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Resolving conflicting objectives in the management of the Plastiras Lake: can we quantify beauty?

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Abstract

The possible water management of the Plastiras Lake, an artificial reservoir in central Greece, is examined. The lake and surrounding landscape is aesthetically degraded when the water level drops, and the requirement of maintaining a high quality of the scenery constitutes one of the several conflicting water uses, the other ones being irrigation, water supply, and power production. This environmental water use, and, to a lesser extent, the requirement for adequate water quality, results in constraining the annual release. Thus, the allowed fluctuation of reservoir stage is not defined by the physical and technical characteristics of the reservoir, but by a multi-criteria decision, the three criteria being maximizing water release, ensuring adequate water quality, and maintaining a high quality of the natural landscape. Each of these criteria is analyzed separately. The results are then put together in a multicriterion tableau, which helps understand the implications of the possible alternative decisions. Several conflict resolution methods are overviewed, namely willingness to pay, hedonic prices, and multi-criteria decision analysis. All these methods attempt to quantify non-quantifiable qualities, and it is concluded that they don't necessarily offer any advantage over merely making a choice based on understanding.

1. Introduction

Reservoir management normally has to take into account several conflicting objectives. This paper explores the case of the Plastiras Lake, a reservoir whose purpose changed to a significant extent since it was built, and whose conflicting objectives include scenery.

The Plastiras Lake (Fig. 1, Table 1) was built in central Greece toward the end of the 1950s mainly for power production, and was also used for irrigation of a significant part of the plain of Thessaly. By making the land more fertile, it contributed to an increase in the population and income of the nearby city of Karditsa. As the economy of Karditsa became dependent on the water of the reservoir, the social and political pressure gradually shifted the reservoir's main objective; by 1990 it was the irrigation needs that dictated water management, reducing power production to a side-effect, and halving the economic value of the 160 GWh produced annually, as a result of the water release not following an energy-efficient schedule. Meanwhile the scenery, combined with the geographical accessibility of the lake, attracted visitors. During the 1990s, a number of villages around the lake, which had almost been deserted since 1980, were revived as tourist resorts. The level of water in the lake greatly affects its appearance, and this resulted in pressures to keep the level high. Furthermore, the water of the lake started to be used for the water supply of Karditsa and other areas, stressing the need for high water quality.

The scenery is rarely mentioned as a kind of water use in reservoir management. Similar uses are recreation, tourism, and environmental. We would classify the requirement to have beautiful scenery as both environmental and tourist water use, not in the traditional sense that associates it with water sports, but rather in the sense of the rapidly growing segment of ecotourism (Neto, 2003).

The methodology used for the study of the Plastiras Lake is presented in the rest of the paper. Specifically, the essential principles which have lead to the formulation of the problem are discussed in Sect. 2; the hydrologic simulation study is outlined in Sect. 3; the water quality study is described in Sect. 4; the landscape study is described in Sect. 5; Sect. 6 explains how these three aspects of the problem have been brought together, explores the shortcomings of various widely used decision making methods, and presents the decision made for the Plastiras Lake.

2. Formulation of the problem

Natural inflows vary irregularly in all temporal scales, including annual and multi-annual scales. The purpose of a reservoir is to regulate inflows and provide outflows at a more regular rate, that is determined by water demand, temporarily storing the surplus, when inflows exceed outflows. The reservoir under study has been designed to perform multi-year regulation with a constant annual release. Although in many cases (e.g. Agrell et al., 1998) the practice followed is releasing a variable quantity of water each year, depending on the amount of water in the reservoir, the adoption of a constant annual release instead, irrespective of the amount of water available, is beneficial: the various water-dependent activities can be scheduled more efficiently, since a specific quantity of water is guaranteed, albeit with a certain probability of failure, to be available each year.

Reservoir design and management is often based on a non-probabilistic basis, which assumes a failure-free concept such as the "firm yield". However, any target release normally has a nonzero probability of failure, and it is more accurate to study the reservoir on a probabilistic basis and talk of "reliable release" rather than firm yield (Koutsoyiannis, 2004); the reliable release is the amount of water that can be released with a specified reliability level or probability of failure. Thus, if the annual release with 90% reliability is 300 hm^3, this means that, on the average, once in a decade the actual release will be less than 300 hm^3.

The reliable annual release is a function of the hydrologic regime of the basin, the reliability level, and the net reservoir capacity. For the Plastiras Lake, the net reservoir capacity is defined by specifying the minimum allowed level (see the net capacity in Fig. 2). We use different values of minimum allowed level as our decision making alternatives, because minimum lake level is a simple notion, easy to incorporate into regulations, and easy to verify. The decision space is continuous; any real value between +776 and +792 m above sea level can, in theory, be chosen. However, we limit our selection to one of the five values of +780, +782, +784, +786, and +788 m.

