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A MANAGEMENT FRAMEWORK FOR THE EFFICIENT USE OF SURFACE WATER RESOURCES IN SITHONIA PENINSULA (GREECE)

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ABSTRACT
The Peninsula of Sithonia is one of many typical regions in Greece in which overexploitation of local aquifers has led to several serious problems related to quantity and quality degradation of groundwater reserves. In this paper, a management plan is presented that aims at the utilization of the so far unexploited surface water resources of the area in order to restore the degraded aquifers and to supplement the groundwater supplies, mostly for domestic use. To this end the total municipal water demand and the potential of surface waters are first estimated at both the local and regional levels. Next, four alternative management schemes are examined, each one consisting of a different number of reservoirs. A preliminary evaluation of these water supply alternatives, that concludes the paper, is based on both operational and economic factors in order to facilitate a future multi-criterion decision-making analysis.

KEY-WORDS: Water resources management, water supply dams, project analysis

INTRODUCTION

Chalkidiki is one of the 52 prefectures, i.e. the major administrative entities, in which Greece is divided (Figure 1). The water resources of Chalkidiki are, in general, characterized by the fact that the current development of their potential hardly meets the total water demand. This is mainly due to the almost complete lack of surface water storage facilities. Although plans for the construction of two major dams of high storage capacity in inland catchments have been approved more than two decades ago, the decision process regarding their implementation is very slow. Moreover the investment rate for the construction of even small-size dams in the region is practically zero. As a consequence the sole water source for all uses in the prefecture is groundwater.

The geomorphology of the three peninsulas (Kassandra, Sithonia and Mount Athos, shown in Fig. 1) results in a large number of small to medium-size hydrologic basins within them. It should

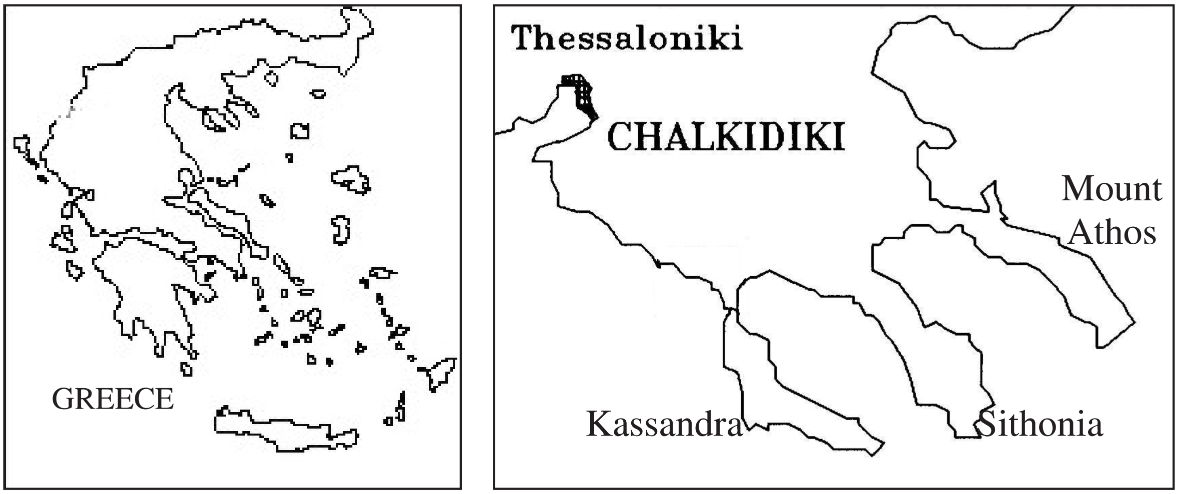

Figure 1. Location map of Chalkidiki and Sithonia

be noted that, due to its religious autonomy, the region of Mount Athos, that occupies most of the third peninsula, is excluded from any development plan of the Prefecture of Chalkidiki, including the management of water resources. From the basins of the other two peninsulas mainly those along the seacoast have been so far exploited, exclusively by pumping the local alluvial aquifers. In almost all of Chalkidiki groundwater is mainly used for agricultural or domestic consumption. Particularly along the seacoast of Kassandra and Sithonia groundwater storage is not continuously available for meeting peak demands, especially during the summer period (Latinopoulos and Theodossiou, 1998). During the hot months of June, July and August, the increased demand for irrigation water but mainly for municipal water, which largely originates from the touristic development of the coastal area, is met by overpumping the local, mostly coastal, aquifers. The immediate consequence of such an overuse is a distinct decline of groundwater levels, which in turn has caused two very serious problems: (a) a high risk of aquifer depletion in the very near future, and (b) severe seawater intrusion at specific locations, a fact that adds to the overall losses of the underground basins water potential.

