Preliminary Water Supply Study

of the Thermoelectric Livadia Power Plant

Contents

1. INTRODUCTION

1.1 SCOPE AND OBJECTIVES OF THE STUDY

The general scope of the *Feasibility Study – Preliminary Water Supply Study of the Thermoelectric Livadia Power Plant* is the examination of the water resources conditions and the alternatives concerning the water supply of the plant. Analytically, the aims of the present study are:

a) The examination of the availability of surface waters or groundwaters in the work area and in the broader area.

b) The estimation of the capacity of the candidate water resources and their ability to cover the plant' s needs especially the cooling needs for the various alternatives of the cooling systems.

c) Support of the overall water use permit procedure.

More specifically, the objectives of the study is:

1) The brief description of the total water use permit procedure and the relative crucial issues according to the law 1739/87 and the other local or national legislative provisions.
2) The examination of the availability of the existing surface waters and groundwaters in the nearest and broader work area.
3) The definition of the current status of these water resources concerning both quantity and quality.
4) Preliminary estimation of the potential of these water resources and their ability to cover the plant' s needs.
5) Preliminary geotechnical estimation of the possible effects from the uptake of groundwaters on the surface of the work area and especially on the foundation of the constructions.
6) Examination of the used water discharge limits and the relative limitations (in terms of the outflow and their quality characteristics).
7) Classification of the water resources with regard to possible further detailed researches.
8) The coverage, under broader concept, of the needs of the water use permit procedure. This means the scientific coverage of the existing issues, part of which will be used in a later stage to create a submission record for the granting of the water use permit.

For the editing of the study, adequate data of surface and groundwater hydrology was collected and processed and the existing literature concerning the broader work area and the legal framework regarding the water resources was surveyed. In additional, in the context of the study, two visits were made in the work area, aiming at the collection of primary data, which were used in the analysis and in the examination of the local conditions.

1.2 BRIEF DESCRIPTION OF THE WORK

The thermoelectric Livadia power plant will consist of one combined cycle unit, of power of about 390 MW, consisting of a gas turbine of power of about 260 MW and a steam turbine of power of about 130 MW, as well as an auxiliary gas turbine unit of open cycle, of power of 60 MW. The power plant will use the natural gas for fuel, but it will also be able to operate with diesel oil as reserve.

The water needs of the power plant arise at the mean annual value of 580 m^3/h, a quantity that corresponds to 4.9 hm^3/year. The water uses refer to the following categories:

Cooling System: The wet cooling tower system discards the heat through the evaporation of water. It must be noted that only 60% of the water quantity required by the tower for replenishment evaporates, while the rest 40% returns to the environment.

Moderation of the NOx emissions: During the oil burning, the gas turbines require the water infusion in order to moderate the emissions of nitrogen oxides and comply with the existing strict limits. This water is discarded in the environment together with the exhausts of the gas turbine.

Water replenishment in the steam turbine and rest industrial uses: The water is used for the steam production in the steam turbine. The 2-5% of the total water and steam quantity circulating in the steam turbine circuit must be replenished.

Other uses: Limited water quantities are also used in the power plant for sanitary purposes, washing of the equipment or the plant area etc.

The Table 1.1 shows the required water quantities for each use (mean annual value).

Table 1.1: Water uses and required discharges of the thermoelectric Livadia power plant.

Water use	Discharge (m^3/hour)	Discharge (m^3/year)
Water replenishment in the cooling system	550 [1]	4 675 000 [2]
Moderation of the NOx emissions for the main gas turbine of 260 MW	100	50 000 [3]
Moderation of the NOx emissions for the auxiliary gas turbine of 60 MW	30	30 000 [4]
Water replenishment in the steam turbine	15	125 000
Other uses	3	20 000
SUM	580	4 900 000

(1) Mean value

(2) 40% of the quantity in question (220 m^3/hour) returns to the environment

(3) Predictable consumption based on oil operation of 500 hours/year

(4) Predictable consumption based on oil operation of 1000 hours/year

It should be noted that the peak flows of the plant should be considered higher than the mean, reaching to 800 m3/h, during the hotest days of the summer.

1.3 BRIEF DESCRIPTION OF THE STUDY AREA

1.3.1 Geographic location

The thermoelectric Livadia power plant is going to be installed in the location "Kommatia", in the area of Agios Vlasios, Viotia, nearby the railway station of Daulia and just after the place where the

Mauroneri stream meets the old highway Livadia – Lamia. The area in question is flat, with an absolute attitude of 110-130m, covered by plats. River Viotikos Kifissos traverses this area, and all the rest streams of its local basin flow in it, with Mauroneri stream being the most basic one. The natural boundaries of this basin are the Filovioto mountain at north, the Idilio mountain at northeast, the Akodio mountain at east and the Parnassos mountain at west-southwest. In the work site there are no very big built-up areas. The communities that are closer to the work site are those of Agios Vlasios and Mauroneri, both under the municipality of Daulia. In the eastern basin boundary there is the Municipality of Heronia, which constitutes the center of the area' s agricultural economy. The broader work area as well as the exact location of the thermoelectric power plant are shown in Map 1.

Map 1: The broader work area

1.3.2 Water uses and water resources exploitation works

In the broader work area, water uptakes are taking place both from the surface waters and the groundwaters as well, designated to cover not only the local needs but also regional ones (including more distant needs like Athens). The local water uses concern the irrigation of the areas of Mauroneri, Agios Vlasios, and Heronia, either by flooding or by sprinkler techniques. According to 1996 data, the near area of cultivated land exceeds 23.000 m^2, from which an area of 2.300 m^2 is under Heronia TOEB (Local Organization of Land Reclamation) water supply net, the rest land being not irrigated from public water supply nets (Zarris a.o., 1999). Taking that the annual irrigation needs in the area come up to 800 mm, the local irrigation needs are estimated at 18.4 hm^3/year (*h stands for million*). The rest water uses concern uptakes that take place for the irrigation of Kopaida and, in emergencies, for the water supply of Athens.

The main technical works for the exploitation of the regional water resources including the major drills have been constructed by EYDAP (State Association for drinking water supply and sewarage of Athens) and YPGE (Ministry of Agriculture) aiming for Athens supply as well as for irrigation support of Kopaida area. These works include the water conveyance system of drilled waters along the middle flow of Viotikos Kifissos, the water supply system of Distomo, which starts at the regulator structures in Mauroneri and ends at the water supply system of Mornos, as well as the water supply reservoir of Kopaida, starting at the regulator structures and ending at the inland ditch of Kopaida. The exploitation works are shown in map 2, which follows. It must be noted here that the surface waters of Viotikos Kifissos do not require particular exploitation works (except for some small water uptake works of temporal nature, in order to serve irrigation aims), as they all gather in the Iliki lake, from where they are pumped for the water supply of Athens and the irrigation of Kopaida.

Concerning the drills of the Ministry of Agriculture, which are 14 in total, were opened up in the seventies and extend parallel to the Viotikos Kifissos, along the axis of the areas Akondio, Heronia and Mauroneri. The waters of the drills are disposed through the water supply system of Kopaida for the irrigation of the Kopaida field, while the quantities pumped annually are estimated at about 15.9 hm^3 (Zarris a.o., 1999). Before the construction of the water supply system, the waters were canalized directly in the river, resulting to great losses due to infiltration and evaporation. On the other hand, the drills of EYDAP, which are 12 in total, were opened up in the period of the intense drought in the beginning of the nineties and they are located uphill the study area, in the sites of Vasilika and Parori. These last ones serve two water uses (water supply and irrigation), as they can supply both the water supply system of Mornos (through the water supply reservoir of Distomo) and the water supply reservoir of Kopaida, with discharges of about 3.0 hm^3/month (Antoniou-Peppas a.o. 1993 · Zarris a.o., 1999). The irrigation uptakes from the drills of Vasilika and Parori during the last years, which are taking place following a special agreement between EYDAP and peasants, are shown in the Table 1.2 (Vlagoulis 2001, personal contact).

Map 2: Major exploitation works in the broader work area.

Table 1.2: Annual irrigation uptakes from the drills of Vasilika and Parori.

Year	Annual uptake (hm^3)
1996	6.600
1997	4.800
1998	6.336
1999	0.000
2000	0.499
2001	0.000

Apart from the drills of the YPGE and EYDAP, which both drill water from the carstic aquifer, there is also an unknown number of drills of smaller potential, which serve local water uses. Most of them belong to private individuals and drill water mainly from the alluvial aquifer (forth-born depositions). However, there are also some communal drills drilling water from the carstic aquifer. The recording and a more detailed description of the hydro-drills in the neighborhood of the work can be found in the paragraph 3.3.4.

1.4 STRUCTURE OF THE REPORT

The present study includes, apart from the introduction (Chapter 1), five more chapters and two annexes.

In Chapter 2 the features of the surface water resources are analyzed. The analysis focalizes in the sub-basin of river Viotikos Kifissos, where the thermoelectric power plant is going to be installed. In the water potential of this sub-basin, two big streams of torrential flow and the Mauroneri carstic springs are included.

In Chapter 3 the geological formation of the study area and the prevailing hydrogeological conditions, as well as the potentiality of water-drilling from the groundwater aquifers are examined. In addition, the possible impacts from the construction of water-drills for the water supply of the thermoelectric power plant are considered.

In Chapter 4 the relative legislative status concerning the regional water resources management is examined.

In Chapter 5 the emission limits of the used water and the corresponding confinements (regarding the discharge and the qualitative features) are reported.

In Chapter 6 the main conclusions of the study are summarized, the alternative solutions are evaluated and some proposals for further research are formulated.

In Annex A the detailed tables of the hydrologic data that either were used or created in the context of the study are shown.

Closing, the Annex B contains photos that were taken during the visit of members of the study team in the broader work area in the beginning of November 2001.

2. SURFACE WATER RESOURCES

2.1 INTRODUCTION

This chapter investigates the availability and detects the characteristics of the surface water resources around the Livadia power station area. For this purpose, monthly runoff series in specific sites of the study area were produced, taking as basis the historical runoff data at the outlet of Viotikos Kifissos river basin and a set of 12-year discharge measurements, implemented by the Institute of Geology and Mineral Exploration (IGME).

2.2 HYDROGRAPHIC NETWORK

To project belongs to Viotikos Kifissos river basin, which extends in a total area of 2042.6 km^2. The outlet of the basin is Karditsa canal, via which the flow of the river is conducted to the Lake Yliki. The total length of the main river branch, including some local cuts of its bed, exceeds 100 km. Although Viotikos Kifissos is a surface water body, it has strong linkage and interaction with the karstic aquifers of the region. Indeed, it is well-known that the major supply of Viotikos Kifissos is due to karstic springs, the most important of which are those of Melas (Orchomenos). Other important springs are those of Polygyra, Erkyna and Mavroneri. Through the watershed, many small tributaries are also running, which normally have occasional flow.

The main streams that lie into the project's neighborhood are those of Platania and Vathryrema (Agios Vlassios). Both streams are supplied from the runoff of Mountain Parnassos and lead to the Mavroneri channel. Platania catchment has an area of 170.7 km^2, whereas Vathryrema catchment has an area of 31.1 km^2 (see following Map 3). Particularly, Platania watershed, which is the greater of the two basins, includes very high altitudes of more than 2000 m. According to habitants' witnesses, during high-flow periods, Platania stream can retain a permanent flow until April. However, during drought or moderate-flow periods, runoff is rare and happens only in case of intense storms. On the other hand, some small streams on the northeast side of Boeoticos Kifissos that drain an area of 30-35 km^2, are totally out of interest, because they lie on a particularly penetrable geological formulation (karstic limestone), and hence their runoff is negligible.

Map 3: Hydrologic basins

The karstic springs into the project's vicinity are those of Mavroneri (near the homonymus village) and Agios Vassileios, on the foothill of Akontion Mountain (the latter operate occasionally). The outflow of Mavroneri springs (supplied by the upstream karstic aquifers) is collected into a small bog and then is conducted to Viotikos Kifissos, via a terrene channel (Mavroneri channel). In the inlet of the channel there is a lock-gate, via which water can be conveyed to a concrete-faced canal that ends to the Distomo diversion project. Afterwards, it can be pumped and conveyed to the Mornos aqueduct, in order to supply Athens. Along Mavroneri channel there are also some casual withdrawal facilities for the irrigation of the adjacent fields.

The area of Mavroneri springs has a special environmental interest and it is protected (Zarris et al., 1999). According to the related environmental impact assessment study, the minimum water-level of the bog has to be 0.5 m (Antoniou-Peppas et al., 1993). Generally, Mavroneri springs have a significant water potential. Nevertheless, the intensive withdrawals from Vassilika and Parori wells had as consequence the interruption of their operation in two cases. First, in 1994, when 44 hm^3 were pumped (mainly for the supply of Athens), their discharge was interrupted during all the year, apart from the period between March and June. Next year, pumping was stopped and the aquifer was reverted to the former situation. However, due to the recent water shortage and albeit the almost totally interruption of pumping during 2001, the springs were drought again. This situation is continuing for more than one year (from August 2000), except a small period of few days during April 2001 (IGME, Livadia dept., personal communication).

2.3 HYDROLOGIC DATA

The surface hydrology data that was used in this study were a) the monthly runoff sample at the outlet of Viotikos Kifissos watershed, which covers a period of about 100 hydrological years (1907-2001) and has been extracted within the framework of various research projects of the National Technical University of Athens (Roti et al., 1990· Nalbantis, 1999· Efstratiadis et al., 2001), and b) a set of discharge measurements in various sites through Viotikos Kifissos river basin, implemented by the Institute of Geology and Mineral Exploration during the period 1983-94 (Pagounis et al., 1994).

The monthly runoff record of Viotikos Kifissos, which is the longest in Greece, is based on daily stage measurements in Karditsa canal that are implemented from the beginning of the 20th century (1907). During the long operation of the canal, there were many changes in both the geometry of the section and the stage gauge. At present, runoff data is daily recorded by the Athens Water Supply and Sewage Company (EYDAP), who manages and exploits the water resources of Lake Yliki.

The discharge measurements by IGME were made at 11 different places of Viotikos Kifissos and its main tributaries. Three of them lie near the project area, particularly in Heronia (Agios Vassileios), Davlia (railway station) and Mavroneri channel. In the related sites, monthly runoff series were extracted, according to the methodology that is described thereafter. Moreover, IGME has implemented a set of discharge measurements at 11 main springs of Viotikos Kifissos watershed, including Mavroneri springs. Table 2.1summarizes the major characteristics of discharge measurements of interest, providing an approximate estimation about their water potential.

Table 2.1: Characteristic data about the discharge measurements that IGME was implemented in particular sites of interest.

Name	Number of measurements	Mean discharge (m^3/h)	Mean discharge (m^3/s)
Karditsa canal	170	42521	11.8
Heronia (Agios Vassileios)	102	19973	5.5
Davlia (railway station)	144	10555	2.9
Mavroneri channel	109	5767	1.6
Mavroneri springs	255	5371	1.5

2.4 HYDROLOGICAL DATA PROCESSING

2.4.1 Viotikos Kifissos runoff data

Table 2.2 presents the main statistical characteristics (mean and standard deviation) of Viotikos Kifissos runoff in the outlet of its basin, whereas the whole sample is given in Appendix A. We note that during the period 1964-68, when the canal was under repair, as well as the period 1976-77, when a new canal was constructed, they do not exist original discharge measurements. For the above periods, the gaps were completed via linear interpolation between runoff and rainfall data of Aliartos gauge (Efstratiadis et al., 2001).

Table 2.2: Statistical characteristics of Viotikos Kifissos monthly runoff (hm^3) – Hydrologic years 1907-08 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	21.8	31.1	46.2	59.5	62.2	66.5	46.0	24.2	12.0	4.1	3.5	12.9	373.5
Standard deviation	10.8	17.7	32.3	31.0	33.8	31.0	27.1	16.3	11.6	7.3	5.2	8.7	155.4

As Figure 2.1 indicates, there is an evident reduce of Viotikos Kifissos annual runoff during the past 30 years, which is due to both the decrease of groundwater resources because of pumping rising, either for irrigation of Kopais plain or Athens' supply, and the decrease of precipitations; the latter arises after analyzing the Aliartos rainfall record (Nalbantis et al., 1993). Therefore, only part of the runoff sample can be representative of the hydrological regime of the watershed. Thus, in our analysis, we have taken into account part only of the total runoff sample, starting from 1968-69, when the canal was re-operated after a 5-years repair period. The statistical characteristics of this sample are given in Table 2.3.

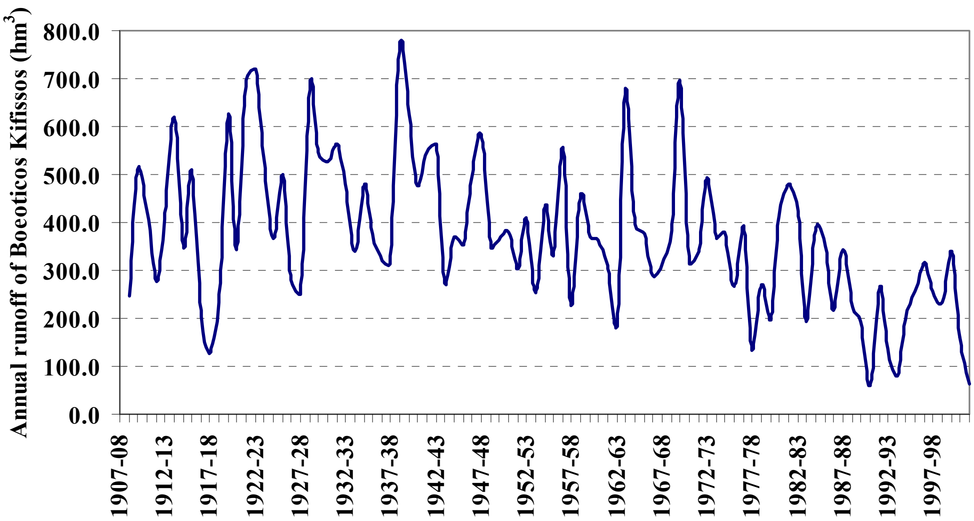

Figure 2.1: Annual runoff of Viotikos Kifissos at Karditsa canal.

Table 2.3: Statistical characteristics of Viotikos Kifissos monthly runoff (hm^3) – Hydrologic years 1968-69 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	16.3	22.7	36.7	48.4	46.9	56.7	37.8	16.2	3.2	0.4	1.1	7.5	286.4
Standard deviation	11.6	11.2	32.9	30.9	24.2	27.1	24.1	14.7	5.0	1.0	2.5	8.0	135.5

According to the above assumptions, the mean annual runoff of Viotikos Kifissos is reduced to 286.4 hm^3, versus the much higher value of 373.5 hm^3, if the whole sample is used. However, the mean annual value of the past 30-years period may be a little underestimated. This is due because, during the irrigation period, the farmers upstream of Karditsa canal quite often construct small dams, blocking the river flow. Recently, this situation was intensified and, especially, last year, when the absolute lowest runoff value of 64.5 hm^3 was observed, the bed of the river was occluded from April.

Given that the sample of Viotikos Kifissos runoff was used as basis for the generation of equivalent historic runoff series upstream of Karditsa canal, its summer values had to be corrected, in order to be consistent with the actual hydrologic state that supposes an almost permanent summer flow, as it is clearly shown in Figure 2.2.

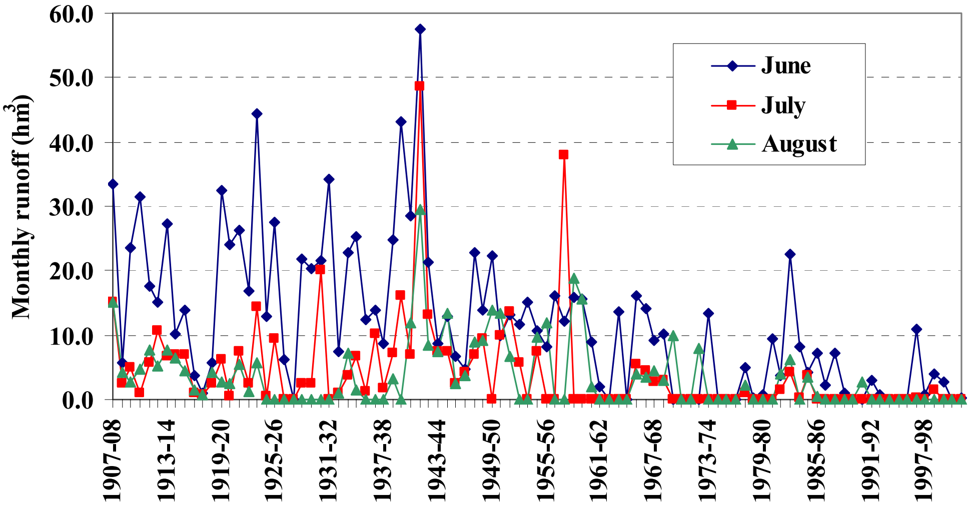

Figure 2.2: Monthly summer runoff of Viotikos Kifissos at Karditsa canal.