In summary, the problem is to select one of the five options for minimum allowed level mentioned above by arranging the three conflicting objectives of maximizing water release, ensuring adequate water quality, and maintaining a high level of landscape quality, subject to the following assumptions:

Constant annual release. Except for the especially dry periods, as mentioned below, the same quantity of water will be taken from the lake, irrespective of the water available.

90% reliability. The annual yield mentioned in the table will be released in 90% of the cases. Once in ten years (on average) it will not be possible to release this quantity without violating the minimum allowed level.

Maintain level rather than release in failures. When the system fails, the minimum allowed level will not be violated; instead, the release will be reduced.

Priority of water supply and irrigation versus power production. The current practice, in which irrigation is the water use that dictates the operation of the reservoir, is assumed to continue in the future to avoid social reactions. Thus, the annual release is distributed nonuniformly throughout the year as required by the water supply and irrigation water uses.

3. Reliable release as a function of minimum level

Initially historical records of rainfall, reservoir inflow (based on the water balance of the lake), and evaporation (based on the Penman method) were constructed on a monthly basis. Then, synthetic time series with the same statistical characteristics as the historical records, but much longer in length (i.e. 1000 years), were generated by employing a stochastic hydrology framework (Koutsoyiannis, 2000) that reproduces the given statistical characteristics of the different variables, their cross-correlations, and the Hurst effect. The operation of the system was next simulated using the synthetic time series. In such simulations, the relationship among the storage capacity, water yield, energy yield and reliability can be established. The details of this process are outside the scope of this paper; for more information, the reader is referred to relative literature (Loucks et al., 1981; Mays and Tung, 1996; ReVelle, 1999; Koutsoyiannis, 2004; Pegram, 1980). Results are given in Fig. 2.

4. Water quality

The effect of lake level variation on water quality was assessed with the aid of two models, which are described by Stamou et al. (1994), Hadjibiros et al. (2002) and Andreadakis et al. (2003). Both models simulate various physical, chemical and biological processes of a reservoir, emphasising on eutrophism and oxygen. The same assumptions about polluting loads were made for both models, and the same input data were used. The output of the hydrologic simulation outlined in the previous section was used as water level variation scenarios. The polluting loads were estimated on the basis of land use in the basin, both nonpoint (mainly agriculture and rearing) and point sources (sewerage of residential locations).

Both models arrive at similar results, which generally match past measurements of chlorophyl concentration. It is concluded that water quality is always acceptable, at least for a minimum level of +782 m or higher, and is particularly high for a minimum level of +786 m or higher, in which case the chlorophyl concentration never exceeds 5 μg/L.

5. The landscape

When the lake is full, that is, when it is at its highest level of 792 m, the trees appear to touch the water. Although there is a sharp contrast of mountains that seem to spring out of water, the observer has the impression that the landscape is unified and pure. When the level of the lake drops, a piece of land is revealed between the trees and the water, and this affects the unity of the landscape. At the north part of the lake, where the slopes are small, large dry areas appear; at the south, where the landscape is rugged, a brown or yellowish narrow strip shows. This phenomenon, which is illustrated in Fig. 3, is not prominent for levels of 787 m or more, because many trees grow from levels of 790–791 m, and they cast their shadows even lower.

Such lifeless areas marking the transition from land to water are common in nature; a sand beach in front of a forest is a typical example. The reason for their existence is that the ecosystem developed on the boundaries of water and land is very sensitive (Nebel and Wright, 1981, p. 28). Transition areas also appear in natural lakes, even if there is no significant exploitation of the water, due to the natural variation of inflow. However, natural transition areas are very different. First, nature creates gradual transitions; for example, immediately after the sand beach there is usually low foliage, and the trees are farther away. Second, in most cases, natural shores either are rocky (as are, for example, fiords) or their slopes are gentle, since the water, during the course of the millenia, smooths the earth down. By contrast, artificial lakes, which are only up to some decades old, can have rugged clay shores; this uncommon element is an asset, and it is one of the things that has made the Plastiras lake well-known; but it has the downside that it results in prominent transition areas of exceptionally regular geometry, as can be seen in the lower left photograph of Fig. 3. Finally, the surface of the transition area leaves a bad impression of unnatural texture. Some decades ago it was forest; some months or years ago it was submerged; but now it has neither forest nor water, and it seems lifeless. In addition, the transition area makes the lake appear empty, because it reveals the lake's potential area and volume and provides the observer with a means of comparison.

Talks with the local people and visitors, and questionnaires, showed that people who live at the lake or visit it regularly notice the degradation of the landscape much more than new visitors. Table 2 shows a classification of landscape quality based mostly on the survey of opinions. This classification, especially in the level of detail in which it is presented, is only an indication, and is, to some extent, arbitrary; aesthetic quality is neither measurable nor objective, and there are no clear division lines. However, Table 2 provides a necessary measure for the arrangement of conflicting objectives.