Within the above framework this paper presents a management scheme for the efficient use of surface water resources in the Peninsula of Sithonia aiming at: (a) reducing and hopefully reversing the two major adverse effects of groundwater overexploitation mentioned above and (b) supplementing or even replacing at places the use of groundwater, as a medium and long-term strategy to meet the steadily increasing water demand in the area. This plan is based on the outcome of a project study that was assigned by the Association for the Development of Sithonia Communities to a research group of the Faculty of Civil Engineering at the Aristotle University of Thessaloniki (Latinopoulos and Papacharisis, 1997).

The proposed management framework introduces the construction of a number of storage dams, mainly for water supply, because, as explained throughout this paper, it is the sole means of utilizing the surface water resources of the Peninsula. Although the decision to build a dam – particularly a large one – has been increasingly contested in many countries, there are still a lot of proponents who point to the social and economic development demands that dams are intended to meet (World Commission on Dams, 2000). Given the present local conditions in the study area, it is believed that all other options, including both non-structural measures (which in the case of domestic water supply are in general limited) and structural measures (such as desalination etc), cannot offer better solutions to the severe water shortage problem. On the other hand, it looks like that building these dams will significantly advance human development on a basis that aims to be economically viable, socially equitable and environmentally sustainable.

ESTIMATION OF WATER DEMAND

Sithonia is the central of the three peninsulas of Chalkidiki (Figure 1) and covers an area of 544.7

Table 1. Permanent population of Sithonia (Source: National Statistical Service of Greece)

Village	1961	1971	1981	1991	2001
Agios Nikolaos	2176	2110	2073	2260	2276
Metagitsi	769	676	726	749	737
Metamorphosis	215	188	240	379	710
Neos Marmaras	1587	1706	2407	2598	2893
Nikiti	1805	1786	1871	2454	3048
Sarti	706	678	777	937	1155
Sikia	2740	2489	2357	2933	2871
Sithonia (total)	**9998**	**9633**	**10451**	**12310**	**13690**
Chalkidiki (total)	**79263**	**73390**	**79036**	**91971**	**105156**

km^2, which corresponds to 18.7% of the total area of Chalkidiki. Its present population is about 13,000 and it is unevenly distributed among seven communities (i.e. villages of up to 3,000 inhabitants). The scenic beauty of the beaches of Sithonia has attracted many individuals who have built their summer houses, either isolated or within settlements, along the coastal area. Tourism accommodation infrastructure consists of numerous family-operated guesthouses or single rooms to let, located mostly in or very close to the villages, with an exception of a large hotel complex near the village of Neos Marmaras.

The present development of tourism in the Peninsula has a positive return from the economic point of view; still undesirable effects are not few, most of which are related to environmental degradation. As far as water is concerned, groundwater mining and saline intrusion in coastal freshwater aquifers are the principal consequences of the rapid and irrational touristic development, especially during the ’80s. Due to the direct cause-effect nature of these phenomena, the most serious problems appear in the areas of high water demand. Thus in the first part of the study, the distribution of municipal water demand is only estimated, as water consumption for irrigation and industry account for less than 8% of the total demand. In this way, the municipal water demand is calculated as the sum of public and household water supplies, including those concerned with tourist accommodation. By the term municipal water, the supplies for public and household uses are referred (tourism accommodation included).

