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# Water flow risks and stakeholder impacts on the choice of a dam site

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This study evaluates three alternative locations for building a fresh water dam in the Yeşilırmak Valley of North Cyprus. Each of the three sites has different investment costs, water storage capabilities and socio-political repercussions. These kinds of trade-offs have in recent years characterised much of the worldwide debate surrounding the construction of electricity and irrigation dams. Another issue raised in this paper is the appropriate treatment of the risk and variability associated with the availability of water to fill the dam through time. This paper demonstrates how an integrated financial-economic-stakeholder analysis can provide the inputs needed by decision-makers in such situations to make rational political and economic choices.

## 1. Introduction

In North Cyprus, efforts have intensified to find a solution to the worsening problem of a shortage of fresh water. These efforts can be classified as: (i) demand-side management policies; and (ii) supply-side management policies. Demand-side policies have involved the conversion of traditional irrigation practices to modern drip irrigation systems, and efforts to implement more rational water pricing policies. Supply-side management solutions involve transporting water from Turkey by tankers or medusa water bags, by bringing water via a sea pipeline from the southern coast of Turkey, by treating municipal wastewater and by building a dam in the Yeşilırmak Valley. The present paper considers a number of issues related to the decision of whether and where to build this dam.

The river on which the dam is to be placed is an underground river. Water that is now running underground and draining into the sea will be brought to the surface. Because it is an underground river, the usual issue concerning the impact of the dam on fisheries is not present (Robbins 1999, pp. 14–15; Wade 1999, p. 28). However, the construction of a dam in the Yeşilırmak Valley of

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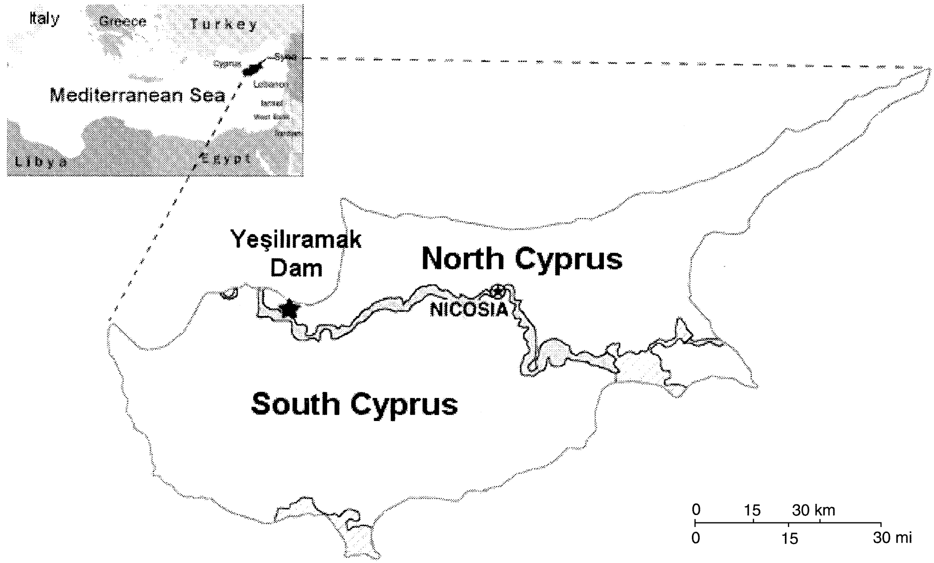


**Figure 1** The Location of Yeşilırmak Valley

North Cyprus (see figure 1) raises a number questions that often arise in the planning of such projects, but are frequently not given proper consideration. These issues include the risk and variability associated with water flows in the catchment area, and the displacement of traditional farmlands. The latter issue focuses attention on the stakeholder impacts of the project. In other words, who will benefit and by how much? Who is going to pay the direct and indirect costs associated with the dam? Such issues have recently come to the forefront when making decisions on how to implement dam projects.[1]

Unlike most infrastructure projects where many people pay the costs and a relatively small number get most of the benefits, in this case, a few people are affected negatively by the project, but essentially all the rest of the population in North Cyprus could potentially benefit from the additional potable water. Hence, if this project is to be implemented, estimation of the appropriate level of compensation to the perceived losers is very important for all the residents of North Cyprus.

This project has three characteristics that are of interest for analysis. First, because the water flows are subterranean, it is very difficult and expensive to

[1] Dorcey *et al.* (1997) and Maurer (2000). The situation of Kuala Lumpur, Malaysia discussed in this article is a good example of the problems that can arise with a dam being built to supply drinking water.

determine accurately a priori the size of the average annual water flows that are available at the three sites to be potentially captured by the dam. For any given level of rainfall, there is considerable risk associated with how much water can be captured by the dam. Second, because Cyprus has a semi-desert climate, the year-to-year variability in rainfall is very large. Even if the annual distribution of rainfall is known, there is considerable uncertainly as to how much water can be captured by the dam in any given year. In some years the dam may be only partially filled, while in other years water will be spilling over the dam.

Third, depending on where in the Valley the dam is built, it will end up flooding a bigger or smaller area containing some of the most fertile land in North Cyprus. There is a positive relationship between the amount of land flooded, the construction cost of the facilities and the volume of water that could potentially be stored by the dam at these three sites. Resettlement costs and opportunity costs of the land needed for the dam site are higher for each location that is progressively further from the border with South Cyprus. The present paper focuses on the development of appropriate analytical approaches for the examination of these three issues.