The proposed methodology was based on the hypothesis that, during the summer period, the aquifer can be simulated as a reservoir that feeds the river by a constant outflow rate (recession coefficient) λ, while its inflow due to rainfall is negligible. Let $S(0)$ be the reservoir storage at May and let $Q(0)$ be the corresponding runoff at the Viotikos Kifissos outlet. Under the above consumption we get:

$$Q(0) = \lambda \, S(0) \quad (2.1)$$

At the end of next month (i.e. June), groundwater storage becomes $S(1) = (1 - \lambda)\, S(0)$, whereas the outflow to the river is $Q(1) = \lambda \, S(1)$. Generalizing for all summer months $t = 1, 2, 3$ (June, July, August) and after manipulations, we get that monthly runoff is given by the exponential equation:

$$Q(t) = (1 - \lambda)^t \, Q(0) \quad (2.2)$$

The above relationship was applied to the summer runoff sample of the period 1907-1960. After optimization, the recession coefficient value was found equal to 46.5%. From Figure 2.3, where the computed versus the historical runoff values of June are compared, it can be clearly shown that, in spite of the simplicity, the application of the model was quite satisfactory.

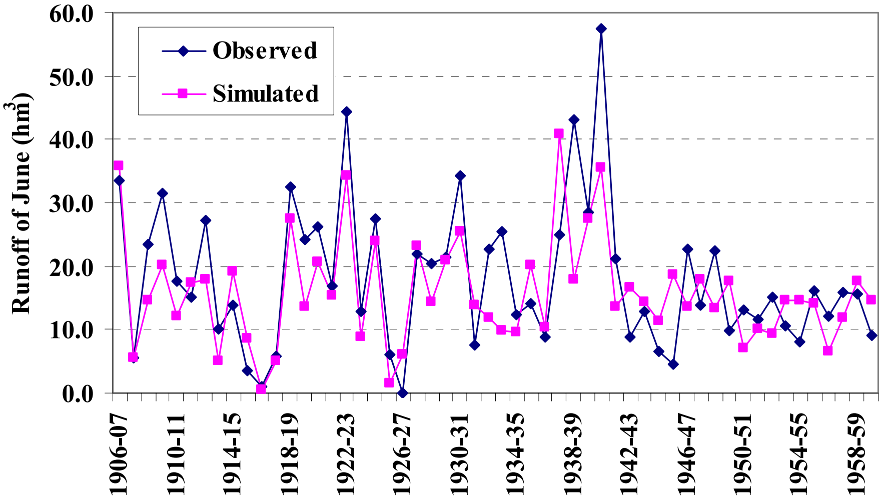

Figure 2.3: Comparison of observed versus simulated runoff values of month June at the outlet of Viotikos Kifissos river basin.

Next, all summer runoff values of the analysis period (1968-2001) were re-estimated by applying the exponential relationship. If any corrected value was smaller that the measured one, the latter was accepted as a better estimator of the actual runoff. After that, the mean summer runoff was increased from 4.7 hm^3 to 17.4 hm^3, a value very close to the mean historical of the whole sample (19.6 hm^3). Also, the mean annual runoff value became 299.2 hm^3 (9.7 m^3/s), versus 286.4 hm^3 of the former sample (Table 2.4).

Table 2.4: Statistical characteristics of Viotikos Kifissos monthly runoff, after correction of the summer values (hm^3) – Hydrologic years 1968-69 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	16.3	22.7	36.7	48.4	46.9	56.7	37.8	16.2	9.4	5.0	3.0	7.5	299.2
Standard deviation	11.6	11.2	32.9	30.9	24.2	27.1	24.1	14.7	7.6	4.1	2.4	8.0	142.6

2.4.2 Generation of Viotikos Kifissos runoff samples at Heronia and Davlia discharge gauges

The calculation of Viotikos Kifissos runoff series at Heronia and Davlia discharge gauges was based on statistical correlation of discharge measurements at the above sites and Karditsa canal (Pagounis et al., 1994).

First, the simultaneous discharge measurements at Heronia (Agios Vassileios) and Karditsa canal were distinguished (24 measurements in total), and then a statistical correlation between them was employed. From the above sample, we excluded one measurement that was made during a storm event and, also, two measurements that were not consistent, because the upstream value (Heronia) was greater than the downstream one (Karditsa canal). After analysis, the optimal correlation between the discharge samples, expressed in m^3/s, was found to be the exponential, which is given by the equation:

$$Q_{HERONIA} = 0.249\ Q_{KARDITSA}^{1.221} \qquad (2.3)$$

The determination coefficient of the above relationship is r^2 = 0.706, which is a quite satisfactory value. Although, we investigated if it is feasible to increase the related coefficient, using more measurements that refer to very close (but not common) measurement dates. Hence, we incorporated the measurements at Karditsa canal that were implemented one day after those at Heronia, which can be accepted under the condition that these are no storm events (27 measurements in total, from which 4 were excluded). Those events were easily distinguished according to discharge values, by setting as offset the value of 30 m^3/s. Then, the regression relationship was slightly modified and became:

$$Q_{HERONIA} = 0.210\ Q_{KARDITSA}^{1.268} \qquad (2.4)$$

Therefore, we managed to increase the determination coefficient up to r^2 = 0.788. The measurements of the two discharge samples that were used in the analysis are given in Appendix A, whereas their scatter diagram is shown in Figure 2.4.

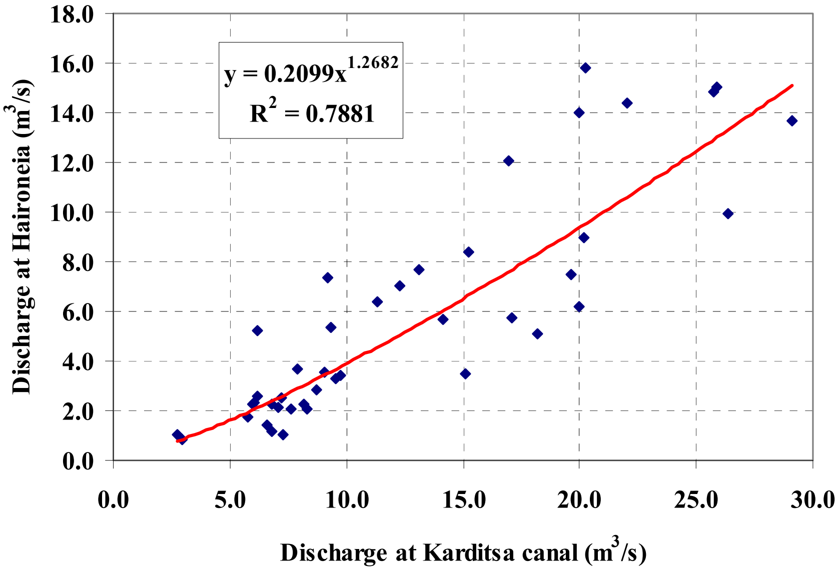

Figure 2.4: Plot of Viotikos Kifissos discharge measurements at Karditsa canal versus Heronia (Agios Vassileios).

The regression relationship (2.4) was applied for the computation of Viotikos Kifissos monthly runoff at Heronia gauge, which lies a little downstream of the project. The main statistical characteristics of the sample, which covers a 33-years period from 1968-69 to 2000-01, are given in Table 2.5. Its mean annual value is 137.5 hm^3 (4.4 m^3/s) and corresponds to 46% of the mean annual runoff at the outlet of Viotikos Kifissos watershed.

Table 2.5: Statistical characteristics of Viotikos Kifissos monthly runoff at Heronia (Agios Vassileios) discharge gauge (hm^3) – Hydrologic years 1968-69 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	6.0	8.9	16.9	23.4	22.8	28.1	17.4	6.2	3.1	1.4	0.7	2.5	137.5
Standard deviation	5.2	5.5	22.7	19.4	14.3	15.9	13.0	6.8	3.0	1.3	0.7	3.0	81.7

The same methodology was applied for the extraction of the runoff sample at Davlia. First, we detected the simultaneous discharge measurements at Karditsa canal (25 measurements in total, from which 7 were excluded) as well as the measurements that were implemented one day after (27 measurements in total, from which 9 were excluded). In that case, the optimal correlation between the two samples was proved the linear one, having a determination coefficient equal to $r^2 = 0.827$. Its analytical expression is (values in m^3/s):

$$Q_{DAVLIA} = 0.424\ Q_{KARDITSA} - 1.866 \qquad (2.5)$$

The above relationship, albeit satisfactory about its determination coefficient value, has the disadvantage that runoff at Davlia becomes negative if the corresponding value at Karditsa canal is less than 4.4 m^3/s, thus eliminating the majority of the relative summer runoff values. Therefore, we searched for an alternative linear regression relationship, based on the Heronia runoff sample. In that case, we used only simultaneous discharge measurements canal (56 measurements in total, from which 5 were excluded). In order to avoid negative values, we adopted the homogenous expression:

$$Q_{DAVLIA} = 0.591\ Q_{HERONIA} \qquad (2.6)$$

The determination coefficient of the above relationship is equal to $r^2 = 0.819$, that is slightly reduced if compared with the former value. The scatter diagram of the two samples is shown in Figure 2.5.

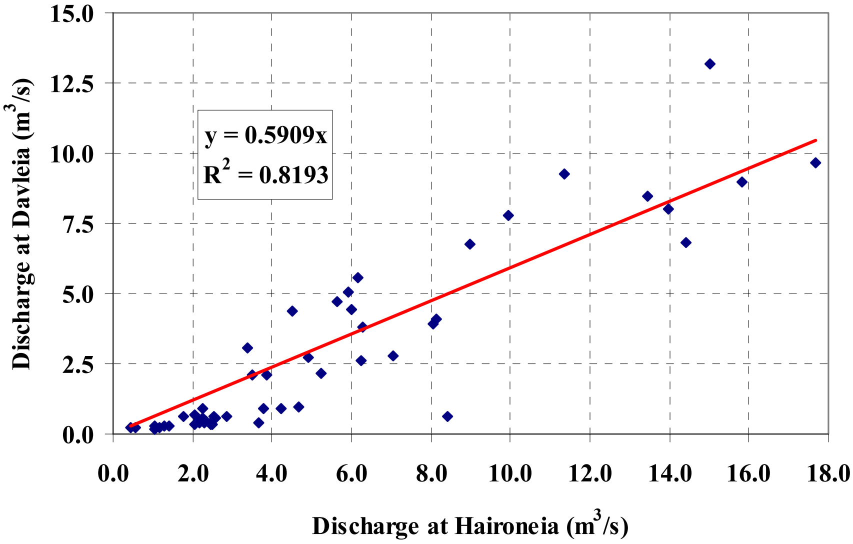

Figure 2.5: Plot of Viotikos Kifissos discharge measurements at Heronia (Agios Vassileios) versus Davlia (railway station).

The regression relationship (2.6) was applied for the computation of Viotikos Kifissos monthly runoff at Davlia gauge, which lies a little upstream of the project. The main statistical characteristics of the sample are given in Table 2.6. Its mean annual value is 181.2 hm^3 (2.6 m^3/s) and corresponds to 27% of the mean annual runoff at the outlet of Viotikos Kifissos watershed.

Table 2.6: Statistical characteristics of Viotikos Kifissos monthly runoff at Davlia (railway station) discharge gauge (hm^3) – Hydrologic years 1968-69 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	3.6	5.2	10.0	13.8	13.5	16.6	10.3	3.7	1.8	0.8	0.4	1.5	81.2
Standard deviation	3.0	3.2	13.4	11.5	8.4	9.4	7.7	4.0	1.8	0.8	0.4	1.8	48.3

The annual runoff series at the three sites examined (i.e., Karditsa canal, Heronia and Davlia) are plotted in Figure 2.6. The diagram clearly indicates that the intermediate watershed between Heronia and Davlia has a significant water potential that represents, in average, 19% of the mean annual runoff at the outlet of Viotikos Kifissos watershed. An further investigation of the related potential is done below.

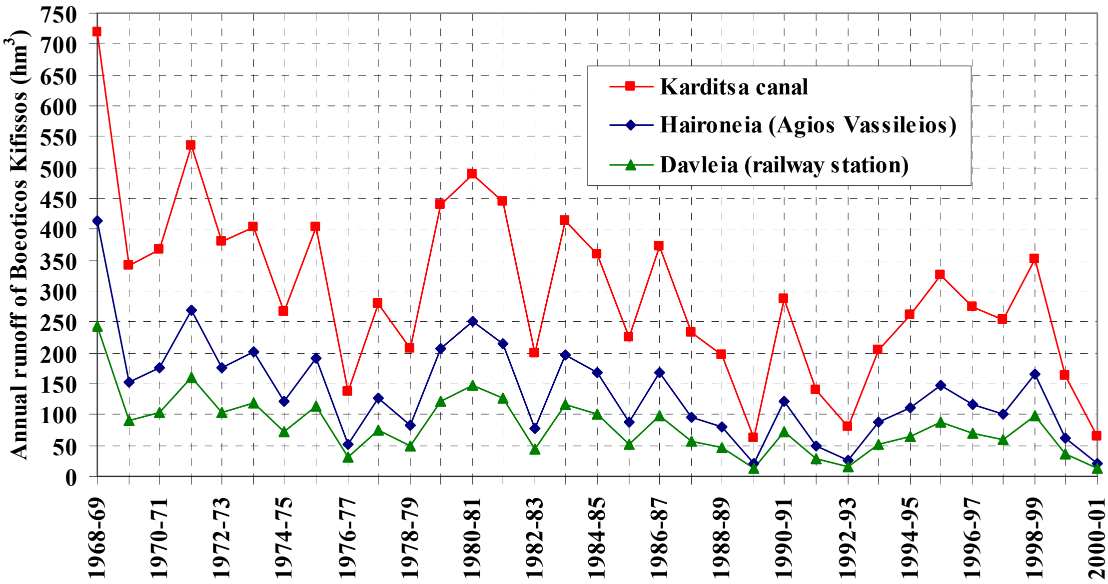

Figure 2.6: Annual runoff series of Viotikos Kifissos at Karditsa canal (outlet of the river basin), Heronia and Davlia.

2.4.3 Estimation of Heronia-Davlia watershed potential

According to the above analysis, the sub-basin between Heronia and Davlia discharge gauges, where the project is sited, seems to have a quite rich water potential. This potential arises by extracting the runoff sample at Davlia from the corresponding runoff sample at Heronia. The remaining sample has a mean annual value of 56.2 hm^3 (Table 2.7). However, only a limited percentage of this potential derives from surface runoff, because the rest part is due to Mavroneri springs supply. In order to evaluate the surface water potential it is necessary to calculate the outflows of Mavroneri springs. A direct evaluation of it is not possible, because they do not exist discharge measurements into the watershed (mainly at Platania stream).

Table 2.7: Statistical characteristics of total (surface and spring) monthly runoff of Heronia-Davlia watershed (hm^3) – Hydrologic years 1968-69 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	2.5	3.6	6.9	9.6	9.3	11.5	7.1	2.5	1.3	0.6	0.3	1.0	56.2
Standard deviation	2.1	2.2	9.3	8.0	5.8	6.5	5.3	2.8	1.2	0.6	0.3	1.2	33.4

IGME has implemented discharge measurements at two sites along Mavroneri channel. The upstream measurements have been done near the springs, whereas the downstream ones were done after the contribution of Platania and Vathyrema streams, particularly at the junction with the road Livadia-Lamia, very close to the project site. However, because the flow of the streams in only occasional, we can assume that in both sites the same discharge is measured and thus, the two samples are almost equivalent. This is clearly shown in Figure 2.7, where the simultaneous measurements are plotted; moreover the average values of the discharge samples are almost equal (Table 2.1).

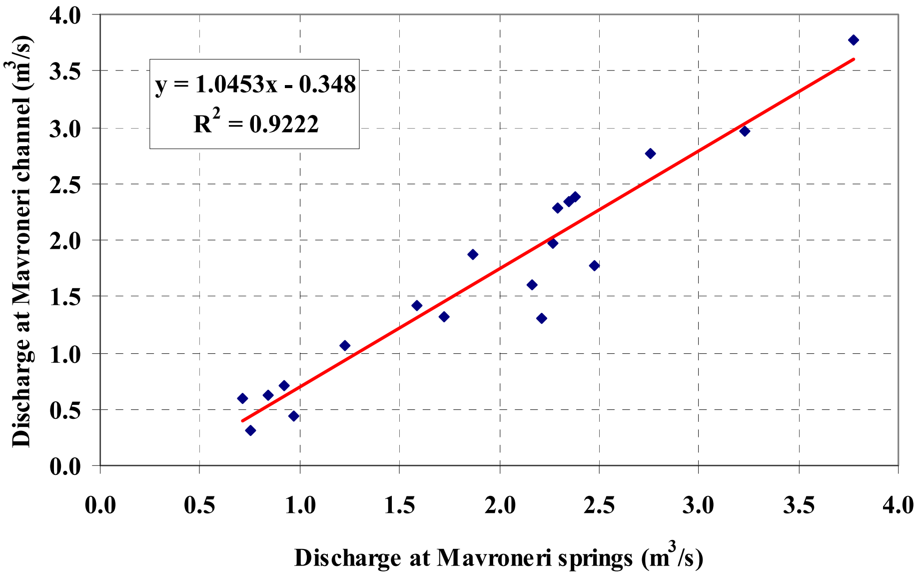

Figure 2.7: Plot of discharge measurements at Mavroneri springs versus Mavroneri channel.

For the computation of Mavroneri springs outflow, we employed a statistical correlation between the discharge measurements at Mavroneri channel and the corresponding sample of Viotikos Kifissos at Heronia. We finally chose the downstream sample at Mavroneri channel, which contained over than twice (45 versus 20) simultaneous measurements with Heronia gauge. After analysis, we found that the optimal correlation between the two samples is the logarithmic one. Its determination coefficient is equal to r^2 = 0.842 and its analytical expression (in m^3/s) is:

$Q_{MAVRONERI}$ = 0.878 Ln ($Q_{HERONIA}$) + 0.649(2.7)

The logarithmic correlation between the samples (Figure 2.8 confirms the initial hypothesis that the discharge measurements at Mavroneri channel derive almost exclusively from the springs. The latter can maintain a permanent flow, with the exception of periods of persistent droughts, when, simultaneously, intensive withdrawals from upstream groundwater resources are taken place. We can also observe that, even if Viotikos Kifissos discharge take high values, the outflow of the spring remains constant, around 3.5 to 4.0 m^3/s.

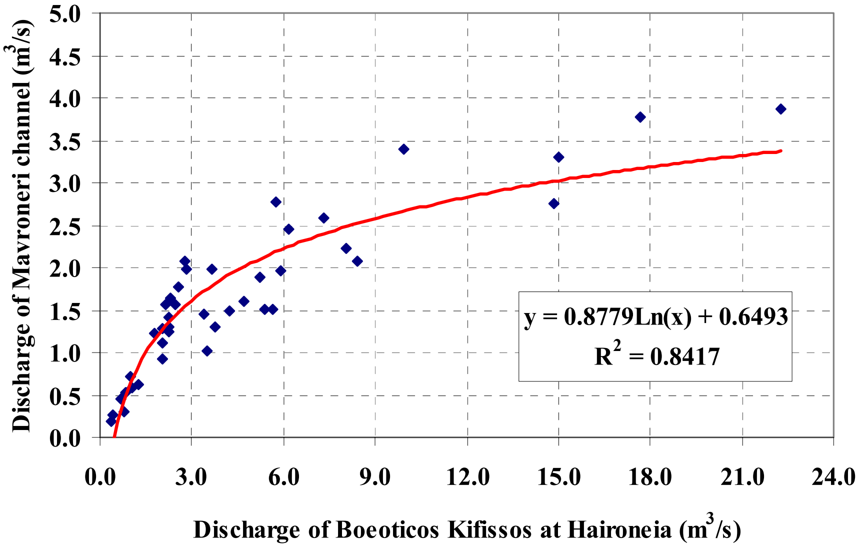

Figure 2.8: Plot of discharge measurements at Viotikos Kifissos (Heronia gauge) versus Mavroneri channel.

The main statistical characteristics of Mavroneri springs outflow sample, that was computed by applying the logarithmic regression relationship, are given in Table 2.8. Its mean annual value is 42.4 hm^3 (1.3 m^3/s), versus 56.2 hm^3 (1.8 m^3/s), which is the average value of the whole annual runoff sample of the watershed (Table 2.7). That indicates that only 25% of water resources of Heronia-Davlia catchment are due to pure surface runoff.