In order to refine our opinion and appreciation of the landscape, we observed and photographed the lake from different locations and altitudes, in different seasons, and for different lake levels. In addition, we analyzed the landscape from several viewpoints: specifically, by identifying its dominant form, lines, colours and texture; examining the essential aesthetic factors, namely contrast, gradualness, convergence, balance, axes; identifying variable factors, such as observing location and distance, and movement; investigating psychological associations and symbolisms, such as whether the landscape appears to be fair, honest, useful, respectful, holy, and communicative; studying its orientation, sights, and its degree of surprise, uniqueness, and variety; and by assessing its ability to optically absorb human-incurred alterations. These techniques are described in more detail by Sargentis et al. (2005), Hadjistathis and Ispikoudis (1995), and Stefanou (2001).

All this analysis appears at first to contradict our belief that there is little objectivity in aesthetics. If I like something, then I like it; this needs no justification, and there is very little that analysis can do in order to change my mind or enforce my opinion. However, all the aforementioned analysis helps to learn the landscape, to get acquainted with its details, and to get the bigger picture, so that afterwards we are more confident when we just look at the lake and say “I like it more today than a month ago”, or “I find the landscape impressive and powerful at the south, but more relaxing at the west”. In addition, the analysis is a form of self observation, which leads us to understand some of the reasons underlying our liking or not liking, and thus enabling us to predict whether other people might also agree or disagree with us.

6. Making the decision

The problem is summarized in Table 3, a multicriterion tableau (Hipel, 1992), where we describe criteria against alternatives.

All candidate solutions of Table 3 are acceptable as far as water quality is concerned, thus leaving annual yield to compete with landscape aesthetics. An additional problem not mentioned in the table is that of possible social pressure for high release. Although the study has been made with the assumption of constant annual release, if this proves to be a difficult concept for the local community to understand, social pressure may result in releasing more water than the constant annual amount in wet periods, when the level of the lake increases. This would result in the level of the lake being close to the minimum allowed level for a larger fraction of the time than that mentioned in Table 3. Thus, selecting, for example, +784 m rather than +782 m, we ensure adequate landscape quality for most of the time, even if the rules of good water management are violated; this, however, implies a non-negligible loss of about 6.5 hm^3 of water per year.

With the problem sufficiently analyzed in all aspects, we need a method to make the decision. Classical decision theory states that rational decisions are those that maximize some utility function (Wierzbicki, 1997). One common way to construct such a function is to use benefit-cost analysis, that is, translate all criteria into monetary values. For some criteria, such as available water quantity, this is straightforward; but it is very hard to measure landscape quality in monetary units. A common method of doing so is to make surveys and use the people's willingness to pay (WTP) as the supposed monetary value of landscape quality. There is, however, important criticism on this approach. Wenstøp and Seip (2001) mention several studies which cause serious doubts about any validity in WTP. "These surveys only bring forward unreflective prejudices of people, most of [whom] are not well equipped to make decisions about these matters, because they have never taken part in any relevant public inquiry and deliberation" (Arler, 2000). There are also ethical objections: "For example, market mechanisms do not supply incentives for sustainable harvesting in an 'open access' economy; it does not protect species that have growth rates much less than current interest rates ... and it does not provide categorical exclusions from use of, for example, natural wonders" (Wenstøp and Seip, 2001).

An alternative method of benefit-cost analysis is the hedonic price method or HPM (Rosen, 1974), in which the prices of similar marketable goods, such as similar houses, are compared in order to identify differences that can reasonably be attributed to the presence of a non-marketable good such as silence, the basic idea being that, if all other factors could be assumed to be equal, the price difference would be an indicator of the cost of the non-marketable good. Loomis and Feldman (2003) use this method in a study of Lake Almanor, California, similar to that of Lake Plastira. They examine the prices at which houses around the lake have been sold and they correlate them to the level of the lake at the time of sale. Although the use of HPM is interesting, it is questionable whether it is really possible to make all other factors equal. Loomis and Feldman assume that the price of a house is a linear function of twelve items (number of bathrooms, building size, distance from the lake, garage, etc.), the twelfth being the length of exposed shore. Even if we discard the fact that assuming a linear function is already a simplification, the function is still too complex to be of value, and the results have marginal statistical significance.

Given the problems of benefit-cost analysis, some prefer multi-criteria decision analysis (MCDA), in which the utility function is usually approximated by the weighted sum of the scores of the criteria. Of course, the scoring and the selection of weights are, to a certain extent, arbitrary. Proponents claim that such decisions cannot be objective, that this arbitrariness reflects the subjective preferences of the decision, and that MCDA is valuable because it makes the subjectivity explicit rather than present the decision as a black box (Bonte et al., 1998).

