minimum Temperature of Alpu (No:3343) and Eskişehir Blg. Mdr. (No:17126) Meteorological Stations

2.3.3. Relative Humidity

The monthly relative humidity values of the stations 3343 Alpu (1984-2002) and 17126 Eskişehir Met. Blg. Md. (1929-2015) are shown in Figure 2-10. When Figure 2-10 is examined, the highest monthly relative humidity values are measured at December and January (81%) and the lowest monthly relative humidity values are measured at July and August (55%) at station 17126 Eskişehir Met. Blg. Md. Considering the Alpu station, altough the distribution of relative humidity values are similar to Eskişehir city center, the actual values are %2 - %9 lower.

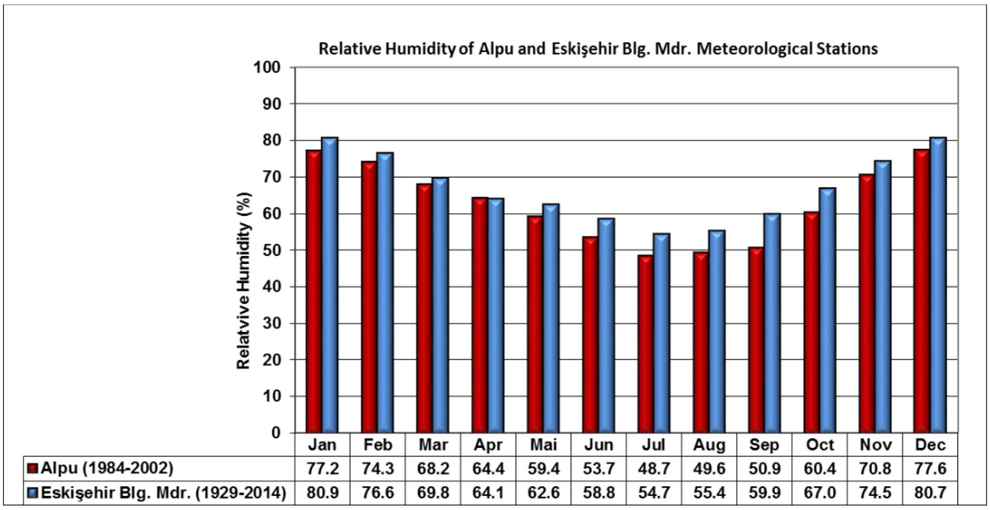


Figure 2-10: Monthly Relative Humidity Values of Alpu (No:3343) and Eskişehir Blg. Mdr. (No:17126) Meteorological Stations

2.3.4. Evaporation

The monthly total open surface evaporation was observed in Eskişehir Met. Blg. Md. Station no:17126 (between 1962 and 1978) and in Eskişehir Anadolu Sivil Myd. Met. Blg. Md. (No:17123) meteorology station (between 1990 and 2012) between April and October (Figure 2-11). No observatıon was made in these stations during winter time (between November – March). As it is seen in Figure 2-11, the measured open surface evaporation values are 30% higher in Eskişehir Anadolu Sivil Myd. Met. Blg. Md. (No:17123), which has more recent values, compared to Eskişehir Met. Blg. Md. Station no:17126. The difference between two stations may occur due to the location of the stations and the urbanization. When the more recent values of Eskişehir Anadolu Sivil Myd. Met. Blg. Md. (No:17123) are considered, the highest open surface evaporation is seen in July (317.8 m) and the lowest one is seen in April (146.3 m).

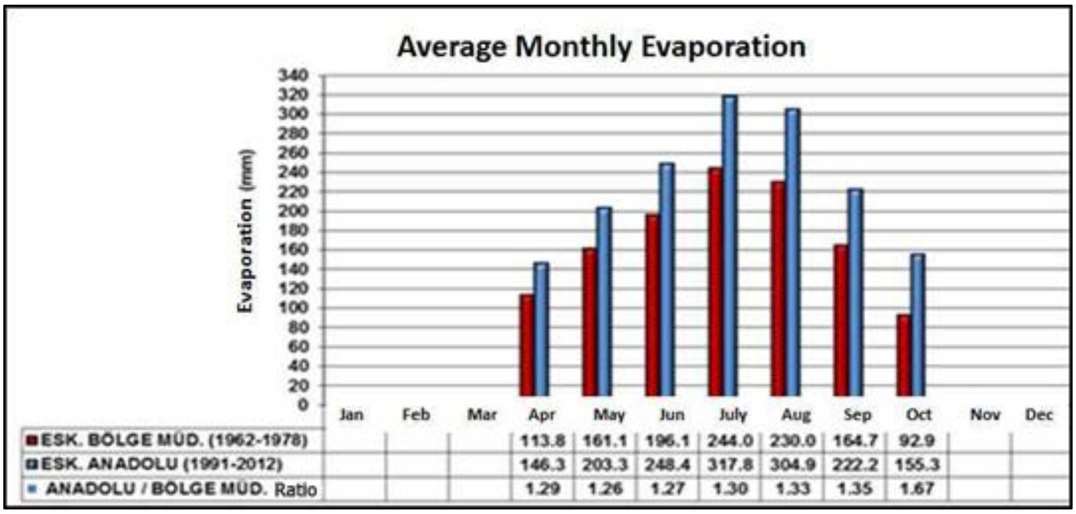


Figure 2-11: The observed monthly average total open surface evaporation values of Eskişehir Anadolu Sivil Meydan Met. Bölge Müdürlüğü (No:17123) Meteorology station and Eskişehir Bölge Müdürlüğü station (No:17126)

The average evaporation data for Eskişehir Met. Blg. Md. (No:17126) and Eskişehir Anadolu Sivil Myd. Met. Blg. Md. (No:17123) and precipitation data for Eskişehir Met. Blg. Md. (No:17126) are given in Figure 2-12. As seen Figure 2-12 the evaporation values are much higher than the precipitation values during the months when the evaporation data were measured. The evaporation is expected to be much less and below precipitation values during the winter months during which there were no evaporation measurements.

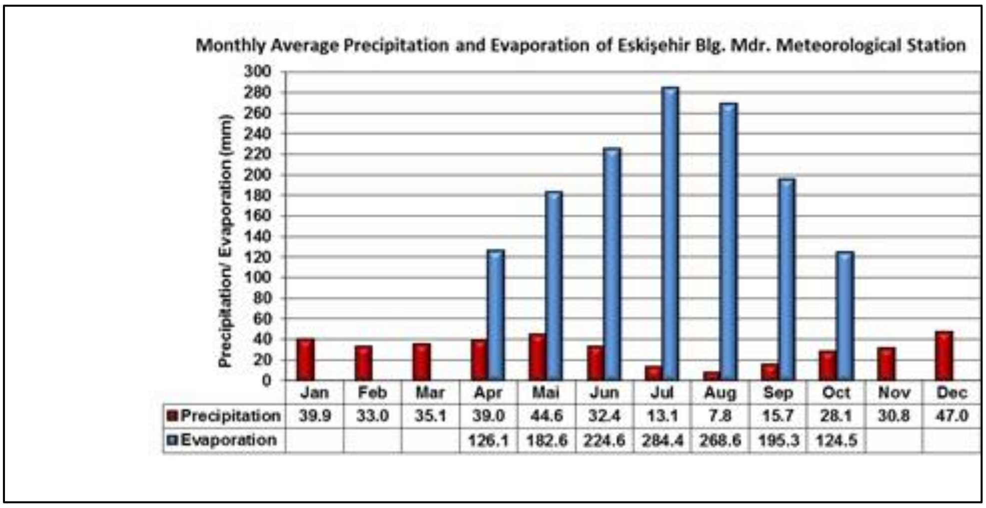


Figure 2-12: Monthly Average Precipitation and Evaporation Values of Eskişehir Blg. Mdr. Meteorological Station

2.4. Geology

2.4.1. Regional Geology

Regionally, the study area is located between the Sakarya Continent and Anatolide-Tauride block (Figure 2-13). The Intra-Pontide suture zone, which separates these two blocks, approximately passes through the Bozüyük-Eskişehir line. The NW-SE to WNW-ESE trending Eskişehir Fault zone extending from Uludağ in the northwest to Sultanhanı in the southeast shows a parallel trend to this line (Toprak et al. 2015). Eskişehir fault zone has been active since the Pleistocene and it is younger than the Upper Pliocene according to the neotectonic and sedimentary data. The fault zone has played a major role in the formation of Eskişehir and İnönü basins. Lower-Middle Miocene deposits in the Eskişehir graben, preserved in a restricted area at the northern end of Anatolide block, were cut by the İnönü segment of Eskişehir fault. The coal bearing sediments were preserved beneath the Upper Miocene-Lower Pliocene deposits (Şengüler, 2013).

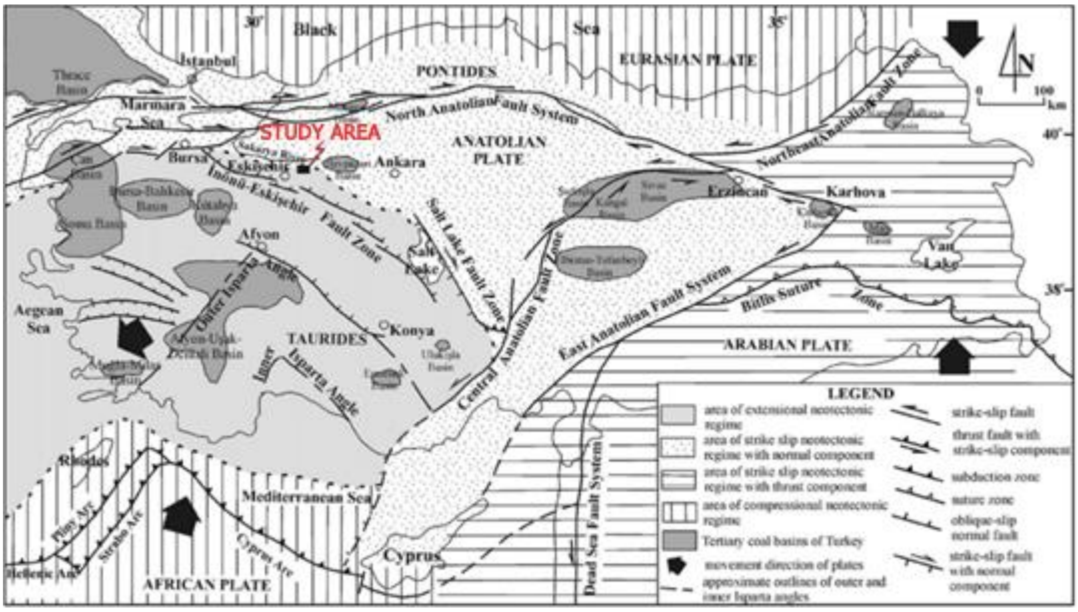


Figure 2-13: The simplified neotectonic sub basin of Turkey and its vicinity (Toprak and other, 2015)

2.4.2. Geology and stratigraphy of the Study Area

Generalized columnar section and 1/50.000 scaled geological map of the study area are presented in Figure 2-14 and 2-15, respectively. The basement rocks of the study area, located in the Eskişehir Graben, are composed of Palaeozoic aged metamorphic rocks and tectonically contacted Mesozoic aged units, located at southeast and northwest of the study area, to these metamorphic rocks (Figure 2-14 and Figure 2-15). This tectonic relation is developed from the north to south (Gözler at al., 1997). It is hard to observe the thickness of the metamorphic rocks due to folded, fractured and jointed nature of the rocks. However it can be approximately said that, schist has 1000 meters, marble has 200 meters thicknesses (Şengüler, 2013).

Triassic aged melange (Mja) which is observed as nappe on the metamorphics and tectonic slice under the ophiolites is composed of radiolaritine, crystalline limestone and marble, mudstone, diabase, serpentine, metamorphic, peridotite and gabbro blocks. Triassic aged ophiolites are composed of peridotite, serpentine, pyroxene, metapyroxene, hornblendite, metahornblende, gabbro, metagabbro, diabase, metadiabase, listwaenite which is determinant of the tectonic zones, and eclogite, metamorphic equivalent of oceanic crust, units. These units are generally observed as nappes but it is also possible to encounter these units as slices (Gözler at al., 1997). Also, this mixed-up oceanic crust material shows an overturned sequence. Metadetritics that overlies ophiolites are composed of metaconglomerate, metasandstone and phyllites and its metamorphism changes according to its relationship between ophiolites. Jura-Cretaceous aged limestone overlies this unit unconformably. Mesozoic basement rocks are cut by Upper Cretaceouss aged granodiorite. This granodiorite has high degree alteration and shows generally porphyritic, locally granular texture, approximately in E-W direction (Figure 2-14, Figure 2-15).

In the vicinity of the study area, Middle-Upper Miocene aged sediments which also include lignite seams overlie unconformably on the basement rocks (Figure 2-14). The basal conglomerates (m1 series), which are composed of conglomerate, sandstone and claystone, form the base of these deposits. This unit appears as thick layer, reddish, yellowish, grey and light grey colour and generally reddish, brown-red colour. Gravels of the conglomerates are generally composed of schist, marble, radiolarite, chert, gabbro, diabase, serpentine, granodiorite and limestones.

The overlying series is represented from the bottom to the top a sequence of conglomerate, green claystone, coal seam (C), gray sandstone, bituminous shale, coal seam (B), bituminous shale, coal seam (A) and green claystone-sandstone-conglomerate alternation (m2 series). The thickness of this series varies from 100 m to 500 m within the study area. Tuff, tuffite and marl are also observed within the sequence. Tuffite and marl inter layers are widespread at the eastern parts of the study area and shows lateral and vertical transition with the units above and below.

The upper section of this Miocene sequence is formed by silicified limestone (m3 series), which outcrops on the high hills at the southwestern and western part of the license area (Figure 2-14 and 2-15). These limestones are creamy, white to grey coloured and includes local silicified bands and tuff layers. Its thickness varies between 5 m to 60 m within the study area.

The Miocene units are unconformably overlain by Pliocene deposits which include from the bottom to the top reddish variegated colored conglomerate, sandstone, claystone, tuffites alternated red mudstone with variegated colored clayey limestone, marl and gray/light brown clay. Pliocene deposits outcrop in the eastern and western part of the study area and these are unconformably overlain by Quaternary alluvium.

The Quaternary aged alluvium which is composed of sand and gravel intercalated with silt and clay overlies the Pliocene aged units uncomformably. Pleistocene aged older alluvium units observed at patios and flats and Holocene aged younger alluvium units observed around the Porsuk Stream could be distinguished from each other. However, no distinction has been made between the older and younger alluvium in this study. Thickness of the alluvium changes between 10 m – 50 m and increases towards the Porsuk Stream.

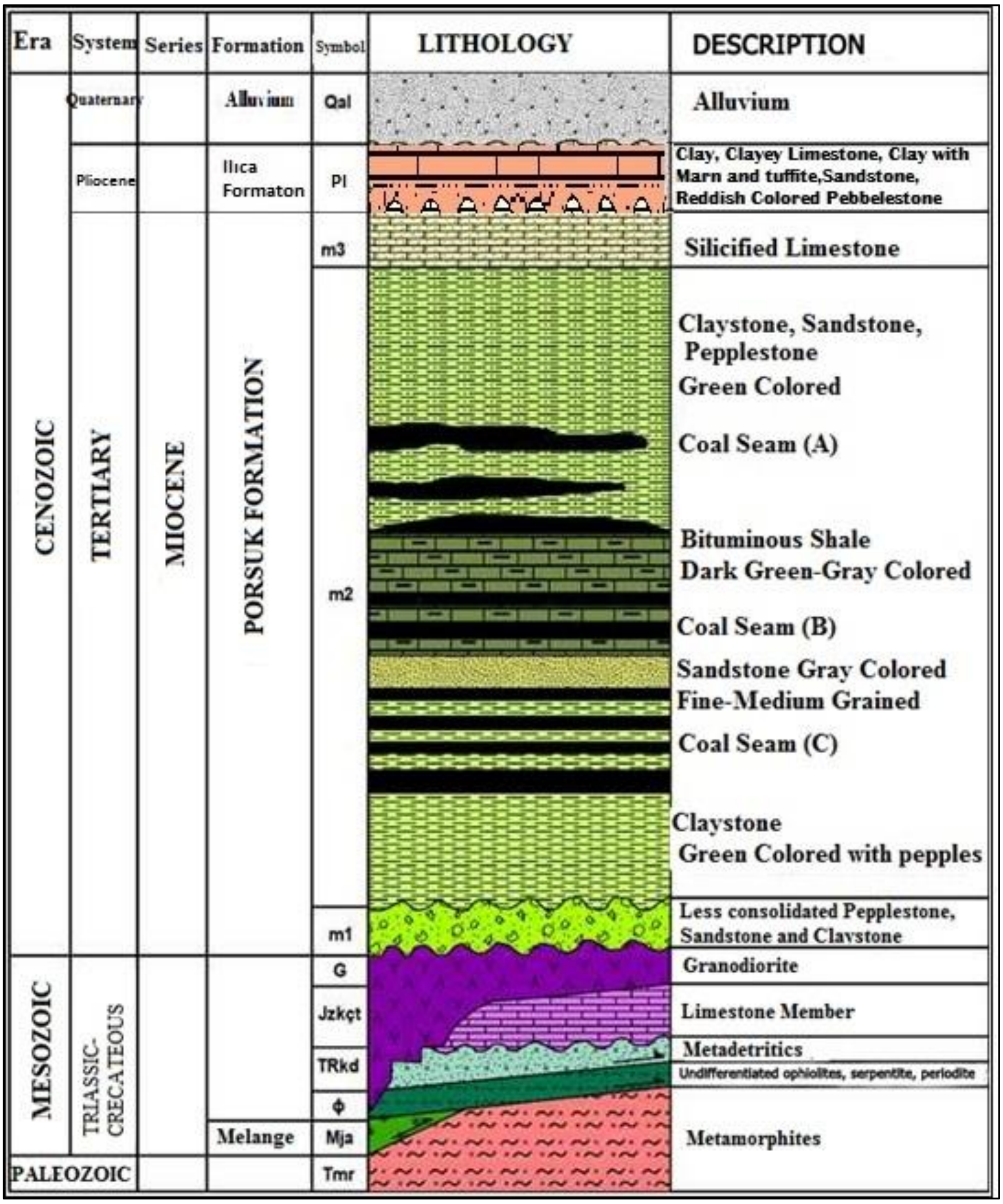


Figure 2-14: Generalized columnar section of study area and its vicinity (Modified from Gözler et al., 1997 and Şengüler, 2013)

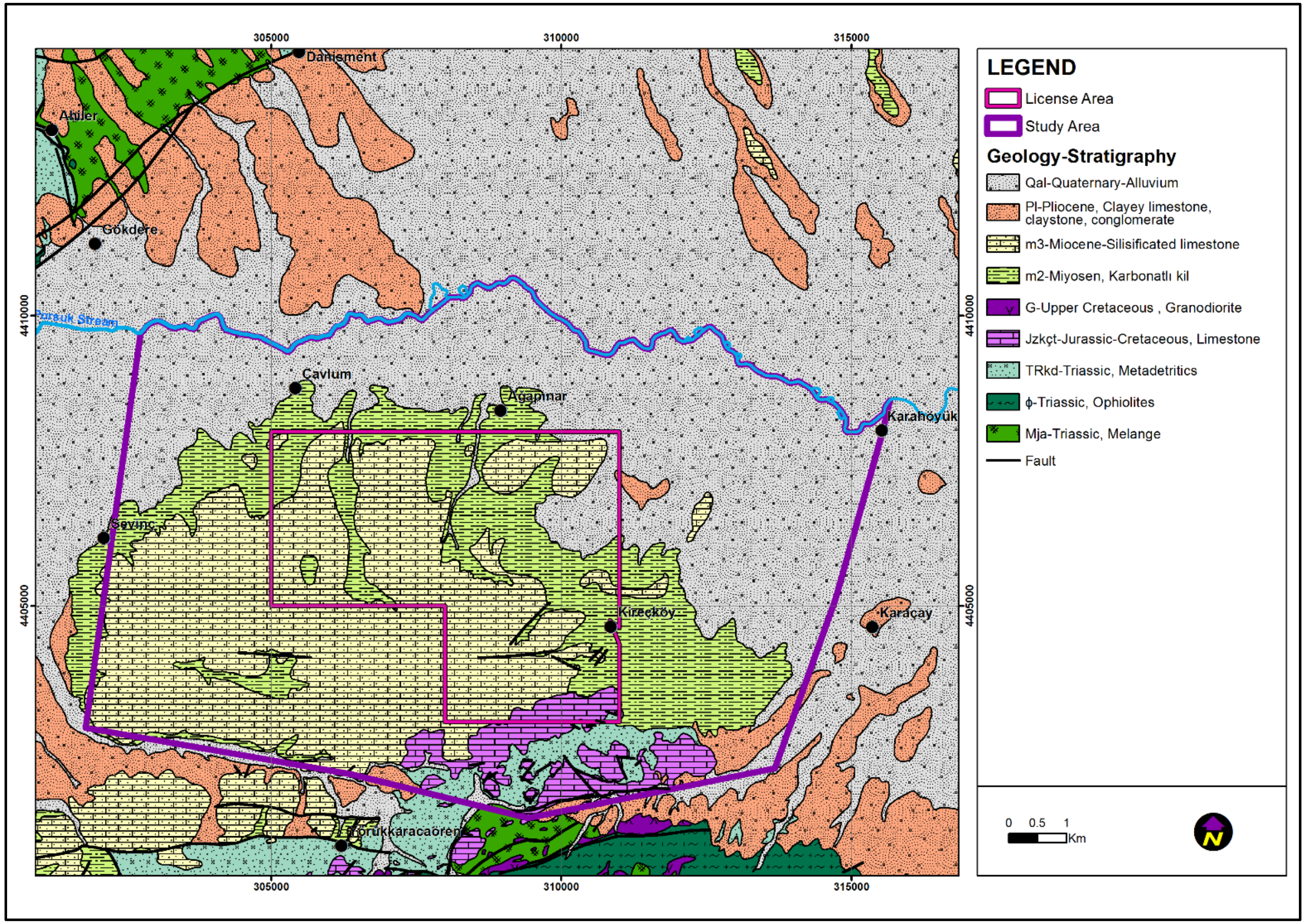


Figure 2-15: 1/50.000 scaled geological map of study area and its vicinity (Modified from Gözler et al., 1997 and Şengüler, 2013)

CHAPTER 3

HYDROLOGY

To understand the hydrologic structure and surface water potential of the watershed encompassing the study area, the surface water drainage network, the discharge of the rivers and creeks with significant drainage area and the water structures located upstream, downstream and around the study area have been investigated. In the paragraphs below, regional scale surface water hydrology will be evaluated first, followed by information on current water structures in the region. Next, hydrological observations and analysis at the study area scale will be provided including the conceptual water budget.

3.1. Regional Drainage Network

The most important surface water in the vicinity of the study area is the Porsuk Stream, flowing from east to west (Figure 3-1). The Porsuk Stream starts drainage from Murat Dağı, passes through Kütahya plain and after being collected at the Porsuk Dam, located in southwest of Eskişehir, it passes through the Eskişehir plain and Eskişehir city center. After passing through Eskişehir city center, it flows approximately 1 km north of Çavlum Village and 2 km north of Ağapınar village towards east. It reaches to Sakarya River around Yassıhöyük, which is located approximately 100 km east of the study area. The Porsuk Stream is the longest branch of the Sakarya River.

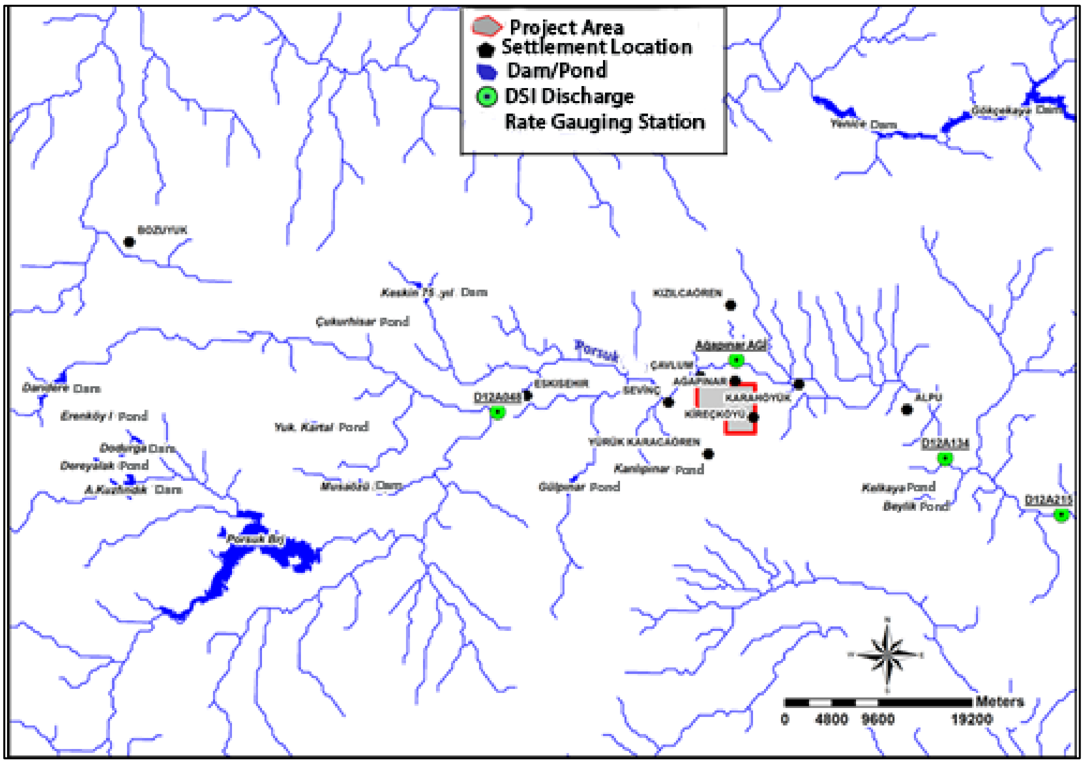


Figure 3-1: Map of regional drainage network, flow gauging stations and water structures

3.1.1. Discharge Measurement Stations (DMS)

Discharge of surface water units are needed in order to determine hydrological structure and surface water potential of the catchment basins encompassing the license area. For this purpose, discharge rates of flow gauging stations operated by State Hydraulic Works (DSI) were examined.

There are four flow gauging stations, operated by DSI, at the Porsuk Stream catchment basin that also encompasses the study area (Table 3-1). Table 3.1 shows the data inventory of flow gauging stations operated by DSI. The flow gauging station around Ağapınar was operated for short term under a study conducted by DSI (DSI, 2010) and monthly instantaneous discharge measurements were available. The flow gauging station D12A215 was operated only between 2012-2014 water years. The remaining stations have longer term data.

Table 3-1: Information for flow gauging stations operated by DSI

No	Station No	Station No	River/Lake Name	Operating Period	Coordinates		Elevation	Precipitation Area
					Latitude	Longitude	(m)	(km^2)
1	E12A048	Eskişehir	Porsuk Stream	1973-2003	284619	4405262	793	6340
2	D12A134	Yeşildon	Porsuk Stream	1977-1984;1988-1990	330032	4400112	750	7580
3	D12A215	Parsibey	Porsuk Stream	2012-2014	342300	4395025	750	8671
4	Ağapınar AGİ	Ağapınar	Porsuk Stream	2007-2009	309147	4410574	771	--

Monthly discharge values measured between 2007-2009 water years at Ağapınar flow gauging station are shown in Figure 3-2. Monthly highest and lowest discharge values were measured at May (4.733 m^3/s) and July (2.993 m^3/s) respectively for the water year 2008 during which complete data was available. Although the general trends of 2007 and 2009 water years' measurements are the same, there is a significant decrease at discharge rate from 2007 to 2009. When the annual precipitation data shown in Figure 2-4 is analysed, it is seen that there is a clear drought at that time period. Average discharge rate is 3.5 m^3/s at Ağapınar station when the measurements of 2008 water year were taken into account.

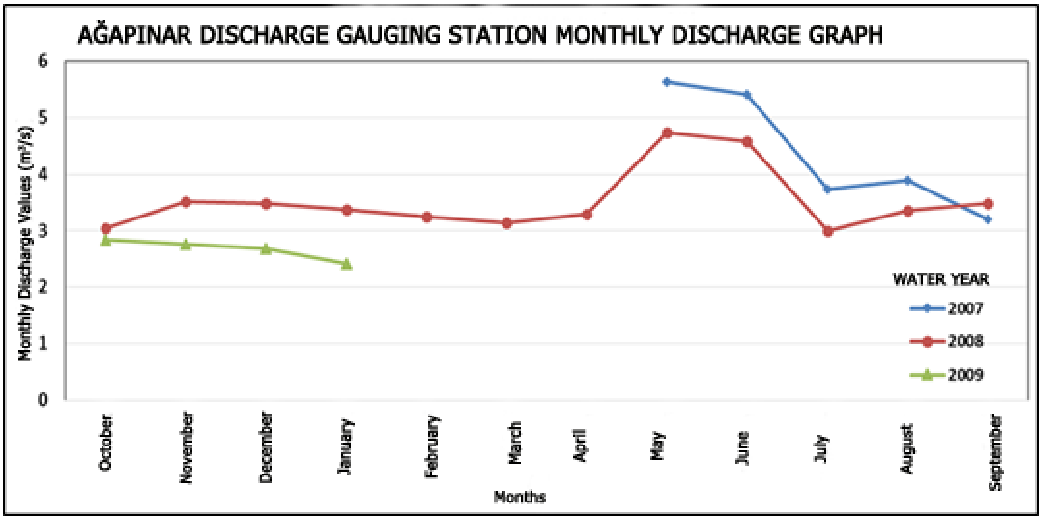


Figure 3-2: Monthly discharge values measured at discharge rate gauging station at Ağapınar between 2007-2009 water years

Figure 3-3 shows the monthly average discharge graph belonging to other flow gauging stations operated by DSI at Porsuk Stream. Monthly average discharge rate at DOS E12A048 located at upstream of the study area ranges between 2.90 m^3/s and 5.19 m^3/s and long term average discharge rate is 3.99 m^3/s. Average monthly discharge rate of the DOS D12A134, east of Alpu, ranges between 8.62 m^3/s and 16.54 m^3/s and long term average discharge value is 11.91 m^3/s. It is expected that the discharge rate of DOS D12A134 is higher than DOS E12A048 since the former has a larger catchment area than the latter. Additionally, difference between operating periods (Table 3-1) of flow gauging stations complicates the comparison of discharge rates among the stations. For example; although DOS D12A215 operated only between 2012 and 2014, has a larger catchment area than DOS D12A134, operated between 1977-1990, shows lower discharge rates.

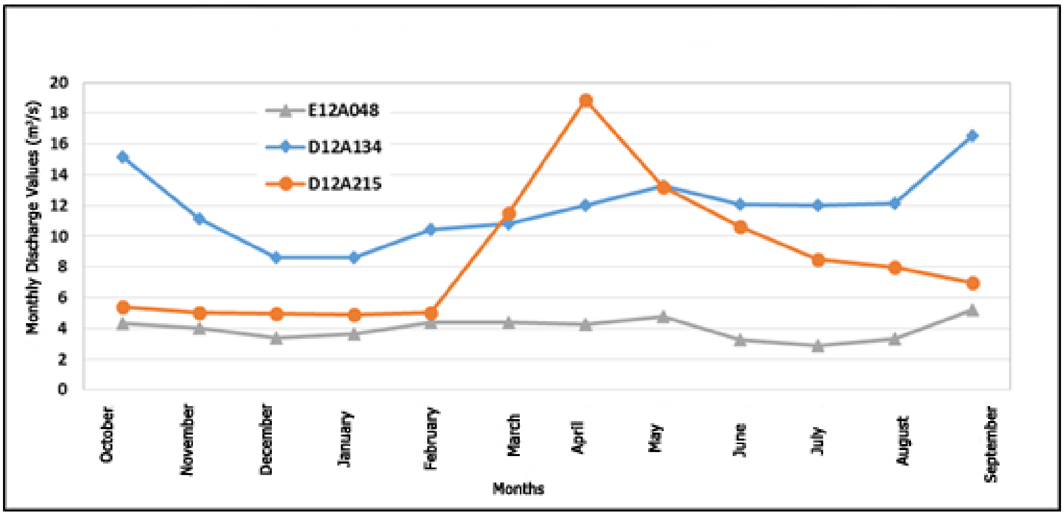


Figure 3-3: Monthly average discharge values belong to discharge rate gauging stations operated by DSI

3.2. Study Area Drainage Network

Surface water drainage map for study area is given in Figure 3-4. The study area which is bounded by the Porsuk River in the North, contains generally dry valleys that may start short-term flow by sudden rainfall. Apart from these surface water units, Eskişehir-Alpu irrigation canals (right-hand) that start at Karacaşehir regulator and de-watering canals are situated in the region located between the North of the license area and the Prosuk River (northern part of the Eskişehir-Alpu highway).

In the Monitoring Plan Report prepared by Yazıcıgil et al. (2015a), eight surface water drainages draining the license area were identified. The surface water units that are flowing through these drainages show seasonal flow or short-term flow after sudden rainfall and are generally dry. Table 3.2 lists the information about the catchments of these eight creeks draining the license area. The creeks with the largest catchment area are Pınar Creek (4.90 km^2), Çürüksu Creek (4.16 km^2) and Akpınar Creek (3.95 km^2), respectively. Among these creeks, Pınar Creek drains the southeast of the license area towards east and leaves the license area after flowing through the Kireçköyü. Other creeks drain the middle and North parts of the license area towards North and recharge the Alpu plain. Yazıcıgil et al. (2015a) identified two surface water monitoring stations to investigate the surface water potential of the license area. These stations are shown as SW-1 and SW-2 in Figure 3-4 and the details are listed in Table 3-3. SW-1 station is located on a suitable location along the Çürüksu Creek bed to monitor the disharge. SW-2 station is situated on a suitable location along the Pınar Creek, upstream of the Kireçköyü. The instantenous discharge conditions at SW-1 and SW-2 stations have been monitored on January 28, February 27, March 28, April 26, May 26, June 27, July 25, August 16, September 20, November 7, December 5 2015 and January 10, February 7 2016 (once in-a-month) and it was determined that both creeks were dry in all these observations. During the field studies, it was observed that some of the creeks are fed by fountains and spring located at the upstream locations, however as moving towards low elevations in the North the surface water infiltrates into the soil and the creek valley becomes dry. Short term instantaneous flow could be seen at the creeks in the license area after instantaneous rainfall and snowmelt.

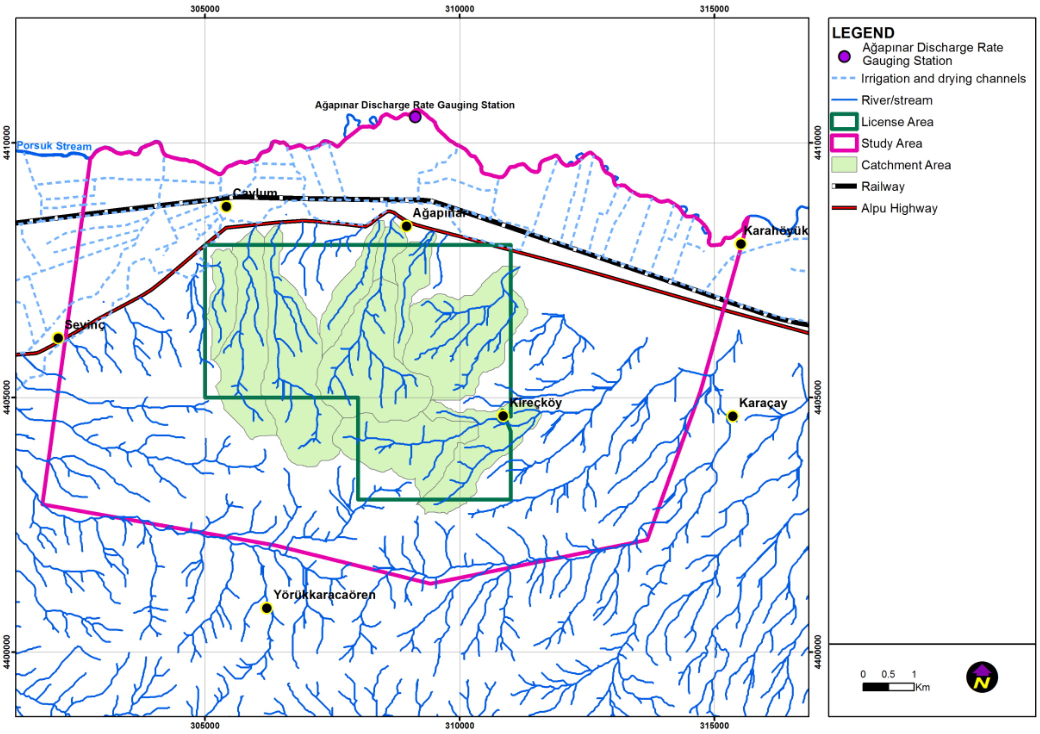


Figure 3-4: Surface water drainage network

Table 3-2: Information about creeks draining the license area

Cathment No.	Area (km^2)	Stream Name
1	0.910	
2	2.844	İnönü Creek
3	3.945	Akpınar Creek
4	1.082	
5	4.163	Çürüksu Creek
6	1.017	
7	3.846	Ören Local
8	4.899	Pınar Creek
SW-1	3.678	Çürüksu Creek
SW-2	2.662	Pınar Creek

Table 3-3: Information about surface water discharge rate gauging points for monthly instantaneous measurements

Station No.	Longitude	Latitude	Area (km^2)	Location	Stream Name
SW-1	308474	4407371	3.678	Zeybek Yatağı	Çürüksu Creek
SW-2	310367	4404474	2.662	Kireçköyü	Pınar Creek

3.3. Conceptual Water Budget of the Study Area

Total precipitation of an area can be decomposed into surface runoff, infiltration and evapotranspiration. For hydrologic water budget studies the ratio of these components to the total precipitation is calculated. Components of the hydrologic water budget for the study area were calculated for each month by using the long term average values. Evapotranspiration values and surface water runoff values were calculated by using Thorntwaite and Curve Number (CN) methods, respectively. Remaining portion of the total precipitation is accepted as infiltration, recharging the groundwater.

In order to calculate the potential evapotranspiration by Thornwaite method, monthly total precipitation and monthly potential evapotranspiration values of the study area are needed. Potential evapotranspiration is calculated by using monthly average temperature values and latitude value of the study area.

Long term monthly total precipitation values representing the study area were estimated by using 17123 (17 km northwest of the study area) and 17126 (15 km west of the study area) meteorological stations which are operated by General Directorate of Meteorology and 3343 meteorological station which was operated in Alpu (15 km east of the study area). It is accepted that Alpu meteorological station (3343) represents the study area better than other stations. Because this station had been operated only between 1984 and 2002, long term precipitation values of the Eskişehir city centre were corrected in order to represent the Alpu meteorological station. Since the meteorological stations in Eskişehir operated in echelon, the data of the stations Eskişehir Met. Blg. Md between 1984-1990 and Eskişehir Anadolu

Sivil Myd. Met. Blg. Md between 1990 and 2002 was used against the data on Alpu station between 1984 and 2002. Monthly total precipitation values belonging to the years between 1984 and 2002 of Alpu (3343), Eskişehir (17126) and Sivil Meydan (17123) meteorological stations are compared in Figure 3-5. Diagonal line is 1:1 line which represents equal precipitation of vertical and horizontal axis. Dashed blue line is linear trend line which is used to calculate the correlation coefficient (R^2). Values such as; %BIAS and % absolute BIAS |BIAS|) were used for statistical comparison (Table 3-4). These values are calculated by using the equations 3.1 and 3.2.

$$\%\,\mathrm{BIAS} = \frac{y - x}{x}.100 \qquad (3.1)$$

$$\%\,|\mathrm{BIAS}| = \frac{|y - x|}{|x|}.100 \qquad (3.2)$$

In these equations “y” and “x” shows monthly total precipitation values (mm/month) at Alpu and Eskişehir and Sivil Meydan meteorological stations, respectively.

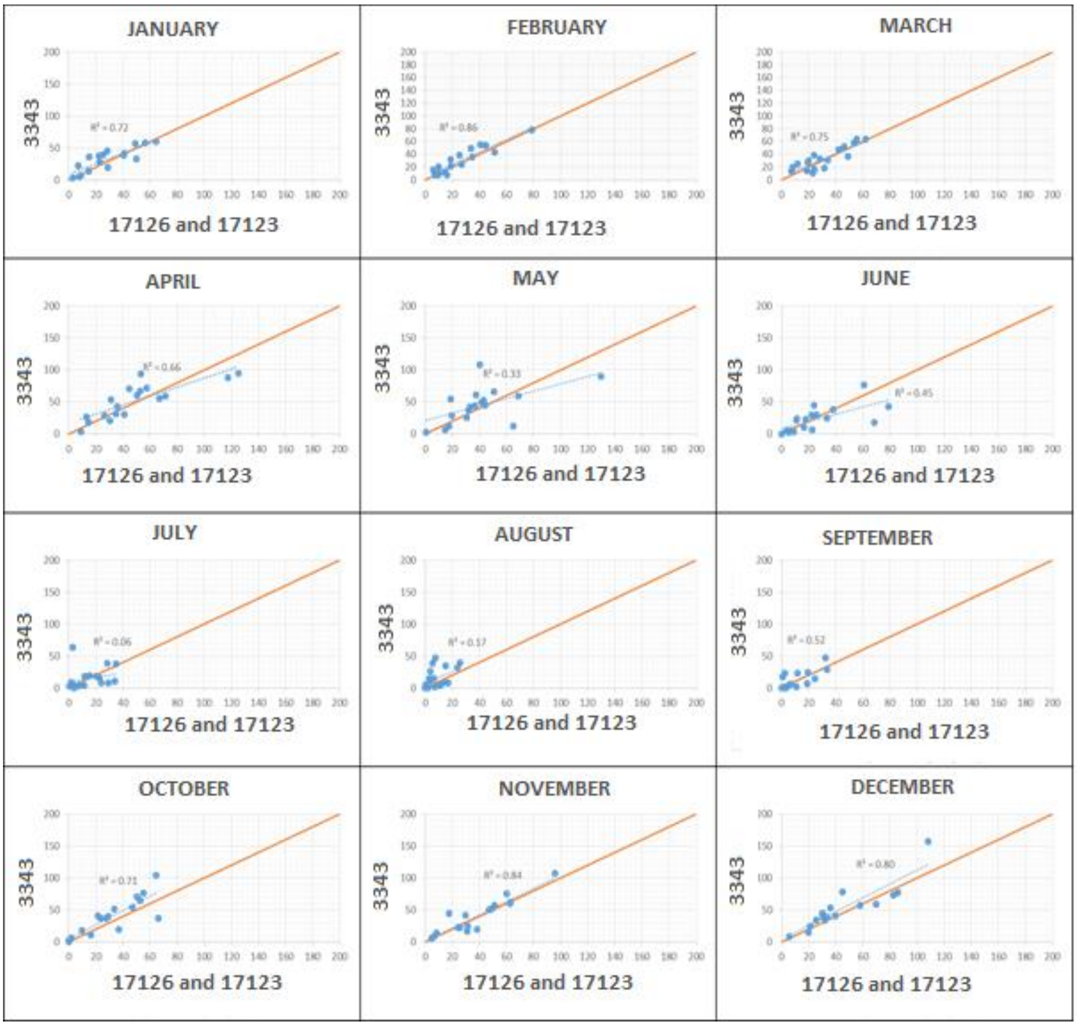


Figure 3-5: Scatter graphs of monthly total precipitations of Alpu (3343) meteorological station and Eskişehir (17126) and Sivil Meydan (17123) meteorological stations between 1984 and 2002

Table 3-4: Statistical values of the calculation of Alpu meteorological station and Eskişehir and Sivil Meydan meteorological stations between 1984 and 2002

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
R^2	0.72	0.86	0.75	0.66	0.33	0.45	0.06	0.17	0.52	0.71	0.84	0.8
% BIAS	12.34	15	7.51	4.9	9.86	-10.91	1.76	78.08	-7.32	24.7	5.67	16.8
% |BIAS|	27.96	25.47	25.87	30.32	43.1	45.41	70.32	126.2	43.5	44.2	20.81	25.94

The best statistics are achieved when correlation coefficient is 1, %BIAS and % absolute BIAS are zero. % BIAS values that are less than zero indicate that Alpu meteorological station recevies less precipitation on average compared to Eskişehir meteorological stations.

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As seen in Table 3-4, the correlation values of monthly total precipitation of Eskişehir and Alpu meteorological stations range between 0.33 and 0.86 in winter, spring and fall seasons and these values are significantly more when compared to the calculated correlation values that range between 0.06 and 0.52 in summer months. It is thought that lower correlation values in summer depend on the convective precipitation system. When the statistics at Table 3-4 are analysed, % BIAS values greater than the zero mean that Alpu meteorological station has more precipitation values than Eskişehir meteorological station. % BIAS values are around %15 in December-February period while the values range between -10.91 and 78.08 in June-August period. Marginal changes in %BIAS values in summer months could be due to low precipitation values and convective precipitation character in this season. In conclusion, monthly total precipitation values of meteorological stations of the Eskişehir for 1929-2015 period are corrected to represent the Alpu meteorological station by using the % BIAS values in Table 3-4. In Eskişehir meterological stations annual average precipitation value prior to the correction is 367 mm, whereas it is 404 mm after correction. These corrected precipitation values were used in the conceptual water budget model. This correction procedure have been checked with the precipitation-elevation relationship. Figure 3-6 shows the relationship between elevation and average annual precipitation measured in meterological stations around the license area (DSİ, 2010). Area-elevation relationship (hypsometric curve) for the license area is given 3-7. As can be seen from this figure, %50 of the total area of the license area is in between 775-885 meter elevation range, whereas remaining %50 is in between 885-1050 meter range. If 885 meter is accepted as the representative elevation (correspond to %50 of the area) of the license area, based on the linear fit equation given in Figure 3-6, the average annual total precipitation corresponding to this elevation is 407 mm. This precipitation value is very close to the average annual total precipitation value (404 mm) obtained after the correction procedure listed in Table 3-5.

To determine the mean monthly temperature values that will be used in conceptual water budget, the values in Eskişehir and Alpu meterological stations were compared following the same methodology provided above. Investigation of the scatterplots given in Figure 3-8 indicate that mean monthly temperature values measured in Eskişehir and Alpu stations scattered around and/or follow the 1:1 line with generally high correlation coefficient values (generally higher than 0.9).

Table 3-5: Average total precipitation data belongs to Eskişehir meteorological stations 1929-2014 period correction in order to represent Alpu meteorological station

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eskişehir (mm/month)	40.16	33.25	35.48	38.88	44.13	33.01	12.95	8.34	15.64	28.34	30.51	46.43
% ERROR	12.34	15	7.51	4.9	9.86	-10.91	1.76	78.08	-7.32	24.7	5.67	16.8
Corrected (mm/month)	45.1	38.2	38.1	40.8	48.5	29.4	13.2	14.9	14.5	35.3	32.2	54.2

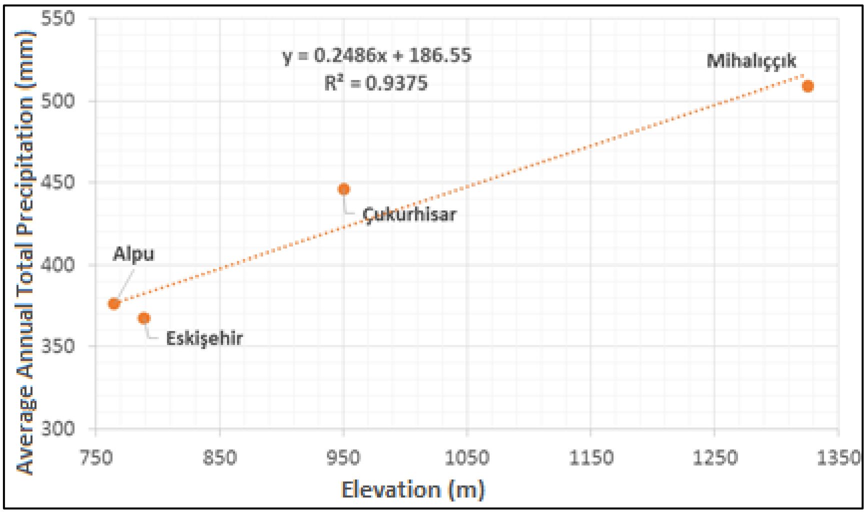

Figure 3-6: Average annual precipitation and elevation relation of the meteorological stations nearby the study area (DSİ, 2010)

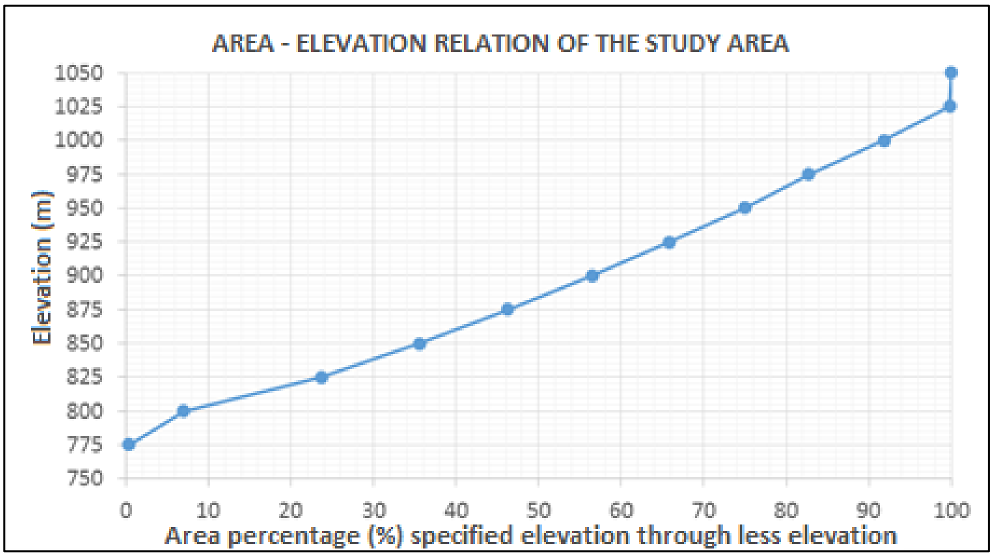

Figure 3-7: Area – Elevation relation of the study area

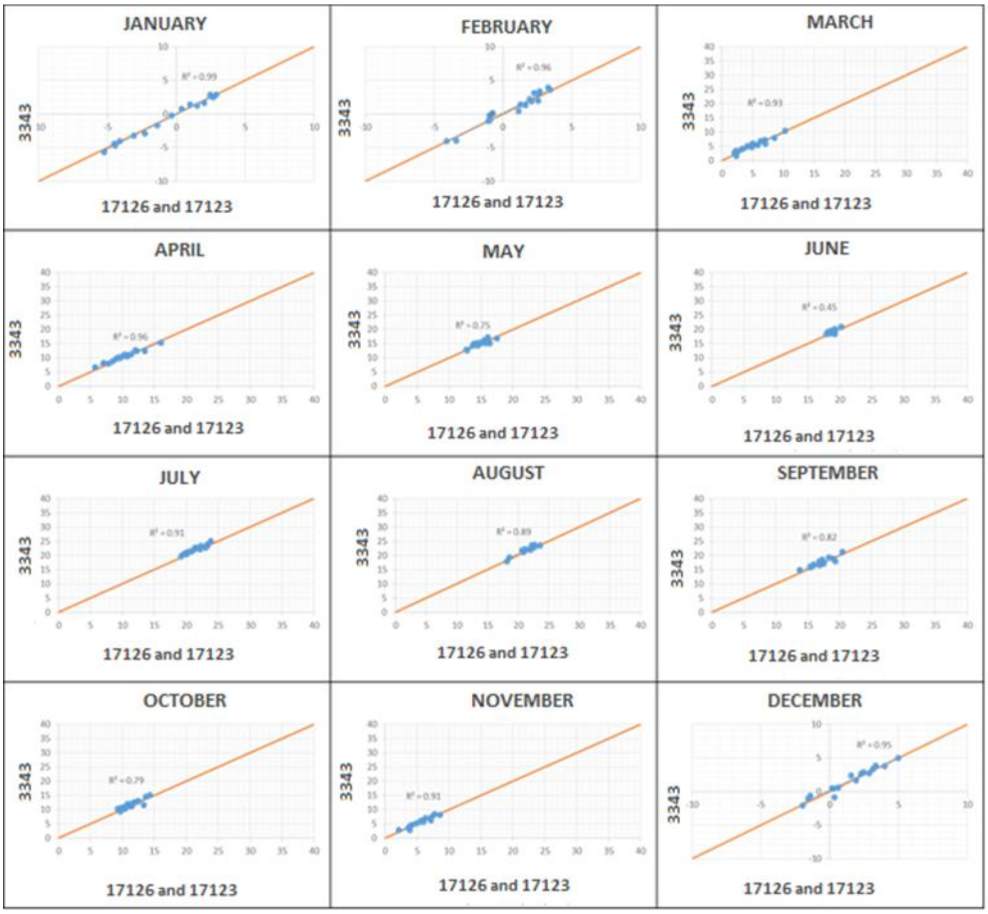

Figure 3-8: Scatter graphs of monthly average temperature of Alpu (3343) meteorological station and Eskişehir (17126) and Sivil Meydan (17123) meteorological stations between 1984 and 2002

When Table 3-6 analysed, the highest % BIAS values change between 9% and 18% and these values occurred during winter months when the temperatures are low. Therefore, making a correction by using % BIAS would not make a significant change in temperature values. In other words, the temperature values measured at Eskişehir and Alpu meteorological stations are very similar. Considering the location of the study area it is expected that temperature would change as a function of the elevation. Temperature changes approximately 1^{o}C with every 100 meter elevation. If representative elevation of meteorological station in Eskişehir was chosen as 785 meter and representative elevation of license area was chosen as 885 meter (Figure 3-7), it is expected that average temperature of the study area is expected to be 1^{o}C less than the Eskişehir meteorological stations. The representative temperatures of the Eskişehir and the study area are shown in Table 3-7. Corrected temperature values were used in conceptual model calculations.

Table 3-6: Statistical values calculated monthly average temperature data of Alpu meteorological station (3343), Eskişehir meteorological station (17126), Sivil Meydan meteorological station (17123)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
R^2	0.99	0.96	0.93	0.96	0.75	0.45	0.91	0.89	0.82	0.79	0.91	0.95
% Error	12.41	17.99	5.63	2.75	1.89	1.69	2.75	2.43	2.43	3.18	2.02	9.18
% lErrorl	10.44	19.99	12.39	5.14	3.95	3.03	2.93	2.63	4.03	5.86	7.78	17.39

Table 3-7: Estimated temperature values for the license area by using measured monthly temperature data (1929-2014) at the center of Eskişehir

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eskişehir Center (785 meter)	-0.1	1.3	4.9	10.3	15.1	18.9	21.6	21.5	17.2	11.9	6.5	2
Project Area (885 meter)	-1.1	0.3	3.9	9.3	14.1	17.9	20.6	20.5	16.2	10.9	5.5	1

According to Thornwaite method, uncorrected monthly potential evapotranspiration (UPET, mm/month) is calculated by:

$$UPET_m = 16x\left(\frac{10t_m}{I}\right)^a \qquad (3.3)$$

In this equality m is month index, t is monthly average temperature (^oC), I is annual heat index and a is a coefficient depending on heat index and calculated as:

$$a = (675x10^{-9})I^3 - (771x10^{-7})I^2 + (179x10^{-4})I + 0.492 \qquad (3.4)$$

I is the sum of monthly heat indexes, i:

$$i = \left(\frac{t}{5}\right)^{1.514} \tag{3.5}$$

Surface runoff values were estimated using the "Curve Number (CN)" method developed by US Soil Conversion Service (SCS ,1964). In CN method the surface runoff values are calculated on the basis of: (a) direct runoff (or excess rainfall), Pe, is less than or equal to total precipitation (P); (b) soil moisture retention occurring after runoff begins (Fa) is less than or equal to the potential soil moisture retention (S). Until precipitation reaches a certain value (Ia, initial abstraction) runoff is not observed, thus, potential runoff is equal to P- Ia. In the CN method, the ratio of two real and two potential values mentioned above, are equal:

$$\frac{F_a}{S} = \frac{P_e}{P - I_a} \tag{3.6}$$

Also, according to principles of continuity:

$$P = P_e + I_a + F_a \tag{3.7}$$

When the equations 3.6 and 3.7 combined and solved for $P_{e,}$ direct surface water runoff (or excess precipitation) is obtained:

$$P_e = \frac{(P - I_a)^2}{P - I_a + S} \tag{3.8}$$

Generally, based on the data from small catchment basins I_a=0.2S equality is obtained empirically. According to this, equation 3.8 is defined as:

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{3.9}$$

This equation is general equation of the Curve Number method (Chow et al., 1988). Curve Number (CN), is obtained from the standardized relationship between P and P_e data of many basins. The relationship between Curve Number (CN) and potential soil water retention is defined with CN:1000/(S+10), or S(inch)=(1000)/CN-10 equations. Curve Number (CN) can be used for calculation of the potential runoff for a specific soil type and soil cover when there is no soil freezing. High CN value indicates the high potential for surface water runoff. Curve Number varies according to vegetation and land use cover and hydraulic soil groups. Soil hydraulic groups are divided into four:

- Group A: Well-drained soils that have low runoff potential and high infiltration even if they are thoroughly saturated (sand, gravel, silt etc.)
- Group B: Soils that have moderate runoff potential and moderate infiltration (such as sandy loam)
- Group C: Soils that have high runoff potential and low infiltration (such as clayey loam)
- Group D: Soils that have very high runoff potential and low infiltration (such as plastic clay)

Land use/vegetation data which is needed for calculation of Curve Number is obtained from the National Soil Database (NSDB) 1/25000 scale maps. Figure 3-9 shows the current land use map that is prepared by using this data and major soil groups map is given in Figure 3-10. The soils in the study area have been classified in Group B which has moderate runoff potential and moderate infiltration. Also, soil slope and depth information data, obtained from NSDB, were used. The soils along steep slopes classified as Group C. Land use, vegetation and spatial distribution of hydraulic soil groups for all catchment basins (sub-basins) were calculated via geographic information system. In the light of this information, weighted curve numbers were calculated for each sub-basin (Table 3-8). Calculated curve numbers range between 65 and 75, weighted value is determined as 71 for all sub-basins. Considering the whole study area shown in Figure 3-9 and Figure 3-10, CN value is 72.

The Curve Number, which is calculated by the method described above, is used to determine the runoff based on the monthly precipitation. Long term monthly average precipitation values are compared for the license area with the method explained above. Thorntwaite method is used for the calculation of the potential evapotranspiration. The remaining part of the total precipitation is accepted as infiltration to groundwater. Consequently, components of the long term hydrologic water budget have been obtained for each month conceptually as shown in Table 3-9. Rows 1-6 in Table 3-9 show the calculation of potential evapotranspiration values with Thorntwaite method.

Table 3-8: SCS Curve Number (CN) calculation for sub-basins

Sub-basin No.	Land Use/ Vegetation	Hydraulic Soil Group	CN	Area (km^2)	% Area	%Area x CN/100	Sub-basin CN
1	Pasture	B	61	0.63805	70.12	42.77	65
1	Pasture	C	74	0.07654	8.41	6.22	
1	Dry Farming (Fallowing)	B	75	0.19529	21.46	16.10	
2	Pasture	B	61	1.03061	36.27	22.12	69
2	Pasture	C	74	1.55403	54.68	40.46	
2	Wet Farming	B	78	0.00595	0.21	0.16	
2	Pasture	B	61	0.08619	3.03	1.85	
2	Dry Farming (Fallowing)	B	75	0.16525	5.81	4.36	
3	Pasture	B	61	0.4892	12.41	7.57	70
3	Pasture	C	74	2.39884	60.84	45.02	
3	Pasture	B	61	0.83522	21.18	12.92	
3	Dry Farming (Fallowing)	B	75	0.17453	4.43	3.32	
3	Dry Farming (Fallowing)	B	75	0.04508	1.14	0.86	
4	Pasture	B	61	0.45064	41.66	25.41	69
4	Pasture	C	74	0.631	58.34	43.17	
5	Pasture	B	61	0.47644	11.45	6.98	70
5	Pasture	B	61	0.76554	18.40	11.22	
5	Pasture	C	74	2.16036	51.93	38.43	
5	Rock	C	85	0.05222	1.26	1.07	
5	Dry Farming (Fallowing)	B	75	0.69754	16.77	12.58	
5	Settlement	B	72	0.00816	0.20	0.14	
6	Pasture	B	61	0.83222	81.90	49.96	63
6	Pasture	C	74	0.06317	6.22	4.60	
6	Dry Farming (Fallowing)	B	75	0.1208	11.89	8.92	
7	Pasture	B	61	1.31615	34.24	20.89	72
7	Wet Farming	B	78	0.01724	0.45	0.35	
7	Pasture	C	74	0.13146	3.42	2.53	
7	Dry Farming (Fallowing)	B	75	1.46367	38.08	28.56	
7	Dry Farming (Fallowing)	B	75	0.16208	4.22	3.17	
7	Rock	C	85	0.75318	19.59	16.65	
8	Pasture	B	61	0.08523	1.74	1.06	75
8	Pasture	B	61	0.54088	11.05	6.74	
8	Pasture	C	74	1.05784	21.60	15.98	
8	Pasture	C	74	0.50281	10.27	7.60	
8	Pasture	C	74	0.00599	0.12	0.09	
8	Dry Farming (Fallowing)	B	75	0.02996	0.61	0.46	
8	Rock	C	85	0.77186	15.76	13.40	
8	Rock	C	85	0.70825	14.46	12.29	
8	Pasture	B	61	0.23678	4.84	2.95	
8	Pasture	B	61	0.11851	2.42	1.48	
8	Dry Farming (Fallowing)	B	75	0.50298	10.27	7.70	
8	Settlement	B	72	0.14541	2.97	2.14	
8	Dry Farming (Fallowing)	B	75	0.18995	3.88	2.91	

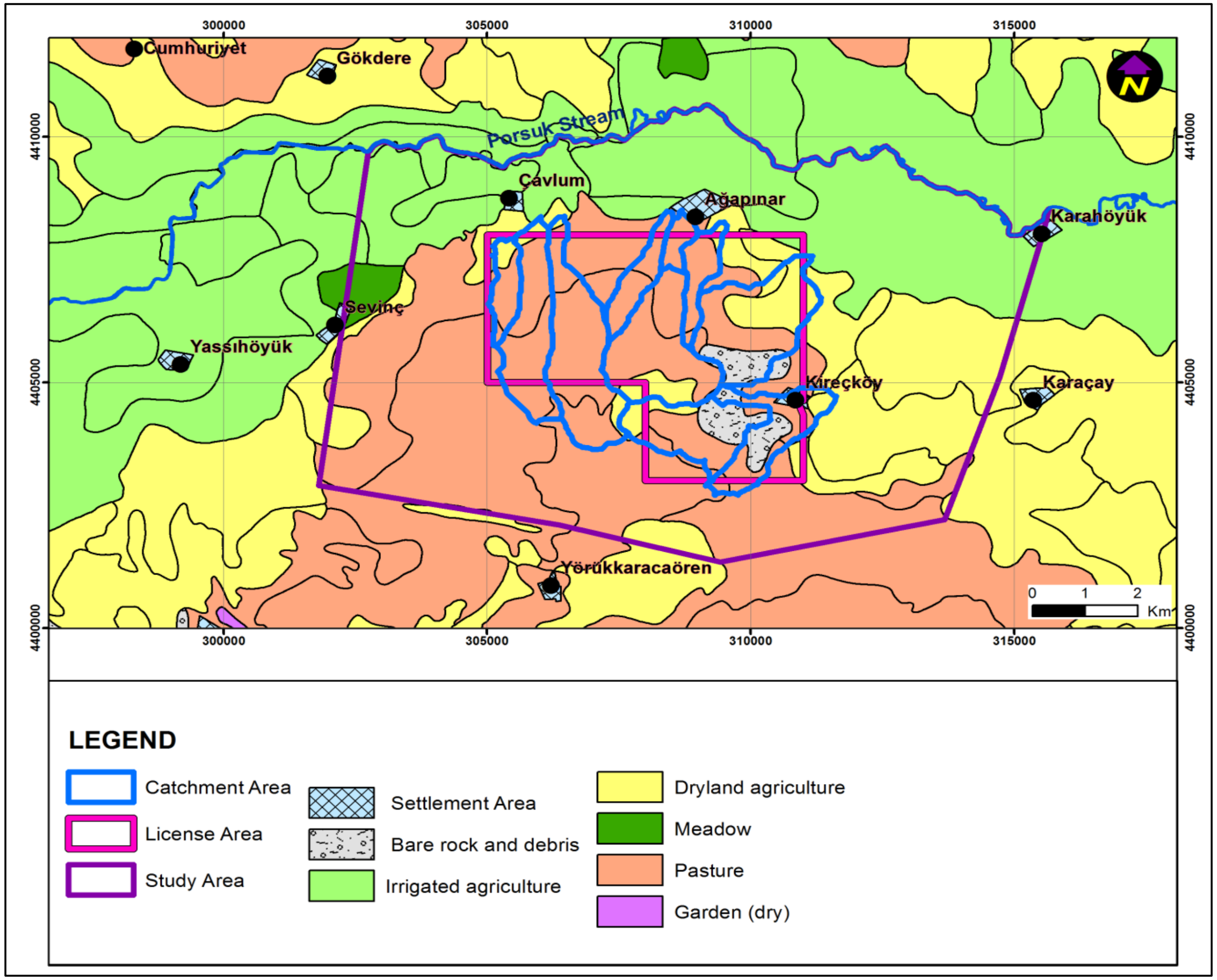

Figure 3-9: Current land use map in the vicinity of the study area (Prepared due to National Soil Database (UTVT)

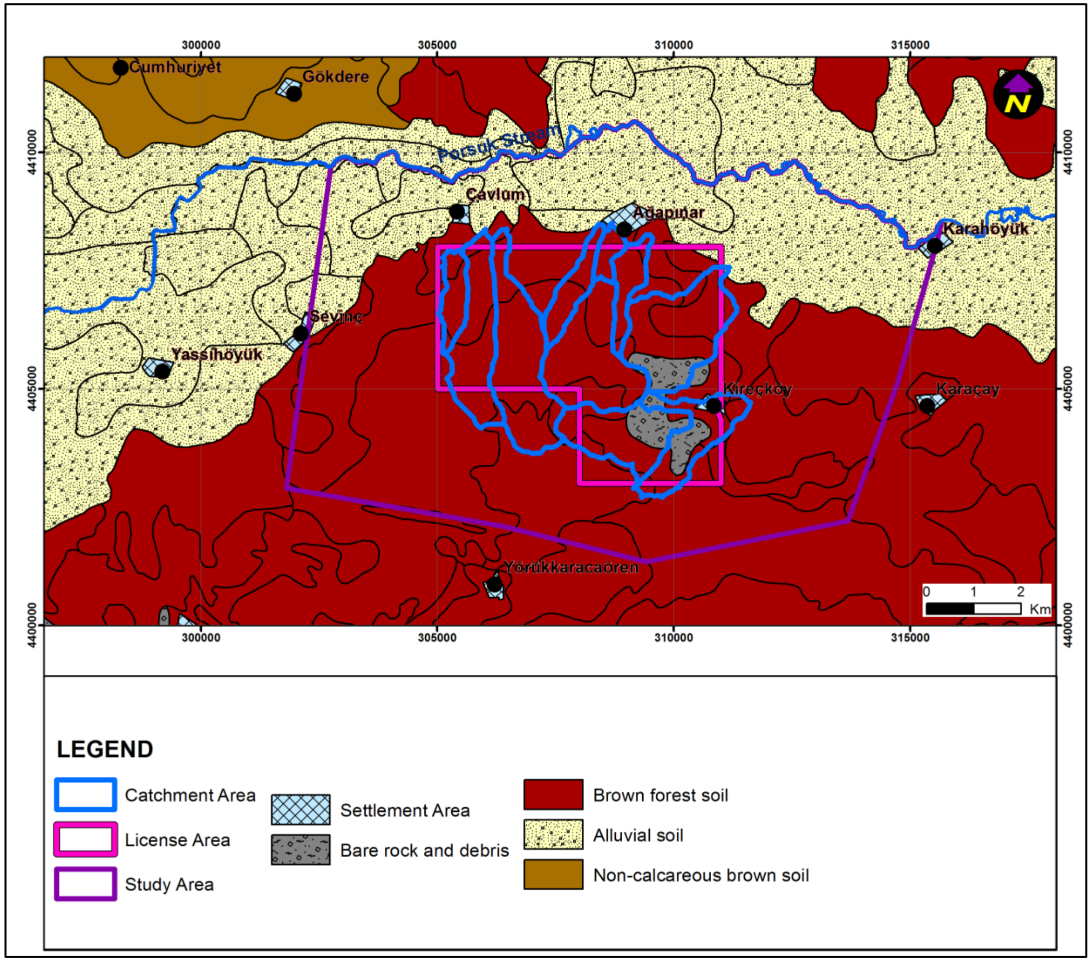

Figure 3-10: Large soil group map in the vicinity of study area (Prepared due to National Soil Database (UTVT)

Table 3-9: Long term monthly conceptual water budget model of the study area

Row No.	Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Ratio to Precipitation (%)
1	**Monthly Average Temperature (°C)**	**-1.10**	**0.30**	**3.90**	**9.30**	**14.10**	**17.90**	**20.60**	**20.50**	**16.20**	**10.90**	**5.50**	**1.00**		
2	**i**	0.00	0.01	0.69	2.56	4.80	6.90	8.53	8.47	5.93	3.25	1.16	0.09	42.38	
3	**a;**	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	13.96	
4	**UPET**	0.00	0.73	14.52	39.92	64.79	85.53	100.72	100.15	76.15	48.02	21.67	2.98	555.19	
5	**PET**	0.00	0.62	14.96	44.32	79.69	106.05	126.90	118.17	79.20	46.10	18.20	2.44	636.66	
6	**r: monthly correction coefficient**	0.85	0.84	1.03	1.11	1.23	1.24	1.26	1.18	1.04	0.96	0.84	0.82		
7	**Precipitation (mm)**	**45.10**	**38.20**	**38.10**	**40.80**	**48.50**	**29.40**	**13.20**	**14.90**	**14.50**	**35.30**	**32.20**	**54.20**	404.40	
8	**Coefficient of Surface Runoff**	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	1.00	1.00	1.00		
9	**Surface Runoff (mm)**	5.17	2.90	2.87	3.70	6.48	0.86	0.00	0.00	0.00	2.11	1.39	8.91		
10	**Infiltration (I)**	39.92	35.30	35.23	37.10	42.02	28.54	13.20	14.90	14.50	33.19	30.81	45.29		
11	**I-PET**	39.92	34.68	20.27	-7.21	-37.67	-77.51	-113.70	-103.27	-64.70	-12.92	12.61	42.85		
12	**TOTAL (P-PET)**	0.00	0.00	0.00	-7.21	-44.89	-122.40	-236.10	-339.37	-404.07	-416.99	0.00	0.00		
13	**Soil Moisture**	100.00	100.00	100.00	93.04	63.84	29.41	9.43	3.36	1.76	1.55	14.15	57.00		
14	**Change of Soil Moisture**	39.92	3.08	0.00	-6.96	-29.21	-34.43	-19.97	-6.07	-1.60	-0.21	12.61	42.85		
15	**AET**	0.00	0.62	14.96	44.06	71.23	62.97	33.17	20.97	16.10	33.40	18.20	2.44	**318.13**	79%
16	**Excess Precipitation (I-AET)**	5.17	34.51	23.14	3.70	6.48	0.86	0.00	0.00	0.00	2.11	1.39	8.91	**86.26**	
17	**Surface Runoff**	5.17	2.90	2.87	3.70	6.48	0.86	0.00	0.00	0.00	2.11	1.39	8.91	**34.39**	9%
18	**Infiltration**	0.00	31.60	20.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**51.87**	13%
													Total	**404.39**	100%

In this table, monthly potential evapotranspiration value (PET) is obtained from UPET value calculated via equation (3.3) by correction with *r* coefficient according to the longitude of the study area (39˚). Runoff values was obtained by using monthly total precipitation (P) and curve number (CN=72) by the help of equation (3.9). The difference between monthly total precipitation and surface runoff is equal to infiltration (I). Soil water storage (moisture) value was accepted as 100 mm and for each month change in water storage (moisture) value was calculated. By the help of these values, evapotranspiration (AET), surface runoff and groundwater recharge values were calculated. Additionally, soil water storage value is taken as 100 mm in the conceptual model. According to this, calculated infiltration value is 51.9 mm. According to monthly conceptual water budget model shown in Table 3-9, 78.7%, 8.5%, 12.8% of annual precipitation is converted to evaporation, surface runoff and infiltration, respectively (Table 3-10).

Table 3-10: Annual water budget results

Hydrologic Component	Amount (mm/year)	Ratio to Annual Precipitation (%)
Precipitation	404.4	100
Evaporation	318.1	78.7
Surface Runoff	34.4	8.5
Infiltration	51.9	12.8

Reliability of the annual conceptual water budget given above could be improved by continuous observations (for example, precipitation and surface runoff) and identification of the soil hydraulic properties and developing a numerical hydrogeologic model.

3.4. Existing Water Structures and Usage Properties

The Porsuk Stream is controlled by important water structures before reaching the study area. The most important water structure is the Porsuk Dam. The Porsuk

Dam started operation in 1948 and expanded in 1972 for the purpose of supplying water to Eskişehir city center and flood control, in addition to irrigation water supply. The Porsuk Dam is located at 41 km southwest of the license area. Other dams located in the vicinity of the study area are shown in Figure 3-1 and detailed information about them is listed in Table 3-11. The closest dam to the license area is Keskin 75. Yıl Dam which is 28 km away (in northwest direction). There are eight ponds around study area (Figure3-1, Table 3-12). These ponds are generally used for irrigation and the closest one is Kanlıpınar pond which is located at 7 km southwest of the license area.

Table 3-11: Information about operating dams in the vicinity of study area

Name	Location	Stream Name	Operation Year	Purpose	Lake Volume (hm^3)	Irrigation Area	Drinking/ Domestic (hm^3/yıl)	Distance to License Area
						(ha)	Energy (MW)	(km)
Aşağı Kuzfındık Dam	Eskişehir	Kocadere	2006	Irrigation	21.1	3241	--	58
Keskin 75. Yıl Dam	Eskişehir	Karaöz Dere	1998	Irrigation	8.4	1112	--	28
Musaözü Dam	Eskişehir	Mollaoğlu	1969	Irrigation	1.55	400	--	35
Porsuk Dam	Eskişehir	Porsuk	1972	Irrigation+Drinking /Domestic+Flood	525	26970	--	41
Darıdere Dam	Bilecik	Sarısu	1977	Irrigation + Flood	19.21	3103	--	64
Yenice Dam	Eskişehir	Sakarya	2000	Energy	57.6	--	38 MW	28
Gökçekaya Dam	Eskişehir	Sakarya	1972	Energy	910	--	20 MW	32

Table 3-12: Information about operating ponds in the vicinity of study area

No.	Name	Location	Stream Name	Operation Year	Purpose	Lake Volume (hm^3)	Irrigation Area	Distance to License Area
							(ha)	(km)
1	Beylik Pond	Eskişehir	Beylik	1985	Irrigation	0.395	150	17
2	Çukurhisar Pond	Eskişehir	Ilgın Creek	1994	Irrigation	0.585	140	35
3	Dereyalak Pond	Eskişehir	Söğütbaşı	1991	Irrigation	0.35	113	61
4	Erenköy I Pond	Eskişehir	Karanlık Creek	1994	Irrigation	0.601	150	61
5	Gülpınar (Sarısungur, ESKİ) Pond	Eskişehir	Sarısu Creek	2007	Drinking/Domestic +Recreation + Flood	3.5	--	13.7
6	Kanlıpınar Pond	Eskişehir	Tıngır Creek	1978	Irrigation	0.7	120	7
7	Kelkaya Pond	Eskişehir	Kelkaya Creek	1986	Irrigation	0.402	84	15
8	Yukarı Kartal	Eskişehir	Kartal Creek	1971	Irrigation	0.49	144	39

CHAPTER 4

HYDROGEOLOGY

4.1. Water Points

4.1.1. Surface Waters

The most important surface water body of the study area is the Porsuk Stream which flows from west to east (Figure 4-1). The Porsuk Stream which starts drainage from Murat Mountain, flows through Kütahya Plain and stored in the Porsuk Dam which is located at southwest of the Eskişehir city center. After leaving the Eskişehir city center, it flows through northern side of the Çavlum and Ağapınar Villages toward east. It reaches the Sakarya River around the Yassıhöyük which is located 100 km east of the study area. The Porsuk Stream is the longest tributary of the Sakarya River.

In a scope of the study carried out by DSI (2010) in 2007-2009, monthly instantaneous flow measurements were conducted on the Porsuk Stream. One of these points is near the Ağapınar village, the other one is in Süleymaniye which is approximately 60 km downstream. The measured instantaneous flow rates at these stations can be seen in Figure 4-2. At the measurement period instantaneous flow rates at the Ağapınar station which is upstream were observed in the range between 2.42 m^3/s (January 2009) and 5.64 m^3/s (May 2007), and the average value of the flow rate is 3.56 m^3/s. In the same period, flow rates at the Süleymaniye station which is downstream range between 2.57 m^3/s (December 2009) and 5.86 m^3/s

(June 2007), and the average value of the flow rate is 3.81 m^3/s. It is noted that the flow rates at Ağapınar station (upstream) is greater than the Süleymaniye station (downstream) for May-August 2008 period,. Although the precipitation is low in this period, the high discharge rate measured at Ağapınar is most likely due to the release of irrigation water from the Porsuk Dam.

The interaction between surface water and groundwater as well as the recharge/discharge values should be known for the calculation groundwater budget for the study area. The Porsuk Stream which forms the northern boundary of the study area is recharged from groundwater. In other words, the Porsuk stream is a gaining river. To calculate groundwater discharge to the Porsuk stream from the study area, the measured flow rates at Ağapınar and Süleymaniye stations were used. The difference between the dry season's (September) average flow rates at both stations give information about the groundwater discharge to the Porsuk Stream (base flow) from the area in between them. Accordingly, the base flow from an area of 2152.5 km^2 is calculated as (0.836 m^3/s) 26.36x10^6 m^3/year. When appropriated using the size of the drainage areas, the base flow from the study area (95.6 km^2) is estimated as (0.037 m^3/s) 1.17x10^6 m^3/year.

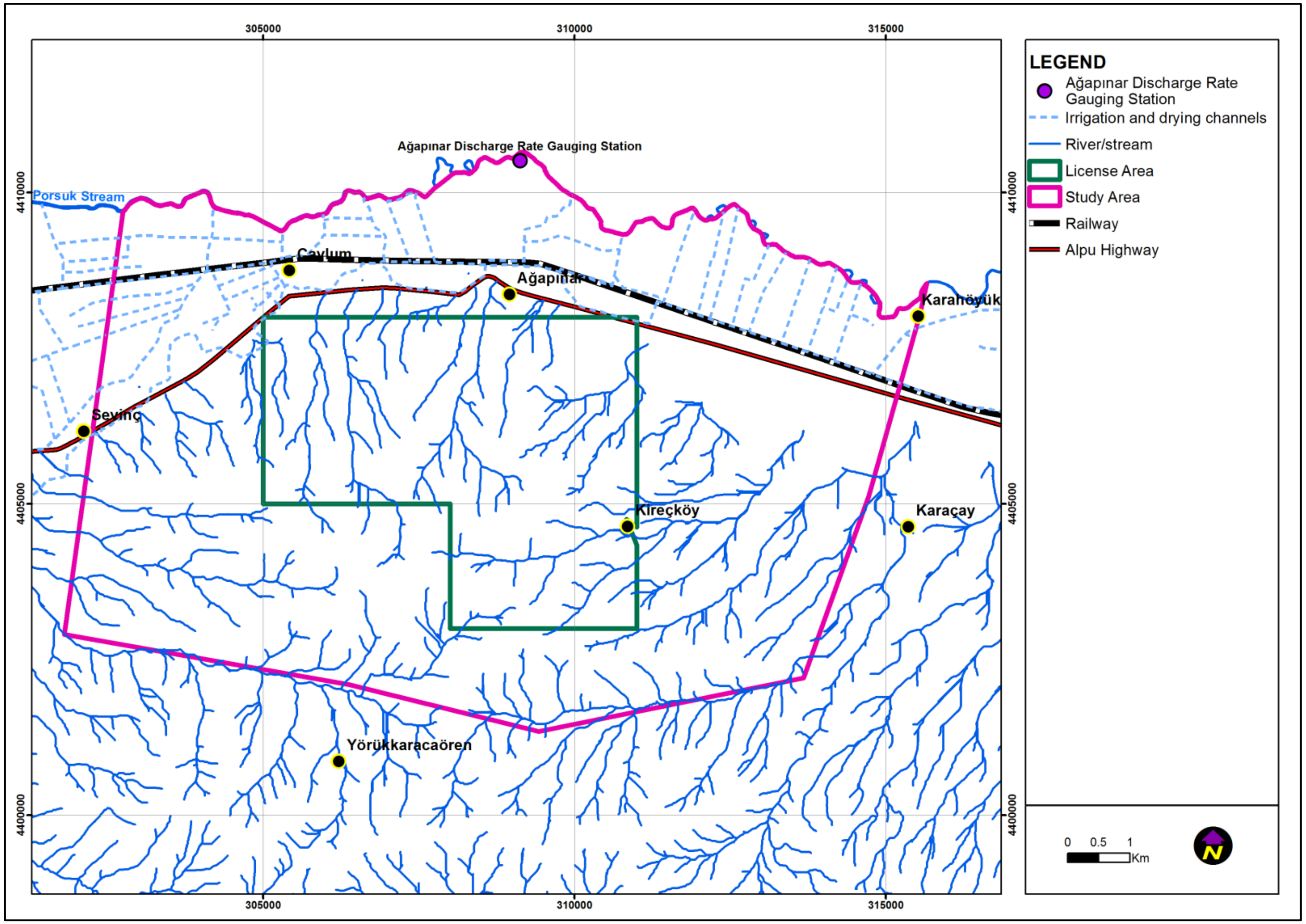

Figure 4-1: Drainage network of study area and its vicinity

The baseflow value which was calculated for the whole plain area by DSİ (2010) using discharge coefficient method is (0.879 m^3/s) 27.71X10^6 m^3/year. This value is similar with the preceeding value which was calculated simply. When discharge to the Porsuk Stream is calculated by using DSİ (2010) value, the baseflow contribution from the staudy area is (0.039 m^3/s) 1.23X$10^6 m^3$/year. Finally, the discharge to the Porsuk Stream is (0.038 m^3/s) 1.2X$10^6 m^3$/year, by taking the average of the two calculated baseflow values. The calculated baseflow value is used for the calculation of the conceptual groundwater budget for the study area.

There is not any perennial creek in the study area except the Porsuk Stream. In the region between the Eskişehir-Alpu highway (located in the northern part of the study area) and the Porsuk Stream, the Eskişehir-Alpu irrigation channels starting from the Karacaşehir regulator as well as the drainage channels are located.