Table 2.8: Statistical characteristics of Mavroneri springs monthly runoff (hm^3) – Hydrologic years 1968-69 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	2.9	4.0	5.3	6.2	5.8	6.7	5.1	2.7	1.7	0.6	0.2	1.3	42.4
Standard deviation	2.0	1.5	1.7	1.8	1.8	2.1	2.4	2.4	1.6	1.0	0.5	1.7	15.3

We have to note that the approach for the evaluation of Mavroneri springs potential was based on the assumption that their outflow is statistically correlated with Viotikos Kifissos discharge, which is the final receiver of the springs. Actually, the water potential of the springs is related with the state of the karstic aquifer, which is strongly affected by the upstream and downstream pumping rates. However, this problem is too complicated, and its analysis is out of the scope of this study.

The surface runoff of Heronia-Davlia watershed is occasional, because its two great streams flow only in case of intense storms. The monthly runoff series arises by extracting the corresponding sample of Mavroneri springs from the total runoff sample of the catchment. If their difference is negative, the pure runoff is assumed to be zero. The main statistical characteristics of the sample are given in Table 2.9.

Table 2.9: Statistical characteristics of pure monthly surface runoff of Heronia-Davlia watershed (hm^3) – Hydrologic years 1968-69 to 2000-01.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Annual
Average	0.1	0.3	2.1	3.7	3.7	5.0	2.3	0.3	0.1	0.1	0.2	0.1	18.0
Standard deviation	0.3	0.7	7.9	6.1	4.2	4.6	3.0	0.8	0.2	0.2	0.1	0.1	19.6

Figure 2.9 illustrates the annual surface runoff of Heronia-Davlia watershed versus its total runoff, where the outflow of Mavroneri springs is incorporated. A specific characteristic is that the outflow of the springs appears to have much smaller fluctuations, in relation with the surface runoff. Indeed, while the annual variability of Mavroneri discharge (i.e., the ratio of the annual standard deviation to the annual mean value) is only 36%, the corresponding variability of surface runoff reaches 109%. In case of low flows, the latter is very limited and the watershed is almost exclusively supplied by Mavroneri springs.

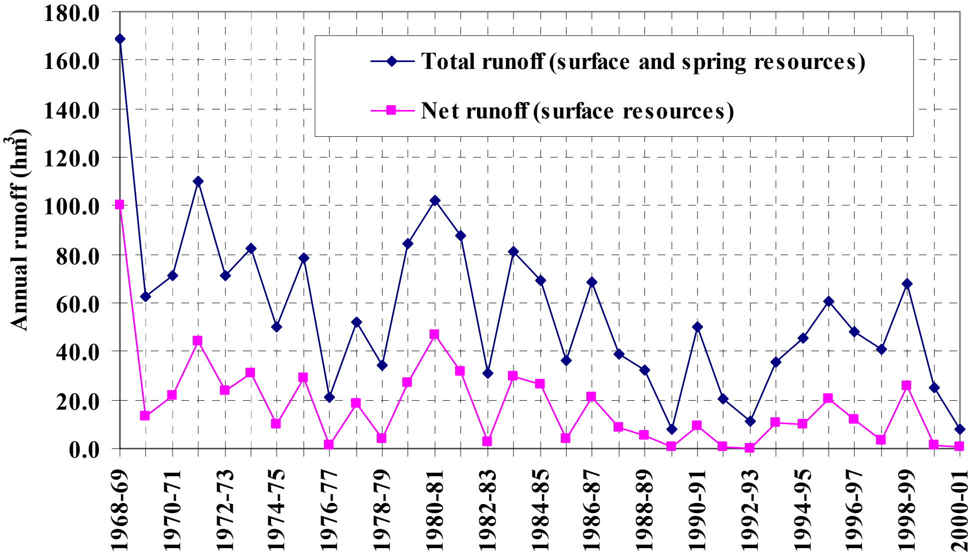

Figure 2.9: Plot of annual runoff series at Heronia-Davlia watershed.

2.5 RAINFALL-RUNOFF CORRELATION

Based on the above analysis, the mean annual surface runoff value of Heronia-Davlia watershed, where the project belongs, is 18.0 hm^3. Taking into account that, practically, all runoff derives from Platania and Vathyrema basins (an area of approximately 100 km^2), we estimate that the mean annual runoff depth does not exceed 180 mm. On the other hand, the corresponding annual precipitation depth, as measured at the rain gauge of Davlia village (which is unique into the study area), is 840 mm (Efstratiadis et al., 2000). Certainly, the altitude of the gauge is 380 m, which may be a little smaller than the man altitude of the basin. This fact indicates that the actual average annual precipitation may be slightly greater, about 900-1000 mm. Therefore, the mean annual runoff coefficient may not exceed 20%. This low value is due to the karstic layer of the watershed and indicates that most percentage of rainfall is infiltrated.

2.6 WATER SUPPLY FROM SURFACE WATERS

Basing on the existing situation of the main surface water resources of the area (Viotikos Kifissos, Mauroneri springs, Platanias stream), it can be estimated that construction of **some kind of storage facilities is not technically and economically beneficial**. This statement is based on the following arguments:

- The surface water potential of the Viotikos Kifissos river basin is reducing in constant rate for decades, with the minimum peak of 64,5 hm^3 outflow in the exit of the basin this year, equal to only 17% of the mean annual outflow of the time-series. The main reason for this degradation is the intensive exploitation of the carstic aquifers, which are developed in the whole basin area and constitute the basic water suppliers of the river. During this time period, the outflow of Viotikos Kifissos at the work area and specifically at the water measurement position of Agios Vasilios Heronias, as calculated basing on statistical anagogic relations (2.4.2), is estimated to have been less than 20 hm^3. However, taking account that during the whole hydrological year 2000-01 the effluence of Mauroneri springs, which constitute the basic water suppliers of the local sub-basin with a mean contribution of about 75%, was minimal, it can be derived that the real outflow of the river was much smaller (probably less than the annual water needs of the work). In any case, the water supply of the thermoelectric plant from Viotikos Kifissos, even with annual uptake of about 5 hm^3, will further degrade the water potential of the river, intensifying the environmental pressures in the region and introducing a new competitive water use (private - industrial) in the already existing ones (water supply and irrigation).
- During the dry period, usually lasting from the end of spring up to the middle or end of autumn, the outflow of Viotikos Kifissos river in the work area is very low and in many cases zero. This is due to either physical reasons (no water in the uphill springs) or artificial interferences along the river, in order to create substandard irrigation dams in its riverbed. A characteristic fact is that in 2001 the drought period lasted to the end of November, which is typically not a dry month. As a result, assuming that a water storage work (lake-reservoir) is constructed nearby Viotikos Kifissos river, it must be capable to cover the water needs of the thermoelectric plant for a time period of more than a semester. Consequently, taking account of the losses due to evaporation, leakage, etc, the required capacity of the work must exceed the 3 hm^3. The construction cost of such a big storage work is expected to be extremely high. For example, considering a typical lake-reservoir depth of about 10 m, an area of more than 300.000 m^2 is required in the work area.
- Regarding the carstic Mauroneri springs and considering that they have been drought up for a time period of more than one year (since August 2000), it is obvious that any proposal for its exploitation must be excluded. In any case, it isn't certain at all that the springs' waters could be used for industrial use, given that the water uptakes are used both for local irrigation and for EYDAP. Moreover, environmental conditions have been

set for the springs (the minimum water level at the springs' marsh has defined at 0,5 m), given that they constitute a protected area. Of course, in theory, these springs could be a satisfactory solution for the water supply of the work, considering that their capacity is very worthy (mean annual outflow more than 40 hm^3 or 1.5 m^3/s) with no great fluctuations in general, neither in annual nor in over-annual basis (except periods 1994 and 2000-01). Moreover, the springs' waters are driven to the stream passing almost nearby the location of the thermoelectric plant, so just a small technical work for the uptake of the necessary water quantity would be required.

- The ultimate solution for the water supply of the plant could be the gathering of the torrential outflows of the stream Platanias, which remain unexploited. However, as analyzed in the chapter 2.4.3 (very small runoff coefficient of about 20% towards the very high outflow variability coefficient of about 110%), the hydrological regime of this stream couldn't permit the exploitation of the water potential unless an extremely large work of over-annual flow adjustment (dam and reservoir) is constructed - solution which apart from having manifold technical difficulties, it appears to be entirely unprofitable regarding the economics, and very insecure regarding the environment.

3. GROUNDWATER RESOURCES

3.1 INTRODUCTION

The investigation of the groundwater resources is one of the basic considerations for the evaluation of the available water resources in the area, where the new plant will be situated. In the following paragraphs, the geological structure of the valley of Viotikos Kifissos river NW of Livadia, as well as the hydrogeological conditions are under examination. Through historical data, geological maps and sections conclusions are delivered regarding the possibilities of exploiting local aquifers.

3.2 GEOLOGY

3.2.1 General comments

The spot where the new plant will be situated is located somewhere in the region of Livadia, of the Viotia prefecture. The latter is included in two separate geological map sheets (Livadia sheet and Elateia sheet), which have been published by the Greek Institute for Geological and Mineral Exploration (I.G.M.E.) in 1:50,000 scale. The geological mapping has been performed by Papastamatiou, Tataris, Marangoudakis, Monopolis (1961-66) and Maratos (1961, 1963) respectively. The actual estate of the new plant is depicted in the Elateia sheet (map 4, following). In general, the petrological formations, which dominate the area, from the oldest to the youngest are the following:

Upper Palaeozoic: It includes clayey – sandstone schists, graubakes and conglomerates, among which basic rocks and thin-plated limestones are interfering. They are widely spread on surface of the north of Chlomon Mountain, of the Atalanti area, probably continuing under the Triassic formations (Pagounis, 1994), as in the Pavlos Viotias case.

Mesozoic: It is represented primarily by limestones and dolomites and secondly by flysch, flyschoid and shales-cherts formations. Dolomites serve as an aquiclude substratum and above them there are limestones up to middle Jurassic age. The total thickness of these is between 300 m and 700 m. According to the tectonic zone, the overlying formations are either limestones with ofiolites (mt. Kallidromon, Chlomon-Ptoon-Ktypas mt., Kopais field), or bauxite limestones (mt. Parnassos and Elikon). The former are up to 200 m thick and the latter between 100 m and 300 m. Peridotites, shales-cherts with ofiolites, as well as the conglomerates take less area, mainly on the eastern side, in the Kopais substratum, and other places. The flysch is represented by clayey-marly schists, sandstones and conglomerates, and also schist layers. It can be seen in the eastern parts and in the Parnassos zone.

Neogene: They show great extension in parts of the Kallidromon – Chlomon mountains, Bralos area, Elateia are etc.)Furthermore they spread under the quaternary deposits in the basins of Bralos, Elateia and Kopais. They are generally divided into two systems: the lower system consists of alternating layers of conglomerates, clays, sandstones, marls and marly limestones. Its thickness varies between 50 m and 170 m. The upper system consists of conglomerates, clays, silts alternating with sandstones and sands.

Quaternary: The deposits consist of conglomerates mixed with fine-grained material (sands, clays etc). Their thickness is thought not to exceed 30 m.

Map 4. Geological map

3.2.2 Geological conditions at the plant site

The place of interest is situated closely to the Viotikos Kifissos river κοίτη where the elevation is approximately 120 m. The area is structured by allouvial deposits, which are lose in the upper layers and cemented in the lower. The thickness is around 100 m, although local differentiations up to 200 m cannot be excluded. In the neighborhood, from top to bottom, appear:

- Limestones (Upper Cretaceus), mostly thin-plated marly limestones and massive limestones;
- Cretaceus conglomerate, rich in cemented gravel, in well-formed layers;
- Diabase, that is tuffs of igneous basic rocks, pillow lavas, etc;
- Limestones (Lower Cretaceus), medium to thin bedded.

Two limestone horizons (Jurassic) discontinuous to each other, which host bauxitic orebodies. They are frequently oolitic and the footwall consists of dolomites. They lay under the quaternary formations, invisible from surface, in the site of interest.

3.3 HYDROGEOLOGY

3.3.1 General

In 1993, I.G.M.E. published the hydrogeological map of the Viotikos Kifissos river basin and the surrounding area, in 1:150,000 scale. The map (Pagounis, 1994) is based on 1:50,000 geological mapping of the basin. Despite the obscurity of the season and year of the hydrogeological mapping, one can get valuable clues for the behavior of the formations and the position of important hydraulic limits.

According to Pagounis (1994), the geological-tectonic structure of the area is characterized by extended rock folding and fracturing, and the blocks are put along the basin axis in the form of steps. The multiple interference of aquiclude formations in the limestone blocks resulted in the existence of several hydrogeological units, which can be independent or related to each other.

The limestones are the main geological formations in the basin (~40% of the surface area), in which the aquifers are hosted. The usual model is the existence of an upper aquifer in the quaternary and conglomerate deposits, and also a lower (main), karstic aquifer in the limestones. In certain cases the upper aquifer could be hosted in limestones as well (perched aquifers). The main aquifer is either confined or unconfined. Its state depends on whether there is a water-protected layer above the aquifer and a good feedback from up-stream. In many places in the basin there are overflow sources of different capacities (e.g. Mavroneri sources).

3.3.2 Historical data

During the last years, there have been several efforts to record the constructed boreholes (drills) in the Viotikos Kifissos basin, by various scientists. Such recordings concern exploring and productive boreholes owned by public services (E.YD.A.P., IGME, Ministry of

Agriculture-YPGE) and individual farmers. The task has proved to be very difficult and the data recorded by different scientist have gaps and contradictions.

According to published data (Nalbantis and Rozos, 1999), a drilling program was conducted by the Ministry of Agriculture (YPGE) in the vicinity of mountain Akontion (Table 1) and EYDAP (1988-1994) in the area of Vassilika and Parori (Table 2). The boreholes were drilled in the outer limits of the quaternary formations and directly on the karstic limestones. The yields recorded for them are very high and it is not known whether they are average or maximum annual, or whether they have been recorded in the dry or wet season. Groundwater measurements in the boreholes closer to the plant site (Heronia and Akontion) during the 1995-1995 period, showed that the average groundwater level varies between 102 m and 109 m. Given the elevation of the area, it seems that the karstic aquifer, which is highly productive, is in confined state, under the alluvial deposits.

Table 3.1: Record of boreholes constructed by YPGE (Ministry of Agriculture), in the vicinity of the plant site.

Code	Area	Yield (m^3/s)	Yield (m^3/d)	Yield (hm^3/y)
XP1	Heronia	0.32	27648	10.1
XP2	Heronia	0.20	17280	6.3
XP3	Heronia	0.32	27648	10.1
XP4	Heronia	0.23	19872	7.3
AK1	Akontion	0.31	26784	9.8
AK4	Akontion	0.22	19008	6.9
AK5	Akontion	0.14	12096	4.4
AK6	Akontion	0.22	19008	6.9
AK7	Akontion	0.09	7776	2.8

In case the above withdrawals operate simultaneously then the total yield reaches about 180.000 m3/d. Yet it is not known the operating status of the above boreholes.

Table 3.2: Record of boreholes constructed by EYDAP during the period 1988-1994, in the vicinity of the plant site.

Code	Area	Yield (m^3/s)	Yield (m^3/d)	Yield (hm^3/y)
EMP3	Vassilika	0.14	12096	4.4
EMP4	Vassilika	0.11	9504	3.5
EMP7	Vassilika	0.14	12096	4.4
EMP6	Vassilika	0.14	12096	4.4
EMP11	Vassilika	0.14	12096	4.4
EMP22	Parori	0.14	12096	4.4
YMPΣ10	Vassilika	0.11	9504	3.5
YMPΣ14	Parori	0.14	12096	4.4
YMPΣ16	Parori	0.14	12096	4.4
YMPΣ17	Parori	0.07	6048	2.2
YMPΠ3	Parori	0.11	9504	3.5
YMPΠ4	Parori	0.11	9504	3.5
YMPΠ7	Parori	0.11	9504	3.5
YMΠΣ11	Parori	0.14	12096	4.4
MP1	Mavroneri	0.25	21600	7.9
MP2	Mavroneri	0.23	19872	7.3
MP3	Mavroneri	0.21	18144	6.6

In case the above withdrawals operate simultaneously then the total yield of EYDAP wells gives about 210.000 m3/d. Yet it is not known the operating status of the above boreholes.

3.3.3 Field investigations

Up-dating of the historical hydrogeological information, as well as further recording of boreholes in the area around the plant site, was performed by members of the investigation team, during November 2001. The basic questions faced were the following:

- What is the thickness of quaternary formations underneath the site;
- What is the necessary drilling depth, in order to efficiently exploit the aquifer(s);
- What will the behavior of borehole and the aquifer be, after long-term exploitation.

First, information regarding the existence and location of boreholes, owned by the state or individuals, was sought after. So, files of private boreholes, which are given official permit in the whole Viotia region were investigated in official archives, especially for Agios Vlassios and Mavroneri areas. Data were acquired from geological studies and drilling/pumping tests reports.

Second, the recorded boreholes were sought on site and their positions were recorded approximately on suitable maps (map 5) with the aid of a portable GPS device (Global Positioning System). Furthermore, a few unrecorded boreholes were found on the near area of the project; local farmers gave useful information about the latter.

According to the above findings, in the area around the plant site, there were 7 borehole spots recorded, as shown on the map 5. The plant site is presented as No 1. All the rest concern private and state-owned boreholes, which are in operation. Information regarding these boreholes are given in table 3.3. In a distance greater than 1.5 km around point no1, there is an undefined number of shallow wells (7 m – 15 m). Their present state, in general is unknown; some of them are not operating any more, others have been replaced by boreholes.

Table 3.3. Record of boreholes in the vicinity of the plant site.

Borehole	Owner	Area	Total depth (m)	Limestone depth (m)	Water-table level (m)
1	Livadia IPP	Komatia	–	–	–
2	Individual farmer (unknown)	Komatia	50	–	–
3	Agios Vlassios municipality	Komatia	170	130	–
4	Individual farmer (unknown)		–	–	–
5	Agios Vlassios municipality	Malkades	106.5	56	5
6	Calypso A.E.(industry)		130	46	–
7	L. Ioannou (individual farmer)	Ayios Ioannis	110	–	–
8	K. Karaiskos (individual farmer)	Ayios Ioannis	150	–	–

In addition, the following information has been acquired:

- In the area of Agios Vlassios village, the flysch is met on the depth of 50 – 70 m;

- The thickness of the quaternary deposits in the center of the basin can reach 200 m (Bourantas, 2000);
- In certain locations, the alluvial aquifer yield could reach 80 m^3/h, 0.022 m^3/s (Trakis, 2000);
- The borehole of "Calypso A.E." industry, after the first 46 m, drilled 24 m of massive limestone followed by fragmented (not only karstic) limestone.

The most important information come from borehole 5, owned by the municipality of Agios Vlassios, at "Malkades" place, to which pump tests were applied. The pump was set to 85 m depth and the yield was between 110 to 130 m^3/h. The resulted drawdown was about 42 m, in 48 h. The distance between this borehole and the plant site is a little more than 500 m.

In the study area there is a verified relationship between the karstic aquifer and Mavroneri springs, which are, along with Agios Vassilios springs at Akontion Mountain, the most important of the area. In 2000, when systematic but not full exploitation of the Vassilika-Parori boreholes took place, Mavroneri springs (which have an elevation of 121.0 m to 123.5 m) went dry. Consequently, the water requirements had to be covered by extended exploitation of the boreholes of Platania and Agios Vlassios basins. This exploitation depressed the water level further and, in 2001, outflow from Mavroneri springs just reappeared at the end of April (look at paragraph 2.2).

Map 5: Boreholes in the near work area

3.3.4 Interpretation of hydrogeological and drilling information

According to the collected information, the quaternary formations consist of alternating layers of coarse and fine-grained material, mostly clays, sands and gravel, originating from the erosion of limestones and flysch. The hosted aquifers are fed by their contact with the rim limestones. Their extent and capacity varies in space and time. According to farmers, since the exploitation of local groundwater begun, their shallow wells of about 7 m to 12 m had to be replaced by deeper ones (50 m). This phenomenon does not reflect exactly water level depression, but a move of farmers to exploitation of deeper and deeper aquifers, which are in a confined state and their water level is high. The achievable yields reach almost to 80 m^3/h, in extremely wet seasons. In any case, their capacity is limited.

In certain locations, to the southwestern part of the valley, flysch is the substratum of the deposits. But, even in these areas, all the underneath formations consist of the jurassic limestones, either massive or tectonised. The latter are mainly supplied by percolations from three sources: Viotikos Kifissos river, the mountain karstic masses and the upstream aquifer parts. Hence, due to the quasi-waterproof roof, the aquifers can be assumed to be confined.

Although detailed records of the karstic aquifer piezometric load was not found, it is estimated that its seasonal fluctuation in general is about 5 m. In the last five years, a slight decrease occured, which was worsened by the exploitation of Vassilika-Parori boreholes, owned by EYDAP, to provide water for the supply of Athens and the irrigation of Kopais plain. In general, in the Akondion area, the average level during 1994-1995 was at 108-116 m (absolute elevation), which is not expected to have significantly changed. At the same time, in the Mavroneri area, the average piezometric level was about 116 m.