Several schools of criticism, however, have challenged the fundamental assumption of mainstream decision theory that a rational decision maximizes some kind of utility function. Wierzbicki (1997) provides an overview of these schools, the most extreme of which, well represented by Dreyfus and Dreyfus (1986), claims that decisions are mostly intuitive, because the complexity of the problems does not allow them to be tackled by analytical theory. "Ask any great athlete, or artist, or charismatic leader – ask any great decision maker. All of them describe a similar process, in which analytical and rational means are used extensively both in preparation for and in review of a central moment of performance. But in the moment itself, the actual decisions are made intuitively" (Moore, 1999). "The spontaneous, speedy and effortless way in which intuitive thinking allows the nub of a problem to be grasped is possible because of the non-conscious use of a non-linear reasoning process. The intuiter perceives the situation in a holistic way because of his or her deep involvement in the problem" (Easen and Wilcockson, 1996). Wierzbicki (1997) argues that language was one of the last features to appear in the evolution of humans, and thus that for solving many problems other, older abilities of the brain may be more appropriate: "our minds work also on a deeper layer of non-verbal image processing – which task employs a large part of the mind's processing potential, is sometimes conscious but often subconscious and uses rather multivalued than binary logic". Dreyfus and Dreyfus (1986) criticize western society of overemphasizing scientific, analytical thought, and of dismissing, as irrational, thought processes whose results cannot be analytically explained. "Against such a yard-stick, intuitive thinking is considered to be both inferior and unprofessional" (Easen and Wilcockson, 1996).

Answering these questions is obviously not straightforward, but rather it depends on one's philosophical and political ideology. Most of the authors of this paper agree that there is not much point in attempting to quantify the non-quantifiable aspects of the problem; we believe that the decision should be justified by using simple words to explain the choice that has been made after deep, holistic understanding of the problem, and this is what we have attempted to do in this paper. We all agree that the accepted solution will be in the range of 782–786 m, and that choosing a solution from that range is entirely subjective (in fact, while debating this, the opinions heard covered the whole range). The decision finally proposed is to maintain a minimum level of +784 m, with a recommendation of +786 m.

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Table 1. Characteristics of the lake and its basin.

Basin area	161.3 km^2
Highest basin altitude	2140 m
Maximum design lake level	794 m
Spill level	792 m
Minimum release level	776 m
Lake area at spill level	25 km^2
Lake area at minimum release level	15 km^2
Mean annual inflow	153 hm^3
Mean annual inflow depth	1029 mm

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Table 2. Assessment of landscape quality as a function of lake level.

Level (m)	Quality	Remarks
788–792	Excellent	The transition area is almost (788–790) or totally (790–792) absent.
786–788	Very good	The transition area is barely perceived and the landscape appears slightly affected.
784–786	Good	The transition area is clearly visible. The landscape is considerably affected, but is still satisfactory.
782–784	Fair	The landscape is significantly affected, and it only just satisfies observers.
776–782	Bad	The landscape is seriously degraded and the lake seems empty to most observers.

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Table 3. Multicriterion tableau for deciding the minimum lake level.

Min level	Reliable yield (hm^3)*	Time distribution of level and resulting landscape quality		Mean summer chlorophyll-α concentration (μg/L)
+780 m	137.9 (+10.4)	7%	Bad	5.6
		8%	Fair	
		12%	Good	
		27%	Very good	
		46%	Excellent	
+782 m	134.0 (+6.5)	8%	Fair	3.9
		11%	Good	
		28%	Very good	
		53%	Excellent	
+784 m	127.5	10%	Good	3.6
		29%	Very good	
		61%	Excellent	
+786 m	117.3 (-10.2)	26%	Very good	3.1
		74%	Excellent	
+788 m	96.3 (-31.2)	100%	Excellent	

* The value shown in brackets is the quantity of water gained annually with reference to +784 m.

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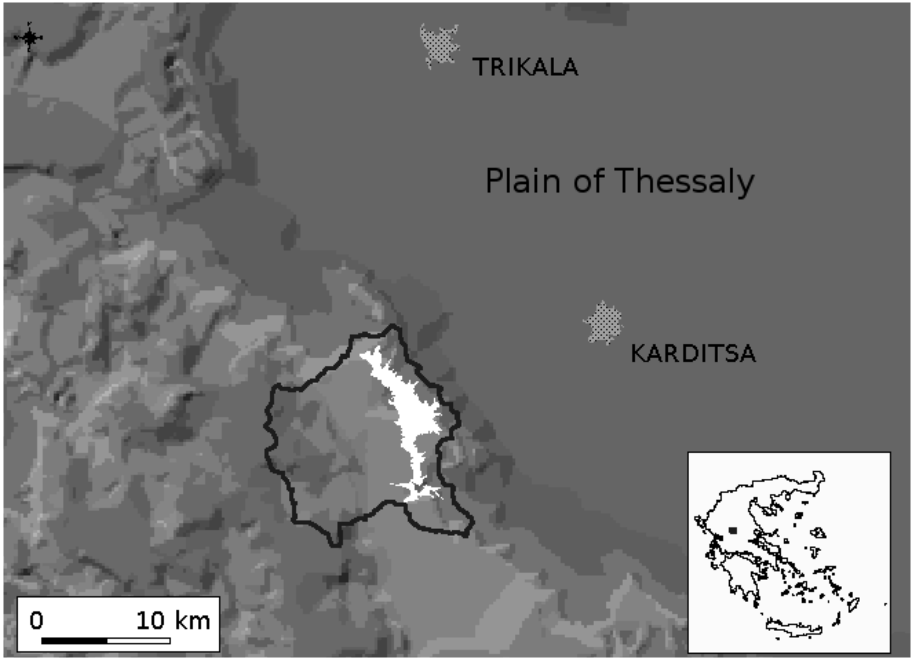

Fig. 1. The Plastiras Lake and its surroundings. The lake is shown in white, the dark line indicating the watershed. The spot on the small map of Greece indicates the position of the watershed.