As the work presented herein was faced from an engineer’s perspective, some concepts were adopted according to this specific point of view. The estimation of water demand is a typical example of such an approach, as it was made on the basis of consumption data only, that is without taking into account the economist’s concept of effective demand (Merrett, 1997), which in the case of water is inevitably exacerbated by a number of various factors (Easter *et al.*, 1997). The requirements approach was thus applied in our study by looking particularly at two variables: (a) the total annual consumption, and (b) the seasonal (summer) consumption peaks. In estimating both variables, official data and locally elicited information were combined. Population figures, which were taken from the archives of the National Statistical Service of Greece and refer to the last five published national censuses (in the years 1961, 1971, 1981, 1991 and 2001), are the only official population data available and are given in Table 1.

The absence of valid and reliable data regarding the summer increase of population in Sithonia was a crucial factor in the estimation of the peak values of water demand. According to a local report (Union of Chalkidiki Hotel Owners, 1995), figures from the inventory of the Greek Tourism Organization regarding tourism mobility in Chalkidiki are rather misleading, and in any case they underestimate the actual situation. This is due to the fact that declared licensed accommodation (hotels, rooms to let and campings) does

Table 2. Municipal water consumption in Sithonia

Village	Peak population	Max. consumption (m^3 day^{-1})	Annual consumption (10^3 m^3)
Agios Nikolaos	13000	5000	525
Metagitsi	1300	500	84
Metamorphosis	13000	5000	415
Neos Marmaras	35000	13750	1205
Nikiti	7000	2500	370
Sarti	11000	4250	386
Sikia	10000	3750	476

not exceed half of the total number of operating accommodation units and also because, even legally operating, many owners tend to report but only a small fraction of their guests.

For the above reasons the research group asked for assistance from the local authorities, which are largely familiar with the actual situation. Local surveys in the seven communities of the Peninsula were carried out by the means of a, specially designed and suitably organized for the occasion, questionnaire eliciting issues of water demand and availability of water resources (Latinopoulos and Theodossiou, 1997; Latinopoulos *et al.*, 1997). By combining official data and elicited information, in order to overcome the previously mentioned problems concerning mainly the population variations and the extend to which the currently exploited water resources meet the respective demands, a final estimation was made for each of the following: (a) the maximum daily water consumption, which was calculated by taking into account the peak population demand over the summer period (estimated to as 385 l day^{-1} per inhabitant), and (b) the total annual water consumption, which was estimated by considering the population variation over a typical year.

The final estimates of the above two water consumption variables for each of the seven communities are given in Table 2. In summary, the total annual demand for municipal water in the Peninsula is in the order of $4{\times}10^6$ m^3, while local (community) values vary from about $0.1{\times}10^6$ m^3 to $1.2{\times}10^6$ m^3. This significant variation is due to the great disparity in the spatial distribution of the permanent population and also to different rates of touristic development in the areas surrounding the communities.

SELECTION CRITERIA OF DAMS

In the second part of this study, the focus was on the identification of a number of catchments in which the construction of storage dams should meet specific feasibility criteria. As mentioned in the introduction, the geomorphology of the region is characterized by a large number of small and medium-size catchments. After a preliminary identification of 80 catchments and sub-catchments and considering geomorphological only criteria, derived from both an extensive in-situ investigation and a desk analysis, 36 of them were selected for further assessment.

The two histograms of the catchment areas and their lowest ground elevations, respectively, shown in Figure 2, are indicative of the local geomorphology of the 36 catchments: (a) Although the range of catchment areas is from 1 to 23 km^2, their average value is only 7.7 km^2, as most of them (78%) are less than 11 km^2. (b) The rather mild topography of the Peninsula (maximum ground elevation is 753 m) is reflected upon the distribution of the lowest ground elevations of the catchments. The fact that the average value of the lowest ground elevations is 54 m and 60% of them are below 40 m shows that these catchments end in low plains, some of which are very close to the seacoast.