Generally, the total thickness of the quaternary deposits increases while one moves towards the center of the basin, where is the location of the old river bed (Papapetrou, 1995). In order to estimate this thickness at the project site, we used data from the neighboring boreholes. On the map, we measured the distances d_{1i} between the plant site (point 1) and the i-th point that corresponds to a neighborhood drill, and we calculated the weighting factors:

$$k_i = \frac{1}{d1i} \qquad (3.1)$$

If b_i is the deposit thickness at point i, then the asked thickness at point 1 is estimated as:

$$b_1 = \frac{\sum_{i=1}^{n} k_i b_i}{\sum_{i=1}^{n} k_i} \qquad (3.2)$$

The results are given in Table 3.4. In the spots where the thickness was not known, it was considered to be 20 m greater than the drilled depth. Finally, the thickness was found to be 95 m (at least).

Table 3.4. Computation of deposit thickness via interpolation of drill depths No 3, 4, 5, 7, 8.

Drill	Distance d_{1i} (m)	Weighting factor k_i	Deposit thickness b_i (m)	k_i b_i
3	600	0.00167	130	0.21667
2	950	0.00105	70	0.07368
5	500	0.00200	56	0.11200
7	1850	0.00054	120	0.06486
8	1700	0.00059	150	0.08824
Total		0.00585		0.55545

Based on the aforementioned information and calculations, two geological sections (Figures 3.1 and 3.2) were constructed, in directions SWW-NEE and NNW-SSE, crossing the project site (the axis of sections are shown in the attached geological map).

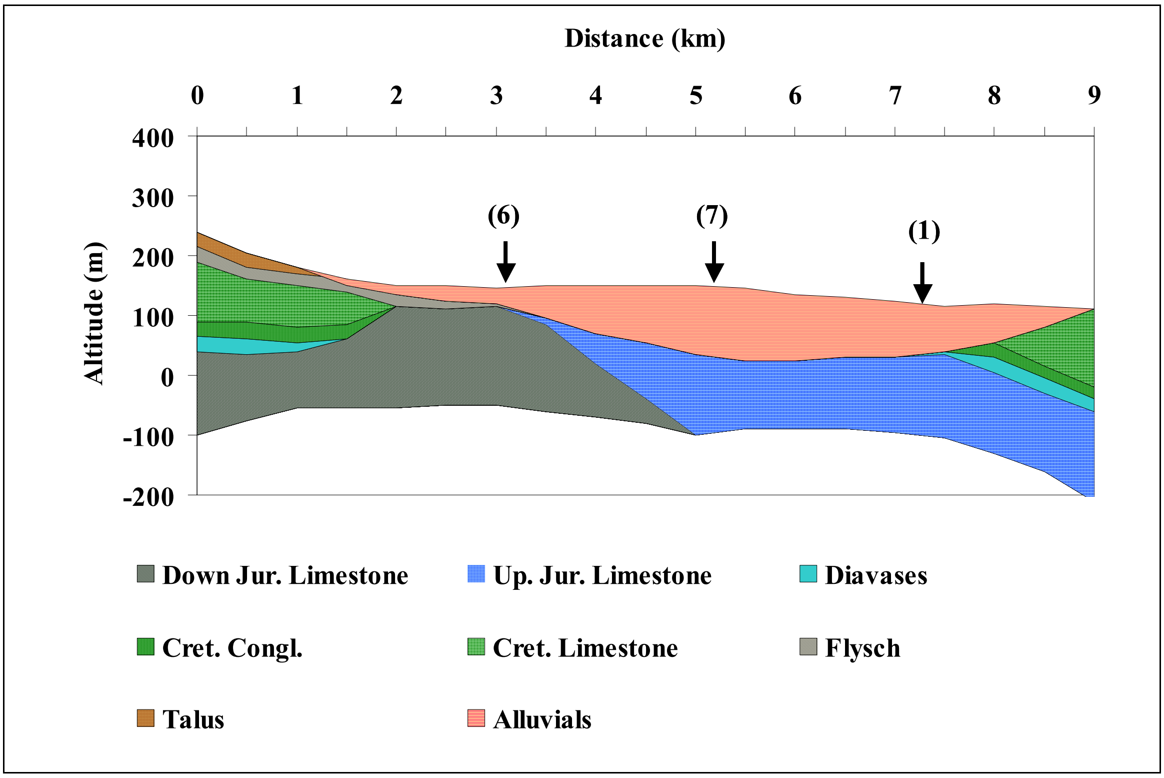

Figure 3.1: Geological section in SWW-NEE direction, with the positions of drills No 6 and 7, as well as the project position (point 1).

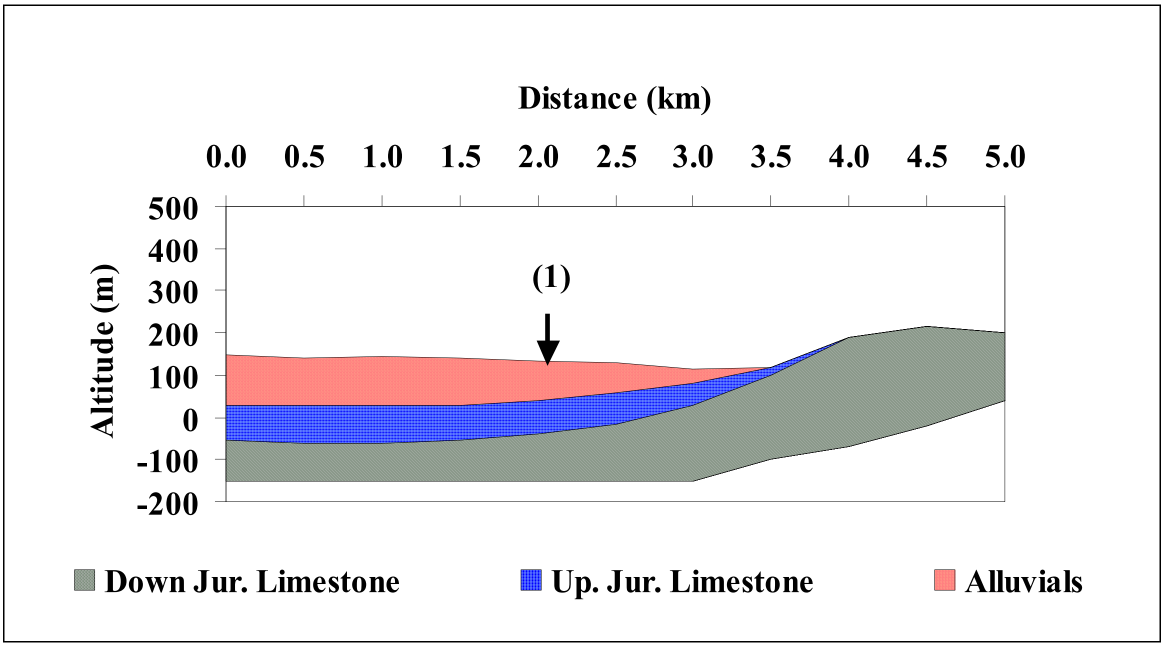

Figure 3.2: Geological section in NNW-SSE direction, with the project position (point 1).

3.4 IMPACT ASSESSMENT OF PUMPING FROM THE KARSTIC AQUIFER

In this paragraph, we estimate (preliminary) the impacts of drilling the necessary water for the plant from the karstic aquifer. The amounts of water needed are estimated to be around 5 hm^3 per year or 580 m^3/h on average. Herein, it is assumed that the withdrawal is constant in time and that the returned water is discharged either to a ditch or to Viotikos Kifissos.

The impacts of a continuous pumping of 580 m^3/h could be seen both, as short-term and long-term ones. The former are related to the water depression cone, which is created during pumping, and its impact on adjacent boreholes. The latter are related to general impacts concerning the water balance of the broader region in an over-year time basis (e.g. five or ten-year period).

3.4.1 Evaluation of short-term impacts

Considering the status of limestone and the geology in the area as well as the recorded piezometric head of existing boreholes, the media through which the water flows, although karstic, can be simulated with good approximation as porous due to its tecnonized and fractured character (at least for approximate calculations). This aquifer can also be interpreted as confined. Then, according to the theory, a depression cone of the piezometric surface will start developing around the pumping wells of the plant and will extent latteraly while pumping. Under the estimations stated before about the kind of aquifer, assuming homogenity and isotropy for the ground and accepting a fully penetrating well in the aquifer (or wells), the nonequilibrium equation of Theis (3.3) can be applied to estimate the drawdown of hydraulic head in various distances from the wells as time proceeds (Domenico et al, 1988):

$$s = \frac{Q}{4\pi T} W(u), \text{ where} \qquad (3.3)$$

where s is the drawdown of the piezometric head, Q is the (assumed constant) flow rate of pumping, T is the transmitivity of the aquifer, w(u) is the well function of u, with values taken from relevant tables depended on calculated values of u according to the equation

$$u = \frac{r^2 S}{4\pi t}$$

where r is the horizontal distance from the well of the examined point, S is the storativity of aquifer, t is the pumping time from the beginning of the withdrawal.

Also, the radius of the final cone that represents the greater practically distance that may be influenced by the wells, can be approximated with equations 3.4 and 3.5, according to bibliography (Nanou-Giannarou, 1999):

$$r = 2.45\ (b\ K\ t\ /\ S)^{0.5} \text{ (Weber, 1924)} \qquad (3.4)$$

$$r = 1.90\ (b\ K\ t\ /\ S)^{0.5} \text{ (Kusakin, 1953)} \qquad (3.5)$$

r is the radius of influence, *b* is the thickness of the aquifer, *K* is its hydraulic conductivity, *t* is the pumping time and *S* is the storativity. The above equations, which stand for confined aquifers of infinite distance, include the effect of time in calculating the radius of influence. Assuming horizontal flow conditions, the product $T = b\ K$ is constant and is called transmissivity (Koutsoyiannis and Xanthopoulos, 1999).

Alternatively, the drawdown as a function of the distance from the drill, can be estimated by the Thiem equation, (Koutsoyiannis and Xanthopoulos, 1999):

$$s = \varphi(r_2) - \varphi(r_1) = s(r_2) - s(r_1) = \frac{Q}{4\pi T} Ln(\frac{r_2}{r_1}) \tag{3.6}$$

where s is the drawdown, φ is the piezometric load, r_i is the distance from the well and Q is the pumped flow rate.

It is known that the average transmissivity of the middle Viotikos Kifissos basin aquifer is around 5.000 m^2/month (166,7 m^2/d) or even more, while the aquifer thickness can be taken about 50 m. In addition, the average storativity is around 0.01 or greater.

Applying the above equations, and assuming three pumping wells (boreholes) operate to achieve the average of 580 m3/h or 13.920 m3/d in a yearly basis, the depression cone of piezometric level that is anticipated for each drill point could drop about 50 m or more after one year of operation. At the same time, in a distance of about 500 m, where the municipal well number 5 operates (table 3.4), the estimated drawdown will be about 25 m. After 5 years of operation from the beginning the drawdown of piezometric surface at the same municipal well is estimated at about 35 m. Those estimations as well as the equipotential lines are shown in figures of next two pages that follow (outputs of model WELLz1 from Domenico, 1998).

Also, the radius of maximum practically influence is estimated about 5 km from the plant wells (6.0 km or 4.7 km, from equations (3.4) and (3.5) respectively).

Figure 3.3 Drawdown equipotential lines after 1 year of pumping from 3 wells of the plant.

Figure 3.4 Drawdown equipotential lines after 5 year of pumping from 3 wells of the plant.

3.4.2 Evaluation of long-term impacts

The long-term impacts from an annual withdrawal of 5 million m^3 depend on various factors, most of them unpredictable, such as:

- the discharge of streams and springs;
- the local irrigation demand, that varies from period to period;
- the irrigation demand of Kopais plain;
- the water supply demand of Athens;
- the exploitation of YPGE and EYDAP boreholes.

Recently, in the framework of a Viotikos Kifissos river basin study, Tentes (2001) developed a semi-distributed hydrological model, named 4Xcell, which simulates the hydrological processes by dividing the whole basin into three units (upper, middle and low basin). Each unit consists of four cells (Figure 3.5) and the hydraulic communication among them is based on Darcy's law. The model calibration, that was done for a 5-years period from October 1984 to September 1989, as well as its verification for several periods between 1967 and 1984, indicated that results are quite satisfactory.

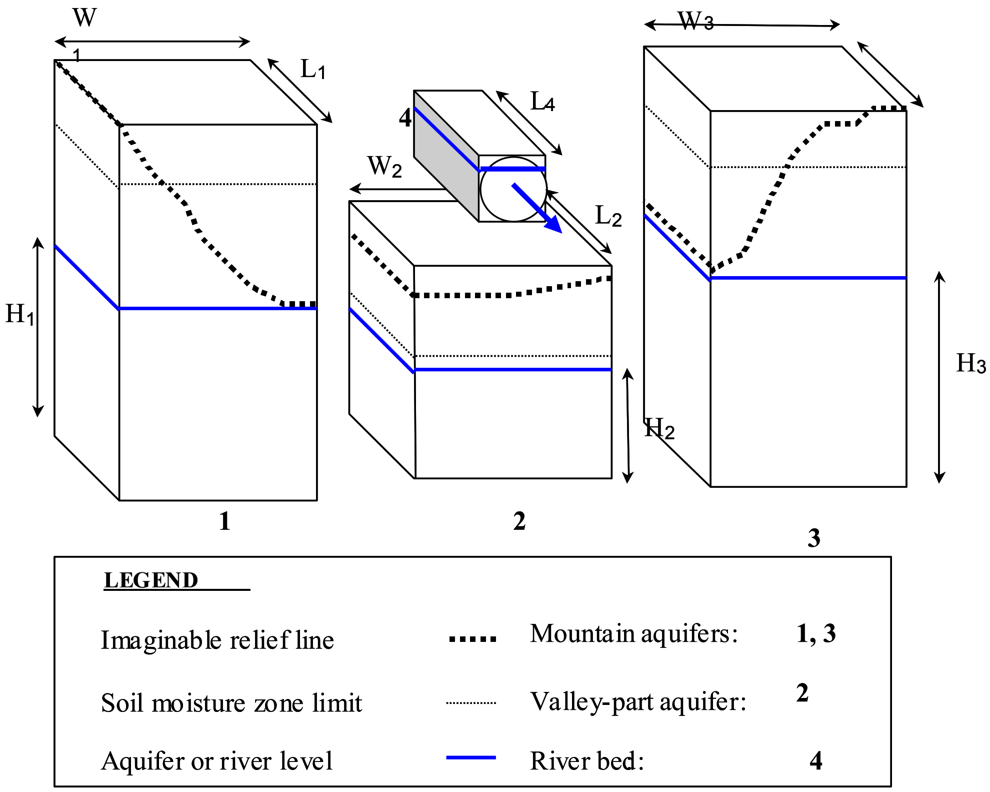

Figure 3.5: Layout of the semi-distributed multi-cell hydrological model 4Xcell.

In order to estimate the long-term impacts on water level conditions, the model was re-applied for the period 1984-1989, adding a hypothetical withdrawal of 5 hm^3 on the karstic aquifer of the middle basin, where the project will be sited. The results for the middle basin are presented in Figure 3.6, where the actual (historical, with blue line) and the predicted drawdown (in the predicted the plant water withdrawal is included). We can observe that the drawdown on a 5-years horizon is significant, reaching about 1 m. On the other hand, the impacts at the upper basin are negligible, whereas the drawdown difference at the low basin is only 1 cm.

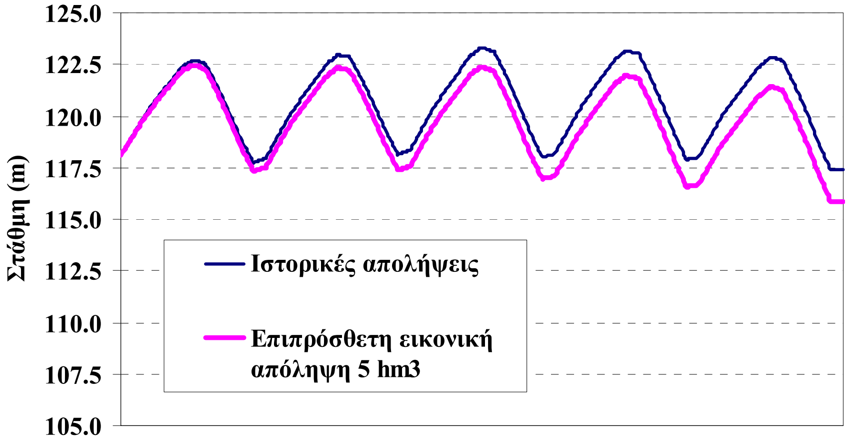

Figure 3.6: Comparison of the simulated aquifer level at the middle basin of Viotikos Kifissos during 1984-1989, according to the historical withdrawals and an additional withdrawal of 5 hm^3 per year.

It should be pointed out that on the above actual drawdown, the great withdrawals from YPGE and EYDAP are not included.

3.4.4 Impacts from adjacent wells on the plant withdrawal

Up to now the impacts from the uptake of groundwater for the needs of the plant have been examined (in a preliminary base always). There is still an issue to be examined, namely the potential impacts of other external withdrawals to the uptake potential of the wells of the plant. This issue, should taken in account when making decision about the risk of the available groundwater resources for the plant.

Actually the main users that might influence the availability of adequate quantities of groundwater for the plant are the wells of EYDAP upstream the plant site as well as the municipal wells. As a matter of fact a full investigation of these likely impacts is out of the scope of this project, yet a preliminary approach might give some clue on the problem.

Following will be examined the potential impacts from steady withdrawal of the tho municipal wells in the near vicinity of the plant site, that is well number 3 and well 5, according to table 3.3. Those wells withdraw from the same aquifer as the plant and are relatively big compaired to other of individual farmers. Also the wells of EYDAP in the area or Mavroneri-Parori-Vassilika will be considered and finally the wells of YPGE near Heronia. The two municipal wells 3 and 5 will be examined as one, the same also for EYDAP withdrawals and for YPGE. The water flows of the wells will be considered approximately since no exact data exist. The simulation will use the assumptions stated in section 3.4.1, for one confined aquifer of infinite dimensions according to Theis theory, with the same transmissivity and storativity values as in the aforementioned simulation. The data used for the simulation are presented in table 3.5. Actually will be examined three scenarios, s1 for the concurrent operation of three groups of withdrawals as stated before after 3 months of operation (the center of gravity of the wells of each group is accounted for the distance from the plant), s2 for the operation of the two nearest wells of each group (to account for more realistic distance) and s3 that is identical with s2 but after operation of 5 months. The meaning of operation for 3 months is to account for the impact in the plant after operation of April, May and June, while after 5 months by the end of August, which is still the peak demand for the plant water.

Table 3.5 Data for the scenario 1 of concurrent operation of three main withdrawals in the vicinity of the plant and scenario 2 of concurrent operation of two main withdrawals.

Parameter	A.Vlassios	EYDAP	YPGE
Scenario 1			
wells included	3, 5	MP1, MP2, MP3, EMP22, YMPS13, EMPS14	XP1, XP2,XP3, XP4, AK5, AK6 ,AK7
Q1 (m3/d)	4800	95.904	131.728
t (days)	90	90	90
distance from the plant (m)	500	4.000	3.000
Scenario 2			
wells included	3,5	MP1, MP3	XP2, XP4
Q2 (m3/d	4.800	Q2,MP1=21.600 Q2,MP3=18.100	Q2,XP2=17.280 Q2,XP4=19.870
t (days)	90	90	90
distance from the plant (m)	500	d,MP1=3200, d,MP3=3800	d,XP2=1.200, d,XP4=1.800
Scenario 3			
wells included	3,5	MP1, MP3	XP2, XP4
Q3 (m3/d	4.800	Q2,MP1=21.600 Q2,MP3=18.100	Q2,XP2=17.280 Q2,XP4=19.870
t (days)	150	150	150
distance from the plant (m)	500	d,MP1=3200, d,MP3=3800	d,XP2=1.200, d,XP4=1.800

The results of the simulations with the aid of WELLz1 model, are presented in figures 3.7, 3.8 and 3.9 for each scenario respectively. As it is shown, the expected drawdown in the piezometric level in the plant area due to the operation of the above 3 groups of sinks is about 30 m by the end of August, provided of course that those wells really operate with the above flowrates. Naturally this is an approximate estimation as stated from the beginning of the analysis.

Figure 3.7: Drawdown equipotential lines of scenario 1 after 3 months of operation

Figure 3.8: Drawdown equipotential lines of scenario 2 after 3 months of operation

Figure 3.9: Drawdown equipotential lines of scenario 3 after 5 months of operation

3.4.5 Surface ground settlements

Surface ground settling has several causes like tectonic movements, dilution in water, compaction of sediments due to great loads-vibrations-water level drawdown, and changes in dam pressures because of water losses. Some of them are particularly interesting in case of using pumped groundwater to provide water for the plant.