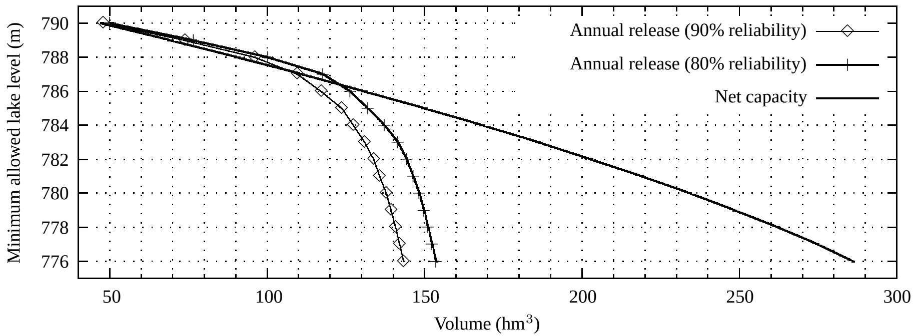

Fig. 2. Reliable yield as a function of minimum level.

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Fig. 3. The transition area. The photographs on the left have been taken on the north and south part of the lake when its level was 781.3 m. On the right the same photographs are digitally processed to show how the landscape would be if the lake were full.

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1 Introduction

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2 Formulation of the problem

Natural inflows vary irregularly in all temporal scales, including annual and multi-annual scales. The purpose of a reservoir is to regulate inflows and provide outflows at a more regular rate, that is determined by water demand, temporarily storing the surplus, when

inflows exceed outflows. The reservoir under study has been designed to perform multi-year regulation with a constant annual release. Although in many cases (e.g. Agrell et al., 1998) the practice followed is releasing a variable quantity of water each year, depending on the amount of water in the reservoir, the adoption of a constant annual release instead, irrespective of the amount of water available, is beneficial: the various water-dependent activities can be scheduled more efficiently, since a specific quantity of water is guaranteed, albeit with a certain probability of failure, to be available each year.

Reservoir design and management is often based on a non-probabilistic basis, which assumes a failure-free concept such as the “firm yield”. However, any target release normally has a nonzero probability of failure, and it is more accurate to study the reservoir on a probabilistic basis and talk of “reliable release” rather than firm yield (Koutsoyiannis, 2004); the reliable release is the amount of water that can be released with a specified reliability level or probability of failure. Thus, if the annual release with 90% reliability is 300 hm^3, this means that, on the average, once in a decade the actual release will be less than 300 hm^3.

The reliable annual release is a function of the hydrologic regime of the basin, the reliability level, and the net reservoir capacity. For the Plastiras Lake, the net reservoir capacity is defined by specifying the minimum allowed level (see the net capacity in Fig. 2). We use different values of minimum allowed level as our decision making alternatives, because minimum lake level is a simple notion, easy to incorporate into regulations, and easy to verify. The decision space is continuous; any real value between +776 and +792 m above sea level can, in theory, be chosen. However, we limit our selection to one of the five values of +780, +782, +784, +786, and +788 m.

In summary, the problem is to select one of the five options for minimum allowed level mentioned above by arranging the three conflicting objectives of maximizing water release, ensuring adequate water quality, and maintaining a high level of landscape quality, subject to the following assumptions:

Constant annual release. Except for the especially dry periods, as mentioned below, the same quantity of water will be taken from the lake, irrespective of the water available.

90% reliability. The annual yield mentioned in the table will be released in 90% of the cases. Once in ten years (on average) it will not be possible to release this quantity without violating the minimum allowed level.

Maintain level rather than release in failures. When the system fails, the minimum allowed level will not be violated; instead, the release will be reduced.

Priority of water supply and irrigation versus power production. The current practice, in which irrigation is the water use that dictates the operation of the reservoir, is assumed to continue in the future to avoid social reactions. Thus, the annual release is distributed nonuniformly throughout the year as required by the water supply and irrigation water uses.