Before proceeding to the next stage of evaluating the specific characteristics of the catchments, the hydrological budget within each of them was drawn up. The calculation, which was based on available meteorological data from stations with-

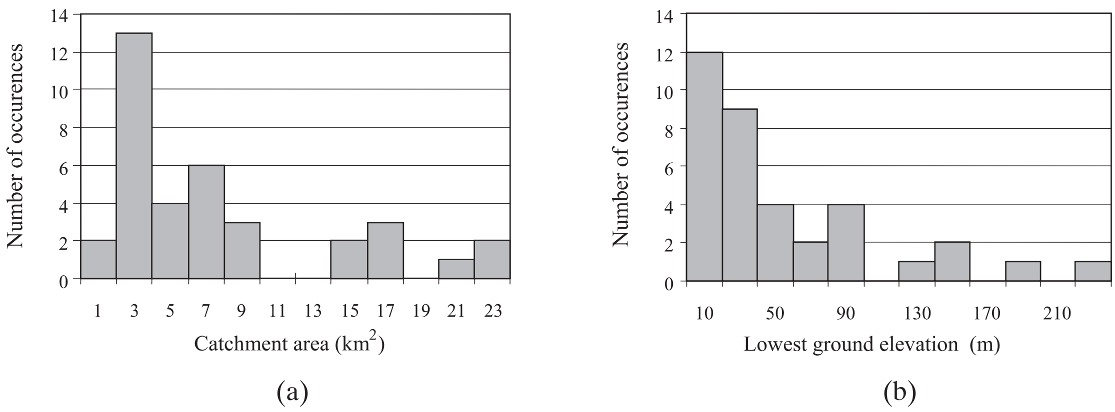

Figure 2. Histograms of (a) catchment areas and (b) their lowest ground elevations

in and close to the study area, was made on an annual basis, using standard hydrological methods and models (Shaw, 1983). The summary of the results for the 36 basins shows that the annual catchment values of rainfall vary from 440 to 725 mm and of evapotranspiration from 611 to 760 mm, while the average annual temperature is within the range of 12.3 °C to 16.2 °C. A complete absence of streamflow records did not allow for a more accurate estimation of the yields of reservoirs; therefore the relevant calculations were based on the average annual runoff from the catchments.

For each of the 36 catchments several specific calculations were next made regarding: (a) the average annual runoff, (b) the design flood peak discharge, (c) the height of the dam, and (d) the storage capacity of the reservoir. As far as the height of the dam is concerned, an 'optimum' value was estimated by maximizing the ratio of reservoir storage over the volume of the dam. As long as this height meets the safety requirements against flooding, its selection guaranties economic efficiency of the dam-reservoir system.

In the present management study of the surface water resources of Sithonia the following characteristics of each catchment were taken into consideration: (a) the yield of the reservoir, using the catchment's annual runoff as its surrogate, (b) the volume of the dam structure, calculated for its optimum height value, (c) the actual cost of the dam, (d) the dam's location, as related to the distances from water supply areas and to the allocation of other proposed reservoirs, and (e) a set of additional physical factors and ecological, environmental and economic considerations.

SURFACE WATER MANAGEMENT SCHEMES

The current water resources management in Sithonia, which relies solely on groundwater, is about to reach an almost irreversibly adverse status. This is because if groundwater basins are depleted then users will not only lose the comparative advantages of underground water storage and distribution but they will probably suffer enormous financial costs. Under these conditions the proposed management framework for the efficient use of the so far unexploited surface water resources, that is proposed in our study, aims at two distinct targets: (a) to reduce the rate of groundwater resources degradation, and (b) to meet additional future water demands, by relaxing, at the same time, the conflict between groundwater mining and tourism development.

The main point of the proposed plan is eventually to provide public water resource managers with specific alternative solutions in order to achieve multiple objectives. The first objective is concerned with the protection of the hydrological cycle and specifically of its capacity to renew the groundwater flows and stocks. This particular field of action is a predominant factor of the sustainability principle, as related to water resources management (Merrett, 1997). Unfortunately the complete lack of valuation studies for the region's resources does not allow for the necessary engagements in order to meet also the requirements of efficiency and precautionary policy principles. As a result the urgently needed resolution process, regarding the conflict of the economic-environmental values (Turner and Postle, 1994), cannot be implemented but through engineering-based solutions. In conclusion, the construction of dams in the area, despite the high costs, will definitely serve the first objective, as the stored surface water can be used to: (a) supplement or even replace the existing groundwater supplies, reverting thus the aquifers to their natural function, and (b) prevent seawater intrusion, by reversing groundwater gradients, either naturally (as less water will be abstracted from coastal aquifer) or artificially (by recharging the coastal aquifers with excess surface storage). Undoubtedly both actions will have positive economic effects on the area regarding the value of groundwater resources (National Research Council, 1997).