The geological conditions favor settling on top of alluvial deposits. In some cases the phenomena are very intensive, while in other cases, albeit they exist, attention is not being paid. The main reason is the lack of control via accurate topographic methods.

The impacts of ground settling could be very serious. There is a strong possibility that the, usually upward, force of friction that keeps the borehole casing in the ground, would change direction and literary suck the casing downwards. The usual ending is the filling of the borehole with soil. Besides, water channel inclination may change, and consequently surface flow conditions may also change. In case of differential settling, damages or small movements of buildings may occur.

From different viewpoints (Domenico and Schwartz, 1990), it can be concluded that the magnitude of ground settling depends on the soil constituents, the material layering and the kind of change in shallow water table conditions. In case of pumping an alluvial confined aquifer, the following dangers are at hand:

- During drilling and because of the rising of water level into the hole, the upper (dry) clay layers may be wetted and swell;
- If pumping is persistent, the confined aquifer layers may be transformed to unconfined, resulting in compaction;
- Unconfined aquifers may be exhausted, having as a result the reduction of the buoyancy and the compression of the land underneath buildings, tanks, etc.

A comparative measure of over-pumping impacts to land surface is the ratio of subsidence and drawdown, which is equal to the depth of subsidence per unit of drawdown. Its values vary, but some values of even 9% are reported.

In the case of this project, the alluvial aquifer on which the plant will be founded, will not be used for pumping, thus the third hazard, as stated above, cannot be met. Moreover, the drawdown will be monitored, so the hazard of overpumping can be clearly avoided. Finally, the upper part of wells should be sealed by concrete, so that the upper layers of the ground would not be wet, thus protected from settling.

As a conclusion, according to this preliminary approach, if relevant mitigation measures are taken, no significant settling may occur during the operation of the wells, that can pose danger on the constructions of the plant or on the adjacent properties.

4. LEGISLATION FOR THE WATER RESOURCES MANAGEMENT AND THE WATER USE PERMITS

4.1 INTRODUCTION ON THE LEGISLATION ABOUT GROUNDWATER EXPLOITATION

In Greece, the authorization to give official permit for constructing new drills does not belong to only one public service. Depending on the beneficiary and also the requested water use, the relevant public service could be the Department of Land Reclamation (YEB) of the Agriculture Supervision (in case of agricultural use), the Technical Service of the District (in case of urban use) or the Industry Supervision (in case of industrial use). In the present case, the responsible service is the latter (headquarters in Thebes, Viotia), with the cooperation of the Department of Land Development. In general, in case of multiple water use, the Water Resources Administration of the Sterea Hellas (headquarters in Lamia) is responsible.

The legislation (N.Δ. 3881/58, N.Δ. 1277/72, N.Δ. 1739/87, Π.Δ. 256/89) of the Greek Government, which refers to the management of water resources, the land development projects and the permits about water uses, leave to the local authorities the right to define the specific requirements and procedures, under which one can get official permit. Currently, for the Prefecture of Viotia, two directives are active, the decision 486/1-3-2000 and its amendment 1445/3-7-2000. The above-mentioned directives specify the conditions under which one can get official permit for constructing a drill for industrial use that are the same as for agricultural use.

4.2 LAW 1739/87 REGARDING WATER RESOURCES MANAGEMENT

This law defines the competent authorities according to the water uses (Ministries, Organizations, Prefectural and Peripheral Services). In general, water resources management is under the authority of the Ministry of Development, which is competent for the natural resources. So, the law determines the authorities of the Water Resources Supervision, existing in the Ministry of Development, and additionally institutes the following authorities: a) centrally: Interministerial Water Commission (I.W.C.) in the Ministry of Development, b) in each water district: Peripheral Services of Water Resources Management (P.S.W.R.M.) which are under the authority of the Ministry of Development, and Peripheral Water Commissions (P.W.C.).

Every legal and natural person has the right of water use. However, the construction of a water resources exploitation work is permitted only if the project is incorporated or in line with the prevailing water resources development programs. In this case, a united permit for use of water and construction of the corresponding work is granted. A respective application from those interested is required for this permit. Together with the application, adequate study elements must be included in order to report the quantity and quality status of the water resources, before and after the construction of the work. These elements are defined by a Ministerial of Development verdict. The competent authority according to the water uses grants the permit, following the suggestion of the corresponding Prefectural Service of Water Resources Management, provided that it secures that the requested exploitation is in line with the provisions of this law. The permit determines the quantity, the conditions and the terms of the water use. Presidential decrees, which are instrumented following proposal of the Minister of Development and the competent Minister according to the water uses, define the content of the application, the type and elements of the permit, the procedure and the deadlines of the permit issuance, the services in which it is communicated, the types and size of works which don't require study submission, the measures and the procedure of controlling permit observance, the administrative penalties imposed in case of violation, as well as the procedures and the enforcement bodies. The law forbids the issuance of any permit for installation or expansion of units, which need water to operate, unless they have granted water use permit.

The Ministry of Development determines, according to the water uses, the minimum and maximum limits of the required quantity and the appropriate quality in order to have sustainable water use. These limits are approved with Common Ministerial Verdict, following I.W.C. 's opinion. The approved limits are taken into account by the competent authorities according to the water uses in order to extract the real needs and issue the water use permit. The water use permit can be withdrawn by decision of the authority which issued it, following a proposal of the competent P.S.W.R.M., if the released water resources are given to uses demanding higher water quality, provided that the essential water quantities have been secured for the eligible person 's needs, with the same or smaller cost. Public or private agencies, which manage commonwealth waters, ought to conserve their plants in such a condition so that any loss is prevented or avoided and any damage is repaired immediately, especially when it results to water losses. The Prefect and the P.S.W.R.M. of the region are also competent to supervise and control the implementation of this provision. A Presidential Decree, which is instrumented following a Ministerial of Development proposal, defines the administrative penalties imposed in case of violation, as well as the procedures and the enforcement bodies.

In case of a water resource 's quantity decrease or quality degradation, due to natural reasons, a redistribution of the water quantities corresponding to each user can take place, with the analogous amendment of the relevant programs. Restrictions of the essential water quantities according to the water uses can be imposed in order to conserve water, in cases that recycling can be applied (repeated use) in either existing or new activities. A Presidential Decree, which is instrumented by a Minister 's of Development and the other competent each time Ministers' proposal, following I.W.C. 's opinion, defines the preconditions, the procedure, the cases of motivations providing and every detail necessary for the implementation of this provision. The procedure and the water cost accounting methods in existing and new uses, the cases of water pricing, the authority defining its price and the cashing authority are determined by Minister 's of Development and the other competent each time Minister' decisions, following I.W.C. 's opinion.

The engagement of a certain water quantity in order to protect and conserve the aquatic ecosystem and achieve the quality goals, which have been set based on the prevailing provisions, is considered as use and obeys the provisions of this law. The P.S.W.R.M. in collaboration with the Services of the Ministry of Agricultural and the Ministry of Environment, Physical Planning and Public Works, define the water quantities required for the satisfaction of the needs of this use and work on their incorporation in the water resources development programs. All those who use water resources are obliged to applicate means and methods, which ensure that the quantity and quality status of water resources lies in the limits set by the competent authorities. The type, the way and the procedure of setting the guarantee limits of the water resources' quantitative parameters, as well as the consequences of violating these protective provisions are defined by a Presidential Decree, which is instrumented following opinion of Minister of Development, Minister of Agricultural and Minister of Environment, Physical Planning and Public Works. If those above refer to qualitative parameters, they are defined according to the provisions of Law 1650/1986. If it is necessary for the conservation or restoration of groundwater and surface water resources in quantitative and qualitative limits that serve the common wealth or the predicted needs, to impose restraints or other measures in their use, these are imposed by the competent Prefects each time, following P.S.W.R.M. 's proposal. Water resources designated for water supply are protected from activities, which threaten their quality, by taking measures or by doing works. The Ministry of Development, in collaboration with the Ministry of Agriculture and the Ministry of Environment, Physical Planning and Public Works determine the minimum preservable flow in the rivers and the minimum water level in the lakes of the country, in order to conserve their ecologic balance.

The disposal of wastewater, industrial waste and in general degrading, regarding the quality, waters or other materials in the aquatic recipients must be in line with the Law 1650/1986. For the prohibition of the disposal of those materials in places and time periods harmful for the aquatic environment or the water uses, special regulations can be introduced through Common Ministerial Verdict. The constructions and works that alter the quantity or the quality status of water resources, are also subject to the approval of the P.S.W.R.M.. The cases which require approval, the granting procedure and the consequences of the violation of these provisions, are defined by Presidential Decree issued following proposal of the Minister of Development and the Minister of Environment, Physical Planning and Public Works.

In case of competitive water uses, the decision for the distribution of water according to the uses is taken by the Minister of Development and the other competent Ministers, following I.W.C. 's and relevant P.W.C. 's opinions.

4.3 PRESIDENTIAL DECREE 256/89 AND VERDICT S16/5813/89

The presidential decree concern the permit for water use while the Common Ministerial Verdict S16/5813/89 concernw the permit for the construction of a water resources exploitation work

The decree describes first the water uses (in the Annex I of the law).

The general provisions of the laws are as follows.

When it concerns non-industrial regions and energy uses (except for hydroelectric energy production), the competent Services for the issue of industrial water use permit are the Prefectural Industry Supervisions or Departments.

The safeguarding of the rational exploitation of groundwater and surface water resources constitutes a necessary precondition for the issue of a water use permit, in line with the provisions of L. 1739/87 and its normative decisions, which descend it into the districts of the country.

The type and content of the application form – statement are included in the enclosed Annex II of the L. 256/89. More specifically, this application form contains data concerning the applicant, the place of the water use and work construction, the water use itself, the exploitation, as long as the use premises the construction of a relevant work, and the quantity and quality of water, too.

The documents required for the issue of a water resources exploitation work construction permit can be divided in general documents, which are required in every case, regardless of the position, the type and the size of the work, and specific documents.

The general documents are determined as follows:

Topographic chart, in appropriate scale each time (1:500, 1:1000, 1:2000, 1:5000), depending on the type and size of the work, which shows the location of the construction works and water use, the contours of the buildings and rest installations, the nearest existing water uptakes for each use, as well as the generalized land uses in a radius of 200 m. from the boundaries of the work location. More specifically, in cases of small works and works of the categories 3a(ιι) and 3a(ιιι), instead of the topographic chart, the extemporary chart of the paragraph B3 in the documents' list of Annex II is submitted, where the work location is shown additionally.

General description of the work, including in brief: ι) the type and the technical features of the separate works and installations, and ιι) the type and size of the exploitation plant, in case they aren't defined in the application form - statement, because of the complex kind of the work they refer to.

The specific documents are determined as follows:

Adequate study elements, in which the quantity and quality of the water resources is mentioned, before and after the construction of the work. These elements are defined by a Verdict of Minister of Development, apart from the basic elements, which are included in the application form - statement.

In case of an industrial water use work, the required documents for the installation permit granting of the proposed industrial plant, as long as a united permit for water use and construction of the exploitation work is going to be issued, with incorporation of the industrial plant installation permit:

- conclusive evidence, that justify the required water quantity (e.g. technical report)

- conclusive evidence for the quality parameters mentioned in the application form - statement (e.g. certificate of chemical analysis)

In case that the application includes construction of a water uptake work from groundwaters, the above quality elements are submitted after the construction of the work. If the competent service knows the quality status of the water, for which the water use permit is requested, it can decide whether there is a need of submitting quality elements.

Apart from the above documentation, the competent services can define, for each case, additional documentation, as well as their type and level of details required, taking into consideration the social impacts from the work operation.

The exploitation work construction permit determines:

The basic features of the work (technical elements, type and size of the plant - exploitation)

The work construction deadline

The recall, abolition or amendment abilities

The common utility serviced and the management terms, in case of relevant work, as well as

The terms, commitments and obligations of the interested

The competent permitting service, after the necessary spot or no-spot tests in order to discover the accuracy and adequacy of the submitted elements, acts as follows:

it can ask from the interested any other additional element that it justifiably thinks necessary

when it gathers all the necessary elements, it forwards the relevant record to the competent P.S.W.R.M., which introduces relatively

it grants the relevant permit, taking into consideration all the elements, provided that the requested exploitation is in line with the provisions of Law 1739/87.

The united permits for water use - construction of the exploitation work and installation for industrial or energy water use are issued in a deadline of forty days after the permit The permit is valid exclusively and only for the particular use and work and cease to be valid in case that the predicted work completion deadlines pass and the work isn't completed, unless a prolongation is given in time following relevant application of the interested. This prolongation must not exceed the half of the first deadline 's time period.

The permits are determined to be valid for 10 years after their issuance date. However, they are subject to retroactive recall, abolition or amendment before their expiration, and then their validness can be replenished for the period defined by the prevailing provisions. The permits are replenished, following an application of the interested, for the period defined for the new permits. The applications can be submitted up to one year before the permit expiration, so that the competent services know a priori the given commitments.

The interested is bound:

to conserve the water use installations in such a condition, so that any loss is prevented or avoided and to repair immediately any damage, especially when it results to water losses.

to comply with the prevailing legislation concerning the protection of waters from pollution (Law 1650/87) and the disposal of waste (Sanitary Provision EIB/221/1965).

in case of granting permit for hydro-drill excavation, for any cause, to install piezometer or observation well anyway and to submit to the permit granting service, after the work construction, any element obtained regarding the development capacity and the depth of the underground horizon or aquifer.

The permit granting services, depending on the case, can impose specific terms and commitments in the water use or work construction. The granting of the work construction permit doesn't absolve the interested from the obligation of obtaining other predicted affirmations or permits and the observance of terms and confinements for the installation and operation of the total work.

The competent and responsible authorities for the supervision and inspection of the observance of the permits' terms and water' s correct use are the Local Self-Administration Organisms (L.S.O.) and the Rural Security Police, with the assistance of the competent permit granting services. The violation of this decision consists legally punishable act.

4.4 REGULATIVE DECISION OF VIOTIA PERFECTURE ON GROUNDWATER

This desision concerns Restrictive – Regulative measures for the protection of Viotia Prefecture water groundwater potential (No. 486/1-3-2000, 1445/3-7-2000)

The construction of water resources' exploitation works for industrial or energy use and the excavation of drills and wells is permitted following permit from the competent service (Industry Supervision in collaboration with the Department of Land Reclamation and the Agriculture Supervision), in the regions where there are no prohibitory measures and the hydrogeological conditions permit it, under the following terms:

a) The minimum required area for the drill or well excavation (with depth more than 15m) is determined up to 15.000 m^2.

b) The minimum distance of the drill or well excavation (with depth more than 15m) from existing similar uptakes are determined up to 200m in the province of Livadia (apart from the Zone 1).

c) The new uptakes must have a distance of at least:

- i) 500m from the irrigation wells or drills existing, constructing, or going to be constructed following collective works' granted permits of Municipalities, Communities, characterized settlements, Land Reclamation Organisms (L.R.O.), acknowledged farmer teams.
- ii) 500m from existing and under exploitation irrigation or water supply springs of Municipalities, Communities, characterized settlements, L.R.O., acknowledged farmer teams.
- iii) 500m from water supply wells or drills of Municipalities, Communities and legally existing settlements, existing, constructing, or going to be constructed following relevant permits.
- iv) 500m from the under exploitation drills of the Company of Water supply and Sewerage of Metropolis (C.W.S.M./ EYDAP) or other Public Agency.
- v) 500m from research drills of big diameter (at least 20") of the Ministry of Agriculture or 300m from the similar ones of smaller diameter (less than 20").
- vi) 20m from the axis of natural gas and fuel pipe.
- vii) 40m from the boundaries of the highway, 20m from the boundaries of the province road, 10m from the boundaries of the community roads, 5m from the boundaries of the rural roads and estates.
- viii) 15m from the boundaries of the expropriated zone of the Greek Railroads' Organism.
- ix) 100m from the outer foot of River B. Kifissos and the principal canals of the Kopaida irrigation network.
- x) The distance of the uptake works from the waste disposal places will be determined by the Service depending on the hydrogeological conditions of the area, in order to avoid the danger of pollution or contamination of the aquifer horizon.

An up to 5% variation is permitted in the above-mentioned distances or areas, apart from the distances from boundaries and roads.

The permit for all the above cases will be granted following application of the interested to the competent authority, which will be accompanied by the required documents, depending on the case:

a) Possession contract or 10-years contract of lease
b) Topographic chart of the area where the uptake will be constructed, in 1.1000 scale, from an engineer, member of the Technical Chamber of Greece (T.C.G.) showing the locations of the neighbor private uptakes in a radius of 200m, the watering uptakes of L.S.O. and C.W.S.M. and the irrigation uptakes of L.S.O., L.R.O., etc. in a radius of 500m and 300m respectively.
c) Geological report from a private Geologist, member of the Geological Technical Chamber of Greece (G.T.C.G.), reporting in detail the hydrogeological conditions of the area as well as the technical prescriptions of the under-construction uptake.
d) Any other element that the competent service will deem necessary.

The permit issued will define the site, the location (which will be shown in the topographic chart), the technical features of the work and the water needs that the uptake will be allowed to cover.

The commission which will examine the applications of the interested will consist of two members: Agriculture Engineers or Geologists or Engineers or Technologists with the one of them being obligatorily Geologist.

In the excavated drills a piezometric pipe must be placed obligatorily out of the permanent piping of the drill for the measurement of the water level. In addition, after the end of the works, the supervisor Geologist must submit a results report to the Service, containing:

a) Geological section of the drill
b) Technical section of the drill
c) The results of the testing pump
d) Chemical water analysis

These above elements are preconditions for the uptake' s supply of electric power.

The transfer of water for private use is allowed up to 1500m from the uptake location (taking into consideration the boundaries of the remote property).

The disposal of urban and industrial wastes in the water horizons and the qualitative degradation of the surface waters and groundwaters in any way is forbidden.

The procedure to get the permit includes:

- registration of the related file of documents to the appropriate public service
- autopsy by a commission of the public service
- first approval by the Sterea Hellas District
- signature of the related permission by the Prefect

5. LIMITATIONS REGARDING THE DISPOSAL OF USED WATERS

The used waters of the power plant and mainly the waters after the cooling of the towers will be disposed in the environment as industrial wastewater. Apparently a relevant study is required as well as a wastewater disposal permit issued by the competent authority, that is the Supervision of Hygiene of the Prefecture of Viotia.

The limitations regarding the effluents quality are set by the current legislation and depend on the receiver of the disposal. It seems that the most possible receiver is Viotikos Kifissos directly or indirectly (through ditch). It is also possible that the groundwaters are used as receiver through recharging.

As long as Kifissos is the receiver, the effluent quality standards must comply to the Sanitary Provision A5/1983 and E1b 221/1965. The first one, as also presented in the legislation chapter, concerns the waters of the Iliki and V. Kifissos basins, while the general second one applies all over Greece and concerns in general the wastewater disposal either in surface waters or in groundwaters.

A5 Sanitary Provision does not set emission limits, but it sets limits in the receiver that must not be exceeded after the discharge of the treated wastewaters. These limits are shown in Table 6.1 (only the most interesting parameters for the plant are included):

Table 6.1: Standards for the surface waters designated to be used as drinking water, taking as criterion the distance from the upper level of lakes Mornos, Iliki, Paralimni, Marathonas and Stamata (distances>10.000 m from Iliki).

A/A	Parameters	Measurement units	Limit values	
			desirable *	imperative **
1	pH		6,5-8,3	
2	Color (after simple infiltration)	mg/l Pt-Co climax	50	100 (***)
3	Suspended solids	mg/lt	25	50 (***)
4	Temperature	° C	22	25 (***)
5	Conductivity	μs/cm $^{-1}$ in 20° C		1.000
6	Cl^-	mg/l Cl	100	200

Remarks

* Desirable limit values (permanent violation due to manmade activities is prohibited)

** Imperative limit values (any violation due to manmade activities is prohibited)

*** Violation is possible due to special climatological or ecological conditions

As it is shown from the aforementioned table, the temperature value mainly seems to be limitary, although it can be outflanked through the deviations of this same law or through the indirect discharge (e.g. through a ditch). Generally, the competent authorities we communicated with (Supervision of Hygiene of the Prefecture of Viotia, Supervision of the Environment of the Prefecture, Central Supervision of the Ministry of Health, Central

Supervision of the Ministry of the Environment, EYDAP) appear to confront the project positively (or at least not negatively).

In any case, until the end of 2003, the 2000/60 Directive for the waters will be enforced in our country, setting new effluent quality standards for the various activities - works. It is estimated that this directive will act positively in the obscurities of the A5 Sanitary Provision as well as in the possible exaggerations from the prefectural services.