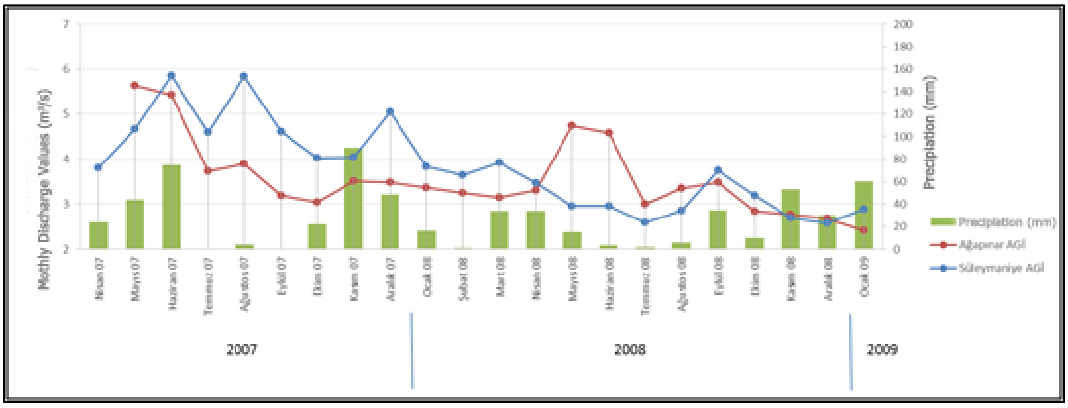

Figure 4-2: Monthly flow rates at Ağapınar and Süleymaniye gauging stations between 2007-2009 (DSİ, 2010)

4.1.2. Spring, Fountains and Captages

A total of seven springs and four captages were determined during the field study conducted in December 2014 within the study area (Figure 4-3). Springs are generally in captage and used as unmounted fountain for watering the animals by the local people. Monthly discharge rates have been measured from the springs throughout the study period in addition to the field water quality parameters (temperature, electrical conductivity, pH, dissolved oxygen, oxidation-reduction potential). The spring and captage locations are also shown in Figure 4-4 on the geological map in order to determine the effects of the lithological and structural changes. As can be seen in this figure all springs and captages discharge from the contact between green coloured claystone, bituminous shale and sandstone series which includes lignite veins (m2 series) and silicified limestones (m3 series). The silicified limestones located at elevated parts in the study area recharges from the current precipitations and have high hydraulic conductivity due to their karstic nature. Thus, they discharge their groundwater at the contact of the relatively low conductivity claystone, bituminous shale and sandstone.

The coordinates, elevation and discharge values of the springs and captages are given in Table 4-1. Discharge values of the springs were regularly measured to observe the seasonal changes. Table 4-1 summarizes the measured maximum, minimum and average values of the spring discharges. In the study area, generally, discharge amount from springs is not too much. Average discharge values range between 0.04 and 0.39 L/s while the total average is approximately 1 L/s.

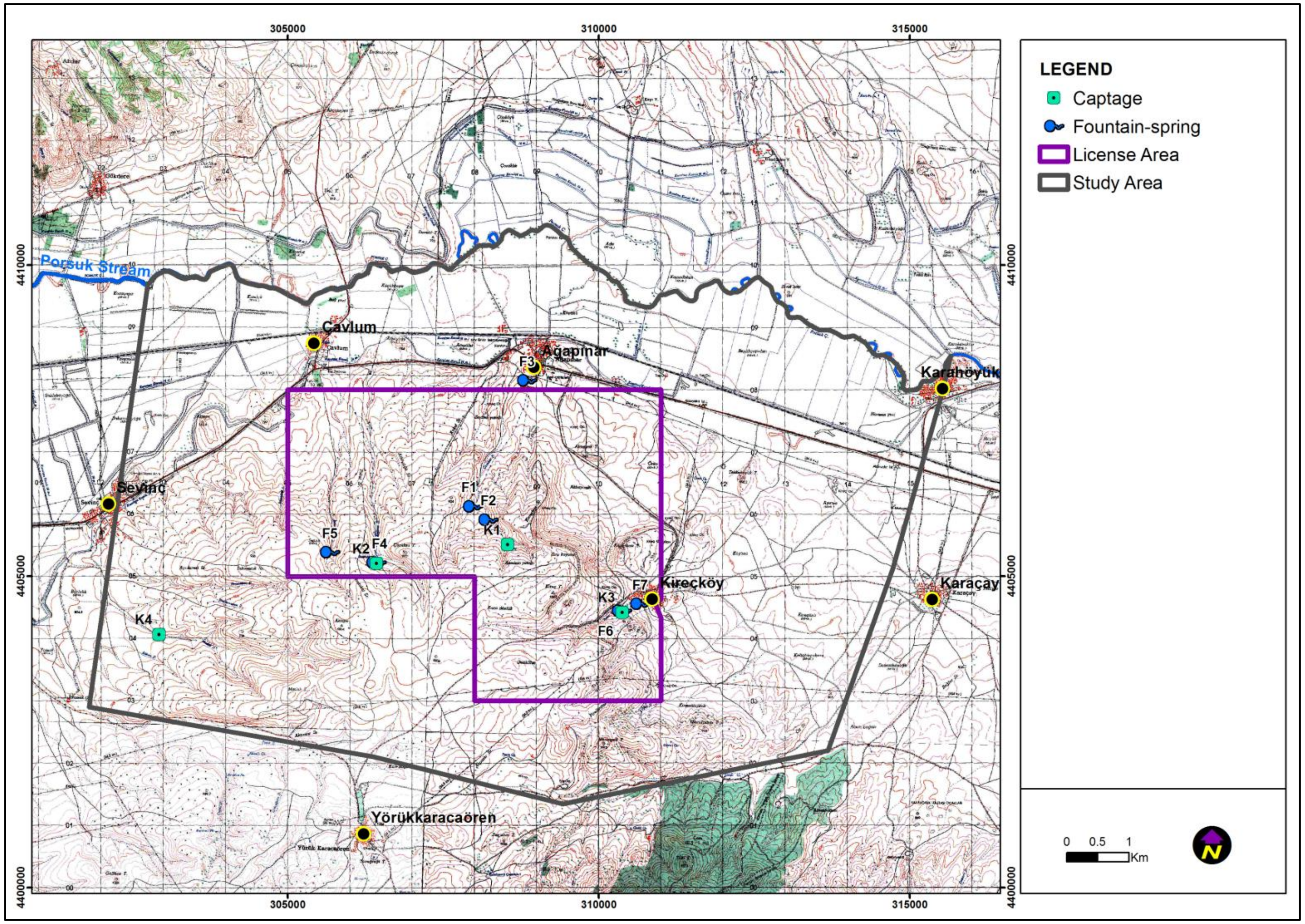

Figure 4-3: Location of spring and captages on topographic map in the study area

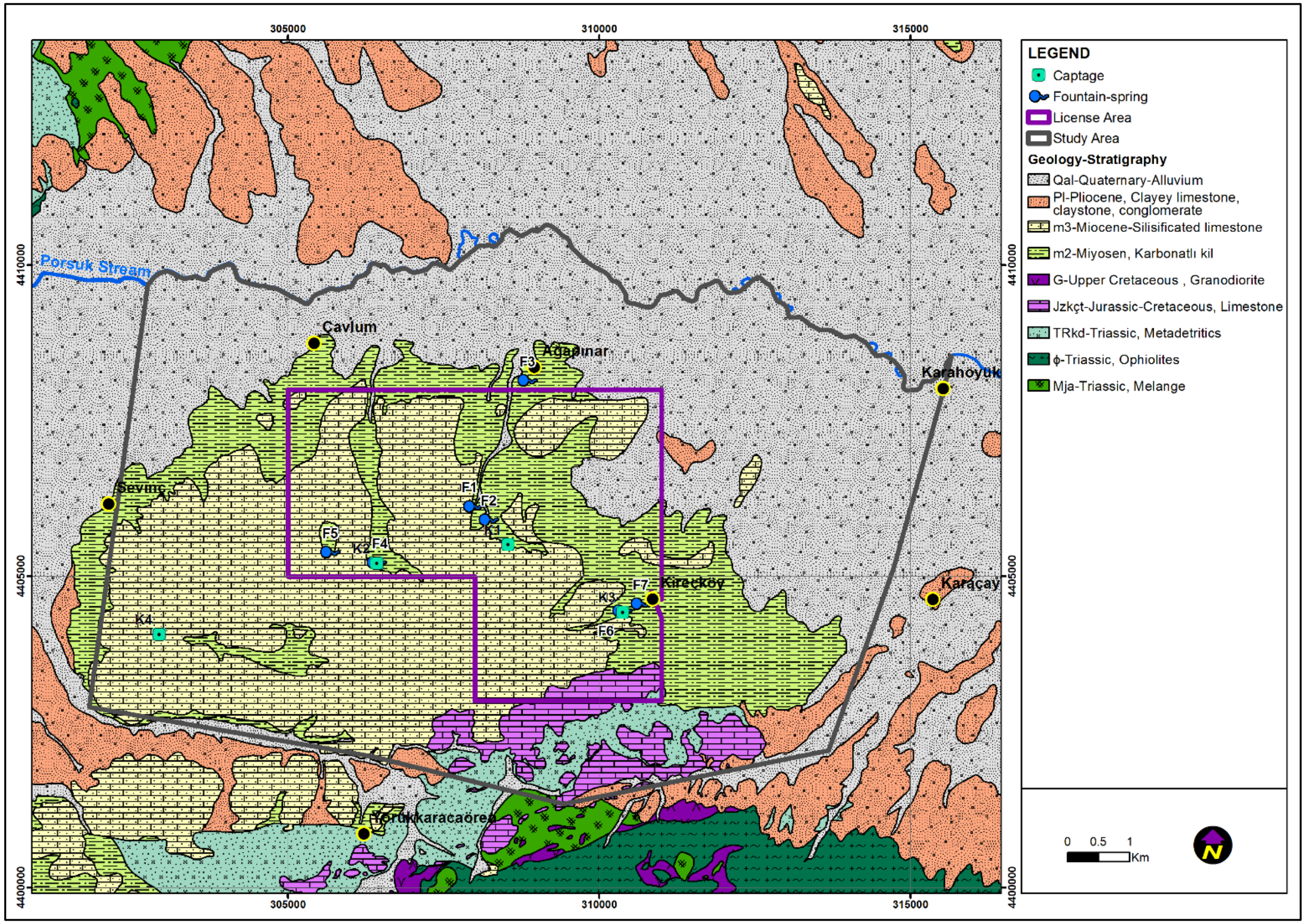

Figure 4-4: Locations of springs and spring tappings on the geological map in the study area

Table 4-1: Information about spring and captages

Spring/ Captage No	Type	Residential Area	Coordinate		Elevation (m)	Discharge (L/s)		
			Easting (m)	Northing (m)		Minimum	Maximum	Average
F1	Spring	Agapinar	307979	4406132	871	0.03	0.08	0.05
F2			308227	4405919	882	0.05	0.23	0.12
F3			308850	4408153	795	0.04	0.16	0.08
F4		Cavlum	306427	4405230	923	0.02	0.08	0.04
F5			305681	4405393	901	0.01	0.07	0.04
F6		Kireckoy	310369	4404456	880	0.06	0.66	0.24
F7			310666	4404564	863	0.1	1	0.39
K1	Captage	Agapinar	308537	4405511	929	No Measurement		
K2		Cavlum	306428	4405211	928			
K3		Kireckoy	310375	4404026	884			
K4		Sevinc	302932	4404069	835			

Temporal variations in discharge values of springs and their relation with precipitation can be seen in Figure 4.5. Eskişehir Meteoroloji Bölge Müdürlüğü (17126) meteorological station's daily precipitation values were used in this graph since there is not any meteorological station in the study area. As can be seen in Figure 4.5, there is a relation between precipitation and discharge of the springs. In general, discharge amount reaches high levels in winter and spring while it reaches low level in summer and autumn.

In spite of low discharge amount from springs and fountains, there are four captages with significantly higher discharge rates. They were developed within the silicified limestones to supply water to four villages (Ağapınar, Çavlum, Kireçköy and Sevinç. K1, K2, K3 and K4 captages supply water to the Ağapınar, Çavlum, Kireçköy and Sevinç villages, respectively. Discharge values were estimated because the discharge measurements from the captages were not possible. The total discharge from four captages in the study area is estimated to be 14 L/s.Thus, the total discharge amount of the springs and captages in the study area is 15 L/s.

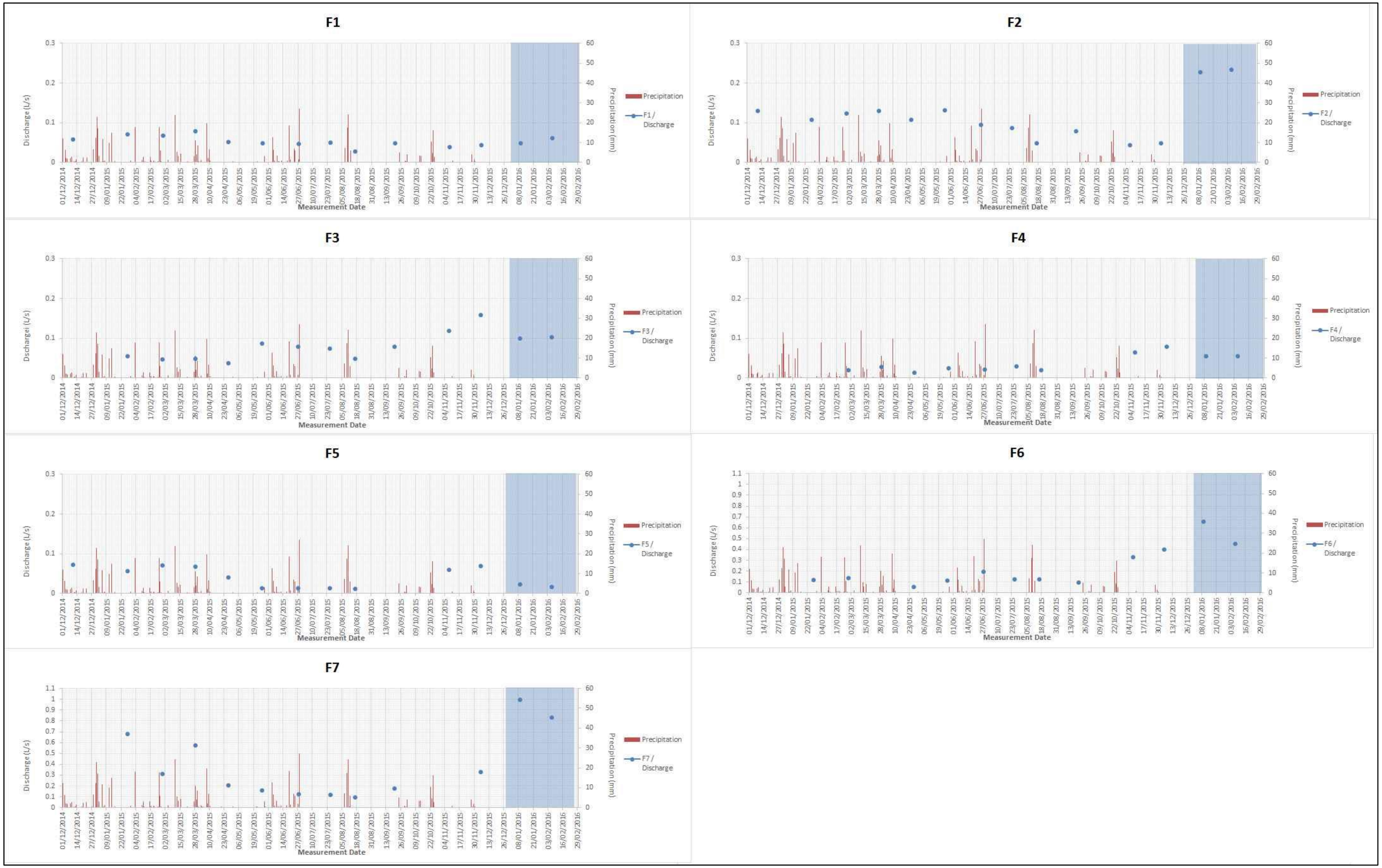

Figure 4-5: Discharge rate variations observed at springs (Blue areas show the time interval with no precipitation measurements after 31.12.2015)

4.1.3. Wells

The wells in the study area and its vicinity can be grouped into four: (i) DSI wells, (ii) village wells, (iii) private wells, and (iv) pumping and observation wells drilled for this study. Locations of these wells are shown in Figure 4.6.

DSI Wells

Eleven water wells have been drilled in the study and its vicinity by DSI and sub-contractors between 1988 and 2012 for exploration, operation and observation purposes.(Figure 4-6). All information (coordinates, elevation, depth, filtered levels, water bearing formations, static and dynamic water levels) related with those wells are provided in Table 4.2. There is not any DSI well in the license area. Seven DSI wells are located outside the eastern border of the license area. Five of these wells (44130, 55322, 55323, 55324, and 55325) are still used for irrigation of 189 hectare area by Kireckoy Irrigation Cooperative. The other two wells (39005 and 44096) are drilled for exploration purposes by DSI. These wells are joinly screened in Pliocene sandstone, conglomerate and limestone and the overlying Quaternary alluvium. The other three wells are located in the western part of the license area and Sevinc Village. One of those wells (39411) is drilled for exploration purposes and the other two are (52927, 53044) drilled to supply water to the Organized Industrial District. Quaternary alluvium and Pliocene aged conglomerate and limestone units provide water to these wells.

There is one more well (61357) at the northern border of the license area near Agapinar Village. This well is drilled for observation purposes. The well gets water from Miocene (m2) series marl and sandstone levels.

Village Water Supply Wells

There are three wells drilled for drinking and domestic purposes in Ağapınar, Kireçköy and Sevinç Villages (Figure 4-6). These three wells provide additional water to the captage water of (W1) Ağapınar, (W2) Kireçköy and (W4) Sevinç water depots. Unfortunately, it was not possible to gather any additional information about these wells. The last well that can be examined in this category, is the artesian well outside the eastern border of the license area, near Kireckoy Ören fountain. The field water quality parameters were measured in W3 and W2 wells for every monitoring session and the measured values are presented in section 5.3.2. Unfortunately, it was not possible to measure field water quality parameters in the other two wells.

Private Wells

The distribution of the private wells in the vicinity of the study area is presented in Figure 4-6. All of those wells are found outside the northeast and eastern border of the license area. The information about these wells are limited. Elevation and coordinate of these wells were measured during the field studies. According to field observations, 82 of the wells are drilled for agricultural irrigation and other five wells provide water for animals and other purposes.

Pumping and Observation Wells

Pumping and observation well clusters in three different locations within the licence area is established to determine the water bearing properties of various hydrogeological units, to estimate their hydraulic parameters and to investigate the hydraulic relations between each other and coal seams. (Figure 4-7). A total of 2515 m of drilling is conducted between March and July 2015 for a total of nine wells with depths ranging between 50 m and 420 m. All well information such as, type, depth, diameters and filtered lengths are provided in Table 4-3. The detailed well logs are presented in Appendix-A.

After the completion and washing with clean water, each well is developed with air lifting using a compressor and pumping with submerged pumps. Pumping and recovery tests were conducted at some pumping wells to determine the hydraulic parameters (transmissivity, hydraulic conductivity and storativity) of the water bearing units. In those wells that were not possible to conduct pump tests due to low yields, slug tests were conducted to determine the hydraulic conductivity of the units.

Well groups are located at the northeast, south and northwest part of the license area. These locations were defined after analysing the general hydrogeology and coal exploration well logs in the license area.

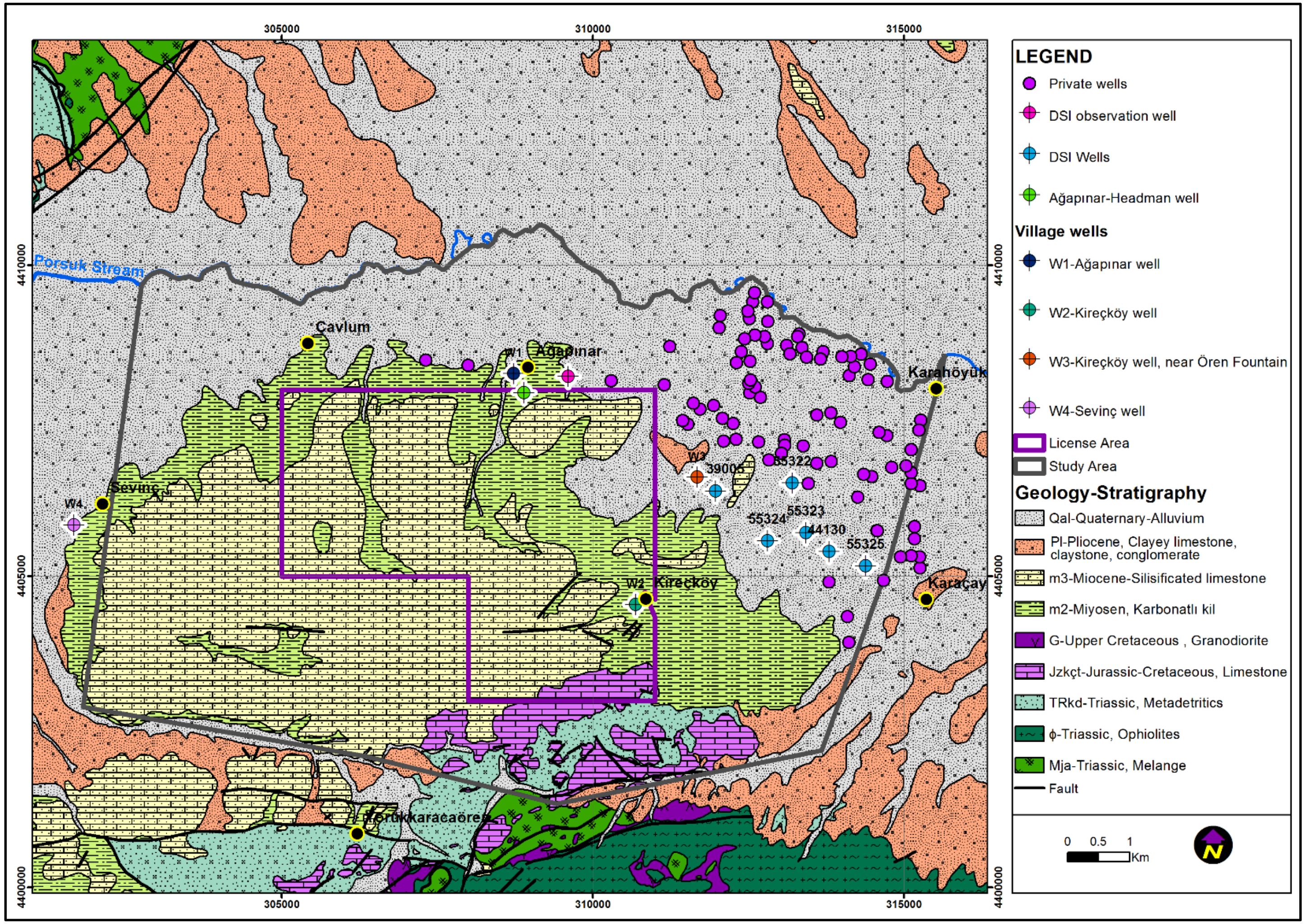

Figure 4-6: Location of wells around study area and its vicinity

Table 4-2: Information about DSI wells around study area and its vicinity

Well No	Drilling Contractor	Drilling Purpose	Province	Vicinity Area	Section No	Year	Coordinates		Elevation	Depth	Filter (m)		Total Filter Length (m)	Aquifer Lithology	Formation	Static Level (m)	Dynamic Level (m)	Information (m)		Specific Capacity
							Easting	Northing			Top	Bottom						Artesian	Pumping	
39005	DSI	Research	Center	Agapinar	125b4	1988	311975	4406375	780	150	24	128	68	Tuf, Conglomerate	Pliocene	0.05	54.05	1	4	0.07
39411	DSI	Research	Center	Yassihoyuk	125a3	1989	299750	4405625	793	105	28	98	44	Calcerous marl	Quaternary-Pliocene	8.9	41.71		40.62	1.24
44096	DSI	Research	Center	Karacay	125b4	1993	316975	4404750	779	238	32	223	78	Calcerous marl, Tuffite	Pliocene	7.78	43.66		31.17	0.87
44130	DSI	Research	Center	Kireckoy	125b4	1993	313800	4405400	787	130	24	120	44	Limestone, Tuffite, Conglomerate	Pliocene	17.6	50.98		24.97	0.75
52927	DSI	Operation	Center	OSB	125a3	1997	300075	4404250	785	102	8	100	32	Calcerous marl, Clay, Sand, Pebbles	Quaternary-Pliocene	9	43.8		51.6	1.48
53044	DSI	Operation	Center	OSB	125a3	1997	300575	4404750	782	100	10	78	36	Limestone, Conglomerate, Clay, Sand, Pebble	Quaternary-Pliocene	2.3	50.04		23.46	0.49
55324	G&M Eng.	Operation	Center	Kireckoy	125b4	2001	312808	4405572	795	70	24	60	24	Limestone, Claystone	Pliocene	28	44.68		35.34	2.12
55325	G&M Eng.	Operation	Center	Kireckoy	125b4	2001	314383	4405170	782	140	32	132	52	Marly Limestone, Claystone, Shale	Pliocene	16	54.66		36.85	0.95
55322	G&M Eng.	Operation	Center	Kireckoy	125b4	2001	313207	4406502	766	78	24	64	26	Limestone, Claystone, Marl	Pliocene	11.05	50.27		22.08	0.56
55323	G&M Eng.	Operation	Center	Kireckoy	125b4	2001	313426	4405702	782	93	28	88	36	Shale, Marl, Limestone	Pliocene	16.2	48.96		37.23	1.14
61357	DSI	Observation	Center	Agapinar	125b4	2012	309601	4408215	784	120	20	112	40	Marl, Sandstone	Miocene (m2)	18.22	91.24		4	0.055

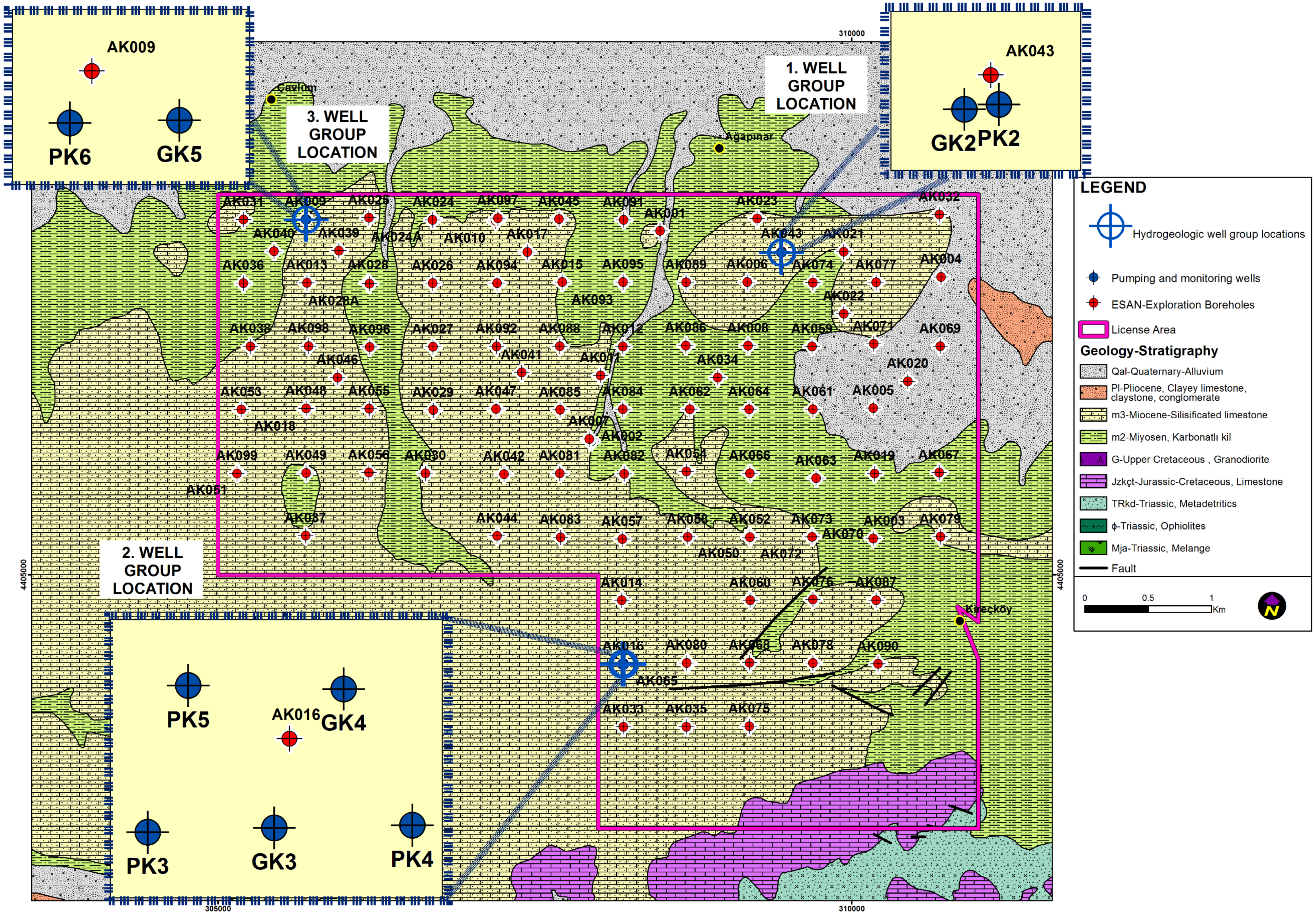

Figure 4-7: Hydrogeological and exploration drilling holes in the license area

Table 4-3: Information about pumping and observation wells in the license area

Well Name	Well Type	Coordinate		Elevation (m)	Water Level Measurement Elevation (m)	Depth (m)	Filter Interval (m)	Filtered Level	Lithology
		Easting	Northing						
PK-2	Pumping	309452	4407540	812.547	812.267	325	21-317	Above, intra, below coal	Shale, Sandstone, Conglomerate, claystone-coal seam (A), shale-coal seam (B), Sandstone- coal
GK-2	Observation	309441	4407539	812.492	812.242	300	28-292	Above, intra coal	Shale, Sandstone, Conglomerate, claystone-coal seam (A), shale-coal seam (B)
PK-3	Pumping	308187	4404292	994.632	994.452	420	352-416	Below coal	Limestone
GK-3	Observation	308197	4404292	994.972	994.702	336	300-330	Below, intra coal	Shale-coal seam (B), Sandstone-coal seam (C), Claystone
PK-4	Pumping	308208	4404292	995.687	994.657	60	26-56	Above coal	Silicified Limestone, claystone,sandstone
GK-4	Observation	308202	4404303	996.309	995.679	50	26-46	Above coal	Silicified Limestone, Shale, Sandstone, Conglomerate
PK-5	Pumping	308190	4404303	996.054	995.634	208	136-204	Above coal	Silicified Limestone
PK-6	Pumping	305689	4407799	800.614	800.614	420	368-416	Above coal	Shale, Sandstone, Conglomerate
GK-5	Observation	305699	4407800	801.150	800.580	396	372-390	Intra coal	Shale-Coal Seam (A)

The location of the first clusters of the wells is at the northeastern part of the license area, in the vicinity of exploration hole AK043 (Figure 4-7). PK-2 pumping and GK-2 observation wells are drilled to test the coal seams and all the formations above the coal seams. According to the AK043 well’s core data, lithologic units observed from surface to the bottom of the well is 13 m thick Upper Miocene silicified limestone (m3 series), claystone-sandstone-conglomerate alternation and claystone-coal seam (A), shale-coal seam (B) shale and sandstone-coal seam (C) series and then claystone (m2 series). At this location C-coal seam thickness is about 0.1 m. A pumping well (PK-2) with a depth of 325 m and an observation well (GK-2) with a depth of 300 m were completed in such a way to test the coal seams and the overlying units to obtain relevant information for dewatering during mining activities.

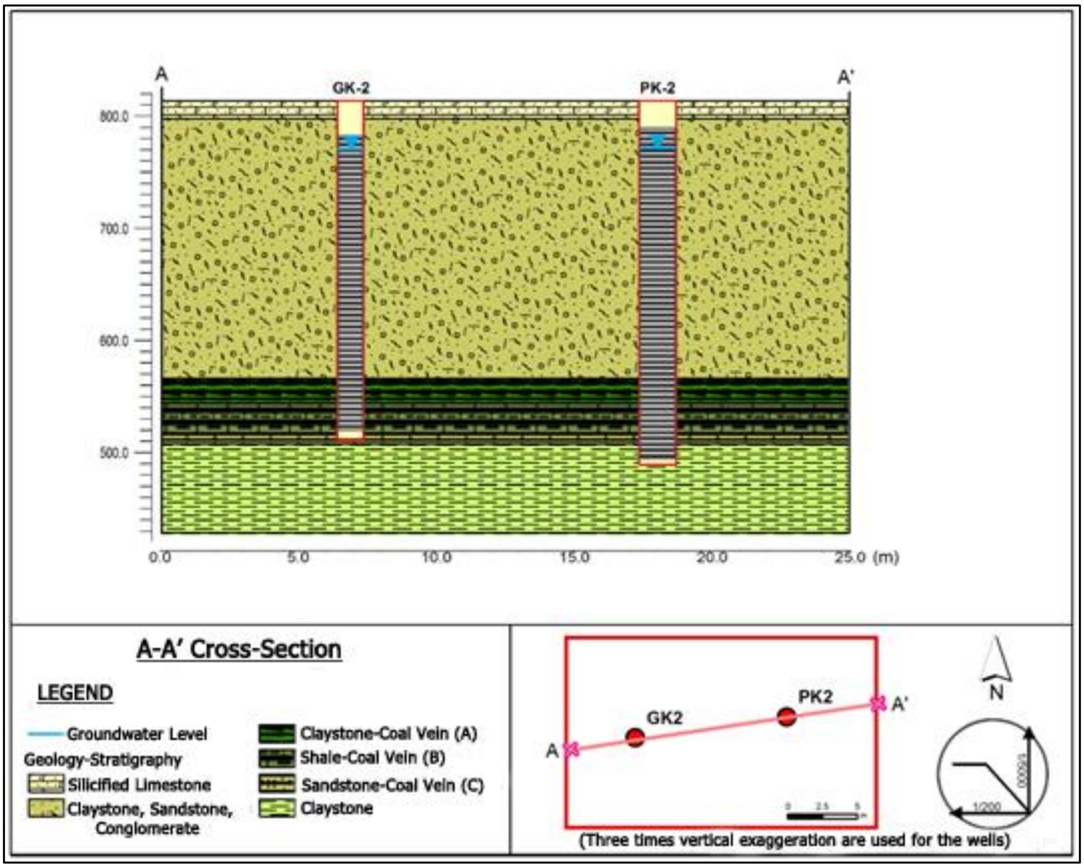

Figure 4-8: First well group locations and the lithologies tapped

Second cluster of wells are located at the southern part of the license area near AK016 well (Figure 4-7). The main reasons selecting this location are: (1) this area being located at the elevated part of the study area may represent the recharge zone; therefore, this needs to be investigated and (2) to test the hydraulic relations between the coal seams and overlying Miocene silicified limestone and underlying Jurassic-Cretaceous limestone units. Hence, three pumping and two observation wells having different depths are drilled at this cluster location (Figure 4-9).

One of those wells, PK-3 with a depth of 420 m, is drilled to determine the water bearing potentialand hydraulic parameters of the Jurassic-Cretaceous limestones and the hydraulic relations between them and the overlying coal seams.. On the other hand, PK-4 and GK-4 wells with depths of 60 and 50 m respectively, are drilled in order to define the hydraulic parameters of the Miocene silicified limestones which are tapped by several captages which supply water to villages as well as to define the hydraulic relations between them and the underlying coal bearing Miocene units (Figure 4-9). PK-5 and GK-3 wells are drilled to determine the hydraulic parameters of the Miocene units overlying the coal seams and the coal seams themselves. Furthermore, these wells will also help to establish the hydraulic relations between coal seams and underlying Jurassic-Cretaceous limestones and overlying silicified limestones.

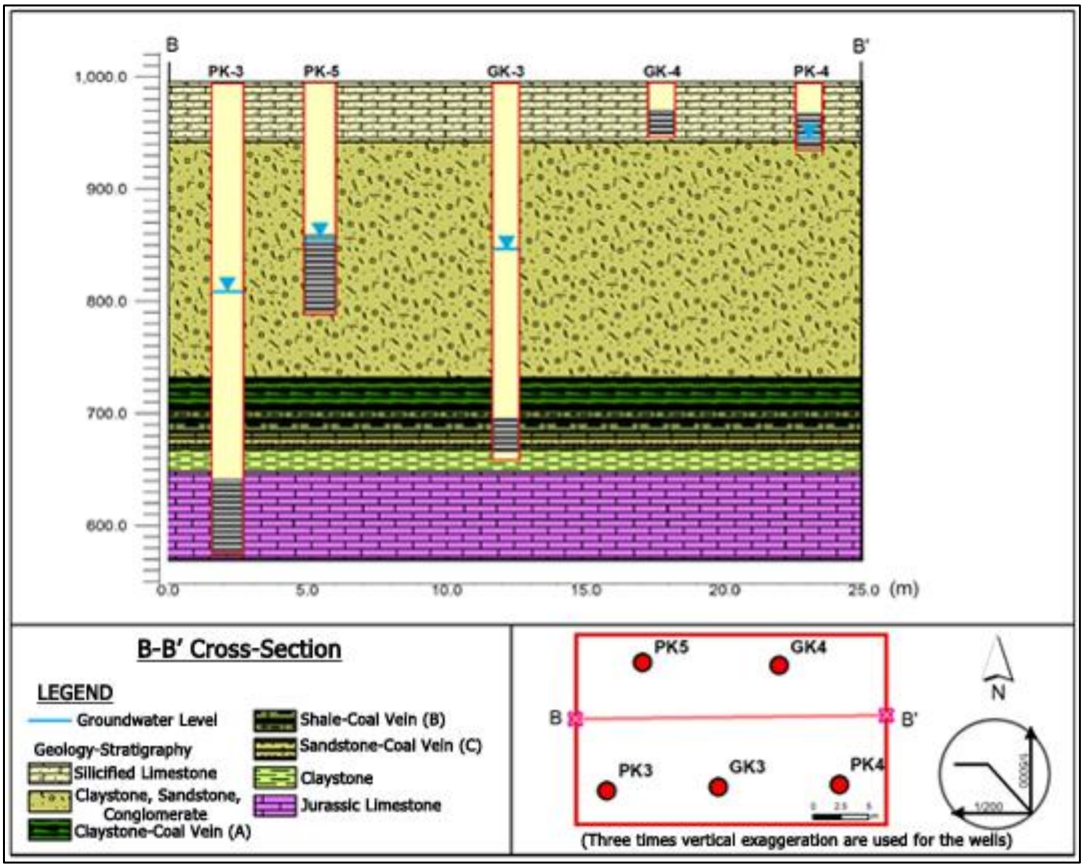

Figure 4-9: Second group of the wells location and penetrated units

Third group of the wells is located at the northwest edge of the license area. At this location, PK-6 pumping well tapping the A-coal seams and the underlying units (screened between 368 m and 416 m) and GK-5 observation well screened in intra-coal levels (372-390 m) are drilled (Figure 4-10). Because lower coal seams (B and C) become deeper toward the northwest part of the license area, it was not possible to test them due to their excessive depth. Therefore, it is aimed to determine the water bearing potential of the A-coal seams and the interveining units and as well as the fluid pressure beneath them.

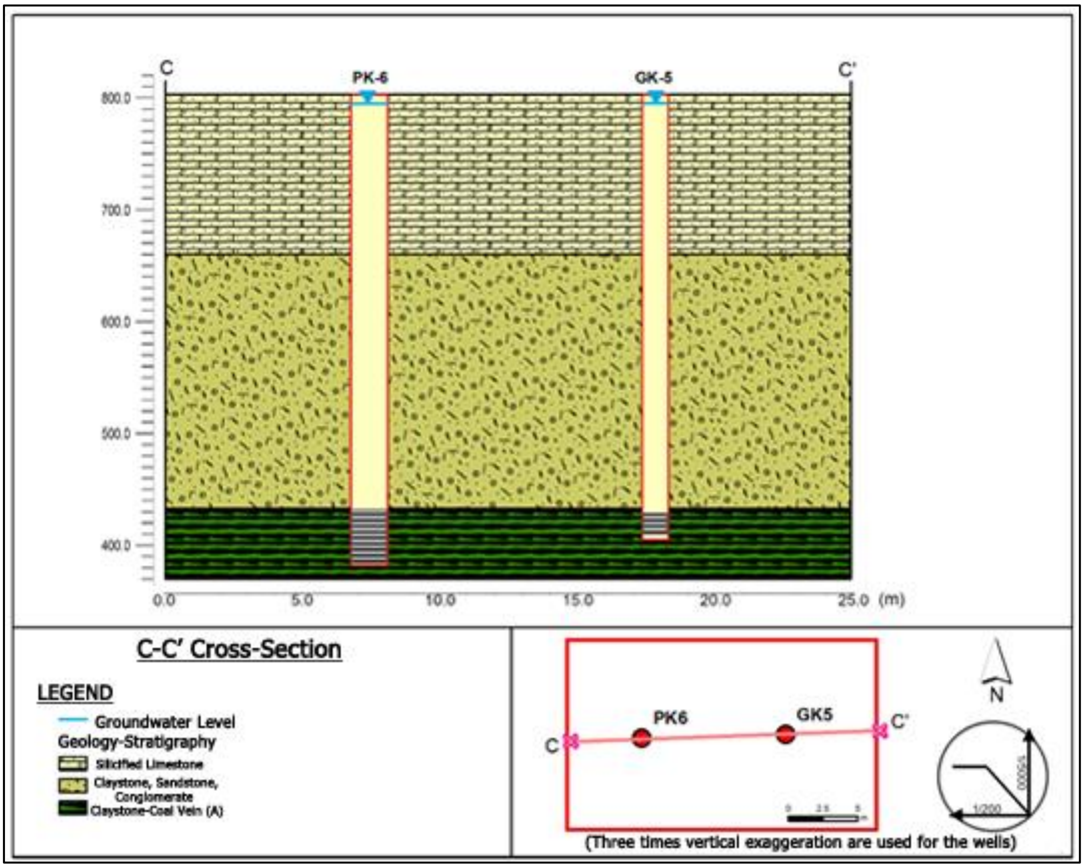

Figure 4-10: Third group of the wells location and penetrated units

The static water levels are measured monthly following the development of the pumping and observation wells. In addition, two sampling has been made from the pumping wells for hydrochemical and water quality analyses. Submersible pumps have been installed in PK-2, PK-3, PK-5 and PK-6 wells to purge them prior to sampling. A water volume of 5-6 times the water volume in the well has been purged before taking samples according to the standards of sampling. Because of the limited water column in the PK-4 well it was not possible to install a pump for purging; hence, bailer is used to remove the standing water in this well prior to sampling.

4.2. Hydrogeology of the Study area

The most important water bearing formations within the study area and its vicinity are Quaternary alluvium and Pliosen aged limestones, sandstone and conglomerates. The Jurassic-Cretaceous limestones, Triasic aged metaclastic rocks and ophiolitic melange that outcops in the southern part of the study area form the basement and are generally impervious and semi-pervious. They may carry groundwater along fractures that result from faulting.. The detailed information about these units is given below.

The basement of the study area and its vicinity consist of Palezoic aged metamorphics (marble, schist and gneiss), Mesosoic aged ophiolites, Triassic aged metadetritics and Jurassic – Cretaceous aged limestones (Figure 4-6). These units are generally impervious or semi-pervious and may carry groundwater along fractures that result from faulting (Figure 4-6).. Schists and gneisses are impervious units. The Jurassic-Cretaceous limestones that crop out in the southern part of the study area is pervious and semi-pervious in nature and have been penetrated by 16 coal exploration holes at depths ranging between 98.3 m and 556.2 m. In a study conducted by Palaris (2016) the top elevations of this limestone unit in these holes were used to construct the top of basement structure contour map. This map shows that limestones make a ridge trending from southwest to northeast in the middle of the licence area (near AK044) and form a divide between two basins for the accumulation of lignite. The basin in the southeast part of the licence area (near AK016) is shallow whereas the one in the northwestern part of the licence area (near AK036 and AK046) is deep. The pumping test conducted at PK-3 well to determine the hydraulic properties of this unit shows that limestones at this locality are relatively impervious with low conductivity ($K=2.35X10^{-8}$ m/s). In addition, the hydrochemical tests conducted showed that this well water has NaCl facies groundwaters. This facies is most likely produced by slowly moving groundwater that have a long contact time with rock due to presence of the subbasin in the southeast and low hydraulic conductivity of limestones. Because there are no other wells in this unit, the water bearing potential and hydraulic parameters of the lower limestones, especially in the northwest part of the study area, is unknown.

The lignite bearing Middle-Upper Miocene aged Porsuk Formation is generally composed claystones, sandstones, conglomerates and bituminous shales. The bottom of these deposits consist of basal conglomerates that are composed of conglomerates, sandstones and claystones (m1 series). This unit is overlain from the bottom to the top a sequence of conglomerate, green claystone, coal seam (C), gray sandstone, bituminous shale, coal seam (B), bituminous shale, coal seam (A) and green claystone-sandstone-conglomerate alternation (m2). The tests conducted in two pumping (PK-2 and PK-6) and two observation (GK-2 and GK-5) wells completed in this unit gave average hydraulic conductivity of $2.4X10^{-7}$ m/s and a storativity of $2.3X10^{-2}$. Thus, m2 series have a low hydraulic conductivity and display unconfined to semi-unconfined behaviour.

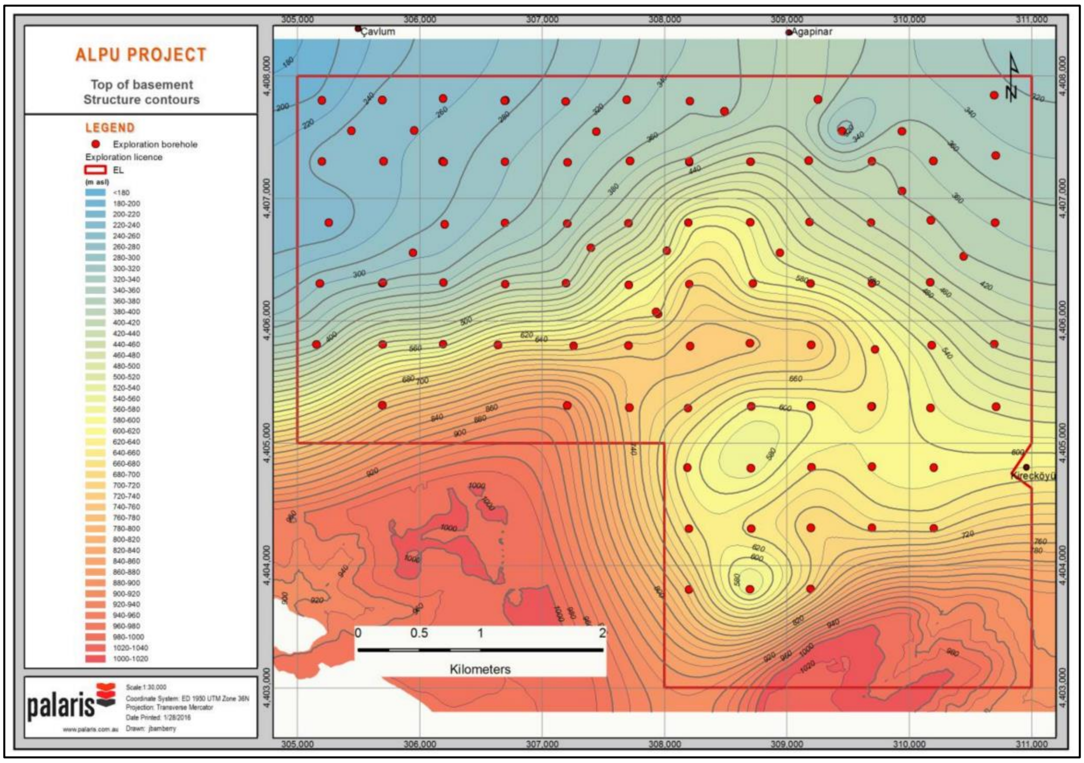

Figure 4-11: Map of top of basement structure contours (Palaris, 2016)

The silicified limestones (m3 series) forming the upper parts of the Miocene units crop out in most part of the licence area and about 1/3 of the whole study area. The field observations and lost circulations in the drilled pump wells show that these series are permeable and have karstic cavities. Springs discharging from this unit is captured and used to supply water to Çavlum, Ağapınar, Sevinç and Kireçköy villages to meet part of their drinking and domestic water needs. The slug tests conducted in PK-4 well comleted in this unit yielded relatively high hydraulic conductivity (K= $8.6X10^{-7}$ m/s).

The Pliocene units copping out in the eastern and western parts of the study area is one of the important water bearing units in the area. The Pliocene deposits from the bottom to the top consist of reddish variegated colored conglomerate, sandstone, clayey limestone, tuffite bearing red mudstone with variegated colored clayey limestone, marl and gray/light brown clay. The conglomerates, sandstones and limestones within Pliocene deposits carry groundwater and many wells have been drilled in these deposits by DSI for operation and exploration purposes. The DSİ wells drilled around the license area are shown in Figure 4-6. The depths, filter levels, tapped units, static and dynamic groundwater levels, yields and specific capacities of DSI wells are summarized in Table 4-2. The pumping tests conducted by DSI (1977) in two wells completed in Pliocene deposits resulted in transmissivity values of $2.66X10^{-4}$ m^2/s and $5.67X10^{-4}$ m^2/s, and hydraulic conductivity of $1.86X10^{-6}$ m/s and $4.10X10^{-6}$ m/s. These results show that, after the Quaternary alluvium, the Pliocene deposits are the most permeable unit within the study area.

The Quaternary alluvium consists of silt and clay intercalated sands and gravels. Forming the main aquifer system in the Alpu plain, the thickness of the alluvium increases toward the Porsuk Stream, reaching values of 35-50 m. The drinking, domestic and agricultural water needs in the basin is basically met from this unit and there are several wells drilled by private people and State Hydraulic Works (Figure 4-6). In a hydrogeological investigation study in Alpu Plain conducted by DSI in 1977, 22 pumping tests were conducted in drainage wells to determine the hydraulic parameters of the alluvium. The test results show that the transmissivity of the alluvium ranges between $2.31X10^{-3}$ m^2/s and $4.21X10^{-2}$ m^2/s, the geometric mean being equal to $9.11X10^{-3}$ m^2/s. The hydraulic conductivity of the alluvium, on the other hand, varies between $1.29X10^{-4}$ m/s and $2.63X10^{-3}$ m/s, the geometric mean is $5.00X10^{-4}$ m/s. These values show that the alluvium has high transmissivity and hydraulic conductivity. The test results show that the storativity of the alluvium ranges between $3.00X10^{-3}$ ile $2.00X10^{-1}$, indicating that the alluvium behaves as unconfined to semi-unconfined aquifer. Most of the wells drilled by DSI in the plain are screened in both the alluvium and Pliocene deposits. The Quaternary alluvium deposits that are seen along the creeks within the license area are not important water bearing unit due to their limited areal extent and thickness.

4.2.1. Hydraulic Parameters

The main hydraulic parameters that affect the groundwater flow are hydraulic conductivity and storage coefficient (storativity). These parameters are generally obtained from the results of pumping tests. Thus, after developing each well, constant rate pumping tests and recovery tests were conducted when required pumping yield was procured. In other cases, slug tests are carried out to determine the hydraulic conductivities. Besides, in some wells (PK-2, PK-6, GK-2 and GK-5) in which pumping tests were conducted, the slug tests were also performed to compare the calculated hydraulic conductivity values obtained from pumping tests and the slug tests.

In order to determine the hydraulic properties of the units outcropping in the study area and to reveal the hydraulic relations/interactions between each other and the coal seams, the intersected units were differentiated by screening each well in the target units.

The locations of the wells that pumping tests were conducted in the license area are shown in Figure 4.7. In the pumping well PK-6, three pumping and recovery tests were conducted on 20-21 June 2015 (0.5 L/s rate and 18 hr 50 sec), 22-23 June 2015 (1.0 L/s rate and 22 hr 12 sec) and 1-3 July 2015 (1.0 L/s rate and 48 hr) due to different reasons. Pumping tests at PK-2 on 6-9 August 2015 and PK-3 on 27

July 2015 with 1 L/s pumping rate were conducted. The pumping test could not been carried on in PK-4 and PK-5 due to inadequate water column and/or poor well yield. The measurements conducted during pumping tests and the results of the analyses are given in Appendix-B. The pumping and recovery data obtained from these tests are analysed using Aquifer Test Pro 4.2 program. The hydraulic parameters obtained from pumping and recovery tests are summarized in Table 4-4.

The slug tests were conducted in observation wells (GK-2, GK-3 and GK-5) and pumping wells PK-4 and PK-5 where pumping tests could not have been performed. In addition to these wells, the slug tests were also conducted in PK-2 and PK-6 pumping wells to verify the hydraulic parameters obtained.. The slug test results are analysed by using Aquifer Test Pro 4.2 program. The measurements conducted during slug tests and the results of the analyses are given in Appendix_C. The calculated hydraulic conductivities obtained from slug tests are summarized in Table 4-5. The results show that the hydraulic conductivity values obtained from the slug and pumping tests are similar to each other.

Table 4-4: Pumping tests results and calculated hydraulic parameters and well information

Well No.	Elevation (m)	Filter		Average GWL (m)	Filtered Level	Lithology	Test Type	Method	Calculated Values (m/s)	Calculated Storage Coefficient	Average K Value (m/s)	
		Start (m)	End (m)								Aritmetic Mean	Geometric Mean
PK-2	812.267	21	317	38.28	Above coal, Coal, Below Coal	Siltstone-sandstone-conglomerate, claystone- coal bed (A), shale-coal bed (B), sandstone-coal seam (C), claystone	Pumping Test	Neuman	6.34E-08	-	6.57E-08	6.56E-08
								Boulton	6.56E-08			
								Theis-Jacob correction	7.12E-08			
								Theis high	6.26E-08			
PK-3	994.452	352	416	184.82	Below Coal	Limestone	Pumping Test	Cooper&Jacob	3.51E-08	-	2.78E-08	2.35E-08
								Theis	3.88E-08			
								Theis high	9.48E-09			
PK-6	800.614	368	416	7.37	Coal	Claystone- coal seam (A)	Pumping Test	Cooper&Jacob	2.63E-07	-	2.32E-07	2.20E-07
								Theis	1.39E-07			
								Theis high	2.94E-07			
GK-2	812.242	28	292	39.07	Above coal, Coal	Siltstone-sandstone-conglomerate, claystone- coal bed (A), shale-coal bed (B), sandstone-coal seam (C), claystone	Pumping Test	Neuman	6.88E-07	8.55E-02	6.32E-07	6.23E-07
								Boulton	6.49E-07	8.55E-03		
								Theis-Jacob correction	7.23E-07	7.82E-03		
								Theis high	4.67E-07	-		
GK-5	800.58	372	390	5.6	Coal	Claystone- coal seam (A)	Pumping Test	Cooper&Jacob	3.40E-07	6.94E-03	3.67E-07	3.66E-07
								Theis	3.58E-07	8.24E-03		
								Theis high	4.04E-07	-		

Table 4-5: Hydraulic conductivity values obtained from slug tests and well information

Well No.	Elevation (m)	Filter Start (m)	Filter End (m)	Average GWL (m)	Filtered Level	Lithology	Test Type		Method	Calculated Values (m/s)	Average K Value (m/s) Aritmetic Mean	Average K Value (m/s) Geometric Mean
PK-2	812.267	21	317	38.28	Above coal, Coal, Below Coal	Siltstone-sandstone-conglomerate, claystone- coal bed (A), shale-coal bed (B), sandstone-coal seam (C), claystone	Slug Test	Falling Phase	Hvorslev	1.69E-07	1.61E-07	1.58E-07
									Bouwer&Rice	1.22E-07		
								Rising Phase	Hvorslev	2.08E-07		
									Bouwer&Rice	1.45E-07		
PK-4	994.657	26	56	48.05	Above Coal	Silicified Limestone, claystone	Slug Test	Falling Phase	Hvorslev	1.06E-06	8.59E-07	8.37E-07
									Bouwer&Rice	6.87E-07		
								Rising Phase	Hvorslev	1.04E-07		
									Bouwer&Rice	6.47E-07		
PK-5	995.634	136	204	144.98	Above Coal	Claystone, sandstone	Slug Test	Falling Phase	Hvorslev	3.20E-07	3.40E-07	3.27E-07
									Bouwer&Rice	2.10E-07		
								Rising Phase	Hvorslev	4.31E-07		
									Bouwer&Rice	3.97E-07		
PK-6	800.614	368	416	7.37	Coal	Claystone- coal seam (A)	Slug Test	Falling Phase	Hvorslev	3.91E-07	2.51E-07	2.31E-07
									Bouwer&Rice	3.00E-07		
								Rising Phase	Hvorslev	1.72E-07		
									Bouwer&Rice	1.40E-07		
GK-2	812.242	28	292	39.07	Above coal, Coal	Siltstone-sandstone-conglomerate, claystone- coal bed (A), shale-coal bed (B), sandstone-coal seam (C), claystone	Slug Test	Falling Phase	Hvorslev	1.52E-07	1.36E-07	1.35E-07
									Bouwer&Rice	1.16E-07		
								Rising Phase	Hvorslev	1.50E-07		
									Bouwer&Rice	1.25E-07		
GK-3	994.702	300	330	146.58	Coal	l bed (B), sandstone-coal seam (C),	Slug Test	Falling Phase	Hvorslev	1.59E-07	1.37E-07	1.36E-07
									Bouwer&Rice	1.19E-07		
								Rising Phase	Hvorslev	1.48E-07		
									Bouwer&Rice	1.21E-07		
GK-5	800.58	372	390	5.6	Coal	Claystone- coal seam (A)	Slug Test	Falling Phase	Hvorslev	1.26E-07	1.61E-07	1.54E-07
									Bouwer&Rice	1.09E-07		
								Rising Phase	Hvorslev	2.30E-07		
									Bouwer&Rice	1.77E-07		

The hydraulic conductivity and storativity values of the various lithologic units that crop out in the study area are summarized in Table 4-6.

Table 4-6: Hydraulic parameters of the various units in the study area

Geologic Units	Hydraulic conductivity (m/s)			Storativity	
	Min	Max	Geomean	Min	Max
Alluvium (sand, gravel)	$1.29x10^{-4}$	$2.63x10^{-3}$	$5x10^{-4}$	$3x10^{-3}$	$2x10^{-1}$
Pliocene (clayey limestone, claystone, conglomerate)	$1.86x10^{-6}$	$4.1x10^{-6}$	$2.76X10^{-6}$		
Silicified limestone (m3)	$6.47x10^{-7}$	$1.06x10^{-6}$	$8.37x10^{-7}$		
Claystone, sandstone, shale and coal seams (m2)	$6.26x10^{-8}$	$7.23x10^{-7}$	$2.34x10^{-7}$	$6.94x10^{-3}$	$8.55x10^{-2}$
Basement limestone	$9.48x10^{-9}$	$3.88x10^{-8}$	$2.35x10^{-8}$		

4.2.2. Groundwater Elevation

4.2.2.1. Areal distribution of Groundwater Elevations

To determine the groundwater flow directions and hydraulic gradients in the study area, the static water levels, measured in wells drilled in the project, in DSI wells, as well as in some private wells, along with the elevations of springs and captages are used to develop a groundwater level (groundwater table) map. The groundwater table contours developed for the study area is shown on the geogical map given in Figure 4-12.

The groundwater flow in the study area, in general, is from the elevated land in the south toward the Porsuk Stream in the north (Figure 4-12). In addition, there are also groundwater flow in western, northwestern and northeastern directions. The groundwater levels vary from 940-950 m at the elevated land in the south to 760-770 m in the vicinity of the Porsuk Stream in the north. Thus, the elevated land in the south forms the recharge area for the groundwater system. The vertical downward gradient observed in wells drilled in the 2. nested wells location in the southern part of the license area supports this hypothesis.

Although the Porsuk Stream generally forms the discharge area for the groundwater system, there is also subsurface outflow along the western boundary between the south of the study area and the Sevinç village (Figure 4-12). The hydraulic gradient increases from a value of 0.02 in the south to 0.07 toward north in the middle of the license area and afterwards decreases to 0.004 in the alluvium area of the Porsuk Stream. The rapid decrease in hydraulic gradient in the vicinity of the Porsuk stream is mainly due to the high transmissivity of the alluvium and underlying Pliocene system.

4.2.2.2. Temporal Distribution of Groundwater Levels

Groundwater levels are measured monthly in all wells after the drilling of pumping and monitoring wells. However, static water levels were not measured in October 2015 due to the purging for sampling. In addition, groundwater levels weren't measured in GK-2 well in January and February 2016 because the protection cover of GK-2 well could not be opened. The measured static groundwater levels since the completion of each well are shown in Table 4-7. As it is seen from the table, groundwater levels of GK-4 Well drilled in upper Miocene aged silicified limestones have dropped below the bottom of the filter level by falling continuously since July 2015. This well is practically dry. Groundwater level measured in PK-4 well drilled in the same unit confirms that GK-4 is dry. Groundwater levels measured right after the wells had been drilled were affected by drilling and developing activities; as a result, these measurements are not reliable.

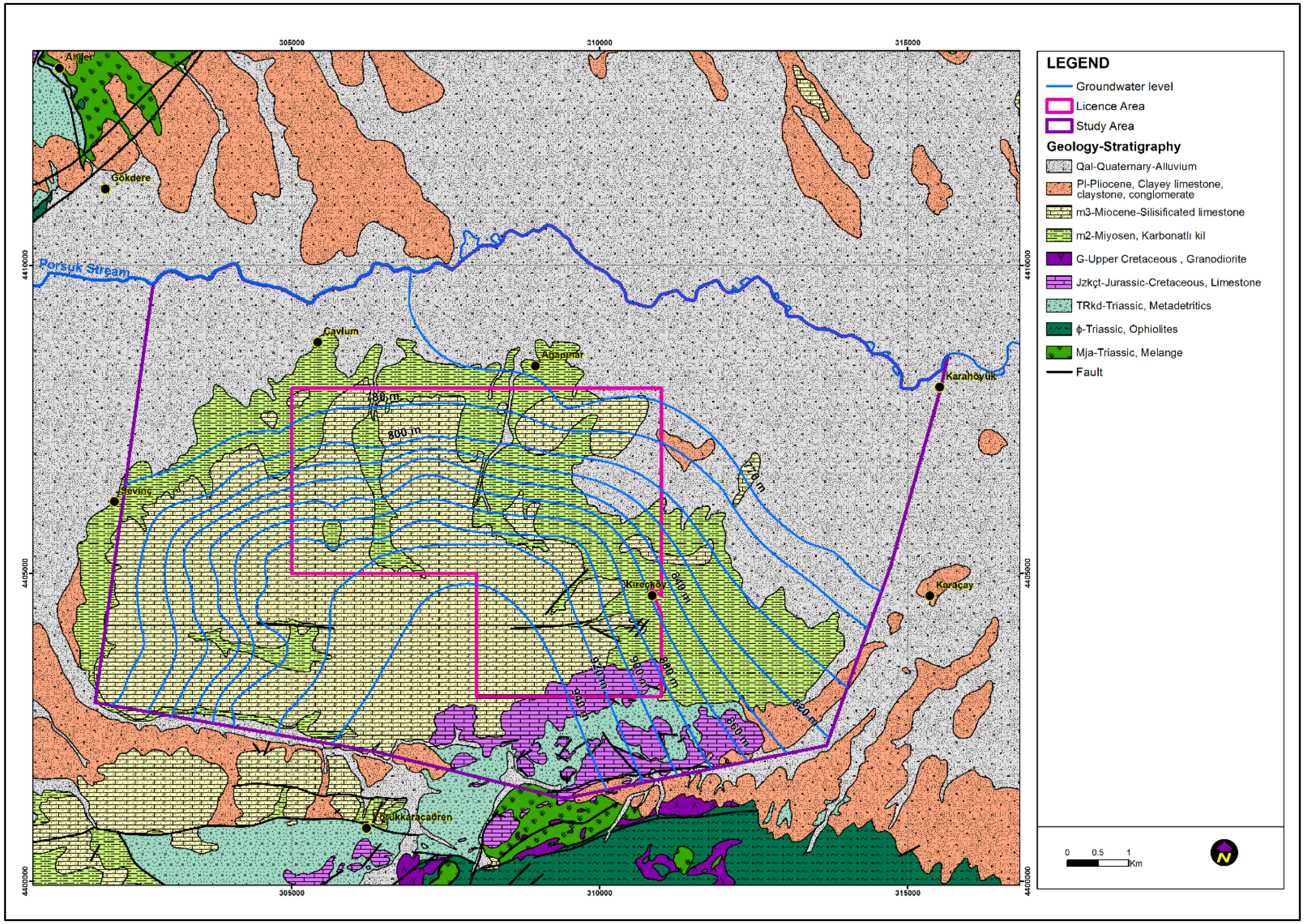

Figure 4-12: Distribution of groundwater levels on geological map

Table 4-7: Static water level depth and elevations for pumping and observation well

Well Name	Static Water Level (m) / Measured from top of the pipe)													
	20.06.2015	22.06.2015	01.07.2015	11.07.2015	14.07.2015	23.07.2015	27.07.2015	16.08.2015	20.09.2015	07.11.2015	05.12.2015	09.01.2016	06.02.2016	10.03.2016
PK-2	x	x	x	x	38.66	38.62	38.65	41.26	41.05	40.99	40.58	39.97	39.94	39.87
GK-2	x	x	x	x	x	39.42	39.44	41.06	40.87	40.88	40.21	-	-	40.00
PK-3	x	x	x	185.22	185.19	185.14	185.10	186.21	185.78	186.71	186.24	181.82	180.52	180.74
GK-3	x	x	x	146.92	146.89	146.85	146.82	146.79	146.47	146.52	146.17	146.30	146.23	146.28
PK-4	x	x	x	48.69	48.56	48.68	48.65	48.71	48.55	49.01	48.83	49.03	49.02	49.08
GK-4	x	x	x	45.96	45.99	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
PK-5	x	x	x	141.16	141.14	140.40	140.53	140.20	139.83	140.02	139.88	140.20	140.18	140.29
PK-6	7.89	7.88	8.10	7.72	7.71	7.68	7.66	5.26	5.23	5.17	4.99	4.76	4.62	4.67
GK-5	6.98	6.14	6.40	5.92	5.91	5.86	5.85	5.02	5.01	4.98	4.77	3.95	3.82	3.92
Well Name	**Groundwater Elevation (m)**													
	20.06.2015	22.06.2015	01.07.2015	11.07.2015	14.07.2015	23.07.2015	27.07.2015	16.08.2015	20.09.2015	07.11.2015	05.12.2015	09.01.2016	06.02.2016	10.03.2016
PK-2	x	x	x	x	773.89	773.93	773.90	771.29	771.50	771.56	771.97	772.58	772.61	772.68
GK-2	x	x	x	x	x	773.07	773.05	771.43	771.62	771.61	772.28	-	-	772.49
PK-3	x	x	x	809.41	809.44	809.49	809.53	808.42	808.85	807.92	808.39	812.81	814.11	813.89
GK-3	x	x	x	848.05	848.08	848.12	848.15	848.18	848.50	848.45	848.80	848.67	848.74	848.69
PK-4	x	x	x	946.60	946.73	946.61	946.64	946.58	946.74	946.28	946.457	946.257	946.267	946.207
GK-4	x	x	x	950.25	950.22	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY	DRY
PK-5	x	x	x	854.89	854.91	855.65	855.52	855.85	856.22	856.03	856.17	855.85	855.87	855.76
PK-6	793.03	793.04	792.82	793.20	793.21	793.24	793.26	795.66	795.69	795.75	795.93	796.16	796.30	796.25
GK-5	793.87	794.71	794.45	794.93	794.94	794.99	795.00	795.83	795.84	795.87	796.08	796.90	797.03	796.93

Groundwater level hydrographs developed from monthly water level monitoring data till March 2016 for all observation and pumping wells drilled in the license are shown in Figure 4-13. Precipitation data is also added to these hydrographs in order to determine the relationship between the groundwater levels measured in wells and precipitation. Since there is no meteorological station in the license area, daily precipitation data obtained from 17126 Meteorological Station of Eskisehir Regional Directorate of Meteorology till 01.01.2016 is used in order to relate them with the groundwater level changes as shown in Figure 4-13. As it is seen in this figure, while groundwater levels did not vary with respect to precipitation in some wells (such as in PK-4 and PK-5), groundwater levels increased from a minimum of 0.3 m to a maximum of 6.2 m in other wells.

The variations in groundwater levels observed in PK-2 and GK-2 wells drilled in the northeastern part of the license area are similar to each other. While groundwater levels increased 1.18 m in PK-2 well during September 2015-March 2016 period, they increased 0.87 m in GK-2 well over the same period (Figure 4-13).

No temporal variations in groundwater levels are observed in PK-4 and PK-5 wells that were respectively completed in silicified limestones and above the coal seams in the southern part of the area (Figure 4-13). In the same locality, while groundwater levels increased only 0.3 m in GK-3 well screened within the coal seams during November 2015 – February 2016 period, they increased 6.2 m in PK-3 well completed below the coal seams within the Jurassic-Cretaceous limestones over the same period. The excessive rise in groundwater levels observed in PK-3 well shows that the limestones are recharged through the outcrop zones in the south. On the other hand, no response to precipitation in observed groundwater levels in PK-4 well completed in silicified limestones can be attributed to the karstified nature of these limestones. The cavities that developed as result of karstification become avenues for the rapid circulation and discharge of groundwater through springs and captages; thereby, eliminating the storage of the water within the system. In addition, the small saturated thickness (10-11 m) and relatively deeper grounwater levels seem to support the effect of karstication explained above.

The variations in groundwater levels observed in PK-6 and GK-5 wells screened within the A-coal seams in the northwestern part of the license area are similar to each other. While groundwater levels increased 0.61 m in PK-6 well during September 2015-February 2016 period, they increased 1.19 m in GK-5 well over the same period. (Figure4-13).

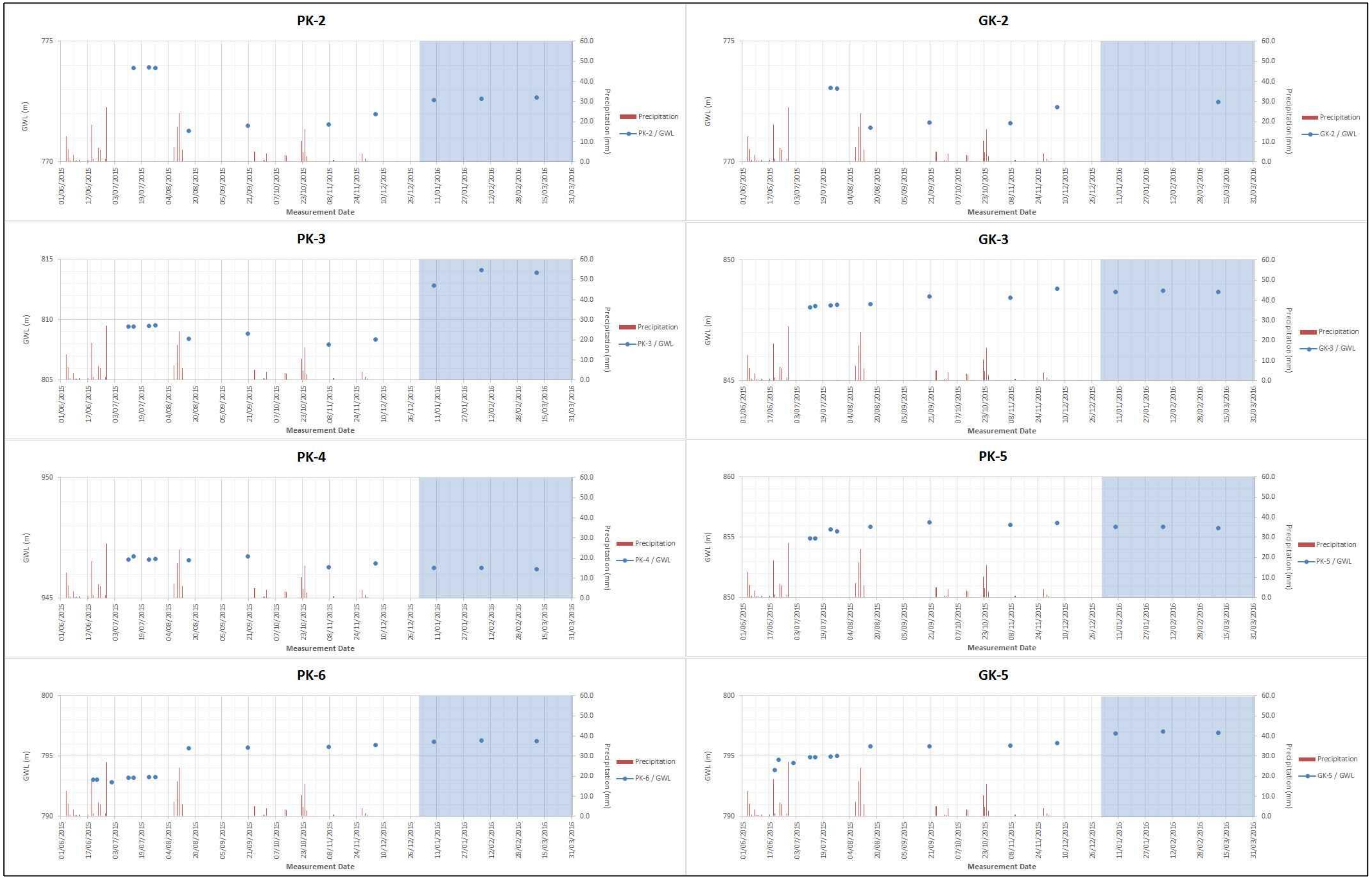

Figure 4-13: Temporal variations of groundwater levels measured at pumping and observation wells (Blue areas show the time interval with no measurements after 31.12.2015)

To investigate the hydraulic relations among layers above, within, and below the coal seams, the groundwater levels in the nested wells are shown in the same graph (Figur 4-14). In this context, hydrographs of PK-2/GK-2, PK-3/GK-3/PK-4/PK-5 and PK-6/GK-5 wells are drawn together. The groundwater levels in nested wells PK-2 & GK-2 and PK-6 & GK-5 are very similar to each other because each pair is screened within the same layer. On the contrary, the groundwater levels in nested wells located in the south are significantly different from each other because they are screened in different layers. The groundwater level has the highest elevation in PK-4 completed in silicified limestones in this location. While groundwater level in PK-5 screened above the coal seams are slighly greater than the groundwater levels in GK-3 screened within the coal seams, they are close to each other. The lowest groundwater levels are observed in PK-3 well completed below the coal seams within the Jurasssic limestones. Thus, it can be stated that there is a vertical hydraulic gradient in downward direction, producing flow from the silicified limestones to coal seams at the lower elevations and to Jurassic-Cretaceous limestones at the bottom. This phenemonen which is seen in the recharge zones proves the presence of a recharge area in the south.

Groundwater levels were not monitored to cover one hydrologic cycle (wet and dry seasons) completely due to delays encountered during the drilling of pumping and observation wells. Hence, it is recommended that the groundwater levels are monitored at monthly intervals at all pumping and observation wells in the future.

The coal seams in the license area become deeper toward the northwest. The depth to seam-C reaches to 450 m in some wells (AK036 ve AK040) in this location. The AK009 hole in this vicinity close to PK-6 and GK-5 wells has a depth of 406 m and it ended up in A-seams and did not penetrate B- and C-coal seams. To have an idea about the groundwater presssures that may be encountered during the extraction of coal seams at this depth, the groundwater pressure in GK-5 is calculated. The groundwater pressure at mid-screen level corresponding to a depth of 381 m (below A3 coal seam) is 3.7 Mpa. The expected groundwater pressure below the coal seams at a depth of 450 m is about 4.4 Mpa assuming that no vertical gradient exists from bottom to top. The groundwater pressures below the C-coal seams at the location of GK-3 well in the south however is relatively smaller (1.7 Mpa).

The calculated groundwater pressures below the coal seams are excessive and may cause groundwater inrush into galleries or pits during mining activities in addition to stability problems; hence, they have to be taken into account. Therefore, it is necessary to conduct both theoretical as well as field studies to determine the extent that groundwater pressures can be lowered for safe mining.

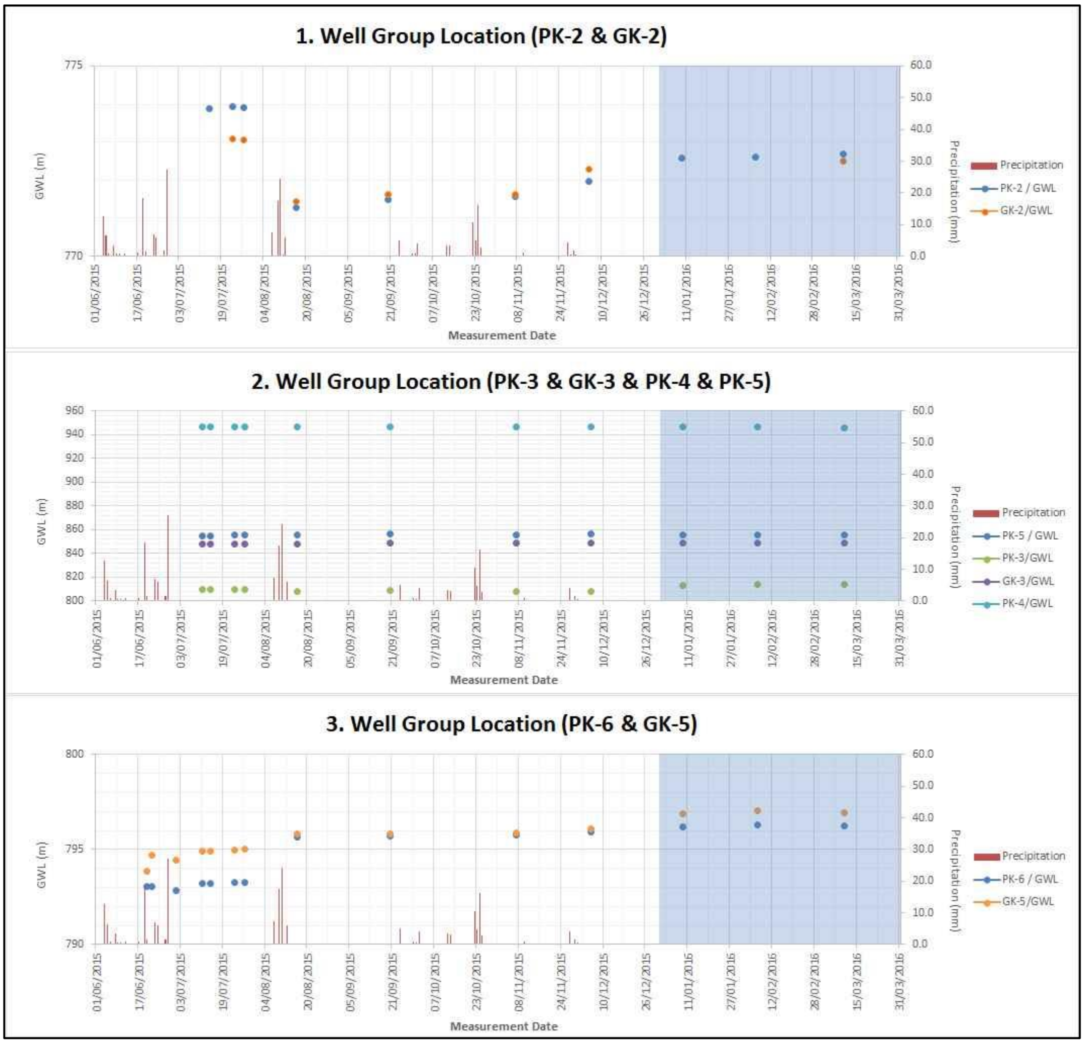

Figure 4-14: Temporal variations of groundwater levels at well groups (Blue areas show the time interval with no measurements after 31.12.2015)

4.3. Conceptual Groundwater Budget

It is necessary to know the groundwater budget for the study area prior to mining activities so that the impacts on groundwater budget during and after the mining activities can be assessed properlyThere are different methods to calculate groundwater budget, including numerical models. Whatever method is used, obtained results should be compared with conceptual groundwater budget estimated using the basic hydrogeological data. Hence, the recharge and discharge components as well as their quantities are calculated to develop a conceptual groundwater budget for the study area.

The study area has 95.6 km^2 surface area. It is considered that there are two components of the recharge within the area. One of them is infiltration from precipitation and the other is the infiltration from surface runoff. According to the conceptual water budget developed in Section 3.3, 12.8% (51.9 mm/year) of the total precipitation (404.4 mm/year) infiltrates into ground. In the light of this data, recharge amount from direct precipitation is calculated as $4.96x10^6$ m^3/year. Surface runoff from elevated parts of the study area infiltrates into ground at the lower elevations. In order to calculate this recharge component, surface runoff that occurs at the elevated areas (31 km^2) above the median elevation (885 m) ın the study area is calculated first. According to water budget, 8.5% of the precipitation (34.4 mm/year) converts into the surface runoff. Thus, the total surface runoff from the elevated areas above 885 m of elevation is calculated as $1.07x10^6$ m^3/year and this amount of surface runoff infiltrates into the ground at the lower elevations. Consequently, the total annual recharge was calculated as $6.03x10^6$ m^3/year for the study area (Table 4-8).

Table 4-8: Conceptual Groundwater Budget of the study area

RECHARGE (m^3/year)		DISCHARGE (m^3/year)	
Recharge from rainfall	4.96E+06	Discharge from springs and catchments	4.73E+05
Infiltration from surface runoff	1.07E+06	Base flow to Porsuk Stream	1.20E+06
		Well Discharge	2.34E+06
		Evaporation-Transpiration	1.91E+06
		Lateral outflow	1.05E+05
TOTAL	6.03E+06	TOTAL	6.03E+06

Discharge from the study area occurs from springs and captages, base flow to the Porsuk Stream, pumpage from wells, evaporation-transpiration losses from groundwater and lateral subsurface outflow.

Discharge from springs and captages are calculated based on discharge measurements and observations of springs and captages as given in Section 4.1.2. In the study area, the average total discharge from seven springs (F1, F2, F3, F4, F5, F6, F7) and four captages (K1, K2, K3, K4) is 15L/s; therefore, thetotal discharge from springs and captages is calculated as 4.73×10^5 m^3/year.

The Porsuk Stream which forms the northern boundary of the study area is recharged from the groundwater. In other words; a part of the base flow of the Porsuk Stream is met from groundwater from the study area. In order to determine discharge to the Porsuk Stream from the study area, the flow measurements at Ağapınar and Süleymaniye flow gauging stations were used, the details of which were given in Section 4.1.1. According to the calculations made, discharge amount to the Porsuk Stream from the study area is (0.038 m^3/s) 1.20×10^6 m^3/year.