The second objective of the proposed plan concerns the creation of a water system far more flexible than the one currently operating in the Peninsula. That is because a group of surface water reservoirs could be further used to supply water in excess of their average yield by applying a periodically varying schedule of withdrawals from the reservoir system alone or in conjunction with controlled groundwater abstractions. Assuming that the reservoir system will serve most of the area, an efficient market, facilitating water transfers and eventually water trades, could then be easily created (Easter *et al.*, 1997).

The evaluation of surface water management schemes, which is next presented, is based on economic and operational factors under some basic assumptions and estimated projections: (a) Current demand is not significantly different from the water consumption values presented in Table 2. (b) In the worst case of a complete absence of demand management in the near future, water needs will increase up to 40% of the current values within the next 20 years. (c) The total groundwater abstraction should eventually decrease by 40% in order to satisfy the first objective above and at the same time to be adequate for serving the second objective.

With the above in mind the least-cost requirement for total storage capacity is about 3.4×10^6 m^3, which is roughly 20% of the estimated aggregate annual runoff would the 36 catchments be fully exploited all together. Due to this obvious abundance of surface water resources, a careful evaluation of alternative management schemes was made, based on the following criteria: (a) the number of dams should not be greater than seven, i.e. equal to the number of communities to be served by them, (b) the total storage capacity should range between the least-cost value of 3.4×10^6 m^3 and 4×10^6 m^3, a maximum value required mainly in schemes with a small number of dams in order to cope with conveyance losses, and (c) the size of the distribution system to be also constructed should be kept minimum, which means that each community will be served only by the nearest reservoir(s).

Among many feasible schemes, four of them, which better satisfy the above criteria, are presented in Table 3 and Figure 3 below. These schemes were further ranked according to their degree of collective responsibility and function. Thus scheme A consists of only two dams which are operated and utilized collectively by at least three communities each, while at the other end scheme D, consisting of seven dams each serving only one community, is characterized by a complete financial and operational autonomy.

A preliminary evaluation of the four alternative schemes resulted in some interesting findings. When fixed costs only are taken into account (as shown in Table 3), the differences in the total costs of the four schemes are rather non-significant. So, at the government level, total investment is not a crucial factor in the decision-making process. Maintenance costs were not calculated but they are in general considered low for the dam structures and high for the distribution systems. Therefore

Table 3. Total yield and costs of the alternative management schemes

Management scheme	**Number of dams**	**Estimated yield** (million m^3)	**Cost of dams** (million €)	**Cost of distribution systems** (million €)	**Total cost** (million €)
A	2	4.0	10.6	14.1	24.7
B	3	4.0	14.1	12.9	27.0
C	5	3.4	19.1	7.3	26.4
D	7	3.4	23.2	5.6	28.8