3 Reliable release as a function of minimum level

Initially historical records of rainfall, reservoir inflow (based on the water balance of the lake), and evaporation (based on the Penman method) were constructed on a monthly basis. Then, synthetic time series with the same statistical characteristics as the historical records, but much longer in length (i.e. 1000 years), were generated by employing a stochastic hydrology framework (Koutsoyiannis, 2000) that reproduces the given statistical characteristics of the different variables, their cross-correlations, and the Hurst effect. The operation of the system was next simulated using the synthetic time series. In such simulations, the relationship among the storage capacity, water yield, energy yield and reliability can be established. The details of this process are outside the scope of this paper; for more information, the reader is referred to relative literature (Loucks et al., 1981; Mays and Tung, 1996; ReVelle, 1999; Koutsoyiannis, 2004; Pegram, 1980). Results are given in Fig. 2.

4 Water quality

The effect of lake level variation on water quality was assessed with the aid of two models, which are described by Stamou et al. (1994), Hadjibiros et al. (2002) and Andreadakis et al. (2003). Both models simulate various physical, chemical and biological processes of a reservoir, emphasising on eutrophism and oxygen. The same assumptions about polluting loads were made for both models, and the same input data were used. The output of the hydrologic simulation outlined in the previous section was used as water level variation scenarios. The polluting loads were estimated on the basis of land use in the basin, both nonpoint (mainly agriculture and rearing) and point sources (sewerage of residential locations).

Both models arrive at similar results, which generally match past measurements of chlorophyl concentration. It is concluded that water quality is always acceptable, at least for a minimum level of +782 m or higher, and is particularly high for a minimum level of +786 m or higher, in which case the chlorophyl concentration never exceeds 5 μg/L.

5 The landscape

When the lake is full, that is, when it is at its highest level of 792 m, the trees appear to touch the water. Although there is a sharp contrast of mountains that seem to spring out of water, the observer has the impression that the landscape is unified and pure. When the level of the lake drops, a piece of land is revealed between the trees and the water, and this affects the unity of the landscape. At the north part of the lake, where the slopes are small, large dry areas appear; at the south, where the landscape is rugged, a brown or yellowish narrow strip shows. This phenomenon, which is illustrated in Fig. 3, is not prominent for levels of 787 m or more, because many trees grow from levels of 790–791 m, and they cast their shadows even lower.

Such lifeless areas marking the transition from land to water are common in nature; a sand beach in front of a forest is a typical example. The reason for their existence is that the ecosystem developed on the boundaries of water and land is very sensitive (Nebel and Wright, 1981, p. 28). Transition areas also appear in natural lakes, even if there is no significant exploitation of the water, due to the natural variation of inflow. However, natural transition areas are very different. First, nature creates gradual transitions; for example, immediately after the sand beach there is usually low foliage, and the trees are farther away. Second, in most cases, natural shores either are rocky (as are, for example, fiords) or their slopes are gentle, since the water, during the course of the millenia, smooths the earth down. By contrast, artificial lakes, which are only up to some decades old, can have rugged clay shores; this uncommon element is an asset, and it is one of the things that has made the Plastiras lake well-known; but it has the downside that it results in prominent transition areas of exceptionally regular geometry, as can be seen in the lower left photograph of Fig. 3. Finally, the surface of the transition area leaves a bad impression of unnatural texture. Some decades ago it was forest; some months or years ago it was submerged; but now it has neither forest nor water, and it seems lifeless. In addition, the transition area makes the lake appear empty, because it reveals the lake's potential area and volume and provides the observer with a means of comparison.

Talks with the local people and visitors, and questionnaires, showed that people who live at the lake or visit it regularly notice the degradation of the landscape much more than new visitors. Table 2 shows a classification of landscape quality based mostly on the survey of opinions. This classification, especially in the level of detail in which it is presented, is only an indication, and is, to some extent, arbitrary; aesthetic quality is neither measurable nor objective, and there are no clear division lines. However, Table 2 provides a necessary measure for the arrangement of conflicting objectives.

In order to refine our opinion and appreciation of the landscape, we observed and photographed the lake from different locations and altitudes, in different seasons, and for different lake levels. In addition, we analyzed the landscape from several viewpoints: specifically, by identifying its dominant form, lines, colours and texture; examining the

essential aesthetic factors, namely contrast, gradualness, convergence, balance, axes; identifying variable factors, such as observing location and distance, and movement; investigating psychological associations and symbolisms, such as whether the landscape appears to be fair, honest, useful, respectful, holy, and communicative; studying its orientation, sights, and its degree of surprise, uniqueness, and variety; and by assessing its ability to optically absorb human-incurred alterations. These techniques are described in more detail by Sargentis et al. (2005), Hadjistathis and Ispikoudis (1995), and Stefanou (2001).

All this analysis appears at first to contradict our belief that there is little objectivity in aesthetics. If I like something, then I like it; this needs no justification, and there is very little that analysis can do in order to change my mind or enforce my opinion. However, all the aforementioned analysis helps to learn the landscape, to get acquainted with its details, and to get the bigger picture, so that afterwards we are more confident when we just look at the lake and say "I like it more today than a month ago", or "I find the landscape impressive and powerful at the south, but more relaxing at the west". In addition, the analysis is a form of self observation, which leads us to understand some of the reasons underlying our liking or not liking, and thus enabling us to predict whether other people might also agree or disagree with us.