Pumping from DSİ and privatel wells for irrigation purposes and from village water supply wells and some private wells for drinking and domestic water water use constitutes the annual total discharge from wells. Detailed information about DSI wells, village water supply wells and private wells were given in section 4.1.3; hence, only pumpage quantities from these wells will be discussed herein. Five DSİ wells (44130, 55322, 55323, 55324, and 55325) are used for irrigation of the 189 ha area of Kireçköyü Irrigation Cooperative; and the quantity of pumpage allocated for them is 9.90×10^5 m^3/year. Eighty seven private wells were determined during field studies conducted in the study area. Eighty two of them are used for agricultural irrigation. In order to calculate the pumpage amount from these wells, the coordinated private wells were put on the Google Earth image of 07.05.2015 and the irrigated area by each well is determined. The analysis results show that the area irrigated by 82 private wells is 241 ha. To calculate the pumpage amount needed to irrigate this area, the amount of pumpage allocated to the Kireçköy Irrigation Cooperative to irrigate 189 ha is proportioned using the irrigated areas. Accordingly, the total discharge amount from the private wells in the study area is $1.26X10^6$ m^3/year. The pumpage amount from the village and private wells used for drinking, domestic and animal watering is not significant and this amount was calculated as $9.00x10^4$ m^3/year. Consequently, the total pumpage from the wells in the study area is $2.34X10^6$ m^3/year.

Evaporation and transpiration losses from shallow groundwater (1-2 m below ground surface) may become an important source of discharge; hence should be considered while calculating the groundwater budget. Especially at the valley bottoms and eastern side of the study area (around the Ören çeşme), the losses from the groundwater system through evaporation and transpiration occur.. To calculate these losses, groundwater contours were extracted from the digital elevation model to determine the area (total 6 km^2) where the groundwater is 1 m below the ground surface. According the conceptual water budget given in Section 3.2, 78.7% (318.1 mm/year) of the total precipitation (404.4 mm/year) is lost with evaporation-transpiration. Accordingly, the evaporation-transpiration loses from the 6 km^2 area is $1.91X10^6$ m^3/year.

The other discharge component from the study area is lateral subsurface outflow along a line of 2.9 km, extending from south to the the Sevinç Village along the western border of the study area. Darcy's Law was used to determine the lateral outflow. Groundwater contour map (Figure 4.12) was used to calculate the hydraulic gradient (0.038). Lateral outflow amount is calculated as $1.05x10^5$ m^3/year byusing an average depth of 300 m and a hydraulic conductivity of $1X10^{-7}$ m/s.

The conceptual groundwater budget of the study area is summarized in Table 4.7. Total recharge amount, ($6.03x10^6$ m^3/year), is equal to the total discharge amount in the study area where the equilibrium conditions were accepted. The components of this budget as well as their quantities may change as a result of dewatering and/or depressuration activities that may take place during mining.

The groundwater budget conceptually estimated is subject to certain assumptions. A groundwater numerical model is needed to validate these assumptions, to investigate in detail the hydraulic relations between various aquifers, and to simulate the response of these systems to different conditions.

4.4. Existing and Planned Groundwater Usage

The groundwater in the study area is mainly used to meet the drinking and domestic water needs of the settlements as well as to supply irrigation water requirements. The groundwater for industrial use is pumped at the Organized Industrial District located near the western boundary of the study area. Apart from these, groundwater is used in limited quantities at a few operations and watering for animals in a few barns. The springs, captages and wells in the study area can be seen in Figure 4-15 on the topographical map. No planned groundwater usage is available within the license area.

The Ağapınar, Çavlum, Sevinç ve Kireçköy villages meet an important part of their drinking and domestic water needs from captages developed within the license area boundaries. Additionally, Ağapınar, Sevinç ve Kireçköy villages meet part of their drinking and domestic water needs through pumping wells. The groundwater captages and wells supplying water to the settlements are likely to be negatively impacted from the mining activities. Hence, planning of the studies for finding alternative sources of water supply to these settlements is recommended. Futhermore, it is also recommended to conduct detailed studies to determine the alternative sources of water supply for the mining activities.

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Additionally, the impacts of mining activities on irrigation and industrial water usage in the area should be assessed though groundwater modelling studies.

4.5. Thermal Water Resource

No area with thermal potential has been encountered in the study area. However, there are four geothermal areas nearby the study area which have water temperatues ranging between 26°C and 45°C. The most important of them is Alpu-Uyuzhamamı geothermal field which is located at the 15 km east of the study area. This field has one source with 30°C and it is used for the spa. Kızılinler and Hasırca geotermal fields are located at 20 km west of the study area. Kızılinler geothermal field has 5 sources with temperatues ranging between 30°C and 45°C and are used for balneology and swimming pools. Hasırca geothermal field has 4 sources with temperatues ranging between 30°C and 33.5°C and are used for Kızılay Atatürk Youth Camp and in a small fish pool. The last one is Aşağıılıc gjeothermal field which is located at 20 km northwest of the study area. This field is not used for anything due to the low temperature of the sources (26-27°C) (MTA, 2015).

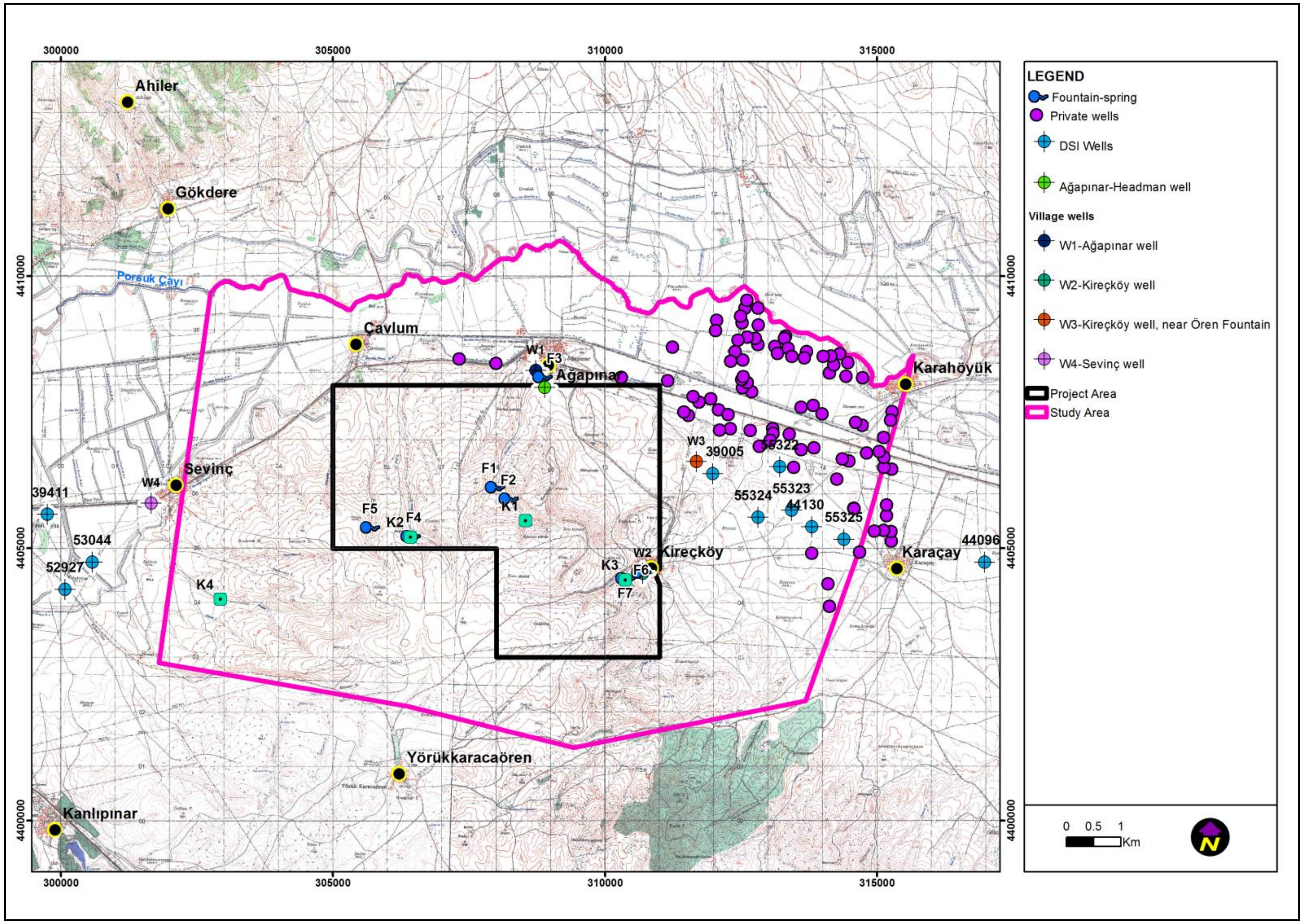


Figure 4-15: Water supply points around study area and its vicinity

CHAPTER 5

HYDROCHEMISTRY AND WATER QUALITY

5.1. Data Collection and Quality Control

5.1.1. Data Collection

Field works related to the hydrochemical monitoring program have been carried out between December 2014 and February 2016 on the monitoring locations (Table 5.1 and Figure 5.1). It was not possible to monitor SW1, SW2 and W1 locations because no flow has been observed in these locations during the monitoring period and W1 well location was not suitable for water sampling. Temperature (T), electrical conductivity (EC), total dissolved solids (TDS), salinity (S), pH, oxidation-reduction potential (ORP), dissolved oxygen (DO) and fountain discharge measurements were carried out during the monthly monitoring program for waters of stream, fountain, spring, well and village water depots. Because special pumpage is required for PK coded wells to purge, monthly monitoring of field parameters for these well waters were not carried out.

Table 5-1: Hydrochemical monitoring locations

STATION NO	LATITUDE	LONGITUDE	EXPLANATION
F1	307979	4406132	Ağapınar, Çürüksu creek; spring (monitoring from fountain)
F2	308227	4405919	Ağapınar, Çürüksu creek; spring (monitoring from fountain)
F3	308850	4408153	Ağapınar; D1 water depot (monitoring from fountain in the village)
F4	306427	4405230	Çavlum, Akpınar creek; spring (monitoring from discharge of depot on spring)
F5	305681	4405393	Çavlum, İnönü creek; spring (monitoring from fountain)
F6	310369	4404456	Kireçköyü; spring (monitoring from fountain)
F6D	310605	4404377	Kireçköyü; depot (monitoring from nozzle on pipe in the depot)
F7	310666	4404564	Kireçköyü; F6D water depot (monitoring from fountain)
W1	308730	4408265	Ağapınar; well feeds D1 depot, no sampling
W2	310689	4404546	Kireçköyü; well (monitoring from nozzle on pipe)
W3	311678	4406595	Kireçköyü NE; well nearby Ören fountain, artesian
PK2	309452	4407540	Above coal (AC) siltstone-sandstone-conglomerate, in coal (IC) claystone-shale-coal and below coal (BC) siltstone
PK3	308187	4404292	BC limestone
PK4	308208	4404293	AC silicified limestone
PK5	308190	4404303	AC siltstone-sandstone-conglomerate
PK6	305689	4407799	IC siltstone and coal
D1	308645	4407782	Ağapınar, water depot (monitoring from nozzle on pipe in the depot)
D2	306093	4407634	Çavlum, water depot (monitoring from outside discharge)
D3	310545	4404295	Kireçköyü, water depot (monitoring from village mosque fountain)
SW1	308474	4407371	Ağapınar; on Çürüksu creek
SW2	310367	4404474	Kireçköyü; on Pınar creek
SW3	312750	4409550	Porsuk stream; downstream of study area
SW4	304150	4409700	Porsuk stream; upstream of study area

In addition to the measurement of parameters listed above; waters from all monitoring locations and sediments from upstream and downstream locations of Porsuk stream were sampled in May 2015 (wells PK-3, PK-5, PK-6 in July and PK-2 in August after drillings) and in November 2015 (PK-2, PK-3, PK-4, PK-5 and PK-6 in October) representing the dry and wet periods, respectively, by the staff of TÜRKAK accredited ARTEK (wet period) and ALKA (dry period) laboratories. These samples were chemically analysed by the laboratories. Chemical parameters for the analyses were determined using the water body (stream, groundwater, water depot etc.) related regulations (İSYSKY 2012, İTAS 2005, SKKY 2008, YKBKK 2012, YSKYY 2012, YSYSİY 2014, YSKYYD 2015) and the previously submitted monitoring report.

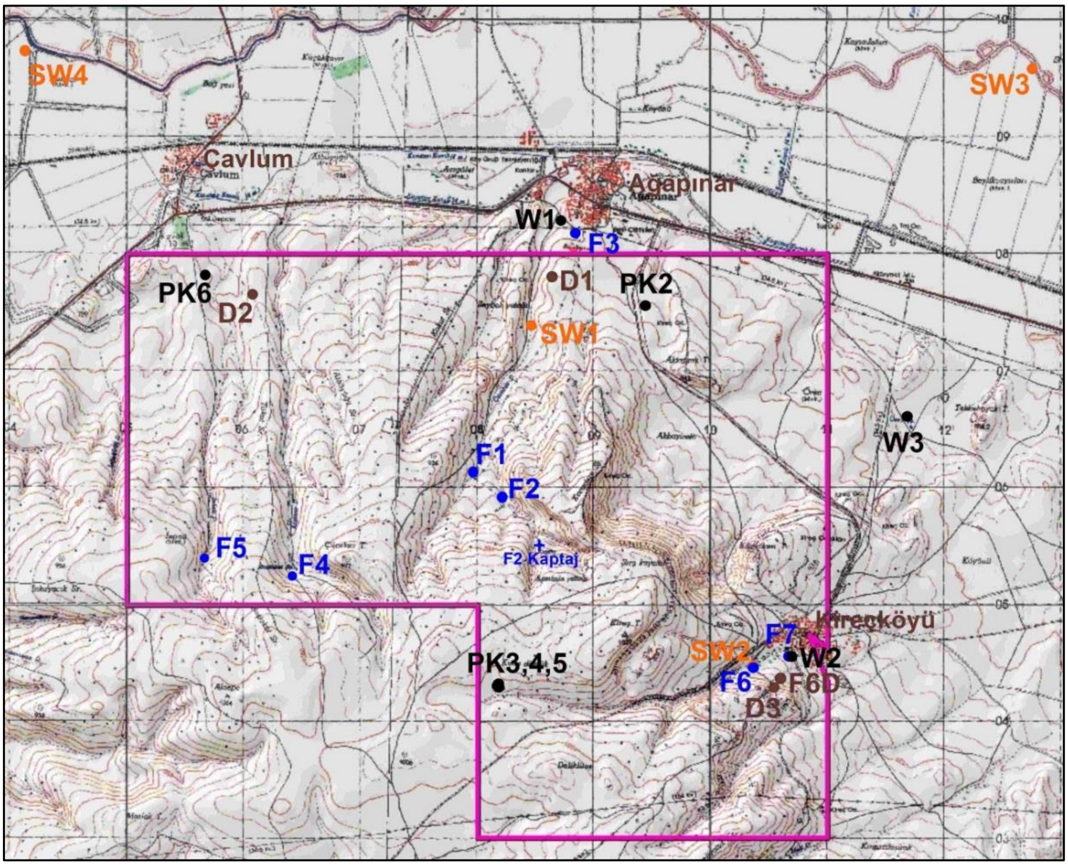


Figure 5-1: Distribution of hydrochemical monitoring locations

5.1.2. Quality Control

The standard and replicate measurements related to the measurement quality of field parameters indicate that the following error percentages are associated with these measurements: EC 1.0%, pH 0.3%, dissolved oxygen 1.1% and ORP 4.4%.

Duplicate samples under different names (May 2015 period; F4-F10, SW4-SW7 and November 2015 period; F3-Y1, W2-Y2) were submitted to the laboratories in order to perform quality evaluations for the reported values. Evaluations of the analytical results (APPENDIX-D) suggest about 6.6% average deviation if bacteriological parameters are excluded. The average deviation percentages estimated using duplicate samples are listed in Table 5-2. Deviations in Al, As, B, Cr, Cu, Fe, Mn and Zn parameters (47%, 21%, 27%, 67%, 49%, 78%, 48% and 49%, respectively) of the wet period and Al, COD, Fe, TKN, N-NO2, Pb and Zn parameters (26%, 35%, 31%, 26%, 35%, 34% and 22%, respectively) of the dry period are much higher than those of the other parameters. When these high measurements are excluded the average deviation of all parameters lowers to about 2.4%. When only parameters (Al, Fe and Zn) that show high deviations in both monitoring periods are excluded, the average deviation becomes about 4.8%. Duplicate sample results of organic parameters (excluding pesticides and oil & grease) are all below detection limits.

Table 5-2: Average error percentages estimated from duplicate measurements

Parameter	Error%	Parameter	Error%	Parameter	Error%
Ag	5.0	Fe	54.5	NH3	2.8
Al	36.5	P,reac	2.7	P-PO4	0.1
Alk.(t)	4.6	Hg	0.0	Pb	25.4
As	13.0	K	1.2	P	0.1
B	14.1	Li	2.8	Sb	0.0
Ba	9.8	Mg	1.7	Se	0.0
Be	0.0	H2S	0.0	Si	2.9
Bi	0.0	Mn	24.1	Sn	8.3
Ca	4.3	Mo	0.0	SO4	0.8
Cd	0.0	TKN	16.3	S	0.0
Cl	2.4	N(Org)	20.5	Sr	3.4
CN	0.0	Ortho-P	2.7	Ti	0.0
Co	0.0	Na	4.1	Tl	0.0
COD	23.1	Ni	1.6	TOC	0.0
Cr	33.3	N-NH4	0.0	U	0.0
Cu	24.7	N-NO2	19.0	V	7.8
F	9.8	N-NO3	0.9	Zn	35.7
Turbidity	5.4	Oil&grease	8.0	f-Streptecoc	5.9
Color	3.9	Coli-f	5.3	E-Coli	9.1
Pesticides	6.0	Coli-t	31.6	Enterococ	5.9

Zero error in the list indicates below detection limit measurements.
All organic parameters that are not shown in the list have below detection limit values (error% 0.0).

The average ionic charge balance error calculated using all measurements is about 5.8%. When the data of relatively high balance error including samples (May period of PK-5; 36%, W2; 23%, PK-6; 18% and November period of PK3; 21%) are excluded, the charge balance error reduces to about 3.7%.

Quality control evaluation results indicate that measurements performed in the field as well as in the laboratories are reliable and could be used for hydrochemical evaluations. Duplicate samples suggest that evaluations related to high deviation including parameters (Al, Fe and Zn) in all periods and additionally COD, Cr, Cu, Mn, N (org), NO2 and Pb parameters should be carried out carefully.

5.2. Surface Water Hydrochemistry

5.2.1. Field Measurements

The results of hydrochemical field parameter measurements in two monitoring locations of Porsuk stream are given in APPENDIX-E and average values (AV) together with average deviations (ADEV) are listed in Table 5.3. No flow was observed in the locations of SW1 and SW2 during monitoring period. The characteristic values of surface water field parameters are estimated in 95% confidence interval and additionally for pH in 5% interval (Table 5.4) according to the methodology and criteria (first three years: less than 10 measurements arithmetic average; 11-19 measurements Hazen method and greater than 19 measurements Weibull method) stated in the surface water quality regulation (YSKYY, 2012).

Table 5-3: Average (AV) and average deviation (ADEV) values of hydrochemical field parameters measured in Porsuk stream

AV (ADEV)	T(oC)	pH	ORP (mv)	EC 25oC (µS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%
SW3	14.6(4.6)	8.15(0.12)	130(34)	903(52)	0.44(0.03)	587(33)	4.3(1.08)	47(13.0)
SW4	14.0(4.8)	8.12(0.19)	124(22)	904(90)	0.45(0.05)	588(59)	2.6(1.22)	28(13.4)

Table 5-4: Characteristic values of hydrochemical field parameters measured in Porsuk stream

No	Method	T(oC) %95	pH %95	pH %5	ORP (mv) %95	EC 25oC (µS/cm) %95	S (ppt) %95	TDS (mg/l) %95	DO (mg/l) %95	DO% %95
SW3	HAZEN	23.0	8.45	7.96	190	1020	0.50	663	5.66	68
SW4	HAZEN	21.4	8.55	7.86	174	1033	0.51	671	6.19	62

Average values of T, EC, pH, DO and ORP parameters are shown in Figure 5.2. EC values are similar (903-904 μS/cm) in the upstream and downstream locations. TDS and salinity average values estimated using EC measurements are about 587 mg/l and 0.44 ppt, respectively.

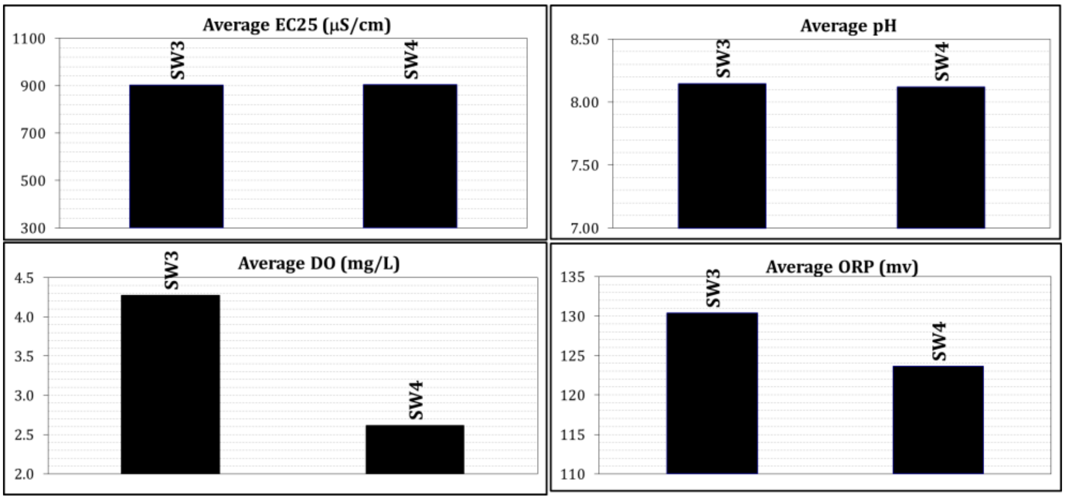


Figure 5-2: Average pH, EC, DO and ORP values measured in Porsuk stream

Porsuk stream water is in basic character and monitoring period averages of pH values (SW4; 8.12 and SW3; 8.15) are similar in both locations with slight increase toward downstream.

Average dissolved oxygen concentrations are very low in the stream water and exhibit increasing trend from upstream (SW4 location; 2.6 mg/l) to downstream (SW3 location; 4.3 mg/l). The difference between the upstream and downstream locations probably suggests that either DO consuming reactions are missing in SW3 location or relatively high DO including groundwater feeds the stream water between the locations.

The stream water shows oxidizing character with average ORP values of 130 mv and 124 mv in SW4 and SW3 locations, respectively. The oxidizing value decreases slightly toward downstream.

Monitoring period percent changes in the field parameter values are shown in Figure 5.3 as percent average deviation (PAD=ADEV*100/AV) which is determined after the measurement percent error subtraction. The averages of percent average deviations from higher to lower values were determined in dissolved oxygen (35%), temperature (33%), ORP (18%), EC (7%) and pH (1.6%) parameters.

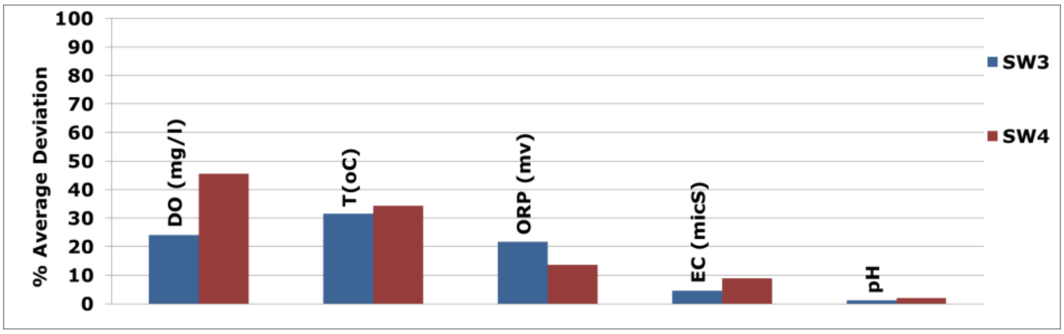


Figure 5-3: Percent average deviations of the field parameters measured in Porsuk stream waters

Monthly changes of the field parameters in the stream water are shown in Figure 5.4. The chemical content of the stream water is affected not only by natural processes but also by many anthropogenic discharge sources as it flows through different basins. Therefore evaluations of monthly value changes due to natural processes should be based on the assumption that anthropogenic inputs are nearly constant. The explanations in this section are based on this assumption.

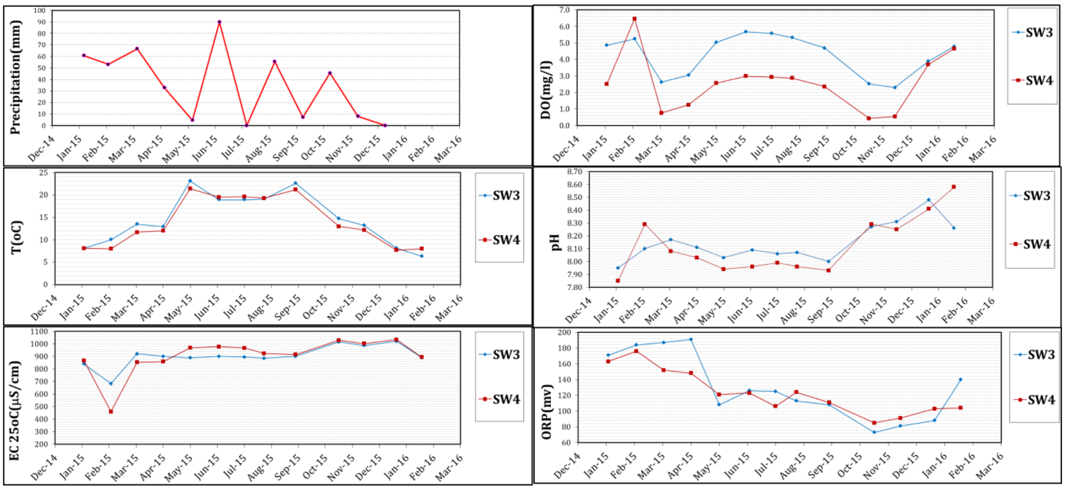


Figure 5-4: Monthly changes of temperature, pH, EC, DO, ORP values in Porsuk stream and precipitation distribution

In order to determine the effect of precipitation on the field parameters, averages and average deviations between the dry period (2015 May, July, September, December) and the wet period [2014 December; 2015 January, February, March, April, June, August, October, November (although it is a dry month, the data were collected early days of the month and October was wet), 2016 January, February] were calculated and are listed in Table 5.5 together with the decreasing/increasing/unchanging trends which were determined after the measurement percent error subtraction. As a general trend, EC values increase after February 2015, exhibit little change between April and September, increase after September again with little change between November and January and finally decrease in 2016 February to the values of pre-September.

Table 5-5: Average (average deviation) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of field parameters between dry and wet periods at upstream and downstream locations of Porsuk stream

Dry-Wet AV(ADEV)	T(oC)	pH	ORP (mv)	EC (μS/cm) 25C	DO (mg/l)
SW3	15.9(3.5)AZ	8.13(0.03)AR	123(18)AR	907(11)AZ	4.3(0.09)AZ
SW4	15.3(3.3)AZ	8.09(0.07)AR	119(12)AR	921(43)AZ	2.5(0.37)AR

The trend indicates that as precipitation decreases, EC value increases. EC parameters with 2% average deviation between the periods of dry months and wet months decrease in the wet months. pH values decrease between 2015 March and May, show little change between May and September and increase between September and February 2016 as a general trend. It is possible to reversely relate the monthly changes observed in pH values to that of temperature. This indicates that rather than changing reaction types, pH changes are related to the effects of temperature on the existing reaction relations. pH values with 0.3% average deviation between periods of dry months and wet months increase in wet months. The values of dissolved oxygen in general increase between March and July, decrease between July and October and increase between December and February 2015. The trend in general is proportional to that of temperature. The DO values with 14% average deviation between periods of dry months and wet months increase in the wet period at the upstream and decrease with 1% deviation at the downstream. The decrease between February and May, little change between May and August, decrease between August and November and increase after November of ORP values in general are linearly correlate with precipitation. ORP values of wet-dry periods with 7.8% average deviation increase in the wet period. Average percent deviation of all parameters (excluding temperature) is about 4.4%. Variations of EC, pH and DO parameters between the dry and wet periods are relatively low.

5.2.2. Laboratory Measurements

The results of detailed chemical analyses from Porsuk stream monitoring locations are given in APPENDIX-F and average values together with average deviations (ADEV) are listed in Table 5.6 which also includes the decreasing/increasing/ unchanging concentration trends (which were determined after the measurement percent error subtraction) between the dry and wet periods.

Table 5-6: Average (AV), average deviation (ADEV) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of laboratory parameters between dry and wet periods in upstream and downstream locations of Porsuk stream **(Unit: mg/l, turbidity: NTU, color: pt/co, bacteriological: cfu/100 mL)**

AV(ADEV) Dry-Wet */AR/AZ	SW3	SW4	AV(ADEV) Dry-Wet */AR/AZ	SW3	SW4
Ag	0.0005*	0.0005*	**N-NO2**	0.253(0.057)AR	0.103(0.077)AR
Al	0.079*	0.056(0.041)AZ	**N-NH3**	3.67*	4.23*
Alk.(t)	369(37)AZ	362(24)AZ	**N-NO3**	0.51(0.23)AR	0.19(0.17)AR
Turbidity	15.5(1.3)AZ	13.4(3.1)AR	**Pb**	0.0130*	0.0030*
As	0.007*	0.013(0.003)AZ	**P**	1.819(0.381)AR	2.466(0.664)AR
B	0.229*	0.430(0.170)AR	**Sb**	0.002*	0.002*
Ba	0.085(0.014)AZ	0.080(0.014)AZ	**Se**	0.005*	0.005*
Be	0.00004*	0.00004*	**Si**	8.49(0.45)AZ	7.42(0.70)AZ
Bi	0.01*	0.01*	**Sn**	0.001*	0.002*
Ca	65.29(7.12)AZ	75.77(12.58)AZ	**SO4**	76.67(9.34)AR	78.59(16.42)AR
Cd	0.1595(0.1565)AR	0.0002*	**Sr**	0.405(0.038)AZ	0.411(0.017)AZ
Cl	71.84(11.64)AZ	77.74(5.74)AZ	**TDS**	495*	483(23)AZ
CN	0.01*	0.01*	**Ti**	0.0020*	0.0002*
Co	0.0005*	0.0005*	**Tl**	0.003*	0.003*
COD	61*	83(27)AZ	**TOC**	5.9(4.9)AZ	6.6(5.6)AZ
Color	19.6(1.6)AZ	23.6*	**U**	0.0035(0.0005)AR	0.0035(0.0005)AR
Cr	0.004*	0.0020*	**V**	0.003*	0.003*
Cu	0.003*	0.0030*	**Zn**	0.044(0.032)AR	0.019*
F	0.25(0.04)AZ	0.20(0.10)AZ	**Oil&grease**	0.22*	0.16*
Fe	0.072*	0.052*	**Benzene**	0.00084*	0.00084*
P,reac	0.833(0.453)AZ	1.046(0.626)AZ	**-PAH**	0.00100*	0.00100*
Hg	0.00008*	0.00008*	**-Pesticides,t**	0.00007(0.00006)AR	0.00014(0.00006)AR
K	10.809(2.041)AZ	12.975(1.945)AZ	**-VOC**	0.0034*	0.0034*
Li	0.040(0.022)AZ	0.020*	**1,2-dichloroethane**	0.0006*	0.0006*
Mg	50.77(3.98)AZ	56.12(7.72)AZ	**Surface reac mat.**	0.025(sm)	0.025(sm)
H2S	0.01*	0.01*	**-PSAH**	0.00005*	0.00005*
Mn	0.0505(0.0305)AZ	0.0510(0.0140)AZ	**-Phenols**	0.00052*	0.00030*
Mo	0.003*	0.001*	**Benzo(a)pyrene**	0.00005*	0.00005*
TKN	8.03(1.38)AR	10.11(2.34)AR	**BOD5**	15.1*	21.3(10.2)AZ
N(Org)	3.61(2.21)AZ	4.95(2.81)AZ	**Coli-f**	50100(49900)AZ	50500(49500)AZ
OrthoP	1.31(0.15)AZ	1.55(0.27)AZ	**Coli-t**	50200(49800)AZ	51250(48750)AZ
Na	62.24(9.80)AZ	74.58(11.53)AZ	**f-Streptecoccus**	50075(49925)AZ	50400(49600)AZ
Ni	0.0165(0.0025)AR	0.0140(0.0030)AR	**E-Coli**	50150(49850)AZ	50600(49400)AZ
N-NH4	3.89(3.06)AR	4.48(4.47)AR	**Enterococcus**	150(sm)	800(sm)

- Parameters grouped with respect to quality limits. sm: single measurements.

The unchanging trend shown "*" symbol in the table reflects the conditions that either ADEV value is less than the measurement error (determined from the duplicate samples) or is less than the detection limit. Water facies of Porsuk stream as determined from relative major ion concentration distributions are shown in Figure 5.5. The stream includes mixed-HCO_3 type of water in both monitoring locations. The distributions of major ion concentrations are similar as shown in Schoeller graph (Figure 5-6). The downstream water is more diluted than the upstream water and this probably indicates that the stream is fed by groundwater between the upstream and downstream locations. Mixing calculations based on chloride concentrations of PK4 (silicified limestone), PK5 (siltstone-sandstone-conglomerate) well waters or the spring waters as potential groundwater input components suggest that about 91-92% SW4 upstream water and about 8-9% groundwater mixing is required for the formation of SW3 downstream water.

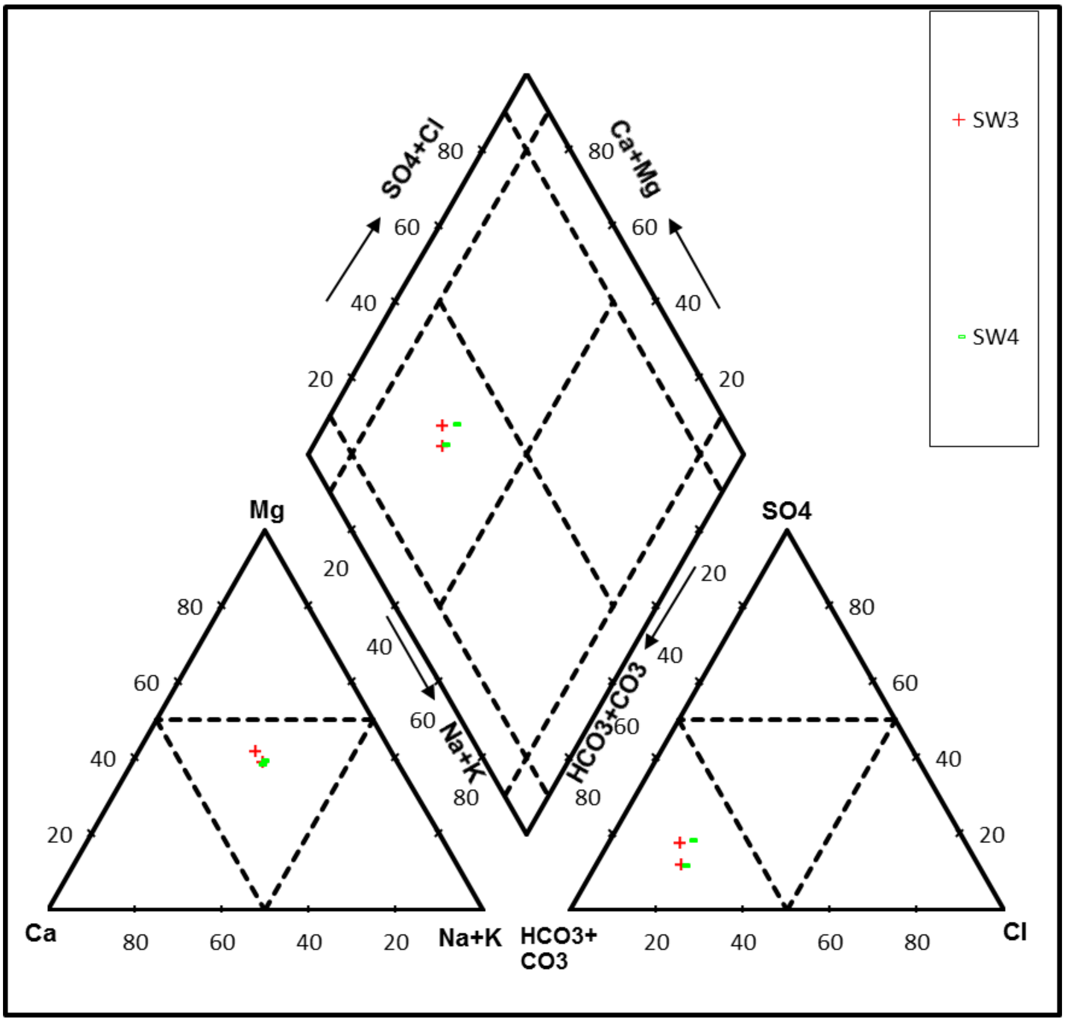


Figure 5-5: Relative major ion concentration distribution in Porsuk stream waters on Piper graph

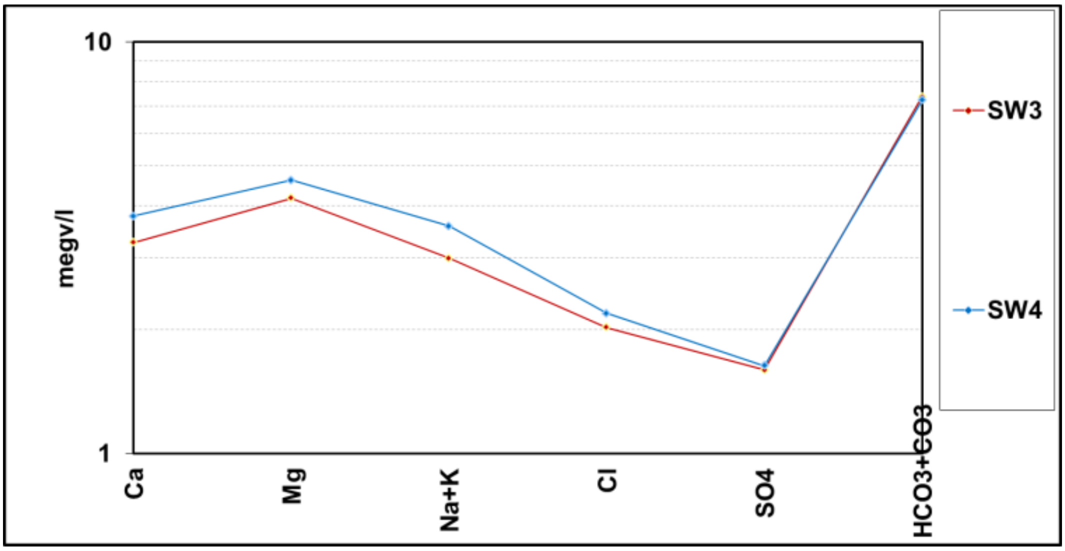


Figure 5-6: Major ion average concentration distribution in Porsuk stream waters on Schoeller graph

The comparison of parameter average concentrations (which are greater than the detection limits) at upstream and downstream locations of Porsuk stream is shown in Figure 5-7. Among the organic parameters which are not shown on the figure, above detection limit values were measured only for pesticides (SW3 and SW4 locations May measurement trifluralin 0.12 µg/l and 0.18 µg/l, respectively and SW3 location November measurement atrazin 0.01 µg/l), nonylphenol (SW3 location November measurement 0.52 µg/l) and oil&grease (November measurement 0.16-0.22 mg/l) parameters. Concentrations of Ag, Be, Bi, Co, CN, Hg, H_2S, Sb, Se and Tl parameters are below the detection limits in both monitoring locations. From upstream to downstream; Al, Cd, Cr, F, Fe, Li, Mo, Pb, Ti and Zn average concentrations increase, As, B and Sn values decrease and the others show very little change.

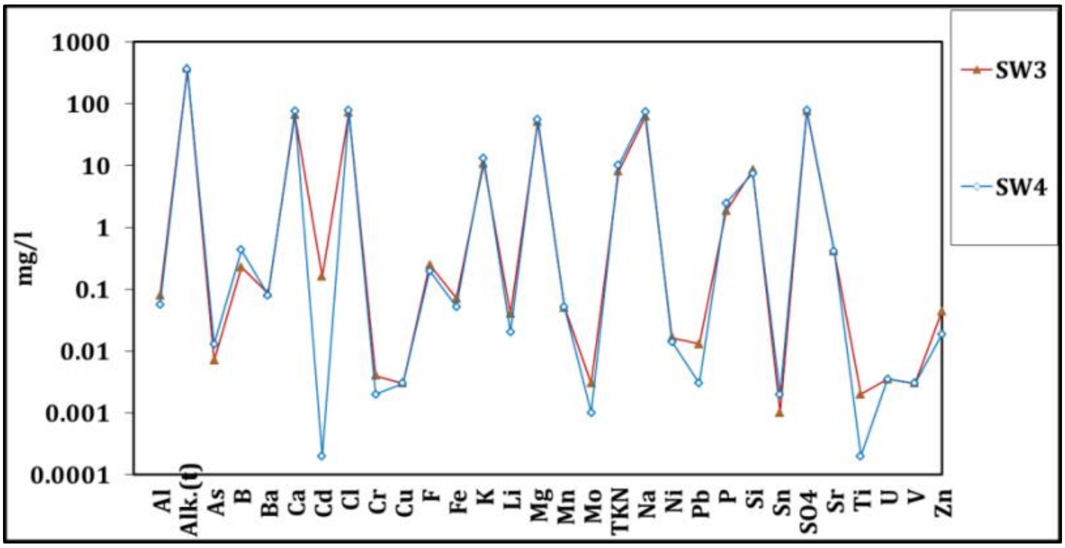


Figure 5-7: Average ion concentration distribution in Porsuk stream waters

There is no hydrochemical water facies difference between the dry and wet periods. Concentration changes of inorganic parameters between the periods are determined as percent average deviations and plotted on Figure 5.8 after the measurement error percent is extracted. As shown in the figure, other than Ag, Be, Bi, Cd, CN, Co, Cr, Cu, Fe, Hg, Li, Mo, Pb, Sb, Se, Sn, Ti, Tl, V and Zn concentrations in the upstream location (SW4) and Ag, Al, As, B, Be, Bi, CN, Co, COD, Cr, Cu, Fe, Hg, Mo, Pb, Sb, Se, Sn, Ti, Tl and V concentrations in the downstream location (SW3), parameters exhibit variations. The variations in parameter concentrations according to the percent average deviations from higher to lower are: in the upstream location NH4, NH3, NO3, TOC parameters 100-55%; F, Al, P, B, SO4 and Ni parameters 39-20% and others 14-1%; in the downstream location Cd, TOC, NH4, NH3 parameters 98-79%; Li, NO3, Zn and Mn parameters 52-36% and the others 21-1%. The average of all parameters indicates 16% and 14% deviations for the upstream and downstream waters, respectively, between concentrations of the dry and wet periods.

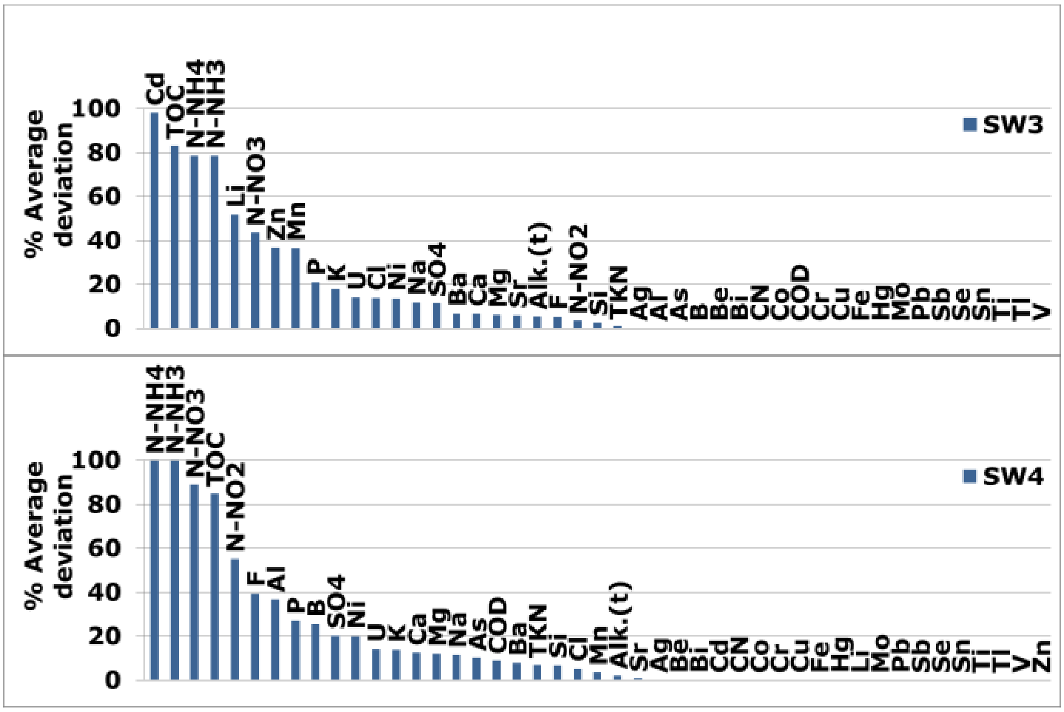


Figure 5-8: Percent average deviations of concentrations from the monitoring period average in Porsuk stream waters

According to the increasing/decreasing/unchanging trends between the dry and wet periods (Table 5-6), concentrations of Ni, TKN, NH4, NO2, NO3, P, SO4, U and pesticide parameters are higher and the concentrations of alkalinity, Ba, Ca, Cl, F, reactive P, K, Mg, Mn, Norg, orto-P, Na, Si, Sr, TOC and bacteriological parameters are lower in the wet period on both locations.

5.2.3. Sediment Chemistry

The results of detailed chemical analyses measured in Porsuk stream sediment samples from upstream (SW4) and downstream (SW3) locations are given in APPENDIX-F. The average and average deviation values of the metal parameters are listed in Table 5.7. According to the average values, except parameters Mo, Sb, Se and Tl (having below detection limit concentrations in both locations), concentrations of Ba, Ca, Li, Mg, Sr and relatively at lower rate Al, Be, K, Mn, Si and U parameters increase from upstream to downstream locations while those of the others decrease.

Table 5-7: Average (AV) and average deviation (ADEV) values of metal parameters measured in upstream (SW4) and downstream (SW3) samples of Porsuk stream sediments (Unit: mg/kg, * ADEV value below detection limit)

AV (ADEV)	SW4	SW3	AV (ADEV)	SW4	SW3
Ag	2.2*	2.0*	**Mg**	14902(1560)	15771(3124)
Al	6893(2565)	10775(5691)	**Mn**	365.9(13.9)	394.7(43.7)
As	9.7(4.3)	9.5(5.5)	**Mo**	2.0*	2.0*
B	16.3(4.0)	10.2(5.2)	**Na**	1574(1259)	241.0(215.1)
Ba	140.5(39.5)	145.7(7.2)	**Ni**	209.8(34.8)	139.0(26.7)
Be	0.4*	0.8*	**P**	1667(183)	1632(469)
Bi	1.7*	1.6*	**Pb**	13.6(4.5)	13.5(1.7)
Ca	36248(5520)	40656(3444)	**Sb**	1.0*	1.0*
Cd	0.3*	0.3*	**Se**	1.0*	1.0*
Co	17.5(2.2)	16.1(1.2)	**Si**	376.5(240.5)	389.5(154.5)
Cr	145.4(33.4)	84.6(16.8)	**Sn**	34.7*	25.5*
Cu	49.0(28.2)	36.6(9.7)	**Sr**	129.8(6.2)	150.5(11.5)
Fe	15606(3074)	14280(4145)	**Ti**	125.0(49.8)	72.6(14.7)
Hg	0.3*	0.2*	**Tl**	1.3*	1.3*
K	1235(99)	1985(158)	**U**	1.1*	1.7*
Li	36.6(27.4)	49.3(36.3)	**V**	19.5*	15.2*
			Zn	447.9(269.9)	365.6(17.0)

Majority of the measured organic parameters in sediments has below detection limit values. Above detection limit values are only measured for parameters of total organic carbon (1.05-3.4%), organic nitrogene (2080-2350 mg/kg), PAH (0.149 mg/kg), phenols (0.12-0.36 mg/kg), chlorinated hydrocarbons (Hexachlorocyclohexane 0.0066 mg/kg) and bis (2-Ethylhexyl) Phthalate (0.081 mg/kg).

The comparison of average metal concentrations in sediments to those of average upper crustal concentrations (Rudnick and Gao, 2003) is shown as a ratio in Figure 5-9. Those parameters which have below detection limit values are not shown in the figure. Porsuk stream sediments have higher Ag, As, Bi, Ca, Cd, Cr, Cu, Hg, Li, Ni, P, Sn and Zn concentrations than the upper crustal average.

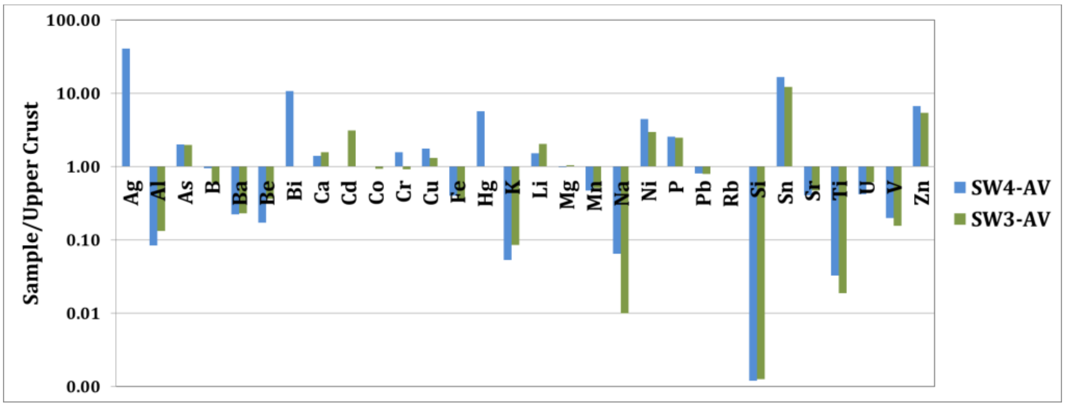


Figure 5-9: Comparison of average metal concentrations in Porsuk stream sediments to those of average upper crustal concentrations

5.3. Groundwater Hydrochemistry

5.3.1. Spring and Fountain waters

5.3.1.1. Field Measurements

The results of hydrochemical field parameter measurements in spring and fountain monitoring locations are given in APPENDIX-E and average values together with average deviations are listed in Table 5-8. The characteristic values of field parameters are also estimated in 95% confidence interval and additionally for pH in 5% interval (Table 5-9).

Table 5-8: Average (AV) and average deviation (ADEV) values of hydrochemical field parameters measured in spring and fountain monitoring locations

AV (ADEV)	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%	Q (L/sn)
F1	12.7(2.4)	7.83(0.18)	287(99)	431(13)	0.21(0.01)	280(9)	5.5(0.41)	58(2.1)	0.05(0.01)
F2	13.3(1.9)	8.21(0.22)	204(36)	340(12)	0.16(0.01)	221(8)	6.9(0.39)	72(4.7)	0.12(0.04)
F3	13.8(2.0)	8.00(0.11)	199(24)	566(22)	0.28(0.01)	368(14)	5.3(0.24)	56(3.5)	0.08(0.03)
F4	13.4(2.1)	8.40(0.20)	195(38)	366(22)	0.18(0.01)	238(14)	7.0(0.27)	75(3.4)	0.04(0.02)
F5	13.1(2.0)	7.79(0.26)	191(36)	397(23)	0.19(0.01)	259(15)	6.4(0.41)	66(4.1)	0.04(0.02)
F6	13.6(1.2)	8.13(0.07)	211(28)	383(14)	0.18(0.01)	249(9)	6.9(0.25)	73(4.7)	0.22(0.15)
F7	13.6(1.0)	8.10(0.12)	233(30)	380(12)	0.18(0.01)	247(8)	7.1(0.32)	75(4.6)	0.39(0.26)

Table 5-9: Characteristic values of hydrochemical field parameters measured in spring and fountain waters

No	Method	T(oC) %95	pH %95	pH %5	ORP (mv) %95	EC 25oC (μS/cm) %95	S (ppt) %95	TDS (mg/l) %95	DO (mg/l) %95	DO% %95	Q (L/s) %95
F1	HAZEN	15.9	8.20	7.53	448	479	0.23	312	6.5	63	0.078
F2	HAZEN	16.2	8.64	7.84	253	374	0.18	243	7.7	81	0.233
F3	HAZEN	17.5	8.21	7.86	233	602	0.29	392	6.2	64	0.154
F4	HAZEN	17.4	8.71	8.01	274	411	0.20	268	7.6	82	0.079
F5	HAZEN	16.4	8.41	7.46	281	427	0.21	278	7.3	75	0.073
F6	HAZEN	15.7	8.37	8.00	263	426	0.21	277	7.2	79	0.629
F7	HAZEN	15.4	8.30	7.96	282	420	0.20	274	7.8	84	0.983

Average values of discharge, T, pH, EC, DO and ORP parameters are shown in Figure 5-10. Average discharge values of spring and fountains change between 0.05 L/s and 0.39 L/s.

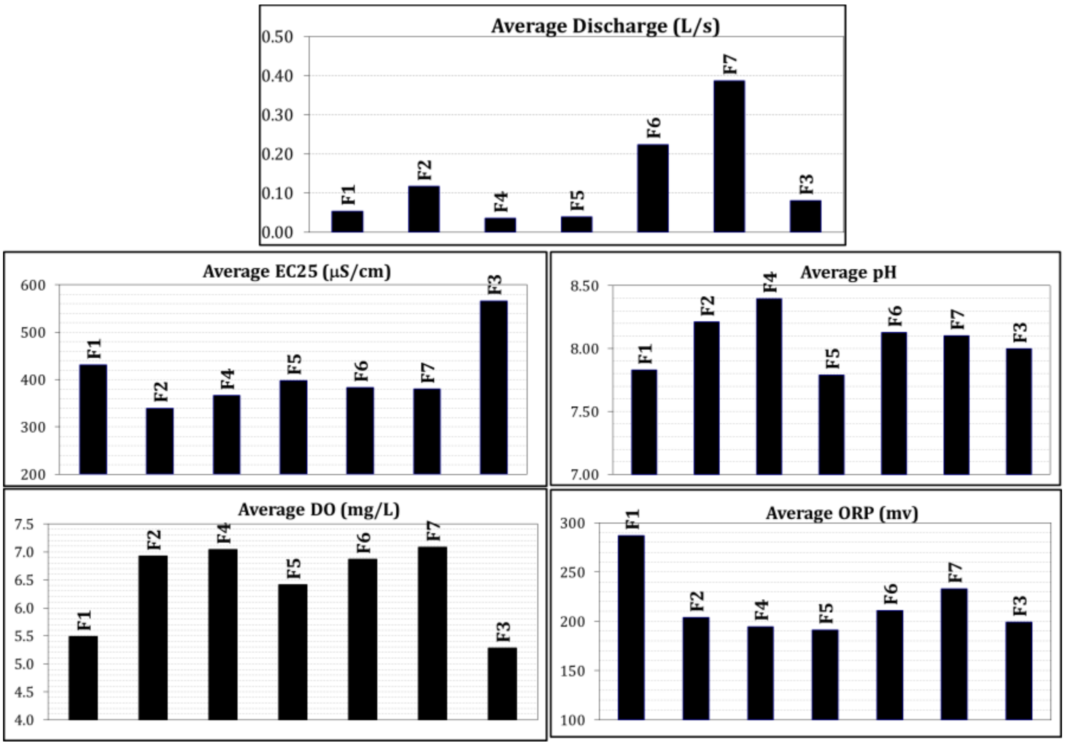


Figure 5-10: Average discharge, pH, EC, DO and ORP values measured in spring and fountain monitoring locations

Average electrical conductivity values (excluding that of F3 water, 566 μS/cm, which is fed by the well water mixed depot water) change in the interval of 340-

431 μS/cm. Other than relatively high value including F1 (431 μS/cm), medium value including F4 (366 μS/cm) and low value including F2 (340 μS/cm), spring and fountain waters (F5, F6, F7) include similar EC values (380-397 μS/cm). Average values of total dissolved solids and salinity which are determined using measured EC values, change in the intervals of 221-280 mg/l and 0.16-0.21 ppt, respectively, excluding F3 water.

Spring and fountain waters are in basic character in the monitoring locations and average pH values change in the interval of 7.79-8.40. Other than relatively high value including F4 and low value including F1 and F5 waters, pH values of spring and fountains (F2, F6, F7) are similar (8.10-8.21).

Average dissolved oxygen values of spring and fountains are between 5.3 mg/l and 7.1 mg/l excluding well water effected F3 (5.24 mg/l) water. Other than the low value including F1 and relatively F5, fountain waters (F2, F4, F6, F7) include similar DO values (6.9-7.1 mg/l).

Average values of oxidation-reduction potential change in the interval of 191-287 mv and all waters show oxidizing character. ORP values are between 191 mv and 233 mv excluding relatively high value of F1 water.

Percent changes in the field parameter values during monitoring period are shown in Figure 5-11 for spring and fountain waters (discharge values of depot water fed F3 and F7 are not included) as percent average deviations which are determined after measurement percent error subtraction. The averages of percent average deviations from higher to lower values are determined in discharge (48%), ORP (14%), temperature (13.5%), dissolved oxygen (4%), EC (3%) and pH (1.8%) parameters.

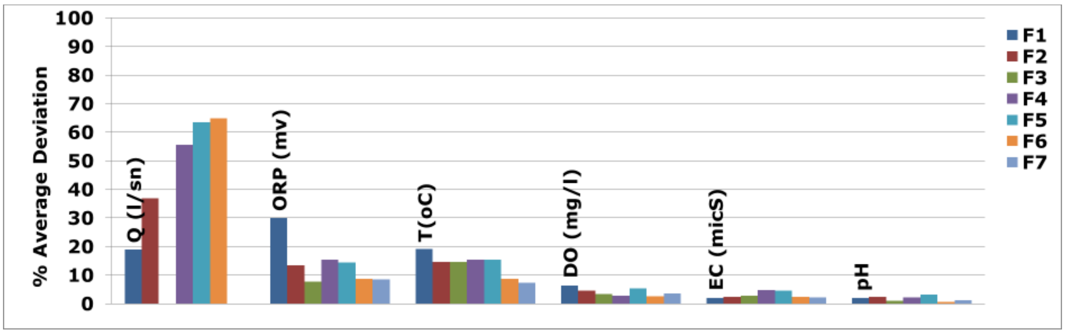


Figure 5-11: Percent average deviations of the field parameters measured in spring and fountain waters

Monthly changes of field parameter values (except depot water fed F3 and F7 waters) are shown in Figure 5-12. Averages and average deviations of the dry-wet periods are listed in Table 5-10 together with the decreasing/increasing /unchanging trends. Temperature parameter having 8.6% deviation decreases in the wet period but the discharge increases (except at F3 location). The general monthly trend of EC values indicates that they decrease in and after the wet months and increase in the dry months.

Table 5-10: Average (AV), average deviation (ADEV) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of field parameters between dry and wet periods in spring and fountain monitoring locations

Dry-Wet AV(ADEV)	T(oC)	pH	ORP (mv)	EC (μS/cm) 25C	DO (mg/l)	Q (l/sn)
F1	13.4(1.7)AZ	7.79(0.10)AR	311(55)AZ	432*	5.4(0.19)AR	0.05(0.00)AR
F2	13.8(1.3)AZ	8.18(0.08)AR	203*	341(4)AZ	7.0(0.16)AZ	0.11(0.02)AR
F3	14.4(1.4)AZ	7.97(0.07)AR	196*	568(6)AZ	5.3*	0.09(0.01)AZ
F4	14.2(1.4)AZ	8.35(0.09)AR	185(18)AR	374(14)AZ	7.0*	0.03(0.00)AR
F5	13.7(1.2)AZ	7.70(0.17)AR	186(10)AR	399*	6.4*	0.03(0.01)AR
F6	13.9(0.7)AZ	8.12*	211*	380(6)AR	6.9(0.10)AZ	0.21(0.03)AR
F7	13.8(0.6)AZ	8.08(0.06)AR	237*	377(6)AR	7.2(0.26)AZ	0.34(0.14)AR

EC parameter with very low average seasonal deviation (0.6%) shows the following trends in the wet period; decreasing in F2, F3, F4 locations, increasing in F6, F7 locations and unchanging in F1 and F5 locations. The monthly changes observed in pH values (January-July decrease and increase afterwards) are reversely related to that of temperature, except in F6 location where pH exhibits generally unchanging trend except in the last two months. pH values with very low average deviation (0.8%) between the dry and wet periods increase in the wet period except in F6 water which shows unchanging trend probably due to buffering reactions (e.g. carbonate mineral reactions). DO values (excluding F1 water) increase in January-July period, decrease in July-December 2015 period and increase afterwards except in decreasing F6 water. The monthly trend of dissolved oxygen is generally controlled by temperature. On the other hand, the increasing and decreasing trends of F1 water in the monitoring period seems to be controlled by discharge (precipitation). DO values with 1% average deviation between the dry and wet periods exhibit unchanging trend in F3, F4 and F5 waters, increasing trend in F1 water and decreasing trend in F2, F6, F7 waters from the dry period to the wet period.

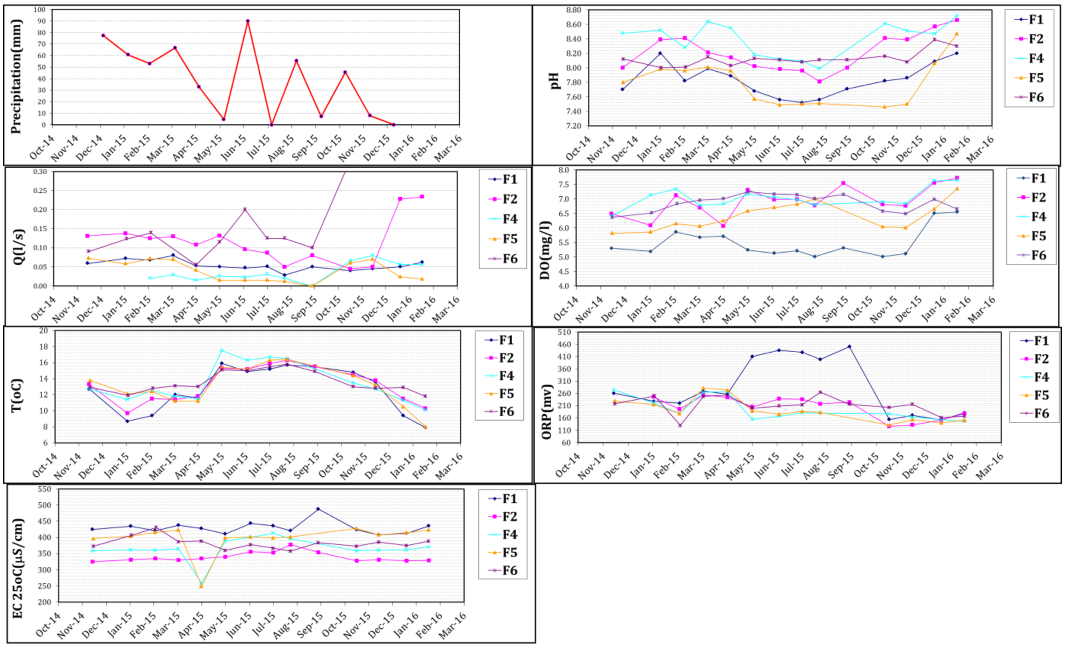


Figure 5-12: Monthly changes of temperature, pH, EC, DO, ORP values in spring and fountain waters and precipitation distribution

In comparison to the dry period, ORP values indicate that in the wet period; values of F1 water decreases, F4 and F5 waters increase and F2, F3, F6, F7 waters unchanged. The average percent deviation of ORP parameter is about 2.8% between the dry and wet periods. The average percent deviation of all parameters (excluding temperature and discharge) considering all locations is about 1.3%. The evaluations indicate that field parameter value changes between the dry and wet periods are very low.

5.3.1.2. Laboratory Measurements

The results of detailed chemical analyses from spring and fountain monitoring locations are given in APPENDIX-F and average values together with average deviations are listed in Table 5-11 which also includes the decreasing/increasing /unchanging concentration trends (which were determined after measurement percent error subtraction) between the dry and wet periods. Water facies of spring and fountain waters as determined from relative major ion concentration distributions are shown in Figure 5-13. The field distribution of the facies is given in Figure 5-14.

Table 5-11: Average (AV), average deviation (ADEV) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of laboratory parameters between dry and wet periods in spring and fountain monitoring locations (Unit: mg/l, color: pt/co)

AV(ADEV) Dry-Wet */AR/AZ	F1	F2	F3	F4	F5	F6	F7
Ag	0.0005*	0.0005*	0.0078(0.0073)AZ	0.0005*	0.0005*	0.0005*	0.0005*
Al	0.037(0.034)AZ	0.042(0.039)AZ	0.025(0.022)AZ	0.071*	0.135(0.129)AZ	0.077(0.074)AZ	0.032(0.029)AZ
Alk.(t)	217(13)AZ	161(9)AZ	257(29)AZ	160*	200(20)AZ	182*	194(22)AZ
As	0.0034*	0.0034*	0.0230(0.0040)AZ	0.0034*	0.0040*	0.0034*	0.0034*
B	0.270(0.161)AR	0.152(0.109)AR	0.312(0.112)AZ	0.147(0.053)AR	0.081*	0.078*	0.078*
Ba	0.067*	0.075*	0.162(0.045)AZ	0.241(0.139)AZ	0.126*	0.039*	0.040*
Be	0.00004*	0.00004*	0.00004*	0.00004*	0.00004*	0.00004*	0.00004*
Bi	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
Ca	36.18*	31.51*	19.75(2.51)AZ	31.77*	42.84(2.84)AZ	34.48(4.35)AZ	32.08*
Cd	0.0002*	0.0002*	0.1185(0.1155)AR	0.0002*	0.0002*	0.0002*	0.0002*
Cl	5.77(0.16)AZ	5.40(0.28)AZ	21.85(2.06)AR	8.84(0.66)AR	8.37*	5.13(0.27)AR	5.39(0.27)AZ
CN	0.02(sm)	0.02(sm)	0.02(sm)	0.02(sm)	0.02(sm)	0.02(sm)	0.02(sm)
Co	0.0005*	0.0005*	0.0005*	0.0005*	0.0005*	0.0005*	0.0005*
COD	15*	33(23)AR	32(23)AR	7*	22(15)AR	6*	12*
Color	6.6(sm)	6.3(sm)	6.3(sm)	5.0(sm)	8.8(sm)	8.5(sm)	4.8(sm)
Cr	0.0003*	0.0003*	0.0010*	0.2160(0.2060)AR	0.0020*	0.0003*	0.0003*
Cu	0.0002*	0.0002*	0.0002*	0.0002*	0.006*	0.0002*	0.0002*
F	0.33(0.04)AZ	0.32(0.04)AZ	0.32(0.07)AZ	0.35(0.04)AZ	0.26(0.04)AZ	0.25(0.03)AZ	0.25(0.03)AZ
Fe	0.037(0.035)AZ	0.012(0.012)AZ	0.033(0.032)AZ	0.022(0.021)AZ	0.113(0.113)AZ	0.316*	0.027(0.026)AZ
P,reac	0.009*	0.008*	0.012(0.002)AR	0.012(0.002)AR	0.008*	0.012(0.002)AR	0.012(0.002)AR
Hg	0.00008*	0.00008*	0.00008*	0.00008*	0.00008*	0.00008*	0.00008*
K	0.219(0.051)AZ	0.274(0.074)AZ	2.619*	0.394(0.048)AZ	0.750(0.164)AZ	0.394(0.078)AZ	0.388(0.126)AZ
Li	0.026*	0.024*	0.106(0.007)AR	0.020*	0.015*	0.027*	0.027*
Mg	29.28*	21.04*	53.74*	23.46(0.63)AZ	25.67(1.99)AZ	26.17(0.90)AZ	26.57(1.69)AZ
Mn	0.0002*	0.0051(0.0049)AZ	0.0002*	0.0050*	0.0002*	0.0181(0.0179)AZ	0.0096(0.0094)AZ
Mo	0.001*	0.001*	0.001*	0.001*	0.001*	0.006(0.005)AZ	0.001*
TKN	2.37*	1.74(0.62)AR	2.82*	2.98(1.02)AR	2.13(1.63)AR	7.85(7.35)AR	1.00(0.50)AR
N(Org)	2.36*	1.73(0.62)AR	2.82*	2.98(1.03)AR	2.13(1.63)AR	7.85(7.35)AR	1.00(0.50)AR
Na	8.70(4.60)AZ	3.43(0.16)AR	16.63(2.39)AZ	9.08(2.31)AZ	4.50*	5.40(2.25)AZ	5.01(1.82)AZ
Ni	0.0005*	0.0005*	0.0005*	0.0005*	0.0005*	0.0005*	0.0005*
N-NH4	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
N-NO2	0.001*	0.001*	0.001*	0.002(0.001)AR	0.001*	0.001*	0.002*
N-NH3	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
N-NO3	3.32(0.22)AZ	3.04(0.34)AZ	6.38(0.18)AZ	3.28(0.28)AZ	6.04(0.59)AZ	3.23(0.36)AZ	3.29(0.33)AZ
Pb	0.0015*	0.0015*	0.027(0.026)AZ	0.0015*	0.0015*	0.0015*	0.0015*
P	0.009*	0.008*	0.012(0.002)AR	0.012(0.002)AR	0.008*	0.012(0.002)AR	0.012(0.002)AR
Sb	0.002*	0.002*	0.002*	0.002*	0.004(0.002)AZ	0.002*	0.002*
Se	0.005*	0.005*	0.005*	0.005*	0.005*	0.006(0.001)AR	0.005*
Si	6.86(0.22)AZ	6.17(0.20)AZ	21.98(2.57)AR	9.32(0.70)AR	6.59*	6.97*	6.90*
Sn	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*
SO4	7.97(0.53)AR	10.00(3.00)AR	13.93(0.63)AZ	12.73(1.27)AR	11.03(1.17)AR	11.41*	11.31(0.11)AZ
S	0.10(sm)	0.10(sm)	0.10(sm)	0.10(sm)	0.10(sm)	0.10(sm)	0.10(sm)
Sr	0.567(0.044)AZ	0.512(0.099)AZ	1.949(0.211)AZ	0.386(0.040)AZ	0.464(0.083)AZ	0.437(0.033)AZ	0.429(0.029)AZ
TDS	177(21)AZ	177(23)AR	323(65)AR	178(10)AR	196(6)AZ	192(20)AR	133(47)AZ
Ti	0.0002*	0.0002*	0.0002*	0.0002*	0.0002*	0.0002*	0.0002*
Tl	0.003*	0.003*	0.003*	0.003*	0.003*	0.003*	0.003*
TOC	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*	1.0*
U	0.0012*	0.0009*	0.0044(0.000)AZ	0.0013*	0.001*	0.0011*	0.0011*
V	0.005*	0.004*	0.013*	0.004*	0.004*	0.002*	0.002*
Zn	0.026*	0.010(0.009)AZ	0.011*	0.0002*	0.023(0.010)AZ	0.013(0.006)AZ	0.011(0.008)AZ
Oil&grease	0.10(sm)	0.16(sm)	0.10(sm)	0.10(sm)	0.10(sm)	0.16(sm)	0.12(sm)
Trichloroethylene	0.0008*	0.0008*	0.0008*	0.0008*	0.0008*	0.0008*	0.0008*
Tetrachloroethylene	0.0008*	0.0008*	0.0008*	0.0008*	0.0008*	0.0008*	0.0008*
-Pesticides,t	0.00008*	0.00008*	0.00008*	0.00008*	0.00008*	0.00008*	0.00008*
-VOC	0.0034(sm)	0.0034(sm)	0.0034(sm)	0.0034(sm)	0.0034(sm)	0.0034(sm)	0.0034(sm)

- Parameters grouped with respect to quality limits. sm: single measurements.

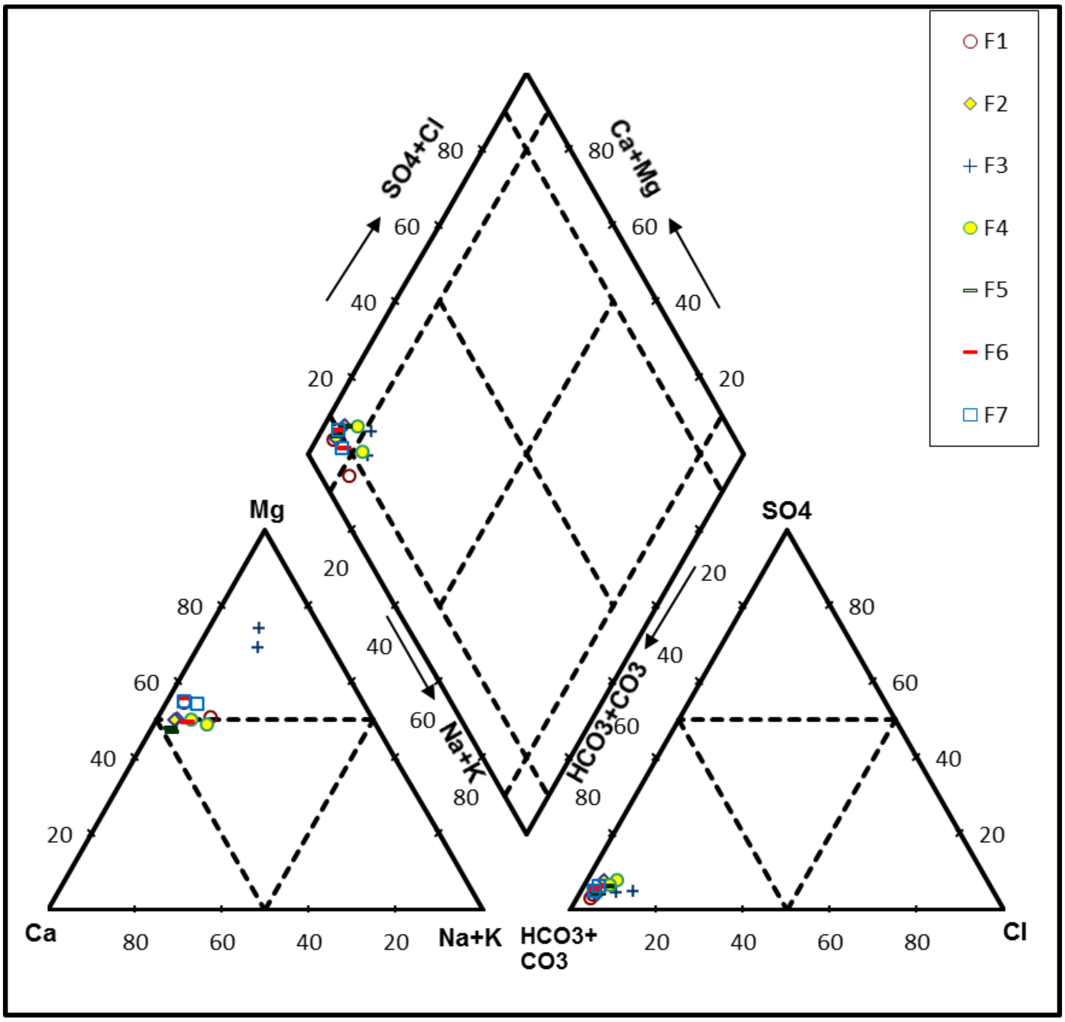


Figure 5-13: Relative major ion concentration distribution in spring and fountain waters on Piper graph

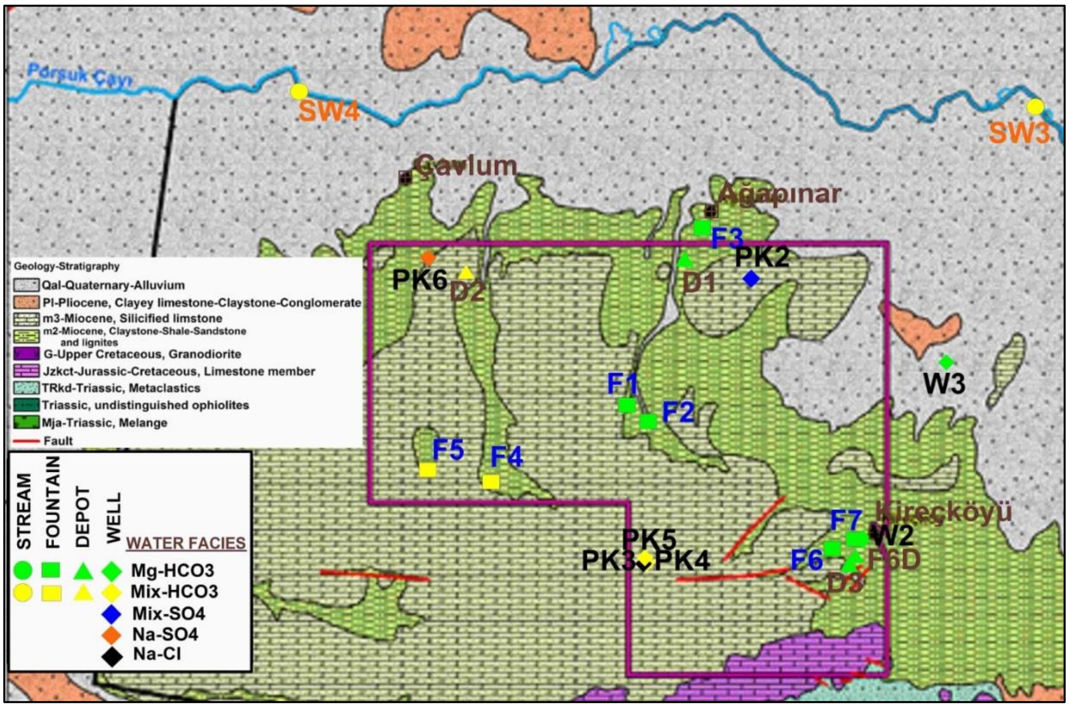


Figure 5-14: Relative major ion average concentrations related hydrochemical facies distribution in the monitoring locations

The spring and fountain waters include HCO_3 facies water in terms of anion content in all monitoring locations. Cation contents of all waters but F3 are similar and plot close to the mix area near by Mg-Ca boundary. Average cation concentrations indicate that F4 and F5 waters are mix type and the others are Mg type. F3 water reflecting well water effect with high Mg content connected to Ağapınar village water depot (D1) which is fed by both well (W1) and spring (F2) waters. The differences and similarities of the major ion average concentration distributions are shown in Schoeller graph (Figure 5-15).

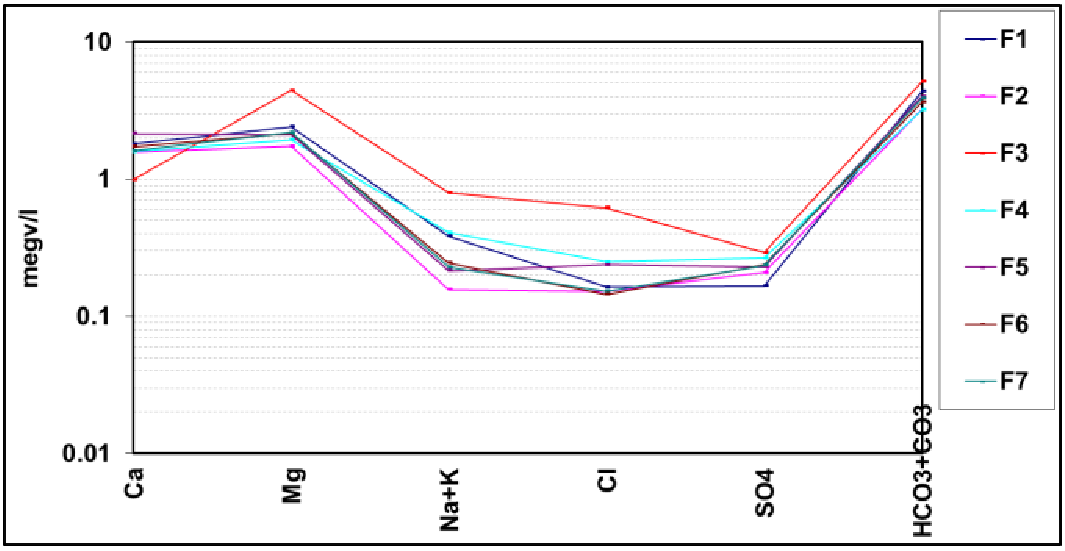


Figure 5-15: Major ion average concentration distributions in spring and fountain waters on Schoeller graph

Major ion chemistry indicates that spring waters are effected by similar source lithologies. When chloride concentrations of well waters from potential source lithological units of silicified limestone (PK4) and siltstone-sandstone-conglomerate (PK5) are compared with those of spring and fountains; it is estimated that F1, F2, F6, F7 waters include 82-91% silicified limestone groundwater and 9-18% siltstone-sandstone-conglomerate groundwater mixing components. On the other hand, F4 and F5 waters include 37-44% silicified limestone groundwater and 56-63% siltstone-sandstone-conglomerate groundwater.

The comparison of parameter average concentrations (which are greater than the detection limits) in spring and fountain waters is shown in Figure 5-16. Except in F3 water, concentrations of Ag, Be, Bi, Cd, Co, CN, Hg, NH4, NH3, Pb, Sn, Ti, Tl, TOC, trichloroethylene, tetrachloroethylene, pesticides and volatile organic parameters are below the detection limits in the waters. Oil&Grease values of F6 (0.15 mg/l) and F7 (0.12 mg/l) waters measured in November period are very close to the detection limit (0.1 mg/l). Alkalinity, Ca, Cl, F, Mg and U concentrations of spring and fountain waters include small differences in comparison to those of the others. The well water fed F3 fountain water includes relatively higher concentrations. Ba concentrations of F4 and F5 waters characterized with mix cation facies are higher than those of the others.