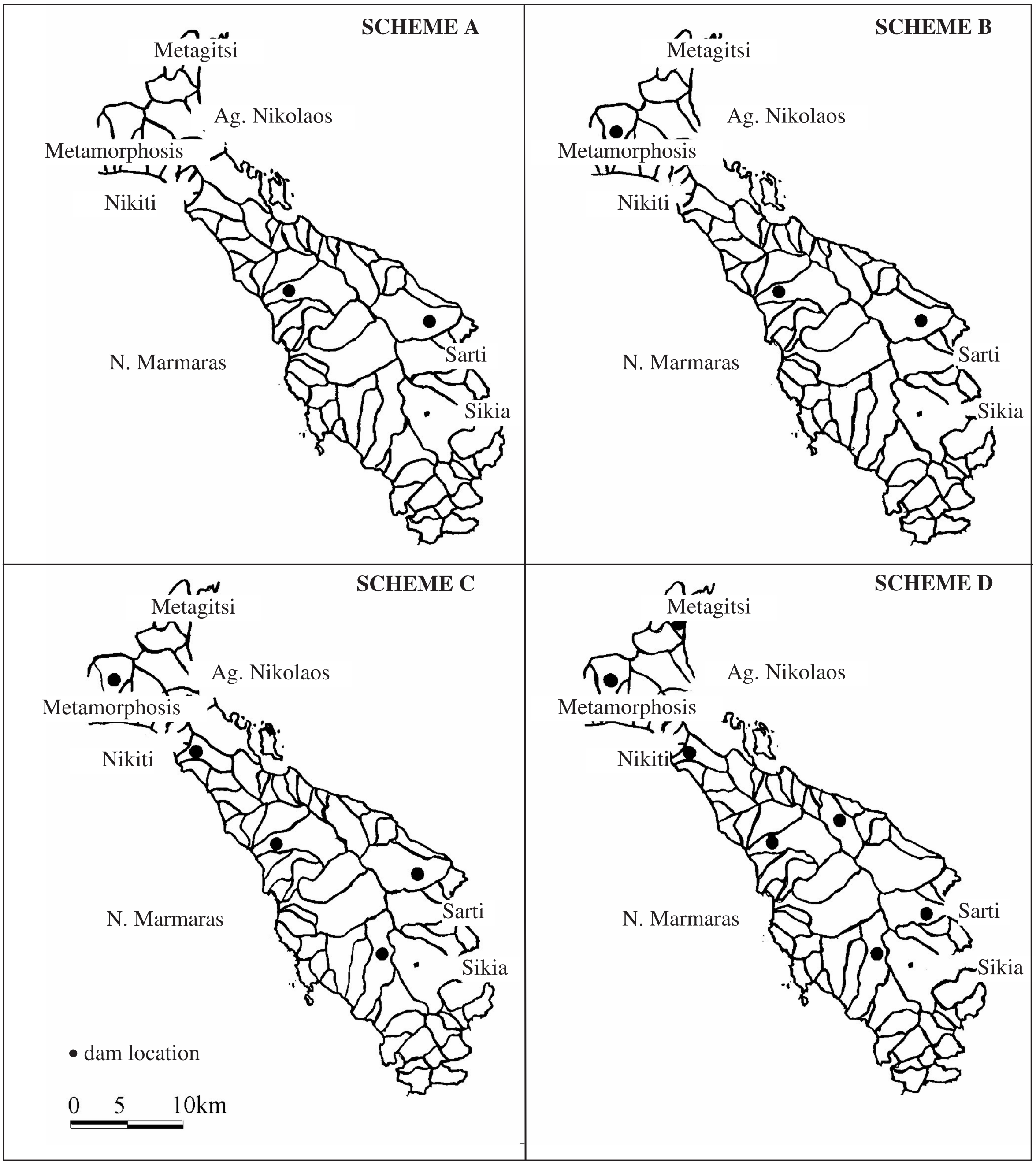

Figure 3. Allocation of dams for the alternative management schemes (also shown are the initially examined 80 catchments)

schemes C and D would be more preferable to schemes A and B, specifically by the local authorities, which are expected to pay these expenses.

From the operational point of view scheme D would be more suited to greek conditions, as the local authorities should opt for the highest possible operational autonomy provided. Still, from a general point of view, such a solution can be considered a luxury for the specific area. In addition it may cause some adverse environmental effects, which were not examined in the present study. So, taking also into account that in a future development a number of reservoirs could operate conjunctively, we suggest that schemes like B and C should be further examined towards a most efficient use of surface water resources.

A final note should be devoted to negative externalities that would probably add to the total costs of the dam projects. Such externalities can be either in the form of possible impact on the environment (i.e. loss of land, impact on landscape, wildlife etc.) or of a more general type, like negative impact on housing, productive and service functions, historical and cultural heritage, agricultural framework etc. The local conditions of all proposed dam locations are similar; moreover, resources and activities in these areas are of negligible importance, so that, in practical terms, none of the above mentioned negative externalities has a significant cost worth to be taken into consideration in the economic analysis of the whole management plan.

CONCLUSIONS

In the present study a radical change in the water resources management in Sithonia Peninsula is proposed. The urgent need to upgrade the damaged aquifers in the area and to ensure safe yields to meet future demands inevitably leads to the exploitation of the abundant surface water resources of the area. Despite their costs, the construction of a number of dams in the region seems to be the only solution to the problem at hand. Preliminary guidelines and criteria to enable the selection of an efficient water management scheme are proposed following a detailed investigation of demand and surface water potential characteristics.

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