6 Making the decision

The problem is summarized in Table 3, a multicriterion tableau (Hipel, 1992), where we describe criteria against alternatives.

All candidate solutions of Table 3 are acceptable as far as water quality is concerned, thus leaving annual yield to compete with landscape aesthetics. An additional problem not mentioned in the table is that of possible social pressure for high release. Although the study has been made with the assumption of constant annual release, if this proves to be a difficult concept for the local community to understand, social pressure may result in releasing more water than the constant annual amount in wet periods, when the level of the lake increases. This would result in the level of the lake being close to the minimum allowed level for a larger fraction of the time than that mentioned in Table 3. Thus, selecting, for example, +784 m rather than +782 m, we ensure adequate landscape quality for most of the time, even if the rules of good water management are violated; this, however, implies a non-negligible loss of about 6.5 hm^3 of water per year.

With the problem sufficiently analyzed in all aspects, we need a method to make the decision. Classical decision theory states that rational decisions are those that maximize some utility function (Wierzbicki, 1997). One common way to construct such a function is to use benefit-cost analysis, that is, translate all criteria into monetary values. For some criteria, such as available water quantity, this is straightforward; but it is very hard to measure landscape quality in monetary units. A common method of doing so is to make surveys and use the people's willingness to pay (WTP) as the supposed monetary value of landscape quality. There is, however, important criticism on this approach. Wenstøp and Seip (2001) mention several studies which cause serious doubts about any validity in WTP. "These surveys only bring forward unreflective prejudices of people, most of [whom] are not well equipped to make decisions about these matters, because they have never taken part in any relevant public inquiry and deliberation" (Arler, 2000). There are also ethical objections: "For example, market mechanisms do not supply incentives for sustainable harvesting in an 'open access' economy; it does not protect species that have growth rates much less than current interest rates ... and it does not provide categorical exclusions from use of, for example, natural wonders" (Wenstøp and Seip, 2001).

An alternative method of benefit-cost analysis is the hedonic price method or HPM (Rosen, 1974), in which the prices of similar marketable goods, such as similar houses, are compared in order to identify differences that can reasonably be attributed to the presence of a non-marketable good such as silence, the basic idea being that, if all other factors could be assumed to be equal, the price difference would be an indicator of the cost of the non-marketable good. Loomis and Feldman (2003) use this method in a study of Lake Almanor, California, similar to that of Lake Plastira. They examine

the prices at which houses around the lake have been sold and they correlate them to the level of the lake at the time of sale. Although the use of HPM is interesting, it is questionable whether it is really possible to make all other factors equal. Loomis and Feldman assume that the price of a house is a linear function of twelve items (number of bathrooms, building size, distance from the lake, garage, etc.), the twelfth being the length of exposed shore. Even if we discard the fact that assuming a linear function is already a simplification, the function is still too complex to be of value, and the results have marginal statistical significance.

Given the problems of benefit-cost analysis, some prefer multi-criteria decision analysis (MCDA), in which the utility function is usually approximated by the weighted sum of the scores of the criteria. Of course, the scoring and the selection of weights are, to a certain extent, arbitrary. Proponents claim that such decisions cannot be objective, that this arbitrariness reflects the subjective preferences of the decision, and that MCDA is valuable because it makes the subjectivity explicit rather than present the decision as a black box (Bonte et al., 1998).

Several schools of criticism, however, have challenged the fundamental assumption of mainstream decision theory that a rational decision maximizes some kind of utility function. Wierzbicki (1997) provides an overview of these schools, the most extreme of which, well represented by Dreyfus and Dreyfus (1986), claims that decisions are mostly intuitive, because the complexity of the problems does not allow them to be tackled by analytical theory. "Ask any great athlete, or artist, or charismatic leader – ask any great decision maker. All of them describe a similar process, in which analytical and rational means are used extensively both in preparation for and in review of a central moment of performance. But in the moment itself, the actual decisions are made intuitively" (Moore, 1999). "The spontaneous, speedy and effortless way in which intuitive thinking allows the nub of a problem to be grasped is possible because of the non-conscious use of a non-linear reasoning process. The intuiter perceives the situation in a holistic way because of his or her deep involvement in the problem" (Easen and Wilcockson, 1996). Wierzbicki (1997) argues that language was one of the last features to appear in the evolution of humans, and thus that for solving many problems other, older abilities of the brain may be more appropriate: “our minds work also on a deeper layer of non-verbal image processing – which task employs a large part of the mind’s processing potential, is sometimes conscious but often subconscious and uses rather multivalued than binary logic”. Dreyfus and Dreyfus (1986) criticize western society of overemphasizing scientific, analytical thought, and of dismissing, as irrational, thought processes whose results cannot be analytically explained. “Against such a yard-stick, intuitive thinking is considered to be both inferior and unprofessional” (Easen and Wilcockson, 1996).