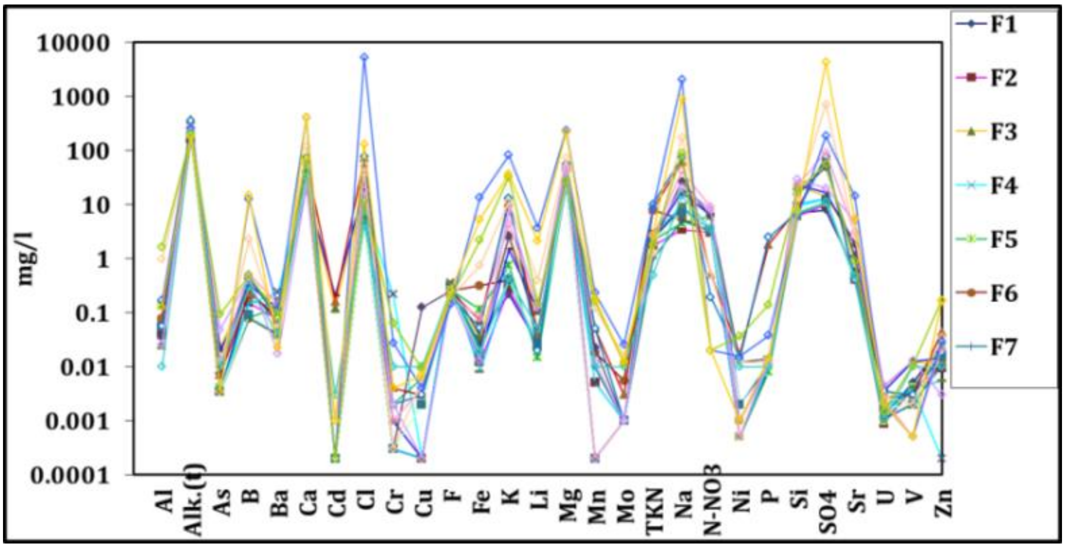
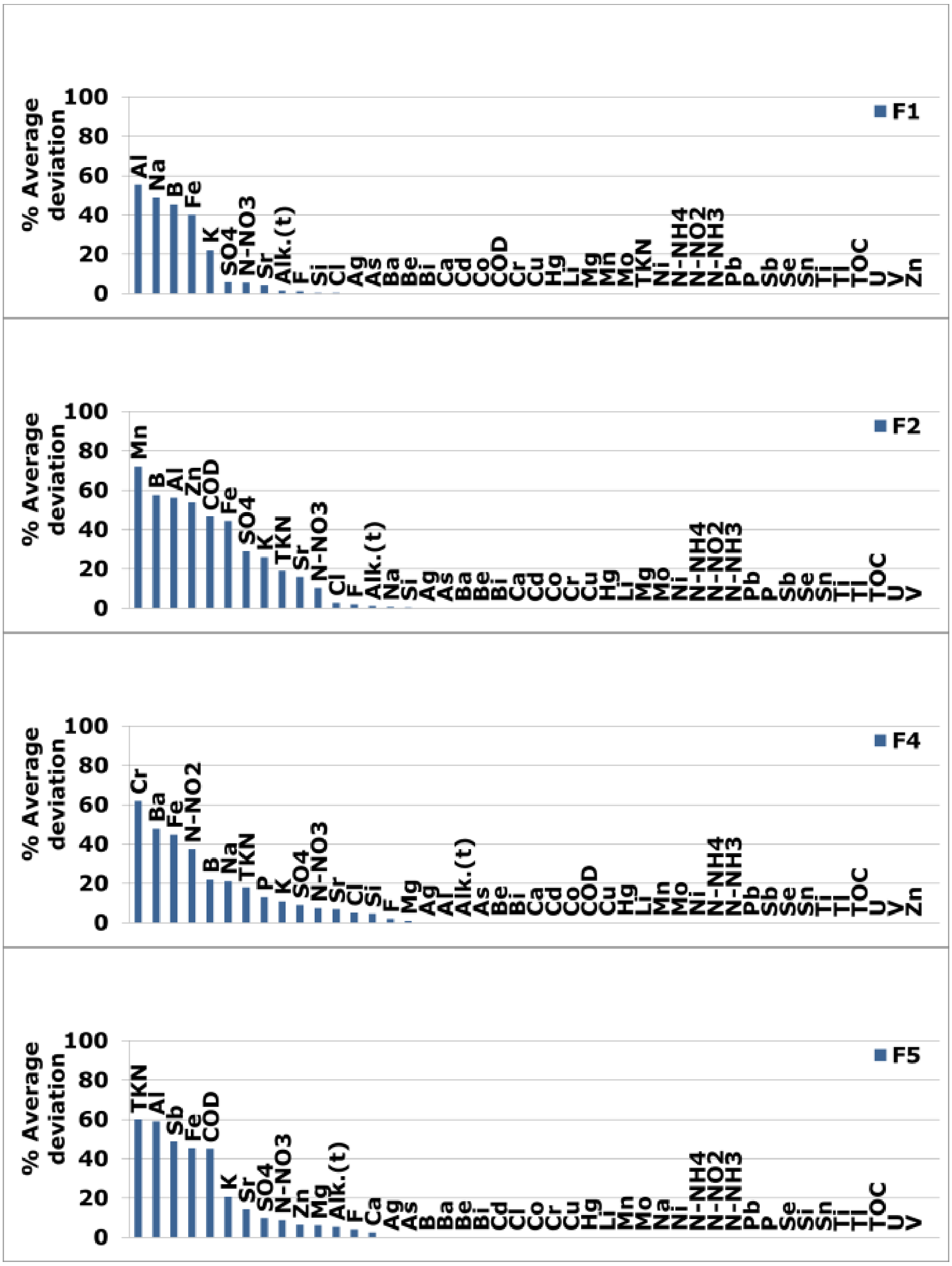


Figure 5-16: Average ion concentration distribution in spring and fountain waters

When hydrochemical water facies differences studied in the monitoring period, it is observed that cation differences exit only in waters of F2 and F6 (Mg type of waters in the wet period changes to mix type). Concentration changes of parameters between the dry and wet periods are determined for each spring and fountain water (other than well affected F3 water) as percent average deviation and plotted in Figure 5-17 after the measurement error percent is subtracted. Based on all parameter and all monitoring locations, average deviation is calculated to be about 8%. According to the increasing/decreasing/unchanging trends between the dry and wet periods (Table 5.11), concentrations of B, Cl, P and TKN parameters are higher and those of Al, F, Fe, K, Mg, Mn, Na, NO3, Sr and Zn parameters are lower in the wet period. Concentrations of the other parameters are similar (unchanging) between the periods.


% Average deviation
100
80
60
40
20
0
F1
Al Na B Fe K SO4 N-NO3 Sr Alk.(t) F Si Cl Ag As Ba Be Bi Ca Cd Co COD Cr Cu Hg Li Mg Mn Mo TKN Ni N-NH4 N-NO2 N-NH3 Pb P Sb Se Sn Ti Tl TOC U V Zn
F2
Mn B Al Zn COD Fe SO4 K TKN Sr N-NO3 Cl F Alk.(t) Na Si Ag As Ba Be Bi Ca Cd Co Cr Cu Hg Li Mg Mo Ni N-NH4 N-NO2 N-NH3 Pb P Sb Se Sn Ti Tl TOC U V
F4
Cr Ba Fe N-NO2 B Na TKN P K SO4 N-NO3 Sr Cl Si F Mg Ag Al Alk.(t) As Be Bi Ca Cd Co COD Cu Hg Li Mn Mo Ni N-NH4 N-NH3 Pb Sb Se Sn Ti Tl TOC U V Zn
F5
TKN Al Sb Fe COD K Sr SO4 N-NO3 Zn Mg Alk.(t) F Ca Ag As B Ba Be Bi Cd Cl Co Cr Cu Hg Li Mn Mo Na Ni N-NH4 N-NO2 N-NH3 Pb P Se Si Sn Ti Tl TOC U V

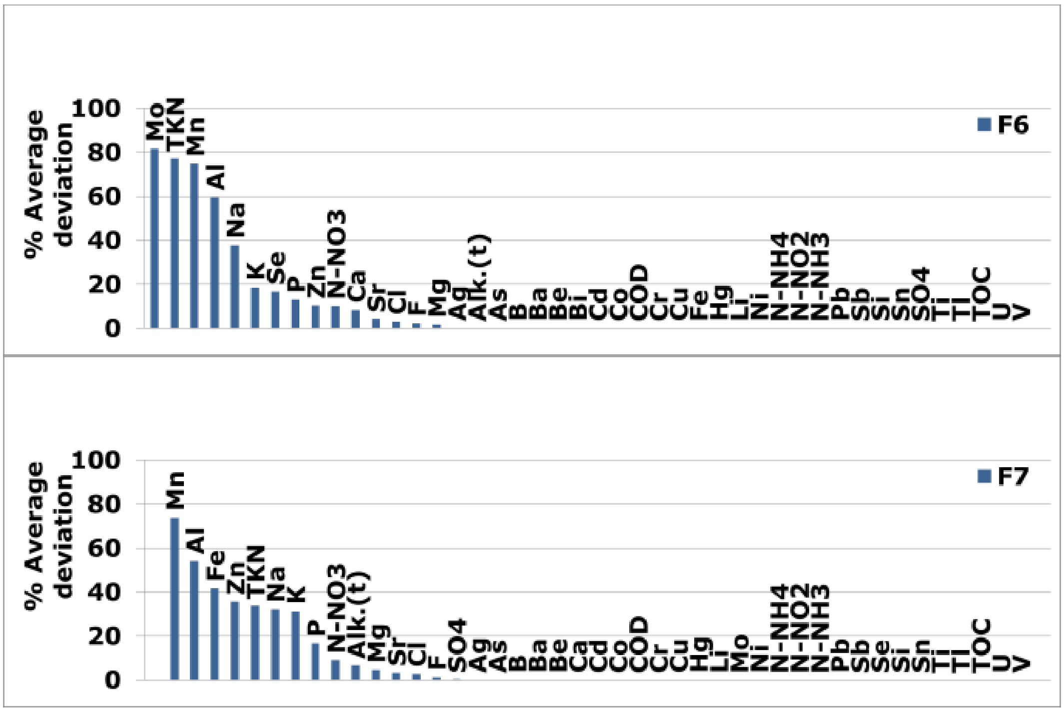


Figure 5-17: Percent average deviations of concentrations from the monitoring period average in spring and fountain waters

5.3.2. Well Waters

5.3.2.1. Field Measurements

The results of hydrochemical field parameter measurements in well water monitoring locations are given in APPENDIX-E and average values together with average deviations are listed in Table 5-12. Because it was not possible to purge PK-coded wells during monthly monitoring, only W2 and W3 coded wells have been monitored. Because W1 well is not suitable for water sampling, it was not also monitored. The characteristic values of field parameters are estimated for W2 and W3 waters in 95% confidence interval and for pH additionally in 5% interval (Table 5-13).

Table 5-12: Average (AV) and average deviation (ADEV) values of hydrochemical field parameters measured in well water monitoring locations (*: ADEV is in error limits, sm: single measurement)

AV (ADEV)	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%
W2	16.1(0.8)	8.06(0.12)	203(24)	760(38)	0.37(0.02)	494(25)	6.6(0.53)	73(6.1)
W3	15.8(0.9)	7.92(0.04)	207(32)	611(13)	0.30(0.01)	397(9)	4.8(0.41)	52(4.7)
PK2	23.4(1.1)	8.03*	189(32)	530(29)	0.26(0.01)	345(19)	3.7(sm)	41(sm)
PK3	22.0(0.2)	7.98*	183*	4985*	2.49(0.00)	3236(3)	2.5(sm)	29(sm)
PK4	18.7(0.0)*	8.08*	265*	355*	0.17*	231*	3.0(sm)	32(sm)
PK5	18.4(0.3)	7.90*	215(16)	629(30)	0.31(0.01)	409(19)	3.2(sm)	34(sm)
PK6	23.3(0.4)	8.05*	171(18)	5200(310)	2.59(0.16)	3375(201)	2.1(sm)	24(sm)

Table 5-13: Characteristic values of hydrochemical field parameters measured in well waters

No	Method	T(oC) %95	pH %95	pH %5	ORP (mv) %95	EC 25oC (μS/cm) %95	S (ppt) %95	TDS (mg/l) %95	DO (mg/l) %95	DO% %95
W2	HAZEN	18.4	8.40	7.9	251	813	0.40	528	7.3	88
W3	HAZEN	18.3	7.99	7.8	279	635	0.31	413	5.5	61

Average values of T, pH, EC, DO and ORP parameters are shown in Figure 5.18. The average electrical conductivity of well waters changes in 355-5200 μS/cm interval. The highest values around 5000 μS/cm were measured in the groundwater of below coal and in coal units. The lowest value is measured in PK4 well filtering silicified limestone above the coal seams. EC values of groundwater show reverse relation with hydraulic conductivities of the lithological units; low hydraulic conductivity-high electrical conductivity, high hydraulic conductivity-low electrical conductivity. High EC values are probably related to long water-rock interactions due to low hydraulic conductivity. Average values of total dissolved solids and salinity which are determined using measured EC values, change in 231-3375 mg/l and 0.17-2.56 ppt intervals, respectively.

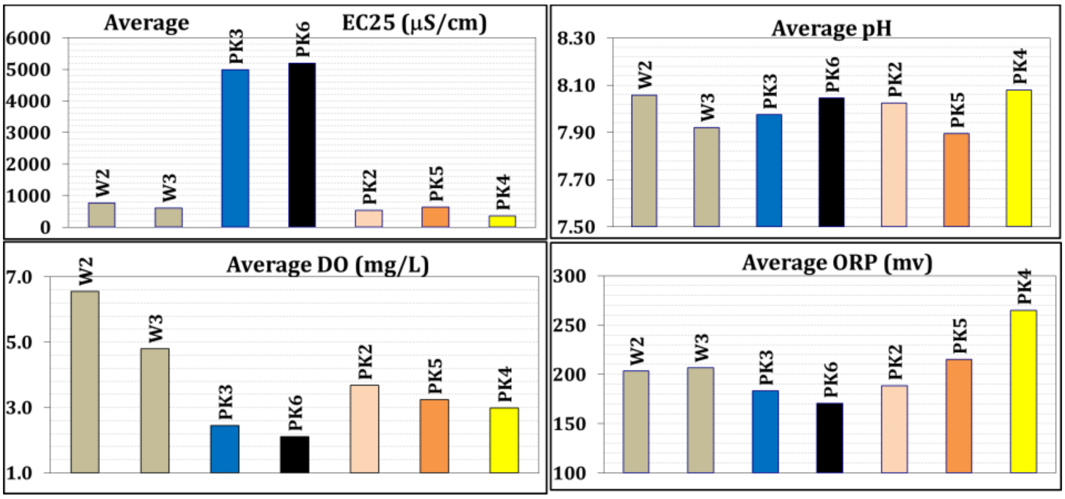


Figure 5-18: Average pH, EC, DO and ORP values measured in well water monitoring locations. Blue below coal (BC) limestone; black in coal (IC)-coal, siltstone; yellow above coal (AC) silicified limestone; orange KU siltstone-sandstone-conglomerate; pink BC (siltstone), IC, AC (siltstone-sandstone-conglomerate); grey unknown

Well waters are basic and average pH values change between 7.90 and 8.08 and are close to each other. The highest value is measured in silicified limestone filtered PK4 well and the lowest value is measured in siltstone-sandstone-conglomerate filtered PK5 well.

The average dissolved oxygen of well waters change in 2.1-6.6 mg/l interval. The waters filtered from deeper depths in coal (PK6; 368-416 m) and below coal seams (PK3; 352-416 m) include lower oxygen values (2.1-2.5 mg/l) and the waters filtered from the above coal seams relatively closer to the surface (PK4;26-56 m and PK5 136-204 m) include relatively higher oxygen values (3.0-3.2 mg/l) probably reflecting relatively faster recharge conditions.

The average oxidation-reduction potential of well waters bears oxidizing character and changes in the interval of 171-265 mv. ORP values are relatively low in deep aquifer waters and high in relatively shallow aquifer waters.

Value changes in the field parameters during the monitoring period are calculated for W-coded well waters as percent average deviation excluding the measurement percent error. The averages of percent average deviations are low and from higher to lower values are determined in ORP (9%), dissolved oxygen (7%), temperature (5.5%), EC (2.6%) and pH (0.7%) parameters.

Monthly changes of field parameters in W-coded well waters are shown in Figure 5-19. Averages and average deviations of the dry-wet periods are listed in Table 5-14 together with the decreasing/increasing/unchanging trends (which were calculated after the measurement percent error subtraction). EC values do not change in W3 well water between the dry and wet periods but in W2 well water it decreases in the wet period and associated average deviation is about 2%.

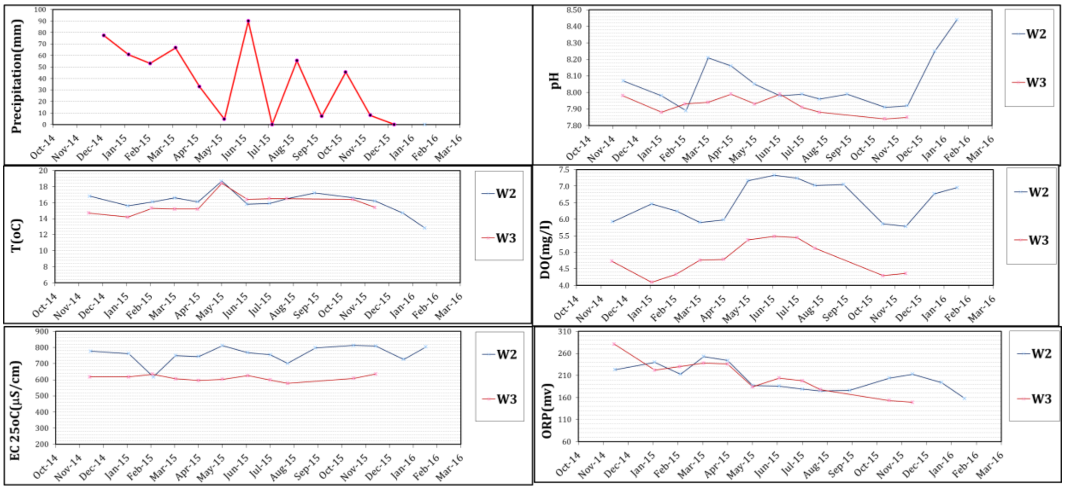


Figure 5-19: Monthly changes of temperature, pH, EC, DO, ORP values in well waters and precipitation distribution

pH deviation between the dry and wet periods in W3 well water is within the measurement error. In W2 well water, the change is very low (0.8%) with increasing trend in the wet period. Dissolved oxygen in W2 water decreases in January-March period, increases in March-June period, decreases in June-November period and decreases afterwards. The trend in W3 water is increasing in January-June, decreasing in June-November and increasing afterwards.

Table 5-14: Average (AV), average deviation (ADEV) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of field parameters between dry and wet periods in well water monitoring locations

Dry-Wet AV(ADEV)	T(oC)	pH	ORP (mv)	EC (μS/cm) 25C	DO (mg/l)
W2	16.4(0.6)AZ	8.04(0.05)AR	199(10)AR	770(24)AZ	6.6(0.18)AZ
W3	16.1(0.6)AZ	7.91*	197(20)AR	611*	4.9(0.18)AZ

Dissolved oxygen parameter with 2% average deviation decreases in the wet months. ORP values with 3% deviation increase in the wet period but generally show decreasing trend in the monitoring period. Average percent deviation of all field parameters (excluding temperature) is about 1.7%. The evaluations indicate that parameter value changes between the dry and wet periods are very low.

5.3.2.2. Laboratory Measurements

The results of detailed chemical analyses from well water monitoring locations are given in APPENDIX-F and average values together with average deviations are listed in Table 5-15 which also includes the decreasing/increasing /unchanging concentration trends (which were determined after measurement percent error subtraction) between dry and wet periods. Water facies of well waters as determined from relative major ion concentration distributions are shown in Figure 5-20. The field distribution of the facies is given in Figure 5-14. According to the average values when anion content is considered; waters of W2, W3, PK4 [above coal (AC) silicified limestone] and PK5 [AC siltstone-sandstone-conglomerate] wells are in HCO_3 facies; waters of PK2 [AC siltstone-sandstone-conglomerate, in coal (IC) claystone, shale, coal and below coal seam (BC) siltstone] and PK6 (IC siltstone and coal) are in SO_4 facies; and water of PK3 (BC limestone) is in Cl facies.

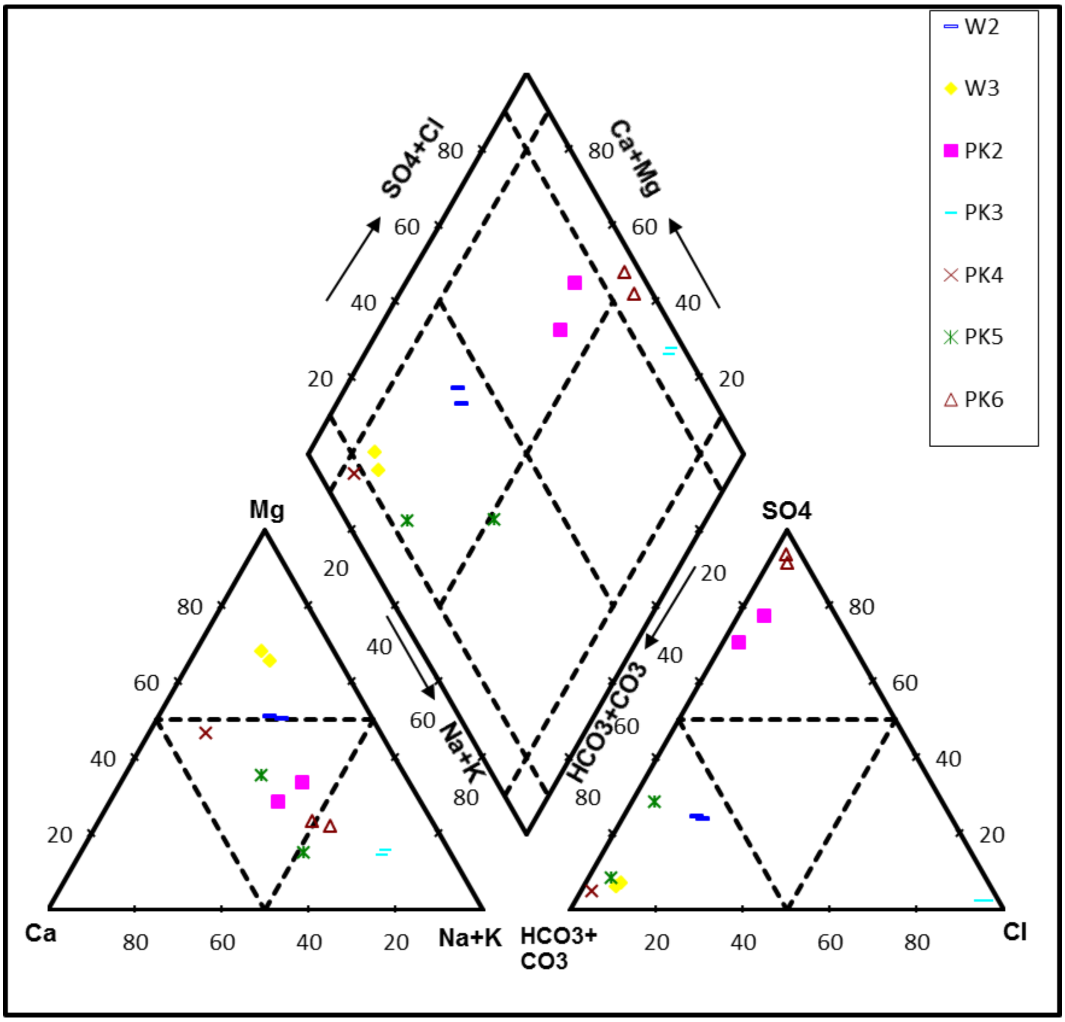


Figure 5-20: Relative major ion concentration distribution in well waters on Piper graph

Table 5-15: Average (AV), average deviation (ADEV) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of laboratory parameters between dry and wet periods in well water monitoring locations (Unit: mg/l, color: pt/co, bacteriological: cfu/100 mL)

AV(ADEV) Dry-Wet */AR/AZ	W2	W3	PK2	PK3	PK4	PK5	PK6
Ag	0.0030*	0.0058(0.0053)AZ	0.0010*	0.0128(0.0123)AZ	0.0100(sm)	0.0005*	0.0058(0.0053)AZ
Al	0.026(0.023)AZ	0.026(0.017)AZ	0.972(0.889)AZ	0.167(0.124)AR	0.010(sm)	1.652*	0.127(0.065)AZ
Alk.(t)	229(14)AR	269*	201*	257(48)AZ	210(sm)	195(16)AZ	180*
As	0.0130(0.0050)AZ	0.0480(0.0080)AZ	0.0100*	0.0034*	0.0100(sm)	0.0930(0.0650)AZ	0.0034*
B	0.511(0.291)AZ	0.447*	2.270(2.070)AZ	12.500(12.300)AZ	0.304(sm)	0.485(0.285)AZ	14.635(14.435)AZ
Ba	0.145*	0.018*	0.051*	0.116(0.015)AR	0.038(sm)	0.086(0.014)AZ	0.023(0.009)AR
Be	0.00004*	0.00004*	0.00004*	0.00004*	0.01000(sm)	0.00004*	0.00010*
Bi	0.01*	0.01*	0.01*	0.01*	0.01(sm)	0.01*	0.01*
Ca	32.42(10.71)AZ	21.42(1.08)AZ	116.90(45.77)AZ	400.95(118.55)AR	40.09(sm)	70.36(26.76)AR	406.94(23.64)AZ
Cd	0.0002*	0.0010*	0.0010*	0.0002*	0.0030(sm)	0.0002*	0.0010*
Cl	50.93*	18.00(0.53)AR	38.25(15.25)AZ	5306.50(350.50)AR	4.54(sm)	11.41(1.99)AR	132.15(19.15)AZ
CN	0.02(sm)	0.02(sm)	0.01(dl)	0.01(dl)	0.02(sm)	0.01*	0.01*
Co	0.0005*	0.0005*	0.0010*	0.0005*	0.0100(sm)	0.0010*	0.0005*
COD	30(10)AZ	13*	8*	179(61)AZ	10(sm)	40(28)AR	23(8)AZ
Color	4.7(sm)	0.005(sm)	3.3(1.1)AZ	17.8(1.8)AZ	4.7(sm)	15.9(0.7)AZ	10.8(7.8)AZ
Cr	0.0010*	0.0020*	0.0003*	0.0275(0.0175)AR	0.0100(sm)	0.0640*	0.0040*
Cu	0.0040*	0.0002*	0.0060*	0.0040*	0.0100(sm)	0.0090*	0.0070*
F	0.21(0.04)AZ	0.21(0.04)AZ	0.20(0.05)AZ	0.14(0.04)AZ	0.27(sm)	0.20(0.10)AZ	0.25(0.05)AR
Fe	0.080(0.062)AZ	0.013*	0.745*	13.440*	0.019(sm)	2.187*	5.258*
P,reac	0.014(0.004)AR	0.011(0.001)AR	0.012(0.002)AR	0.038(0.028)AR	0.010(sm)	0.075(0.065)AR	0.015(0.005)AR
Hg	0.00008*	0.00008*	0.00008*	0.00008*	0.00100(sm)	0.00008*	0.00008*
K	4.386(1.425)AZ	7.723(0.707)AZ	11.150(0.980)AZ	81.725*	0.442(sm)	32.580(19.350)AR	36.245(7.345)AZ
Li	0.137*	0.124(0.004)AR	0.395(0.072)AZ	3.705(0.345)AZ	0.050(sm)	0.149*	2.112(0.219)AZ
Mg	44.22(12.48)AZ	52.88(2.55)AZ	72.07(13.44)AZ	234.90(51.20)AR	27.95(sm)	27.29(0.91)AZ	216.38(21.08)AZ
Mn	0.0002*	0.0120*	0.1210(0.0780)AZ	0.2330(0.1580)AR	0.0100(sm)	0.1630(0.0640)AZ	0.1800*
Mo	0.001*	0.001*	0.016(0.007)AZ	0.026(0.013)AR	0.010(sm)	0.012(0.002)AR	0.013(0.004)AZ
TKN	2.55(2.05)AR	2.70(2.20)AR	1.25(0.75)AR	8.49*	0.50(sm)	1.80(1.30)AR	2.75(2.25)AR
N(Org)	2.55(2.05)AR	2.70(2.20)AR	1.16(0.66)AR	2.92*	0.50(sm)	1.60(1.10)AR	1.65(1.15)AR
Na	41.87(9.15)AZ	20.74(3.50)AZ	174.80(41.20)AZ	2051.60(534.40)AR	14.77(sm)	89.64(49.97)AR	921.85(158.15)AZ
Ni	0.0005*	0.0010*	0.0120(0.0020)AR	0.0155(0.0055)AR	0.0100(sm)	0.0365(0.0155)AZ	0.0010*
N-NH4	0.01*	0.01*	0.10(0.09)AR	5.74(0.94)AR	0.01(sm)	0.22(0.21)AR	1.16(1.15)AR
N-NO2	0.005*	0.001*	0.195(0.105)AR	0.007(0.005)AZ	0.003(sm)	0.002*	0.012(0.010)AZ
N-NH3	0.01*	0.01*	0.10*	5.42*	0.01(sm)	0.21*	1.09*
N-NO3	8.97(0.13)AZ	8.06(0.11)AZ	0.50(0.18)AR	0.02*	3.53(sm)	0.02*	0.02*
Pb	0.0040*	0.0015*	0.0015*	0.0015*	0.0100(sm)	0.0100*	0.0020*
P	0.014(0.004)AR	0.011(0.001)AR	0.012(0.002)AR	0.038(0.028)AR	0.010(sm)	0.141(0.001)AZ	0.015(0.005)AR
Sb	0.002*	0.002*	0.002*	0.002*	0.005(sm)	0.002*	0.002*
Se	0.005*	0.005*	0.005*	0.005*	0.005(sm)	0.008(0.003)AR	0.005*
Si	23.35(1.34)AR	29.07(1.20)AR	14.60(3.37)AR	6.12(1.30)AZ	6.83(sm)	18.92(1.99)AZ	7.65(0.49)AR
Sn	0.001*	0.001*	0.004*	0.002*	0.050(sm)	0.003*	0.003*
SO4	92.05(5.95)AR	19.99(1.21)AR	714.70(169.70)AZ	183.75(2.25)AR	11.05(sm)	55.55(35.95)AR	4261.45(287.55)AR
S	0.10(sm)	0.10(sm)	0.00*	0.00*	0.10(sm)	0.00*	0.00*
Sr	3.022(0.378)AZ	4.979(0.612)AZ	2.604(0.756)AZ	14.195*	0.473(sm)	0.872(0.218)AZ	5.417*
TDS	424(38)AR	323(29)AR	966(12)AR	8216(1536)AR	174(sm)	286(72)AR	4094(1234)AR
Ti	0.0002*	0.0002*	0.0010*	0.0002*	0.0100(sm)	0.0150(0.0030)AR	0.0002*
Tl	0.003*	0.003*	0.003*	0.003*	0.050(sm)	0.003*	0.003*
TOC	1.0*	1.0*	1.0*	1.0*	5.0(sm)	4.3(3.3)AZ	1.0*
U	0.0025(0.0005)AZ	0.0045(0.0025)AZ	0.0029(0.0001)AR	0.0020*	0.0011(sm)	0.0015*	0.0021(0.0019)AR
V	0.001*	0.013*	0.002*	0.001*	0.010(sm)	0.011(0.003)AZ	0.001*
Zn	0.022(0.012)AR	0.003*	0.035(0.025)AR	0.029(0.019)AR	0.010(sm)	0.171*	0.162(0.152)AR
Oil&grease	0.10(sm)	0.12(sm)	0.13*	0.29*	0.10(sm)	0.15*	0.12*
Trichloroethylene	0.0008*	0.0008*	0.0008*	0.0008*	0.0050(sm)	0.0008*	0.0008*
Tetrachloroethyl	0.0008*	0.0008*	0.0008*	0.0008*	0.0050(sm)	0.0008*	0.0008*
-Pesticides,t	0.00008*	0.00008*	0.00008*	0.00008*	0.00008(sm)	0.00008*	0.00008*
-VOC	0.0034(sm)	0.0034(sm)	0.0034(sm)	0.0034(sm)	nm	0.0034(sm)	0.0034(sm)
Alfa-ac	nm	nm	0.07(sm)	0.27(sm)	nm	0.05(sm)	0.25(sm)
Beta-ac	nm	nm	0.35(sm)	1.22(sm)	nm	2.04(sm)	1.13(sm)
BOD5	nm	nm	2.5(sm)	33.5(sm)	nm	19.2(sm)	1.5(sm)
Coli-f	nm	nm	0(sm)	0(sm)	nm	0(sm)	0(sm)
Coli-t	nm	nm	0(sm)	0(sm)	nm	0(sm)	0(sm)

- Parameters grouped with respect to quality limits. sm: single measurements. nm: no measurement.

This indicates that groundwater anion facies changes stratigraphically downward as HCO_3 (PK4-W3-PK5-W2) → SO_4 (PK2-PK6) and → Cl (PK3). In other words, it indicates that groundwater; below coal seams is in chloride, in coal seams is in sulphate and above coal seams is in bicarbonate facies. According to the cation content, groundwater stratigraphically downward includes; Mg (W3-W2) → mix (PK4-PK5-PK2) → Na (PK6-PK3) facies with nearly constant Ca, decreasing Mg and increasing Na ratios. In other words, it indicates that groundwater; below and in coal seams is in sodium and above coal seams is in mix facies.

The differences and similarities of the major ion average concentration distributions are shown in Schoeller graph (Figure 5-21). High sulphate content of coal groundwater is probably related to the oxidation of high pyrite content (Toprak et al., 2015) in coal seams. None-reactive chloride concentrations from lower to higher values are observed in the following order: PK4 (4.5 mg/l) – PK5 (11.4 mg/l) – W3 (18 mg/l) - PK2 (38.3 mg/l) - W2 (51) - PK6 (132.6 mg/l) – PK3 (5306 mg/l). This order is similar to the decreasing hydraulic conductivity order of PK-coded well units. When all units filtered PK2 and unknown filtering units of W2 and W3 are excluded; hydraulic conductivity decreases stratigraphically downward in the order of PK4, PK5, PK6 and PK3.

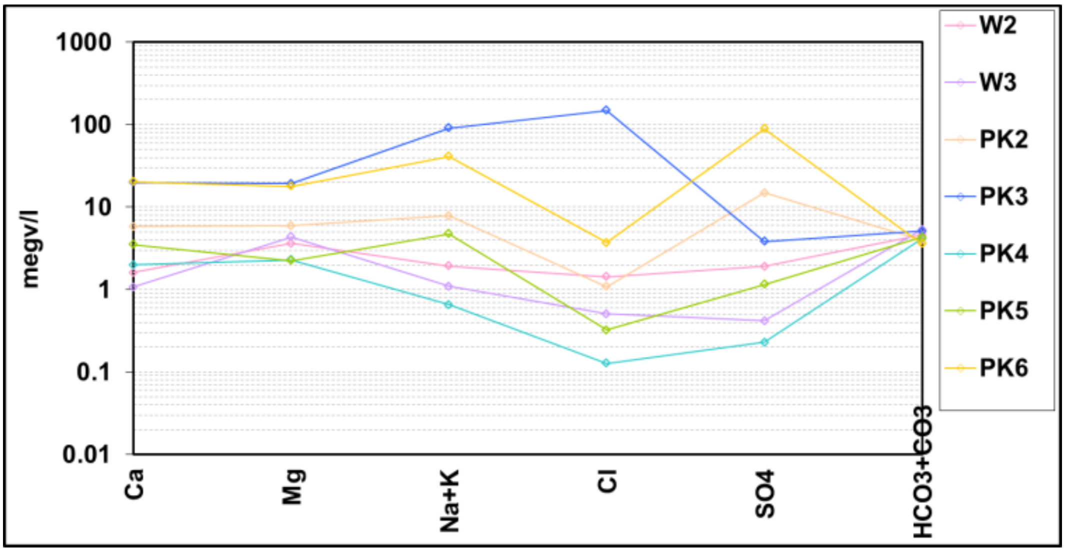


Figure 5-21: Major ion average concentration distributions in well waters on Schoeller graph

Due to longer residence time hence more reaction time, sodium cation has the highest concentration, which is probably exchange reactions related, in the deep groundwater. Groundwater of the units above coal seams (PK4 and PK5) has compatible water facies (Mg, mix-bicarbonate) with the springs which are thought to be related.

The comparison of parameter average concentrations (which are greater than the detection limits) in well waters is shown in Figure 5-22. Concentrations of Bi, CN, Hg, Tl, TOC (except PK5 October measurement 7.64 mg/l) and organic parameters trichloroethylene, tetrachloroethylene, pesticides (except nearby detection limit values of PK3 October measurement pp-DDT 0.00248 microg/l and endosulfan 0.00104 microg/l) and volatiles are below the detection limits in all monitoring locations. Oil & grease parameter which has values close to the detection limit in November measurement is not also shown in the figure. From upper stratigraphic level groundwater to those of down [in the order of PK4 (AC), PK5 (AC), PK2 (BC-IC-AC), PK6 (IC) and PK3 (BC)], concentrations of Ag, B, Ca, Cl, Fe, K, Li, Mg, Mn, Na, NH4, SO4 (except PK3), Sr, TDS and TKN parameters increase and those of As, Co, Cu, Si and V decrease (Figure 5-22).

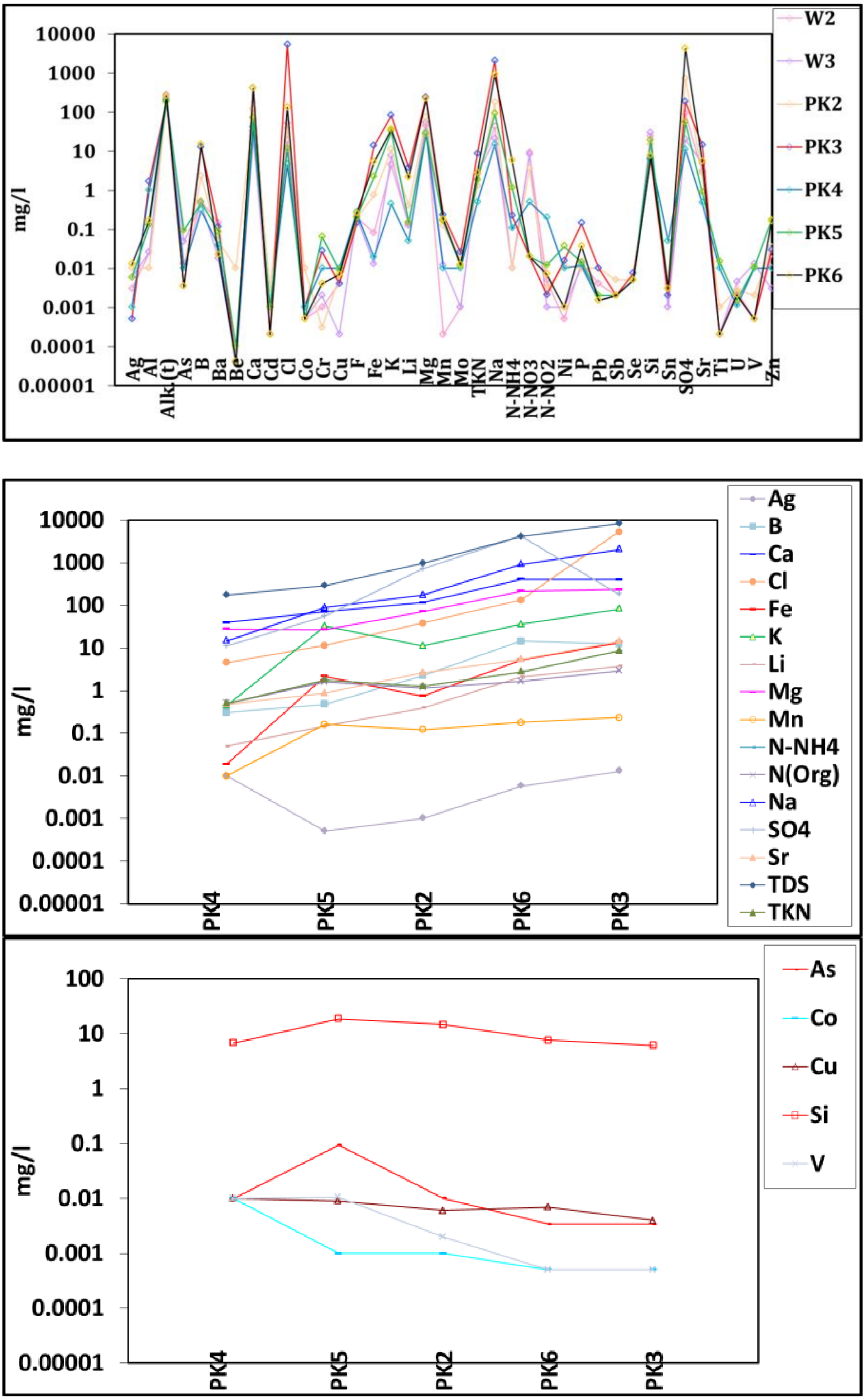


Figure 5-22: Average ion concentration distribution in well waters

Concentrations of ammonia/ammonium are much higher than generally expected values (<0.2 mg/l) in groundwater of coal seams and in the underlying unit (PK6; 1.1 mg/l and PK3; 5.4 mg/l). This level of ammonia/ammonium is most probably not anthropogenic but related to the degradation of natural organic material in the units. There is no such agricultural, cattle feeding or industrial operations/activities that could cause the high concentrations and furthermore, existing cattle feeding facilities (except one small facility) are located downgradient of well locations. Similarly, septics of lightly populated villages are also located at downgradient. Moreover, concentrations of amonnia/ammonium are low in shallow well waters (W2, W3 and PK4; 0.01 mg/l, PK5; 0.2 mg/l). However detailed studies including nitrogene isotopes are needed to define the source of nitrogene better.

When hydrochemical water facies differences studied in the monitoring period, it is observed that cation differences exit only in waters of PK5 and PK6 (Na type of PK5 water in wet period changes to mix type and mix type of PK6 water in the wet period changes to Na type). Concentration changes of parameters between the dry and wet periods are determined for well waters as percent average deviations and plotted in Figure 5-23 after the measurement error percent is subtracted. Based on all parameter and all monitoring locations, the average deviation is calculated to be about 15%.

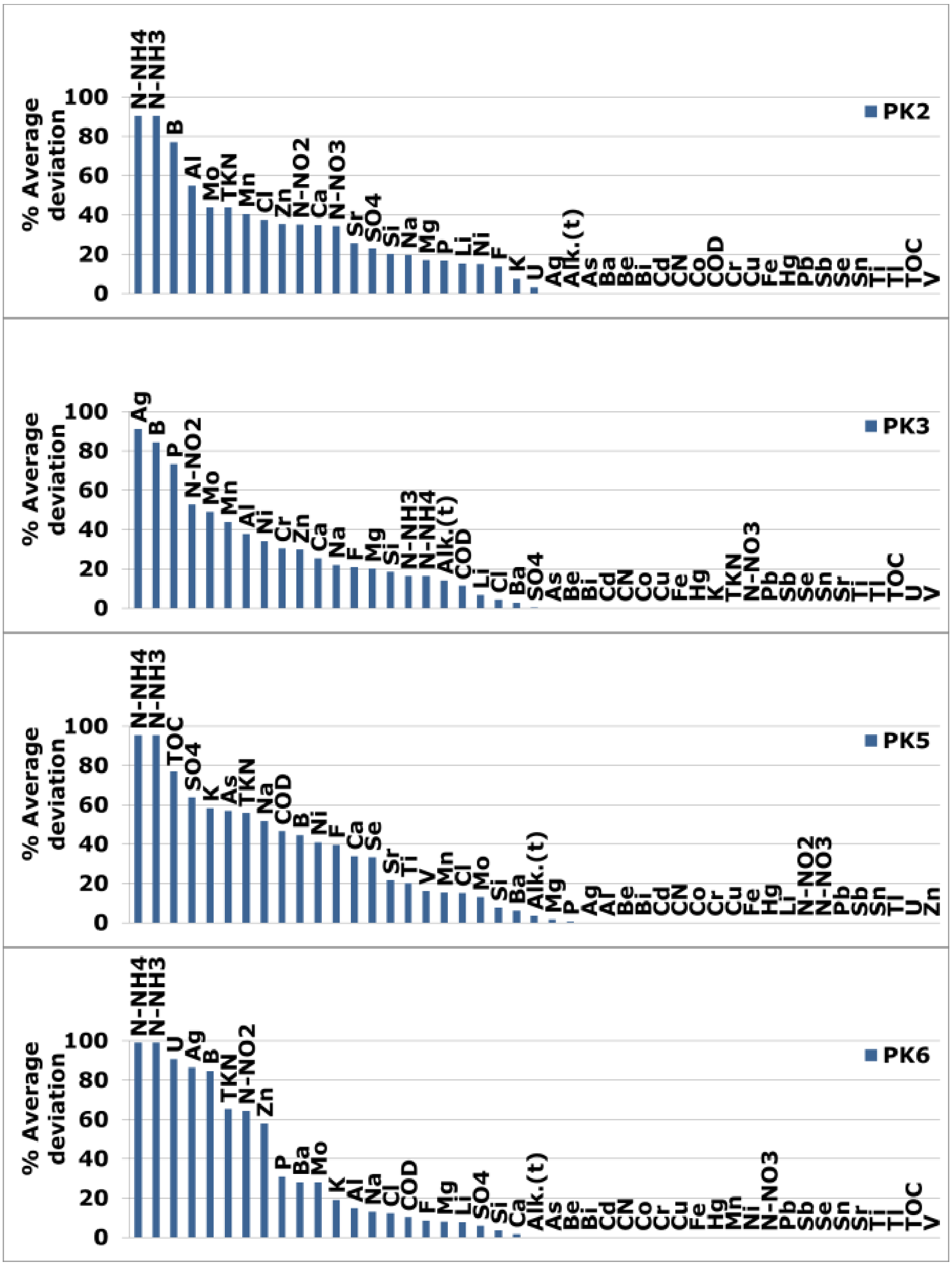


Figure 5-23: Percent average deviations of concentrations from the monitoring period average in well waters

According to the increasing/decreasing/unchanging trends between the dry and wet periods (Table 5-15), generally concentrations of P, Si, SO4, TKN and Zn parameters are higher and those of Al, B, Ca, F, K, Mg, Na and Sr parameters are lower in the wet period. Concentrations of the other parameters are similar (unchanging).

5.3.3. Village Depot Waters

Water to the depot (D1) of Ağapınar village is supplied form spring F2 and well W1, to the depot (D2) of Çavlum village is supplied form spring F4 and to the depot (D3) of Kireçköy village is supplied form spring F6 and well W2. The F6D water is transfer depot of F6 spring.

5.3.3.1. Field Measurements

The results of hydrochemical field parameter measurements in village water depot monitoring locations are given in APPENDIX-E and average values together with average deviations are listed in Table 5-16. The characteristic values of field parameters are estimated in 95% confidence interval and for pH additionally in 5% interval (Table 5-17).

Table 5-16: Average (AV) and average deviation (ADEV) values of hydrochemical field parameters measured in village water depots

AV (ADEV)	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%
D1	15.0(1.3)	7.99(0.09)	208(18)	570(13)	0.28(0.01)	371(9)	5.3(0.25)	57.2(2.5)
D2	13.8(2.2)	8.20(0.14)	189(33)	360(6)	0.17(0.00)	234(4)	7.1(0.25)	75.6(4.0)
D3	14.9(4.7)	8.14(0.10)	204(35)	578(12)	0.28(0.01)	376(8)	6.7(0.19)	72.4(5.8)
F6D	12.9(1.7)	8.17(0.13)	238(16)	410(53)	0.20(0.03)	267(34)	6.9(0.40)	71.6(2.3)

Table 5-17: Characteristic values of hydrochemical field parameters measured in village water depots

No	Method	T(oC) %95	pH %95	pH %5	ORP (mv) %95	EC 25oC (μS/cm) %95	S (ppt) %95	TDS (mg/l) %95	DO (mg/l) %95	DO% %95
D1	HAZEN	17.3	8.18	7.8	242	597	0.29	388	6.1	63
D2	HAZEN	17.4	8.48	8.0	268	384	0.19	250	7.8	83
D3	HAZEN	21.7	8.33	8.0	259	601	0.29	391	7.2	87
F6D	HAZEN	15.3	8.41	8.0	274	560	0.27	364	8.0	76

Average values of T, pH, EC, DO and ORP parameters are shown in Figure 5-24. Average electrical conductivity values change between 360 μS/cm and 578 μS/cm. Waters of well water mixed D1 and D3 depots have higher EC values. Average values of total dissolved solids and salinity which are determined using measured

EC values, changes in the intervals of 234-376 mg/l and 0.17-0.28 ppt, respectively.

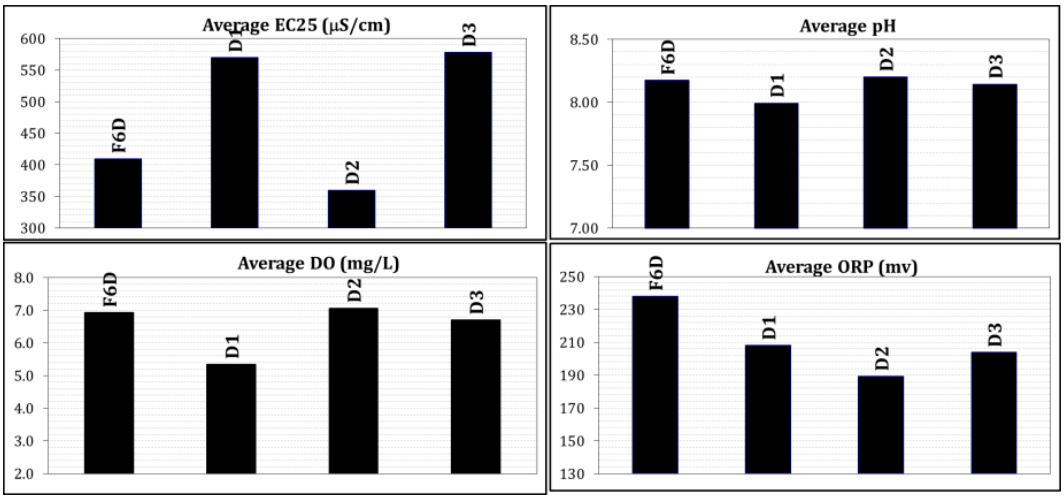


Figure 5-24: Average pH, EC, DO and ORP values measured in village water depot monitoring locations

Waters in the monitoring locations are in basic character and average pH values change in the interval of 7.99 and 8.20; dissolved oxygen average values change in the interval of 5.3-6.1 mg/l. Average values of oxidation-reduction potential change in the interval of 189-238 mv and all waters show oxidation characteristics.

Percent changes in the field parameter values during the monitoring period are shown in Figure 5-25 for village depot waters as percent average deviation which is determined after the measurement percent error subtraction. The averages of percent average deviations from higher to lower values are determined in temperature (17%), ORP (8%), EC (3.7%) dissolved oxygen (3.1%), and pH (1.1%) parameters.

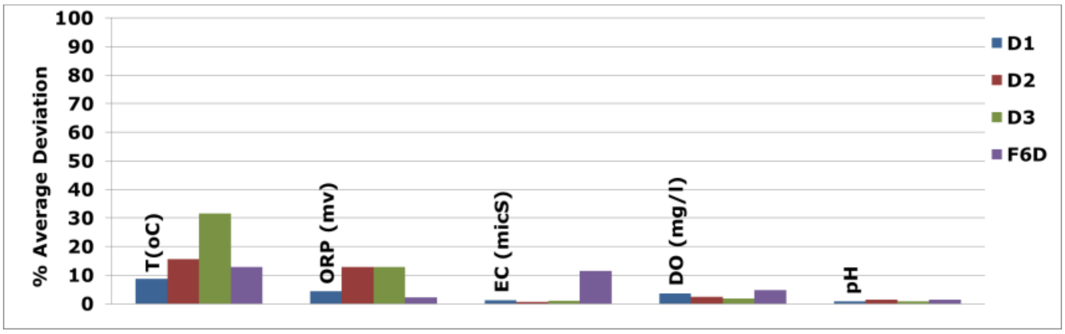


Figure 5-25: Percent average deviations of the field parameters measured in village depot waters

Monthly changes of field parameters in the waters are shown in Figure 5-26. Averages and average deviations of the dry-wet periods are listed in Table 5-18 together with the decreasing/increasing/unchanging trends (which were determined after measurement percent error subtraction). Temperature parameter with 10% average deviation decreases in the wet period. Values of EC parameter with 1.3% average deviation increases in D2 and F6D waters in the wet period and the deviation is within analytical error limits for the well water fed D1 (form well W1) and D3 (from well W2) waters. Monthly trend of pH seems to be reversely related to that of temperature.

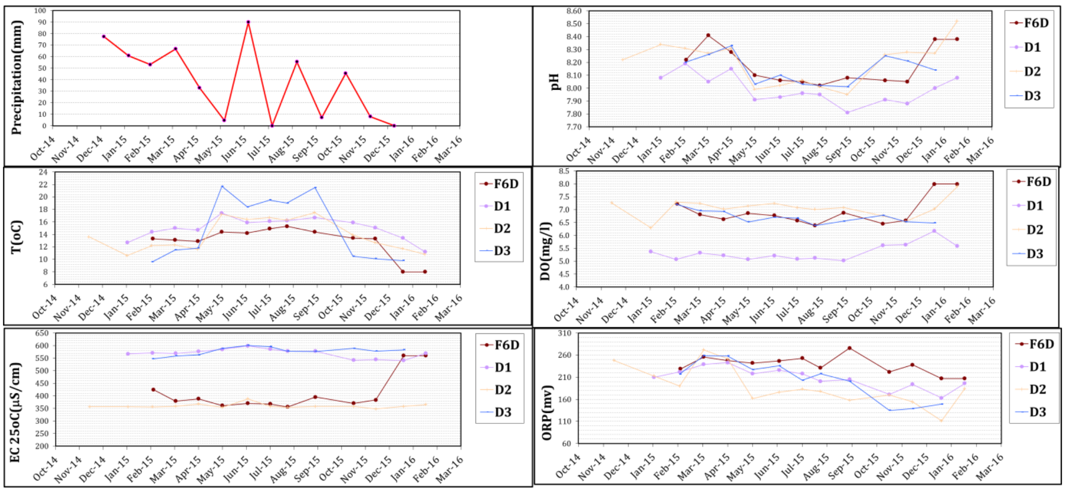


Figure 5-26: Monthly changes of temperature, pH, EC, DO, ORP values in village depot waters and precipitation distribution

Table 5-18: Average (AV), average deviation (ADEV) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of field parameters between dry and wet periods in village water depot monitoring locations

Dry-Wet AV(ADEV)	T(oC)	pH	ORP (mv)	EC (μS/cm) 25C	DO (mg/l)
D1	15.4(1.0)AZ	7.96(0.07)AR	208*	571*	5.3(0.10)AR
D2	14.5(1.5)AZ	8.16(0.09)AR	182(18)AR	358(4)AR	7.0*
D3	15.6(2.6)AZ	8.13(0.06)AR	201(9)AR	580*	6.7(0.10)AR
F6D	13.3(1.0)AZ	8.15(0.08)AR	242(11)AZ	402(25)AR	6.9(0.15)AR

pH values with low average deviation (0.6%) increse in the wet period. Dissolve oxygen parameter shows very little change (%0.6) between the dry and wet periods and it exhibits unchanging trend in D2 location but slightly increases in the others. ORP values with 1.3% average deviation show generally decreasing trend during the measurement period and in the wet period it increases in D2 and D3 waters, decreases in F6D water and does not change in D1 water. The average percent deviation of all field parameters (excluding temperature) between the dry and wet periods is about 1%. The evaluations indicate that field parameter value changes in village water depots between the dry and wet periods are very low.

5.3.3.2. Laboratory Measurements

The results of detailed chemical analyses from village water depot monitoring locations are given in APPENDIX-F and average values together with average deviations are listed in Table 5-19 which also includes the decreasing /increasing/unchanging concentration trends between the dry and wet periods. Water facies of depot waters as determined from relative major ion concentration distributions are shown in Figure 5-27. Çavlum depot water (D2) is in mix-HCO_3 facies and the others are in Mg-HCO_3 facies. Comparisons of parameter average concentrations (which are greater than the detection limits) in depot waters is shown in Figure 5.28. Concentrations of Ag, Be, Bi, Co, CN, Hg, Mo, Se, Sn, Ti and TOC and organic parameters are below the detection limits in all monitoring locations.

Table 5-19: Average (AV), average deviation (ADEV) values and increasing (AR)/decreasing (AZ)/unchanging (*) trends of laboratory parameters between dry and wet periods in village water depot monitoring locations (Unit: mg/l, color: pt/co, bacteriological: cfu/100 mL)

AV(ADEV) Dry-Wet */AR/AZ	D1	D2	D3	F6D
Ag	0.0005*	0.0005*	0.0005*	0.0005*
Al	0.045(0.042)AZ	0.035(0.032)AZ	0.037(0.024)AZ	0.054(0.047)AZ
Alk.(t)	216(51)AR	171(15)AZ	218(17)AZ	185(21)AZ
As	0.0190*	0.0034*	0.0075(0.0025)AZ	0.0034*
B	0.328(0.108)AZ	0.167(0.063)AR	0.419*	0.091*
Ba	0.121*	0.123*	0.080(0.016)AZ	0.042*
Be	0.00004*	0.00004*	0.00004*	0.00004*
Bi	0.01*	0.01*	0.01*	0.01*
Ca	19.76(3.96)AZ	33.23(0.73)*	36.63(2.16)AZ	31.13(1.48)AZ
Cd	0.2035(0.2005)AR	0.0002*	0.0002*	0.0002*
Cl	20.88(1.82)AR	8.84(0.67)AR	27.66(0.06)*	4.93(0.68)AR
CN	0.01*	0.01*	0.01*	0.01*
Co	0.0005*	0.0005*	0.0005*	0.0005*
COD	22(17)AR	15(8)AR	10*	18(3)*
Color	2.2(sm)	2.2(sm)	2.2(sm)	2.2(sm)
Cr	0.0010*	0.0003*	0.0003*	0.0003*
Cu	0.0002*	0.0002*	0.1260(0.1160)AR	0.0020*
F	0.32(0.06)AZ	0.35(0.04)AZ	0.26(0.06)AZ	0.25(0.03)AZ
Fe	0.015(0.012)AZ	0.008(0.008)AZ	0.021*	0.017(0.013)AZ
Preac	0.011(0.001)AR	0.011(0.001)AR	0.014(0.004)AR	0.013(0.003)AR
Hg	0.00008*	0.00008*	0.00008*	0.00008*
K	1.460(1.410)AR	0.395(0.006)AZ	2.646(0.284)AZ	0.410(0.043)AZ
Li	0.110(0.011)AR	0.021*	0.048(0.029)AZ	0.027*
Mg	55.44(2.95)AR	25.12(1.30)AZ	42.39(3.69)AZ	25.22(0.52)AZ
Mn	0.0002*	0.0002*	0.0225(0.0125)AR	0.0002*
Mo	0.001*	0.001*	0.001*	0.001*
TKN	2.55(2.05)AR	2.75(1.00)AR	1.88(1.32)AR	2.09(1.39)AR
N(Org)	2.53(2.03)AR	2.75(1.01)AR	1.88(1.33)AR	2.08(1.39)AR
Na	16.96(1.98)AZ	9.40(2.48)AZ	26.97(2.35)AZ	7.05(3.67)AZ
Ni	0.0020*	0.0005*	0.0120(0.0020)AR	0.0020*
N-NH4	0.02(0.01)AR	0.01*	0.01*	0.01*
N-NO2	0.001*	0.001*	0.002*	0.001*
N-NH3	0.02*	0.01*	0.01*	0.01*
N-NO3	6.32(0.06)AZ	3.29(0.27)AZ	6.11(0.37)AZ	3.32(0.30)AZ
Pb	0.0020*	0.0015*	0.0040*	0.0125*
P	0.011(0.001)AR	0.011(0.001)AR	0.014(0.004)AR	0.013(0.003)AR
Sb	0.002*	0.002*	0.002*	0.003*
Se	0.005*	0.005*	0.005*	0.005*
Si	23.06(3.38)AR	10.35(1.19)AR	15.53(1.59)AR	7.42(0.78)AR
Sn	0.001*	0.001*	0.001*	0.001*
SO4	16.48(2.52)AR	12.65(1.36)AR	49.43(0.57)AR	11.47(0.53)AR
Sr	1.872*	0.399(0.015)AZ	1.112(0.748)AZ	0.430(0.029)AZ
TDS	224(34)AZ	148(20)AZ	248(32)AZ	177(5)AR
Ti	0.0002*	0.0002*	0.0002*	0.0002*
Tl	0.003*	0.003*	0.003*	0.004*
TOC	1.0*	1.0*	1.0*	1.0*
U	0.0036(0.0016)AZ	0.0018(0.0003)AR	0.0027(0.0003)AR	0.0017(0.0004)AR
V	0.013*	0.004*	0.003*	0.002*
Zn	0.015*	0.006(0.005)AZ	0.017*	0.016*
Acrylamide	0.00005*	0.00005*	0.00005*	0.00005*
Bromate	0.01*	0.01*	0.01*	0.01*
Trichloroethylene	0.0008*	0.0008*	0.0008*	0.0008*
Tetrachloroethylene	0.0008*	0.0008*	0.0008*	0.0008*
Benzene	0.00084*	0.00084*	0.00084*	0.00084*
-PAH	0.00005*	0.00005*	0.00005*	0.00005*
-Pesticides,t	0.00008*	0.00008*	0.00008*	0.00008*
-VOC	0.0034(sm)	0.0034(sm)	0.0034(sm)	0.0034(sm)
1,2-dichloroethane	0.0006*	0.0006*	0.0006*	0.0006*
-Trihalomethanes	0.0019*	0.0019*	0.0019*	0.0019*
Vinyl chloride	0.0005*	0.0005*	0.0005*	0.0005*
-PSAH	0.00005*	0.00005*	0.00005*	0.00005*
Benzo(a)pyrene	0.00005*	0.00005*	0.00005*	0.00005*
BOD5	2.7*	3.5(1.5)AR	3.5(1.5)AR	3.7*
Coli-f	0*	0*	0*	15(15)AR
Coli-t	15000(15000)AZ	50000(50000)AZ	7500(7500)AZ	7515(7485)AZ
f-Streptecoccus	0*	0*	5(5)AR	10(10)AR
E-Coli	30(30)AZ	50(50)AZ	20(20)AZ	55(25)AZ
Enterococcus	0*	0*	0*	10(10)AR

- Parameters grouped with respect to quality limits. sm: single measurements.

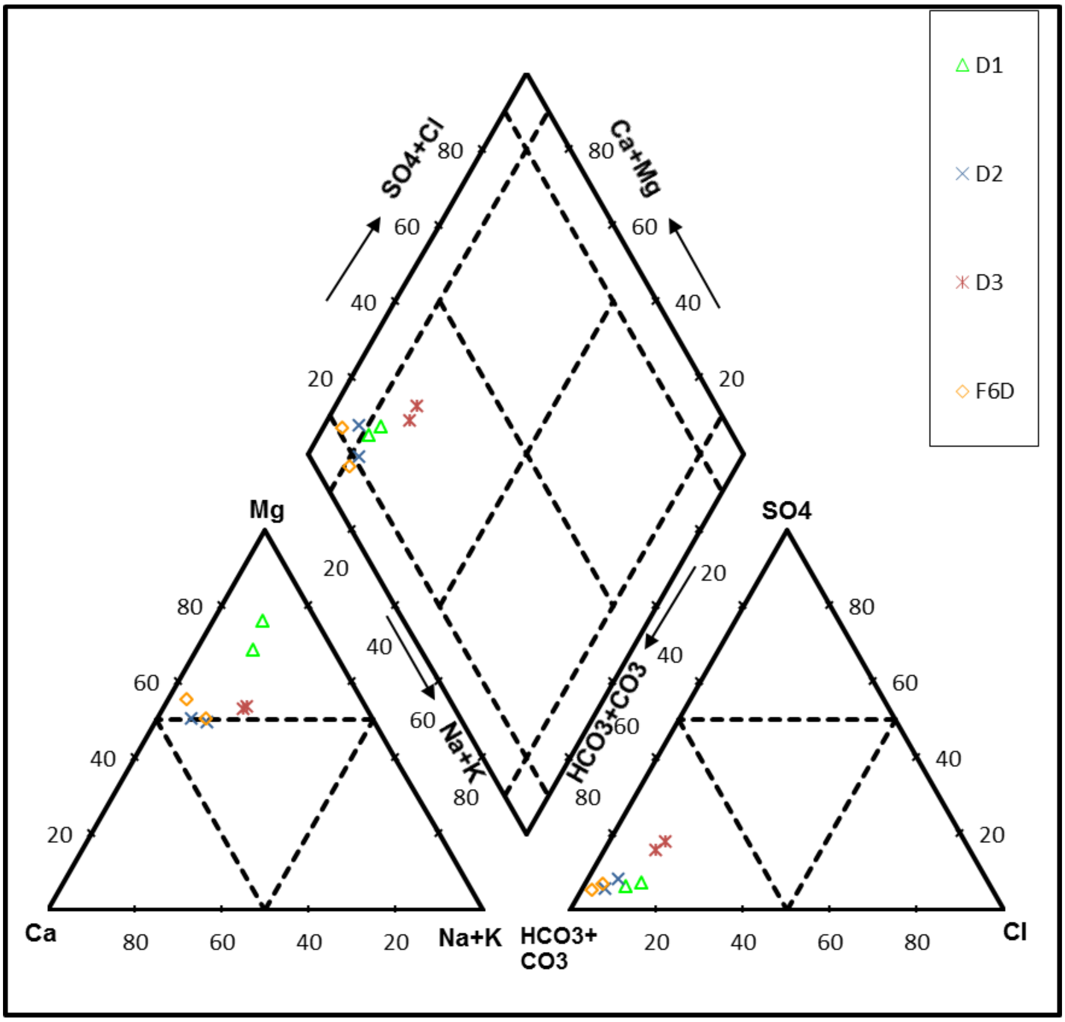


Figure 5-27: Relative major ion concentration distribution village depot waters on Piper graph

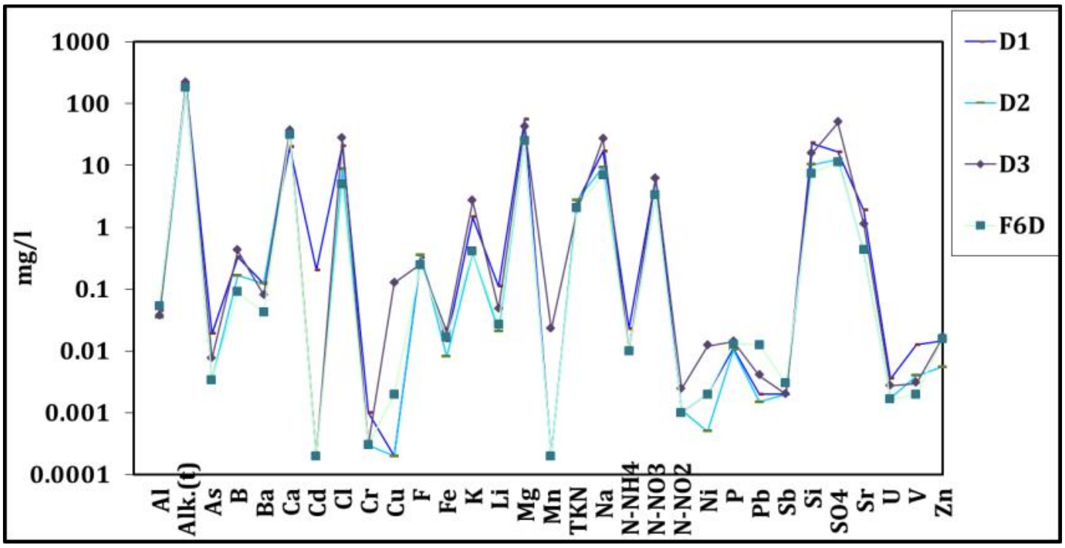


Figure 5-28: Average ion concentration distribution in village depot waters

When hydrochemical water facies differences studied in the monitoring period, it is observed that only Mg type of D2 water in the wet period changes to mix type in the dry period. Concentration changes of parameters between the dry and wet periods are determined for depot waters as percent average deviations and plotted in Figure 5-29. Based on all parameter and all monitoring locations, average deviation is calculated to be about 9%.

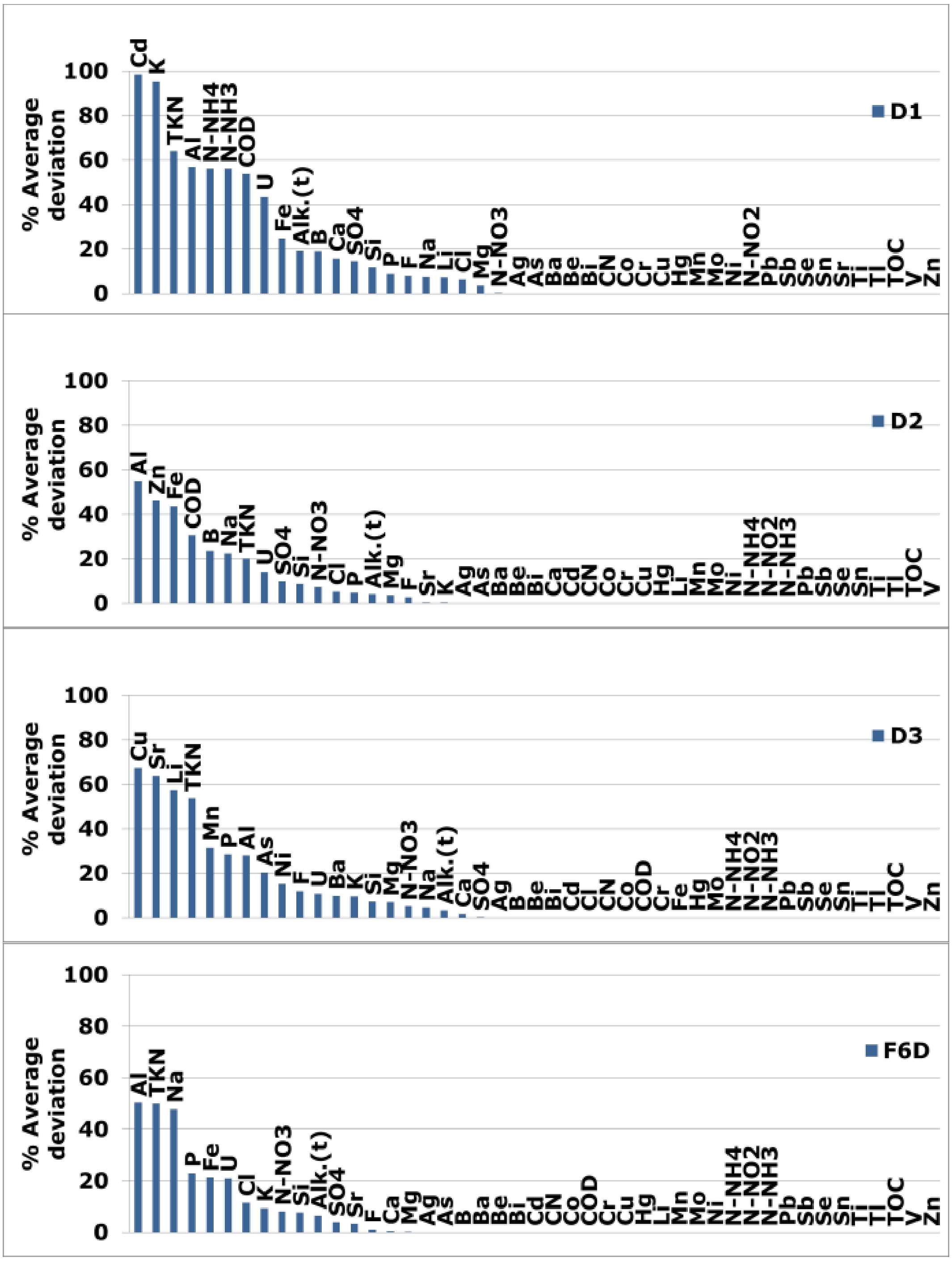


Figure 5-29: Percent average deviations of concentrations from the monitoring period average in village depot waters

According to the increasing/decreasing/unchanging trends between the dry and wet periods (Table 5-19), generally concentrations of Cl, P, TKN Si, SO4, U and Zn parameters are higher and Al, Alk, Ca, F, Fe, K, Mg, Na and Sr parameters are lower in the wet period. Concentrations of the other parameters are similar (unchanging).

5.4. Water Quality

The surface water classification (YSKYY, 2012, 2015), groundwater classification (SKKY, 2008; YKBKK, 2012), irrigation water classification (AATTUT, 2010), drinking water supply surface water classification (İSYSKY, 2012) and human consumption water limits (İTAS, 2005) are used for the evaluation of water quality. In addition, parameters listed in surface water monitoring related regulation (YSYSİY, 2014) are taken into consideration.

In the evaluation of water quality, arithmetic average values are used as characterisitic values because existing data covers less than 10 set of measurements in the first three years period as required by the regulations of Surface Water Quality Management (YSKYY, 2012) and Drinking Water Related Surface Water Quality (İSYSKY, 2012).

After the regulation of groundwater protection against contamination and degradation (YKBKK, 2012), previously used groundwater quality determinations related classification limits (SKKY, 2008) are abolished. Because groundwater quality standards and threshold values have not been established yet by Water Management Directorate as required by the fore mentioned regulation, in the report, previously used quality classification limits (**SKKY, 2008) are used by adapting Cd and P limits of** YSKYY (2012) and adding parameters **(pesticides, tetrachloroethylene, trichloroethylene)** of **YKBKK (2012).**

5.4.1. Surface Waters

Quality of surface waters based on the surface water classification, irrigation water classification, drinking water supply surface water classification for each monitoring period is given in APPENDIX-G and average concentrations related quality summary is listed in Table 5-20. In addition, detailed results of the surface water classification based on average values are also given in Table 5-21.

Table 5-20: Water quality classifications of Porsuk stream

	SURFACE WATER CLASSIFICATION	IRRIGATION WATER CLASSIFICATION
SW3	CLASS IV-Cd, TKN, N-NH4, N-NO2, P, Coli-f	CLASS III-Cd, Na(I), TSS(A), TSS(B), Coli-f.(A), Coli-f(B)
SW4	CLASS IV-BOD5, COD, TKN, N-NH4, O2, P, Coli-f	CLASS III-BOD5(A), Na(I), Na(II), TSS(A), Coli-f.(A), Coli-f(B)

	DRINKING WATER SUPPLY SURFACE WATER CLASSIFICATION
SW3	UNSUITABLE-BOD5, Cd, COD, TKN, P,reak, Coli-f, Coli-t, f-Streptecoc
SW4	UNSUITABLE-BOD5, COD, TKN, N-NH3, O2%, P reac, Coli-f, Coli-t, f-Streptecoc

Irrigation water explanation:

(I): Surface water irrigation, (II): Drip irrigation

(A): CLASS A Good quality irrigation water due to human contact with edible products and plants in park, garden areas. Irrigation of food products that are not commercially processed and irrigation of city park, garden etc.

(B) CLASS B Low quality irrigation water used for the irrigation of food products that are commercially processed (fruit gardens and vineyards), people resricted areas such as grass growth and agricultural areas and meadow and hay growth areas for range cattles.

Metal parameters are for continuous irrigation of all soil media types.

Table 5-21: Surface water quality classification of Porsuk stream

	SURFACE WATER CLASSIFICATION				SW3	SW4
PARAMETER	Class I	Class II	Class III	Class IV	CLASS IV	CLASS IV
Al	0.3	0.3	1	> 1	0.079	0.056
As	0.02	0.05	0.1	> 0.1	0.007	0.013
B	1	1	1	> 1	0.23	0.43
Ba	1	2	2	> 2	0.09	0.08
BOD	4	8	20	> 20	15	21
Cd	0.002	0.005	0.007	> 0.007	0.1595	-0.0002
CN	0.01	0.05	0.1	> 0.1	-0.0100	-0.0100
Co	0.01	0.02	0.2	> 0.2	-0.001	-0.001
COD	25	50	70	> 70	61	83
Cr	0.0200	0.0500	0.2000	> 0.2	0.0040	0.0020
Cu	0.0200	0.0500	0.2000	> 0.2	0.0030	0.0030
EC	400	1000	3000	>3000	953	999
F	1	1.5	2	> 2	0.2	0.2
Fe	0.3	1	5	> 5	0.072	0.052
Hg	0.0001	0.0005	0.002	> 0.002	-0.00008	-0.00008
Mn	0.1	0.5	3	> 3	0.0505	0.0510
TKN	0.5	1.5	5	> 5	8.0	10.1
N-NH4	0.2	1	2	> 2	3.89	4.48
N-NO2	0.01	0.06	0.12	> 0.3	0.253	0.103
N-NO3	5	10	20	> 20	0.51	0.19
Ni	0.02	0.05	0.2	> 0.2	0.017	0.014
O2	8	6	3	< 3	3.78	1.50
O2%	90	70	40	< 40	46.5	20.1
P	0.03	0.16	0.65	> 0.65	1.819	2.466
Pb	0.01	0.02	0.05	> 0.05	0.0130	0.0030
pH	6.5-8.5	6.5-8.5	6.0-9.0	<6.0 ->9.0	8.15	8.12
Color**	5	50	300	>300	19.6	23.6
S-2	0.002	0.002	0.01	>0.01	-0.01	-0.01
Se	0.01	0.01	0.02	> 0.02	-0.005	-0.005
Temperature	25	25	30	> 30	18.9	17.2
Zn	0.2	0.5	2	> 2	0.0435	0.0185
Coli-f	10	200	2000	> 2000	50100	50500
Coli-t	100	20000	100000	> 100000	50200	51250

(Detection limits are shown as minus. Unit: mg/l, EC: uS/cm, Coliform: cfu/100 mL. ** Color limits are changed for pt-co scale)

Average concentrations indicate that based on the surface water classification limits, Porsuk stream includes highly contaminated quality (Class IV) water due to high TKN, N-NH4, P and fecal coliform values. In addition, values of Cd and N-NO2 in SW3 location and values of BOD, COD and O2 in SW4 location are also in Class IV quality. Changes of the surface water quality between the dry and wet periods indicate that high BOD, COD and fecal coliform values are also in Class IV quality in the dry period of upstream water. In the downstream location, Cd is not in Class IV of the dry period but fecal coliform is.

According to the drinking water supply surface water limits, Porsuk stream water is in unusable (A4) quality due to high average concentrations of BOD, Cd, COD, TKN, N-NH3, reactive P, coliform and f-streptecoc (Table 5-22). Quality changes between the dry and wet periods indicate that in the dry period coliform and f-streptecoc parameters are added to the unusable quality class but N-NH3 parameter is not in this class.

Porsuk stream water is not suitable (hazardous, Class III) for irrigation in SW4 location due to high Na content however concentrations are suitable for the drip irrigation in SW3 (Table 5-22). But SW3 water includes high TSS and f-coliform values of Class B level. Moreover, SW3 water includes Cd concentration that exceeds the limit of continuous irrigation in all soil types. The stream water as irrigation water does not cause any infiltration rate decrease in soils. The irrigation water quality distribution in terms of SAR and EC values and effects on the infiltration rate are shown in Figure 5.30. Changes of the irrigation water quality between the dry and wet periods indicate that SW3 water in the wet period is suitable for the drip irrigation and in Class-A level but in the dry period, water is not suitable for the irrigation due to high Na, TSS and f-coliform concentrations and in Class B level. The drip irrigation suitable SW4 water in the wet period, is not suitable due high Na concentration in the dry period.

5.4.2. Spring and Fountain Waters

The quality of spring and fountain waters based on the groundwater classification, irrigation water classification and human consumption limits for each monitoring period is given in APPENDIX-G and average concentrations related quality summary is listed in Table 5-23. In addition, detailed results of groundwater classification based on average values are given in Table 5-24 and distributions of the quality are shown in Figure 5-31.

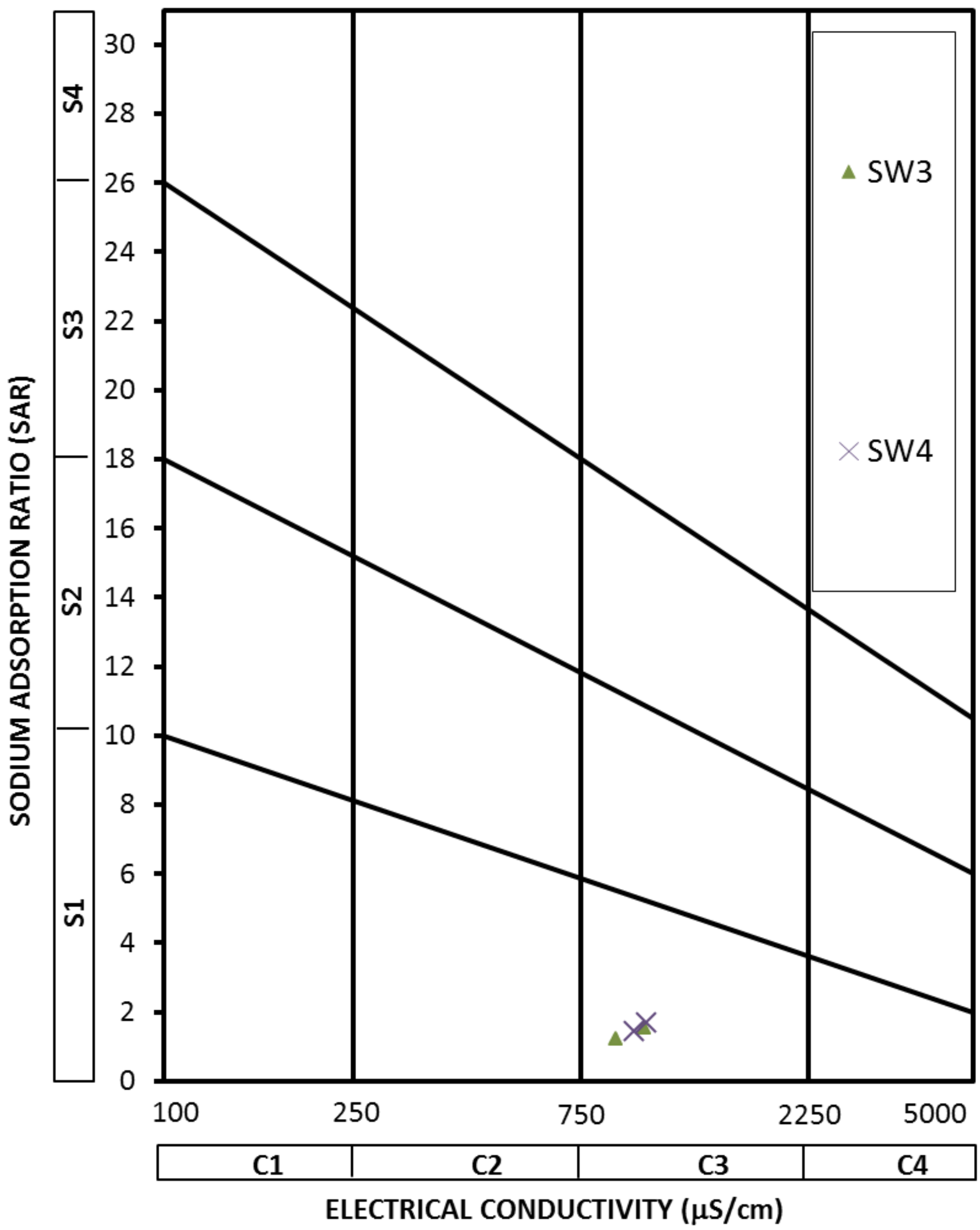
Average concentrations indicate that based on the groundwater classification limits, all spring and fountain waters except F7 include low quality (Class III) groundwater due to high TKN/Cd/Cr/Pb or low O2 values. F7 water is in moderate quality (Class II) due to relatively high TKN, NO2, oil & grease and low oxygen values. Quality classes of spring and fountain waters do not change between the dry and wet periods except at the location of F2 where due to decreasing COD content in the dry period the water quality improves to the moderate class (II).