As for the groundwaters, from the viewpoint of effluent receiver, the only valid legislation for the disposal is the E1b 221/1965 Sanitary Provision. In this point it should be mentioned that the Directive 80/68/EU is valid in general, but it isn't valid for wastewaters with low concentrations as in our case. It seems that there is a lack in the current legislation as it was shown through our discussions with the competent Ministry. In any case, it seems that today the wastewater can be disposed in the subsoil according to the E1β/1965 Sanitary Provision, however an appropriate geological study is required concerning the technical applicability of this solution.

6 CONCLUSIONS

The conclusions of this study concerning the water resources in the broad area of the work, are summarized as follows:

1. In the broader area of the plant there exist surface waters and groundwater as well. Viotikos Kifissos is the river crossing the nearby area that consists the main surface water body of the broader area. At the same time, there exist some ephimeral flow streams, like Mavroneri ditch, which is the most significant of them, flowing nearby the plant and confluencing Viotikos Kifissos. Groundwaters exist in the nearest area mainly as unconfined aquifers in small depth in allouvial ground and as one major confined aquifer of great significance flowing through deep karstic limestones. Finally, a lot of springs exist in the area, Mavroneri spring being the most important and near the plant.
2. There are a lot of intense and competitive water uses in the broad and near area of the work. Moreover, the existing water resources (both surface waters and groundwaters) are used not only to cover the relatively limited regional needs, but mainly to cover some high priority needs, such as the water supply of Athens and other uses with important social and economic benefit, such as the irrigation of Kopaida.
3. A lot of water resources exploitation works, concerning mainly the groundwaters, have been constructed in the area (boreholes, pumping stations, aqueducts). In general, these works belong to public agencies of different interests (Company of Water supply and Sewerage of Metropolis / Athens (EYDAP), Ministry of Agriculture YPGE, Municipalities, Local Organizations of Land Reclamation (TOEB)). There is also an unknown number of private drills, legal or not. From the private and municipal drills the 7 nearest ones were recorded, in the context of this study, based on local services' records.
4. Viotikos Kifissos and most surface waters are rather overexploitated for irrigation purposes. As a result, its water flow regime is very poor with a clear declining trend in an overyearly period. As a matter of fact its flow rate near the plant is non existing during the major dry months of the year, as it is clearly shown in the photographs attached in present report. Moreover, the water basins near the plant, mainly due to the ground they have, cannot be used for water supply of the plant. Thus, surface waters definetely should not be considered further as a viable alternative for the water supply of the plant.
5. Groundwaters in the alluvial zone is of low potential and already being overexploitated mainly by small farmers. So it cannot be a viable alternative for the plant water supply.
6. Groundwaters in the deep karstic zone is a rich water resource. This aquifer that extends in a depth of more than 100 m in the plant area (probably more than 150 m) is already extensively exploitated in the broader area by Athens EYDAP, YPGE (ministry of Agriculture), municipalities and farmers. In the near area of the plant the aquifer is also used from two municipal deep wells and some other individual farmers and one industry. The existing exploitation may arise some risk to the availability of the groundwater for the plant. According to preliminary estimations, the drawdown in the plant area after summer withdrawals from EYDAP in Parori-Mavroneri area, YPGE in Heronia area and Municipality of Agios Vlassios will reach 30 m, not considering the withdrawal of other individuals.
7. There is no agency responsible for the overall water resources management of the region and the current water management practice is characterized by lack of planning and controls. This status reduces significantly the credibility of the water uptake works and

has affected negatively the sustainability of available resources, a phenomenon that escalates in crisis periods. That means that any new water uptake work will operate with an additional risk, as it will exploit in common the same water resources with all the other agencies (state or private), under an almost entirely arbitrary status regarding the actual uptakes.

8. The intensive exploitation of the available water resources in combination with the hard hydrological regime of the last two years has resulted in the great degradation of the once rich water potential of the region, with the most representative example being the springs of Mavroneri, drought up for the last two years.

9. With all the above restrictions and reservations concerning the karstic groundwaters, it seams that this water resource is the only practical source of water for the plant supply. The quantity of 4.900.000 m3 on average per year can be supplied from this aquifer with the construction of two or three boreholes of about 200-220 m depth, with some sideeffects being expected. According to the preliminary analysis of this project, a significant drawdown in piezometric load is expected in the near area due to the withdrawal of groundwater for the plant. A likely drawdown of about 25 m after one year of operation or 35 m after 5 years can be expected near the A. Vlassios municipal existing well, which lies in a distance of about 500 m from the plant. Yet it is not known the practical consequences on the water uses of this well or others in the near area. In the broader area, in a distance more than approximately 5 km, the expected impacts will be of rather small magnitude, the drawdown of the major aquifer expected to be about 1 m after a 5 years operation of the wells.

10. The uptake of groundwater for the plant from deep karstic ground is not expected to have any practical consequences on surface ground settling and on the structures of the plant. Obviously suitable geotechnical studies will be needed.

11. The permit procedure has been explained in this report. The permit can be issued by the Industry Division of Viotia Prefecture in Livadia after a suitable application form with some attachments would applied. It is expected that some difficulties may arise due to the expected drawdown in the near area, while a potential negative perspective would translate existing laws with unfavorable manner. This might concern the local area as being irrigated by municipal drainage system, which in our view is not correct. From the point of suitable distances from adjacent uptakes, it seams that the relevant limits of 200 m from individual farmers wells or 500 m from municipal wells can be ensured. It should be pointed out that the construction of this high water consuming industrial plant might generate reactions mainly in the local society which exploit the water resources of the area. This fact will add difficulties in the permit procedure or later during the operation phase of the plant..

12. Finally it should be pointed out that a quite smaller uptake for the plant, as it is obvious, would avoid any practical impact both on near area as well as in far area and would overcome any difficulties in the permit procedure and the operation of the plant.

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Annex A: Hydrological data

Discharge measurements

Table A.1: Discharge measurements, implemented by IGME, that were used for the correlation of Viotikos Kifissos runoff at Heronia (Agios Vassileios) gauge and at Karditsa canal; italic fonts represent discharge measurements of Karditsa canal that were implemented one day after those of Heronia.

Date	Discharge at Karditsa (m^3/h)	Discharge at Heronia (m^3/h)	Discharge at Karditsa (m^3/s)	Discharge at Heronia (m^3/s)
21/11/1983	*10544*	3100	2.9	0.9
14/12/1983	47271	27543	13.1	7.7
27/1/1984	*33624*	19351	9.3	5.4
3/3/1984	93275	54053	25.9	15.0
4/5/1984	79268	51892	22.0	14.4
21/3/1985	*92769*	53495	25.8	14.9
4/4/1985	*71948*	50372	20.0	14.0
23/10/1985	*29375*	8033	8.2	2.2
7/11/1985	*25887*	8995	7.2	2.5
5/12/1985	*28356*	13178	7.9	3.7
11/12/1985	*31509*	10236	8.8	2.8
16/1/1986	*65419*	18255	18.2	5.1
30/1/1986	*32636*	12660	9.1	3.5
6/2/1986	*44299*	25378	12.3	7.0
25/2/1986	72937	56973	20.3	15.8
7/3/1986	61030	43526	17.0	12.1
13/3/1986	*54944*	30254	15.3	8.4
28/3/1986	40733	23062	11.3	6.4
9/4/1986	22220	18782	6.2	5.2
16/10/1986	*24498*	4260	6.8	1.2
23/10/1986	*9945*	3772	2.8	1.0
19/11/1986	*21820*	8365	6.1	2.3
12/12/1986	21503	8132	6.0	2.3

22/1/1987	*70662*	27056	19.6	7.5
5/2/1987	*50791*	20358	14.1	5.7
20/2/1987	61627	20708	17.1	5.8
15/4/1987	94926	35746	26.4	9.9
15/10/1987	*22281*	9186	6.2	2.6
26/11/1987	24439	8090	6.8	2.2
9/12/1987	25429	7703	7.1	2.1
23/12/1987	*27378*	7364	7.6	2.0
20/1/1988	20726	6329	5.8	1.8
8/2/1988	*35114*	12198	9.8	3.4
29/3/1988	72686	32301	20.2	9.0
27/4/1988	33092	26446	9.2	7.3
29/12/1988	54319	12608	15.1	3.5
3/2/1989	29802	7418	8.3	2.1
30/3/1989	*104699*	49351	29.1	13.7
17/4/1991	71804	22244	19.9	6.2
20/11/1991	23807	5114	6.6	1.4
15/1/1992	*26091*	3735	7.2	1.0
31/3/1992	*34285*	11954	9.5	3.3

Table A.2: Discharge measurements, implemented by IGME, that were used for the correlation of Viotikos Kifissos runoff at Davlia (railway station) gauge and at Karditsa canal; italic fonts represent discharge measurements of Karditsa that were implemented one day after those of Davlia.

Date	Discharge at Karditsa (m^3/h)	Discharge at Davlia (m^3/h)	Discharge at Karditsa (m^3/s)	Discharge at Davlia (m^3/s)
3/3/1984	93275	47360	25.9	13.2
4/5/1984	79268	24516	22.0	6.8
20/3/1985	92769	31327	25.8	8.7
4/4/1985	*71948*	28832	20.0	8.0
7/11/1985	*25887*	1267	7.2	0.4
5/12/1985	*28356*	1427	7.9	0.4
11/12/1985	*31509*	2182	8.8	0.6
30/1/1986	*32636*	7588	9.1	2.1
6/2/1986	*44299*	10065	12.3	2.8

25/2/1986	*72937*	32413	20.3	9.0
6/3/1986	*61030*	21203	17.0	5.9
27/3/1986	*40733*	12399	11.3	3.4
9/4/1986	22220	7870	6.2	2.2
17/4/1986	*17069*	6492	4.7	1.8
8/5/1986	*13132*	3336	3.6	0.9
16/10/1986	*24498*	904	6.8	0.3
4/12/1986	*17789*	2081	4.9	0.6
12/12/1986	21503	1953	6.0	0.5
9/1/1987	61129	20112	17.0	5.6
5/2/1987	*50791*	16932	14.1	4.7
19/2/1987	*61627*	17539	17.1	4.9
15/4/1987	94926	28080	26.4	7.8
10/7/1987	7097	5028	2.0	1.4
15/10/1987	*22281*	2305	6.2	0.6
26/11/1987	24439	1994	6.8	0.6
9/12/1987	25429	1581	7.1	0.4
23/12/1987	*27378*	2464	7.6	0.7
20/1/1988	20726	2268	5.8	0.6
8/2/1988	*35114*	10966	9.8	3.0
29/3/1988	72686	24293	20.2	6.7
29/12/1988	54319	7231	15.1	2.0
3/2/1989	29802	1356	8.3	0.4
23/1/1991	*56613*	12368	15.7	3.4
17/4/1991	71804	20029	19.9	5.6
20/11/1991	23807	1117	6.6	0.3

Table A.3: Discharge measurements, implemented by IGME, that were used for the correlation of Viotikos Kifissos runoff at Davlia (railway station) and Heronia (Agios Vassileios) gauges.

Date	Discharge at Heronia (m^3/h)	Discharge at Davlia (m^3/h)	Discharge at Heronia (m^3/s)	Discharge at Davlia (m^3/s)
1/2/1984	13950	7533	3.9	2.1
7/2/1984	29279	14704	8.1	4.1
3/3/1984	54053	47360	15.0	13.2

30/3/1984	48478	30577	13.5	8.5
4/5/1984	51892	24516	14.4	6.8
16/1/1985	63650	34727	17.7	9.6
7/3/1985	40902	33279	11.4	9.2
4/4/1985	50372	28832	14.0	8.0
6/8/1985	8152	3220	2.3	0.9
20/8/1985	7341	1320	2.0	0.4
12/9/1985	8834	1247	2.5	0.3
10/10/1985	9228	1972	2.6	0.5
7/11/1985	8995	1267	2.5	0.4
20/11/1985	7785	1457	2.2	0.4
5/12/1985	13178	1427	3.7	0.4
11/12/1985	10236	2182	2.8	0.6
30/1/1986	12660	7588	3.5	2.1
6/2/1986	25378	10065	7.0	2.8
25/2/1986	56973	32413	15.8	9.0
13/3/1986	30254	2324	8.4	0.6
9/4/1986	18782	7870	5.2	2.2
8/5/1986	13599	3336	3.8	0.9
22/5/1986	15257	3267	4.2	0.9
28/5/1986	16875	3447	4.7	1.0
24/7/1986	1999	876	0.6	0.2
10/9/1986	1562	845	0.4	0.2
9/10/1986	4581	935	1.3	0.3
16/10/1986	4260	904	1.2	0.3
23/10/1986	3772	603	1.0	0.2
19/11/1986	8365	1722	2.3	0.5
28/1/1987	22643	13661	6.3	3.8
5/2/1987	20358	16932	5.7	4.7
11/2/1987	22424	9508	6.2	2.6
25/2/1987	21636	15973	6.0	4.4
15/4/1987	35746	28080	9.9	7.8
13/5/1987	28978	14181	8.0	3.9
15/10/1987	9186	2305	2.6	0.6
4/11/1987	8882	1487	2.5	0.4

12/11/1987	8262	1336	2.3	0.4
26/11/1987	8090	1994	2.2	0.6
9/12/1987	7703	1581	2.1	0.4
23/12/1987	7364	2464	2.0	0.7
20/1/1988	6329	2268	1.8	0.6
8/2/1988	12198	10966	3.4	3.0
25/2/1988	17757	9831	4.9	2.7
29/3/1988	32301	24293	9.0	6.7
12/2/1991	16307	15745	4.5	4.4
12/3/1991	21247	18299	5.9	5.1
17/4/1991	22244	20029	6.2	5.6
20/11/1991	5114	1117	1.4	0.3
15/1/1992	3735	1062	1.0	0.3

Table A.4: Discharge measurements, implemented by IGME, that were used for the correlation of runoff at Mavroneri channel and Viotikos Kifissos (Heronia gauge).

Date	Discharge at Heronia (m^3/h)	Discharge at Mavroneri (m^3/h)	Discharge at Heronia (m^3/s)	Discharge at Mavroneri (m^3/s)
21/11/1983	3100	1933	0.9	0.5
27/1/1984	19356	5413	5.4	1.5
3/3/1984	54053	11901	15.0	3.3
12/12/1984	12700	3700	3.5	1.0
16/1/1985	63650	13605	17.7	3.8
21/3/1985	53495	9936	14.9	2.8
6/8/1985	8152	4696	2.3	1.3
20/8/1985	7341	3356	2.0	0.9
20/11/1985	7785	5619	2.2	1.6
5/12/1985	13178	7161	3.7	2.0
11/12/1985	10236	7100	2.8	2.0
31/12/1985	10059	7463	2.8	2.1
13/3/1986	30254	7498	8.4	2.1
9/4/1986	18782	6817	5.2	1.9
8/5/1986	13599	4654	3.8	1.3
22/5/1986	15257	5356	4.2	1.5
28/5/1986	16875	5778	4.7	1.6

10/9/1986	1562	967	0.4	0.3
9/10/1986	4581	2263	1.3	0.6
23/10/1986	3772	2139	1.0	0.6
19/11/1986	8365	5905	2.3	1.6
12/12/1986	8132	4476	2.3	1.2
5/2/1987	20358	5402	5.7	1.5
20/2/1987	20708	9974	5.8	2.8
2/4/1987	80275	13919	22.3	3.9
15/4/1987	35746	12241	9.9	3.4
13/5/1987	28978	7996	8.0	2.2
15/10/1987	9186	6355	2.6	1.8
4/11/1987	8882	5661	2.5	1.6
26/11/1987	8090	5097	2.2	1.4
23/12/1987	7364	4592	2.0	1.3
20/1/1988	6329	4392	1.8	1.2
8/2/1988	12198	5200	3.4	1.4
27/4/1988	26446	9325	7.3	2.6
25/10/1988	3596	2577	1.0	0.7
3/2/1989	7418	4011	2.1	1.1
18/10/1989	2866	1101	0.8	0.3
11/1/1990	2403	1604	0.7	0.4
15/2/1990	1409	706	0.4	0.2
12/3/1991	21247	7066	5.9	2.0
17/4/1991	22244	8832	6.2	2.5

Monthly runoff series

Table A.5: Monthly runoff series of Viotikos Kifissos at Karditsa canal (hm^3) – Hydrologic years 1907-08 to 2000-01 (without correction of summer runoff values).

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1906-07				90.6	152.4	123.3	121.3	67.1	33.5	15.2	15.1	22.9	
1907-08	29.0	30.6	33.0	40.0	32.5	33.9	24.0	10.5	5.6	2.5	4.1	8.6	254.3
1908-09	27.7	25.4	86.4	114.2	72.6	60.5	65.7	27.4	23.5	5.0	2.7	12.0	523.1
1909-10	14.9	19.6	25.8	38.2	104.8	75.7	67.5	37.9	31.6	1.1	4.8	13.8	435.7
1910-11	20.8	25.4	31.7	38.0	27.3	40.7	38.9	22.5	17.7	5.7	7.8	20.0	296.5
1911-12	18.2	54.9	42.5	71.4	68.0	49.5	38.3	32.6	15.1	10.7	5.1	13.0	419.3
1912-13	18.1	65.8	97.7	42.7	89.1	157.6	75.3	33.4	27.2	6.6	7.6	13.5	634.6
1913-14	48.4	27.4	36.5	84.9	43.7	45.2	26.6	9.5	10.2	7.0	6.5	17.9	363.8
1914-15	19.2	61.2	54.9	92.6	78.9	77.0	63.0	35.6	13.9	7.0	4.5	19.7	527.5
1915-16	29.1	24.2	25.3	25.7	36.3	31.1	9.0	16.0	3.6	1.1	1.5	6.5	209.4
1916-17	13.1	15.3	17.4	20.6	29.6	24.0	2.7	1.1	0.9	0.8	0.7	2.4	128.6
1917-18	11.2	16.3	20.7	25.5	38.1	56.1	42.1	9.6	5.7	2.6	4.2	8.8	240.9
1918-19	18.3	52.5	73.5	103.8	121.5	98.7	64.6	51.5	32.5	6.3	2.7	22.9	648.8
1919-20	23.7	32.7	42.5	39.6	38.8	75.8	37.6	25.3	24.1	0.4	2.5	11.7	354.7
1920-21	46.8	108.1	127.5	109.9	98.3	76.0	53.4	38.5	26.3	7.4	5.5	20.7	718.4
1921-22	43.1	72.5	159.5	158.9	111.0	79.1	46.5	28.7	16.9	2.6	1.3	11.6	731.7
1922-23	19.6	46.3	43.4	97.8	68.1	74.1	60.0	64.0	44.3	14.3	5.6	16.7	554.2
1923-24	20.8	23.8	33.5	66.7	86.2	66.0	39.8	16.4	12.9	0.6	0.0	10.9	377.6
1924-25	16.8	77.3	60.8	44.8	61.7	90.5	66.8	44.8	27.6	9.5	0.0	7.8	508.4
1925-26	20.4	20.9	31.5	53.7	47.0	68.8	29.2	2.9	6.1	0.0	0.0	4.6	285.1
1926-27	13.9	13.1	20.8	48.8	49.9	56.7	38.8	11.1	0.0	0.0	0.0	4.6	257.7
1927-28	38.8	32.1	58.5	111.0	124.3	146.2	112.9	43.4	21.9	2.4	0.0	6.8	698.3
1928-29	35.0	52.2	79.8	72.1	98.3	97.2	62.5	26.8	20.4	2.5	0.0	27.3	574.1
1929-30	27.3	55.1	41.5	46.9	101.9	105.8	67.7	39.0	21.5	20.0	0.0	11.3	538.0
1930-31	22.6	23.8	39.1	77.8	116.3	82.4	120.4	47.5	34.2	0.1	0.0	16.7	580.9
1931-32	22.5	20.9	64.4	62.1	57.3	138.0	78.6	25.8	7.5	1.1	1.0	17.4	496.6
1932-33	22.0	34.8	27.9	48.2	71.1	42.2	37.6	22.2	22.8	3.7	7.1	17.5	357.1
1933-34	15.4	15.0	50.1	73.4	108.4	109.9	55.9	18.6	25.4	6.7	1.6	9.4	489.8
1934-35	16.5	21.8	44.3	86.2	75.9	64.1	37.8	18.0	12.3	1.2	0.0	4.0	382.1
1935-36	11.6	22.7	66.9	51.5	60.5	26.9	17.1	37.8	14.0	10.1	0.1	7.9	327.1
1936-37	18.6	30.7	60.3	38.7	67.4	37.0	32.3	19.1	8.7	1.8	0.0	11.7	326.3
1937-38	37.8	36.7	79.2	91.7	153.2	91.4	167.1	76.2	24.9	7.1	3.1	24.7	793.1
1938-39	30.5	27.0	79.5	82.8	51.3	168.9	90.1	33.6	43.1	16.1	0.0	19.0	641.9
1939-40	23.7	23.3	39.6	110.5	70.0	62.5	47.5	51.2	28.4	7.0	11.9	19.3	494.9
1940-41	20.1	18.5	65.9	81.8	76.3	53.6	29.2	66.5	57.6	48.5	29.6	18.6	566.2
1941-42	32.4	36.8	37.0	69.6	132.5	114.0	68.1	25.4	21.2	13.2	8.5	20.5	579.2
1942-43	28.4	41.0	29.9	31.0	27.7	36.8	25.8	31.0	8.8	7.4	7.4	22.2	297.4
1943-44	21.2	32.9	27.9	48.9	66.8	61.1	50.1	26.9	12.8	7.4	13.5	20.0	389.5
1944-45	20.9	22.1	40.6	76.1	53.9	62.0	49.1	21.1	6.6	2.6	2.6	22.3	379.9
1945-46	22.3	42.9	69.4	125.7	61.5	68.0	56.1	34.7	4.6	4.3	3.7	17.7	510.9
1946-47	25.0	28.8	95.6	138.8	130.3	66.9	33.2	25.4	22.7	7.0	9.0	24.1	606.8
1947-48	26.8	40.4	53.9	36.5	36.9	44.9	45.5	33.4	13.9	9.3	9.1	18.3	368.9
1948-49	21.1	23.0	36.7	48.2	59.9	64.2	47.5	25.0	22.4	0.0	14.0	22.7	384.7
1949-50	28.3	42.0	31.9	42.5	40.3	74.6	53.8	33.2	9.9	10.0	13.4	21.5	401.4
1950-51	23.0	23.7	32.3	52.4	45.8	48.8	31.8	13.0	13.1	13.7	6.7	13.3	317.6
1951-52	42.3	62.9	42.1	77.2	77.2	46.4	26.2	19.0	11.6	5.7	0.0	12.3	422.9