Answering these questions is obviously not straightforward, but rather it depends on one’s philosophical and political ideology. Most of the authors of this paper agree that there is not much point in attempting to quantify the non-quantifiable aspects of the problem; we believe that the decision should be justified by using simple words to explain the choice that has been made after deep, holistic understanding of the problem, and this is what we have attempted to do in this paper. We all agree that the accepted solution will be in the range of 782–786 m, and that choosing a solution from that range is entirely subjective (in fact, while debating this, the opinions heard covered the whole range). The decision finally proposed is to maintain a minimum level of +784 m, with a recommendation of +786 m.

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Table 1. Characteristics of the lake and its basin.

Basin area	161.3 km^2
Highest basin altitude	2140 m
Maximum design lake level	794 m
Spill level	792 m
Minimum release level	776 m
Lake area at spill level	25 km^2
Lake area at minimum release level	15 km^2
Mean annual inflow	153 hm^3
Mean annual inflow depth	1029 mm

Table 2. Assessment of landscape quality as a function of lake level.

Level (m)	Quality	Remarks
788–792	Excellent	The transition area is almost (788–790) or totally (790–792) absent.
786–788	Very good	The transition area is barely perceived and the landscape appears slightly affected.
784–786	Good	The transition area is clearly visible. The landscape is considerably affected, but is still satisfactory.
782–784	Fair	The landscape is significantly affected, and it only just satisfies observers.
776–782	Bad	The landscape is seriously degraded and the lake seems empty to most observers.

Table 3. Multicriterion tableau for deciding the minimum lake level.

Min level	Reliable yield (hm^3)*	Time distribution of level and resulting landscape quality	Mean summer chlorophyll-α concentration (μg/L)
+780 m	137.9 (+10.4)	7% Bad 8% Fair 12% Good 27% Very good 46% Excellent	5.6
+782 m	134.0 (+6.5)	8% Fair 11% Good 28% Very good 53% Excellent	3.9
+784 m	127.5	10% Good 29% Very good 61% Excellent	3.6
+786 m	117.3 (-10.2)	26% Very good 74% Excellent	3.1
+788 m	96.3 (-31.2)	100% Excellent	

* The value shown in brackets is the quantity of water gained annually with reference to +784 m.

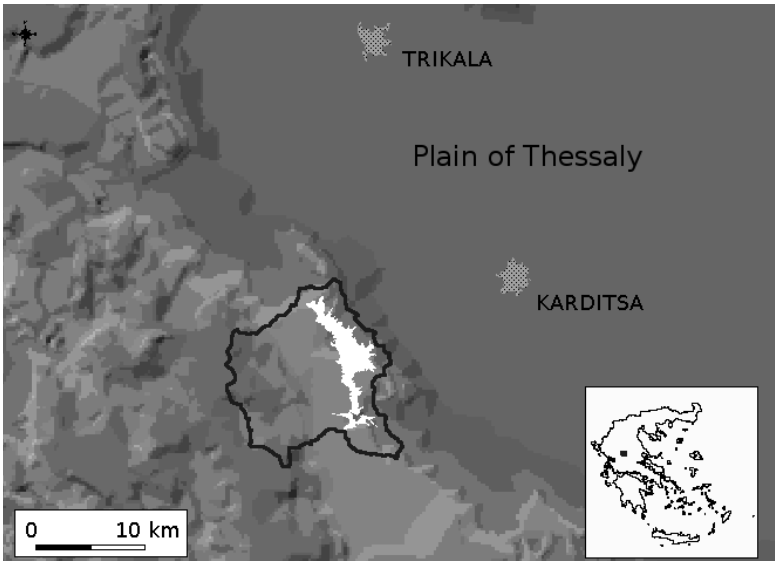

Fig. 1. The Plastiras Lake and its surroundings. The lake is shown in white, the dark line indicating the watershed. The spot on the small map of Greece indicates the position of the watershed.

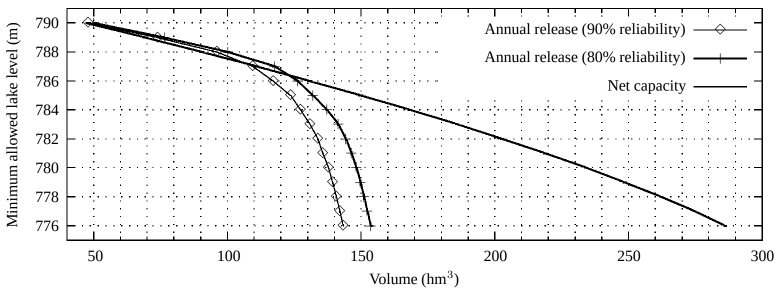

Fig. 2. Reliable yield as a function of minimum level.

Fig. 3. The transition area. The photographs on the left have been taken on the north and south part of the lake when its level was 781.3 m. On the right the same photographs are digitally processed to show how the landscape would be if the lake were full.