Table 5-22: Drinking and irrigation water quality classifications of Porsuk stream

	IRRIGATION WATER CLASSIFICATION			SW3	SW4
PARAMETER	Class I	Class II	Class III	CLASS III	CLASS III
B	0.7	3	>3	0.229	0.43
BOD(A)	20		>20	15.07	21.32
BOD(B)	30		>30	15.07	21.32
Cl(I)	140	350	>350	71.8	77.7
Cl(II)	100		>100	71.8	77.7
EC	700	3000	>3000	953	999
Na(I)	3	9	>9	62.24	74.58
Na(II)	70		>70	62.24	74.58
pH	6.0-9.0		<6->9	8.15	8.12
SAR-EC				I	I
TDS	500	2000	>2000	495	483
TSS(A)	5		>5	33	27
TSS(B)	30		>30	33	27
Al	5		>5	0.079	0.056
As	0.1		>0.1	0.007	0.013
Be	0.1		>0.1	-0.00004	-0.00004
Cd	0.01		>0.01	0.1595	-0.0002
Co	0.05		>0.05	-0.001	-0.001
Cr	0.1		>0.1	0.0040	0.0020
Cu	0.2		>0.2	0.0030	0.0030
F	1		>1	0.25	0.20
Fe	5		>5	0.07	0.05
Li	2.5		>2.5	0.040	0.020
Mn	0.2		>0.2	0.0505	0.0510
Mo	0.01		>0.01	0.003	-0.001
Ni	0.2		>0.2	0.017	0.014
Pb	5		>5	0.013	0.003
Se	0.02		>0.02	-0.005	-0.005
V	0.1		>0.1	0.003	0.003
Zn	2		>2	0.0435	0.0185
Coli-f(A)	0		>0	50100	50500
Coli-f(B)	200		>200	50100	50500

	DRINKING WATER SUPPLY SURFACE WATER CLASSIFICATION				SW3	SW4
PARAMETER	A1	A2	A3	A4	A4	A4
Al	0.3	0.3	1	>1	0.079	0.056
As	0.05	0.05	0.1	>0.1	0.007	0.013
B	1	1	1	>1	0.23	0.43
Ba	0.1	1	1	>1	0.09	0.08
BOD	3	5	7	>7	15.07	21.32
Cd	0.005	0.005	0.005	>0.005	0.1595	-0.0002
Cl	200	200	200	>200	71.8	77.7
CN	0.05	0.05	0.05	>0.05	-0.0100	-0.0100
Co	0.01	0.02	0.2	>0.2	-0.0005	-0.0005
COD	15	30	40	>40	61	83
Cr	0.05	0.05	0.05	>0.05	0.0040	0.0020
Cu	0.05	0.05	1	>1	0.0030	0.0030
EC*	1111	1111	1111	>1111	953.0	999.0
F	1.5	0.7	1.7	>1.7	0.25	0.20
Fe	0.3	2	2	>2	0.072	0.052
Hg	0.001	0.001	0.001	>0.001	-0.00008	-0.00008
Mn	0.05	0.1	1	>1	0.051	0.051
TKN	1	2	3	>3	8.025	10.105
N-NH3	0.05	1.5	4	>4	3.67	4.23
NO3	50	50	50	>50	-2.27	-0.85
Ni	0.02	0.05	0.2	>0.2	0.0165	0.0140
O2%	70	50	30	<30	46.50	20.05
P,reac	0.4	0.7	0.7	>0.7	0.833	1.046
Pb	0.05	0.05	0.05	>0.05	0.0130	0.0030
pH	6.5- 8.5	..5.5-9	<5.5 ->9	<5.5 ->9	8.15	8.12
Color	20	100	200	>200	20	24
Se	0.01	0.01	0.01	>0.01	-0.0050	-0.0050
Temperature	25	25	25	>25	18.9	17.2
SO4	250	250	250	>250	76.67	78.59
TSS	25	>25			33	27
TOC	5	8	12	>12	6	7
Zn	3	5	5	>5	0.044	0.019
Pesticides,t	0.001	0.0025	0.005	>0.005	0.00007	0.00014
Phenols	0.001	0.005	0.1	>0.1	0.0005	-0.0003
PAH	0.05	0.2	1	>1	-0.0010	-0.0010
PSAH	0.0002	0.0002	0.001	>.001	-0.00005	-0.00005
MBAS	0.2	0.2	0.5	>0.5	-0.0250	-0.0250
Coli-f	20	2000	20000	>20000	50100	50500
Coli-t	50	5000	50000	>50000	50200	51250
f-Streptecoc	20	1000	10000	>10000	50075	50400

(Detection limits are shown as minus. Unit: mg/l, color: pt/co, bacteryological: cfu/100 mL, temperature ^{o}C, for **(I), (II), (A) and (B) explanations see foot note of Table 5.20').**


SODIUM ADSORPTION RATIO (SAR)
S4
S3
S2
S1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
SW3
SW4
100
250
750
2250
5000
C1
C2
C3
C4
ELECTRICAL CONDUCTIVITY (µS/cm)

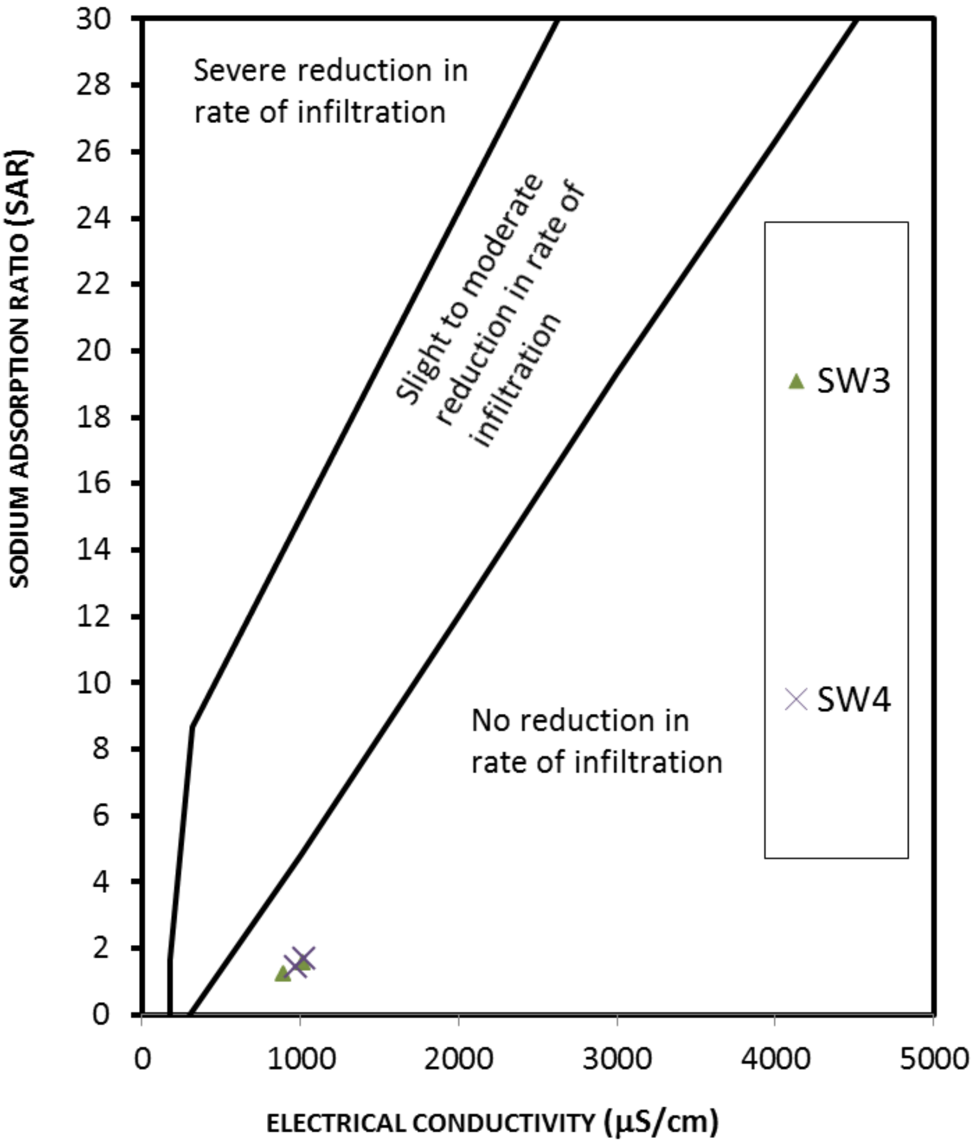


Figure 5-30: According to SAR and electrical conductivity values a) quality distribution and b) effect on the infiltration rate as irrigation water of Porsuk stream

Table 5-23: Water quality classifications of spring and fountain waters (For explanations of irrigation water classification see foot note of Table 5.20)

	GROUNDWATER CLASSIFICATION	IRRIGATION WATER CLASSIFICATION	HUMAN CONSUMPTION	INDICATOR PARAMETERS
F1	CLASS III-TKN, O2	CLASS III-TSS(A)		
F2	CLASS III-TKN	CLASS II-Na(I), SAR-EC		
F3	CLASS III-Cd, TKN, O2, Pb	CLASS III-Cd, Na(I), TSS(A), TSS(B)	As, Cd, Pb	
F4	CLASS III-Cr, TKN	CLASS III-Cr, Na(I)	Cr	
F5	CLASS III-TKN, O2%	CLASS II-Na(I), SAR-EC		
F6	CLASS III-TKN	CLASS II-Na(I), SAR-EC		Fe
F7	CLASS II-TKN, N-NO2, O2, Oil&grease	CLASS II-Na(I), SAR-EC		

Table 5-24: Groundwater quality classification of spring and fountain waters and suitability for human consumption

	GROUNDWATER CLASSIFICATION			HUMAN CONSUMPTION YAS	F1	F2	F3	F4	F5	F6	F7
PARAMETER	Class I	Class II	Class III	ove limit value	CLASS III	CLASS III	CLASS III	CLASS III	CLASS III	CLASS III	CLASS II
As	0.02	0.05	> 0.05	0.01	-0.003	-0.003	0.023	0.003	0.004	-0.003	-0.003
B	1	1	> 1	1	0.27	0.15	0.31	0.15	0.08	0.08	0.08
Ba	1	2	> 2	0.7	0.07	0.07	0.16	0.24	0.13	0.04	0.04
Cd	0.002	0.005	> 0.005	0.005	-0.0002	-0.0002	0.1185	-0.0002	-0.0002	-0.0002	-0.0002
CN	0.01	0.05	> 0.05	0.05	-0.0200	-0.0200	-0.0200	-0.0200	-0.0200	-0.0200	-0.0200
Co	0.01	0.02	> 0.02		-0.0005	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005
COD	25	50	> 50		15.00	33.00	31.50	7.00	22.00	6.00	12.00
Cr	0.02	0.05	> 0.05	0.05	-0.0003	-0.0003	0.0010	0.2160	0.0020	-0.0003	-0.0003
Cu	0.02	0.05	> 0.05	2	-0.0002	-0.0002	-0.0002	-0.0002	0.0060	-0.0002	-0.0002
F	1	1.5	> 1.5	1.5	0.33	0.32	0.32	0.35	0.26	0.25	0.25
Hg	0.0001	0.0005	> 0.0005	0.001	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008
TKN	0.5	1.5	> 1.5		2.37	1.74	2.82	2.98	2.13	7.85	1.00
N-NO2	0.002	0.01	> 0.01	0.15	-0.001	-0.001	-0.001	0.002	0.001	-0.001	0.002
N-NO3	5	10	> 10	11.5	3.32	3.04	6.38	3.28	6.04	3.23	3.29
Ni	0.02	0.05	> 0.05	0.02	-0.0005	-0.0005	-0.0005	-0.0005	-0.0005	0.0010	0.0010
P,t	0.03	0.16	> 0.16		0.009	0.008	0.012	0.012	0.008	0.012	0.012
Pb	0.01	0.02	> 0.02	0.01	-0.0015	-0.0015	0.0273	-0.0015	-0.0015	-0.0015	-0.0015
Sb				0.005	-0.0020	-0.0020	-0.0020	-0.0020	0.0039	-0.0020	-0.0020
Se	0.01	0.01	> 0.01	0.01	-0.0050	-0.0050	-0.0050	-0.0050	-0.0050	0.0060	-0.0050
Temperature	25	25	>25		15.4	14.9	16.4	15.5	14.9	14.1	14.3
TDS	500	1500	> 1500		177	177	323	178	196	192	133
TOC	5	8	> 8		-1	-1	-1	-1	-1	-1	-1
Zn	0.2	0.5	> 0.5		0.0255	0.0095	0.0110	-0.0002	0.0225	0.0130	0.0105
Pesticides,t	0.001	0.01	> 0.01	0.0005	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008
Phenols (v)*	0.002	0.01	> 0.01		-0.0034	-0.0034	-0.0034	-0.0034	-0.0034	-0.0034	-0.0034
Tri-tetraCE				0.01	-0.0008	-0.0008	-0.0008	-0.0008	-0.0008	-0.0008	-0.0008
Oil&grease	0.02	0.3	> 0.3		-0.1	0.161	-0.1	-0.1	-0.1	0.156	0.115
INDICATOR PARAMETERS											
Al	0.3	0.3	> 0.3	0.2	0.037	0.042	0.025	0.071	0.135	0.077	0.032
Cl	25	200	> 200	250	5.8	5.4	21.8	8.8	8.4	5.1	5.4
EC	400	1000	> 1000	2500	417.5	334.0	567.5	374.5	413.5	366.5	365.5
Fe	0.3	1	> 1	0.2	0.037	0.012	0.033	0.022	0.113	0.316	0.027
Mn	0.1	0.5	> 0.5	0.05	-0.0002	0.0051	-0.0002	0.0050	-0.0002	0.0181	0.0096
Na	125	125	> 125	200	8.70	3.43	16.63	9.08	4.50	5.40	5.01
N-NH4	0.2	1	> 1	0.39	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
O2	8	6	< 6	5	5.13	7.06	5.25	7.04	6.32	6.92	7.34
O2%	90	70	< 70		59.15	76.55	58.10	77.45	69.05	72.95	77.55
pH	6.5-8.5	6.5-8.5	<6.5->8.5	≥ 6.5 ve ≤ 9.5	7.75	8.22	7.92	8.40	7.52	8.15	8.04
Color	5	50	> 300		6.601	6.341	6.28	5.046	8.75	8.498	4.84
SO4	200	200	> 200	250	7.97	10.00	13.93	12.73	11.03	11.41	11.31

(Detection limits are shown as minus. Unit: mg/l, EC: uS/cm, color: pt/co, temperature ^{o}C, *VOC analysis results is used)

Spring and fountain waters are suitable for human consumption in the monitoring locations of F1, F2, F5, F6 and F7 but are unsuitable in F3 location due to high As, Cd, Pb and in F4 location due to high Cr concentrations. Fe content of F6 water is slightly higher than the indicator limit. Quality differences between the dry and wet periods indicate that: F3 water includes above limit values of As, Cd concentrations in the wet period and above limit values of As, Pb concentrations in the dry period. The above limit value of Cr in F4 water of the wet period is below the limit value in the dry period and below the limit value of Sb in F5 water of the wet period is above the limit value in the dry period. Qualities of the dry-wet periods in the other waters are similar to those of the average values.

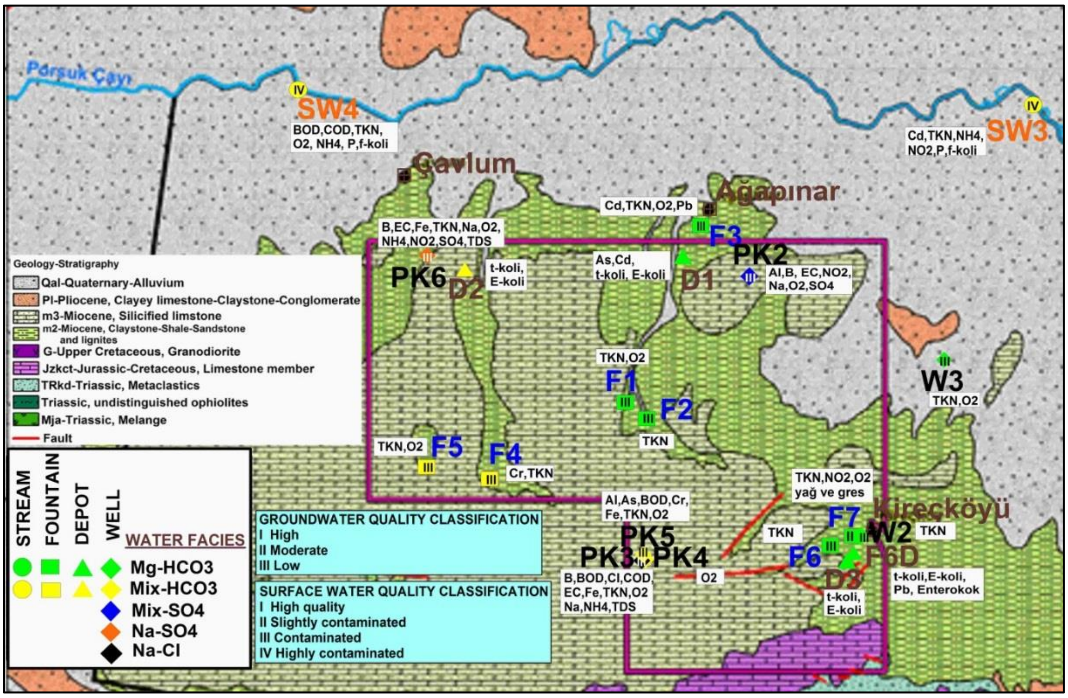
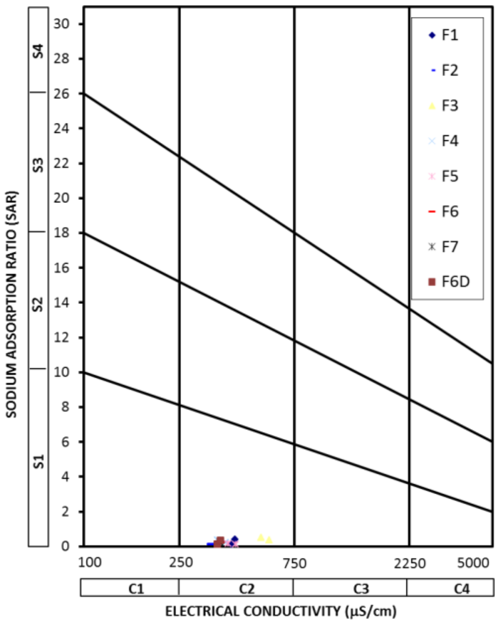


Figure 5-31: Distributions of quality classification in stream, spring, fountain and well water monitoring locations and human consumption suitability of village depot waters according to average concentrations

According to the irrigation water criteria, stream and fountain waters in F2, F5, F6 and F7 locations are low-moderate hazardous (Class II) quality, suitable for the drip irrigation and in Class A level due to SAR-EC and Na concentrations. But in the other locations, the quality class is hazardous (Class III). In F1 location, water is suitable for irrigation but it is in Class B level due to high TSS content. In F3 location, water is suitable for the drip irrigation but includes TSS content that is higher than that of Class B. Moreover, Cd concentrations are higher than the continuous irrigation limits. In F4 location, water is suitable for the drip irrigation and in Class A level but Cr concentrations are higher than the continuous irrigation limits. The irrigation water quality distribution in terms of SAR and EC values and effects on the infiltration rate are shown in Figure 5-32. If used as irrigation water, spring and fountain waters do not decrease the infiltration rate.

The irrigation water quality of spring and fountain waters has not changed in the monitoring period except in the locations of F1, F3 and F4. Due to TSS parameter, Class A changes to Class B in the dry period waters of F1 and F3. F4 water quality on the other hand, changes from surface irrigation to drip irrigation due to high Na content in the dry period.



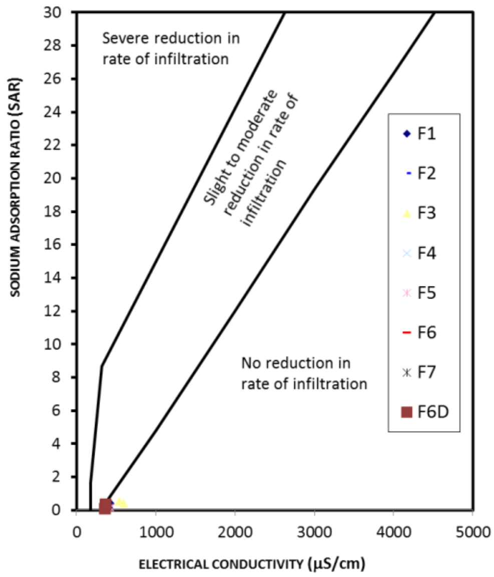


Figure 5-32: According to SAR and electrical conductivity values a) quality distribution and b) effect on infiltration rate as irrigation water of spring and fountain waters

5.4.3. Well Waters

The quality of well waters based on the groundwater classification, irrigation water classification and human consumption limits for each monitoring period is given in APPENDIX-G and average concentrations related quality summary is listed in Table 5-25. In addition, detailed results of groundwater classification based on average values are given in Table 5-26 and distributions of the quality are shown in Figure 5-31.

Average concentrations indicate that based on the groundwater classification limits, all well waters include low quality (Class III) groundwater. Parameters causing low quality in each well are listed Table 5-25. Except in PK2 and PK4 waters, TKN is present among the parameters causing low quality. Although low quality causing parameters change, quality classes of the waters do not change during the monitoring period.

Table 5-25: Water quality classifications of well waters (For irrigation water classification explanations see foot note of Table 5.20)

	GROUNDWATER CLASSIFICATION	IRRIGATION WATER CLASSIFICATION	HUMAN CONSUMPTION	INDICATOR PARAMETERS
W2	CLASS III-TKN	CLASS III-Na(I)	As	
W3	CLASS III-TKN, O2	CLASS III-Na(I)	As	O2
PK2	CLASS III-Al, B, EC, N-NO2, Na, O2, SO4	CLASS III-Mo, Na(I), Na(II), TSS(A)	B	Al, Fe, Mn, SO4
PK3	CLASS III-B, BOD5, Cl, COD, EC, Fe, TKN, N-NH4, Na, O2, TDS	CLASS III-B, BOD5(A), BOD5(B), Cl(I), Cl(II), EC, Fe, Li, Mn, Mo, Na(I), Na(II), TDS, TSS(A), TSS(B)	B, Beta-ac	Cl, EC, Fe, Mn, Na
PK4	CLASS III-O2	CLASS III-Na(I)		O2
PK5	CLASS III-Al, As, BOD5, Cr, Fe, TKN, O2	CLASS III-Mo, Na(I), Na(II), TSS(A), TSS(B)	As, Cr, Ni, Beta-ac	Al, Fe, Mn
PK6	CLASS III-B, EC, Fe, TKN, N-NH4, N-NO2, Na, O2, SO4, TDS	CLASS III-B, Cl(II), EC, Fe, Mo, Na(I), Na(II), TDS, TSS(A), TSS(B)	B	EC, Fe, Mn, Na, SO4

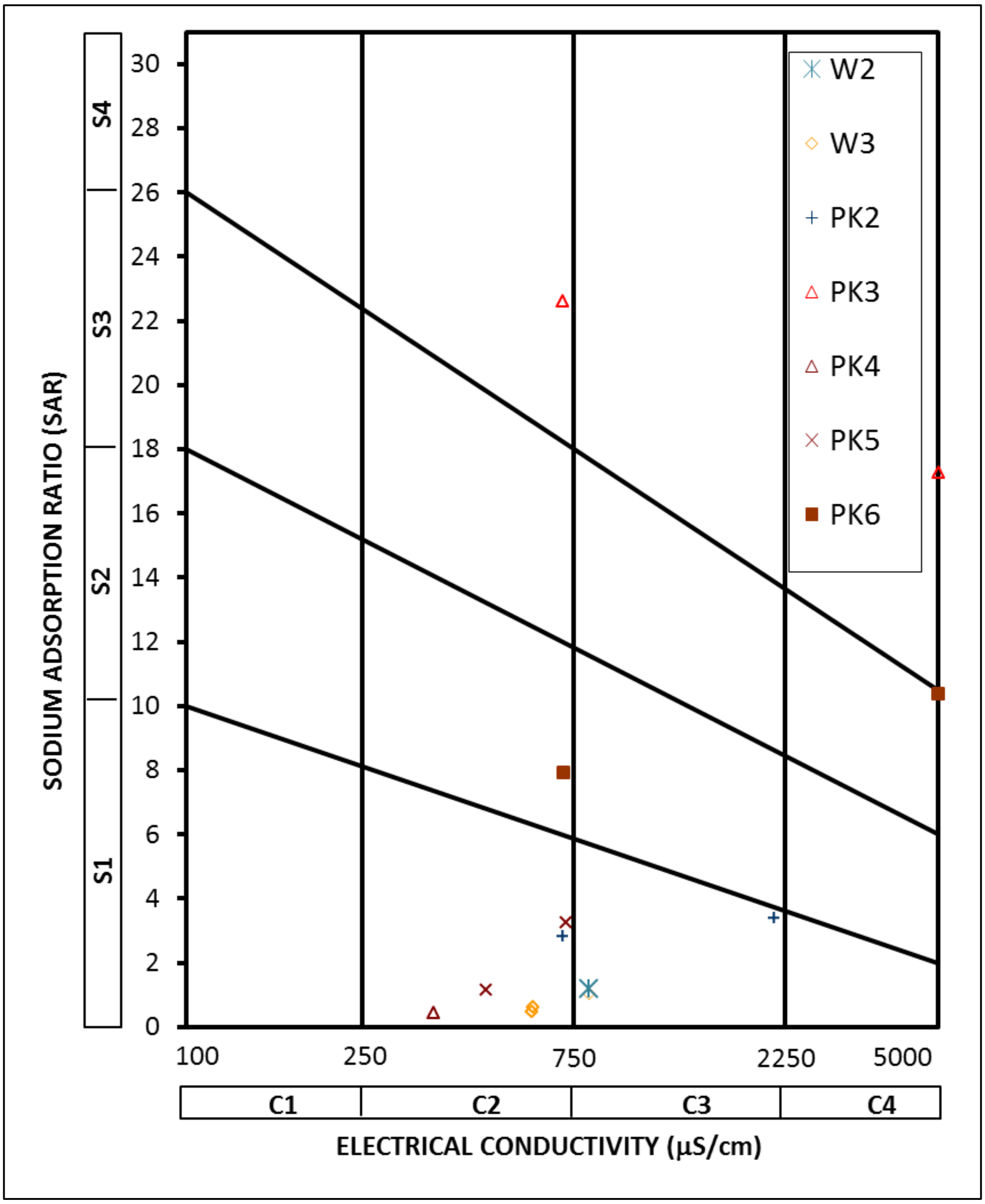
Table 5-26: Groundwater quality classification of well waters and suitability for human consumption

	GROUNDWATER CLASSIFICATION			HUMAN CONSUMPTION YAS	W2	W3	PK2	PK3	PK4	PK5	PK6
PARAMETER	Class I	Class II	Class III	bove limit value	CLASS III	CLASS III	CLASS III	CLASS III	CLASS III	CLASS III	CLASS III
As	0.02	0.05	> 0.05	0.01	0.013	0.048	0.010	-0.003	-0.010	0.093	-0.003
B	1	1	> 1	1	0.51	0.45	2.27	12.50	0.30	0.48	14.64
Ba	1	2	> 2	0.7	0.15	0.02	0.05	0.12	0.04	0.09	0.02
BOD	4	8	> 8		nm	nm	2.5	33.5	nm	19.2	1.5
Cd	0.002	0.005	> 0.005	0.005	-0.0002	0.0010	0.0010	-0.0002	-0.0030	-0.0002	0.0010
CN	0.01	0.05	> 0.05	0.05	-0.0200	-0.0200	-0.0100	-0.0100	-0.0200	-0.0100	-0.0100
Co	0.01	0.02	> 0.02		-0.0005	-0.0005	0.0010	-0.0005	-0.0100	0.0010	-0.0005
COD	25	50	> 50		29.80	13.00	8.00	178.60	10.00	39.60	22.50
Cr	0.02	0.05	> 0.05	0.05	0.0010	0.0020	-0.0003	0.0275	-0.0100	0.0640	0.0040
Cu	0.02	0.05	> 0.05	2	0.0040	-0.0002	0.0060	0.0040	-0.0100	0.0090	0.0070
F	1	1.5	> 1.5	1.5	0.21	0.21	0.20	0.14	0.27	0.20	0.25
Hg	0.0001	0.0005	> 0.0005	0.001	-0.00008	-0.00008	-0.00008	-0.00008	-0.00100	-0.00008	-0.00008
TKN	0.5	1.5	> 1.5		2.55	2.70	1.25	8.49	-0.50	1.80	2.75
N-NO2	0.002	0.01	> 0.01	0.15	0.005	-0.001	0.195	0.007	0.003	0.002	0.012
N-NO3	5	10	> 10	11.5	8.97	8.06	0.50	-0.02	3.53	-0.02	-0.02
Ni	0.02	0.05	> 0.05	0.02	-0.0005	0.0010	0.0120	0.0155	-0.0100	0.0365	0.0010
P,t	0.03	0.16	> 0.16		0.014	0.011	0.012	0.038	-0.010	0.141	0.015
Pb	0.01	0.02	> 0.02	0.01	0.0040	-0.0015	-0.0015	-0.0015	-0.0100	0.0100	0.0020
Sb				0.005	-0.0020	-0.0020	-0.0020	-0.0020	-0.0050	-0.0020	0.0020
Se	0.01	0.01	> 0.01	0.01	-0.0050	-0.0050	0.0050	-0.0050	-0.0050	0.0075	-0.0050
Temperature	25	25	>25		17.7	17.4	23.4	22.0	18.7	18.4	23.3
TDS	500	1500	> 1500		424	323	966	8216	174	286	4094
TOC	5	8	> 8		-1	-1	-1	-1	-5	4	-1
Zn	0.2	0.5	> 0.5		0.0220	0.0030	0.0345	0.0290	-0.0100	0.1710	0.1615
Pesticides,t	0.001	0.01	> 0.01	0.0005	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008	-0.00008
Phenols (v)*	0.002	0.01	> 0.01		-0.0034	-0.0034	-0.0034	-0.0034	nm	-0.0034	-0.0034
Tri-tetraCE				0.01	-0.0008	-0.0008	-0.0008	-0.0008	-0.0050	-0.0008	-0.0008
Oil&grease	0.02	0.3	> 0.3		-0.1	0.119	0.129	0.288	-0.1	0.154	0.117
Coli-f	10	200	> 200		nm	nm	0	0	nm	0	0
Coli-t	100	20000	> 20000	0	nm	nm	0	0	nm	0	0
Alfa ac.	0.5	5	> 5	0.1	nm	nm	0.07	-0.27	nm	-0.05	-0.25
Beta ac.	1	10	> 10	1	nm	nm	0.35	1.22	nm	2.04	-1.13
				INDICATOR PARAMETERS							
Al	0.3	0.3	> 0.3	0.2	0.026	0.026	0.972	0.167	-0.010	1.652	0.127
Cl	25	200	> 200	250	50.9	18.0	38.3	5306.5	4.5	11.4	132.2
EC	400	1000	> 1000	2500	812.5	606.0	1302.0	6409.0	363.0	572.0	3087.5
Fe	0.3	1	> 1	0.2	0.080	0.013	0.745	13.440	0.019	2.187	5.258
Mn	0.1	0.5	> 0.5	0.05	-0.0002	0.0120	0.1210	0.2330	-0.0100	0.1630	0.1800
Na	125	125	> 125	200	41.87	20.74	174.80	2051.60	14.77	89.64	921.85
N-NH4	0.2	1	> 1	0.39	-0.01	-0.01	0.10	5.74	-0.01	0.22	1.16
O2	8	6	< 6	5	6.52	4.83	5.97	5.31	2.99	5.64	5.25
O2%	90	70	< 70		77.30	54.10	69.45	63.20	31.80	65.50	61.40
pH	6.5-8.5	6.5-8.5	<6.5->8.5	≥ 6.5 ve ≤ 9.5	7.98	7.89	8.03	7.98	8.08	7.90	8.05
Color	5	50	> 300		4.657	0.005	3.3255	17.7595	4.726	15.8505	10.791
SO4	200	200	> 200	250	92.05	19.99	714.70	183.75	11.05	55.55	4261.45

(Detection limits are shown as minus. Unit: mg/l, EC: uS/cm, color: pt/co, temperature ^{o}C, *VOC analysis results is used)

Well waters except that of PK4 are not suitable for human consumption due to high average values of As/B/Cr/Ni/Beta activity. The above limit indicator parameters are listed in Table 5-25. Quality differences between the dry and wet periods indicate that except in PK2, PK3 and PK6 waters, consumption qualities are similar in the well waters. PK2 water in the wet period due to high NO2, in the dry period due to high B; PK3 water in the wet period due to high Ni, in the dry period due to high B; and PK6 water in the dry period due to high B concentrations are not suitable for human consumption. PK6 water in the wet period suitable with higher concentrations than those of the indicator parameter limits.

Well waters include hazardous quality (Class III) irrigation water but Class A level of W2, W3 and PK4 well waters are suitable for the drip irrigation. Irrigation water quality distribution in terms of SAR and EC values and effects on the infiltration rate are shown in Figure 5-33. If used as irrigation water, PK3 water could cause severe decrease, PK5 and PK6 waters could cause moderate decrease and PK2, PK4, W2 and W3 waters do not cause any reduction in the infiltration rate. Although parameters change, the irrigation quality classes of well waters do not change in the monitoring period.


SODIUM ADSORPTION RATIO (SAR)
S1
S2
S3
S4
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
W2
W3
PK2
PK3
PK4
PK5
PK6
100
250
750
2250
5000
C1
C2
C3
C4
ELECTRICAL CONDUCTIVITY (µS/cm)

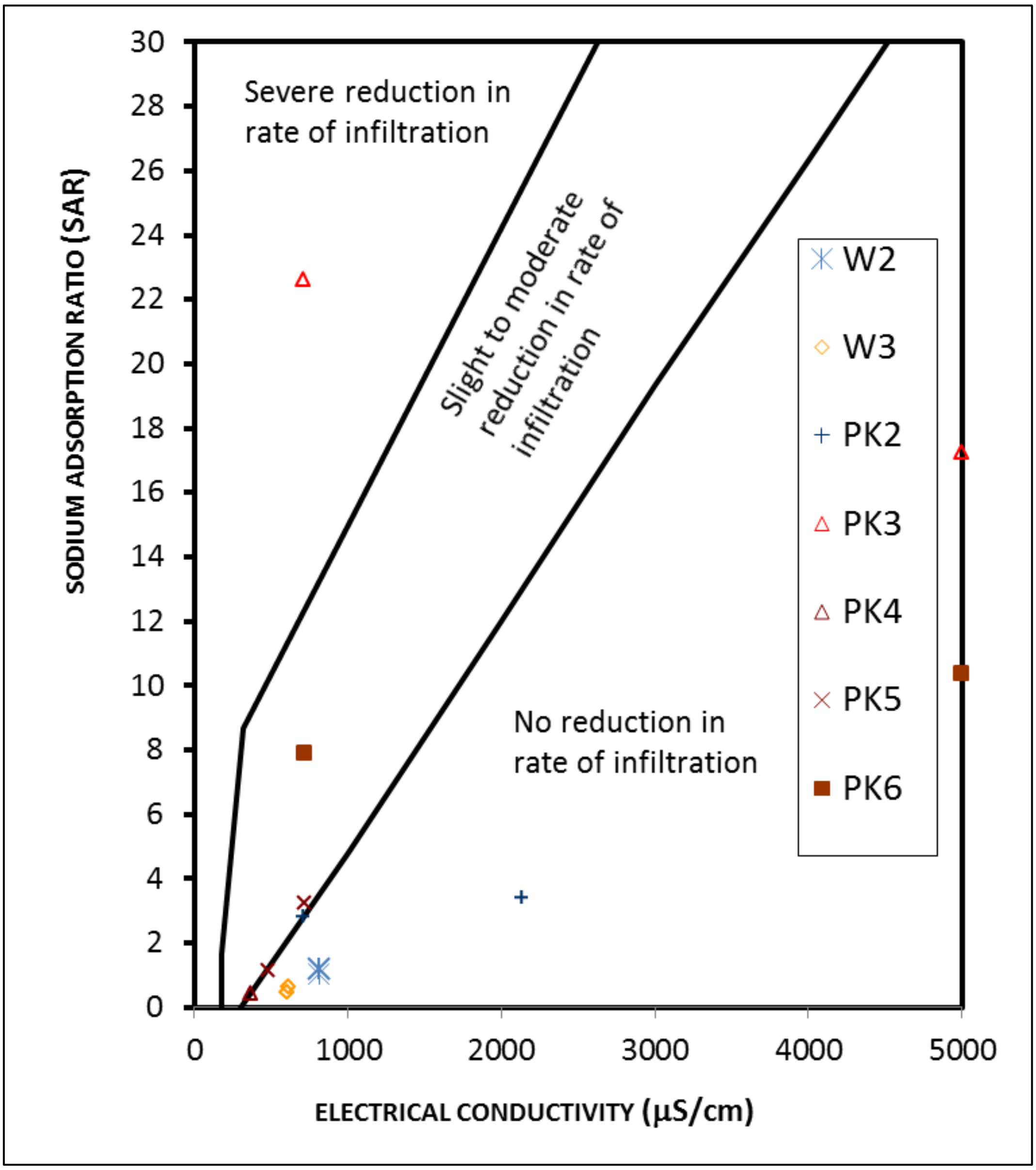


Figure 5-33: According to SAR and electrical conductivity values a) quality distribution and b) effect on infiltration rate as irrigation water of well waters

5.4.4. Village Depot waters

The quality of village depot waters based on the human consumption limits for each monitoring period is given in APPENDIX-G and average concentrations related quality summary is listed in Table 5-27. In addition, detailed results of classification based on average values are given in Table 5-28.

Excluding bacteriological parameters, Çavlum (D2) and Kireçköy (D3) depot waters are suitable for human consumption but that of Ağapınar (D1) is not due to high arsenic (greater that 0.01 mg/l) and Cd (greater than 0.005 mg/l) concentrations. However, according to the values of the bacteriological parameters measured in the dry period none of the depot waters are suitable for human consumption. Lack of high As and Cd concentrations in water of F2 which is feeding Ağapınar village depot, indicates that these parameters in the depot water comes from well water (W1) also feeding the depot. Quality differences between the dry and wet periods indicate that: high Cd value of D1 water and Pb value of F6D water in the wet period is below the limits in the dry period measurements. On the other hand, below limit values of the bacteriological parameters in the wet period waters of D1, D2 and D3 waters are higher than the limit values in the dry period measurements.

Table 5-27: Human consumption quality of village depot waters

		HUMAN CONSUMPTION	**INDICATOR PARAMETERS**
D1	Ağapınar	As, Cd, Coli-t, E-Coli	
D2	Çavlum	Coli-t, E-Coli	
D3	Kireçköyü	Coli-t, E-Coli	
F6D	Kireçköyü	Pb, Coli-t, E-Coli, Enterococ	

Table 5-28: Human consumption suitability of village depot waters

PARAMETER	HUMAN CONSUMPTION YAS	D1	D2	D3	F6D
As	0.01	0.019	-0.003	0.008	-0.003
B	1	0.33	0.17	0.42	0.09
Ba	0.7	0.12	0.12	0.08	0.04
Cd	0.005	0.2035	-0.0002	-0.0002	-0.0002
CN	0.05	-0.0100	-0.0100	-0.0100	-0.0100
Cr	0.05	0.0010	-0.0003	-0.0003	-0.0003
Cu	2	-0.0002	-0.0002	0.1260	0.0020
F	1.5	0.32	0.35	0.26	0.25
Hg	0.001	-0.00008	-0.00008	-0.00008	-0.00008
Ni	0.02	0.002	-0.001	0.012	0.002
NO2	0.5	-0.003	-0.004	-0.008	-0.003
NO3	50	-28.01	-14.56	-27.06	-14.71
Pb	0.01	0.0020	-0.0015	0.0040	0.0125
Sb	0.005	-0.0020	-0.0020	-0.0020	0.0030
Se	0.01	-0.0050	-0.0050	-0.0050	-0.0050
Acrylamide	0.0001	-0.00005	-0.00005	-0.00005	-0.00005
Benzene	0.001	-0.00084	-0.00084	-0.00084	-0.00084
Benzo(a)pyrene	0.00001	-0.00005	-0.00005	-0.00005	-0.00005
Bromate	0.01	-0.01	-0.01	-0.01	-0.01
1,2-dichloroethane	0.003	-0.0006	-0.0006	-0.0006	-0.0006
Pesticides,t	0.0005	-0.00008	-0.00008	-0.00008	-0.00008
PSAH	0.0001	-0.00005	-0.00005	-0.00005	-0.00005
Tri-tetraCE	0.01	-0.0008	-0.0008	-0.0008	-0.0008
Trihalomethanes	0.1	-0.0019	-0.0019	-0.0019	-0.0019
Vinyl chloride	0.0005	-0.0005	-0.0005	-0.0005	-0.0005
Coli-t	0	15000	50000	7500	7515
E- Coli	0	30	50	20	55
Enterococ	0	0	0	0	10
INDICATOR PARAMETERS					
Al	0.2	0.045	0.035	0.037	0.054
Cl	250	20.9	8.8	27.7	4.9
EC	2500	563.5	356.0	589.0	365.5
Fe	0.2	0.015	0.008	0.021	0.017
Mn	0.05	-0.0002	-0.0002	0.0225	-0.0002
Na	200	16.96	9.40	26.97	7.05
NH4	0.5	-0.03	-0.01	-0.01	-0.01
O2	5	5.34	6.95	6.65	6.66
pH	≥ 6.5 ve ≤ 9.5	7.91	8.13	8.14	8.08
SO4	250	16.48	12.65	49.43	11.47

(Detection limits are shown as minus. Unit: mg/l, EC: µS/cm, bacteriological: cfu/100 mL)

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The study area of the project is located in the northwest of the Central Anatolian Region within the Eskişehir graben and it covers the Eczacıbaşı Industrial Raw Materials Inc. license area. The elevation within the study area approximately ranges between 760 and 1000 m. The lowest elevation in the study area is observed along the alluvium plain area around the Porsuk Stream (nearly 760-790 m) while the highest elevation can be seen in the rugged terrain around the southeastern part of the study area (nearly 1000 m).

In the study area and its surroundings, the basement rocks are represented by Paleozoic metamorphics (marble, schist and gneiss) and Mesozoic ophiolites, Triassic metaclastics and Jurassic-Cretaceous limestones. These basement rocks are unconformably overlain by coal seam bearing Middle-Upper Miocene deposits. At the bottom of these deposits, there is basal conglomerate (m1) which contains conglomerate, sandstone and claystone. The overlying series is represented from the bottom to the top a sequence of conglomerate, green claystone, coal seam (C), gray sandstone, bituminous shale, coal seam (B), bituminous shale, coal seam (A) and green claystone-sandstone-conglomerate alternation (m2). On this sequence, the Miocene silicified limestone (m3), which outcrops on the high hills at the southwestern and western part of the license area, is seen. All these Miocene units are unconformably overlain by Pliocene deposits which include from the bottom to the top reddish variegated colored conglomerate, sandstone, claystone, tuffites alternated red mudstone with variegated colored clayey limestone, marl and gray/light brown clay. Pliocene deposits outcrop in the eastern and western part of the study area and these are unconformably overlain by Quaternary alluvium. This Quaternary unit can be seen in the lower elevations of the study area and around the Porsuk Stream and represented by silt and clay intercalated sand and gravels.

The most important surface water unit within the vicinity of the study area is the Porsuk Stream that is flowing from west towards east. There are 8 creeks with significant drainage area within the license area. Among these, the ones with the largest drainage area are Pınar Creek (4.90 km^2), Çürüksu Creek (4.16 km^2) and Akpınar Creek (3.95 km^2), respectively. Two surface water monitoring stations, namely SW-1 and SW-2, were identified on Çürüksu Creek and Pınar Creek, respectively, and instantaneous flow were monitored at monthly time intervals (on dates January 28, February 27, March 28, April 26, May 26, June 27, July 25, August 16, September 20, November 7, December 5, 2015 and January 10, February 7 2016). Based on these observations there was no surface water flow at SW-1 and SW-2.

According to the monthly conceptual water budget model (with the soil water capacity taken as 100 mm), annual precipitation (404.4 mm/year) is converted into the following components in the study area: 78.7% (318.1 mm/year) evaporation, 8.5% (34.4 mm/year) surface runoff and 12.8% (51.9 mm/year) infiltration to groundwater. Hence the groundwater recharge value calculated for the study area is 51.9 mm/year.

The most important water bearing formations within the study area and its vicinity are Quaternary alluvium and Pliocene aged limestones, sandstone and conglomerates. The Jurassic-Cretaceous limestones, Triassic aged metaclastic rocks and ophiolitic melange that outcrops in the southern part of the study area form the basement and are generally impervious and semi-pervious. They may carry groundwater along fractures that result from faulting.

Seven springs and four captages have been determined as a result of field surveys conducted within the study area. All of the springs and captages discharge at the contact between the silicified limestones (m3 series) and coal-bearing green claystone, bituminous shale and conglomerate series (m2 series). The silicified limestones that outcrop at the elevated regions in the study area are recharged from precipitation. The discharge from springs within the study area is low. The average discharge rates vary between 0.04 L/s and 0.39 L/s and the total discharge from seven springs is about 1 L/s. The discharge rates of the springs are affected by the precipitation; they reach the highest values in the winter and spring months and they are lowest in the summer and autumn months. It was not possible to measure the discharges of the captages; hence, they are estimated based upon observations. It is estimated that the total discharge from four captages amount to 14 L/s. Considered with the measured spring discharges, the total discharge from springs and captages within the study area is about 15 L/s.

The hydraulic conductivity and storativity values of the various lithologic units that crop out in the study area are summarized in Table 6-1.

Table 6-1: Hydraulic parameters of the various units in the study area

Geologic Units	Hydraulic conductivity (m/s)			Storativity	
	Min	Max	Geomean	Min	Max
Alluvium (sand, gravel)	$1.29x10^{-4}$	$2.63x10^{-3}$	$5x10^{-4}$	$3x10^{-3}$	$2x10^{-1}$
Pliocene (clayey limestone, claystone, conglomerate)	$1.86x10^{-6}$	$4.1x10^{-6}$	$2.76X10^{-6}$		
Silicified limestone (m3)	$6.47x10^{-7}$	$1.06x10^{-6}$	$8.37x10^{-7}$		
Claystone, sandstone, shale and coal seams (m2)	$6.26x10^{-8}$	$7.23x10^{-7}$	$2.34x10^{-7}$	$6.94x10^{-3}$	$8.55x10^{-2}$
Basement limestone	$9.48x10^{-9}$	$3.88x10^{-8}$	$2.35x10^{-8}$		

The groundwater flow in the study area, in general, is from the elevated land in the south toward the Porsuk Stream in the north. In addition, there is also groundwater flow in western, northwestern and northeastern directions. The groundwater levels vary from 940-950 m at the elevated land in the south to 760-770 m in the vicinity of the Porsuk Stream in the north. Thus, the elevated land in the south forms the recharge area for the groundwater system. The vertical downward gradient observed in wells drilled in the 2. nested wells location in the southern part of the license area supports this hypothesis.

A conceptual groundwater budget is estimated for the study area by determining the discharge and recharge components and calculating their quantities (Table 6-2). The total recharge, 6.03×10^6 m^3/year, is equal to the total discharge in this budget due to the assumption of steady state conditions. The components of the budget as well as their quantities are likely to change as a result of dewatering and/or depressurization activities during mining.

Table 6-2: The conceptual groundwater budget for the study area

RECHARGE (m^3/year)		DISCHARGE (m^3/year)	
Precipitation	4.96E+06	**Springs and captages**	4.73E+05
Surface runoff infiltration	1.07E+06	**Base flow to Porsuk Stream**	1.20E+06
		Pumping from wells	2.34E+06
		Evapotranspiration	1.91E+06
		Subsurface outflow	1.05E+05
TOTAL	**6.03E+06**	**TOTAL**	**6.03E+06**

The groundwater budget conceptually estimated is subject to certain assumptions. A groundwater numerical model is needed to validate these assumptions, to investigate in detail the hydraulic relations between various aquifers, and to simulate the response of these systems to different conditions.

All waters in the monitoring stations bear basic and oxidizing characteristics. Average electrical conductivity value in the Porsuk Stream is about 904 µS/cm and is in the interval of: 340-431 µS/cm in spring and fountain waters; 355-5200 µS/cm in well waters and 234-376 µS/cm in village depot waters. Dissolved oxygen concentration is in the interval of: 2.6-4.3 mg/L in Porsuk Stream; 5.3-7.1 mg/L in spring and fountains; 2.1-6.6 mg/L in well waters and 5.3-6.1 mg/L in the depot waters.

Porsuk Stream includes Mix-HCO_3 type of water in both monitoring locations. The downstream water is more diluted than that of upstream, suggesting about 8% groundwater input between the monitoring locations. Porsuk Stream sediments have higher Ag, As, Bi, Ca, Cd, Cr, Cu, Hg, Li, Ni, P, Sn and Zn concentrations than the Upper Crustal average.

Excluding F4 and F5 fountain waters (Mix-HCO_3 type) located at western side of the study area, all the other spring and fountain waters and W2, W3 well waters are Mg-HCO_3 type. Groundwaters of silicified limestone and siltstone-sandstone-conglomerate sedimentary units which are stratigraphically located above the coal seams are Mix-HCO_3 type; groundwater in the coal seams is Na-SO_4 type and groundwater of limestone below the coal seams is Na-Cl type. Due to longer residence time, hence more reaction time, sodium cation has the highest concentration, which is probably governed by exchange reactions, in deep groundwater. High sulphate content of coal groundwater is probably related to the oxidation of pyrite minerals and high chloride concentration of groundwater below the coal unit is related to the low hydraulic conductivity. High sulphate concentration indicates that oxidation driven acid rock drainage should be taken into consideration during mining phase of the project. Concentration of ammonia/ammonium is much higher than the generally expected values in groundwaters of the coal seams and the underlying unit and this is probably related to the degradation of natural organic materials in the units.

Porsuk Stream includes highly contaminated (Class-IV) quality surface water and cannot be used neither as a drinking water resource nor as an irrigation supply water. All spring and fountains, excluding moderate (Class II) quality F7 groundwater, include low (Class III) quality groundwater due to high TKN/Cd/Cr and low O2 concentrations. Spring and fountain waters are generally suitable for human consumption except well effected F3 water which is unsuitable due to high As, Cd, Pb content and F4 water due to high Cr concentration. All well waters include low (Class III) quality groundwater. Well waters are not suitable for human consumption except that of PK4. Ignoring bacteriological parameters, depot waters of Çavlum and Kireçköy villages are suitable for human consumption but that of Ağapınar is not due to high As and Cd concentrations.

6.2. Recommendations

- Although there are meteorological stations being operated in Eskişehir city center, these may not represent the meteorological conditions of the study area due to the distance. For this reason, it is recommended that an automated meteorological station is established in the study area. In this meteorological station the following parameters are recommended to be measured at 15-minute intervals: precipitation, temperature, humidity, wind speed and direction, air pressure, evaporation, solar radiation.
- There is a possibility of surface runoff in the creeks draining the license area in the event of rapid heavy rainfall and snow melt. In particular, surface runoff after rapid heavy rainfall and snow melt is important for mine planning. Therefore, it is recommended that ESAN personnel measure the discharge at SW-1 and SW-2 monitoring station after rapid heavy rainfall and snowmelt. Alternatively, automated flow monitoring stations could be established at these locations for continuous monitoring of the surface runoff.
- Groundwater levels were not monitored to cover one hydrologic cycle (wet and dry seasons) completely due to delays encountered during the drilling of pumping and observation wells. Hence, it is recommended that the groundwater levels are monitored at monthly intervals at all pumping and observation wells in the future.
- It is recommended to install permanent submersible pumps into pump wells PK-2, PK-3 and PK-6 for monthly groundwater quality monitoring and sampling. These pumps will enable purging the wells and obtaining proper samples from the aquifer fresh water.
- It is recommended to install ‘vibrating wire piezometers’ during operations to monitor the groundwater pressures at the bottom of the C-coal seam at the northwest of the license area due to their excessive depth (450m).
- The conceptual hydrogeological model and the conceptual groundwater budget developed in this study should be continuously updated as new data is collected from the site.

- A 3-dimensional groundwater model of the study area should be developed and calibrated with the field conditions for validation of the results so that it can be used for assessing the mining activities and environmental impacts.
- It is recommended to start 2- and 3-dimensional modelling studies to assess the impacts of the mining activities on groundwater resources within the scope of Environmental Impact Assessment studies. The probable impacts of the mining activities on the agricultural and industrial groundwater use can be assessed by the help of these models.
- The groundwater captages and wells supplying water to the settlements are likely to be negatively impacted from the mining activities. Hence, planning of the studies for finding alternative sources of water supply to these settlements is recommended.
- It is also recommended to conduct detailed studies to determine the alternative sources of water supply for the mining activities.
- Field parameter measurements could be reduced to quarterly periods.
- Chemical analysis of Porsuk Stream should be quarterly carried out for the monitoring parameters of alkalinity, total phosphorus, dissolvable reactive phosphorus, total nitrogen, nitrate, nitrite and ammonium.
- Mineralogical characteristics of all lithological units should be determined with XRD analysis in order to provide data for detailed evaluations of water-rock interactions and acid rock drainage processes.
- A detailed research including nitrogen isotope measurements could be carried out to define the source of high ammonium/ammonia concentrations in groundwater.

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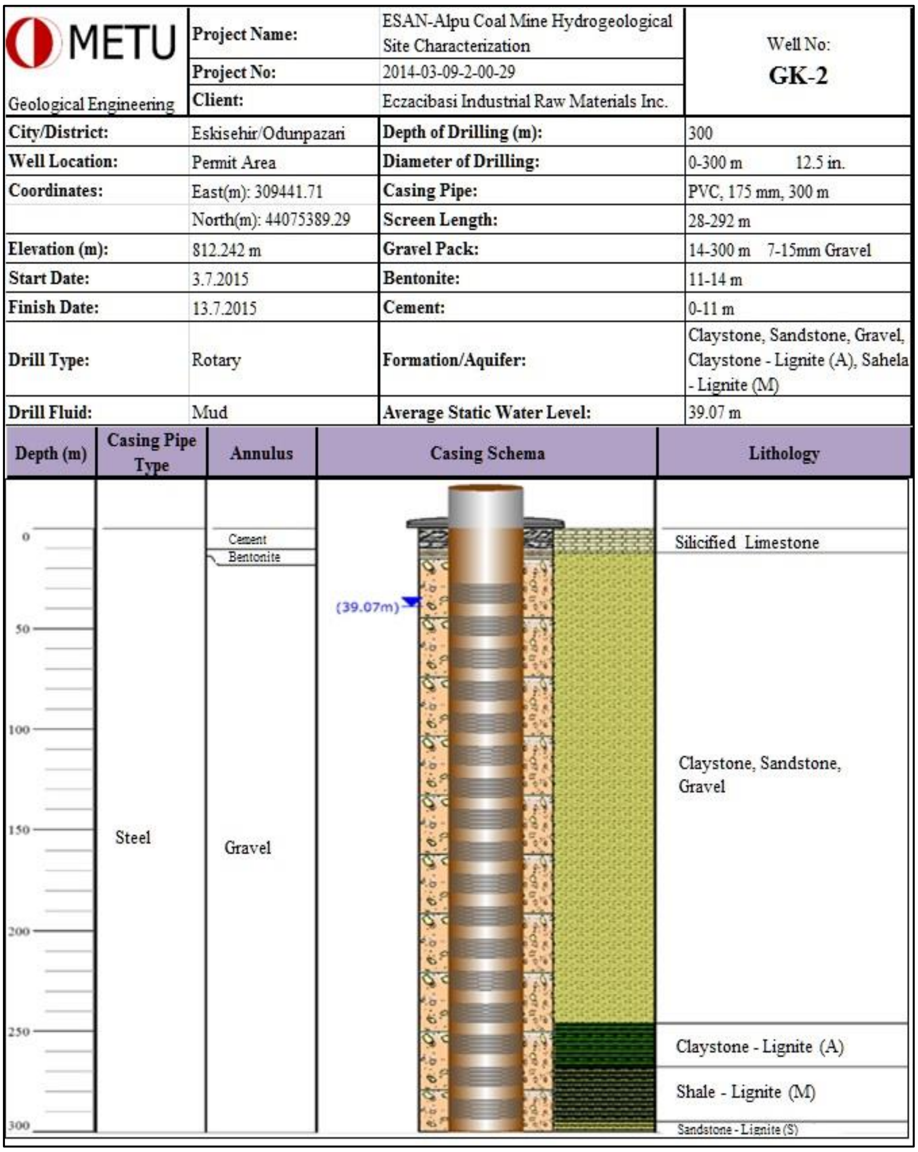
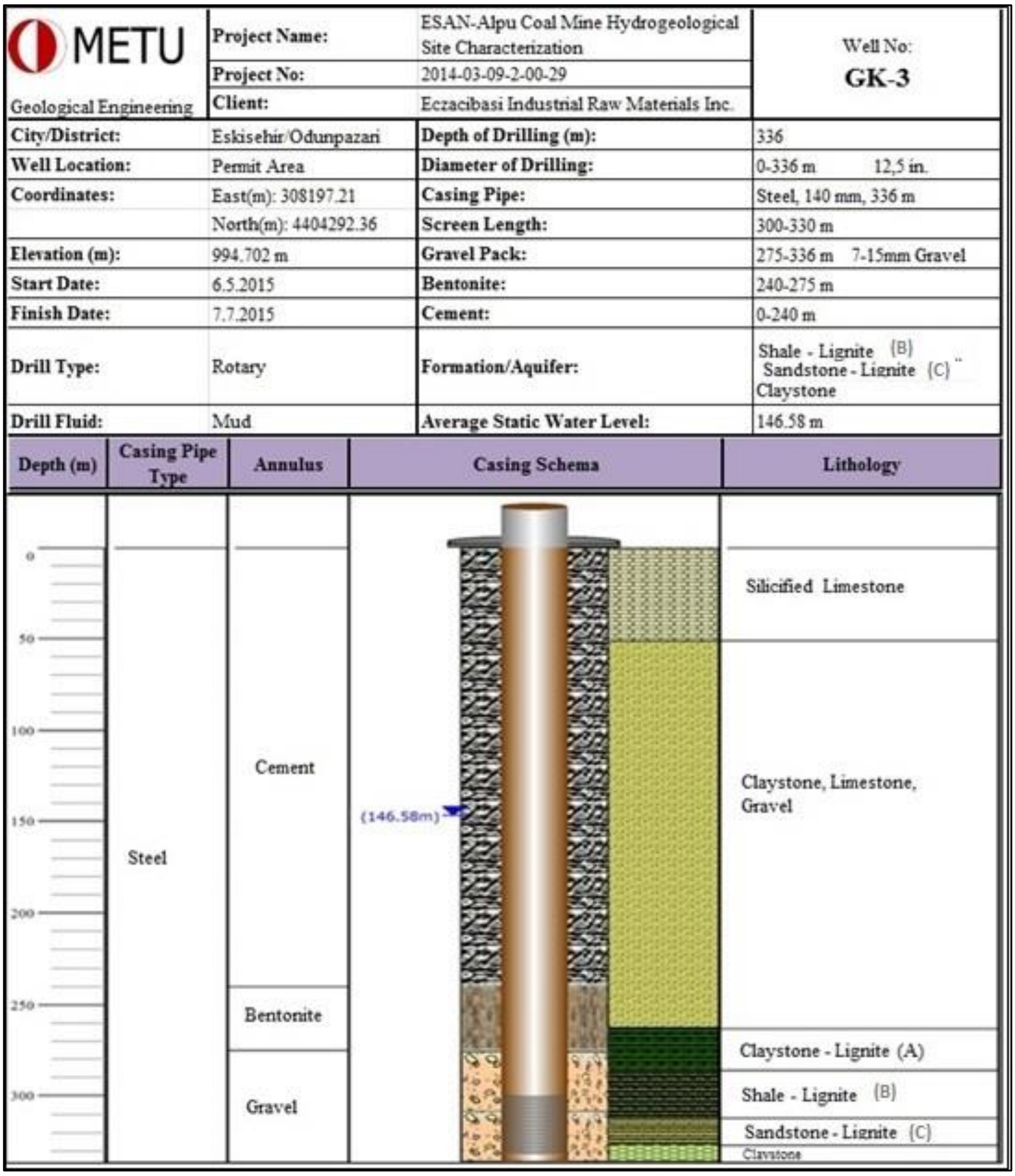
APPENDIX A

WELL LOGS OF THE DRILLED WELLS IN THE STUDY AREA



METU Geological Engineering	Project Name:	ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Well No: GK-2
	Project No:	2014-03-09-2-00-29	
	Client:	Eczacibasi Industrial Raw Materials Inc.	
City/District:	Eskisehir/Odunpazari	Depth of Drilling (m):	300
Well Location:	Permit Area	Diameter of Drilling:	0-300 m 12.5 in.
Coordinates:	East(m): 309441.71	Casing Pipe:	PVC, 175 mm, 300 m
	North(m): 44075389.29	Screen Length:	28-292 m
Elevation (m):	812.242 m	Gravel Pack:	14-300 m 7-15mm Gravel
Start Date:	3.7.2015	Bentonite:	11-14 m
Finish Date:	13.7.2015	Cement:	0-11 m
Drill Type:	Rotary	Formation/Aquifer:	Claystone, Sandstone, Gravel, Claystone - Lignite (A), Sahela - Lignite (M)
Drill Fluid:	Mud	Average Static Water Level:	39.07 m

Figure A-1: The Well Log of GK-2



METU Geological Engineering	Project Name: ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Project No: 2014-03-09-2-00-29	Well No: GK-3
	Client: Eczacibasi Industrial Raw Materials Inc.		
City/District:	Eskisehir/Odunpazari	Depth of Drilling (m):	336
Well Location:	Permit Area	Diameter of Drilling:	0-336 m 12,5 in.
Coordinates:	East(m): 308197.21	Casing Pipe:	Steel, 140 mm, 336 m
	North(m): 4404292.36	Screen Length:	300-330 m
Elevation (m):	994.702 m	Gravel Pack:	275-336 m 7-15mm Gravel
Start Date:	6.5.2015	Bentonite:	240-275 m
Finish Date:	7.7.2015	Cement:	0-240 m
Drill Type:	Rotary	Formation/Aquifer:	Shale - Lignite (B) Sandstone - Lignite (C) Claystone
Drill Fluid:	Mud	Average Static Water Level:	146.58 m

Figure A-2: The Well Log of GK-3

METU Geological Engineering	Project Name:	ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Well No: GK-4
	Project No:	2014-03-09-2-00-29	
	Client:	Eczacibasi Industrial Raw Materials Inc.	
City/District:	Eskisehir/Odunpazari	**Depth of Drilling (m):**	50
Well Location:	Permit Area	**Diameter of Drilling:**	0-50 m 12,5 in.
Coordinates:	East(m): 308202.69	**Casing Pipe:**	PVC, 125 mm, 50 m
	North(m): 4404303.33	**Screen Length:**	26-46 m
Elevation (m):	995.679 m	**Gravel Pack:**	18-50 m 7-15mm Gravel
Start Date:	11.6.2015	**Bentonite:**	13-18 m
Finish Date:	9.7.2015	**Cement:**	0-13 m
Drill Type:	Rotary	**Formation/Aquifer:**	Silicified - Limestone
Drill Fluid:	Mud	**Average Static Water Level:**	45.67 m

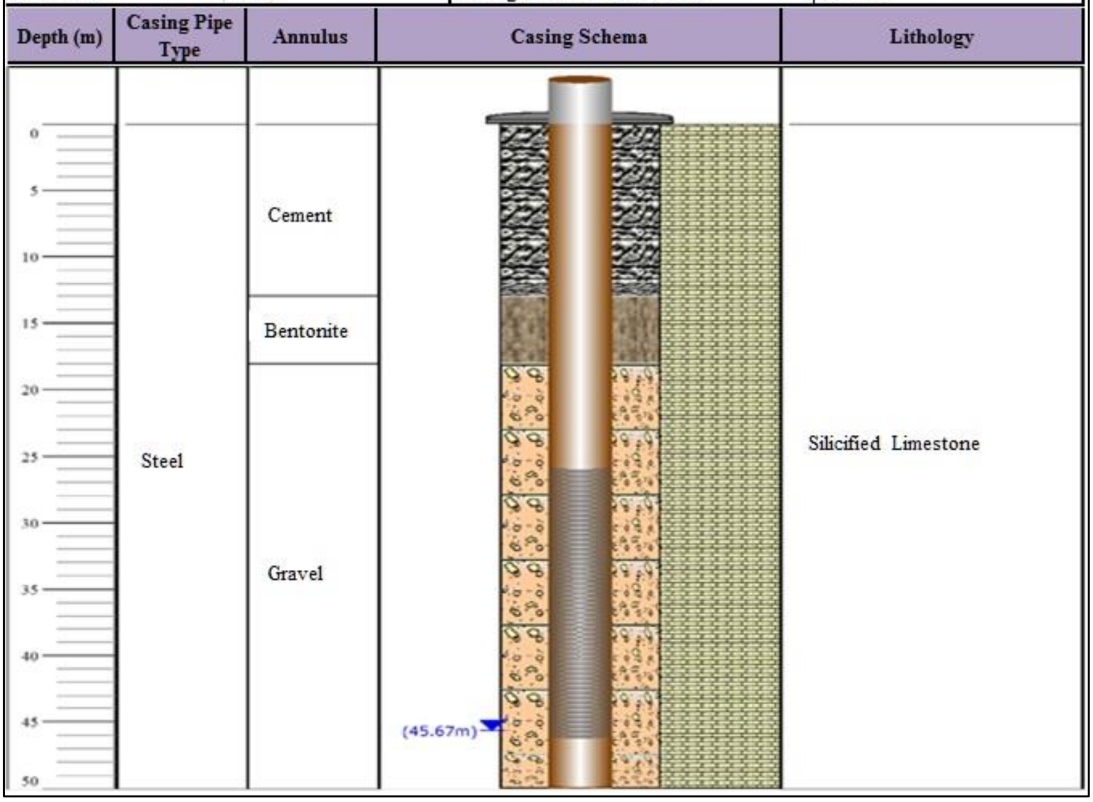


Figure A-3: The Well Log of GK-4

METU Geological Engineering	Project Name:	ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Well No: GK-5
	Project No:	2014-03-09-2-00-29	
	Client:	Eczacibasi Industrial Raw Materials Inc.	
City/District:	Eskisehir/Odunpazari	Depth of Drilling (m):	396
Well Location:	Permit Area	Diameter of Drilling:	0-396 m 12.5 in.
Coordinates:	East(m): 305699.88	Casing Pipe:	Steel, 125 mm, 396 m
	North(m): 4407800.04	Screen Length:	372-390 m
Elevation (m):	800.58 m	Gravel Pack:	340-396 m 7-15mm Gravel
Start Date:	26.3.2015	Bentonite:	300-340 m
Finish Date:	11.5.2015	Cement:	0-300 m
Drill Type:	Rotary	Formation/Aquifer:	Claystone-Lignite (A)
Drill Fluid:	Mud	Average Static Water Level:	5.60 m

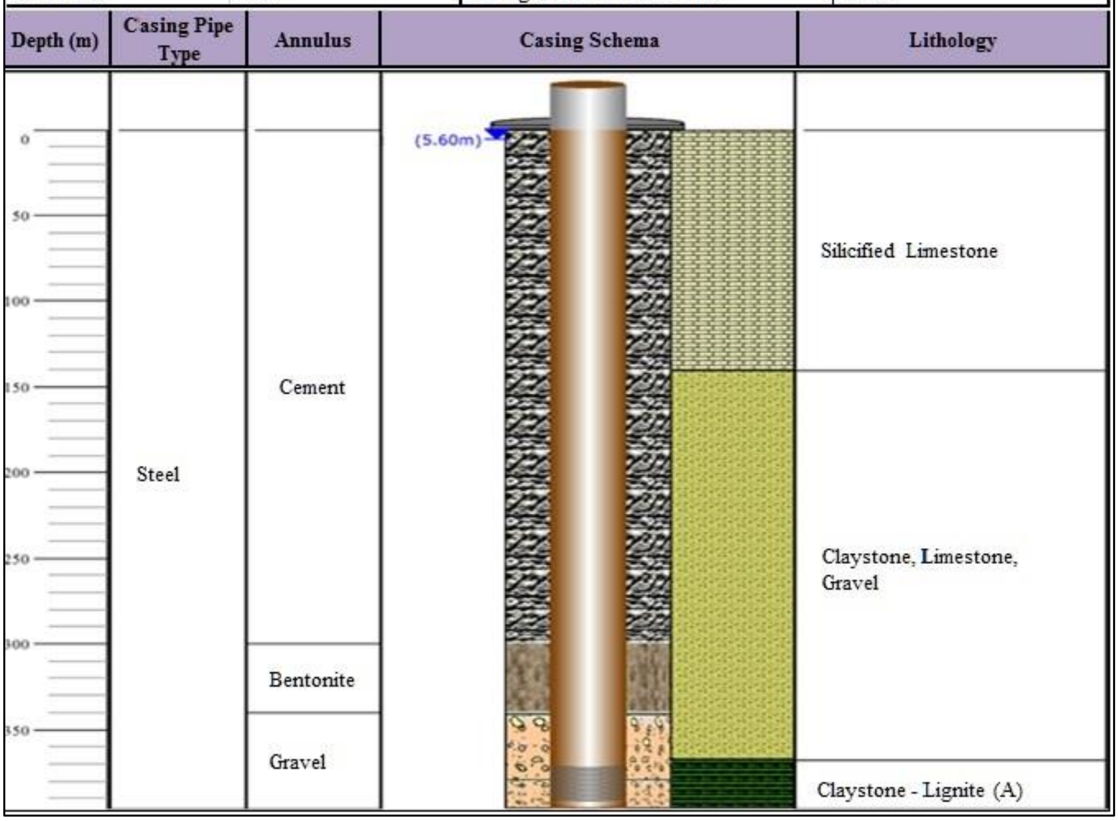
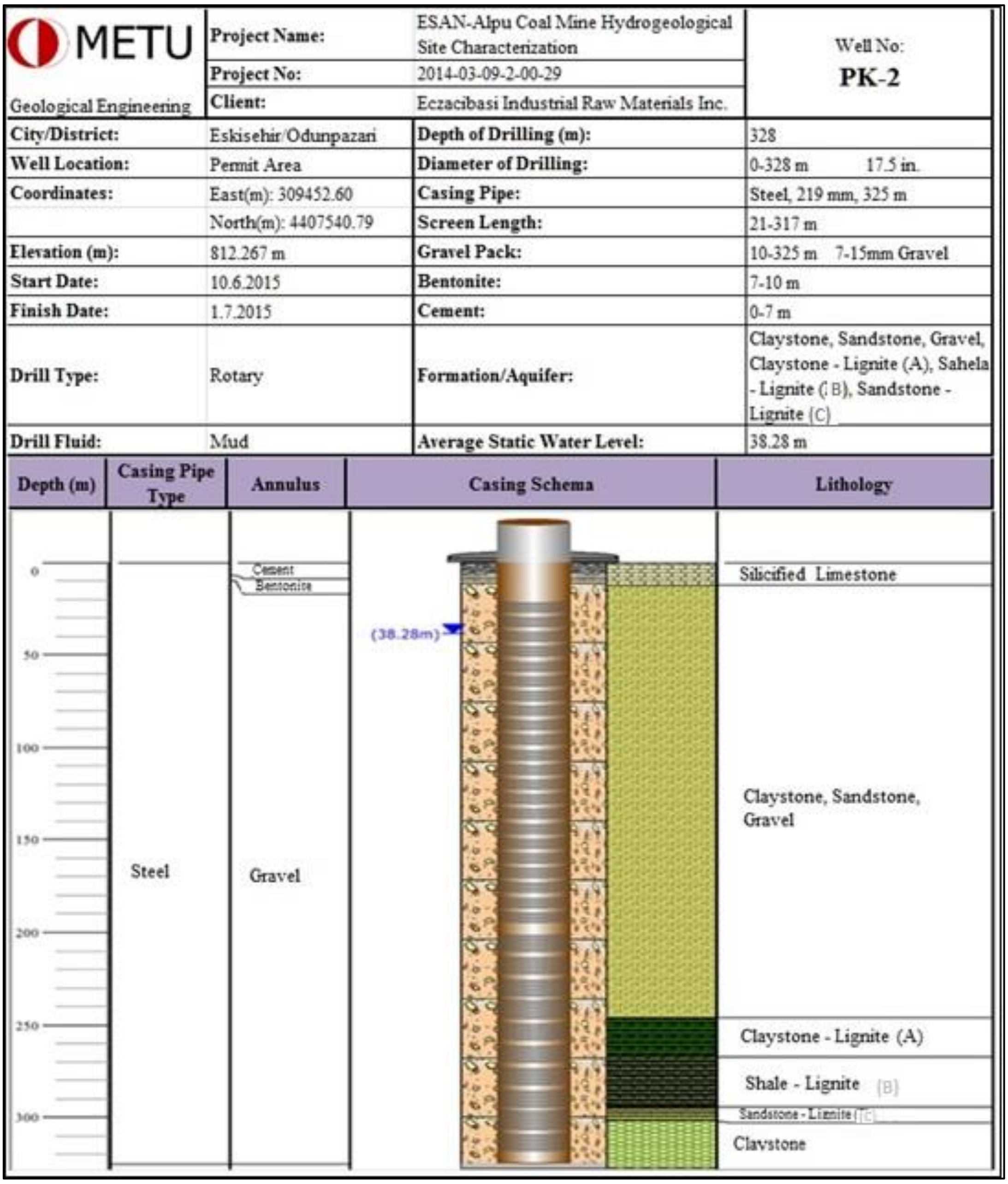


Figure A-4: The Well Log of GK-5



METU Geological Engineering	Project Name:	ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Well No: PK-2
	Project No:	2014-03-09-2-00-29	
	Client:	Eczacibasi Industrial Raw Materials Inc.	
City/District:	Eskisehir/Odunpazari	Depth of Drilling (m):	328
Well Location:	Permit Area	Diameter of Drilling:	0-328 m 17.5 in.
Coordinates:	East(m): 309452.60	Casing Pipe:	Steel, 219 mm, 325 m
	North(m): 4407540.79	Screen Length:	21-317 m
Elevation (m):	812.267 m	Gravel Pack:	10-325 m 7-15mm Gravel
Start Date:	10.6.2015	Bentonite:	7-10 m
Finish Date:	1.7.2015	Cement:	0-7 m
Drill Type:	Rotary	Formation/Aquifer:	Claystone, Sandstone, Gravel, Claystone - Lignite (A), Sahela - Lignite (B), Sandstone - Lignite (C)
Drill Fluid:	Mud	Average Static Water Level:	38.28 m

Figure A-5: The Well Log of PK-2

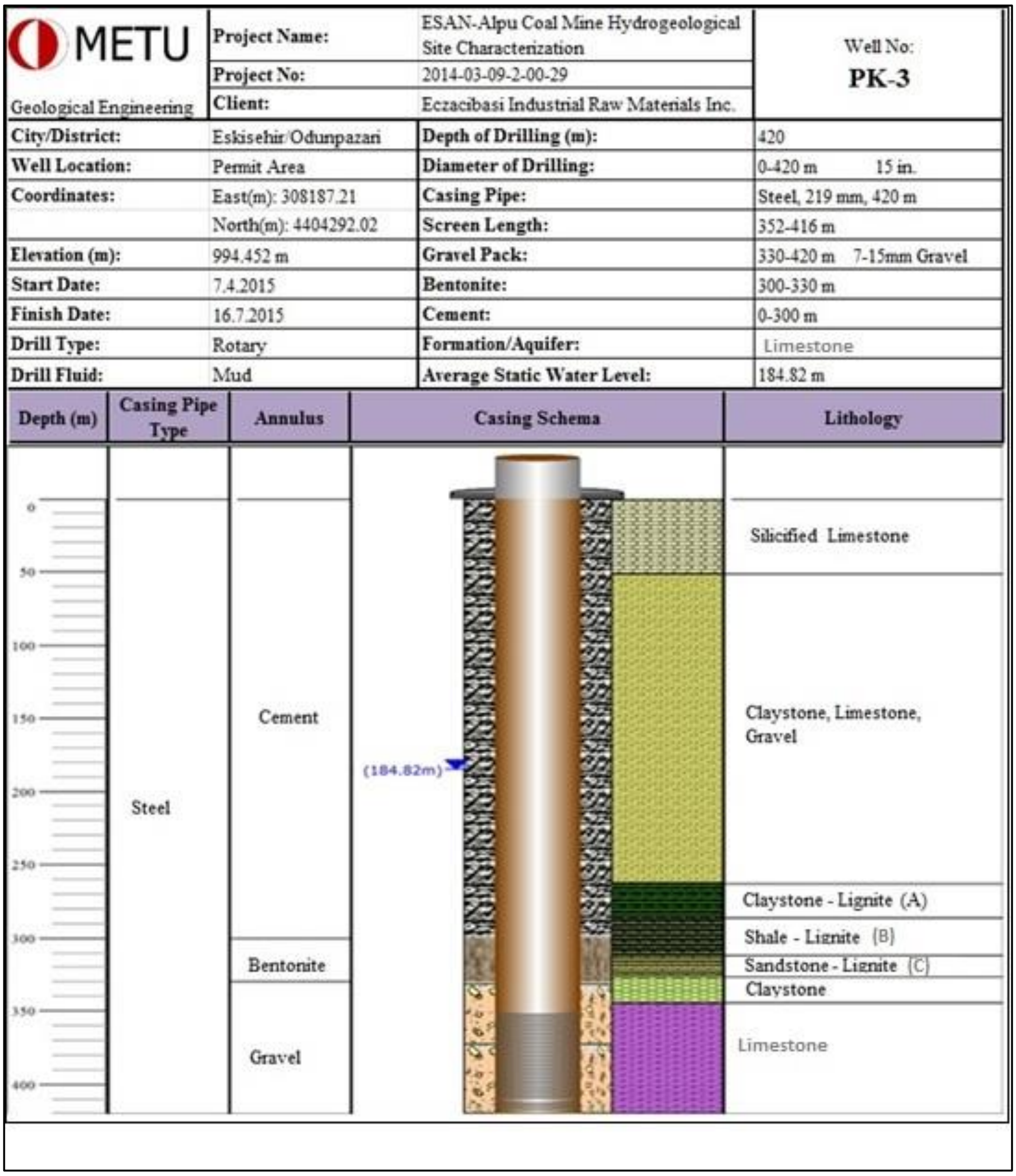


Figure A-6: The Well Log of PK-3 (Bu log yanlış)

METU Geological Engineering	Project Name:	ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Well No: **PK-4**
	Project No:	2014-03-09-2-00-29	
	Client:	Eczacibasi Industrial Raw Materials Inc.	
City/District:	Eskisehir/Odunpazari	**Depth of Drilling (m):**	60
Well Location:	Permit Area	**Diameter of Drilling:**	0-60 m 12,5 in.
Coordinates:	East(m): 308208.10	**Casing Pipe:**	PVC, 175 mm, 60 m
	North(m): 4404292.57	**Screen Length:**	25-56 m
Elevation (m):	994.657 m	**Gravel Pack:**	20-60 m 7-15mm Gravel
Start Date:	19.5.2015	**Bentonite:**	10-20 m
Finish Date:	30.6.2015	**Cement:**	0-10 m
Drill Type:	Rotary	**Formation/Aquifer:**	Silicified - Limestone, Claystone, Sandstone, Gravel
Drill Fluid:	Mud	**Average Static Water Level:**	48.05 m

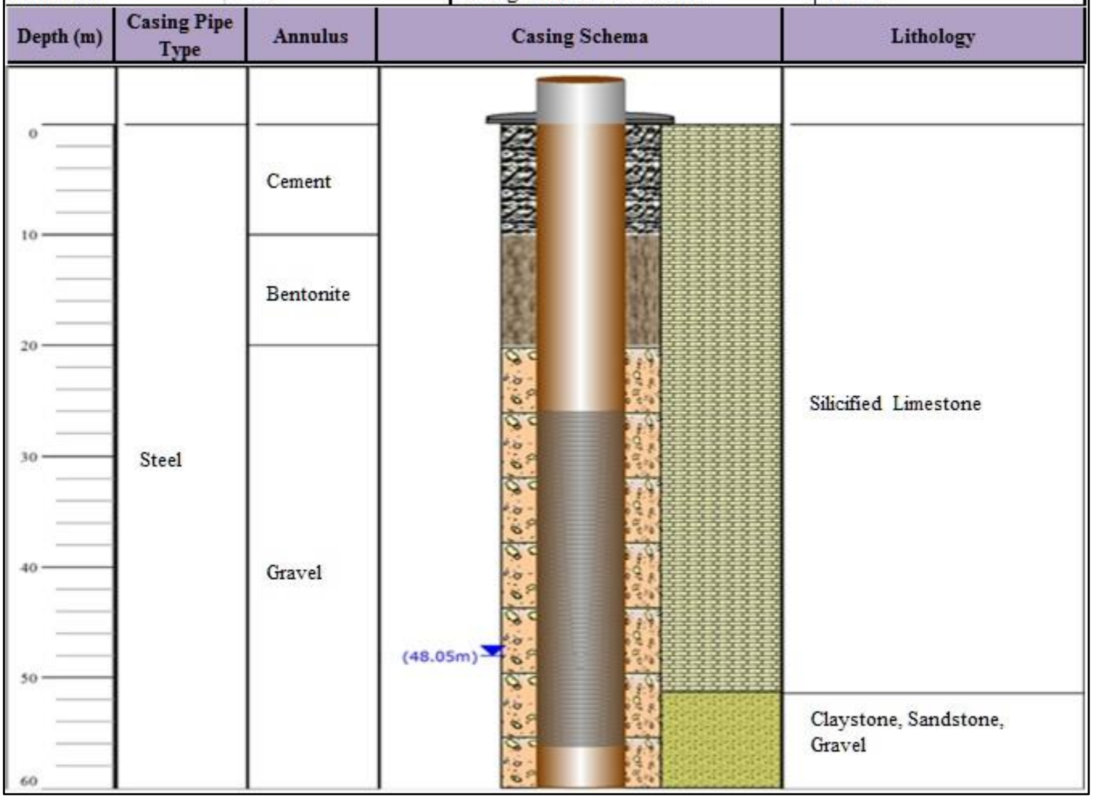


Figure A-7: The Well Log of PK-4

METU Geological Engineering	Project Name:	ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Well No: **PK-5**
	Project No:	2014-03-09-2-00-29	
	Client:	Eczacibasi Industrial Raw Materials Inc.	
City/District:	Eskisehir/Odunpazari	**Depth of Drilling (m):**	208
Well Location:	Permit Area	**Diameter of Drilling:**	0-208 m 15 in.
Coordinates:	East(m): 308190.41	**Casing Pipe:**	PVC, 200 mm, 208 m
	North(m): 4404303.59	**Screen Length:**	136-204 m
Elevation (m):	995.634 m	**Gravel Pack:**	100-208 m 7-15mm Gravel
Start Date:	25.5.2015	**Bentonite:**	80-100 m
Finish Date:	12.7.2015	**Cement:**	0-80 m
Drill Type:	Rotary	**Formation/Aquifer:**	Claystone, Sandstone, Gravel
Drill Fluid:	Mud	**Average Static Water Level:**	144.98 m

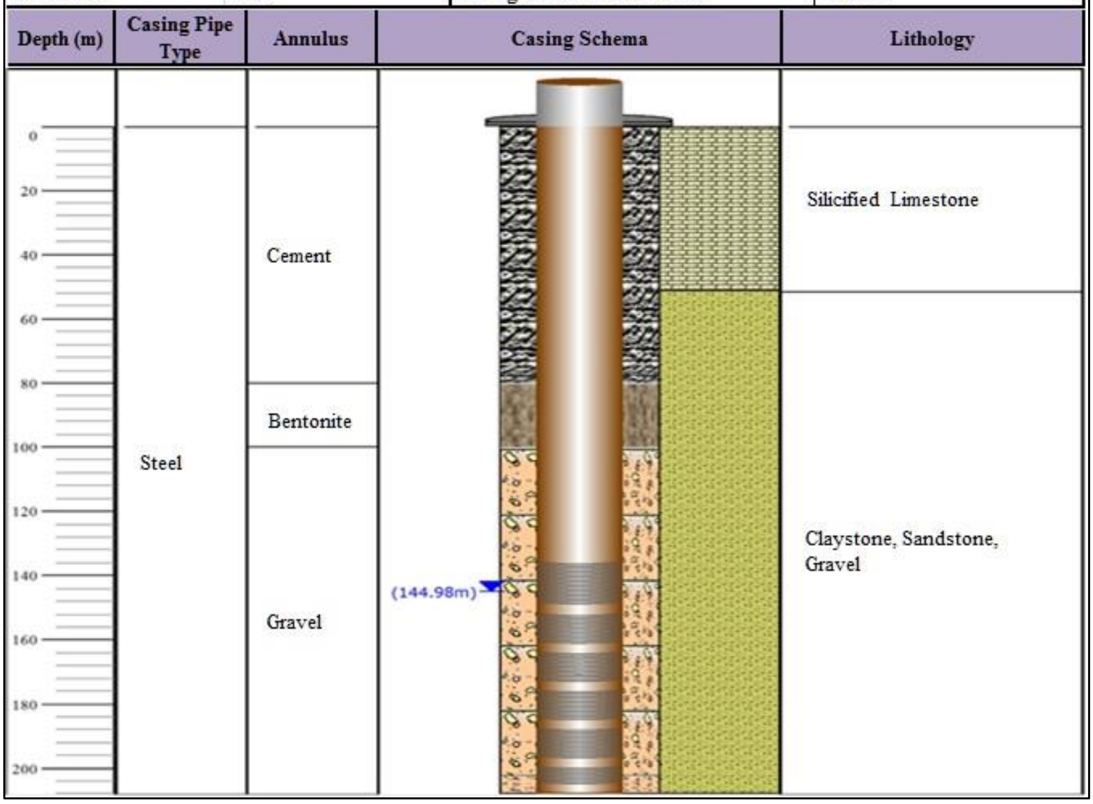
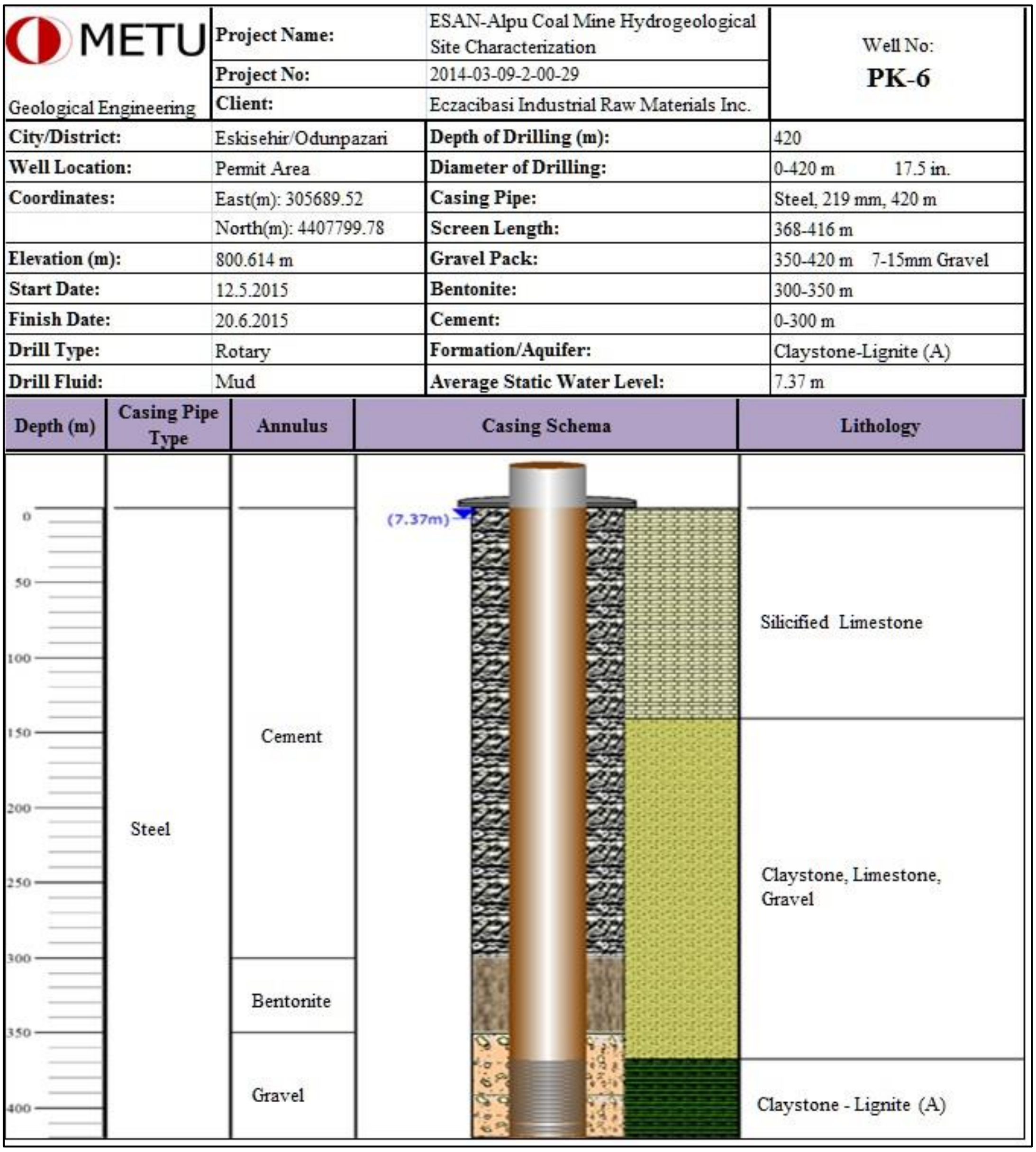


Figure A-8: The Well Log of PK-5



METU Geological Engineering	Project Name:	ESAN-Alpu Coal Mine Hydrogeological Site Characterization	Well No: **PK-6**
	Project No:	2014-03-09-2-00-29	
	Client:	Eczacibasi Industrial Raw Materials Inc.	
City/District:	Eskisehir/Odunpazari	Depth of Drilling (m):	420
Well Location:	Permit Area	Diameter of Drilling:	0-420 m 17.5 in.
Coordinates:	East(m): 305689.52	Casing Pipe:	Steel, 219 mm, 420 m
	North(m): 4407799.78	Screen Length:	368-416 m
Elevation (m):	800.614 m	Gravel Pack:	350-420 m 7-15mm Gravel
Start Date:	12.5.2015	Bentonite:	300-350 m
Finish Date:	20.6.2015	Cement:	0-300 m
Drill Type:	Rotary	Formation/Aquifer:	Claystone-Lignite (A)
Drill Fluid:	Mud	Average Static Water Level:	7.37 m

Figure A-9: The Well Log of PK-6

APPENDIX B

PUMPING TEST RESULTS

In order to characterize the hydrogeological conditions in the study area, nine wells were drilled in 2015. The groundwater levels, groundwater quality and hydraulic parameters of the groundwater bearing units are determined from the data which were taken from these wells. Aquifer tests were conducted in order to determine the hydraulic parameters of these units.