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1952-53	14.7	15.1	34.1	56.2	35.8	36.3	28.4	17.5	15.2	0.0	0.0	13.1	266.4
1953-54	21.9	57.3	30.5	61.0	86.9	72.2	52.0	27.3	10.7	7.5	9.7	15.0	452.0
1954-55	19.2	25.6	64.5	56.6	26.7	39.2	54.1	27.4	8.1	0.0	11.9	18.7	352.0
1955-56	37.4	42.0	33.1	47.4	160.9	128.3	64.6	26.5	16.2	0.0	0.0	18.8	575.2
1956-57	19.2	19.0	23.3	31.7	25.0	32.1	12.9	12.2	12.2	38.0	0.0	14.8	240.4
1957-58	47.3	82.3	62.3	70.3	37.5	55.8	43.1	22.1	15.8	0.0	18.9	54.9	510.3
1958-59	24.8	42.1	47.7	50.6	38.8	59.8	43.8	32.8	15.6	0.0	15.5	20.3	391.8
1959-60	24.1	33.7	34.8	65.2	55.4	66.2	44.1	27.3	9.0	0.0	2.1	22.1	384.0
1960-61	22.4	22.1	36.3	37.7	39.1	95.2	35.5	19.4	2.0	0.0	0.0	7.0	316.7
1961-62	21.0	21.2	31.9	24.6	36.8	44.0	13.9	0.0	0.0	0.0	0.0	8.2	201.5
1962-63	26.0	48.4	178.4	96.0	130.9	88.7	54.6	41.7	13.5	0.0	0.0	13.5	691.8
1963-64	42.4	33.6	48.1	66.6	65.4	80.5	44.5	16.3	0.0	0.0	0.0	18.5	415.9
1964-65	20.7	17.1	25.9	55.8	72.0	78.5	50.3	29.8	16.2	5.5	3.9	11.2	386.8
1965-66	17.9	18.5	17.7	45.8	22.6	73.9	46.4	24.8	14.0	4.4	3.6	13.4	302.9
1966-67	17.6	32.3	45.8	41.7	39.9	58.7	42.0	19.2	9.1	2.8	4.6	14.8	328.6
1967-68	29.3	34.7	55.2	60.8	63.6	67.0	38.2	18.8	10.2	3.0	2.9	14.9	398.6
1968-69	38.3	46.0	205.4	147.5	73.7	90.8	59.4	25.7	0.0	0.0	10.0	27.3	724.2
1969-70	32.0	30.2	51.7	54.7	39.2	62.1	20.9	25.2	0.0	0.0	0.0	17.9	333.9
1970-71	24.9	25.5	25.9	46.9	47.3	91.4	60.2	22.7	0.0	0.0	0.0	22.6	367.3
1971-72	27.0	38.3	36.3	95.8	84.5	82.4	67.5	52.9	0.0	0.0	8.1	22.2	515.0
1972-73	32.0	49.7	28.3	64.3	61.3	69.3	50.2	0.0	13.3	0.0	0.0	0.0	368.4
1973-74	0.0	29.1	43.8	50.1	68.3	105.4	57.3	25.1	0.0	0.0	0.0	23.1	402.2
1974-75	39.0	35.6	37.0	40.4	50.6	54.1	10.5	0.0	0.0	0.0	0.0	12.7	279.9
1975-76	26.9	29.4	58.1	50.4	89.0	64.7	56.1	14.2	0.0	0.0	0.0	6.7	395.5
1976-77	18.8	23.6	24.1	20.2	3.5	16.4	15.9	5.4	4.9	1.0	2.2	11.3	147.2
1977-78	4.8	7.4	28.2	66.8	75.5	46.7	30.7	9.6	0.2	0.0	0.0	6.0	275.9
1978-79	15.1	18.2	43.4	38.4	36.1	27.2	13.3	7.5	0.7	0.0	0.0	7.7	207.7
1979-80	28.3	45.6	38.4	63.4	51.2	93.8	50.5	34.1	9.3	0.0	0.0	10.1	424.7
1980-81	42.1	31.3	55.2	115.0	100.6	62.3	50.2	15.8	3.6	1.4	3.9	17.4	498.6
1981-82	19.1	21.7	31.0	26.5	54.8	95.3	88.3	55.0	22.6	4.2	6.3	12.7	437.3
1982-83	14.7	22.4	33.3	27.9	27.9	42.5	11.4	4.8	8.1	0.4	0.0	0.0	193.3
1983-84	7.5	12.7	52.9	44.0	68.1	77.0	80.1	35.9	4.3	3.8	3.5	12.0	401.8
1984-85	11.8	19.8	27.2	103.4	44.8	65.6	51.3	17.7	7.1	0.0	0.5	6.3	355.4
1985-86	18.1	26.5	31.0	27.7	40.3	42.1	19.0	10.1	2.2	0.0	0.0	1.9	218.9
1986-87	18.1	21.8	20.0	43.6	39.9	79.8	73.5	37.7	7.2	0.0	0.0	4.0	345.7
1987-88	12.6	18.8	19.4	22.6	42.0	66.7	29.8	10.0	1.0	0.0	0.0	0.7	223.8
1988-89	7.2	18.4	43.8	26.9	17.8	52.3	22.6	3.5	0.0	0.0	0.0	0.0	192.7
1989-90	8.5	10.7	13.0	14.9	9.2	2.3	0.0	0.0	0.0	0.0	2.8	5.4	66.8
1990-91	7.1	10.8	37.6	41.7	37.9	54.9	48.0	24.3	3.1	0.0	0.0	5.9	271.3
1991-92	11.0	15.4	20.0	20.8	23.2	27.0	13.4	4.1	0.7	0.0	0.0	3.2	138.9
1992-93	7.9	10.2	12.2	15.4	16.8	18.4	0.0	0.0	0.0	0.0	0.0	0.0	80.9
1993-94	1.6	7.0	10.4	25.9	74.5	43.2	24.9	8.0	0.0	0.0	0.0	0.0	195.5
1994-95	19.9	20.9	26.5	59.5	37.5	49.1	37.1	5.5	0.0	0.0	0.0	2.1	258.2
1995-96	10.9	15.0	31.1	46.7	75.9	70.3	44.7	10.5	11.0	0.3	0.0	5.0	321.4
1996-97	11.7	14.8	18.3	80.2	26.6	46.0	36.7	20.2	0.7	0.0	0.0	1.7	257.0
1997-98	9.5	20.7	38.1	23.1	28.8	40.5	39.5	27.2	4.0	1.4	0.0	0.0	232.8
1998-99	0.0	21.3	39.6	48.6	50.1	94.4	65.5	16.6	2.7	0.0	0.0	2.7	341.6
1999-00	8.5	24.1	20.5	26.3	35.4	30.9	12.5	2.5	0.0	0.0	0.0	0.0	160.7

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
2000-01	2.7	6.5	9.0	16.7	16.3	6.6	5.1	1.5	0.2	0.0	0.0	0.0	64.5
M. O.	21.8	31.1	46.2	59.5	62.2	66.5	46.0	24.2	12.0	4.1	3.5	12.9	386.3
T. A.	10.8	17.7	32.3	31.0	33.8	31.0	27.1	16.3	11.6	7.3	5.2	8.7	160.3

Table A.6: Monthly runoff series of Viotikos Kifissos at Karditsa canal (hm^3) – Hydrologic years 1968-69 to 2000-01 (with correction of summer runoff values).

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1968-69	38.3	46.0	205.4	147.5	73.7	90.8	59.4	25.7	13.8	7.4	10.0	27.3	718.0
1969-70	32.0	30.2	51.7	54.7	39.2	62.1	20.9	25.2	13.5	7.2	3.9	17.9	340.6
1970-71	24.9	25.5	25.9	46.9	47.3	91.4	60.2	22.7	12.1	6.5	3.5	22.6	366.8
1971-72	27.0	38.3	36.3	95.8	84.5	82.4	67.5	52.9	28.3	15.1	8.1	22.2	536.4
1972-73	32.0	49.7	28.3	64.3	61.3	69.3	50.2	0.0	13.3	7.1	3.8	0.0	379.3
1973-74	0.0	29.1	43.8	50.1	68.3	105.4	57.3	25.1	13.4	7.2	3.8	23.1	403.5
1974-75	39.0	35.6	37.0	40.4	50.6	54.1	10.5	0.0	0.0	0.0	0.0	12.7	267.2
1975-76	26.9	29.4	58.1	50.4	89.0	64.7	56.1	14.2	7.6	4.1	2.2	6.7	402.7
1976-77	18.8	23.6	24.1	20.2	3.5	16.4	15.9	5.4	4.9	2.6	2.2	11.3	137.5
1977-78	4.8	7.4	28.2	66.8	75.5	46.7	30.7	9.6	5.1	2.7	1.5	6.0	279.0
1978-79	15.1	18.2	43.4	38.4	36.1	27.2	13.3	7.5	4.0	2.1	1.1	7.7	206.6
1979-80	28.3	45.6	38.4	63.4	51.2	93.8	50.5	34.1	18.2	9.8	5.2	10.1	438.5
1980-81	42.1	31.3	55.2	115.0	100.6	62.3	50.2	15.8	8.5	4.5	3.9	17.4	489.3
1981-82	19.1	21.7	31.0	26.5	54.8	95.3	88.3	55.0	29.4	15.7	8.4	12.7	445.1
1982-83	14.7	22.4	33.3	27.9	27.9	42.5	11.4	4.8	8.1	4.3	2.3	0.0	199.6
1983-84	7.5	12.7	52.9	44.0	68.1	77.0	80.1	35.9	19.2	10.3	5.5	12.0	413.1
1984-85	11.8	19.8	27.2	103.4	44.8	65.6	51.3	17.7	9.5	5.1	2.7	6.3	358.7
1985-86	18.1	26.5	31.0	27.7	40.3	42.1	19.0	10.1	5.4	2.9	1.5	1.9	224.7
1986-87	18.1	21.8	20.0	43.6	39.9	79.8	73.5	37.7	20.2	10.8	5.8	4.0	371.2
1987-88	12.6	18.8	19.4	22.6	42.0	66.7	29.8	10.0	5.4	2.9	1.5	0.7	231.8
1988-89	7.2	18.4	43.8	26.9	17.8	52.3	22.6	3.5	1.9	1.0	0.5	0.0	196.1
1989-90	8.5	10.7	13.0	14.9	9.2	2.3	0.0	0.0	0.0	0.0	2.8	5.4	61.4

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1990-91	7.1	10.8	37.6	41.7	37.9	54.9	48.0	24.3	13.0	6.9	3.7	5.9	285.9
1991-92	11.0	15.4	20.0	20.8	23.2	27.0	13.4	4.1	2.2	1.2	0.6	3.2	138.9
1992-93	7.9	10.2	12.2	15.4	16.8	18.4	0.0	0.0	0.0	0.0	0.0	0.0	80.9
1993-94	1.6	7.0	10.4	25.9	74.5	43.2	24.9	8.0	4.3	2.3	1.2	0.0	203.3
1994-95	19.9	20.9	26.5	59.5	37.5	49.1	37.1	5.5	2.9	1.6	0.8	2.1	261.4
1995-96	10.9	15.0	31.1	46.7	75.9	70.3	44.7	10.5	11.0	5.9	3.1	5.0	325.1
1996-97	11.7	14.8	18.3	80.2	26.6	46.0	36.7	20.2	10.8	5.8	3.1	1.7	274.2
1997-98	9.5	20.7	38.1	23.1	28.8	40.5	39.5	27.2	14.5	7.8	4.2	0.0	253.9
1998-99	0.0	21.3	39.6	48.6	50.1	94.4	65.5	16.6	8.9	4.8	2.5	2.7	352.4
1999-00	8.5	24.1	20.5	26.3	35.4	30.9	12.5	2.5	1.3	0.7	0.4	0.0	163.2
2000-01	2.7	6.5	9.0	16.7	16.3	6.6	5.1	1.5	0.8	0.4	0.2	0.0	65.8
M. O.	16.3	22.7	36.7	48.4	46.9	56.7	37.8	16.2	9.4	5.0	3.0	7.5	299.2
T. A.	11.6	11.2	32.9	30.9	24.2	27.1	24.1	14.7	7.6	4.1	2.4	8.0	142.6

Table A.7: Monthly runoff series of Viotikos Kifissos at Heronia (Agios Vassileios) discharge gauge (hm^3) – Hydrologic years 1968-69 to 2000-01.

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1968-69	16.4	20.9	138.0	90.7	38.7	49.1	28.9	9.9	4.5	2.0	3.0	10.7	412.8
1969-70	13.1	12.2	24.0	25.8	17.3	30.3	7.7	9.7	4.4	2.0	0.9	6.3	153.6
1970-71	9.5	9.9	10.0	21.2	22.0	49.5	29.3	8.4	3.8	1.7	0.8	8.4	174.6
1971-72	10.5	16.5	15.4	52.5	46.0	43.4	34.0	24.7	11.3	5.1	2.3	8.2	269.8
1972-73	13.1	23.1	11.2	31.6	30.6	34.8	23.3	0.0	4.3	1.9	0.9	0.0	174.8
1973-74	0.0	11.7	19.4	23.1	35.1	59.2	27.6	9.6	4.4	2.0	0.9	8.6	201.6
1974-75	16.8	15.1	15.7	17.6	24.0	25.4	3.2	0.0	0.0	0.0	0.0	4.0	121.8
1975-76	10.5	11.9	27.8	23.2	49.1	31.9	26.9	4.7	2.1	1.0	0.4	1.8	191.3
1976-77	6.6	9.0	9.1	7.3	0.8	5.6	5.4	1.4	1.2	0.5	0.4	3.5	50.9
1977-78	1.2	2.0	11.1	33.2	39.8	21.1	12.5	2.8	1.3	0.6	0.3	1.6	127.6
1978-79	5.0	6.4	19.3	16.5	15.7	10.6	4.3	2.1	0.9	0.4	0.2	2.1	83.6
1979-80	11.2	20.7	16.5	31.1	24.4	51.1	23.5	14.2	6.5	2.9	1.3	3.0	206.2
1980-81	18.5	12.8	26.1	66.2	57.4	30.4	23.3	5.4	2.4	1.1	0.9	6.0	250.4
1981-82	6.8	8.0	12.5	10.3	26.6	52.1	47.8	26.0	11.8	5.3	2.4	4.0	213.6
1982-83	4.9	8.4	13.7	11.0	11.3	18.7	3.6	1.2	2.3	1.0	0.5	0.0	76.5
1983-84	2.1	4.1	24.7	19.5	35.0	39.8	42.2	15.1	6.9	3.1	1.4	3.8	197.6
1984-85	3.7	7.2	10.6	57.8	20.6	32.4	24.0	6.2	2.8	1.3	0.6	1.7	168.7
1985-86	6.3	10.4	12.6	10.9	18.0	18.5	6.8	3.0	1.4	0.6	0.3	0.4	89.1
1986-87	6.3	8.1	7.2	19.4	17.7	41.7	37.8	16.1	7.3	3.3	1.5	0.9	167.4
1987-88	4.0	6.7	6.9	8.4	19.0	33.2	12.0	3.0	1.4	0.6	0.3	0.1	95.6
1988-89	2.0	6.6	19.4	10.5	6.4	24.4	8.5	0.8	0.4	0.2	0.1	0.0	79.1
1989-90	2.4	3.3	4.2	5.0	2.8	0.5	0.0	0.0	0.0	0.0	0.6	1.4	20.0
1990-91	1.9	3.3	16.1	18.3	16.6	25.9	22.0	9.2	4.2	1.9	0.8	1.5	121.8
1991-92	3.4	5.2	7.2	7.6	8.9	10.5	4.4	1.0	0.4	0.2	0.1	0.7	49.6
1992-93	2.2	3.1	3.8	5.1	5.9	6.5	0.0	0.0	0.0	0.0	0.0	0.0	26.7

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1993-94	0.3	1.9	3.1	10.0	39.2	19.1	9.6	2.2	1.0	0.5	0.2	0.0	87.2
1994-95	7.2	7.7	10.3	28.7	16.4	22.5	15.9	1.4	0.6	0.3	0.1	0.4	111.5
1995-96	3.3	5.1	12.6	21.1	40.1	35.5	20.1	3.2	3.4	1.5	0.7	1.2	147.8
1996-97	3.7	5.0	6.4	41.9	10.6	20.7	15.7	7.3	3.3	1.5	0.7	0.3	117.0
1997-98	2.8	7.6	16.3	8.7	11.8	17.6	17.2	10.6	4.8	2.2	1.0	0.0	100.5
1998-99	0.0	7.9	17.1	22.2	23.7	51.5	32.7	5.7	2.6	1.2	0.5	0.6	165.7
1999-00	2.4	9.2	7.4	10.2	15.3	12.5	4.0	0.5	0.2	0.1	0.0	0.0	61.9
2000-01	0.6	1.7	2.6	5.7	5.7	1.8	1.3	0.3	0.1	0.1	0.0	0.0	19.9
M. O.	6.0	8.9	16.9	23.4	22.8	28.1	17.4	6.2	3.1	1.4	0.7	2.5	137.5
T. A.	5.2	5.5	22.7	19.4	14.3	15.9	13.0	6.8	3.0	1.3	0.7	3.0	81.7

Table A.8: Monthly runoff series of Viotikos Kifissos at Davlia (railway station) discharge gauge (hm^3) – Hydrologic years 1968-69 to 2000-01.