<u>Pumping Test</u>;

After the wells were developed, the pumping tests were conducted in pumping wells. However; in PK-4 and PK-5 the pumping test did not conducted. The water column in the PK-4 is too short for conducting a pump test and in PK-5 the sustainable yield is too small for conducting a pump test. This information observed from pre-test results.

PK-2; after conducting a different discharged rated pre pump test, in order to determine the hydraulic parameters of a composite system which means the well screened whole units in the porsuk formation, 72 hours pump test was conducted with a 1 L/s constant discharge rate. After the pump test, recovery test was applied for 28.5 hours. The total drawdown in PK-2 and GK-2 are about 55.1 and 2.39 m respectively. The drawdown vs time graph for both tests can be seen Figure B-1 and Figure B-2. Physical parameters of the groundwater were measured during the pump test in PK-2 is shown in Figure B-3 below. The temperature values are getting higher because of the increased temperature of the pump. The other parameters are getting stabilized. The pump test results were evaluated with different methods. The Neuman, Boulton and Theis with Jacob correction methods are used for pumping period and Theis recovery method is used for recovery period. The Transmissivity (T) values vary between $1.77X10^{-5}$ m^2/ and $2.05X10^{-4}$ m^2/s. The average of the Transmissivity value is $9.89X10^{-5}$ m^2/s. The Hydraulic Conductivity (K) values vary between $6.26X10^{-8}$ m/s and $7.23X10^{-7}$ m/s. The average K value is $3.49X10^{-7}$ m/s. The storativity value evaluated by using the data obtained from GK-2. The Storativity values vary between $7.82X10^{-3}$ and $8.55X10^{-2}$. The average Storativity value is $3.38X10^{-2}$. These results are shown in Table B-1.

Table B-1: Hydraulic parameters of PK-2 and GK-2

Well ID	Test Discharge Rate (L/s)	Analysis Method	Transmissivity Coefficient -T- (m2/s)	Average Transmissivity Coefficient -Tavg- (m2/s)	Hydraulic Conductivity -K- (m/s)	Average Hydraulic Conductivity -K avg- (m/s)	Storativity -S-	Average Storativity -S avg-
PK-2	1.0	Neuman	1.80E-05	1.86E-05	6.34E-08	6.57E-08	X	X
		Boulton	1.86E-05		6.56E-08			
		Theis with Jacob Correction	2.02E-05		7.12E-08			
		Theis Recovery	1.77E-05		6.26E-08			
GK-2	1.0	Neuman	1.95E-04	1.79E-04	6.88E-07	6.32E-07	8.55E-02	3.38E-02
		Boulton	1.84E-04		6.49E-07		8.05E-03	
		Theis with Jacob Correction	2.05E-04		7.23E-07		7.82E-03	
		Theis Recovery	1.33E-04		4.67E-07			
AVERAGE			9.89E-05	9.89E-05	3.49E-07	3.49E-07	3.38E-02	3.38E-02

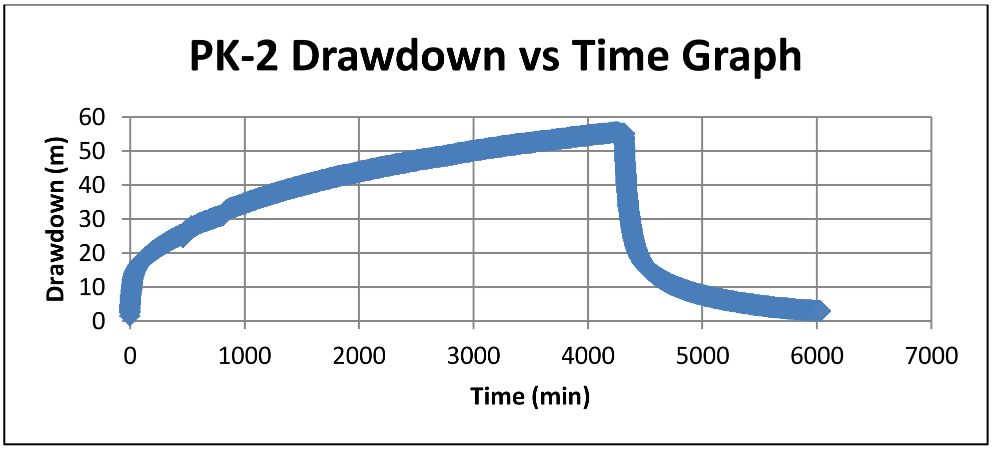


Figure B-1: PK-2 Drawdown vs Time Graph

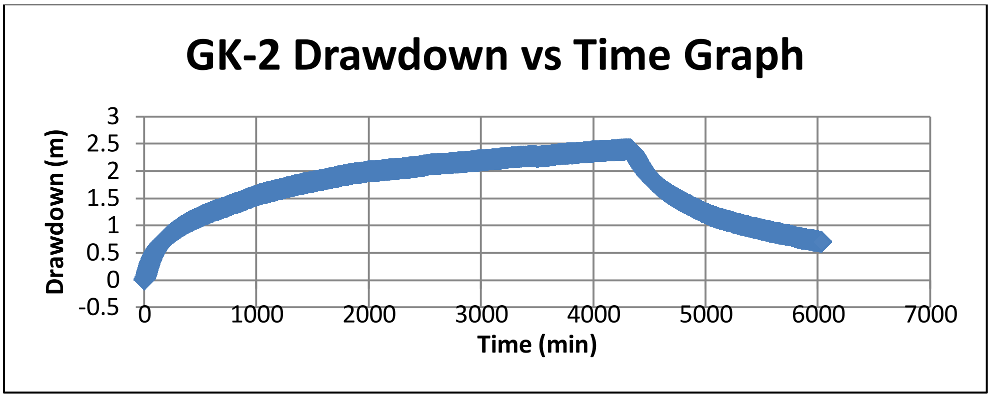


Figure B-2: GK-2 Drawdown vs Time Graph

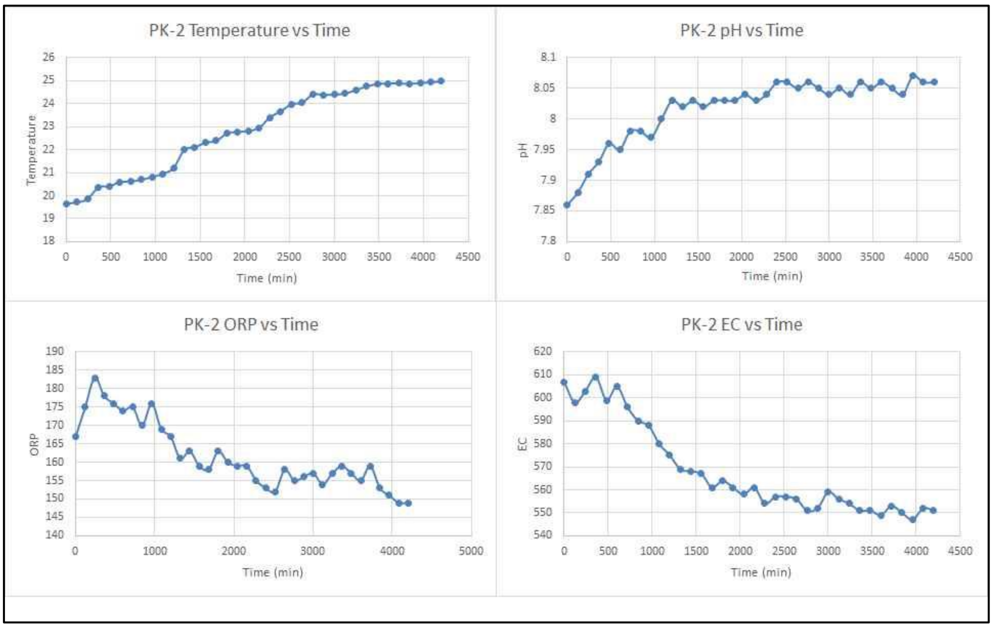


Figure B-3: Physical parameters measured in PK-2 pump test

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

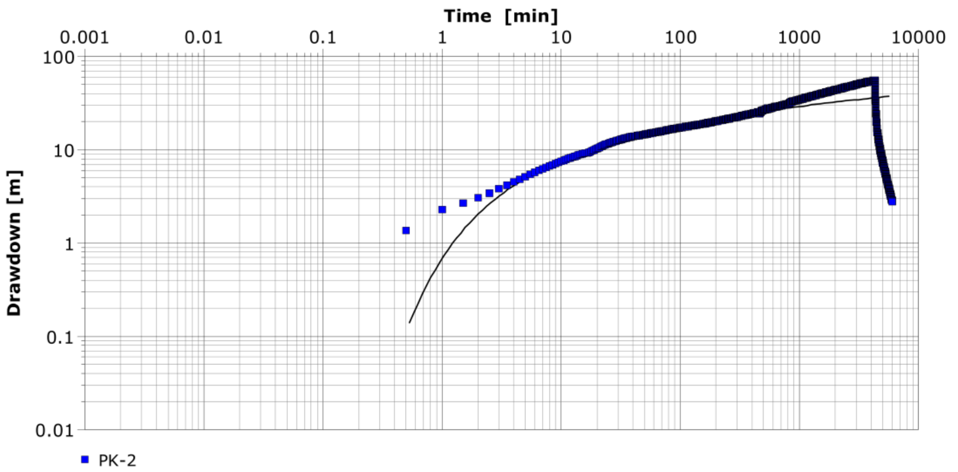
Pumping Test Analysis Report

Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: HK	PK-2 NEUMAN	Analysis Date: 8/13/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



Calculation using Neuman

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Specific Yield	Ratio K(v)/K(h)	Ratio Sy/S	Radial Distance to PW [m]
PK-2	1.80×10^{-5}	6.34×10^{-8}	6.21×10^{-1}	4.29×10^{-8}	1.36×10^{0}	0.11

Figure B-4: Neuman test result for PK-2

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

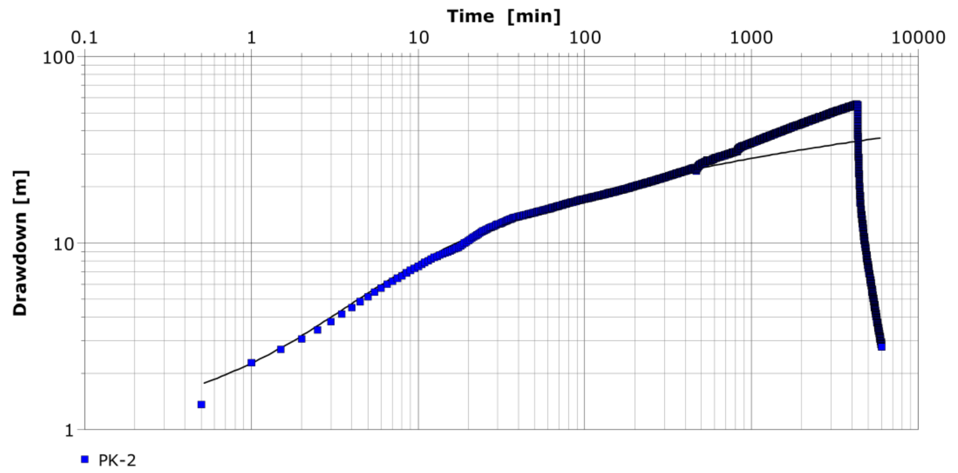
Pumping Test Analysis Report

Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: HK	PK-2 BOULTON	Analysis Date: 8/13/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



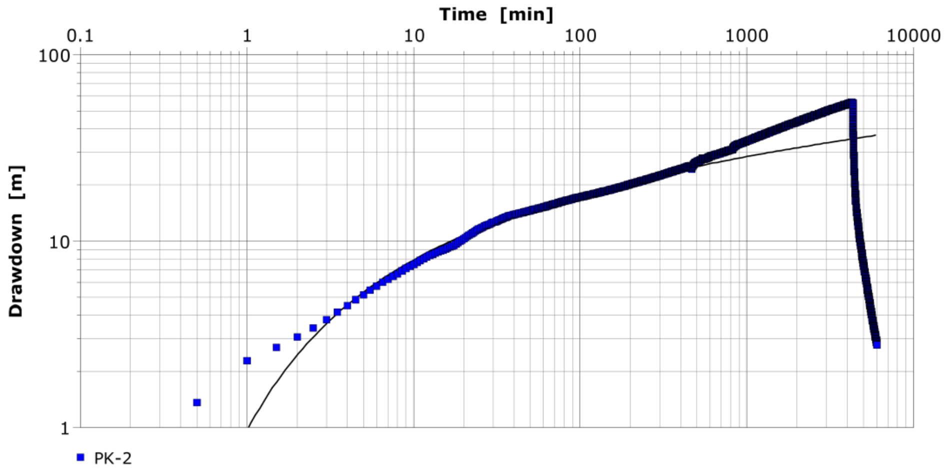
Calculation using Boulton

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Specific Yield	Drainage factor	Ratio Sy/S	Radial Distance to PW [m]
PK-2	1.86×10^{-5}	6.56×10^{-8}	3.97×10^{-1}	2.95×10^{-1}	1.00×10^{1}	0.11

Figure B-5: Boulton test result for PK-2

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Pumping Test Analysis Report**
	Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: HK	PK-2 THEIS WITH JACOB CORRECTION	Analysis Date: 8/13/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



Calculation using Theis with Jacob Correction

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
PK-2	2.02×10^{-5}	7.12×10^{-8}	3.96×10^{-1}	0.11

Figure B-6: Theis with Jacop correction test result for PK-2

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

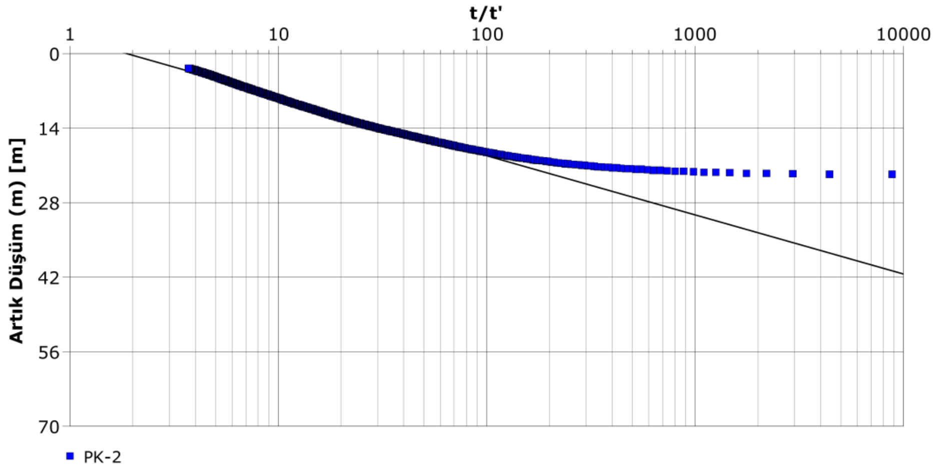
Pumping Test Analysis Report

Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: MOC	PK-2 THEIS RECOVERY	Analysis Date: 8/12/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



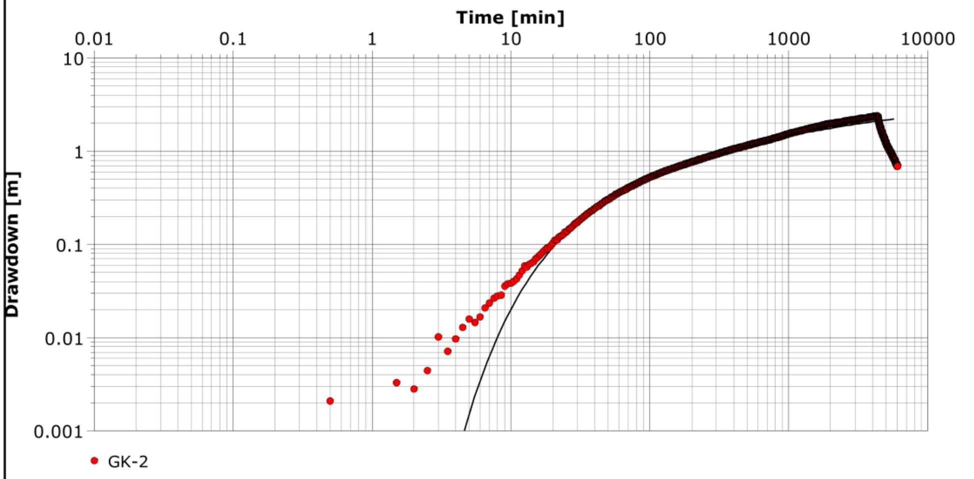
Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]	
PK-2	1.77×10^{-5}	6.26×10^{-8}	0.11	

Figure B-7: Theis recovery test result for PK-2

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Pumping Test Analysis Report**
	Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: HK	GK-2 NEUMAN	Analysis Date: 8/13/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



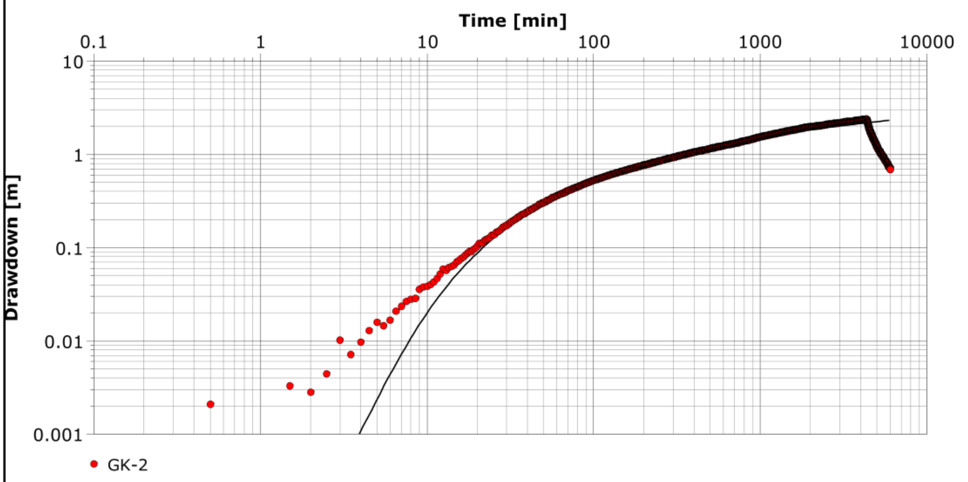
Calculation using Neuman

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Specific Yield	Ratio K(v)/K(h)	Ratio Sy/S	Radial Distance to PW [m]
GK-2	1.95×10^{-4}	6.88×10^{-7}	8.55×10^{-2}	5.31×10^{-1}	1.08×10^{1}	10.99

Figure B-8: Neuman test result for GK-2

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Pumping Test Analysis Report Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: HK	GK-2 BOULTON	Analysis Date: 8/13/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



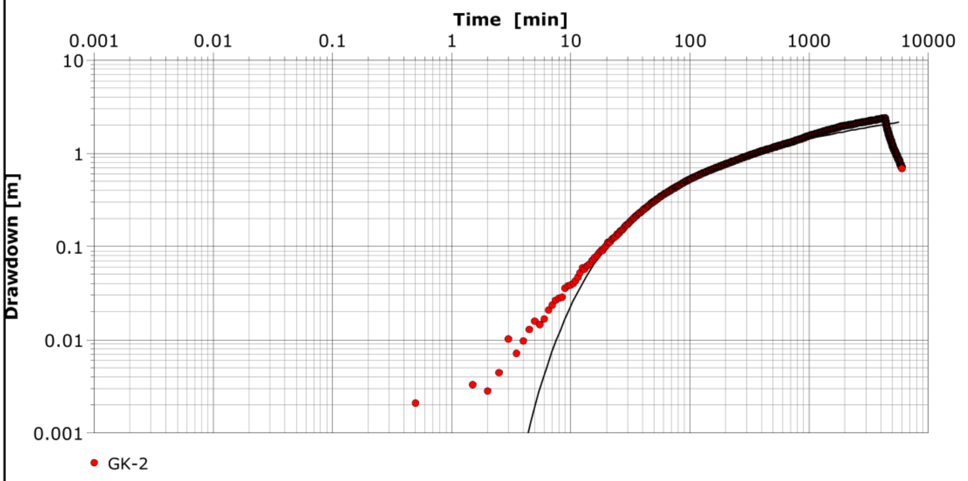
Calculation using Boulton

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Specific Yield	Drainage factor	Ratio Sy/S	Radial Distance to PW [m]
GK-2	1.84×10^{-4}	6.49×10^{-7}	8.05×10^{-3}	3.00×10^{0}	1.00×10^{2}	10.99

Figure B-9: Boulton test result for GK-2

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Pumping Test Analysis Report
	Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: HK	GK-2 THEIS WITH JACOB CORRECTION	Analysis Date: 8/13/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



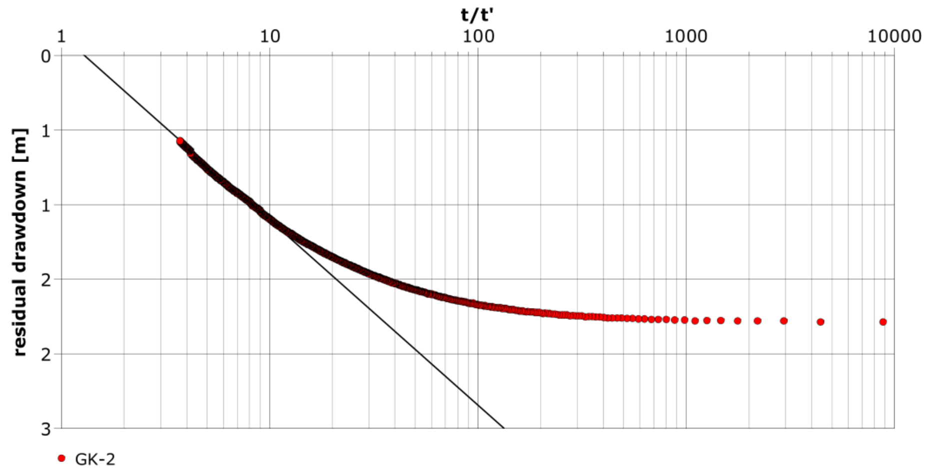
Calculation using Theis with Jacob Correction

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
GK-2	2.05×10^{-4}	7.23×10^{-7}	7.82×10^{-3}	10.99

Figure B-10: Theis with Jacop test result for GK-2

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Pumping Test Analysis Report
	Project: Alpu Kömür Havzasının Hidrojeoloji Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammadeler San. ve Tic. A.Ş.

Location: Eskişehir/Odunpazarı	Pumping Test: PK-2 (1.1L/s) - 72 SAAT	Pumping Well: PK-2
Test Conducted by: MOC		Test Date: 8/6/2015
Analysis Performed by: MOC	GK-2 THEIS RECOVERY	Analysis Date: 8/12/2015
Aquifer Thickness: 283.64 m	Discharge: variable, average rate 1.0776 [l/s]	



Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]
GK-2	1.33×10^{-4}	4.67×10^{-7}	10.99

Figure B-11: Theis recovery test result for GK-2

PK-3; after conducting a different discharge rated pre pump test, in order to determine the hydraulic parameters of below lignite unit which consists of limestone. The pump test was conducted for 10,5 hours with a 1 L/s constant discharge rate. The test was stopped because the pump was getting warm. The recovery test was applied for 35 hours. The pressure meter was squash into the pipe at about 260 meter depth. After that depth, the measurements were not conducted. The Drawdown vs Time graph are presented in Figure B-12 Physical parameters of the groundwater were measured during the pump test and shown in Figure B-13 below. The temperature values are getting higher because of the increased temperature of the pump. The pump test results were evaluated with different methods. The Theis, Cooper&Jacob and Theis recovery methods are used for evaluating the pump test results. The Transmissivity (T) values vary between

$8.54X10^{-7}$ m^2/s and $3.49X10^{-6}$ m^2/s. The average of the Transmissivity value is $2.50X10^{-6}$ m^2/s. The Hydraulic Conductivity (K) values vary between $9.48X10^{-9}$ m/s and $3.88X10^{-8}$ m/s. The average K value is $2.78X10^{-8}$ m/s. The storativity value was not evaluated because of the short pumping period. The water level changes in observation wells were too small.

Figure B-12: PK-3 Drawdown vs Time Graph

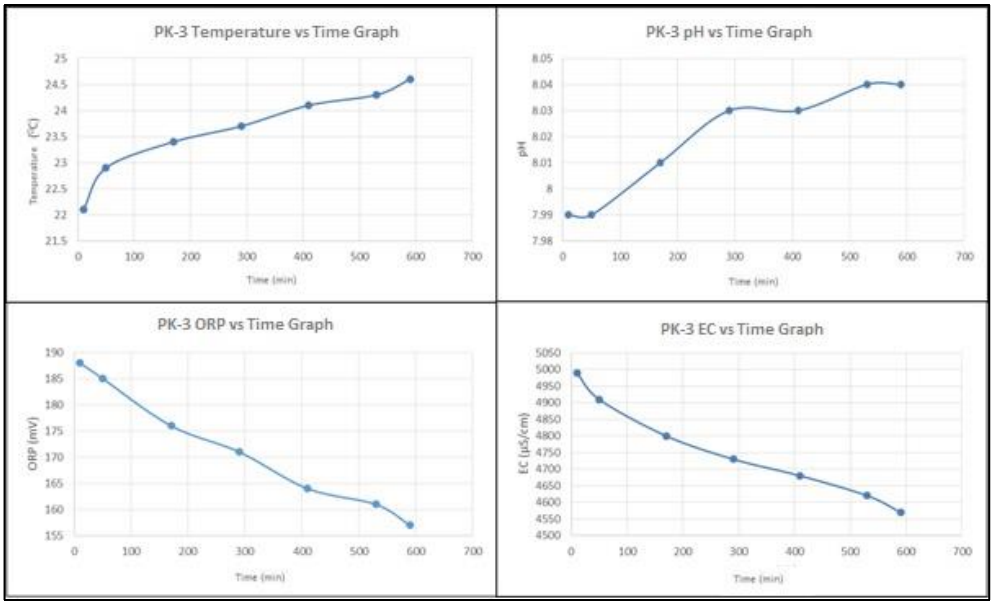


Figure B-13: Physical parameters measured in PK-3 pump test

Table B-2: Hydraulic parameters of PK-3

Well No	DischargeRate (L/s)	Analysis Method	Transmissivity T (m2/s)	Hydraulic Conductivity K (m/s)
PK-3	1.0	Cooper & Jacob	3.16E-06	3.51E-08
		Theis	3.49E-06	3.88E-08
		Theis Recovery	8.54E-07	9.48E-08
AVERAGE			**2.50E-06**	**2.78E-08**

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

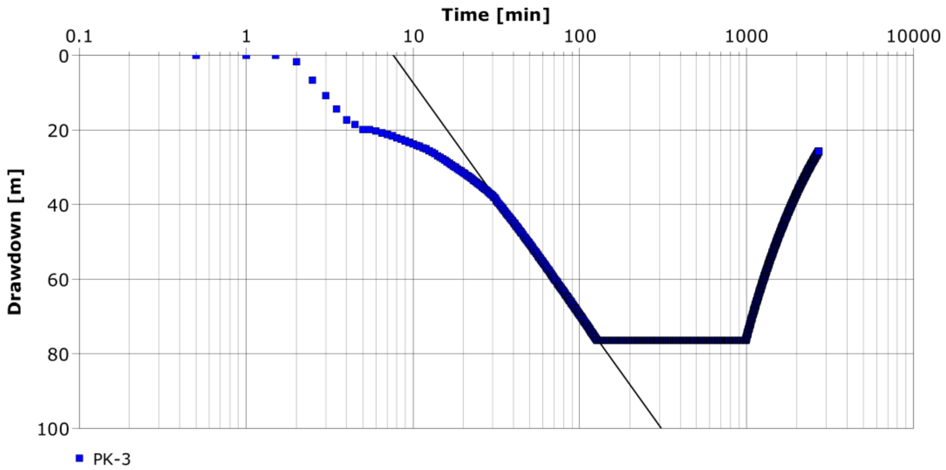
Pumping Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Pumping Test: PK-3 POMPA TESTİ	Pumping Well: PK-3
Test Conducted by: MOC		Test Date: 7/26/2015
Analysis Performed by: MOC	PK-3 COOPER & JACOB	Analysis Date: 11/21/2015
Aquifer Thickness: 90.00 m	Discharge: variable, average rate 1.0737 [l/s]	



Calculation using COOPER & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
PK-3	3.16×10^{-6}	3.51×10^{-8}	2.71×10^{-1}	0.11

Figure B-14: Cooper&Jacop test result for PK-3

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

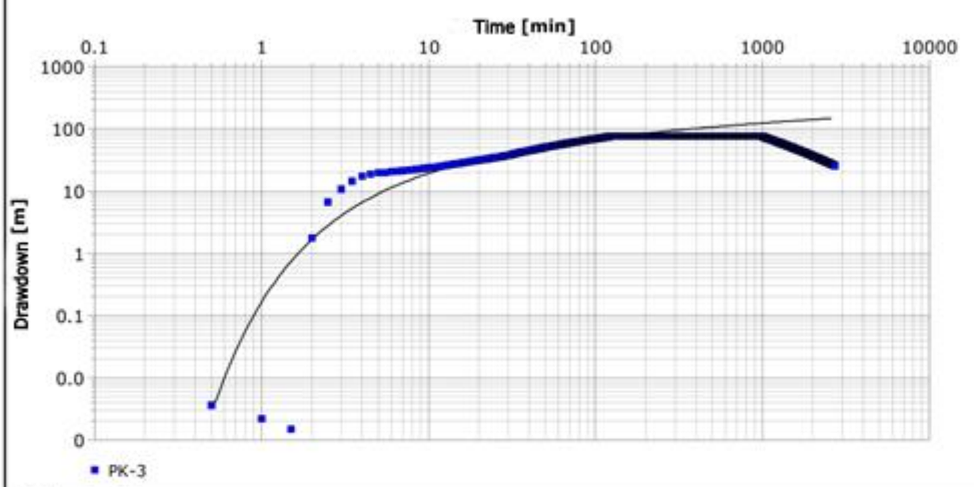
Pumping Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Pumping Test: PK-3 POMPA TESTİ	Pumping Well: PK-3
Test Conducted by: MOC		Test Date: 7/26/2015
Analysis Performed by: MOC	PK-3 THEIS	Analysis Date: 11/21/2015
Aquifer Thickness: 90.00 m	Discharge: variable, average rate 1.0737 [l/s]	



Calculation using Theis

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Ratio K(v)/K(h)	Radial Distance to PW [m]
PK-3	3.49×10^{-6}	3.88×10^{-8}	2.47×10^{-1}	7.77×10^{-2}	0.11

Figure B-15: Theis test result for PK-3

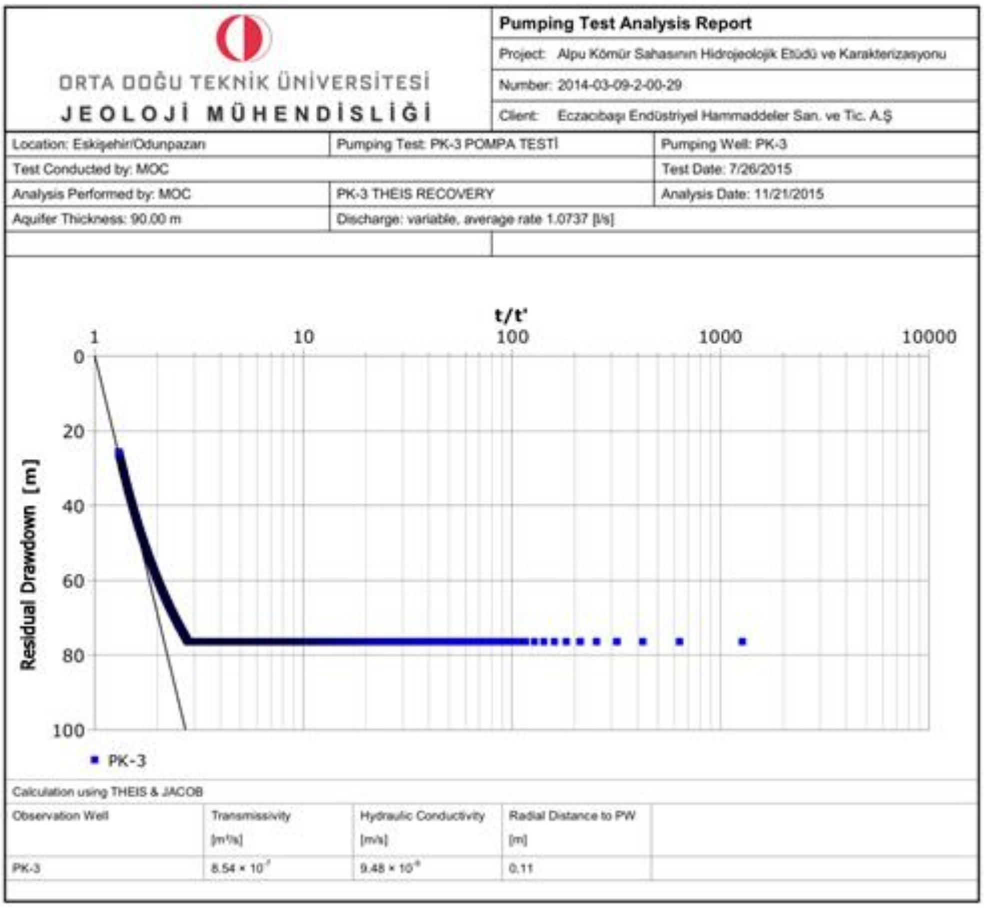


Figure B-16: Theis recovery test result for PK-3

PK-6; after conducting a different discharge rated pre pump test, in order to determine the hydraulic parameters of lignite unit in the Porsuk Formation. The Pump test conducted in this well three times. The pump was stopped in the first and second tests because of getting high temperature. The first test took about 18 hours and 50 minutes. The discharge rate was 0.5 L/s. The test results from PK-6 and its observation well GK-5 were evaluated. The results are presented in Table B-3.

The second test period was about 22 hours and 12 minutes. The test discharge rate was increased to 1 L/s in order to prevent the pump getting warm, however, the pump was stopped. The recovery period took about 9 hours.

The last pump test was conducted for 48 hours with a 1 L/s constant discharge rate. The recovery test was applied for 36 hours. Physical parameters of the groundwater were measured during the pump test and shown in Figure B-17. The temperature values are getting higher because of the increased temperature of the pump. The other parameters are getting stabilized.

The pump test results were evaluated with different methods. The Theis, Cooper&Jacob and Theis recovery methods are used for evaluating the pump test results. The Transmissivity (T) values vary between $6.75X10^{-6}$ m^2/s and $3.57X10^{-5}$ m^2/s. The average of the Transmissivity value is $2.10X10^{-5}$ m^2/s. The Hydraulic Conductivity (K) values vary between $9.64X10^{-8}$ m/s and $5.11X10^{-7}$ m/s. The average K value is $2.99X10^{-7}$ m/s. The storativity value evaluated by using the data which is taken from GK-5. The Storativity values vary between $2.23X10^{-3}$ and $1.95X10^{-2}$. The average Storativity value is $7.59X10^{-3}$. These results are shown in Table B-3.

Table B-3: The results of pump tests

Well ID	Well Type	Test Discharge Rate (L/s)	Pumping Period	Analysis Method	Transmissivity Coefficient -T- (m2/s)	Average Transmissivity Coefficient -Tavg- (m2/s)	Hydraulic Conductivity K- (m/s)	Average Hydraulic Conductivity -K avg- (m/s)	Storativity -S-	Average Storativity -S avg-
PK-6	Pumping Well	0.5	18 hours 50 min	Cooper & Jacob	1.75E-05	1.87E-05	2.50E-07	2.67E-07	X	X
				Theis	1.46E-05		2.09E-07			
				Theis Recovery	2.40E-05		3.43E-07			
GK-5	Observation Well			Cooper & Jacob	3.52E-05	3.46E-05	5.02E-07	4.94E-07	2.23E-03	X
				Theis	3.28E-05		4.68E-07		2.65E-03	
				Theis Recovery	3.57E-05		5.11E-07		X	
PK-6	Pumping Well	1.0	22 hours 12 min	Cooper & Jacob	2.12E-05	1.49E-05	3.03E-07	2.13E-07	X	X
				Theis	6.75E-05		9.64E-07			
				Theis Recovery	1.67E-05		2.39E-07			
GK-5	Observation Well			Cooper & Jacob	2.10E-05	2.32E-05	3.00E-07	3.32E-07	3.39E-07	X
				Theis	2.73E-05		3.90E-07		2.58E-07	
				Theis Recovery	2.14E-05		3.06E-07		X	
PK-6	Pumping Well		48 hours	Cooper & Jacob	1.65E-05	1.51E-05	2.36E-07	2.15E-07	X	X
				Theis	7.77E-06		1.11E-07			
				Theis Recovery	2.09E-05		2.99E-07			
GK-5	Observation Well			Cooper & Jacob	1.52E-05	1.93E-05	2.17E-07	2.76E-07	1.52E-02	X
				Theis	1.51E-05		2.15E-07		1.95E-02	
				Theis Recovery	2.77E-05		3.95E-07		X	
				GENERAL AVERAGE	2.10E-05	2.10E-05	2.99E-07	2.99E-07	7.59E-03	7.59E-03

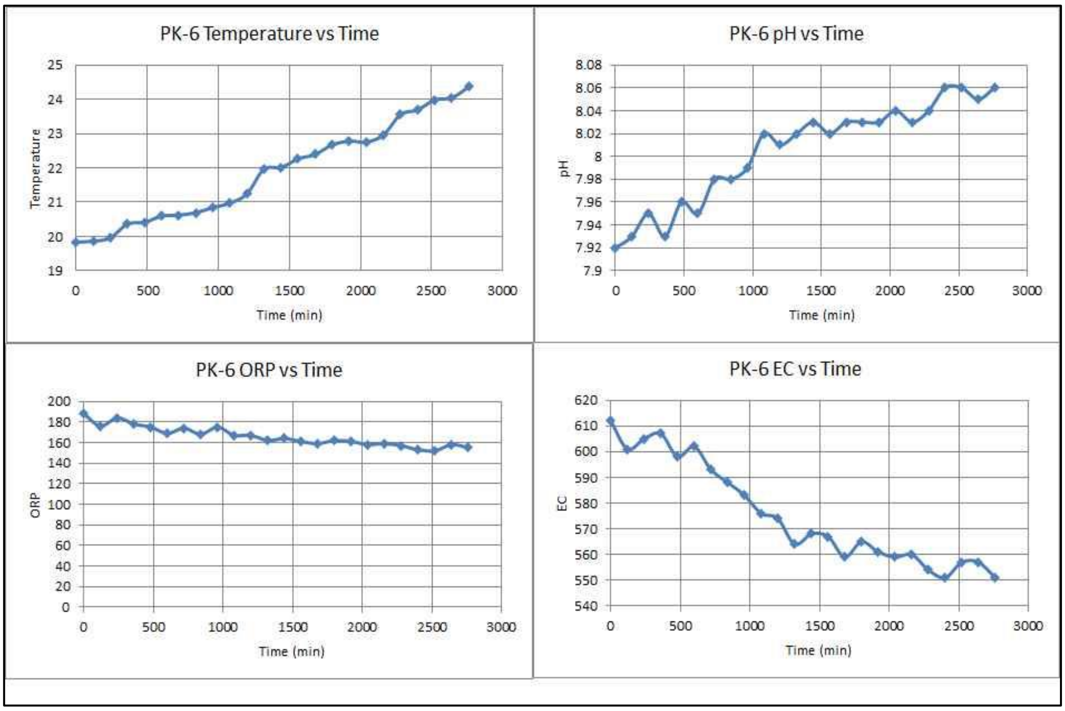


Figure B-17: Physical parameters measured in PK-6 pump test

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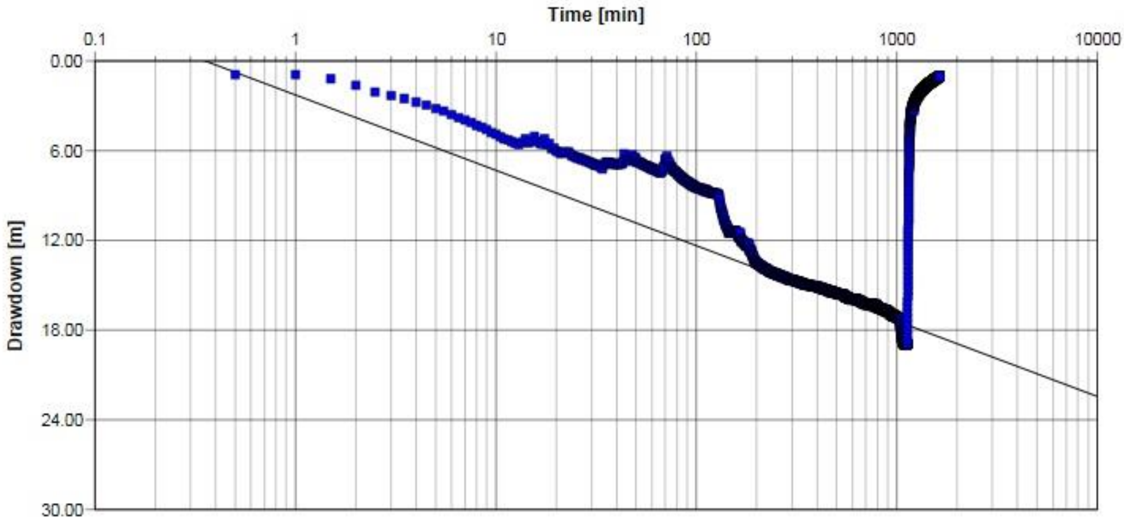
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (0,5 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/20/2015
Analysis Performed by: MOC	PK_6_COOPER&JACOB	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.48107 [l/s]	



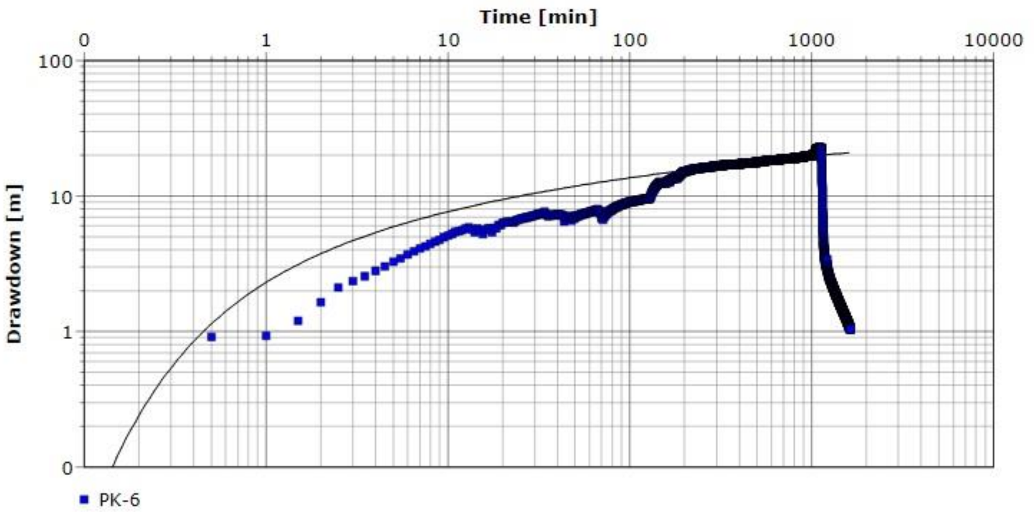
Calculation using COOPER & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
PK-6	1.75×10^{-5}	2.50×10^{-7}	6.97×10^{-2}	0.11

Figure B-18: Cooper&Jacop test result for PK-6 (0.5 L/s)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

Pompa Testi Analiz Raporu		
Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu		
Number: 2014-03-09-2-00-29		
Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş		
Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (0,5 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/20/2015
Analysis Performed by: MOC	PK-6_THEIS	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.48107 [l/s]	



Calculation using Theis

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
PK-6	1.46×10^{-5}	2.09×10^{-7}	9.10×10^{-2}	0.11

Figure B-19: Theis test result for PK-6 (0.5 L/s)

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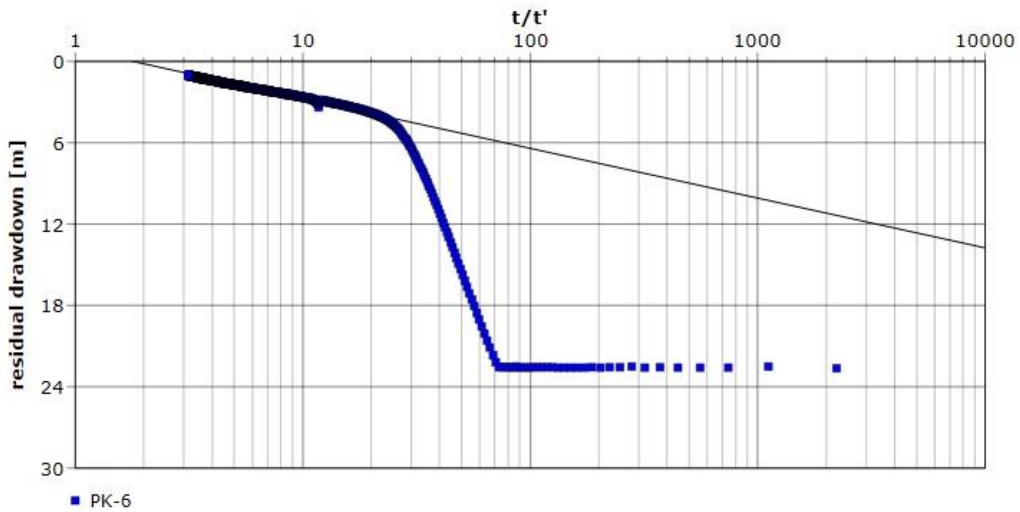
JEOLOJİ MÜHENDİSLİĞİ

Pompa Testi Analiz Raporu
Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
Number: 2014-03-09-2-00-29
Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (0,5 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/20/2015
Analysis Performed by: MOC	PK-6_THEIS_RECOVERY	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.48107 [l/s]	



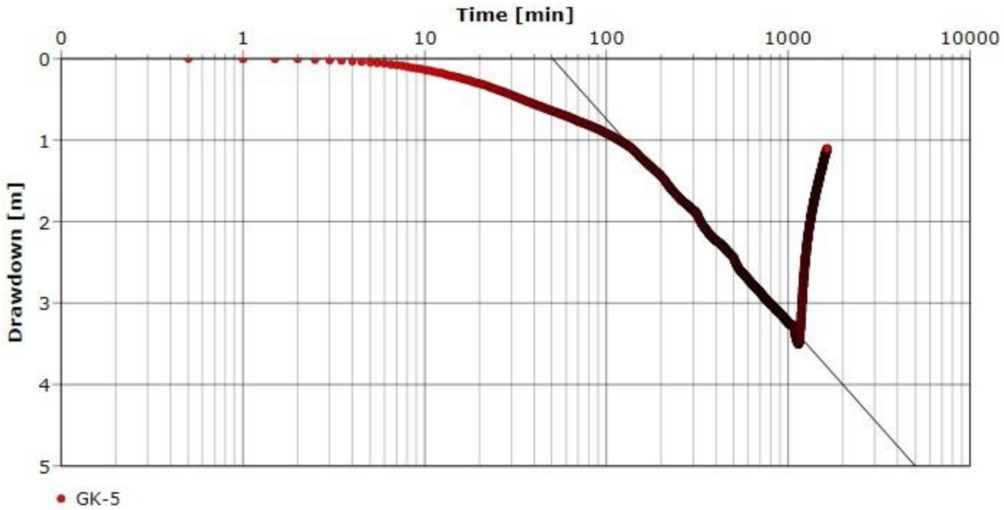
Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]
PK-6	2.40×10^{-5}	3.43×10^{-7}	0.11

Figure B-20: Theis recovery test result for PK-6 (0.5 L/s)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Pompa Testi Analiz Raporu
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (0,5 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/20/2015
Analysis Performed by: MOC	GK-5_COOPER&JACOB	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.48107 [l/s]	



Calculation using COOPER & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
GK-5	3.52×10^{-5}	5.02×10^{-7}	2.23×10^{-2}	10.36

Figure B-21: Cooper&Jacop test result for GK-5 (0.5 L/s)

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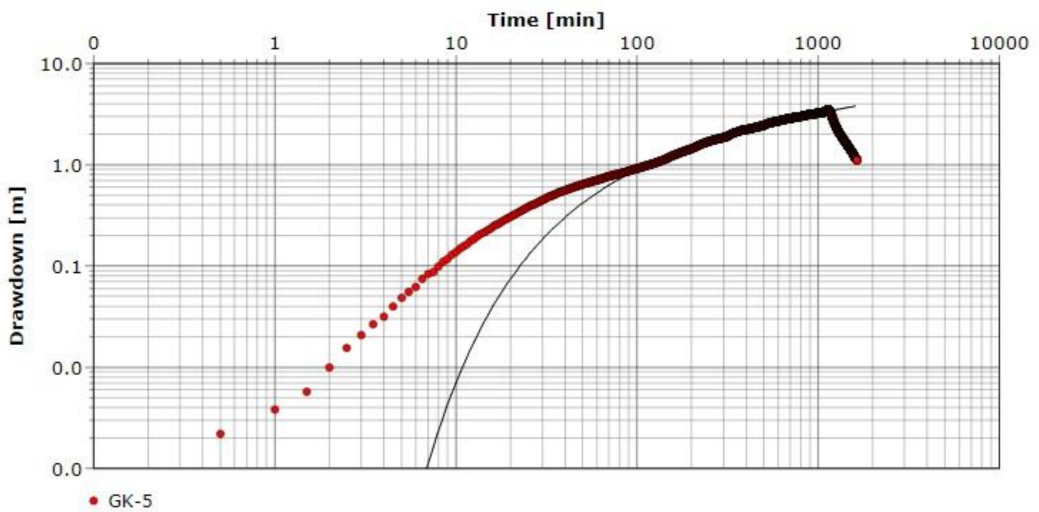
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (0,5 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/20/2015
Analysis Performed by: MOC	GK-5_THEIS	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.48107 [l/s]	



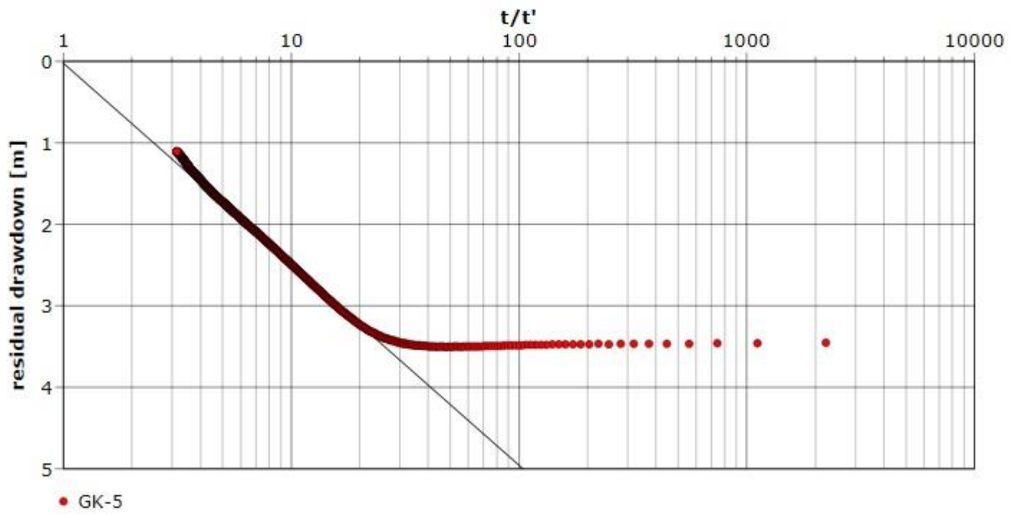
Calculation using Theis

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Ratio K(v)/K(h)	Radial Distance to PW [m]
GK-5	3.28×10^{-5}	4.68×10^{-7}	2.65×10^{-3}	2.36×10^{-1}	10.36

Figure B-22: Theis test result for GK-5 (0.5 L/s)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

Pompa Testi Analiz Raporu		
Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu		
Number: 2014-03-09-2-00-29		
Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş		
Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (0,5 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/20/2015
Analysis Performed by: MOC	GK-5_THEIS_RECOVERY	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.48107 [l/s]	



Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]
GK-5	3.57×10^{-5}	5.11×10^{-7}	10.36

Figure B-23: Theis recoverytest result for GK-5 (0.5 L/s)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

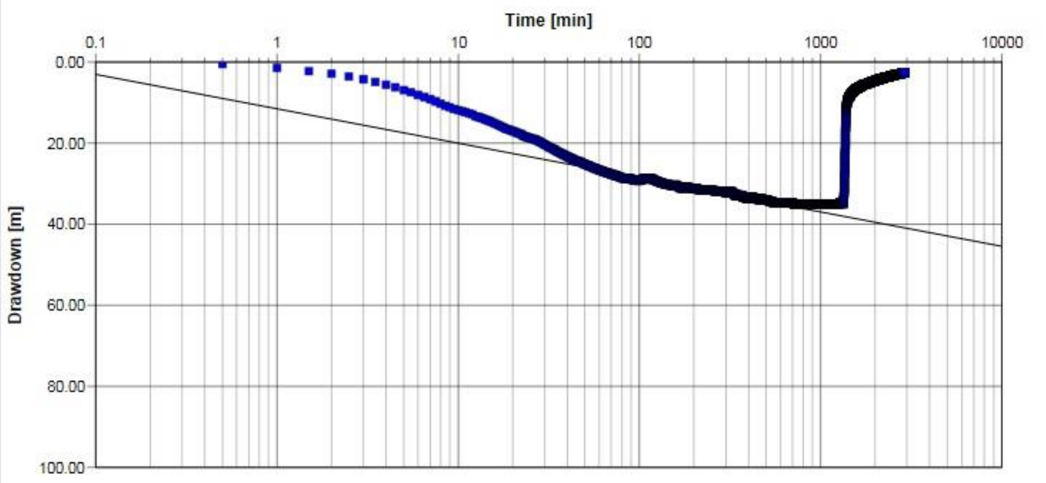
Pumping Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/22/2015
Analysis Performed by: MOC	PK_6_COOPER&JACOB	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.9824 [l/s]	

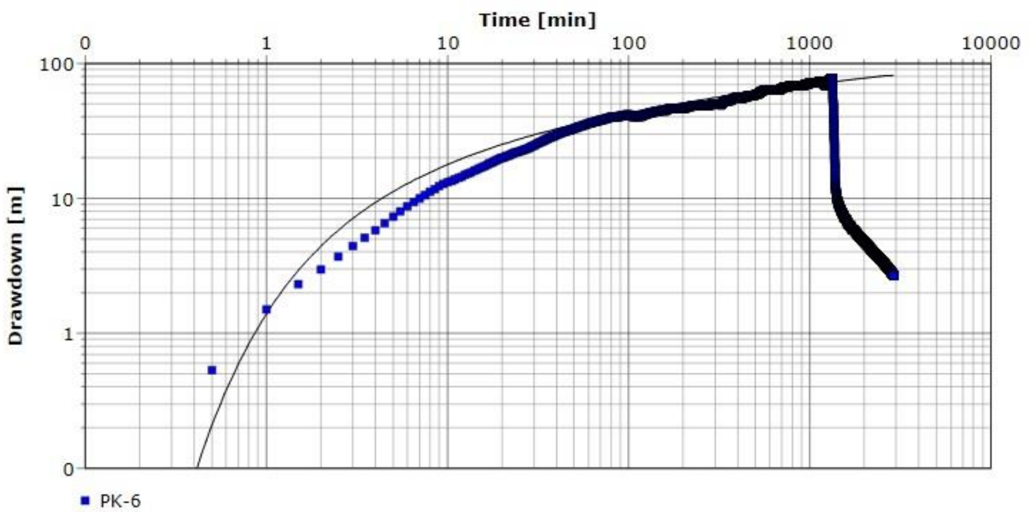


Calculation using COOPER & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
PK-6	2.12×10^{-5}	3.03×10^{-7}	1.04×10^{-2}	0.11

Figure B-24: Cooper&Jacop test result for PK-6 (1 L/s, 22 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ		**Pumping Test Analysis Report**
		Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
		Number: 2014-03-09-2-00-29
		Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş
Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/22/2015
Analysis Performed by: MOC	PK-6_THEIS	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.9824 [l/s]	



Calculation using Theis

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]	
PK-6	6.75×10^{-6}	9.64×10^{-8}	1.86×10^{-1}	0.11	

Figure B-25: Theis test result for PK-6 (1 L/s, 22 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

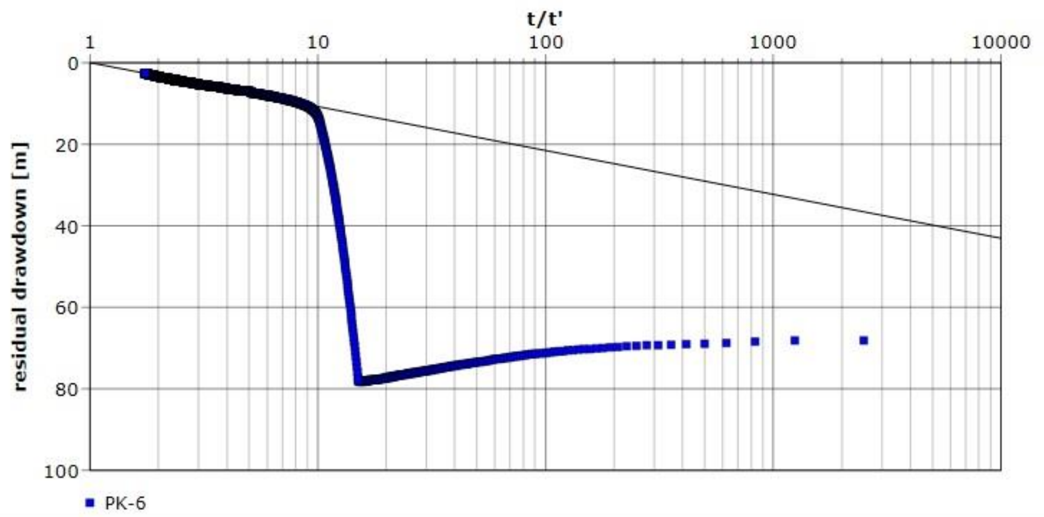
Pumping Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/22/2015
Analysis Performed by: MOC	PK-6_THEIS_RECOVERY	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.9824 [l/s]	



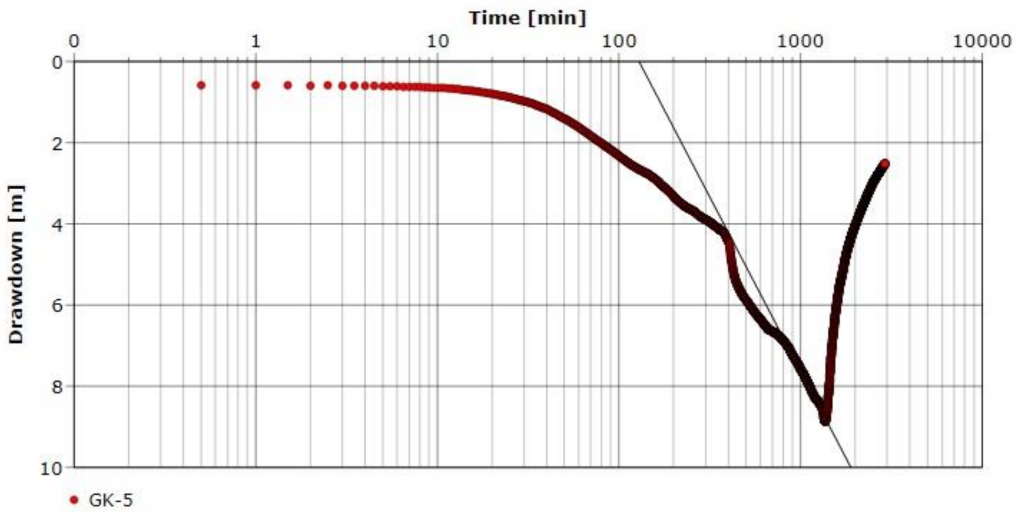
Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]
PK-6	1.67×10^{-5}	2.39×10^{-7}	0.11

Figure B-26: Theis recovery test result for PK-6 (1 L/s, 22 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Pumping Test Analysis Report
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/22/2015
Analysis Performed by: MOC	GK-5_COOPER&JACOB	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.9824 [l/s]	



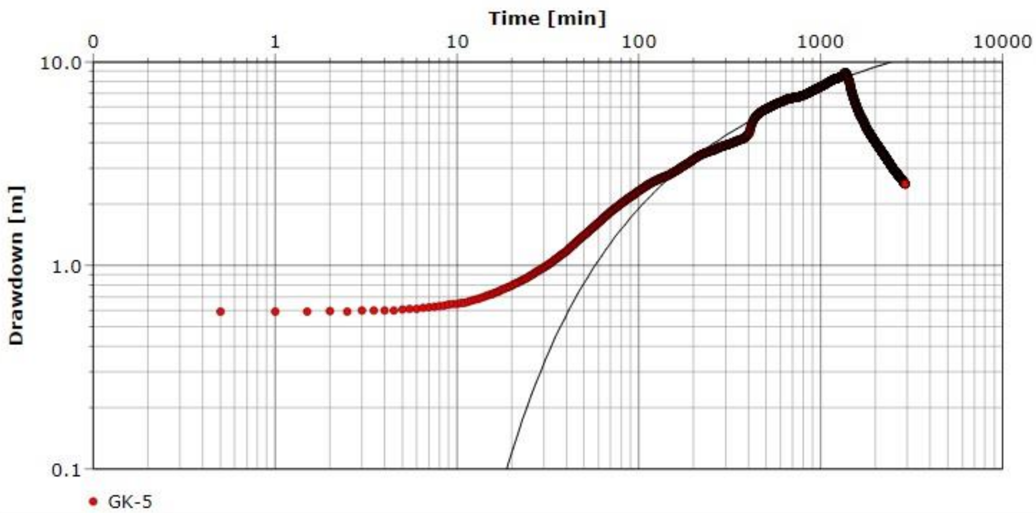
Calculation using COOPER & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
GK-5	2.10×10^{-5}	3.00×10^{-7}	3.39×10^{-3}	10.36

Figure B-27: Cooper&Jacop test result for GK-5 (1 L/s, 22 hour)

Pumping Test Analysis Report	
ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/22/2015
Analysis Performed by: MOC	GK-5_THEIS	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.9824 [l/s]	

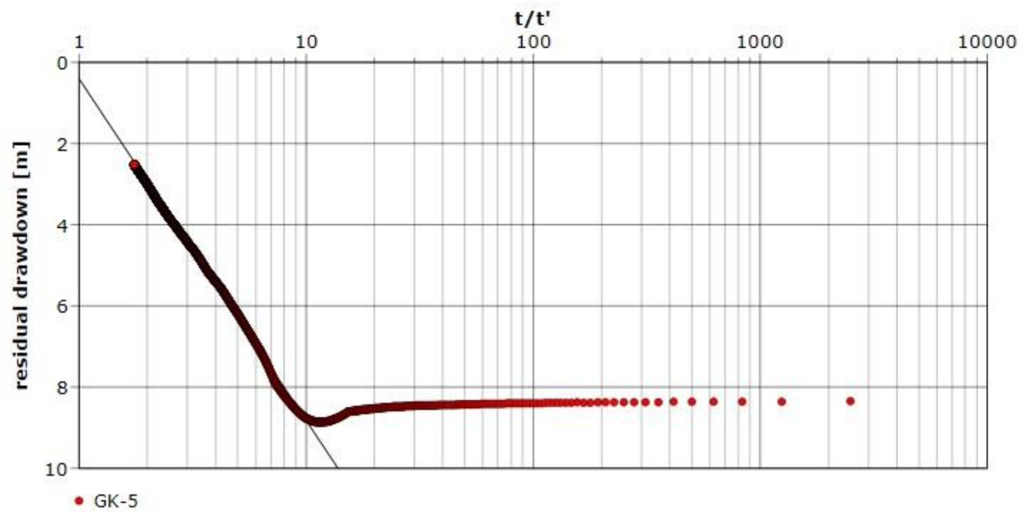


Calculation using Theis

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Ratio K(v)/K(h)	Radial Distance to PW [m]
GK-5	2.73×10^{-5}	3.90×10^{-7}	2.58×10^{-3}	2.53×10^{-1}	10.36

Figure B-28: Theis test result for GK-5 (1 L/s, 22 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ		Pumping Test Analysis Report
		Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
		Number: 2014-03-09-2-00-29
		Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş
Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 LT/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 6/22/2015
Analysis Performed by: MOC	GK-5_THEIS_RECOVERY	Analysis Date: 6/26/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.9824 [l/s]	



Calculation using THEIS & JACOB

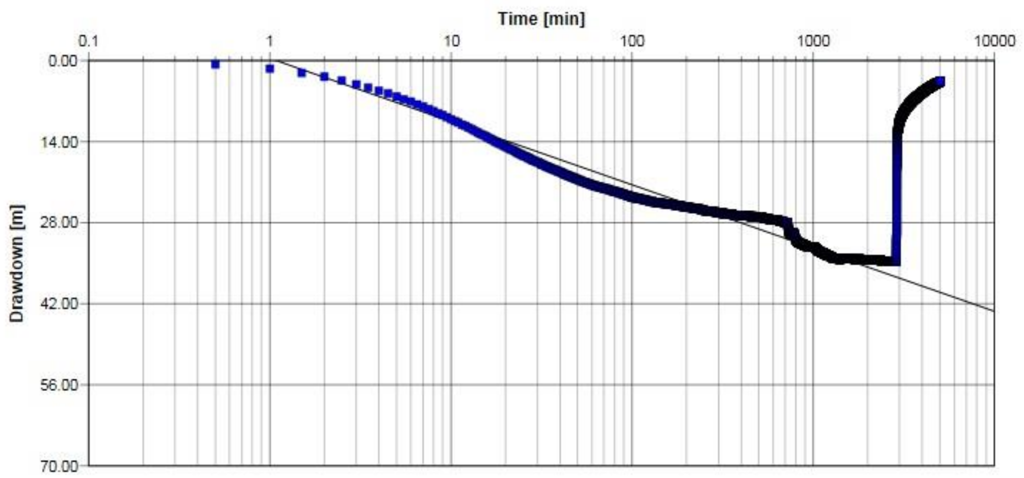
Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]
GK-5	2.14×10^{-5}	3.06×10^{-7}	10.36

Figure B-29: Theis recovery test result for GK-5 (1 L/s, 22 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

Pumping Test Analysis Report	
Project:	Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
Number:	2014-03-09-2-00-29
Client:	Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 L/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 7/1/2015
Analysis Performed by: MOC	PK_6_COOPER&JACOB	Analysis Date: 7/6/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.98423 [l/s]	



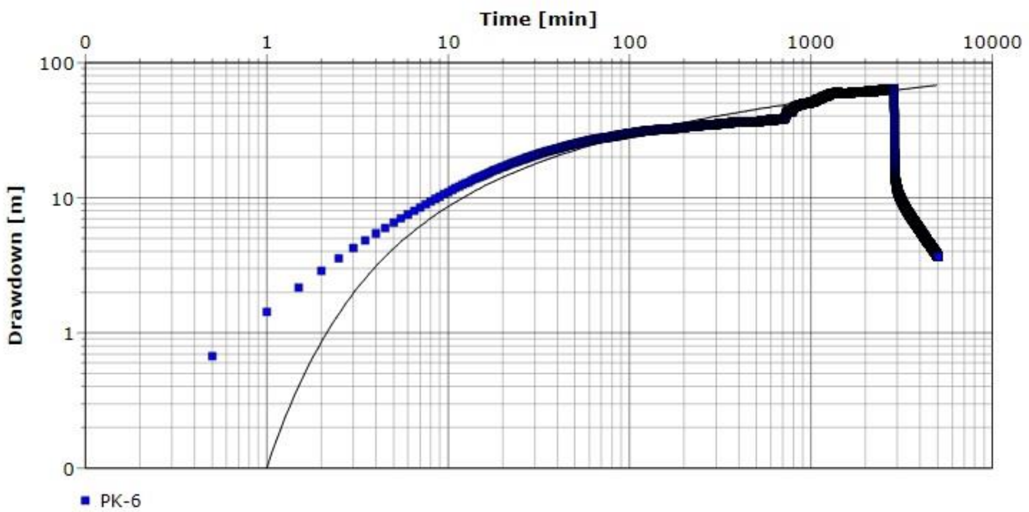
Calculation using COOPER & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
PK-6	1.65×10^{-5}	2.36×10^{-7}	2.01×10^{-1}	0.11

Figure B-30: Cooper&Jacop test result for PK-6 (1 L/s, 48 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Pumping Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 L/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 7/1/2015
Analysis Performed by: MOC	PK-6_THEIS	Analysis Date: 7/6/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.98423 [l/s]	



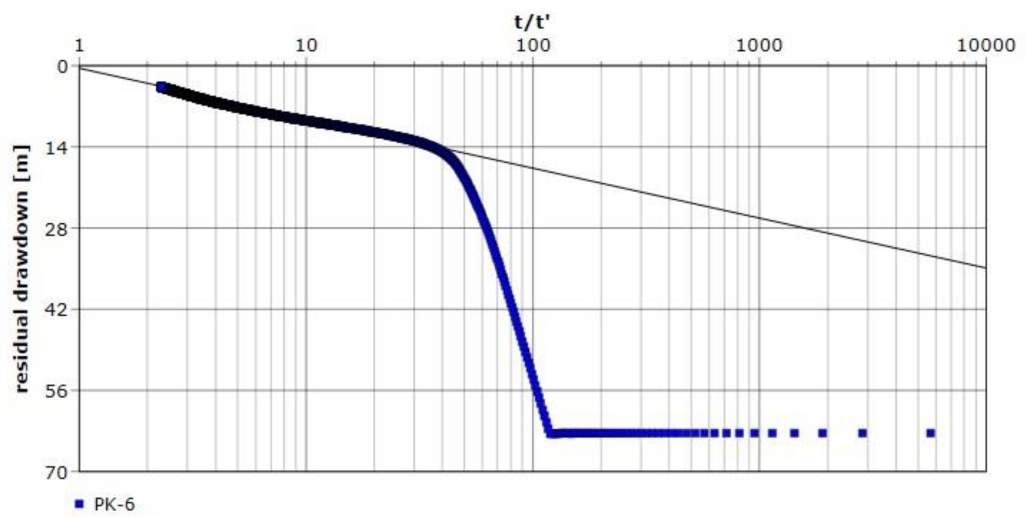
Calculation using Theis

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
PK-6	7.77×10^{-6}	1.11×10^{-7}	5.00×10^{-1}	0.11

Figure B-31: Theis test result for PK-6 (1 L/s, 48 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Pumping Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 L/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 7/1/2015
Analysis Performed by: MOC	PK-6_THEIS_RECOVERY	Analysis Date: 7/6/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.98423 [l/s]	



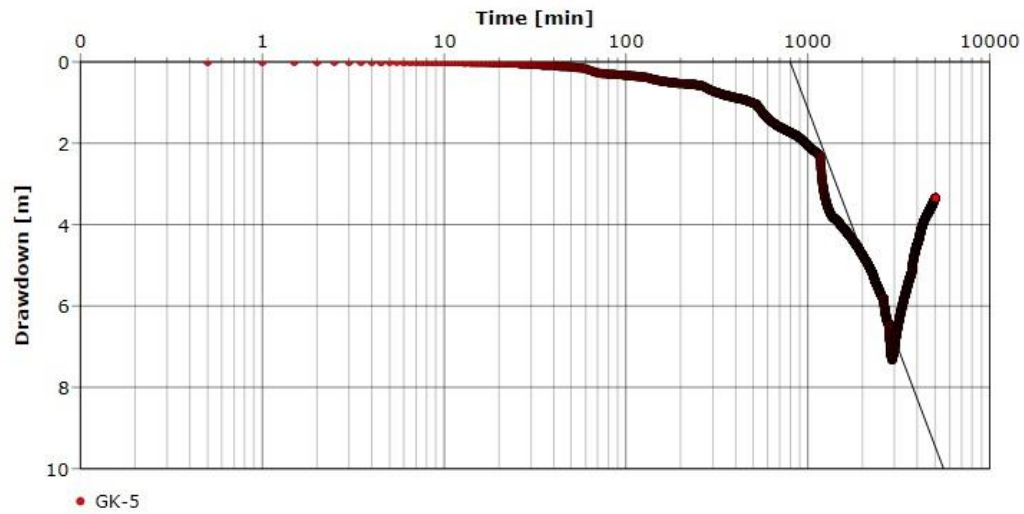
Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]
PK-6	2.09×10^{-5}	2.99×10^{-7}	0.11

Figure B-32: Theis recovery test result for PK-6 (1 L/s, 48 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Pumping Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 L/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 7/1/2015
Analysis Performed by: MOC	GK-5_COOPER&JACOB	Analysis Date: 7/6/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.98423 [l/s]	



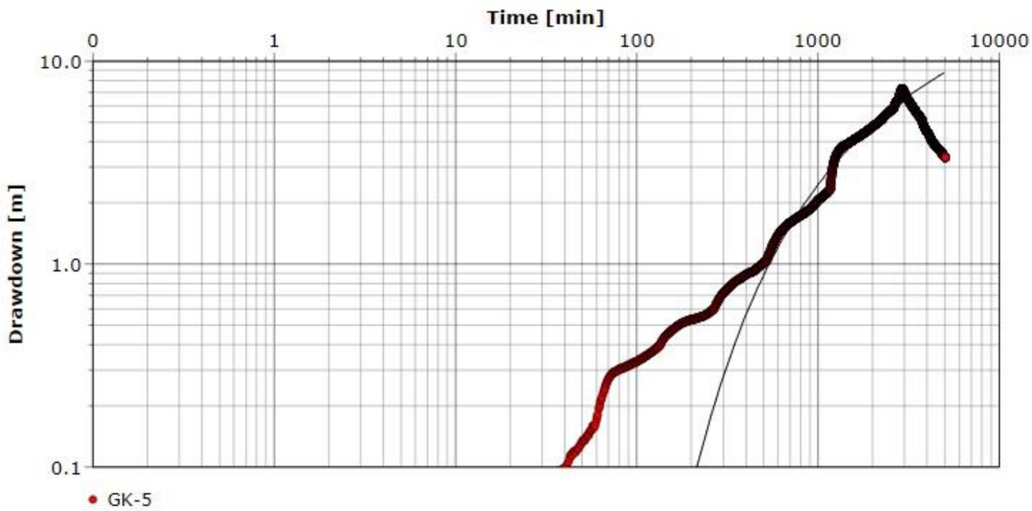
Calculation using COOPER & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Radial Distance to PW [m]
GK-5	1.52×10^{-5}	2.17×10^{-7}	1.52×10^{-2}	10.36

Figure B-33: Cooper&Jacop test result for GK-5 (1 L/s, 48 hour)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Pumping Test Analysis Report**
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir_Alpu	Pumping Test: PK-6 PUMP TEST (1 L/S)	Pumping Well: PK-6
Test Conducted by: MOC		Test Date: 7/1/2015
Analysis Performed by: MOC	GK-5_THEIS	Analysis Date: 7/6/2015
Aquifer Thickness: 70.00 m	Discharge: variable, average rate 0.98423 [l/s]	



Calculation using Theis

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Storage coefficient	Ratio K(v)/K(h)	Radial Distance to PW [m]
GK-5	1.51×10^{-5}	2.15×10^{-7}	1.95×10^{-2}	9.88×10^{-1}	10.36

Figure B-34: Theis test result for GK-5 (1 L/s, 48 hour)

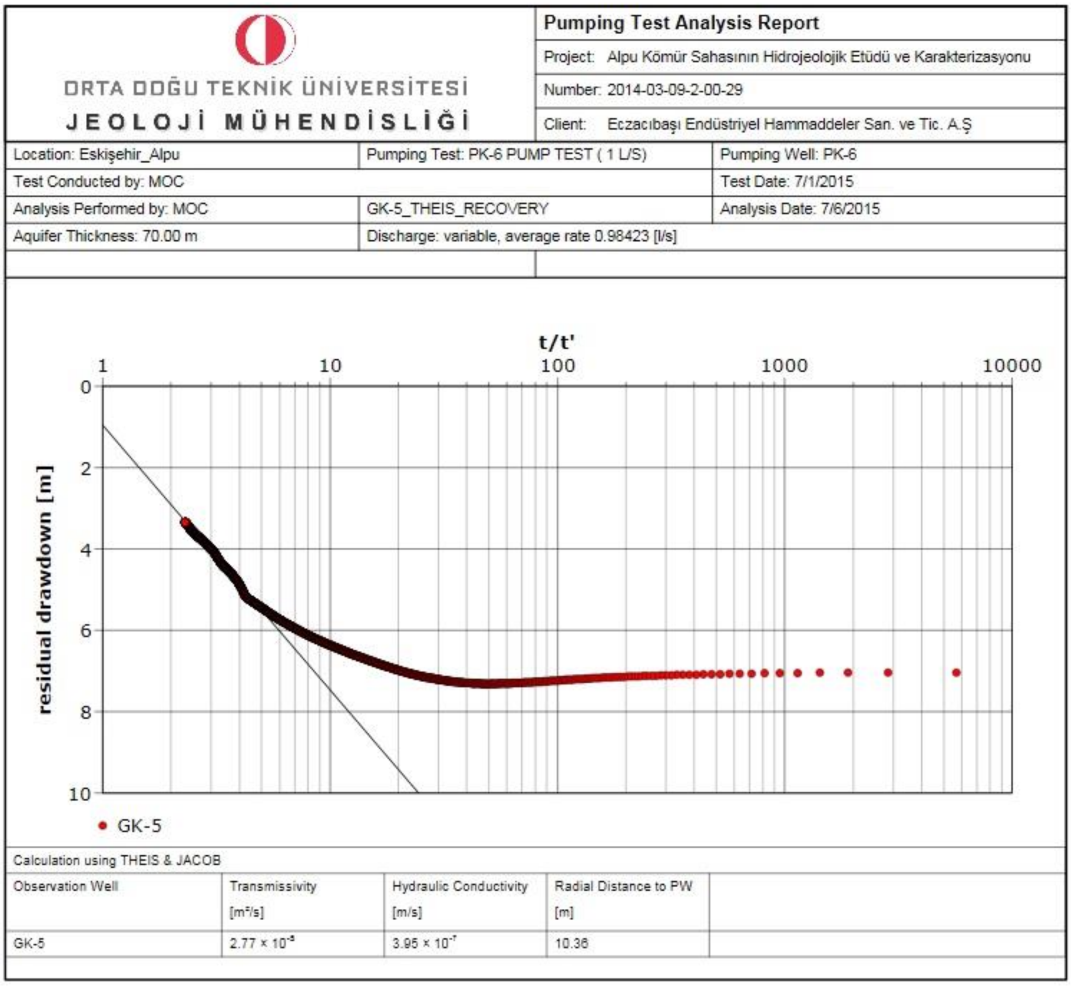


Figure B-35: Theis recovery test result for GK-5 (1 L/s, 48 hour)

APPENDIX C

SLUG TESTS RESULTS

After development of wells, slug tests were conducted in order to determine the hydraulic parameters. These tests were conducted in all wells except GK-4. The water level is lower than the screened level of the well. The test results are compatible with the pump test results so the slug test results are not given for those wells. The slugs with different radius were used for different wells. The HvorslEV and Bouver & Rice methods were used for evaluating both falling and rising head periods. The detailed information for all wells is shown in Table C-1.

GK-2; the slug test in this well took 4500 seconds. The test results are both evaluated separately for falling and rising phases. The drawdown vs time graphs for both phases are shown in Figure C-1 and Figure C-2.

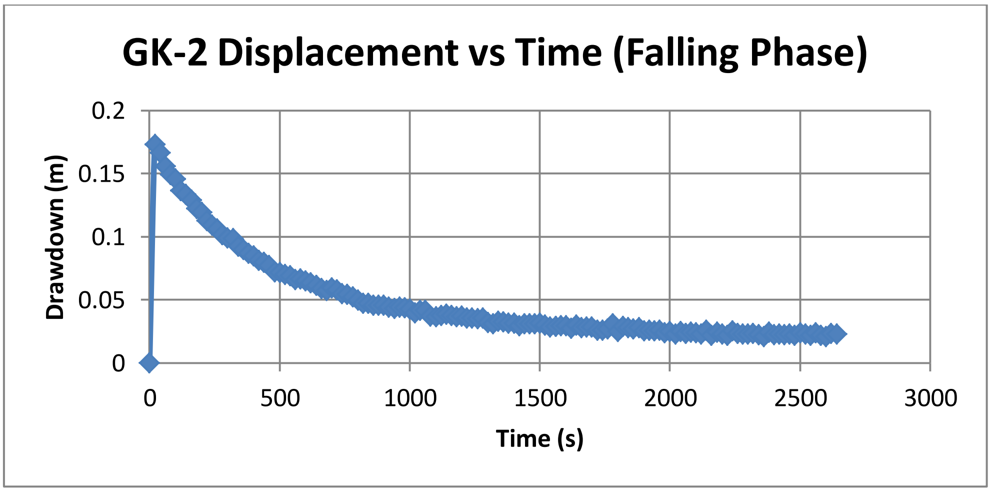


Figure C-1: GK-2 Slug Test Falling Phase

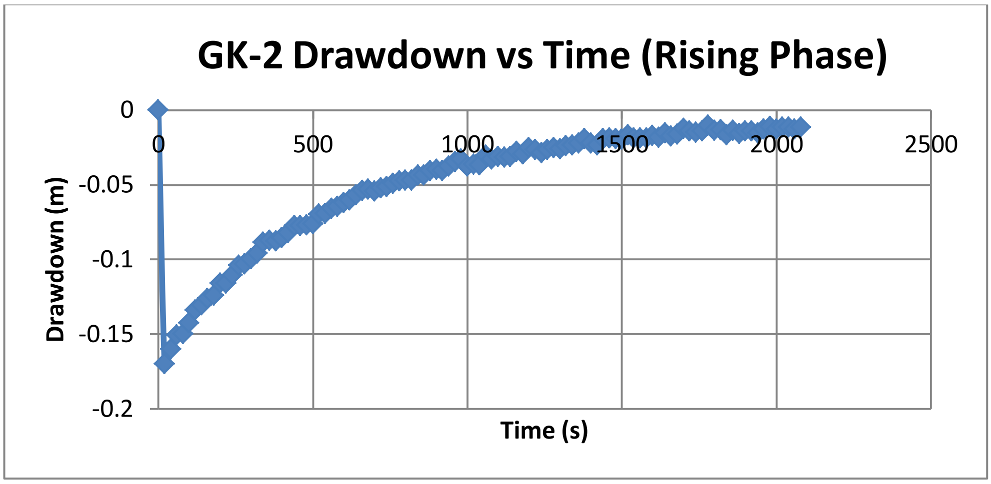


Figure C-2: GK-2 Slug Test Rising Phase

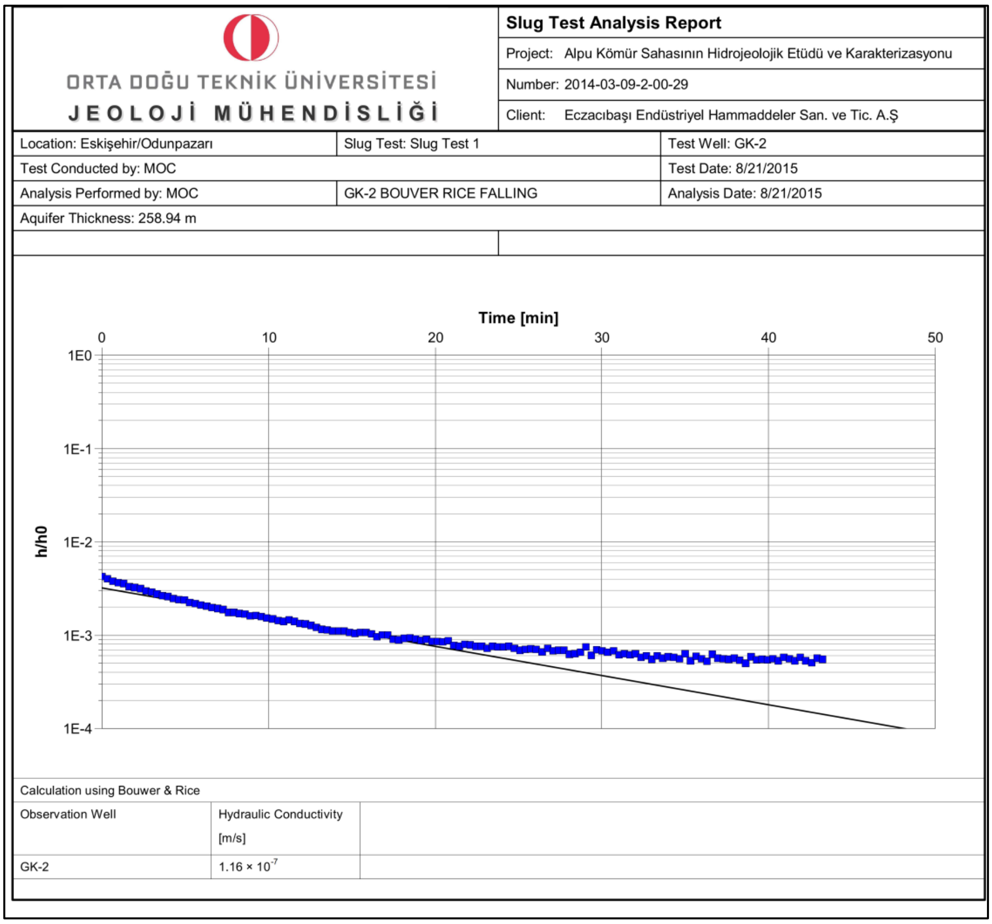
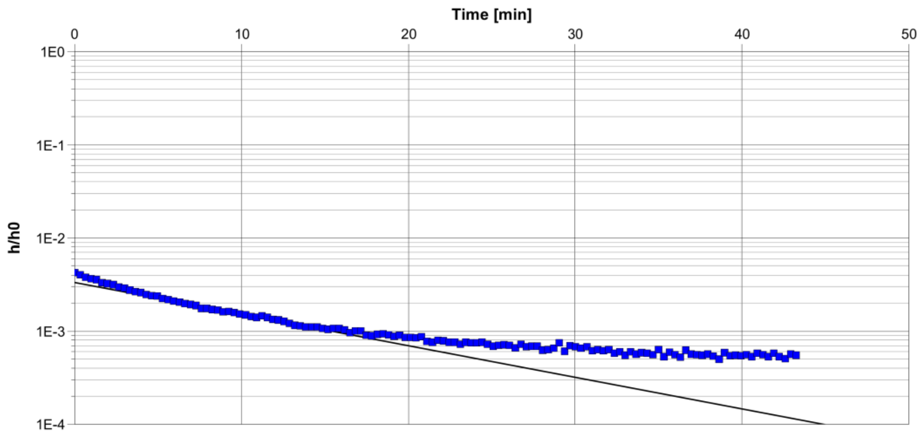


Figure C-3: GK-2 Bouver Rice falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report**
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: Slug Test 1	Test Well: GK-2
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-2 HVORSLEV FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 258.94 m		



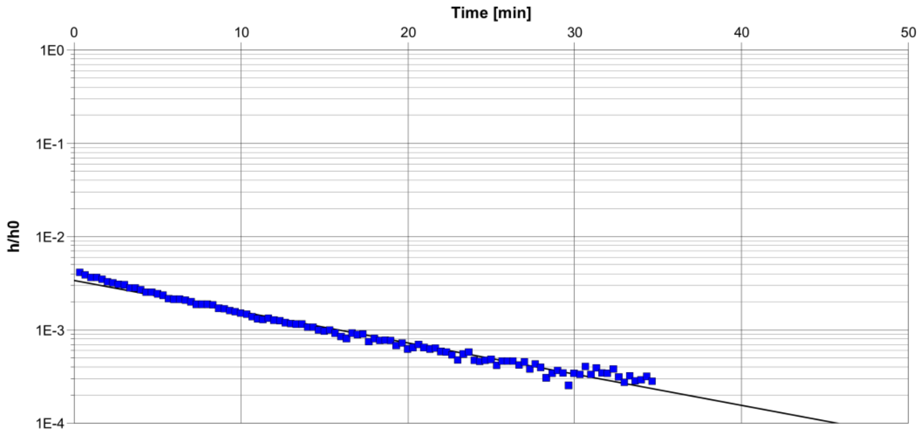
Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
GK-2	1.52×10^{-7}

Figure C-4: GK-2 Hvorslev falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report**
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-2 SLUG TEST RISING	Test Well: GK-2
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-2 BOUVER RICE	Analysis Date: 8/21/2015
Aquifer Thickness: 258.94 m		



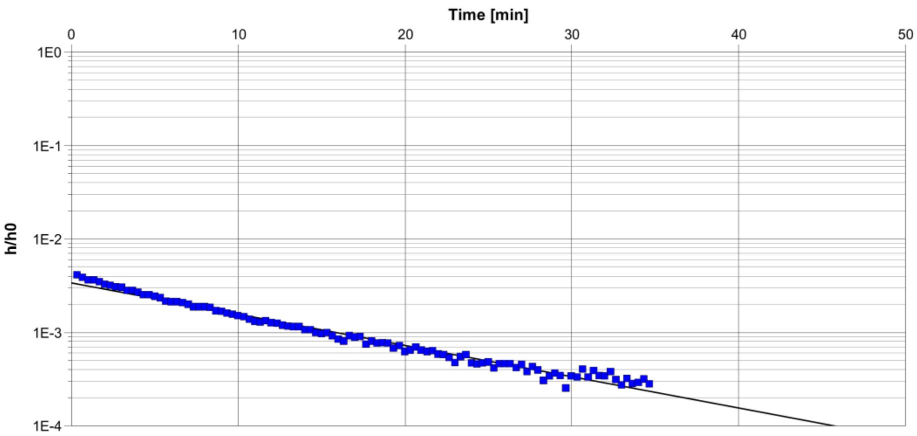
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
GK-2	1.25×10^{-7}

Figure C-5: GK-2 Bouver Rice rising test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

Slug Test Analysis Report		
Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu		
Number: 2014-03-09-2-00-29		
Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş		
Location: Eskişehir/Odunpazarı	Slug Test: GK-2 SLUG TEST RISING	Test Well: GK-2
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-2 HVORSLEV RISING	Analysis Date: 8/21/2015
Aquifer Thickness: 258.94 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
GK-2	1.50×10^{-7}

Figure C-6: GK-2 Hvorslev rising test result

GK-3; the slug test in this well took 13000 seconds. The test results are both evaluated separately for falling and rising phases. The drawdown vs time graphs for both phases are shown in Figure C-7 and Figure C-8.

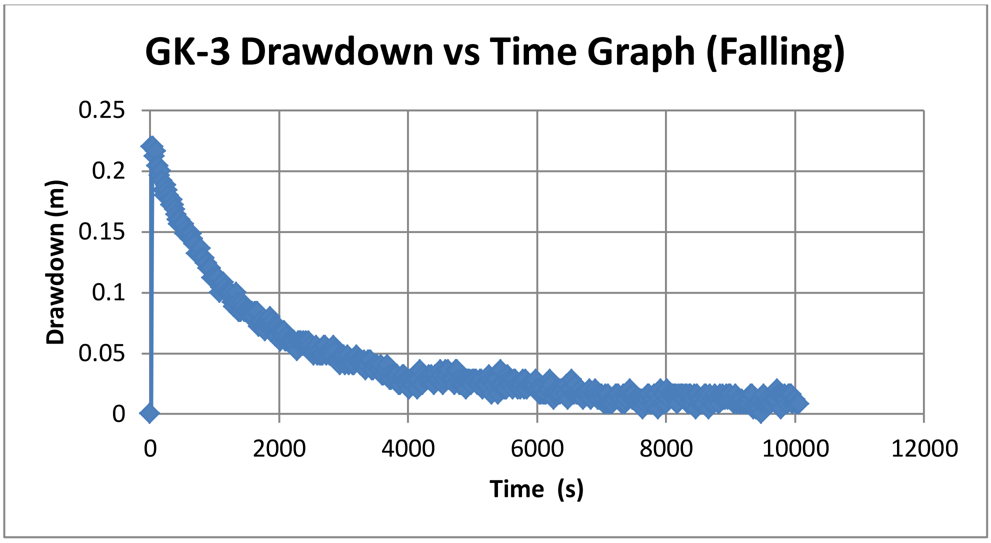


Figure C-7: GK-3 Slug Test Falling Phase

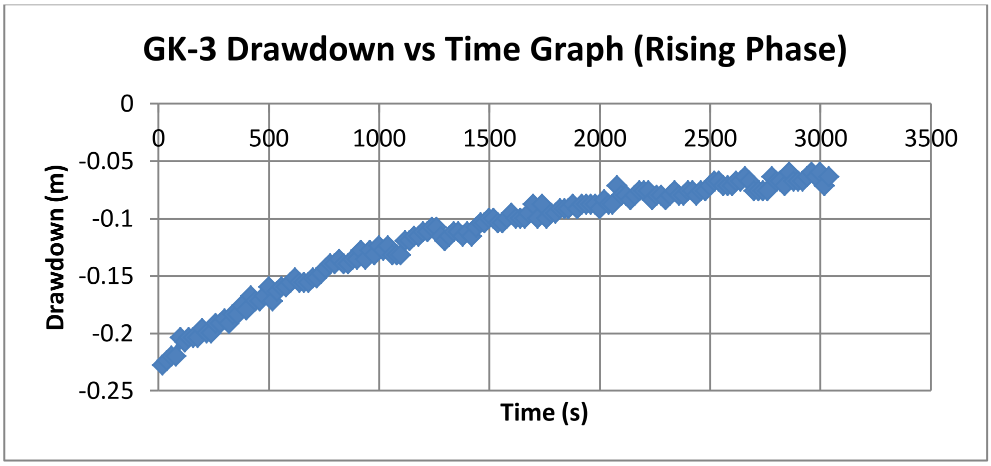
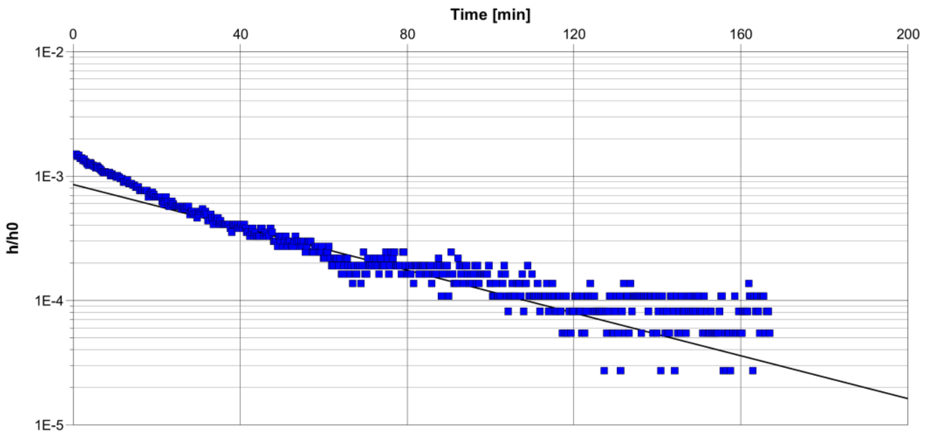


Figure C-8: GK-3 Slug Test Rising Phase

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report**
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-3 SLUG TEST FALLING HEAD	Test Well: GK-3
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-3 BOUVER RICE FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 61.00 m		



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
GK-3	1.19×10^{-7}

Figure C-9: GK-3 Bouver Rice falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

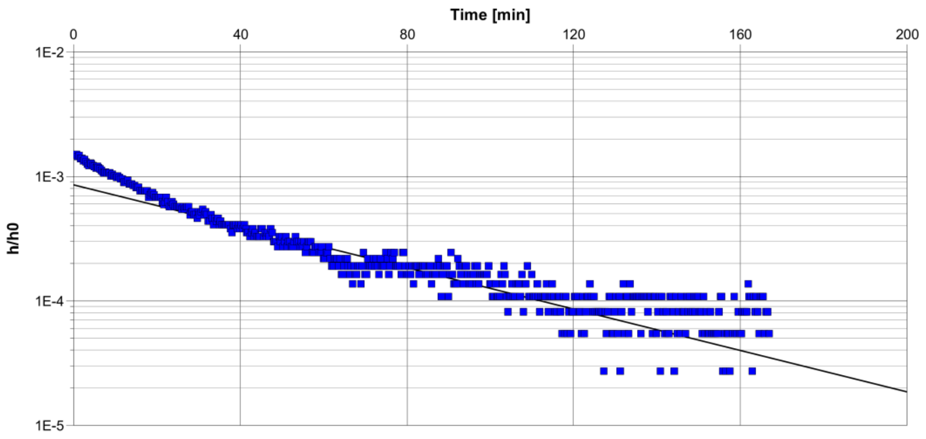
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-3 SLUG TEST FALLING HEAD	Test Well: GK-3
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-3 HVORSLEV FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 61.00 m		



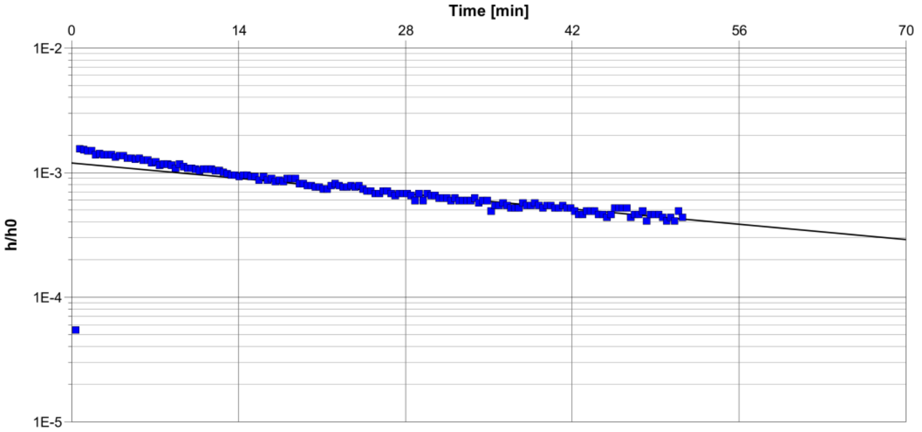
Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
GK-3	1.59×10^{-7}

Figure C-10: GK-3 Hvorslev falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-3 SLUG TEST RISING HEAD	Test Well: GK-3
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-3 BOUVER RICE RISING	Analysis Date: 8/21/2015
Aquifer Thickness: 61.00 m		



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
GK-3	1.21×10^{-7}

Figure C-11: GK-3 Bouver Rice rising test result

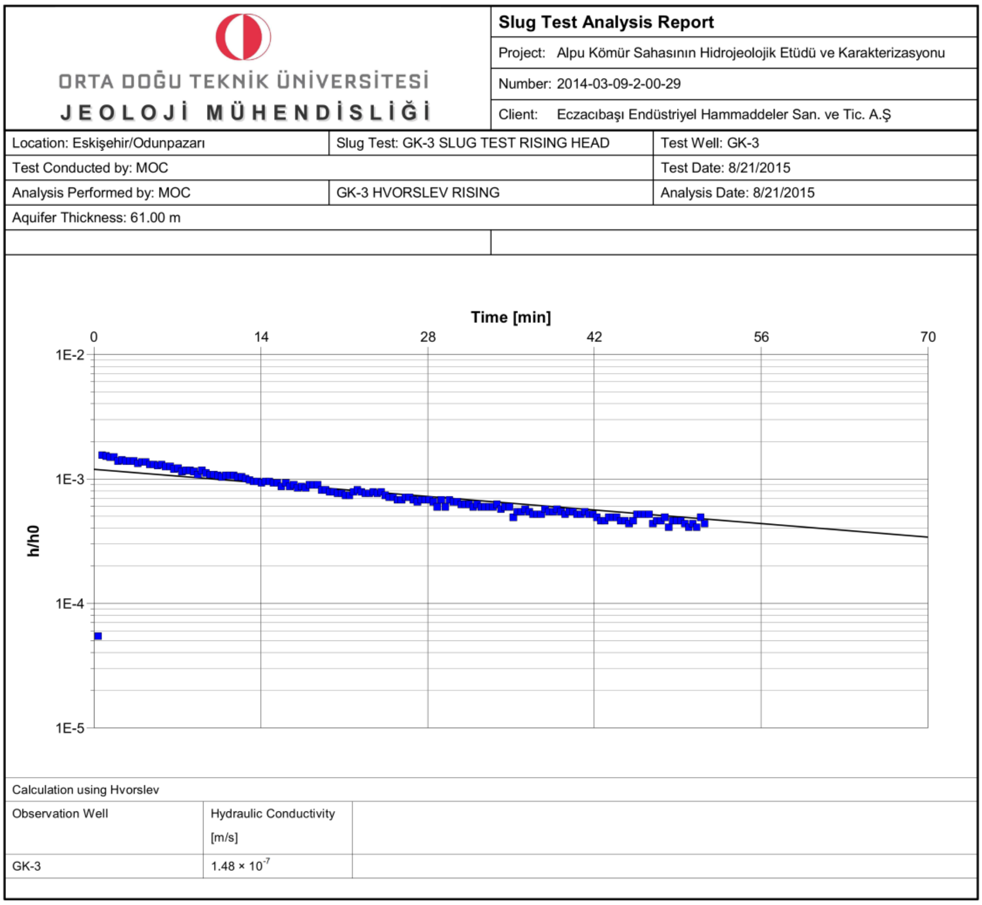


Figure C-12: GK-3 Hvorslev rising test result

GK-5; the slug test in this well took 2100 seconds. The test results are both evaluated separately for falling and rising phases. The drawdown vs time graphs for both phases are shown in Figure C-13 and Figure C-14.

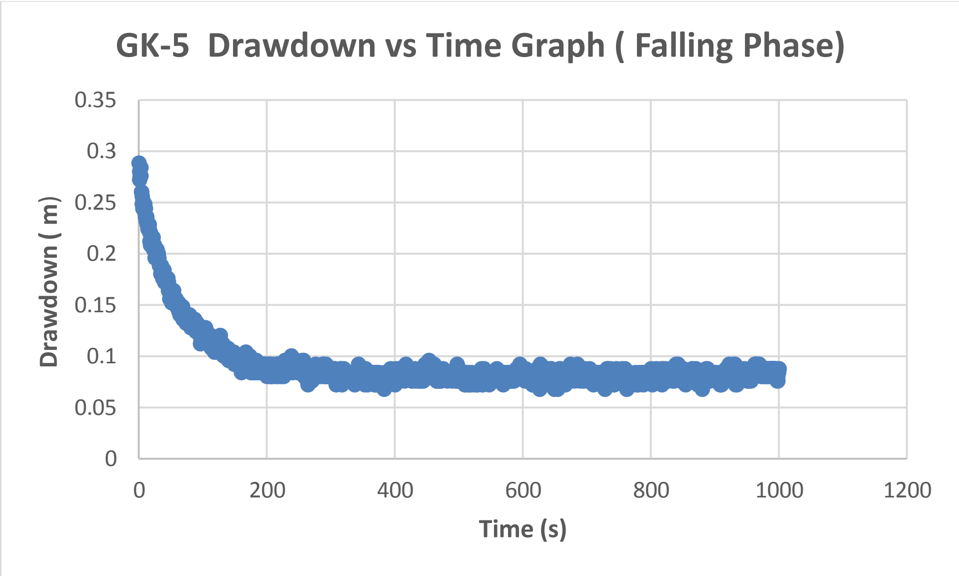


Figure C-13: GK-5 Slug Test Falling Phase

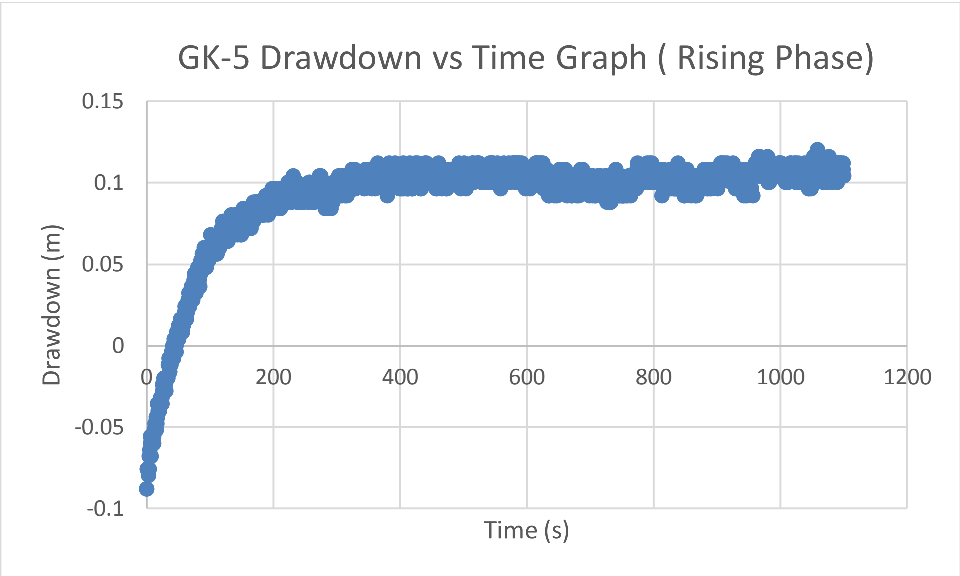
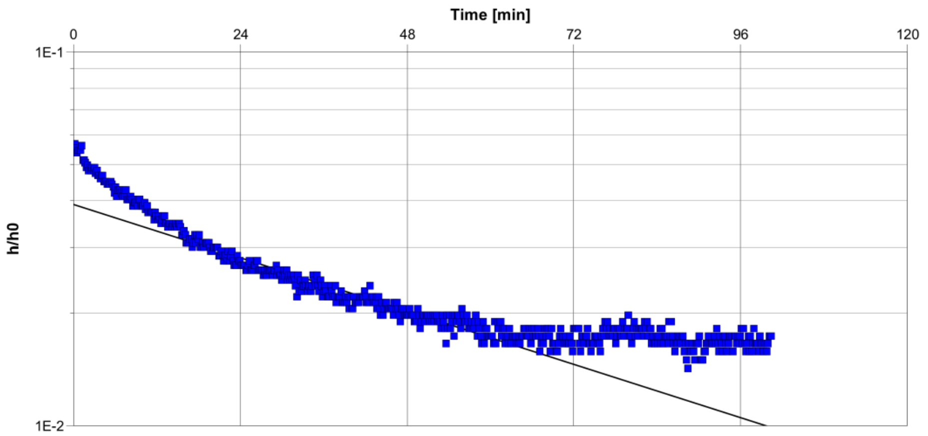


Figure C-14: Slug Test Rising Phase

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-5 SLUG TEST FALLING HEAD	Test Well: GK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-5 BOUVER RICE FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 56.00 m		



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
GK-5	1.09×10^{-7}

Figure C-15: GK-5 Bouver Rice falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

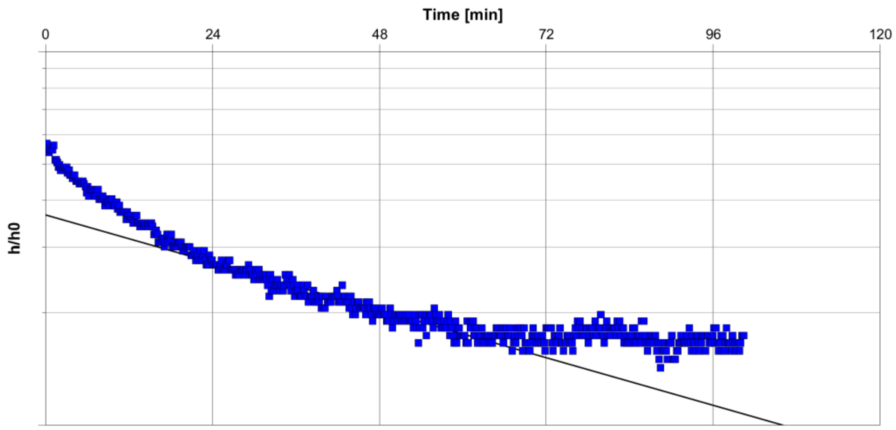
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-5 SLUG TEST FALLING HEAD	Test Well: GK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-5 HVORSLEV FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 56.00 m		



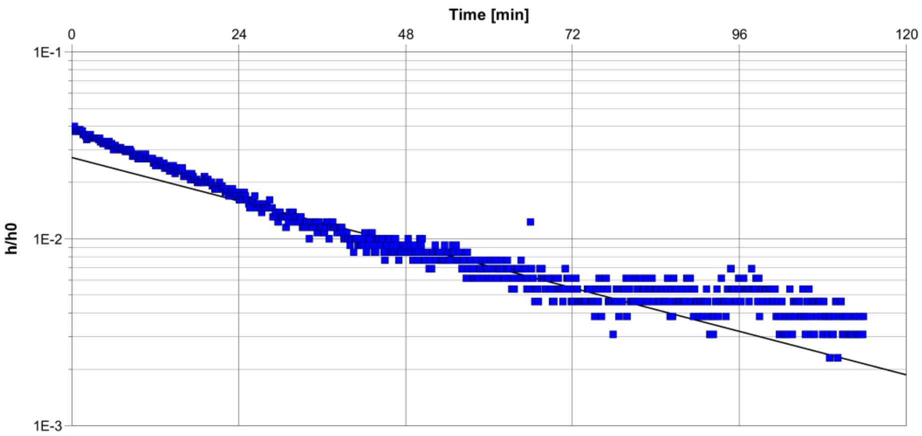
Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
GK-5	1.26×10^{-7}

Figure C-16: GK-5 Hvorslev falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-5 SLUG TEST RISING HEAD	Test Well: GK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-5 BOUVER RICE RISING	Analysis Date: 8/21/2015
Aquifer Thickness: 56.00 m		



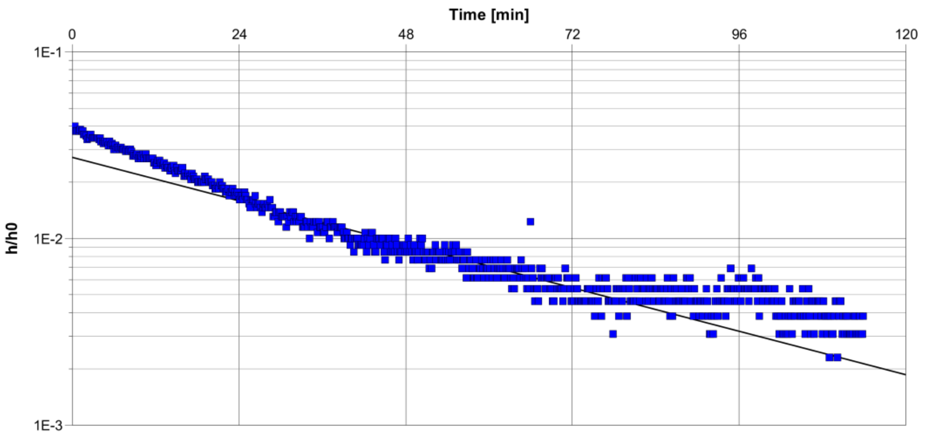
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
GK-5	1.77×10^{-7}

Figure C-17: GK-5 Bouver Rice rising test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report**
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: GK-5 SLUG TEST RISING HEAD	Test Well: GK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	GK-5 HVORSLEV RISING	Analysis Date: 8/21/2015
Aquifer Thickness: 56.00 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
GK-5	2.30×10^{-7}

Figure C-18: GK-5 Hvorslev rising test result

PK-2; the slug test in this well took 4520 seconds. The test results are both evaluated separately for falling and rising phases. The drawdown vs time graphs for both phases are shown in Figure C-19 and Figure C-20.

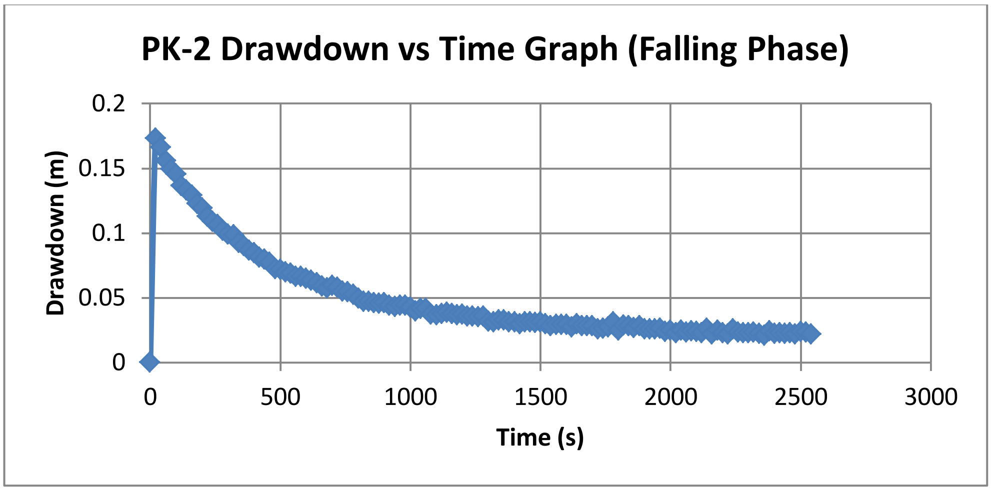


Figure C-19: PK-2 Slug Test Falling Phase

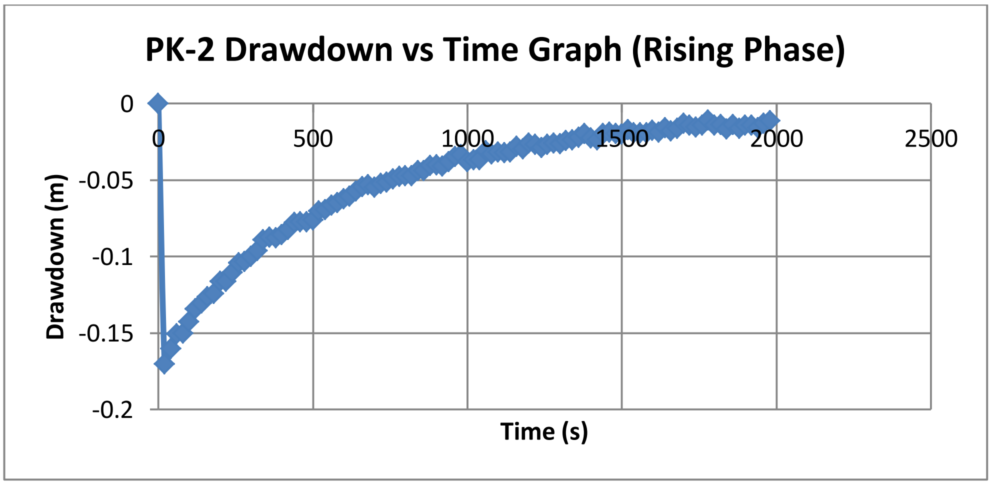
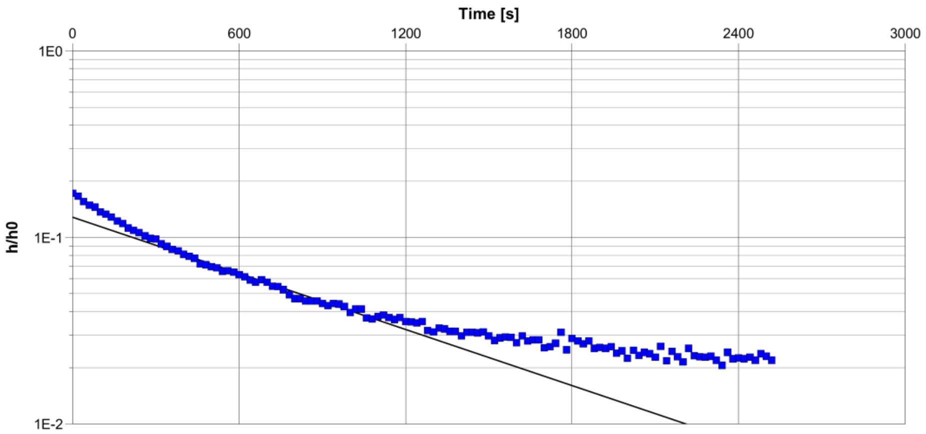


Figure C-20: PK-2 Slug Test Rising Phase

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

Slug Test Analysis Report
Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
Number: 2014-03-09-2-00-29
Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-2 SLUG TEST FALLING	Test Well: PK-2
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-2 BOUVER & RICE	Analysis Date: 11/21/2015
Aquifer Thickness: 283.81 m		



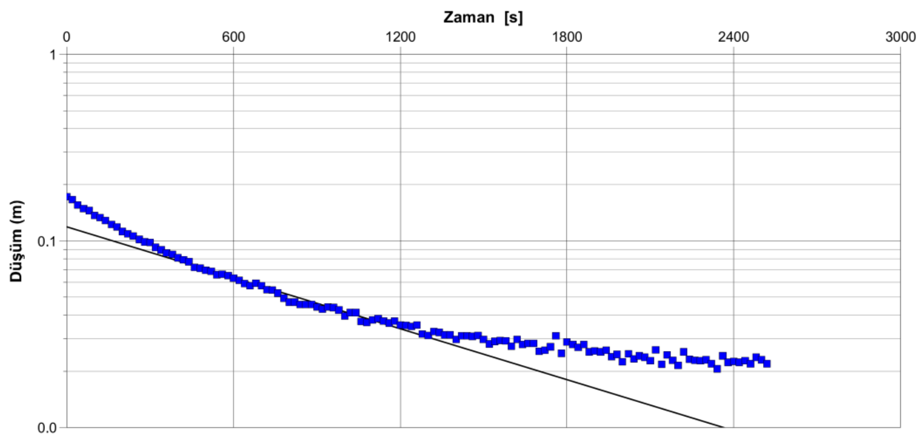
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
PK-2	1.22×10^{-7}

Figure C-21: PK-2 Bouver Rice falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report**
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-2 SLUG TEST FALLING	Test Well: PK-2
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-2 HVORSLEV	Analysis Date: 11/21/2015
Aquifer Thickness: 283.81 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-2	1.69×10^{-7}

Figure C-22: PK-2 Hvorslev falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

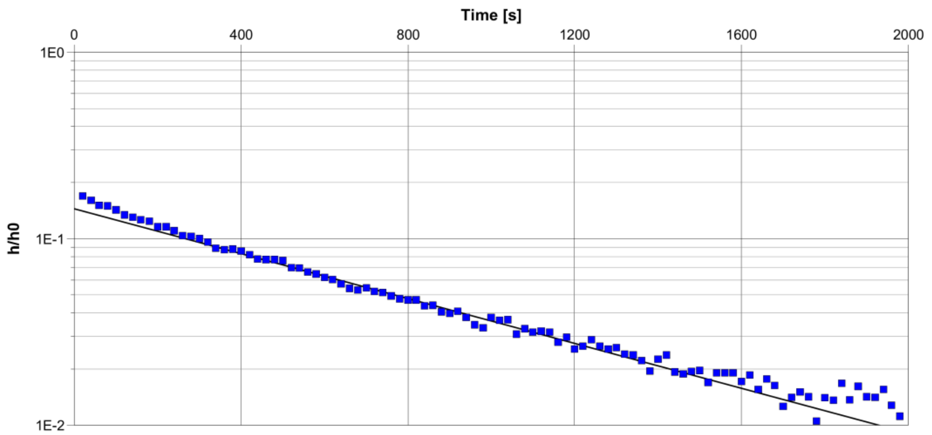
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-2 SLUG TEST RISING	Test Well: PK-2
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-2 BOUVER & RICE	Analysis Date: 11/21/2015
Aquifer Thickness: 283.81 m		



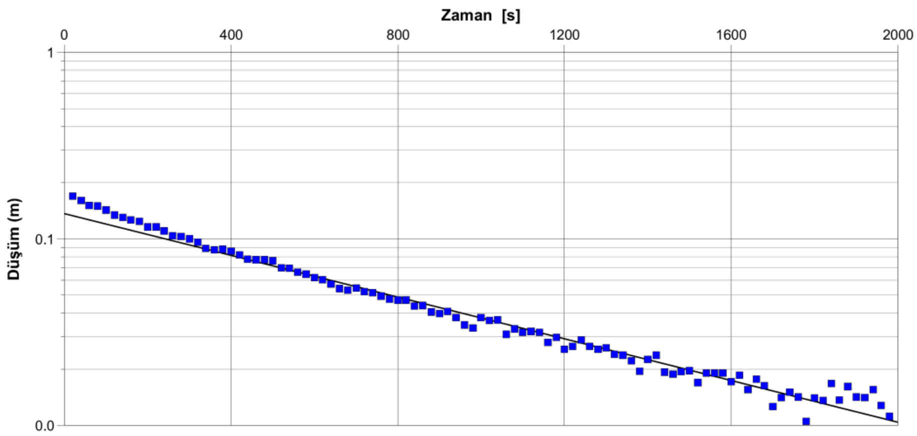
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
PK-2	1.45×10^{-7}

Figure C-23: PK-2 Bouver Rice rising test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Slug Test Analysis Report
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-2 SLUG TEST RISING	Test Well: PK-2
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-2 HVORSLEV	Analysis Date: 11/21/2015
Aquifer Thickness: 283.81 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-2	2.08×10^{-7}

Figure C-24: PK-2 Hvorslev rising test result

PK-4; the slug test in this well took 66 minutes. The test results are both evaluated separately for falling and rising phases. The drawdown vs time graphs for both phases are shown in Figure C-25 and Figure C-26.

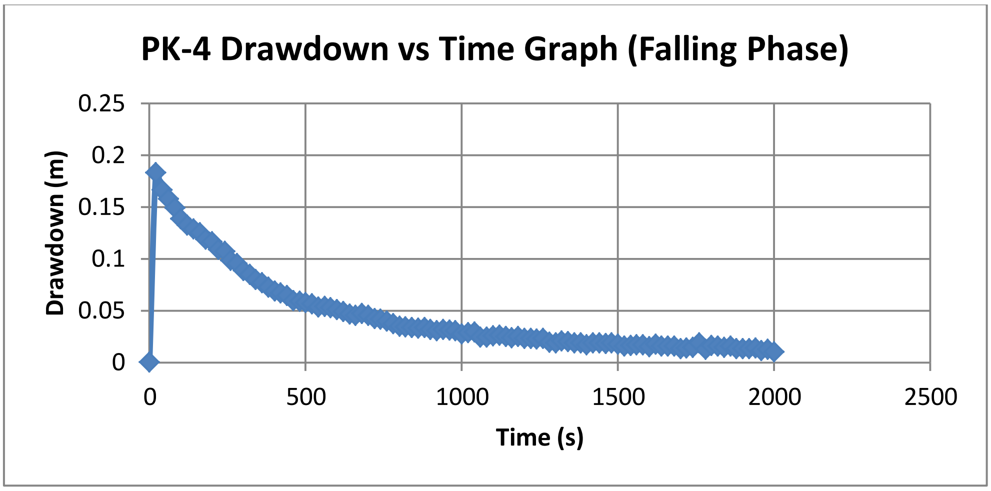


Figure C-25: PK-4 Slug Test Falling Phase

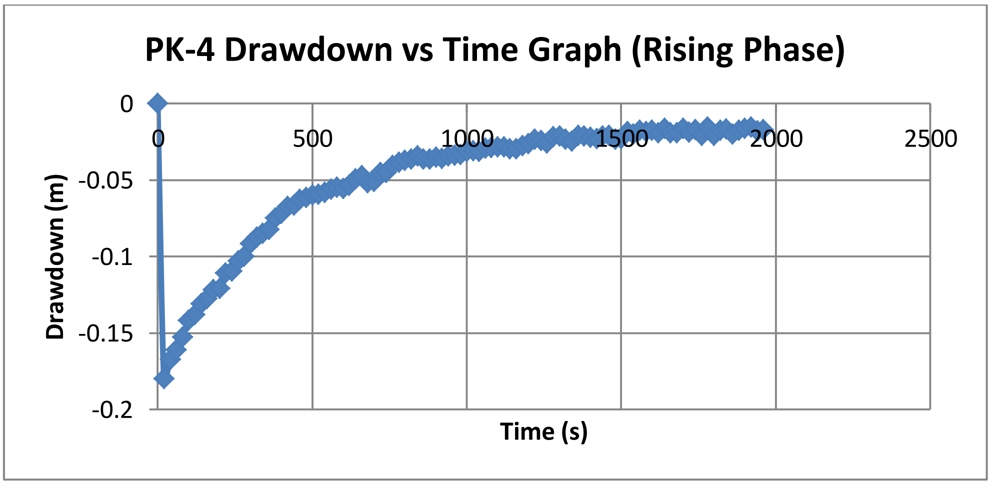
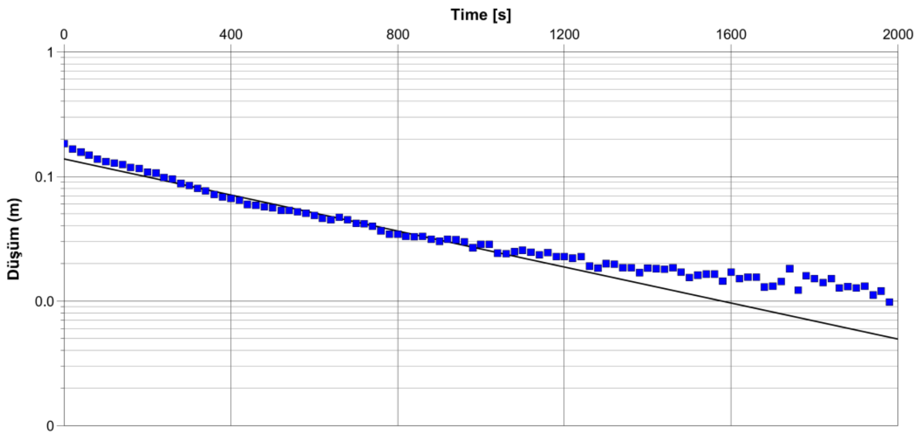


Figure C-26: PK-4 Slug Test Rising Phase

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Slug Test Analysis Report
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-4 SLUG TEST FALLING	Test Well: PK-4
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-4 BOUVER & RICE	Analysis Date: 11/21/2015
Aquifer Thickness: 10.99 m		



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
PK-4	6.87×10^{-7}

Figure C-27: PK-4 Bouver Rice falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

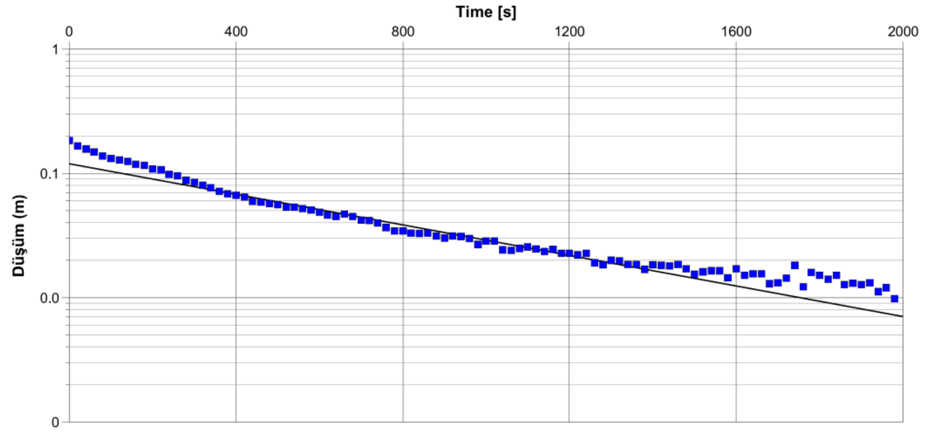
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-4 SLUG TEST FALLING	Test Well: PK-4
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-4 HVORSLEV	Analysis Date: 11/21/2015
Aquifer Thickness: 10.99 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-4	1.06×10^{-6}

Figure C-28: PK-4 Hvorslev falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

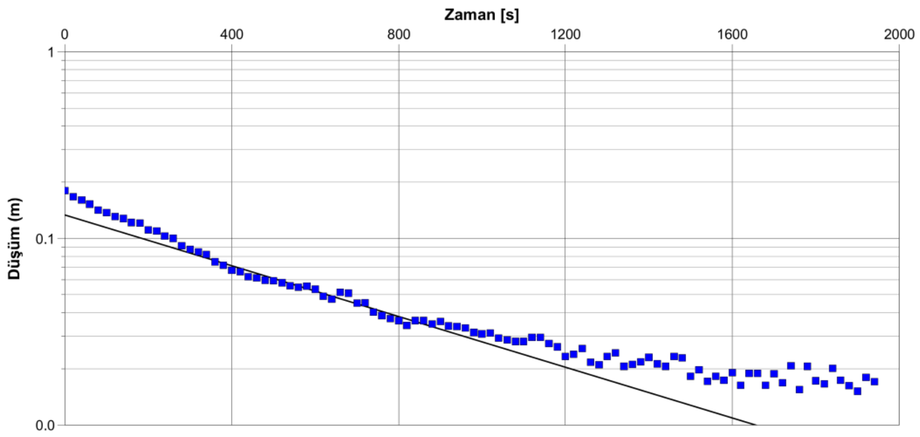
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-4 SLUG TEST RISING	Test Well: PK-4
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-4 BOUVER & RICE	Analysis Date: 11/21/2015
Aquifer Thickness: 10.99 m		

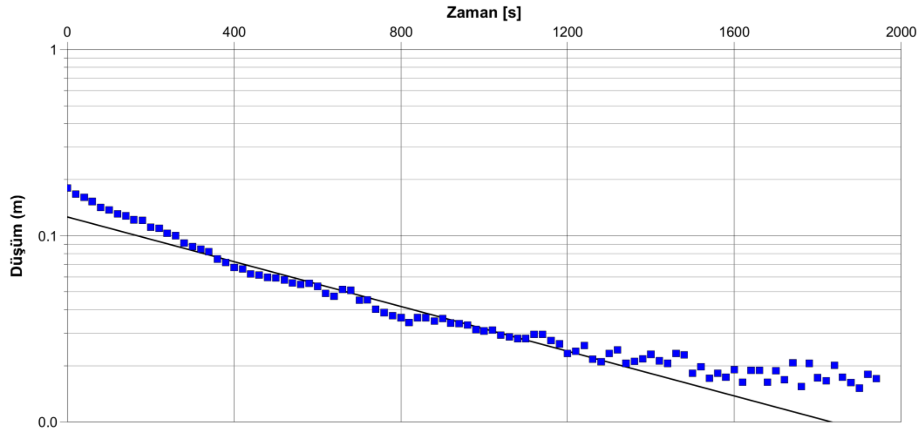


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
PK-4	6.47×10^{-7}

Figure C-29: PK-4 Bouver Rice rising test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Slug Test Analysis Report	
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu	
	Number: 2014-03-09-2-00-29	
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş	
Location: Eskişehir/Odunpazarı	Slug Test: PK-4 SLUG TEST RISING	Test Well: PK-4
Test Conducted by: MOC		Test Date: 11/13/2015
Analysis Performed by: MOC	PK-4 HVORSLEV	Analysis Date: 11/21/2015
Aquifer Thickness: 10.99 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-4	1.04×10^{-6}

Figure C-30: PK-4 Hvorslev rising test result

According to the test results, PK-4 well which screen the limestones in the study area, has 5 times greater hydraulic conductivity values when compared to other water bearing units except alluvium.

PK-5; the slug test in this well took 16000 seconds. The test results are both evaluated separately for falling and rising phases. The drawdown vs time graphs for both phases are shown in Figure C-31 and C-32.

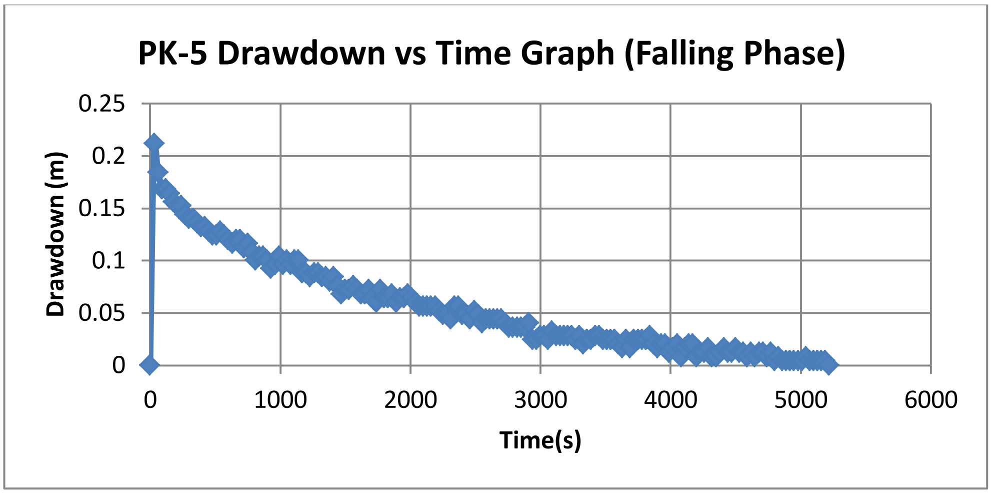


Figure C-31: PK-5 Slug Test Falling Phase

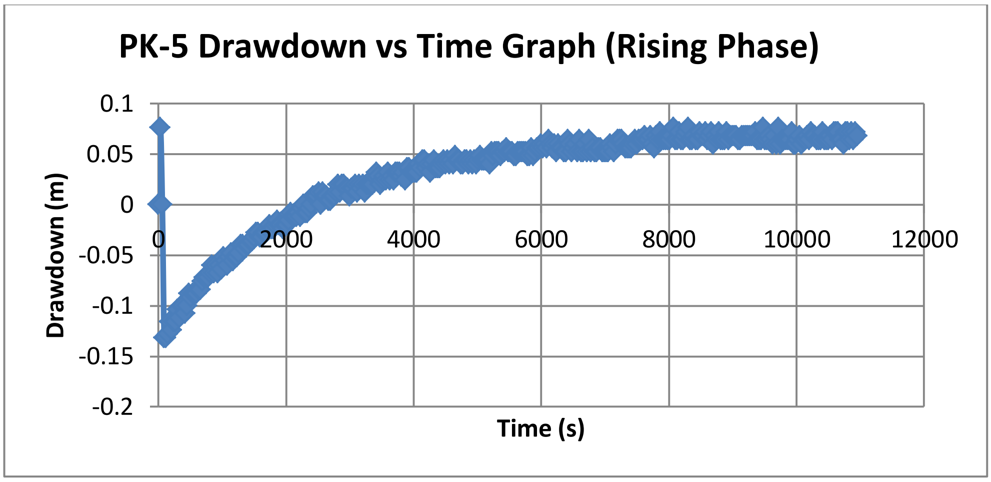
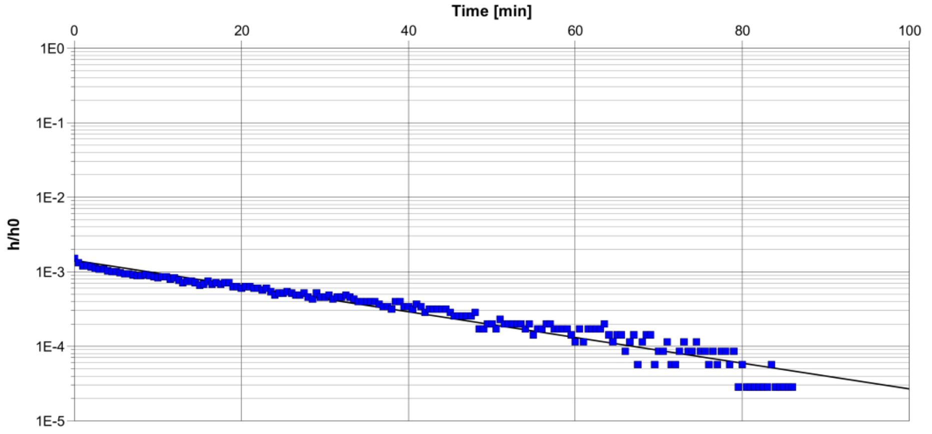


Figure C-32: PK-5 Slug Test Rising Phase

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-5 SLUG TEST FALLING	Test Well: PK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-5 BOUVER RICE FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 67.80 m		



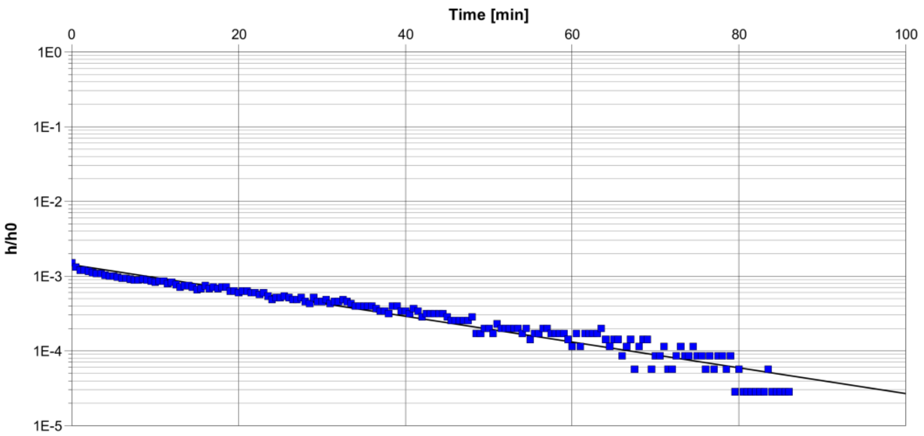
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
PK-5	2.10×10^{-7}	

Figure C-33: PK-5 Bouver Rice falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	Slug Test Analysis Report
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-5 SLUG TEST FALLING	Test Well: PK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-5 HVORSLEV FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 67.80 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-5	3.20×10^{-7}

Figure C-34: PK-5 Hvorslev falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

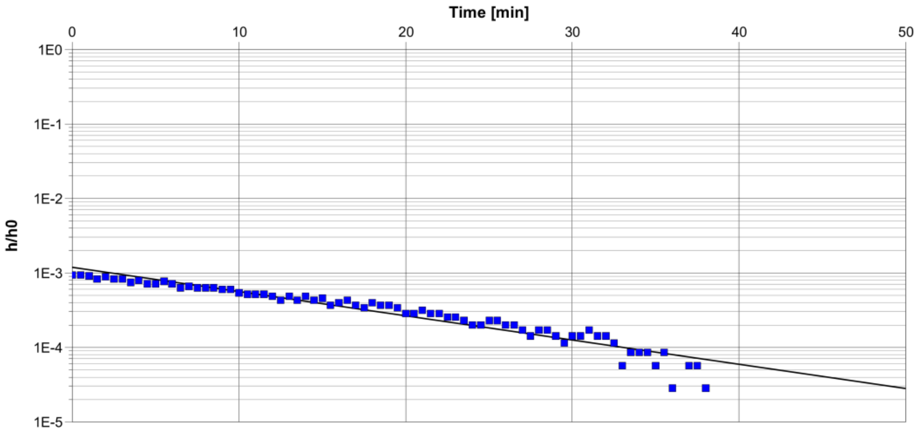
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-5 SLUG TEST RISING	Test Well: PK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-5 BOUVER RICE	Analysis Date: 8/21/2015
Aquifer Thickness: 67.80 m		



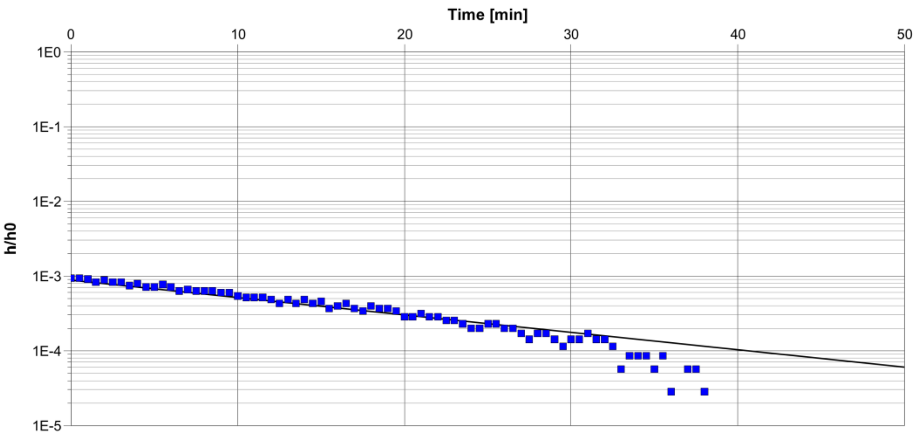
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
PK-5	3.97×10^{-7}

Figure C-35: PK-5 Bouver Rice rising test result:

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report** Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu Number: 2014-03-09-2-00-29 Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-5 SLUG TEST RISING	Test Well: PK-5
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-5 HVORSLEV	Analysis Date: 8/21/2015
Aquifer Thickness: 67.80 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-5	4.31×10^{-7}

Figure C-36: PK-5 Hvorslev rising test result

PK-6; the slug test in this well took 65 minutes. The test results are both evaluated separately for falling and rising phases. The drawdown vs time graphs for both phases are shown in Figure C-37 and Figure C-38.

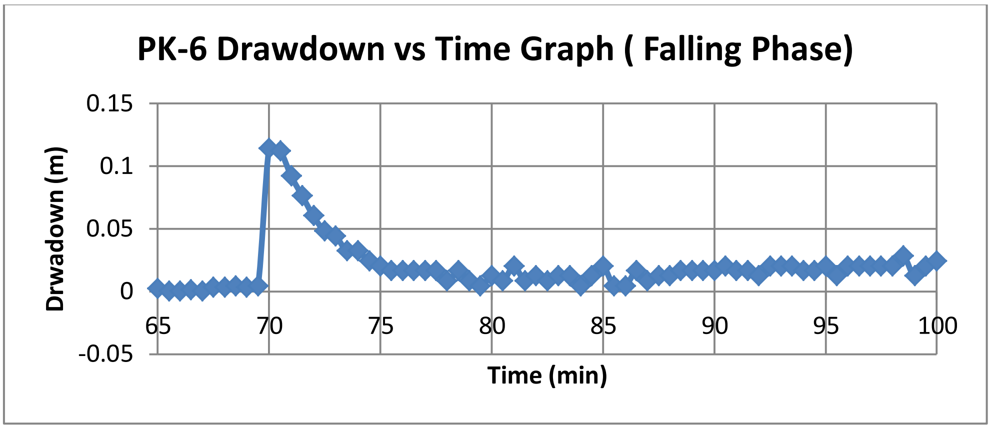


Figure C-37: PK-6 Slug Test Falling Phase

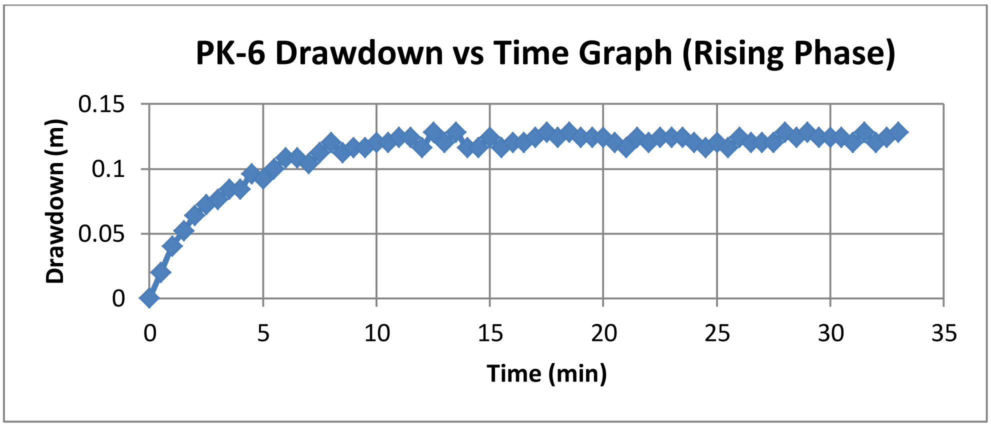
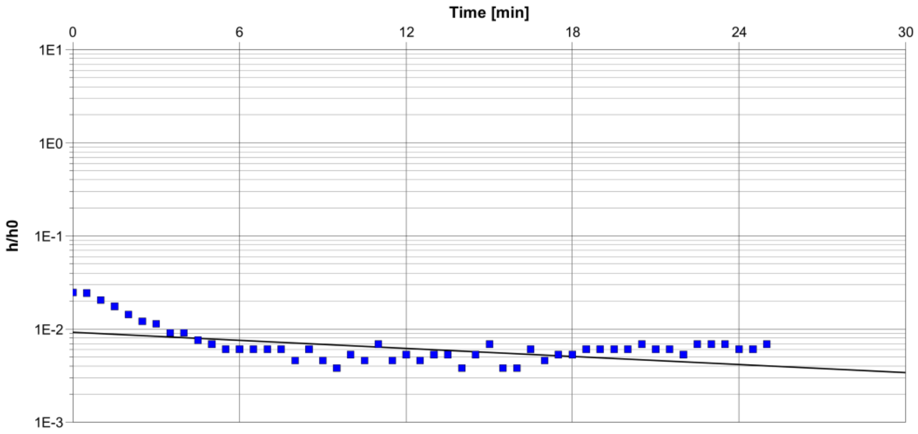


Figure C-38: PK-6 Slug Test Rising Phase

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

Slug Test Analysis Report	
Project:	Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
Number:	2014-03-09-2-00-29
Client:	Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-6 SLUG TEST FALLING HEAD	Test Well: PK-6
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-6 BOUVER RICE RISING	Analysis Date: 8/21/2015
Aquifer Thickness: 70.00 m		



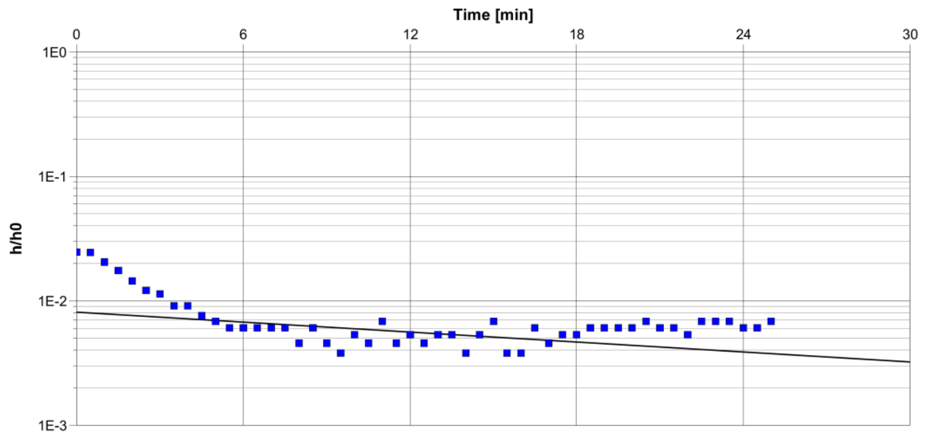
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
PK-6	3.00×10^{-7}

Figure C-39: PK-6 Bouver Rice falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ JEOLOJİ MÜHENDİSLİĞİ	**Slug Test Analysis Report**
	Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu
	Number: 2014-03-09-2-00-29
	Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-6 SLUG TEST FALLING HEAD	Test Well: PK-6
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-6 HVORSLEV FALLING	Analysis Date: 8/21/2015
Aquifer Thickness: 70.00 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-6	3.91×10^{-7}

Figure C-40: PK-6 Hvorslev falling test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

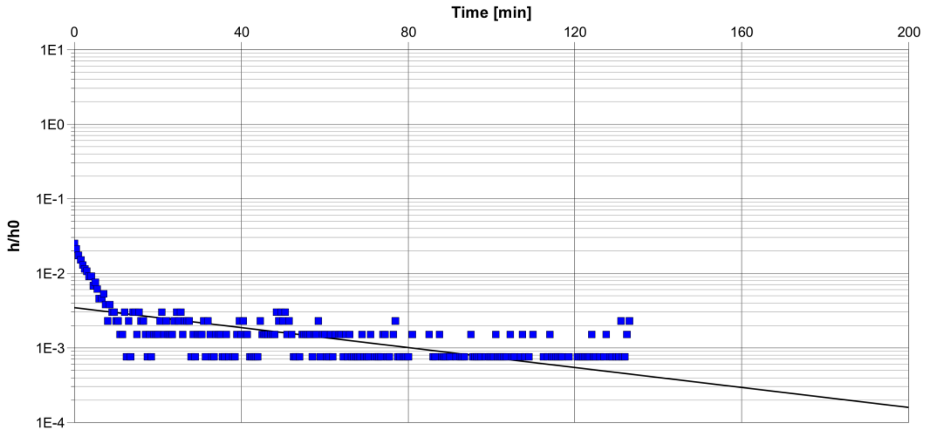
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-6 SLUG TEST RISING HEAD	Test Well: PK-6
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-6 BOUVER RICE RISING	Analysis Date: 8/21/2015
Aquifer Thickness: 70.00 m		



Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]
PK-6	1.40×10^{-7}

Figure C-41: PK-6 Bouver Rice rising test result

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
JEOLOJİ MÜHENDİSLİĞİ

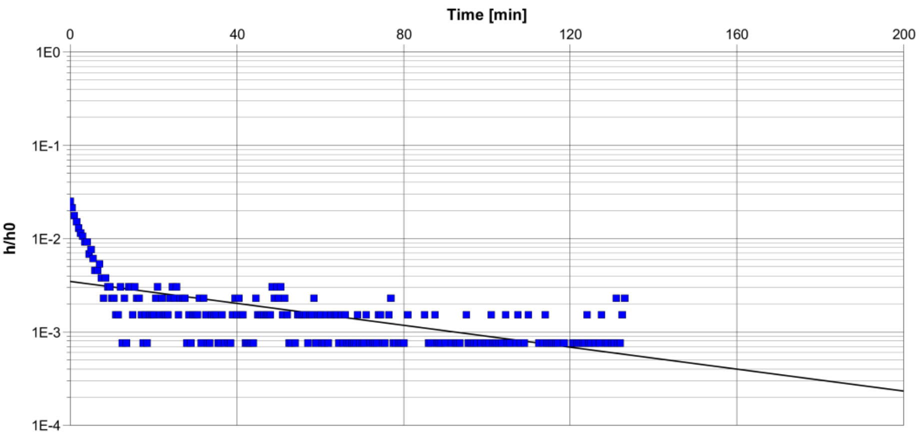
Slug Test Analysis Report

Project: Alpu Kömür Sahasının Hidrojeolojik Etüdü ve Karakterizasyonu

Number: 2014-03-09-2-00-29

Client: Eczacıbaşı Endüstriyel Hammaddeler San. ve Tic. A.Ş

Location: Eskişehir/Odunpazarı	Slug Test: PK-6 SLUG TEST RISING HEAD	Test Well: PK-6
Test Conducted by: MOC		Test Date: 8/21/2015
Analysis Performed by: MOC	PK-6 HVORSLEV RISING	Analysis Date: 8/21/2015
Aquifer Thickness: 70.00 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]
PK-6	1.72×10^{-7}

Figure C-42: PK-6 Hvorslev rising test result

APPENDIX D

LABORATORY MEASUREMENT RESULTS OF DUPLICATE SAMPLES FROM HYDROCHEMICAL MONITORING LOCATIONS

Table D-1: Laboratory measurement results of duplicate samples collected in May period from hydochemical monitoring locations

Parameter	Unit	F4	F10	SW4	SW7
Date		May.15		May.15	
Color	Pt-Co	-	-	24.4	24
TDS	mg/L	188	202	460	462
TSS	mg/L	<4	<4	30	20
Turbidity	NTU	-	-	16.5	14.8
Cl	mg/L	9.5	8.5	72	70.2
SO4	mg/L	14	14	95	95
F	mg/L	0.31	0.31	<0.1	0.21
Alkalinity-Total	mg CaCO3/L	159	160	338	344
Alkalinity-HCO3	mg CaCO3/L	159	160	338	344
Alkalinity-CO3	mg CaCO3/L	0	0	0	0
Alkalinity-OH	mg CaCO3/L	0.04	0.04	0.01	0.01
Total P	mg/L	<0.2	<0.2	3.13	3.1
Ortho phosphate (o-PO4)	mg/L	-	-	1.28	1.35
Reactive P	mg/L	0.013	0.011	0.42	0.44
NH3	mg/L	<0.02	<0.02	10.3	11.5
NO3-N	mg/L	3	3	0.366	0.35
NO2-N	mg/L	0.0036	0.0034	0.18	0.171
N, organic	mg/L	4	4.31	2.14	3.74
TKN	mg/L	4	4.31	12.44	15.24
Ag	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Al	mg/L	0.071	0.008	0.015	0.02
As	mg/L	0.0034	0.004	0.01	0.005
B	mg/L	0.2	0.22	0.6	<0.2
Ba	mg/L	0.102	0.124	0.066	0.069
Be	mg/L	<0.00004	<0.00004	<0.00004	<0.00004
Bi	mg/L	<0.05	<0.05	<0.01	<0.01
Ca	mg/L	31.74	33.5	63.19	59.53
Cd	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Co	mg/L	<0.0005	<0.0005	<0.0005	<0.0005
Cr	mg/L	0.422	<0.0003	0.002	0.001
Cu	mg/L	<0.0002	<0.0002	0.003	0.458
Fe	mg/L	<0.00015	0.002	0.025	0.145
Hg	mg/L	<0.00008	<0.00008	<0.00008	<0.00008
K	mg/L	0.346	0.337	11.03	10.97
Li	mg/L	0.02	0.021	0.02	0.019
Mg	mg/L	22.83	23.58	48.4	48.25
Mn	mg/L	0.005	<0.0002	0.037	0.04
Mo	mg/L	<0.001	<0.001	<0.001	<0.001
Na	mg/L	6.779	7.14	63.05	62.96
Ni	mg/L	<0.0005	<0.0005	0.017	0.015
Pb	mg/L	<0.0015	<0.0015	0.003	<0.0015
Sb	mg/L	<0.002	<0.002	<0.002	<0.002
Se	mg/L	<0.005	<0.005	<0.005	<0.005
Si	mg/L	10.02	9.294	6.712	7.425
Sr	mg/L	0.346	0.37	0.394	0.366
Sn	mg/L	<0.001	<0.001	0.002	<0.001
Ti	mg/L	<0.0002	<0.0002	<0.0002	<0.0002
Tl	mg/L	<0.003	<0.003	<0.003	<0.003
U	mg/L	<0.004	<0.004	0.004	0.004
V	mg/L	0.004	0.005	0.003	0.002
Zn	mg/L	<0.0002	0.009	0.016	0.015

Table D.1. continued

Parameter	Unit	F4	F10	SW4	SW7
Total CN	mg/L	-	-	<0.01	<0.01
Weak acid diss CN	mg/L	-	-	<0.01	<0.01
TOC	mg/L	<1	<1	<1	<1
COD	mg/L	<15	<15	56.8	90.8
H2S	mg/L	-	-	<0.01	<0.01
Oil&Grease	mg/L	-	-	<10	<10
PAH	mg/L	-	-	<0.001	<0.001
Anthracene	mg/L	-	-	<0.0004	<0.0004
Fluoranthene	mg/L	-	-	<0.00024	<0.00024
Naphthalene	mg/L	-	-	<0.00025	<0.00025
Benzo(a)pyrene	mg/L	-	-	<0.0004	<0.0004
Benzo(b)fluoranthene	mg/L	-	-	<0.0004	<0.0004
Benzo(k)fluoranthene	mg/L	-	-	<0.0001	<0.0001
Benzo(g,h,i)perylene	mg/L	-	-	<0.0004	<0.0004
Indeno(1,2,3-cd) pyrene	mg/L	-	-	<0.0001	<0.0001
Total pesticides	μg/L	<0.25	<0.25	-	-
Organophosphate pesticides	μg/L	<0.244	<0.244	<0.244	<0.244
Atrazin	μg/L	-	-	<0.064	<0.064
Chlorfenvinphos	μg/L	-	-	<0.013	<0.013
chlorpyrifos-ethyl	μg/L	-	-	<0.012	<0.012
Simazine	μg/L	-	-	<0.014	<0.014
Organochlorine pesticides	μg/L	<0.06	<0.06	0.19	0.22
Alachlor	μg/L	-	-	<0.0022	<0.0022
Endosulfan	μg/L	-	-	<0.0047	<0.0047
Hexachlorobenzene	μg/L	-	-	<0.0001	<0.0001
Trifluralin	μg/L	-	-	0.18	0.22
Hexachlorocyclohexane	μg/L	-	-	<0.0124	<0.0124
Volatile organic compounds	μg/L	<3.4	<3.4	<3.4	<3.4
Benzene	mg/L	-	-	<0.00084	<0.00084
1,2-Dichloroethane	μg/L	-	-	<0.6	<0.6
Dichloromethane	μg/L	-	-	<1.9	<1.9
Hexachlorobutadiene	μg/L	-	-	<0.1	<0.1
Trichloromethane	μg/L	-	-	<1.1	<1.1
Trichlorobenzenes	μg/L	-	-	<0.4	<0.4
Semi Volatile Organic Compounds	μg/L	-	-	<0.25	<0.25
Di(2-ethylhexyl)phthalate	μg/L	-	-	<0.95	<0.95
Pentachlorobenzene	μg/L	-	-	<0.86	<0.86
Diuron	μg/L	-	-	<0.05	<0.05
Isoproturon	μg/L	-	-	<0.05	<0.05
NPE	μg/L	-	-	<2.32	<2.32
Nonylphenols	μg/L	-	-	<1.19	<1.19
octylphenols	μg/L	-	-	<0.1	<0.1
Pentachlorophenol	μg/L	-	-	<0.1	<0.1
Tributyltin	μg/L	-	-	<1	<1
Yüzey Aktif Maddeler	mg/L	-	-	<0.025	<0.025
Bromodiphenylethers	ng/L	-	-	<31	<31
Pentabromodiphenylether	ng/L	-	-	<4	<4
C10-13 Chloroalkanes	μg/L	-	-	<0.4	<0.4
Tetrachloroethylene	μg/L	<0.8	<0.8	-	-
Trichloroethylene	μg/L	<0.8	<0.8	-	-
BOD5	mg/L	-	-	11.1	26.3
Fecal Coliform	cfu/100 ml	-	-	1000	900
Total Coliform	cfu/100 ml	-	-	2500	1300
Fecal Streptecoc	cfu/100 ml	-	-	800	900
Escherichia Coli	cfu/100 ml	-	-	1200	1000
Enterococ	cfu/100 ml	-	-	800	900