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1968-69	9.7	12.3	81.6	53.6	22.8	29.0	17.1	5.9	2.7	1.2	1.8	6.3	243.9
1969-70	7.7	7.2	14.2	15.3	10.2	17.9	4.5	5.7	2.6	1.2	0.5	3.7	90.8
1970-71	5.6	5.8	5.9	12.5	13.0	29.2	17.3	5.0	2.3	1.0	0.5	5.0	103.2
1971-72	6.2	9.8	9.1	31.0	27.2	25.6	20.1	14.6	6.7	3.0	1.4	4.8	159.4
1972-73	7.7	13.6	6.6	18.7	18.1	20.6	13.8	0.0	2.6	1.1	0.5	0.0	103.3
1973-74	0.0	6.9	11.5	13.6	20.8	35.0	16.3	5.7	2.6	1.2	0.5	5.1	119.1
1974-75	9.9	8.9	9.3	10.4	14.2	15.0	1.9	0.0	0.0	0.0	0.0	2.4	72.0
1975-76	6.2	7.0	16.5	13.7	29.0	18.9	15.9	2.8	1.3	0.6	0.3	1.1	113.0
1976-77	3.9	5.3	5.4	4.3	0.5	3.3	3.2	0.8	0.7	0.3	0.3	2.1	30.1
1977-78	0.7	1.2	6.6	19.6	23.5	12.5	7.4	1.7	0.8	0.3	0.2	0.9	75.4
1978-79	3.0	3.8	11.4	9.7	9.2	6.3	2.6	1.2	0.6	0.3	0.1	1.3	49.4
1979-80	6.6	12.2	9.7	18.4	14.4	30.2	13.9	8.4	3.8	1.7	0.8	1.8	121.8
1980-81	10.9	7.6	15.4	39.1	33.9	18.0	13.8	3.2	1.4	0.6	0.5	3.6	148.0
1981-82	4.0	4.7	7.4	6.1	15.7	30.8	28.2	15.3	7.0	3.1	1.4	2.4	126.2
1982-83	2.9	5.0	8.1	6.5	6.7	11.1	2.1	0.7	1.4	0.6	0.3	0.0	45.2
1983-84	1.2	2.4	14.6	11.5	20.7	23.5	24.9	8.9	4.1	1.8	0.8	2.2	116.8
1984-85	2.2	4.2	6.3	34.1	12.2	19.2	14.2	3.6	1.7	0.7	0.3	1.0	99.7
1985-86	3.7	6.1	7.4	6.4	10.6	10.9	4.0	1.8	0.8	0.4	0.2	0.2	52.6
1986-87	3.7	4.8	4.3	11.4	10.5	24.6	22.3	9.5	4.3	1.9	0.9	0.5	98.9
1987-88	2.4	4.0	4.1	5.0	11.2	19.6	7.1	1.8	0.8	0.4	0.2	0.1	56.5
1988-89	1.2	3.9	11.5	6.2	3.8	14.4	5.0	0.5	0.2	0.1	0.0	0.0	46.7
1989-90	1.4	1.9	2.5	2.9	1.6	0.3	0.0	0.0	0.0	0.0	0.3	0.8	11.8
1990-91	1.1	2.0	9.5	10.8	9.8	15.3	13.0	5.4	2.5	1.1	0.5	0.9	72.0
1991-92	2.0	3.1	4.3	4.5	5.3	6.2	2.6	0.6	0.3	0.1	0.1	0.4	29.3
1992-93	1.3	1.8	2.3	3.0	3.5	3.8	0.0	0.0	0.0	0.0	0.0	0.0	15.8
1993-94	0.2	1.1	1.9	5.9	23.2	11.3	5.7	1.3	0.6	0.3	0.1	0.0	51.5
1994-95	4.2	4.5	6.1	17.0	9.7	13.3	9.4	0.8	0.4	0.2	0.1	0.2	65.9
1995-96	2.0	3.0	7.4	12.5	23.7	21.0	11.9	1.9	2.0	0.9	0.4	0.7	87.3
1996-97	2.2	2.9	3.8	24.8	6.3	12.2	9.2	4.3	2.0	0.9	0.4	0.2	69.1
1997-98	1.6	4.5	9.6	5.1	6.9	10.4	10.2	6.3	2.9	1.3	0.6	0.0	59.4

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1998-99	0.0	4.6	10.1	13.1	14.0	30.4	19.3	3.4	1.5	0.7	0.3	0.3	97.9
1999-00	1.4	5.4	4.4	6.0	9.0	7.4	2.4	0.3	0.1	0.1	0.0	0.0	36.6
2000-01	0.3	1.0	1.5	3.4	3.4	1.0	0.8	0.2	0.1	0.0	0.0	0.0	11.7
M. O.	3.6	5.2	10.0	13.8	13.5	16.6	10.3	3.7	1.8	0.8	0.4	1.5	81.2
T. A.	3.0	3.2	13.4	11.5	8.4	9.4	7.7	4.0	1.8	0.8	0.4	1.8	48.3

Table A.9: Monthly runoff series (surface and spring resources) of Viotikos Kifissos sub-basin, between Heronia (Agios Vassileios) and Davlia (railway station) discharge gauges (hm^3) – Hydrologic years 1968-69 to 2000-01.

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1968-69	6.7	8.6	56.5	37.1	15.8	20.1	11.8	4.1	1.8	0.8	1.2	4.4	168.9
1969-70	5.3	5.0	9.8	10.6	7.1	12.4	3.1	4.0	1.8	0.8	0.4	2.6	62.9
1970-71	3.9	4.0	4.1	8.7	9.0	20.2	12.0	3.5	1.6	0.7	0.3	3.4	71.4
1971-72	4.3	6.8	6.3	21.5	18.8	17.7	13.9	10.1	4.6	2.1	0.9	3.4	110.4
1972-73	5.4	9.4	4.6	12.9	12.5	14.2	9.6	0.0	1.8	0.8	0.4	0.0	71.5
1973-74	0.0	4.8	8.0	9.4	14.4	24.2	11.3	3.9	1.8	0.8	0.4	3.5	82.5
1974-75	6.9	6.2	6.4	7.2	9.8	10.4	1.3	0.0	0.0	0.0	0.0	1.7	49.9
1975-76	4.3	4.9	11.4	9.5	20.1	13.1	11.0	1.9	0.9	0.4	0.2	0.7	78.3
1976-77	2.7	3.7	3.7	3.0	0.3	2.3	2.2	0.6	0.5	0.2	0.2	1.4	20.8
1977-78	0.5	0.8	4.6	13.6	16.3	8.6	5.1	1.2	0.5	0.2	0.1	0.6	52.2
1978-79	2.1	2.6	7.9	6.7	6.4	4.4	1.8	0.8	0.4	0.2	0.1	0.9	34.2
1979-80	4.6	8.5	6.7	12.7	10.0	20.9	9.6	5.8	2.6	1.2	0.5	1.2	84.4
1980-81	7.6	5.2	10.7	27.1	23.5	12.4	9.5	2.2	1.0	0.4	0.4	2.5	102.5
1981-82	2.8	3.3	5.1	4.2	10.9	21.3	19.5	10.6	4.8	2.2	1.0	1.7	87.4
1982-83	2.0	3.4	5.6	4.5	4.6	7.7	1.5	0.5	0.9	0.4	0.2	0.0	31.3
1983-84	0.9	1.7	10.1	8.0	14.3	16.3	17.3	6.2	2.8	1.3	0.6	1.5	80.9
1984-85	1.5	2.9	4.4	23.6	8.4	13.3	9.8	2.5	1.1	0.5	0.2	0.7	69.0
1985-86	2.6	4.3	5.1	4.4	7.4	7.6	2.8	1.2	0.6	0.3	0.1	0.1	36.5
1986-87	2.6	3.3	2.9	7.9	7.3	17.0	15.5	6.6	3.0	1.3	0.6	0.4	68.5
1987-88	1.6	2.8	2.8	3.4	7.8	13.6	4.9	1.2	0.6	0.3	0.1	0.0	39.1
1988-89	0.8	2.7	8.0	4.3	2.6	10.0	3.5	0.3	0.1	0.1	0.0	0.0	32.4
1989-90	1.0	1.3	1.7	2.0	1.1	0.2	0.0	0.0	0.0	0.0	0.2	0.6	8.2
1990-91	0.8	1.4	6.6	7.5	6.8	10.6	9.0	3.8	1.7	0.8	0.3	0.6	49.8
1991-92	1.4	2.1	2.9	3.1	3.6	4.3	1.8	0.4	0.2	0.1	0.0	0.3	20.3
1992-93	0.9	1.3	1.6	2.1	2.4	2.6	0.0	0.0	0.0	0.0	0.0	0.0	10.9
1993-94	0.1	0.8	1.3	4.1	16.1	7.8	3.9	0.9	0.4	0.2	0.1	0.0	35.7
1994-95	2.9	3.1	4.2	11.7	6.7	9.2	6.5	0.6	0.3	0.1	0.1	0.2	45.6
1995-96	1.4	2.1	5.2	8.6	16.4	14.5	8.2	1.3	1.4	0.6	0.3	0.5	60.5
1996-97	1.5	2.0	2.6	17.1	4.4	8.5	6.4	3.0	1.4	0.6	0.3	0.1	47.9
1997-98	1.1	3.1	6.7	3.5	4.8	7.2	7.0	4.3	2.0	0.9	0.4	0.0	41.1

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1998-99	0.0	3.2	7.0	9.1	9.7	21.1	13.4	2.3	1.1	0.5	0.2	0.2	67.8
1999-00	1.0	3.8	3.0	4.2	6.2	5.1	1.6	0.2	0.1	0.0	0.0	0.0	25.3
2000-01	0.2	0.7	1.1	2.3	2.3	0.7	0.5	0.1	0.1	0.0	0.0	0.0	8.1
M. O.	2.5	3.6	6.9	9.6	9.3	11.5	7.1	2.5	1.3	0.6	0.3	1.0	56.2
T. A.	2.1	2.2	9.3	8.0	5.8	6.5	5.3	2.8	1.2	0.6	0.3	1.2	33.4

Table A.10: Monthly outflow series of Mavroneri springs (hm^3) – Hydrologic years 1968-69 to 2000-01.

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1968-69	6.0	6.4	11.0	10.0	7.5	8.6	7.2	4.8	2.9	1.1	2.0	5.0	72.5
1969-70	5.5	5.2	6.9	7.1	5.8	7.4	4.2	4.8	2.9	1.0	0.0	3.7	54.4
1970-71	4.7	4.7	4.8	6.6	6.3	8.6	7.2	4.4	2.6	0.7	0.0	4.4	55.1
1971-72	5.0	5.9	5.8	8.7	7.8	8.3	7.5	7.0	5.0	3.2	1.4	4.4	70.1
1972-73	5.5	6.7	5.1	7.5	7.0	7.8	6.7	0.0	2.8	1.0	0.0	0.0	50.0
1973-74	0.0	5.1	6.4	6.8	7.3	9.0	7.1	4.7	2.9	1.0	0.0	4.5	54.8
1974-75	6.1	5.7	5.9	6.2	6.4	7.0	2.2	0.0	0.0	0.0	0.0	2.7	42.1
1975-76	4.9	5.1	7.2	6.8	8.0	7.6	7.0	3.1	1.2	0.0	0.0	0.8	51.8
1976-77	3.9	4.5	4.6	4.1	0.0	3.5	3.4	0.2	0.0	0.0	0.0	2.4	26.5
1977-78	0.0	1.1	5.1	7.7	7.5	6.6	5.3	1.9	0.1	0.0	0.0	0.5	35.7
1978-79	3.2	3.8	6.4	6.0	5.5	5.0	2.9	1.1	0.0	0.0	0.0	1.2	35.1
1979-80	5.1	6.4	6.0	7.5	6.5	8.7	6.7	5.7	3.8	1.9	0.1	2.0	60.3
1980-81	6.3	5.3	7.1	9.3	8.3	7.5	6.7	3.4	1.5	0.0	0.0	3.6	59.0
1981-82	3.9	4.3	5.4	4.9	6.7	8.7	8.3	7.1	5.1	3.3	1.5	2.7	61.9
1982-83	3.1	4.4	5.6	5.1	4.8	6.3	2.4	0.0	1.4	0.0	0.0	0.0	33.1
1983-84	1.1	2.7	7.0	6.4	7.2	8.1	8.0	5.8	3.9	2.1	0.2	2.5	55.1
1984-85	2.5	4.0	5.0	9.0	6.1	7.6	6.7	3.7	1.9	0.0	0.0	0.6	47.1
1985-86	3.8	4.8	5.4	5.0	5.8	6.3	3.9	2.0	0.3	0.0	0.0	0.0	37.3
1986-87	3.8	4.3	4.1	6.4	5.8	8.2	7.8	6.0	4.1	2.2	0.4	0.0	52.9
1987-88	2.7	3.9	4.0	4.4	5.9	7.7	5.2	2.0	0.2	0.0	0.0	0.0	36.0
1988-89	1.0	3.8	6.4	4.9	3.6	6.9	4.4	0.0	0.0	0.0	0.0	0.0	31.1
1989-90	1.5	2.2	2.8	3.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	11.7
1990-91	1.0	2.2	5.9	6.3	5.7	7.1	6.6	4.6	2.8	0.9	0.0	0.4	43.5
1991-92	2.3	3.3	4.1	4.2	4.3	5.0	2.9	0.0	0.0	0.0	0.0	0.0	26.0
1992-93	1.3	2.1	2.6	3.3	3.5	3.8	0.0	0.0	0.0	0.0	0.0	0.0	16.5
1993-94	0.0	1.0	2.1	4.8	7.5	6.4	4.7	1.3	0.0	0.0	0.0	0.0	27.8
1994-95	4.1	4.2	4.9	7.3	5.6	6.7	5.8	0.2	0.0	0.0	0.0	0.0	38.8
1995-96	2.3	3.2	5.4	6.6	7.5	7.8	6.3	2.2	2.3	0.4	0.0	0.0	44.0
1996-97	2.5	3.2	3.8	8.2	4.7	6.5	5.8	4.1	2.2	0.4	0.0	0.0	41.4
1997-98	1.8	4.1	6.0	4.5	4.9	6.2	6.0	5.0	3.1	1.2	0.0	0.0	42.9
1998-99	0.0	4.2	6.1	6.7	6.4	8.7	7.5	3.5	1.7	0.0	0.0	0.0	44.8
1999-00	1.5	4.6	4.1	4.9	5.5	5.4	2.7	0.0	0.0	0.0	0.0	0.0	28.6

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
2000-01	0.0	0.8	1.7	3.5	3.4	0.8	0.1	0.0	0.0	0.0	0.0	0.0	10.2
M. O.	2.9	4.0	5.3	6.2	5.8	6.7	5.1	2.7	1.7	0.6	0.2	1.3	42.4
T. A.	2.0	1.5	1.7	1.8	1.8	2.1	2.4	2.4	1.6	1.0	0.5	1.7	15.3

Table A.11: Monthly net runoff series (surface water resources) of Viotikos Kifissos sub-basin, between Heronia (Agios Vassileios) and Davlia (railway station) discharge gauges (hm^3) – Hydrologic years 1968-69 to 2000-01.

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1968-69	0.7	2.1	45.5	27.1	8.4	11.5	4.7	0.0	0.0	0.0	0.0	0.0	99.9
1969-70	0.0	0.0	2.9	3.5	1.3	5.0	0.0	0.0	0.0	0.0	0.4	0.0	13.1
1970-71	0.0	0.0	0.0	2.1	2.7	11.6	4.8	0.0	0.0	0.0	0.3	0.0	21.6
1971-72	0.0	0.9	0.4	12.7	11.0	9.5	6.4	3.2	0.0	0.0	0.0	0.0	44.0
1972-73	0.0	2.8	0.0	5.4	5.6	6.5	2.9	0.0	0.0	0.0	0.4	0.0	23.4
1973-74	0.0	0.0	1.6	2.6	7.1	15.2	4.2	0.0	0.0	0.0	0.4	0.0	31.1
1974-75	0.8	0.5	0.5	1.0	3.4	3.4	0.0	0.0	0.0	0.0	0.0	0.0	9.6
1975-76	0.0	0.0	4.1	2.7	12.1	5.5	4.0	0.0	0.0	0.4	0.2	0.0	29.0
1976-77	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.4	0.5	0.2	0.2	0.0	1.6
1977-78	0.5	0.0	0.0	5.9	8.8	2.0	0.0	0.0	0.4	0.2	0.1	0.2	18.2
1978-79	0.0	0.0	1.5	0.7	0.9	0.0	0.0	0.0	0.4	0.2	0.1	0.0	3.7
1979-80	0.0	2.1	0.7	5.2	3.5	12.2	2.9	0.1	0.0	0.0	0.5	0.0	27.2
1980-81	1.3	0.0	3.6	17.8	15.2	5.0	2.9	0.0	0.0	0.4	0.4	0.0	46.5
1981-82	0.0	0.0	0.0	0.0	4.2	12.6	11.2	3.5	0.0	0.0	0.0	0.0	31.6
1982-83	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.5	0.0	0.4	0.2	0.0	2.5
1983-84	0.0	0.0	3.2	1.6	7.1	8.2	9.2	0.4	0.0	0.0	0.4	0.0	30.0
1984-85	0.0	0.0	0.0	14.7	2.3	5.7	3.1	0.0	0.0	0.5	0.2	0.1	26.5
1985-86	0.0	0.0	0.0	0.0	1.5	1.3	0.0	0.0	0.3	0.3	0.1	0.1	3.6
1986-87	0.0	0.0	0.0	1.5	1.5	8.9	7.7	0.6	0.0	0.0	0.3	0.4	20.8
1987-88	0.0	0.0	0.0	0.0	1.8	5.9	0.0	0.0	0.3	0.3	0.1	0.0	8.5
1988-89	0.0	0.0	1.6	0.0	0.0	3.0	0.0	0.3	0.1	0.1	0.0	0.0	5.2
1989-90	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.4	0.8
1990-91	0.0	0.0	0.6	1.2	1.1	3.5	2.5	0.0	0.0	0.0	0.3	0.2	9.5
1991-92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.1	0.0	0.3	1.0
1992-93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993-94	0.1	0.0	0.0	0.0	8.6	1.5	0.0	0.0	0.4	0.2	0.1	0.0	10.8
1994-95	0.0	0.0	0.0	4.4	1.1	2.5	0.7	0.4	0.3	0.1	0.1	0.2	9.6
1995-96	0.0	0.0	0.0	2.0	8.9	6.7	1.9	0.0	0.0	0.2	0.3	0.5	20.5
1996-97	0.0	0.0	0.0	8.9	0.0	1.9	0.6	0.0	0.0	0.3	0.3	0.1	12.2
1997-98	0.0	0.0	0.7	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.4	0.0	3.2
1998-99	0.0	0.0	0.9	2.4	3.3	12.4	5.9	0.0	0.0	0.5	0.2	0.2	25.8

Hydr. year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1999-00	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.2	0.1	0.0	0.0	0.0	1.1
2000-01	0.2	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.1	0.0	0.0	0.0	0.9
M. O.	0.1	0.3	2.1	3.7	3.7	5.0	2.3	0.3	0.1	0.1	0.2	0.1	18.0
T. A.	0.3	0.7	7.9	6.1	4.2	4.6	3.0	0.8	0.2	0.2	0.1	0.1	19.6

Annex B: Photos

Photo 1: Panoramic view of the study area, with N-S direction. Composition of two photos taken uphill Davlia town, a part of which is shown on the foreground. At the left side, we can see Filovioto mountain, the provincial road of Mavroneri-Davlia and Mavroneri. The homonymous karstic springs gush in the foot of Filovioto mountain. At the left of the background we can see Idilio mountain and following, Akontio mountain. In the center of the photo we can see a part of the stream Platanias riverbed. At the right, we can see Agios Vlasios village and the boundaries of the Vathirema basin.

Photo 2: View of the Vathirema riverbed from the road to Agios Vlasios village. The village is built in the foot of the right hill, which is the downhill boundary or the stream basin. At the background we can see a part of Parnassos mountain, which is the SW boundary of the Viotikos Kifissos basin.

Photo 3: View of the Vathirema riverbed, from the other side of the bridge. At the background we can see Idilio mountain.

Photo 4: View of the Vathirema basin. We can clearly see the flyschoid relief of the basin.

Photo 5: View of the stream Platanias basin.

Photo 6: View of the riverbed of Mauroneri stream from the Livadia – Lamia road, a few decades of meters before the site where the power plant will be constructed. At the background we can see Akontio mountain.

Photo 7: View of the riverbed of Mauroneri stream from the other side of the bridge, where there is a special provision for the installation of wears.

Photo 8: View of the riverbed of Mauroneri stream from the road to the homonymous springs (background). Through the wears, the springs' water is gathering uphill and is used for irrigation.

Photo 9: Irrigation canal taking water from the Mauroneri stream through a wear, a bit before the homonymous springs.

Photo 10: View of the area of the karstic Mauroneri springs. When the springs do have water, a shallow lake is formed in this whole area.

Photo 11: Precipitate front of karstic limestone in the area of Mavroneri springs. The limestones are developed in horizontal and precipitate layers and they are extremely broken.

Photo 12: View of the Viotikos Kifissos riverbed near the Daulia railway station, where there is also the corresponding hydro-measurement point.

Photo 13: View of the Viotikos Kifissos riverbed near the hydro-measurement point of Agios Vasilios Heronias. We can see the new bridge and the road connecting Heronia and the built-up areas of Akontio mountain.

Acknowledgements

We would like to express our acknowledgements to the Thebes Land Reclamation Department and to Livadia IGME, as well as to Mr. S. Babalouka, for their assistance during the visit of some members of the study team in the work area. We also express our acknowledgements to Mr. E. Rozos and A. Koukouvinos, for their willing collaboration in providing hydrologic and geographic data.

Study team

The *Preliminary Water Supply Study of the Thermoelectric Livadia Power Plant* was composed by the consulting engineering office *Ypologistiki Meletitiki Ltd*, and the responsible of the study was D. Argyropoulos, Civil Engineer. In the study team the following engineers participated: A. Efstratiadis, Civil Engineer, G. Tentes, Mineralogist – Metallurgist Engineer, A. Tsouni, Civil Engineer and G. Tzeranis, Civil Engineer and Th. Platis, Geotechnical Engineer. D. Koutsoyiannis, Dr Civil Engineer, Assistant Professor NTUA collaborated in the study as consultant.

Athens, December 2001

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