Table D-2: Laboratory measurement results of duplicate samples collected in November period from hydrochemical monitoring locations

Parametre	Unit	F-3	Y-1	W-2	Y-2
Date		May.15		May.15	
Color	Pt-Co	-	-	24.4	24
TDS	mg/L	258	260	386	390
TSS	mg/L	64	<10	<10	<10
Cl	mg/L	19.79	19.575	50.65	48.37
SO4	mg/L	14.555	14.295	86.1	82.01
F	mg/L	0.389	0.368	0.25	0.255
Alkalinity-Total	mg CaCO3/L	285	245	215	260
Alkalinity-HCO3	mg CaCO3/L	285	245	215	260
Alkalinity-CO3	mg CaCO3/L	0	0	0	0
Alkalinity-OH	mg CaCO3/L	0	0	0	0
Total P	mg/L	<0.01	<0.01	<0.01	<0.01
Reactive P	mg/L	<0.01	<0.01	<0.01	<0.01
NH4-N	mg/L	<0.01	<0.01	<0.01	<0.01
NO3-N	mg/L	6.554	6.546	9.109	8.845
NO2-N	mg/L	<0.001	<0.001	0.00583	<0.001
N, organic	mg/L	2.44	0.9	<0.5	0.55
TKN	mg/L	2.45	0.91	<0.5	0.56
Ag	mg/L	0.015	<0.01	<0.01	<0.01
Al	mg/L	0.047	0.112	0.048	0.06
As	mg/L	0.027	0.023	0.018	0.019
B	mg/L	0.423	0.422	0.802	0.828
Ba	mg/L	0.206	0.119	0.148	0.149
Be	mg/L	<0.01	<0.01	<0.01	<0.01
Bi	mg/L	<0.01	<0.01	<0.01	<0.01
Ca	mg/L	22.26	19.3	43.12	47.05
Cd	mg/L	<0.003	<0.003	<0.003	<0.003
Co	mg/L	<0.01	<0.01	<0.01	<0.01
Cr	mg/L	<0.01	<0.01	<0.01	<0.01
Cu	mg/L	<0.01	<0.01	<0.01	<0.01
Fe	mg/L	0.064	0.032	0.141	0.079
Hg	mg/L	<0.001	<0.001	<0.001	<0.001
K	mg/L	2.65	2.65	5.81	5.43
Li	mg/L	0.099	0.091	0.135	0.13
Mg	mg/L	53.95	50.88	56.69	59.33
Mn	mg/L	<0.01	<0.01	<0.01	<0.01
Mo	mg/L	<0.01	<0.01	<0.01	<0.01
Na	mg/L	19.01	14.7	51.02	52.14
Ni	mg/L	<0.01	<0.01	<0.01	<0.01
P	mg/L	<0.05	<0.05	<0.05	<0.05
Pb	mg/L	0.053	<0.01	<0.01	<0.01
Sb	mg/L	<0.005	<0.005	<0.005	<0.005
Se	mg/L	<0.005	<0.005	<0.005	<0.005
Si	mg/L	19.41	19.37	22.01	23.25
Sr	mg/L	2.16	2.06	3.4	3.7
Sn	mg/L	<0.05	<0.05	<0.05	<0.05
Ti	mg/L	<0.01	<0.01	<0.01	<0.01
Tl	mg/L	<0.05	<0.05	<0.05	<0.05
U	mg/L	0.0044	0.0045	0.003	0.003
V	mg/L	0.013	0.013	<0.01	<0.01
Zn	mg/L	<0.01	0.019	<0.01	0.013
Total CN	mg/L	<0.02	<0.02	<0.02	<0.02
TOC	mg/L	<5	<5	<5	<5
COD	mg/L	9	7	40	11
S	mg/L	<0.1	<0.1	<0.1	<0.1
Oil&Grease	mg/L	<0.1	0.138	<0.1	<0.1
Atrazin	µg/L	<0.01	<0.01	<0.01	<0.01
Chlorfenvinphos	µg/L	-	-	<0.08	<0.08
Chlorpyrifos	µg/L	<0.08	<0.08	<0.08	<0.08
Simazine	µg/L	<0.01	<0.01	<0.01	<0.01
pp-DDT	µg/L	<0.001	<0.001	<0.001	0.00123
Alachlor	µg/L	<0.01	<0.01	<0.01	<0.01
Endosulfan	µg/L	<0.001	<0.001	<0.001	<0.001
Trifluralin	µg/L	<0.01	<0.01	<0.01	<0.01
Diuron	µg/L	<0.01	<0.01	<0.01	<0.01
Isoproturon	µg/L	<0.01	<0.01	<0.01	<0.01
Tetrachloroethylene	mg/L	<0.005	<0.005	<0.005	<0.005
Trichloroethylene	mg/L	<0.005	<0.005	<0.005	<0.005

APPENDIX E

FIELD PARAMETER MEASUREMENTS IN HYDROCHEMICAL MONITORING LOCATIONS

Table E-1: Values of field parameters measured in Porsuk stream monitoring locations

NO	DATE	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%
SW3	28.01.15	8.1	7.95	171	841	0.41	547	4.86	46
	27.02.15	10.0	8.10	184	683	0.34	444	5.25	52
	28.03.15	13.5	8.17	187	922	0.45	599	2.63	28
	26.04.15	12.9	8.11	191	901	0.44	586	3.04	36
	26.05.15	23.1	8.03	108	890	0.44	578	5.03	66
	27.06.15	18.9	8.09	126	901	0.44	586	5.67	68
	25.07.15	18.9	8.06	125	896	0.44	582	5.58	64
	16.08.15	19.1	8.07	113	886	0.44	576	5.32	60
	20.09.15	22.6	8.00	108	901	0.44	586	4.69	56
	07.11.15	14.7	8.27	73	1016	0.50	660	2.52	27
	05.12.15	13.2	8.31	81	987	0.49	641	2.29	26
	10.01.16	8.1	8.48	88	1021	0.50	663	3.88	38
	07.02.16	6.3	8.26	140	891	0.44	579	4.79	43
SW4	28.01.15	8.1	7.85	163	868	0.43	564	2.51	23
	27.02.15	8.0	8.29	176	460	0.22	299	6.46	66
	28.03.15	11.7	8.08	152	853	0.42	554	0.76	8
	26.04.15	12.0	8.03	148	858	0.42	558	1.24	12
	26.05.15	21.4	7.94	121	969	0.48	630	2.56	35
	27.06.15	19.5	7.96	123	978	0.48	636	2.99	37
	25.07.15	19.6	7.99	106	968	0.48	629	2.93	36
	16.08.15	19.3	7.96	124	924	0.46	600	2.87	34
	20.09.15	21.2	7.93	111	915	0.45	595	2.35	34
	07.11.15	13.0	8.29	85	1029	0.51	669	0.43	5
	05.12.15	12.2	8.25	91	1002	0.49	651	0.54	6
	10.01.16	7.7	8.41	103	1034	0.51	672	3.69	30
	07.02.16	8.0	8.58	104	894	0.44	581	4.65	43

Table E-2: Values of field parameters measured in spring and fountain monitoring locations

NO	DATE	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%	Q (L/s)
F1	10.12.14	12.7	7.70	261	425	0.21	277	5.30	56	0.06
	27.01.15	8.7	8.20	228	435	0.21	283	5.19	49	0.07
	27.02.15	9.4	7.82	220	421	0.20	274	5.86	58	0.07
	28.03.15	12.0	7.99	269	438	0.21	285	5.68	58	0.08
	26.04.15	11.6	7.89	258	428	0.21	279	5.71	56	0.05
	26.05.15	15.9	7.68	411	411	0.20	268	5.24	62	0.05
	27.06.15	14.9	7.56	436	444	0.22	289	5.13	60	0.05
	25.07.15	15.2	7.52	428	436	0.21	284	5.21	60	0.05
	16.08.15	15.7	7.56	399	421	0.20	274	5.01	58	0.03
	20.09.15	15.5	7.71	451	488	0.24	318	5.31	58	0.05
	07.11.15	14.8	7.82	154	424	0.21	276	5.01	57	0.04
	05.12.15	13.6	7.86	171	408	0.20	266	5.11	57	0.05
	09.01.16	9.4	8.09	152	413	0.20	269	6.51	63	0.05
	06.02.16	7.9	8.20	181	436	0.21	284	6.55	60	0.06
F2	10.12.14	13.3	8.00	-	325	0.16	212	6.49	68	0.13
	27.01.15	9.7	8.39	246	331	0.16	216	6.09	59	0.14
	27.02.15	11.5	8.41	196	335	0.16	218	7.12	74	0.13
	28.03.15	11.4	8.21	254	330	0.16	215	6.70	70	0.13
	26.04.15	11.8	8.14	244	335	0.16	218	6.07	63	0.11
	26.05.15	15.3	8.02	205	340	0.16	222	7.31	81	0.13
	27.06.15	15.2	7.98	238	356	0.17	232	6.98	74	0.10
	25.07.15	15.9	7.96	236	353	0.17	230	6.99	75	0.09
	16.08.15	16.3	7.81	218	378	0.18	246	6.78	72	0.05
	20.09.15	15.5	8.00	224	354	0.17	231	7.54	81	0.08
	07.11.15	14.5	8.41	126	328	0.16	214	6.81	72	0.05
	05.12.15	13.8	8.39	132	331	0.16	216	6.77	70	0.05
	09.01.16	11.5	8.57	152	328	0.16	214	7.56	77	0.23
	06.02.16	10.3	8.66	178	329	0.16	214	7.72	78	0.23
F3	10.12.14	13.6	8.10	215	553	0.27	360	4.76	50	-
	27.01.15	10.2	8.21	227	568	0.28	369	4.85	47	0.06
	27.02.15	11.5	8.08	234	570	0.28	371	5.33	55	0.05
	28.03.15	12.4	7.99	228	570	0.28	371	5.08	53	0.05
	26.04.15	12.4	7.94	229	566	0.28	368	5.14	52	0.04
	26.05.15	17.7	7.90	198	590	0.29	384	5.20	60	0.09
	27.06.15	16.1	7.85	203	588	0.29	382	5.34	59	0.08
	25.07.15	16.3	7.88	211	603	0.30	392	5.28	59	0.08
	16.08.15	16.5	7.91	196	589	0.29	383	5.12	58	0.05
	20.09.15	15.6	7.91	188	599	0.29	390	5.36	60	0.08
	07.11.15	15.0	7.93	143	545	0.27	355	5.29	56	0.12
	05.12.15	13.8	7.93	156	505	0.25	329	5.15	56	0.16
	09.01.16	11.7	8.15	146	536	0.26	349	6.28	65	0.10
	06.02.16	11.0	8.20	214	539	0.26	351	5.78	55	0.10

Table E.2. continued

NO	DATE	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%	Q (L/s)
F4	10.12.14	12.7	8.48	275	359	0.17	234	6.41	67	-
	27.01.15	11.4	8.52	222	362	0.17	236	7.13	74	-
	27.02.15	12.5	8.28	179	361	0.17	235	7.35	78	0.02
	28.03.15	11.8	8.64	265	365	0.18	238	6.78	74	0.03
	26.04.15	11.5	8.55	266	258	0.12	168	6.83	71	0.02
	26.05.15	17.5	8.18	155	390	0.19	254	7.17	82	0.03
	27.06.15	16.3	8.12	167	401	0.19	261	7.06	80	0.02
	25.07.15	16.7	8.09	181	413	0.20	269	6.98	79	0.03
	16.08.15	16.5	7.99	180	396	0.19	258	6.80	75	0.02
	20.09.15	-	-	-	-	-	-	-	-	0.00
	07.11.15	13.5	8.61	177	359	0.17	234	6.90	73	0.07
	05.12.15	12.7	8.51	164	361	0.17	235	6.84	71	0.08
	09.01.16	11.3	8.47	154	362	0.17	236	7.63	78	0.06
	06.02.16	10.1	8.72	146	371	0.18	242	7.65	74	0.06
F5	11.12.14	13.8	7.80	229	397	0.19	258	5.82	61	0.07
	27.01.15	12.1	7.98	215	404	0.20	263	5.86	61	0.06
	27.02.15	12.4	7.96	178	416	0.20	271	6.15	65	0.07
	28.03.15	11.2	8.01	282	423	0.21	275	6.06	61	0.07
	26.04.15	11.2	7.96	274	249	0.12	162	6.25	62	0.04
	26.05.15	15.4	7.57	189	399	0.19	260	6.59	73	0.02
	27.06.15	15.2	7.49	176	402	0.19	262	6.71	72	0.02
	25.07.15	16.3	7.50	187	399	0.19	260	6.82	72	0.02
	16.08.15	16.4	7.51	182	402	0.19	262	7.01	75	0.01
	20.09.15	-	-	-	-	-	-	-	-	0.00
	07.11.15	14.4	7.46	131	428	0.21	279	6.04	65	0.06
	05.12.15	13.2	7.50	153	408	0.20	266	6.01	64	0.07
	09.01.16	10.5	8.06	140	415	0.20	270	6.65	64	0.02
	06.02.16	8.0	8.47	151	423	0.21	275	7.36	66	0.02
F6	11.12.14	12.9	8.12	218	373	0.18	243	6.37	65	0.09
	28.01.15	11.9	8.00	250	407	0.20	265	6.52	68	0.12
	28.02.15	12.8	8.01	130	431	0.21	281	6.83	72	0.14
	28.03.15	13.1	8.15	248	387	0.19	252	6.96	75	-
	26.04.15	13.0	8.03	254	389	0.19	253	7.01	71	0.06
	26.05.15	15.1	8.13	200	360	0.17	234	7.25	79	0.12
	27.06.15	15.0	8.11	209	378	0.18	246	7.17	79	0.20
	25.07.15	15.5	8.08	214	367	0.18	239	7.15	78	0.13
	16.08.15	15.8	8.11	265	358	0.17	233	7.01	76	0.13
	20.09.15	14.9	8.11	216	384	0.19	250	7.16	78	0.10
	07.11.15	13.0	8.16	203	373	0.18	243	6.58	67	0.33
	05.12.15	12.8	8.08	216	386	0.19	251	6.49	66	0.40
	09.01.16	12.9	8.39	161	375	0.18	244	6.99	76	0.66
	06.02.16	11.8	8.30	168	389	0.19	253	6.65	66	0.45
F7	11.12.14	13.4	8.23	229	372	0.18	242	6.77	71	-
	28.01.15	12.1	7.96	251	401	0.19	261	6.99	72	0.68
	28.02.15	13.1	7.99	235	425	0.21	277	6.69	71	0.32
	28.03.15	12.8	8.27	260	379	0.18	247	6.97	74	0.58
	26.04.15	12.7	8.25	261	383	0.19	249	6.91	73	0.21
	26.05.15	15.0	8.07	242	362	0.17	236	7.85	84	0.17
	27.06.15	14.5	8.04	246	366	0.18	238	7.48	81	0.13
	25.07.15	15.3	8.01	274	358	0.17	233	7.44	80	0.12
	16.08.15	15.4	8.03	284	374	0.18	244	7.12	78	0.10
	20.09.15	14.5	8.01	253	388	0.19	253	7.81	84	0.18
	07.11.15	13.6	8.00	209	369	0.18	240	6.63	71	-
	05.12.15	13.1	7.98	215	374	0.18	244	6.74	72	0.33
	09.01.16	12.6	8.29	148	376	0.18	245	7.07	70	1.00
	06.02.16	11.8	8.30	154	388	0.19	253	6.73	66	0.83

Table E-3: Values of field parameters measured in well waters monitoring locations

NO	DATE	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%
W2	11.12.14	16.8	8.07	223	777	0.38	505	5.92	67
	28.01.15	15.6	7.98	240	762	0.37	495	6.46	72
	28.02.15	16.1	7.89	213	617	0.30	401	6.24	70
	28.03.15	16.6	8.21	253	750	0.37	488	5.90	68
	26.04.15	16.1	8.16	244	744	0.37	484	5.98	63
	26.05.15	18.7	8.05	187	812	0.40	528	7.17	89
	27.06.15	15.8	7.98	186	768	0.38	499	7.33	84
	25.07.15	15.9	7.99	179	755	0.37	491	7.24	80
	16.08.15	16.5	7.96	175	701	0.34	456	7.02	75
	20.09.15	17.2	7.99	176	798	0.39	519	7.05	82
	07.11.15	16.6	7.91	204	813	0.40	528	5.86	66
	05.12.15	16.2	7.92	213	809	0.40	526	5.78	64
	09.01.16	14.7	8.25	194	726	0.36	472	6.77	74
	06.02.16	12.8	8.44	158	804	0.40	523	6.96	71
W3	10.12.14	14.7	7.98	281	617	0.30	401	4.73	51
	28.01.15	14.2	7.88	222	617	0.30	401	4.09	43
	27.02.15	15.3	7.93	230	634	0.31	412	4.33	48
	28.03.15	15.2	7.94	238	606	0.30	394	4.76	54
	26.04.15	15.2	7.99	236	596	0.29	388	4.78	52
	26.05.15	18.4	7.93	184	603	0.30	392	5.37	61
	27.06.15	16.4	7.99	204	625	0.31	406	5.48	60
	25.07.15	16.5	7.91	198	599	0.29	390	5.44	57
	16.08.15	16.5	7.88	178	578	0.28	376	5.12	57
	07.11.15	16.4	7.84	153	609	0.30	396	4.29	48
	05.12.15	15.4	7.85	149	635	0.31	413	4.36	48
	09.01.16	-	-	-	-	-	-	-	-
	06.02.16	-	-	-	-	-	-	-	-
PK2	07.08.15	24.4	8.04	157	559	0.27	364	-	-
	28.10.15	22.3	8.01	220	501	0.24	326	3.68	41
PK3	24.07.15	22.1	7.99	188	4990	2.49	3239	-	-
	23.10.15	21.8	7.96	178	4980	2.48	3232	2.45	29
PK4	25.10.15	18.7	8.08	265	355	0.17	231	2.99	32
PK5	29.07.15	18.6	7.88	199	658	0.32	428	-	-
	25.10.15	18.1	7.91	231	599	0.29	390	3.24	34
PK6	02.07.15	23.7	8.06	153	5510	2.75	3576	-	-
	30.10.15	22.9	8.03	188	4890	2.44	3174	2.11	24

Table E-4: Values of field parameters measured in village depot waters monitoring locations

NO	DATE	T(oC)	pH	ORP (mv)	EC 25oC (μS/cm)	S (ppt)	TDS (mg/l)	DO (mg/l)	DO%	Q (L/s)
D1	27.01.15	12.7	8.08	210	567	0.28	369	5.37	56	-
	27.02.15	14.4	8.19	222	571	0.28	371	5.07	54	-
	28.03.15	15.0	8.05	239	569	0.28	370	5.32	58	-
	26.04.15	14.7	8.15	243	577	0.28	375	5.22	54	-
	26.05.15	17.4	7.91	218	585	0.29	380	5.07	56	-
	27.06.15	15.9	7.93	226	599	0.29	390	5.21	57	-
	25.07.15	16.1	7.96	218	586	0.29	381	5.08	56	-
	16.08.15	16.2	7.95	201	578	0.28	376	5.12	55	-
	20.09.15	16.7	7.81	205	578	0.28	376	5.02	56	-
	07.11.15	15.9	7.91	171	542	0.26	353	5.61	63	-
	05.12.15	15.1	7.88	194	545	0.27	355	5.64	61	-
	09.01.16	13.4	8.00	163	541	0.26	352	6.17	63	-
	06.02.16	11.2	8.08	196	570	0.28	371	5.58	56	-
D2	10.12.14	13.6	8.22	248	357	0.17	233	7.26	77	0.81
	27.01.15	10.6	8.34	213	357	0.17	233	6.29	63	0.76
	27.02.15	12.2	8.31	190	356	0.17	232	7.30	74	0.67
	28.03.15	12.3	8.27	272	359	0.17	234	7.24	74	0.70
	26.04.15	11.6	8.31	252	368	0.18	240	7.02	73	0.09
	26.05.15	17.2	7.99	162	354	0.17	231	7.14	83	0.05
	27.06.15	16.4	8.02	176	388	0.19	253	7.24	82	0.03
	25.07.15	16.7	8.06	183	359	0.17	234	7.08	80	0.03
	16.08.15	16.3	8.01	178	354	0.17	231	7.01	79	0.02
	20.09.15	17.5	7.95	158	358	0.17	233	7.08	79	0.05
	07.11.15	13.9	8.26	170	358	0.17	233	6.76	74	-
	05.12.15	12.7	8.28	154	348	0.17	227	6.54	72	-
	09.01.16	11.7	8.27	111	358	0.17	233	7.02	72	0.28
	06.02.16	10.8	8.52	184	365	0.18	238	7.90	77	-
D3	27.02.15	9.6	8.20	217	547	0.27	356	7.20	71	-
	28.03.15	11.5	8.26	259	559	0.27	364	6.96	72	-
	26.04.15	11.8	8.33	258	563	0.28	366	6.93	71	-
	26.05.15	21.7	8.03	227	589	0.29	383	6.52	88	-
	27.06.15	18.4	8.10	236	601	0.29	391	6.70	82	-
	25.07.15	19.5	8.03	203	596	0.29	388	6.67	79	-
	16.08.15	19.0	8.02	218	578	0.28	376	6.38	72	-
	20.09.15	21.5	8.01	201	577	0.28	375	6.55	68	-
	07.11.15	10.5	8.25	135	589	0.29	383	6.78	64	-
	05.12.15	10.1	8.21	139	578	0.28	376	6.53	66	-
	09.01.16	9.8	8.14	149	583	0.29	379	6.48	65	-
	06.02.16	-	-	-	-	-	-	-	-	-
F6D	28.02.15	13.3	8.22	229	425	0.21	277	7.23	77	-
	28.03.15	13.1	8.41	256	379	0.18	247	6.81	72	-
	26.04.15	12.9	8.28	248	388	0.19	253	6.63	70	-
	26.05.15	14.4	8.10	242	361	0.17	235	6.86	75	-
	27.06.15	14.2	8.06	247	370	0.18	241	6.77	73	-
	25.07.15	14.9	8.05	253	368	0.18	240	6.58	70	-
	16.08.15	15.3	8.02	231	356	0.17	232	6.38	68	-
	20.09.15	14.4	8.08	276	395	0.19	257	6.88	75	-
	07.11.15	13.4	8.06	222	370	0.18	241	6.45	69	-
	05.12.15	13.3	8.05	238	384	0.19	250	6.58	69	-
	09.01.16	8.0	8.38	207	560	0.27	364	7.99	71	-
	06.02.16	8.0	8.38	207	560	0.27	364	7.99	71	-

APPENDIX F

VALUES OF LABORATORY PARAMETERS MEASURED IN HYDROCHEMICAL MONITORING LOCATIONS

Table F-1: Values of laboratory parameters measured in the hydrochemical monitoring locations of Porsuk stream

Parameter	Unit	SW3		SW4	
Date		May.15	Nov-15	May.15	Nov-15
Temperature	oC	24.4	15.1	22.9	13.5
pH		7.84	-	7.46	-
EC	µs/cm	868	968	841	1002
DO	mg/L	5.35	46.6	3.32	14.8
DO	%	71.5	4.35	43.5	1.42
Color	Pt-Co	18	21.143	24.4	22.812
TDS	mg/L	494	496	460	506
TSS	mg/L	25	41	30	24
Turbidity	NTU	14.2	16.8	16.5	10.21
Cl	mg/L	60.2	83.48	72	83.48
SO4	mg/L	86	67.33	95	62.17
F	mg/L	0.21	0.284	<0.1	0.293
Alkalinity-Total	mg CaCO3/L	332	0	338	0
Alkalinity-HCO3	mg CaCO3/L	332	405	338	385
Alkalinity-CO3	mg CaCO3/L	0	0	0	0
Alkalinity-OH	mg CaCO3/L	0.03	0	0.01	0
Total P	mg/L	2.2	1.438	3.13	1.802
Ortho phosphate (o-P	mg/L	1.16	1.45	1.28	1.826
Reactive P	mg/L	0.38	1.286	0.42	1.672
NH3	mg/L	8	-	10.3	-
NH4-N	mg/L	-	0.831	-	<0.01
NO3-N	mg/L	0.74	0.285	0.366	<0.02
NO2-N	mg/L	0.31	0.1962	0.18	0.02689
N, organic	mg/L	1.4	5.819	2.14	7.76
TKN	mg/L	9.4	6.65	12.44	7.77
Ag	mg/L	<0.0005	<0.01	<0.0005	<0.01
Al	mg/L	0.085	0.073	0.015	0.097
As	mg/L	0.007	<0.01	0.01	0.016
B	mg/L	<0.2	0.258	0.6	0.26
Ba	mg/L	0.071	0.099	0.066	0.094
Be	mg/L	<0.00004	<0.01	<0.00004	<0.01
Bi	mg/L	<0.01	<0.01	<0.01	<0.01
Ca	mg/L	58.17	72.4	63.19	88.34
Cd	mg/L	0.316	<0.003	<0.0002	<0.003
Co	mg/L	<0.0005	<0.01	<0.0005	<0.01
Cr	mg/L	0.004	<0.01	0.002	<0.01
Cu	mg/L	0.003	<0.01	0.003	<0.01
Fe	mg/L	0.055	0.088	0.025	0.079
Hg	mg/L	<0.00008	<0.001	<0.00008	<0.001
K	mg/L	8.768	12.85	11.03	14.92
Li	mg/L	0.018	0.061	0.02	<0.05
Mg	mg/L	46.79	54.75	48.4	63.83
Mn	mg/L	0.02	0.081	0.037	0.065
Mo	mg/L	0.003	<0.01	<0.001	<0.01
Na	mg/L	52.44	72.04	63.05	86.1
Ni	mg/L	0.019	0.014	0.017	0.011
P	mg/L	-	0.65	-	0.787
Pb	mg/L	0.016	<0.01	0.003	<0.01
Sb	mg/L	<0.002	<0.005	<0.002	<0.005
Se	mg/L	<0.005	<0.005	<0.005	<0.005
Si	mg/L	8.041	8.94	6.712	8.12
Sr	mg/L	0.367	0.443	0.394	0.427
Sn	mg/L	<0.001	<0.05	0.002	<0.05
Ti	mg/L	0.002	<0.01	<0.0002	<0.01
Tl	mg/L	<0.003	<0.05	<0.003	<0.05
U	mg/L	0.004	0.003	0.004	0.003
V	mg/L	0.003	<0.01	0.003	<0.01
Zn	mg/L	0.075	0.012	0.016	0.021

Table F.1. continued, * calculated values

Parameter	Unit	SW3		SW4	
Date		May.15	Nov-15	May.15	Nov-15
Toplam CN	mg/L	<0.01	<0.02	<0.01	<0.02
Weak acid diss CN	mg/L	<0.01	<0.25	<0.01	<0.25
TOC	mg/L	<1	10.71	<1	12.14
COD	mg/L	62.4	60	56.8	110
H2S	mg/L	<0.01	<0.1	<0.01	<0.1
Oil&grease	mg/L	<10	0.219	<10	0.159
Surfactants	mg/L	<0.025	-	<0.025	-
PAH	mg/L	<0.001	<0.05*	<0.001	<0.05*
Anthracene	mg/L	<0.0004	<0.05	<0.0004	<0.05
Fluoranthene	mg/L	<0.00024	<0.00005	<0.00024	<0.00005
Naphthalene	mg/L	<0.00025	<0.00005	<0.00025	<0.00005
Benzo(a)pyrene	mg/L	<0.0004	<0.00005	<0.0004	<0.00005
Benzo(b)fluoranthene	mg/L	<0.0004	<0.00005	<0.0004	<0.00005
Benzo(k)fluoranthene	mg/L	<0.0001	<0.00005	<0.0001	<0.00005
Benzo(g,h,i)perylene	mg/L	<0.0004	<0.00005	<0.0004	<0.00005
Indeno(1,2,3-cd) pyrene	mg/L	<0.0001	<0.00005	<0.0001	<0.00005
Organophosphate pesticides	µg/L	<0.244	0.01*	<0.244	<0.08*
Atrazin	µg/L	<0.064	0.01	<0.064	<0.01
Chlorfenvinphos	µg/L	<0.013	<0.08	<0.013	<0.08
chlorpyrifos-ethyl	µg/L	<0.012	<0.08	<0.012	<0.08
Simazine	µg/L	<0.014	<0.02	<0.014	<0.02
Organo chlorine pesticides	µg/L	0.12	<0.01*	0.19	<0.01*
Alachlor	µg/L	<0.0022	<0.01	<0.0022	<0.05
Endosulfan	µg/L	<0.0047	<0.001	<0.0047	<0.001
Hexachlorobenzene	µg/L	<0.0001	<0.001	<0.0001	<0.001
Trifluralin	µg/L	0.12	<0.01	0.18	<0.01
Hexachlorocyclohexane	µg/L	<0.0124	<0.001	<0.0124	<0.001
Volatile organic compounds	µg/L	<3.4	<5*	<3.4	<5*
Benzene	mg/L	<0.00084	<0.001	<0.00084	<0.001
1,2-Dichloroethane	µg/L	<0.6	<3	<0.6	<3
Dichloromethane	µg/L	<1.9	<20	<1.9	<20
Hexachlorobutadiene	µg/L	<0.1	<0.002	<0.1	<0.002
Trichloromethane	µg/L	<1.1	<5	<1.1	<5
Trichlorobenzenes	µg/L	<0.4	<0.02	<0.4	<0.02
Semi volatile organic compounds	µg/L	<0.25	-	<0.25	-
Di(2-ethylhexyl)phthalate	µg/L	<0.95	<0.5	<0.95	<0.5
Pentachlorobenzene	µg/L	<0.86	<0.002	<0.86	<0.002
Diuron	µg/L	<0.05	<0.01	<0.05	<0.01
Isoproturon	µg/L	<0.05	<0.01	<0.05	<0.01
NPE	µg/L	<2.32	-	<2.32	-
Nonylphenols	µg/L	<1.19	0.52	<1.19	<0.3
octylphenols	µg/L	<0.1	<0.2	<0.1	<0.3
Pentachlorophenol	µg/L	<0.1	<0.02	<0.1	<0.02
Tributyltin	µg/L	<1	<0.005	<1	<0.005
Bromodiphenylethers	µg/L	<0.031	<0.0005	<0.031	<0.0005
Pentabromodiphenylether	µg/L	<0.004	<0.0005	<0.004	<0.0005
C10-13 Chloroalkanes	µg/L	<0.4	<0.5	<0.4	<0.5
BOD5	mg/L	13.6	16.54	11.1	31.54
Fecal Coliform	cfu/100 ml	200	>100000	1000	>100000
Total Coliform	cfu/100 ml	400	>100000	2500	>100000
Fecal Streptecoc	cfu/100 ml	150	>100000	800	>100000
Escherichia Coli	cfu/100 ml	300	>100000	1200	>100000
Enterococ	cfu/100 ml	150	-	800	-

Table F-2: Values measured in the sediments of upstream (SW4) and downstream (SW3) monitoring locations of Porsuk stream monitoring locations

Metals	**SW3**		**SW4**	
mg/kg	May.15	Nov-15	May.15	Nov-15
Ag	<5	<2	<5	2.17
Al	5084	16466.09	4328	9458.74
As	4.01	15.01	5.34	14
B	5.05	15.44	12.25	20.32
Ba	152.9	138.57	101	180.05
Be	0.77	<2	0.36	<2
Bi	<1.25	<2	<1.25	2.19
Ca	37212	44100.35	30728	41767.6
Cd	0.31	<0.6	<0.25	<0.6
Co	14.9	17.34	15.3	19.73
Cr	67.8	101.45	112	178.86
Cu	26.9	46.27	20.8	77.23
Fe	10135	18424.14	12532	18679.03
Hg	<0.25	<0.2	<0.25	0.32
K	2143	1826.73	1136	1334.02
Li	12.98	85.55	9.2	63.96
Mg	12647	18894.55	13342	16461.01
Mn	351	438.45	352	379.82
Mo	<2.5	<2	<2.5	<2
Na	25.82	456.09	2833	314.53
Ni	112.3	165.6	175	244.51
P	2100	1163.07	1850	1483.34
Pb	11.8	15.22	9.17	18.11
Sb	<1.25	<1	<1.25	<1
Se	<1.25	<1	<1.25	<1
Si	235	543.9	136	616.95
Sr	162	139.02	136	123.52
Sn	<1.26	49.76	<1.25	68.22
Ti	57.9	87.39	75.2	174.86
Tl	<1.25	<10	<1.25	<10
U	1.65	<5	1.13	<5
V	<1.25	29.18	<1.25	37.66
Zn	348.6	382.59	178	717.82
Phenolics (mg/kg)				
4-Chloro-3-methylphenol	<20.9	<0.5	<0.170	<0.5
2-Chlorophenol	<0.02	<0.5	<0.02	<0.5
3-Chlorophenol	<0.02	<0.01	<0.02	<0.01
4-Chlorophenol	<0.02	<0.01	<0.02	<0.01
2,3-Dichlorophenol	<0.02	<0.002	<0.02	<0.002
2,4 & 2,5-Dichlorophenol	<0.04	<0.001	<0.02	<0.001
2,6-Dichlorophenol	<0.02	0.002	<0.02	<0.001
3,4-Dichlorophenol	<0.02	<0.002	<0.02	<0.002
3,5-Dichlorophenol	<0.02	<0.001	<0.02	<0.001
2,4-Dimethylphenol	<0.2	< 0.5	<0.02	< 0.5
o-Cresol	<0.1	<0.01	<0.1	<0.01
m-Cresol	<0.2	<0.01	<0.2	<0.01
p-Cresol	<0.2	0.04	<0.2	0.18
Pentachlorophenol	<0.01	<0.001	<0.005	<0.001
Phenol	<0.1	< 0.5	<0.1	< 0.5
2,3,4,5-Tetrachlorophenol	<0.02	<0.002	<0.02	<0.002
2,3,4,6-Tetrachlorophenol	<0.02	0.04	<0.02	0.18
2,3,5,6-Tetrachlorophenol	<0.02	0.04	<0.02	0.18
2,3,4-Trichlorophenol	<0.02	<0.01	<0.02	<0.01
2,3,5-Trichlorophenol	<0.02	<0.001	<0.02	<0.001
2,3,6-Trichlorophenol	<0.02	<0.001	<0.02	<0.001
2,4,5-Trichlorophenol	<0.02	<0.001	<0.02	<0.001
2,4,6-Trichlorophenol	<0.02	< 0.5	<0.02	< 0.5
Organic C%	3.4	-	1.05	-
Organic N (mg/kg)	2080	-	2350	-

PAH&HH	**SW3**		**SW4**	
	May.15	Nov-15	May.15	Nov-15
Polycyclic Aromatic Hydrocarbons (mg/kg)	<1.28	-	<1.28	-
Acenaphthene	<0.8	<0.025	<0.8	<0.025
Acenaphthylene	<0.8	<0.025	<0.8	<0.025
Anthracene	<0.8	0.052	<0.8	<0.025
Benz(a)anthracene	<0.8	<0.025	<0.8	<0.025
Benzo(a)pyrene	<0.8	<0.025	<0.8	<0.025
Benzo(b)fluoranthene	<0.8	<0.025	<0.8	<0.025
Benzo(g,h,i)perylene	<0.8	<0.025	<0.8	<0.025
Benzo(k)fluoranthene	<0.8	<0.025	<0.8	<0.025
Chrysene	<0.8	0.02	<0.8	<0.025
Dibenz(a,h)anthracene	<0.8	<0.025	<0.8	<0.025
Fluoranthene	<0.8	0.029	<0.8	<0.025
Fluorene	<0.8	<0.025	<0.8	<0.025
Indeno(1,2,3-c,d)pyrene	<0.8	<0.025	<0.8	<0.025
2-Methylnaphthalene	<0.8	-	<0.8	-
Naphthalene	<0.8	<0.025	<0.8	<0.025
Phenanthrene	<0.8	0.048	<0.8	<0.025
Pyrene	<0.8	<0.025	<0.8	<0.025
Polychlorinated Biphenyls (mg/kg)	<195	-	<112	-
PCB-1016	<195	<0.316	<112	<0.307
PCB-1221	<195	-	<112	-
PCB-1232	<195	-	<112	-
PCB-1242	<195	<0.316	<112	<0.307
PCB-1248	<195	-	<112	-
PCB-1254	<195	<0.316	<112	<0.307
PCB-1260	<195	<0.316	<112	<0.307
PCB-1262	<195	-	<112	-
PCB-1268	<195	-	<112	-
Total Polychlorinated Biphenyls	<195	<625	<112	<625
Chlorinated Hydrocarbons (mg/kg)				
1,2-Dichlorobenzene	<0.02	<2.5	<0.02	<2.5
1,3-Dichlorobenzene	<0.02	<2.5	<0.02	<2.5
1,4-Dichlorobenzene	<0.02	<2.5	<0.02	<2.5
Hexachlorobenzene	<0.005	<0.002	<0.005	<0.002
Hexachlorobutadiene	<0.01	<0.002	<0.02	<0.002
Hexachlorocyclohexane (Total)	<0.01	0.00658	<0.02	0.00305
Hexachloroethane	<0.01	<0.5	<0.02	<0.4
Pentachlorobenzene	<0.01	<0.002	<0.02	<0.002
1,2,3,4-Tetrachlorobenzene	<0.01	<0.003	<0.01	<0.003
1,2,3,5-Tetrachlorobenzene	<0.02	<0.002	<0.02	<0.002
1,2,4,5-Tetrachlorobenzene	<0.02	<0.002	<0.02	<0.002
1,2,3-Trichlorobenzene	<0.02	<0.01	<0.02	<0.01
1,2,4-Trichlorobenzene	<0.03	<0.01	<0.03	0.01
1,3,5-Trichlorobenzene	<0.05	<0.003	<0.05	<0.003
Semi-Volatile Organics (mg/kg)				
Butylbenzyl Phthalate	<0.8	<0.1	<0.8	<0.1
Diethyl Phthalate	<0.8	<0.1	<0.8	<0.1
Dimethyl Phthalate	<0.8	<0.1	<0.8	<0.1
Di-n-butyl Phthalate	<0.8	<0.1	<0.8	<0.1
Di-n-Octyl Phthalate	<0.8	<0.1	<0.8	<0.1
bis(2-Ethylhexyl)Phthalate	<0.8	0.081	<0.8	<0.1
Diisobutyl Phthalate	<0.8	<0.1	<0.8	<0.1

Table F-3: Values of laboratory parameters measured in the hydrochemical monitoring locations of spring and fountain waters, * calculated values

Parameter	Unit	F1		F2		F3	
Date		May.15	Nov-15	May.15	Nov-15	May.15	Nov-15
Temperature	oC	16.3	15.1	16.7	14.2	18.7	15.4
pH		7.85	7.79	8.02	8.04	7.85	7.91
EC	μs/cm	367	415	326	313	590	554
DO	mg/L	6.83	7.7	8.48	8.97	6.58	7.88
DO	%	81.2	87	96.5	99.6	78.6	85.9
Color	Pt-Co	-	6.601	-	6.341	-	6.28
TDS	mg/L	156	198	200	154	388	258
TSS	mg/L	<4	11	<4	<10	<4	64
Cl	mg/L	5.61	5.927	5.12	5.679	23.9	19.79
SO4	mg/L	8.5	7.437	13	7.008	13.3	14.555
F	mg/L	0.29	0.362	0.28	0.355	0.25	0.389
Alkalinity-Total	mg CaCO3/L	204	230	152	170	228	285
Alkalinity-HCO3	mg CaCO3/L	204	230	152	170	228	285
Alkalinity-CO3	mg CaCO3/L	0	0	0	0	0	0
Alkalinity-OH	mg CaCO3/L	0.04	0	0.05	0	0.04	0
Total P	mg/L	<0.2	<0.01	<0.2	<0.01	<0.2	<0.01
Reactive P	mg/L	0.009	<0.01	0.008	<0.01	0.014	<0.01
NH4-N	mg/L	-	<0.01	-	<0.01	-	<0.01
NH3	mg/L	<0.02	-	<0.02	-	<0.02	-
NO3-N	mg/L	3.1	3.541	2.7	3.381	6.2	6.554
NO2-N	mg/L	<0.002	<0.001	<0.002	<0.001	<0.002	<0.001
N, organic	mg/L	2.63	2.09	2.35	1.11	3.19	2.44
TKN	mg/L	2.63	2.1	2.35	1.12	3.19	2.45
Ag	mg/L	<0.0005	<0.01	<0.0005	<0.01	<0.0005	0.015
Al	mg/L	<0.003	0.071	<0.003	0.08	<0.003	0.047
As	mg/L	<0.0034	<0.01	<0.0034	<0.01	0.019	0.027
B	mg/L	0.43	0.109	0.26	0.043	<0.2	0.423
Ba	mg/L	0.061	0.073	0.068	0.081	0.117	0.206
Be	mg/L	<0.00004	<0.01	<0.00004	<0.01	<0.00004	<0.01
Bi	mg/L	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01
Ca	mg/L	37.21	35.14	31.35	31.66	17.24	22.26
Cd	mg/L	<0.0002	<0.003	<0.0002	<0.003	0.234	<0.003
Co	mg/L	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01
Cr	mg/L	<0.0003	<0.01	<0.0003	<0.01	0.001	<0.01
Cu	mg/L	<0.0002	<0.01	<0.0002	<0.01	<0.0002	<0.01
Fe	mg/L	0.002	0.071	<0.00015	0.024	0.001	0.064
Hg	mg/L	<0.00008	<0.001	<0.00008	<0.001	<0.00008	<0.001
K	mg/L	0.168	0.27	0.2	0.348	2.587	2.65
Li	mg/L	0.026	<0.05	0.024	<0.05	0.113	0.099
Mg	mg/L	29.62	28.93	21.14	20.94	53.53	53.95
Mn	mg/L	<0.0002	<0.01	<0.0002	0.01	<0.0002	<0.01
Mo	mg/L	<0.001	<0.01	<0.001	<0.01	<0.001	<0.01
Na	mg/L	4.102	13.3	3.589	3.27	14.24	19.01
Ni	mg/L	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01
P	mg/L	-	<0.05	-	<0.05	-	<0.05
Pb	mg/L	<0.0015	<0.01	<0.0015	<0.01	<0.0015	0.053
Sb	mg/L	<0.002	<0.005	<0.002	<0.005	<0.002	<0.005
Se	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Si	mg/L	6.633	7.08	5.964	6.37	24.55	19.41
Sr	mg/L	0.523	0.61	0.413	0.611	1.738	2.16
Sn	mg/L	<0.001	<0.05	<0.001	<0.05	<0.001	<0.05
Ti	mg/L	<0.0002	<0.01	<0.0002	<0.01	<0.0002	<0.01
Tl	mg/L	<0.003	<0.05	<0.003	<0.05	<0.003	<0.05
U	mg/L	<0.004	0.0012	<0.004	0.00089	<0.004	0.0044
V	mg/L	0.005	<0.01	0.004	<0.01	0.012	0.013
Zn	mg/L	0.02	0.031	0.001	0.018	0.012	<0.01
Total CN	mg/L	-	<0.02	-	<0.02	-	<0.02
TOC	mg/L	<1	<5	<1	<5	<1	<5
COD	mg/L	<15	15	56	10	54	9
Sulfur	mg/L	-	<0.1	-	<0.1	-	<0.1
Oil&grease	mg/L	-	<0.1	-	0.161	-	<0.1
Atrazine	μg/L	-	<0.01	-	<0.01	-	<0.01
Chlorpyrifos	μg/L	-	<0.08	-	<0.08	-	<0.08
Simazine	μg/L	-	<0.01	-	<0.01	-	<0.01
pp-DDT	μg/L	-	<0.001	-	<0.001	-	<0.001
Alachlor	μg/L	-	<0.01	-	<0.01	-	<0.01
Endosulfan	μg/L	-	<0.001	-	<0.001	-	<0.001
Trifluralin	μg/L	-	<0.01	-	<0.01	-	<0.01
Diuron	μg/L	-	<0.01	-	<0.01	-	<0.01
Isoproturon	μg/L	-	<0.01	-	<0.01	-	<0.01
Total pesticides	μg/L	<0.25	<0.08*	<0.25	<0.08*	<0.25	<0.08*
Organophosphate pesticides	μg/L	<0.244	<0.08*	<0.244	<0.08*	<0.244	<0.08*
Organo chlorine pesticides	μg/L	<0.06	<0.01*	<0.06	<0.01*	<0.06	<0.01*
VOC	μg/L	<3.4	-	<3.4	-	<3.4	-
Tetrachloroethylene	μg/L	<0.8	<5	<0.8	<5	<0.8	<5
Trichloroethylene	μg/L	<0.8	<5	<0.8	<5	<0.8	<5

Table F.3. continued, * calculated values

Parameter	Unit	F4		F5		F6		F7	
Date		May.15	Nov-15	May.15	Nov-15	May.15	Nov-15	May.15	Nov-15
Temperature	oC	19.1	13.6	17.2	14.3	16.4	13.3	16.9	14.2
pH		7.92	8.33	7.28	7.63	7.85	8.04	8.09	8.9
EC	µs/cm	330	335	382	420	364	365	333	358
DO	mg/L	8.35	9.25	7.85	8.28	8.6	9.52	8.64	8.4
DO	%	99	97.2	90	88.4	99.2	99.6	96	102.4
Color	Pt-Co	-	5.046	-	8.75	-	8.498	-	4.84
TDS	mg/L	188	168	190	202	212	172	86	180
TSS	mg/L	<4	<10	<4	<10	<4	<10	<4	<10
Cl	mg/L	9.5	8.173	8.5	8.241	5.4	4.86	5.12	5.666
SO4	mg/L	14	11.465	12.2	9.863	11.4	11.415	11.2	11.415
F	mg/L	0.31	0.392	0.225	0.297	0.22	0.28	0.22	0.274
Alkalinity-Total	mg CaCO3/L	159	160	180	220	174	190	172	215
Alkalinity-HCO3	mg CaCO3/L	159	160	180	220	174	190	172	195
Alkalinity-CO3	mg CaCO3/L	0	0	0	0	0	0	0	20
Alkalinity-OH	mg CaCO3/L	0.04	0	0.01	0	0.04	0	0.06	0
Total P	mg/L	<0.2	<0.01	<0.2	<0.01	<0.2	<0.01	<0.2	<0.01
Reactive P	mg/L	0.013	<0.01	0.008	<0.01	0.013	<0.01	0.014	<0.01
NH4-N	mg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
NH3	mg/L	<0.02	-	<0.02	-	<0.02	-	<0.02	-
NO3-N	mg/L	3	3.552	5.45	6.627	2.87	3.584	2.96	3.619
NO2-N	mg/L	0.0036	<0.001	<0.002	0.0011	<0.002	<0.001	<0.002	0.00225
N, organic	mg/L	4	1.95	3.75	<0.5	15.2	<0.5	1.5	<0.5
TKN	mg/L	4	1.96	3.75	<0.5	15.2	<0.5	1.5	<0.5
Ag	mg/L	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01
Al	mg/L	0.071	0.07	0.006	0.263	<0.003	0.151	<0.003	0.061
As	mg/L	0.0034	<0.01	0.004	<0.01	<0.0034	<0.01	<0.0034	<0.01
B	mg/L	0.2	0.094	<0.2	0.081	<0.2	0.078	<0.2	0.078
Ba	mg/L	0.102	0.379	0.114	0.137	0.037	0.04	0.04	0.04
Be	mg/L	<0.00004	<0.01	<0.00004	<0.01	<0.00004	<0.01	<0.00004	<0.01
Bi	mg/L	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01
Ca	mg/L	31.74	31.8	40	45.68	30.13	38.83	30.98	33.18
Cd	mg/L	<0.0002	<0.003	<0.0002	<0.003	<0.0002	<0.003	<0.0002	<0.003
Co	mg/L	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01
Cr	mg/L	0.422	<0.01	0.002	<0.01	<0.0003	<0.01	<0.0003	<0.01
Cu	mg/L	<0.0002	<0.01	0.006	<0.01	<0.0002	<0.01	<0.0002	<0.01
Fe	mg/L	<0.00015	0.043	<0.00015	0.226	0.296	0.336	0.001	0.052
Hg	mg/L	<0.00008	<0.001	<0.00008	<0.001	<0.00008	<0.001	<0.00008	<0.001
K	mg/L	0.346	0.441	0.586	0.914	0.316	0.471	0.262	0.513
Li	mg/L	0.02	<0.05	0.015	<0.05	0.027	<0.05	0.027	<0.05
Mg	mg/L	22.83	24.08	23.68	27.65	25.27	27.06	24.88	28.26
Mn	mg/L	0.005	<0.01	<0.0002	<0.01	<0.0002	0.036	<0.0002	0.019
Mo	mg/L	<0.001	<0.01	<0.001	<0.01	<0.001	0.01	<0.001	<0.01
Na	mg/L	6.779	11.39	4.658	4.35	3.145	7.65	3.196	6.83
Ni	mg/L	<0.0005	<0.01	<0.0005	<0.01	0.001	<0.01	0.001	<0.01
P	mg/L	-	<0.05	-	<0.05	-	<0.05	-	<0.05
Pb	mg/L	<0.0015	<0.01	<0.0015	<0.01	<0.0015	<0.01	<0.0015	<0.01
Sb	mg/L	<0.002	<0.005	<0.002	0.0058	<0.002	<0.005	<0.002	<0.005
Se	mg/L	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005
Si	mg/L	10.02	8.62	6.507	6.67	6.77	7.16	7.043	6.76
Sr	mg/L	0.346	0.426	0.381	0.546	0.404	0.47	0.4	0.457
Sn	mg/L	<0.001	<0.05	<0.001	<0.05	<0.001	<0.05	<0.001	<0.05
Ti	mg/L	<0.0002	<0.01	<0.0002	<0.01	<0.0002	<0.01	<0.0002	<0.01
Tl	mg/L	<0.003	<0.05	<0.003	<0.05	<0.003	<0.05	<0.003	<0.05
U	mg/L	<0.004	0.0013	<0.004	0.001	<0.004	0.0011	<0.004	0.0011
V	mg/L	0.004	<0.01	0.004	<0.01	0.002	<0.01	0.002	<0.01
Zn	mg/L	<0.0002	<0.01	0.013	0.032	0.007	0.019	0.003	0.018
Total CN	mg/L	-	<0.02	-	<0.02	-	<0.02	-	<0.02
TOC	mg/L	<1	<5	<1	<5	<1	<5	<1	<5
COD	mg/L	<15	7	37	7	<15	6	<15	12
Sulfur	mg/L	-	<0.1	-	<0.1	-	<0.1	-	<0.1
Oil&grease	mg/L	-	<0.1	-	<0.1	-	0.156	-	0.115
Atrazine	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Chlorpyrifos	µg/L	-	<0.08	-	<0.08	-	<0.08	-	<0.08
Simazine	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
pp-DDT	µg/L	-	<0.001	-	<0.001	-	<0.001	-	<0.001
Alachlor	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Endosulfan	µg/L	-	<0.001	-	<0.001	-	<0.001	-	<0.001
Trifluralin	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Diuron	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Isoproturon	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Total pesticides	µg/L	<0.25	<0.08*	<0.25	<0.08*	<0.25	<0.08*	<0.25	<0.08*
Organophosphate pesticides	µg/L	<0.244	<0.08*	<0.244	<0.08*	<0.244	<0.08*	<0.244	<0.08*
Organo chlorine pesticides	µg/L	<0.06	<0.01*	<0.06	<0.01*	<0.06	<0.01*	<0.06	<0.01*
VOC	µg/L	<3.4	-	<3.4	-	<3.4	-	<3.4	-
Tetrachloroethylene	µg/L	<0.8	<5	<0.8	<5	<0.8	<5	<0.8	<5
Trichloroethylene	µg/L	<0.8	<5	<0.8	<5	<0.8	<5	<0.8	<5

Table F-4: Values of laboratory parameters measured in the hydrochemical monitoring locations of well waters, * calculated values

Parameter	Unit	W2		W3		PK2	
Date		May.15	Nov-15	May.15	Nov-15	Aug-15	Oct-15
Temperature	oC	18.5	16.4	20.2	17.4	20.8	19.4
pH		8.11	7.89	7.61	7.72	7.91	7.44
EC	µs/cm	835	789	608	583	711	1893
DO	mg/L	8.46	9.01	5.82	6.7	8.26	7.28
DO	%	98.7	100.7	69.5	75.9	98.3	84.6
Color	Pt-Co	-	4.657	-	0.005	<2.2	4.451
TDS	mg/L	462	386	352	294	978	954
TSS	mg/L	<4	<10	<4	<10	7	<10
Cl	mg/L	51.2	50.65	18.53	17.464	23	53.5
SO4	mg/L	98	86.1	21.2	18.784	545	884.4
F	mg/L	0.17	0.25	0.17	0.256	0.15	0.242
Alkalinity-Total	mg CaCO3/L	243	215	262	275	207.4	195
Alkalinity-HCO3	mg CaCO3/L	232	215	262	275	200	195
Alkalinity-CO3	mg CaCO3/L	11	0	0	0	7.4	0
Alkalinity-OH	mg CaCO3/L	0.06	0	0.02	0	0.13	0
Total P	mg/L	<0.2	<0.01	<0.2	<0.01	<0.2	<0.01
Reactive P	mg/L	0.018	<0.01	0.012	<0.01	0.014	<0.01
NH3	mg/L	<0.02	-	<0.02	-	0.23	-
NH4-N	mg/L	-	<0.01	-	<0.01	-	<0.01
NO3-N	mg/L	8.84	9.109	7.95	8.174	0.675	0.324
NO2-N	mg/L	0.004	0.00583	<0.002	<0.001	0.3	0.08931
N, organic	mg/L	4.6	<0.5	4.9	<0.5	1.81	<0.5
TKN	mg/L	4.6	<0.5	4.9	<0.5	2	<0.5
Ag	mg/L	0.003	<0.01	<0.0005	0.011	0.001	<0.01
Al	mg/L	<0.003	0.048	0.009	0.043	0.083	1.86
As	mg/L	0.008	0.018	0.04	0.056	0.01	<0.01
B	mg/L	0.22	0.802	0.4	0.493	<0.2	4.34
Ba	mg/L	0.142	0.148	0.017	0.018	0.051	0.051
Be	mg/L	<0.00004	<0.01	<0.00004	<0.01	<0.00004	<0.01
Bi	mg/L	<0.05	<0.01	<0.05	<0.01	<0.01	<0.01
Ca	mg/L	21.71	43.12	20.34	22.5	71.13	162.66
Cd	mg/L	<0.0002	<0.003	0.001	<0.003	0.001	<0.003
Co	mg/L	<0.0005	<0.01	<0.0005	<0.01	0.001	<0.01
Cr	mg/L	0.001	<0.01	0.002	<0.01	<0.0003	<0.01
Cu	mg/L	0.004	<0.01	<0.0002	<0.01	0.006	<0.01
Fe	mg/L	0.018	0.141	0.012	0.014	0.654	0.835
Hg	mg/L	<0.00008	<0.001	<0.00008	<0.001	<0.00008	<0.001
K	mg/L	2.961	5.81	7.016	8.43	10.17	12.13
Li	mg/L	0.139	0.135	0.128	0.12	0.323	0.466
Mg	mg/L	31.74	56.69	50.33	55.42	58.63	85.5
Mn	mg/L	<0.0002	<0.01	0.014	<0.01	0.043	0.199
Mo	mg/L	<0.001	<0.01	<0.001	<0.01	0.009	0.023
Na	mg/L	32.72	51.02	17.24	24.23	133.6	216
Ni	mg/L	<0.0005	<0.01	0.001	<0.01	0.014	<0.01
P	mg/L	-	<0.05	-	<0.05	-	<0.05
Pb	mg/L	0.004	<0.01	<0.0015	<0.01	<0.0015	<0.01
Sb	mg/L	<0.002	<0.005	<0.002	<0.005	<0.002	<0.005
Se	mg/L	<0.005	<0.005	<0.005	<0.005	0.005	<0.005
Si	mg/L	24.68	22.01	30.26	27.87	17.97	11.23
Sr	mg/L	2.644	3.4	4.367	5.59	1.848	3.36
Sn	mg/L	<0.001	<0.05	<0.001	<0.05	0.004	<0.05
Ti	mg/L	<0.0002	<0.01	<0.0002	<0.01	0.001	<0.01
Tl	mg/L	<0.003	<0.05	<0.003	<0.05	<0.003	<0.05
U	mg/L	<0.002	0.003	<0.002	0.0069	0.003	0.0028
V	mg/L	<0.0005	<0.01	0.012	0.014	0.002	<0.01
Zn	mg/L	0.034	<0.01	0.003	<0.01	0.059	<0.01
Total CN	mg/L	-	<0.02	-	<0.02	<0.01	<0.02
TOC	mg/L	<1	<5	<1	<5	<1	<5
COD	mg/L	19.6	40	<15	13	<15	8
Sulfur	mg/L	-	<0.1	-	<0.1	<0.002	<0.1
Oil&grease	mg/L	-	<0.1	-	0.119	<10	0.129
Atrazine	µg/L	-	<0.01	-	<0.01	-	<0.01
Chlorpyrifos	µg/L	-	<0.08	-	<0.08	-	<0.08
Chlorfenvinphos	µg/L	-	<0.08	-	<0.08	-	<0.08
Simazine	µg/L	-	<0.01	-	<0.01	-	<0.01
pp-DDT	µg/L	-	<0.001	-	<0.001	-	<0.001
Alachlor	µg/L	-	<0.01	-	<0.01	-	<0.01
Endosulfan	µg/L	-	<0.001	-	<0.001	-	<0.001
Trifluralin	µg/L	-	<0.001	-	<0.001	-	<0.001
Diuron	µg/L	-	<0.01	-	<0.01	-	<0.01
Isoproturon	µg/L	-	<0.01	-	<0.01	-	<0.01
Total pesticides	µg/L	<0.25	<0.08*	<0.25	<0.08*	<0.25	<0.08*
Organophosphate pesticides	µg/L	<0.244	<0.08*	<0.244	<0.08*	<0.244	<0.08*
Organo chlorine pesticides	µg/L	<0.06	<0.01*	<0.06	<0.01*	<0.06	<0.01*
VOC	µg/L	<3.4	-	<3.4	-	<3.4	-
Tetrachloroethylene	µg/L	<0.8	<5	<0.8	<5	<0.8	<5
Trichloroethylene	µg/L	<0.8	<5	<0.8	<5	<0.8	<5
BOD5	mg/L	-	-	-	-	2.5	-
Fecal Coliform	cfu/100 ml	-	-	-	-	0	-
Total Coliform	cfu/100 ml	-	-	-	-	0	-
Alfa aktivity	Bq/L	-	-	-	-	0.07	-
Beta aktivity	Bq/L	-	-	-	-	0.35	-

Table F.4. continued, * calculated values

Parameter	Unit	PK3		PK4	PK5		PK6	
Date		July-15	Oct-15	Oct-15	July-15	Oct-15	July-15	Oct-15
Temperature	oC	21	19.4	19.4	20.2	19.4	20.1	19.4
pH		7.96	7.07	7.6	7.79	7.84	7.81	7.37
EC	µs/cm	708	12110	363	720	424	715	5460
DO	mg/L	8.17	7.31	8.4	8.03	4.69	8.38	7.45
DO	%	97.8	84	9.61	97.1	53.9	98.5	85.3
Color	Pt-Co	16	19.519	4.726	15.2	16.501	3	18.582
TDS	mg/L	9752	6680	174	358	214	5328	2860
TSS	mg/L	130	41	<10	193	158	29	63
Cl	mg/L	5657	4956	4.537	13.4	9.424	113	151.3
SO4	mg/L	186	181.5	11.05	91.5	19.6	4549	3973.9
F	mg/L	<0.1	0.188	0.274	<0.1	0.296	0.3	0.207
Alkalinity-Total	mg CaCO3/L	209	305	210	179	210	175.4	185
Alkalinity-HCO3	mg CaCO3/L	200	305	210	179	210	165	185
Alkalinity-CO3	mg CaCO3/L	8.8	0	0	43.4	0	10.5	0
Alkalinity-OH	mg CaCO3/L	0.14	0	0	0.13	0	0.11	0
Total P	mg/L	<0.2	<0.01	<0.01	1.8	<0.01	<0.2	<0.01
Reactive P	mg/L	0.065	<0.01	<0.01	0.14	<0.01	0.019	<0.01
NH3	mg/L	7.7	-	-	0.5	-	2.66	-
NH4-N	mg/L	-	4.8	<0.01	-	<0.01	-	<0.01
NO3-N	mg/L	<0.023	<0.02	3.533	<0.023	<0.02	<0.023	<0.02
NO2-N	mg/L	<0.002	0.01215	0.00304	<0.002	0.00218	<0.002	0.02199
N, organic	mg/L	3.36	2.48	<0.5	2.7	<0.5	2.8	<0.5
TKN	mg/L	9.7	7.28	<0.5	3.1	<0.5	5	<0.5
Ag	mg/L	<0.0005	0.025	<0.01	<0.0005	<0.01	<0.0005	0.011
Al	mg/L	0.291	0.043	<0.01	1.283	2.02	0.062	0.192
As	mg/L	<0.0034	<0.01	<0.01	0.028	0.158	<0.0034	<0.01
B	mg/L	<0.2	24.8	0.304	<0.2	0.769	<0.2	29.07
Ba	mg/L	0.13	0.101	0.038	0.072	0.099	0.031	0.014
Be	mg/L	<0.00004	<0.01	<0.01	<0.00004	<0.01	0.0001	<0.01
Bi	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Ca	mg/L	519.5	282.4	40.09	97.11	43.6	383.3	430.58
Cd	mg/L	<0.0002	<0.003	<0.003	<0.0002	<0.003	0.001	<0.003
Co	mg/L	<0.0005	<0.01	<0.01	0.001	<0.01	<0.0005	<0.01
Cr	mg/L	0.045	<0.01	<0.01	0.069	0.059	0.004	<0.01
Cu	mg/L	0.004	<0.01	<0.01	0.009	<0.01	0.007	<0.01
Fe	mg/L	19.58	7.3	0.019	2.104	2.27	3.025	7.49
Hg	mg/L	<0.00008	<0.001	<0.001	<0.00008	<0.001	<0.00008	<0.001
K	mg/L	81.44	82.01	0.442	51.93	13.23	28.9	43.59
Li	mg/L	3.36	4.05	<0.05	0.149	0.148	1.893	2.33
Mg	mg/L	286.1	183.7	27.95	26.37	28.2	195.3	237.45
Mn	mg/L	0.391	0.075	<0.01	0.099	0.227	0.142	0.218
Mo	mg/L	0.038	0.013	<0.01	0.013	<0.01	0.009	0.016
Na	mg/L	2586	1517.2	14.77	139.6	39.67	763.7	1080
Ni	mg/L	0.021	<0.01	<0.01	0.021	0.052	0.001	<0.01
P	mg/L	-	<0.05	<0.05	-	0.142	-	<0.05
Pb	mg/L	<0.0015	<0.01	<0.01	0.008	0.012	0.002	<0.01
Sb	mg/L	<0.002	<0.005	<0.005	<0.002	<0.005	0.002	<0.005
Se	mg/L	<0.005	<0.005	<0.005	0.01	<0.005	<0.005	<0.005
Si	mg/L	4.811	7.42	6.83	16.93	20.9	8.148	7.16
Sr	mg/L	14.1	14.29	0.473	0.654	1.09	5.314	5.52
Sn	mg/L	0.002	<0.05	<0.05	0.003	<0.05	0.003	<0.05
Ti	mg/L	<0.0002	<0.01	<0.01	0.018	0.012	<0.0002	<0.01
Tl	mg/L	<0.003	<0.05	<0.05	<0.003	<0.05	<0.003	<0.05
U	mg/L	<0.002	<0.0001	0.0011	<0.002	0.0015	0.004	0.00019
V	mg/L	<0.0005	<0.01	<0.01	0.008	0.013	<0.0005	<0.01
Zn	mg/L	0.048	<0.01	<0.01	0.118	0.224	0.313	<0.01
Total CN	mg/L	<0.01	<0.02	<0.02	<0.01	<0.02	<0.01	<0.02
TOC	mg/L	<1	<5	<5	<1	7.64	<1	<5
COD	mg/L	117.2	240	10	67.2	12	<15	30
Sulfur	mg/L	<0.002	<0.1	<0.1	<0.002	<0.1	<0.002	<0.1
Oil&grease	mg/L	<10	0.288	<0.1	<10	0.154	<10	0.117
Atrazine	µg/L	-	<0.01	<0.01	-	<0.01	-	<0.01
Chlorpyrifos	µg/L	-	<0.08	<0.08	-	<0.08	-	<0.08
Chlorfenvinphos	µg/L	-	<0.08	<0.08	-	<0.08	-	<0.08
Simazine	µg/L	-	<0.01	<0.01	-	<0.01	-	<0.01
pp-DDT	µg/L	-	0.00248	<0.001	-	<0.001	-	<0.001
Alachlor	µg/L	-	<0.01	<0.01	-	<0.01	-	<0.01
Endosulfan	µg/L	-	0.00104	<0.001	-	<0.001	-	<0.001
Trifluralin	µg/L	-	<0.001	<0.001	-	<0.001	-	<0.001
Diuron	µg/L	-	<0.01	<0.01	-	<0.01	-	<0.01
Isoproturon	µg/L	-	<0.01	<0.01	-	<0.01	-	<0.01
Total pesticides	µg/L	<0.25	<0.08*	<0.08*	<0.25	<0.08*	<0.25	<0.08*
Organophosphate pesticides	µg/L	<0.244	<0.08*	<0.08*	<0.244	<0.08*	<0.244	<0.08*
Organo chlorine pesticides	µg/L	<0.06	<0.01*	<0.01*	<0.06	<0.01*	<0.06	<0.01*
VOC	µg/L	<3.4	-	-	<3.4	-	<3.4	-
Tetrachloroethylene	µg/L	<0.8	<5	<5	<0.8	<5	<0.8	<5
Trichloroethylene	µg/L	<0.8	<5	<5	<0.8	<5	<0.8	<5
BOD5	mg/L	33.5	-	-	19.2	-	1.5	-
Fecal Coliform	cfu/100 ml	0	-	-	0	-	<1.8	-
Total Coliform	cfu/100 ml	0	-	-	0	-	<1.8	-
Alfa aktivity	Bq/L	<0.27	-	-	<0.05	-	<0.25	-
Beta aktivity	Bq/L	1.22	-	-	2.04	-	<1.13	-

Table F-5: Values of laboratory parameters measured in the hydrochemical monitoring locations of village water depots

Parameter	Unit	D1		D2		D3		F6D	
Date		May.15	Nov-15	May.15	Nov-15	May.15	Nov-15	May.15	Nov-15
Temperature	oC	19.2	16.1	21	14	22.6	10.5	17.3	13.7
pH		7.94	-	7.67	-	7.87	-	8	-
EC	µs/cm	565	535	275	353	588	577	370	360
DO	mg/L	6.63	7.63	7.07	9.96	7.96	9.34	8.85	9.08
DO	%	78.6	84.8	91.3	105.2	100.4	92.1	100.4	95.8
Color	Pt-Co	<2.2	-	<2.2	-	<2.2	-	<2.2	-
TDS	mg/L	190	258	128	168	216	280	182	172
TSS	mg/L	<4	<10	<4	<10	<4	<10	<4	<10
Cl	mg/L	22.7	19.055	9.51	8.178	27.6	27.715	5.61	4.241
SO4	mg/L	19	13.965	14	11.29	50	48.86	12	10.935
F	mg/L	0.26	0.372	0.31	0.398	0.2	0.311	0.22	0.274
Alkalinity-Total	mg CaCO3/L	267	165	156	185	201	235	164	205
Alkalinity-HCO3	mg CaCO3/L	267	165	156	185	194	235	164	205
Alkalinity-CO3	mg CaCO3/L	0	0	0	0	7	0	0	0
Alkalinity-OH	mg CaCO3/L	0.04	0	0.02	0	0.04	0	0.05	0
Total P	mg/L	<0.2	<0.01	<0.2	<0.01	<0.2	<0.01	<0.2	<0.01
Reactive P	mg/L	0.012	<0.01	0.011	<0.01	0.018	<0.01	0.016	<0.01
NH3	mg/L	0.041	-	<0.02	-	<0.02	-	<0.02	-
NH4-N	mg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
NO3-N	mg/L	6.26	6.386	3.02	3.553	5.74	6.477	3.02	3.623
NO2-N	mg/L	<0.002	<0.001	<0.002	0.0011	<0.002	0.00286	<0.002	<0.001
N, organic	mg/L	4.55	<0.5	3.75	1.74	3.2	0.55	3.47	0.69
TKN	mg/L	4.6	<0.5	3.75	1.75	3.2	0.56	3.47	0.7
Ag	mg/L	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01
Al	mg/L	<0.003	0.087	<0.003	0.066	0.013	0.06	0.007	0.1
As	mg/L	0.017	0.021	<0.0034	<0.01	0.005	0.01	<0.0034	<0.01
B	mg/L	0.22	0.436	0.23	0.104	0.4	0.438	<0.2	0.091
Ba	mg/L	0.124	0.118	0.122	0.124	0.064	0.095	0.043	0.041
Be	mg/L	<0.00004	<0.01	<0.00004	<0.01	<0.00004	<0.01	<0.00004	<0.01
Bi	mg/L	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01	<0.05	<0.01
Ca	mg/L	15.8	23.72	32.49	33.96	34.47	38.79	29.65	32.61
Cd	mg/L	0.404	<0.003	<0.0002	<0.003	<0.0002	<0.003	<0.0002	<0.003
Co	mg/L	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01	<0.0005	<0.01
Cr	mg/L	0.001	<0.01	<0.0003	<0.01	<0.0003	<0.01	<0.0003	<0.01
Cu	mg/L	<0.0002	<0.01	<0.0002	<0.01	0.242	<0.01	0.002	<0.01
Fe	mg/L	0.003	0.026	<0.00015	0.016	0.023	0.018	0.004	0.029
Hg	mg/L	<0.00008	<0.001	<0.00008	<0.001	<0.00008	<0.001	<0.00008	<0.001
K	mg/L	2.87	<0.05	0.389	0.401	2.362	2.93	0.367	0.453
Li	mg/L	0.121	0.099	0.021	<0.05	0.019	0.076	0.027	<0.05
Mg	mg/L	58.38	52.49	23.82	26.42	38.7	46.08	24.69	25.74
Mn	mg/L	<0.0002	<0.01	<0.0002	<0.01	0.035	<0.01	<0.0002	<0.01
Mo	mg/L	<0.001	<0.01	<0.001	<0.01	<0.001	<0.01	<0.001	<0.01
Na	mg/L	14.98	18.94	6.916	11.88	24.62	29.31	3.389	10.72
Ni	mg/L	0.002	<0.01	<0.0005	<0.01	0.014	<0.01	0.002	<0.01
P	mg/L	-	<0.05	-	<0.05	-	<0.05	-	<0.05
Pb	mg/L	0.002	<0.01	<0.0015	<0.01	0.004	<0.01	0.015	<0.01
Sb	mg/L	<0.002	<0.005	<0.002	<0.005	<0.002	<0.005	0.003	<0.005
Se	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Si	mg/L	26.43	19.68	11.54	9.16	17.11	13.94	8.204	6.64
Sr	mg/L	1.844	1.9	0.384	0.414	0.364	1.86	0.401	0.459
Sn	mg/L	<0.001	<0.05	<0.001	<0.05	<0.001	<0.05	<0.001	<0.05
Ti	mg/L	<0.0002	<0.01	<0.0002	<0.01	<0.0002	<0.01	<0.0002	<0.01
Tl	mg/L	<0.003	<0.05	<0.003	<0.05	<0.003	<0.05	0.004	<0.05
U	mg/L	0.002	0.0051	0.002	0.0015	0.003	0.0024	0.002	0.0013
V	mg/L	0.012	0.013	0.004	<0.01	0.003	<0.01	0.002	<0.01
Zn	mg/L	0.01	0.019	0.001	0.01	0.013	0.02	0.016	0.015

Table F.5. continued, * calculated values

Parameter	Unit	D1		D2		D3		F6D	
Date		May.15	Nov-15	May.15	Nov-15	May.15	Nov-15	May.15	Nov-15
Total CN	mg/L	<0.01	<0.02	<0.01	<0.02	<0.01	<0.02	<0.01	<0.02
Weak acid diss CN	mg/L	<0.01	<0.25	<0.01	<0.25	<0.01	<0.25	<0.01	<0.25
TOC	mg/L	<1	<5	<1	<5	<1	<5	<1	<5
KOİ	mg/L	38.4	5	23.2	7	<15	10	<15	20
Bromate	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Acrylamid	µg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
PAH	mg/L	<0.001	<0.00005*	<0.001	<0.00005*	<0.001	<0.00005*	<0.001	<0.00005*
Benzo(a)pyrene	mg/L	<0.0004	<0.00005	<0.0004	<0.00005	<0.0004	<0.00005	<0.0004	<0.00005
Benzo(b)fluoranthene	mg/L	<0.0004	<0.00005	<0.0004	<0.00005	<0.0004	<0.00005	<0.0004	<0.00005
Benzo(k)fluoranthene	mg/L	<0.0001	<0.00005	<0.0001	<0.00005	<0.0001	<0.00005	<0.0001	<0.00005
Benzo(g,h,i)perylene	mg/L	<0.0004	<0.00005	<0.0004	<0.00005	<0.0004	<0.00005	<0.0004	<0.00005
Indeno(1,2,3-cd) pyrene	mg/L	<0.0001	<0.00005	<0.0001	<0.00005	<0.0001	<0.00005	<0.0001	<0.00005
Atrazine	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Chlorpyrifos	µg/L	-	<0.08	-	<0.08	-	<0.08	-	<0.08
Chlorfenvinphos	µg/L	-	<0.08	-	<0.08	-	<0.08	-	<0.08
Simazine	µg/L	-	<0.02	-	<0.02	-	<0.02	-	<0.02
pp-DDT	µg/L	-	<0.001	-	<0.001	-	<0.001	-	<0.001
Alachlor	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Endosulfan	µg/L	-	<0.001	-	<0.001	-	<0.001	-	<0.001
Trifluralin	µg/L	-	<0.001	-	<0.001	-	<0.001	-	<0.001
Diuron	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Isoproturon	µg/L	-	<0.01	-	<0.01	-	<0.01	-	<0.01
Total pesticides	µg/L	<0.25	<0.08*	<0.25	<0.08*	<0.25	<0.08*	<0.25	<0.08*
Organophosphate pesticides	µg/L	<0.244	<0.08*	<0.244	<0.08*	<0.244	<0.08*	<0.244	<0.08*
Organo chlorine pesticides	µg/L	<0.06	<0.01*	<0.06	<0.01*	<0.06	<0.01*	<0.06	<0.01*
VOC	µg/L	<3.4	-	<3.4	-	<3.4	-	<3.4	-
Benzene	mg/L	<0.00084	<0.001	<0.00084	<0.001	<0.00084	<0.001	<0.00084	<0.001
1,2-Dichloroethane	µg/L	<0.6	<3	<0.6	<3	<0.6	<3	<0.6	<3
Tetrachloroethylene	µg/L	<0.8	<5	<0.8	<5	<0.8	<5	<0.8	<5
Trichloroethylene	µg/L	<0.8	<5	<0.8	<5	<0.8	<5	<0.8	<5
Trihalomethanes	µg/L	<1.9	<5	<1.9	<5	<1.9	<5	<1.9	<5
Vinyl Chloride	µg/L	<0.5	<5	<0.5	<5	<0.5	<5	<0.5	<5
BOD5	mg/L	3.32	<2	4.9	<2	4.95	2.04	3.3	4.11
Fecal Coliform	cfu/100 ml	0	0	0	0	0	0	30	0
Total Coliform	cfu/100 ml	0	30000	0	>100000	0	15000	30	15000
Fecal Streptecoc	cfu/100 ml	0	0	0	0	10	0	20	0
Escherichia Coli	cfu/100 ml	0	60	0	100	0	40	30	80
Enterococ	cfu/100 ml	0	0	0	0	0	0	20	0

APPENDIX G

RESULTS OF WATER QUALITY EVALUATIONS

Table G-1: Water quality of Porsuk stream waters

NO	DATE	SURFACE WATER CLASSIFICATION	IRRIGATION WATER CLASSIFICATION	DRINKING WATER SUPPLY SURFACE WATER CLASSIFICATION
SW3	May.15	CLASS IV- Cd, TKN, N-NH4, N-NO2, P	CLASS III-Cd, Na(I), TSS(A), Coli-f(A)	UNSUITABLE-BOD5, Cd, COD, TKN, N-NH3
SW3	Nov.15	CLASS IV- TKN, N-NO2, O2, O2%, P, Coli-f	CLASS III-Na(I), Na(II), TSS(A), TSS(B), Coli-f(A), Coli-f(B)	UNSUITABLE-BOD5, COD, TKN, O2%, P,reac, Coli-f, Coli-t, f-Streptecoc
SW4	May.15	CLASS IV- TKN, N-NH4, N-NO2, O2, O2%, P	CLASS III-Na(I), TSS(A), Coli-f(A), Coli-f(B)	UNSUITABLE-BOD5, COD, TKN, N-NH3
SW4	Nov.15	CLASS IV- BOD5, COD, TKN, O2, O2%, P, Coli-f	CLASS III-BOD5(A), BOD5(B), Na(I), Na(II), TSS(A), Coli-f(A), Coli-f(B)	UNSUITABLE-BOD5, COD, TKN, O2%, P,reak, TOC, Coli-f, Coli-t, f-Streptecoc

Table G-2: Water quality of spring and fountain waters

NO	DATE	GROUNDWATER CLASSIFICATION	IRRIGATION WATER CLASSIFICATION	HUMAN CONSUMPTION	INDICATOR PARAMETERS
F1	May.15	CLASS III-TKN, O2, O2%	CLASS II-Na(I), SAR-EC		
F1	Nov.15	CLASS III-TKN, O2, O2%	CLASS III-Na(I), TSS(A)		
F2	May.15	CLASS III-COD, TKN	CLASS II-Na(I), SAR-EC		
F2	Nov.15	CLASS II-TKN, O2, O2%, Renk, Yağ&gres	CLASS II-Na(I), SAR-EC		
F3	May.15	CLASS III-Cd, COD, TKN, O2, O2%	CLASS III-Cd, Na(I)	As, Cd	
F3	Nov.15	CLASS III-TKN, O2, O2%, Pb	CLASS III-Na(I), TSS(A), TSS(B)	As, Pb	
F4	May.15	CLASS III-Cr, TKN	CLASS III-Cr	Cr	
F4	Nov.15	CLASS III-TKN, pH	CLASS III-Na(I)		
F5	May.15	CLASS III-TKN	CLASS II-Na(I), SAR-EC		
F5	Nov.15	CLASS III-O2%	CLASS II-Na(I), SAR-EC	Sb	Al, Fe
F6	May.15	CLASS III-TKN	CLASS II-Na(I), SAR-EC		Fe
F6	Nov.15	CLASS III-O2%	CLASS II-Na(I), SAR-EC		Fe
F7	May.15	CLASS II-TKN, O2, O2%	CLASS II-Na(I), SAR-EC		
F7	Nov.15	CLASS II-N-NO2, O2, O2%, Yağ&gres	CLASS II-Na(I), SAR-EC		

Table G-3: Water quality of well waters

NO	DATE	GROUNDWATER CLASSIFICATION	IRRIGATION WATER CLASSIFICATION	HUMAN CONSUMPTION	INDICATOR PARAMETERS
W2	May.15	CLASS III-TKN	CLASS III-Na(I)		
W2	Nov.15	CLASS III-O2, O2%	CLASS III-Na(I)	As	
W3	May.15	CLASS III-TKN, O2, O2%	CLASS III-Na(I)	As	
W3	Nov.15	CLASS III-As, O2, O2%	CLASS III-Na(I)	As	O2
PK2	Aug.15	CLASS III-TKN, N-NO2, Na, SO4	CLASS III-Na(I), Na(II), TSS(A)	NO2	Fe, SO4
PK2	Oct.15	CLASS III-Al, B, EC, N-NO2, Na, O2, O2%, SO4	CLASS III-B, Mo, Na(I), Na(II)	B	Al, Fe, Mn, Na, O2, SO4
PK3	July.15	CLASS III-BOD5, Cl, COD, Fe, TKN, N-NH4, Na, TDS	CLASS III-BOD5(A), BOD5(B), Cl(I), Cl(II), Fe, Li, Mn, Mo, Na(I), Na(II), TDS, TSS(A), TSS(B), SAR-EC	Ni, Beta-ac	Al, Cl, Fe, Mn, Na, NH4
PK3	Oct.15	CLASS III-B, Cl, COD, EC, Fe, TKN, N-NH4, N-NO2, Na, O2, O2%, TDS	CLASS III-B, Cl(I), Cl(II), EC, Fe, Li, Mo, Na(I), Na(II), TDS, TSS(A), TSS(B)	B	Cl, EC, Fe, Mn, Na, O2, NH4
PK4	Oct.15	CLASS III-O2, O2%	CLASS III-Na(I)		O2
PK5	July.15	CLASS III-Al, BOD5, COD, Cr, Fe, TKN, Na	CLASS III-Mo, Na(I), Na(II), TSS(A), TSS(B)	As, Cr, Ni, Beta-Ac	Al, Fe, Mn, NH4
PK5	Oct.15	CLASS III-Al, As, Cr, Fe, Ni, O2, O2%	CLASS III-As, Mn, Na(I), TSS(A), TSS(B)	As, Cr, Ni, Pb	Al, Fe, Mn, O2
PK6	July.15	CLASS III-Fe, TKN, N-NH4, Na, SO4, TDS	CLASS III-Cl(II), Na(I), Na(II), TDS, TSS(A)		Fe, Mn, Na, NH4, SO4
PK6	Oct.15	CLASS III-B, EC, Fe, N-NO2, Na, O2, O2%, SO4, TDS	CLASS III-B, Cl(II), EC, Fe, Mn, Mo, Na(I), Na(II), TDS, TSS(A), TSS(B)	B	EC, Fe, Mn, Na, O2, SO4

Table G-4: Water quality of village depot waters

NO	DATE	HUMAN CONSUMPTION	INDICATOR PARAMETERS
D1	May.15	As, Cd	
D1	Nov.15	As, Coli-t, E-Coli	
D2	May.15		
D2	Nov.15	Coli-t, E-Coli	
D3	May.15		
D3	Nov.15	Coli-t, E-Coli	
F6D	May.15	Pb, Coli-t, E-Coli, Enterococ	
F6D	Nov.15	Coli-t, E-Coli	