## 2. The three dam sites

The three potential sites for the dam are located in the Yeşilırmak Valley, which is positioned in the southwestern corner of North Cyprus. The villagers in the area support the first site for the project and oppose the third site for the project. With the third option, the stored water would cover much of their fertile land and the wells from which they currently obtain their water. The government, on the other hand, does not want to build the dam at the first site, because a portion of the stored water would lie in the buffer zone along the border with South Cyprus (figure 2). Given the current levels of hostilities between North and South Cyprus, this would almost certainly have political repercussions. The second location is in the middle of the other two and reflects a compromise position, as the catchment area will be completely in North Cyprus. It requires a larger capital input than the first site, while not capturing much more water. It would, however, not cover as much of the fertile land as the third location.

### 2.1 Water supply, collected and distributed

Some of the basic water supply information is provided in table 1. In the base case it is estimated that the mean annual quantity of water flowing underground through the Valley is 6 500 000 $m^3$ at Site I, 7 000 000 $m^3$ at

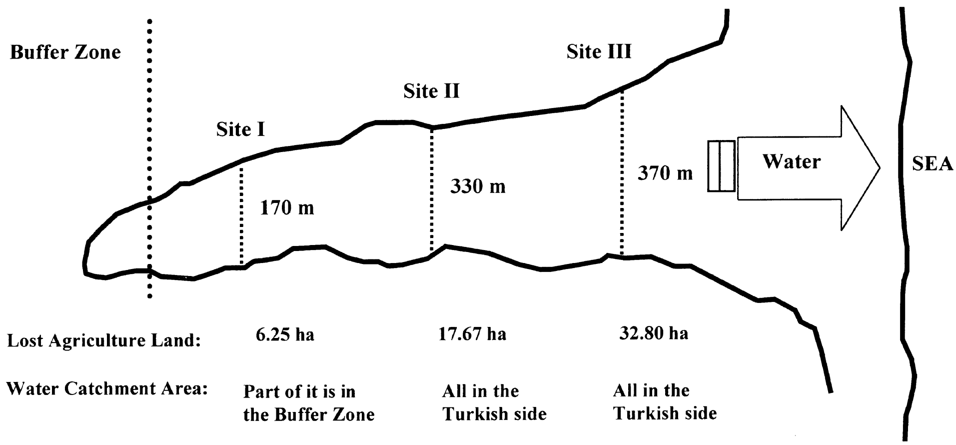


**Figure 2** Three Alternative Sites for Building the Dam on the Yeşilırmak Valley

Site II and 10 000 000 $m^3$ at Site III.[2] Given the scarcity of good geological and soil information in this area, there is some uncertainty associated with these estimates. Moreover, the government of South Cyprus has been periodically building micro dams upstream on some of the underground streams that would otherwise flow into the Valley. This activity would reduce the expected annual groundwater flow that is potentially the source of water for these dams. Hence, only ranges of values are available for the expected annual volumes of water flow. For site I the range is from 5 500 000 $m^3$ to 6 500 000 $m^3$. For site II the range is from 6 000 000 $m^3$ to 7 000 000 $m^3$ and for site III it is from 8 000 000 $m^3$ to 10 000 000 $m^3$.[3]

No further information is available to allow one to attach probabilities to the values within the ranges shown in table 1. Hence, the analysis is undertaken using the base-case values; the pessimistic and optimistic values are used to undertake a sensitivity analysis of the results. For this analysis the volumes associated with the underground water flows is a pure risk variable with an unknown distribution within the ranges specified.

These dams are designed to capture and regulate the seasonal flow of water. Significant underground water flows arise from the catchment area during the rainy season (2–3 months) and for 3–4 months immediately

[2] The data were obtained from the Water Works Office of the Ministry of Agriculture, Energy and Natural Resources, the Turkish Republic of Northern Cyprus.

[3] The data were obtained from the Water Works Office of the Ministry of Agriculture, Energy and Natural Resources, the Turkish Republic of Northern Cyprus.

**Table 1** Expected values of the annual groundwater flows by dam site ($m^3$)

| | Site I | Site II | Site III |
|---|---|---|---|
| Pessimistic | 5 500 000 | 6 000 000 | 8 000 000 |
| Base | 6 500 000 | 7 000 000 | 10 000 000 |
| Optimistic | 7 500 000 | 8 000 000 | 12 000 000 |

following the rains. The water stored by the dam will be drawn down during the remainder of the year.

Due to the design of the dam, a minimum amount of water (dead volume) will be retained at all times amounting to approximately 10 per cent of the dam's potential capacity. The estimated dam capacities reported in the following text have already been reduced by the amount of dead volume that must be retained. Furthermore, the amount of water that will be extracted during the period when the dams are filling was included in the specification of the capacities of the dams. Given the rather well-defined period when the rains occur in Cyprus, it is assumed that the amount of water extracted for consumption when the dams are filling is a constant each year. This simplifying assumption allows us to specify the actual amount of water extracted over the entire year from a given dam site as a function of the annual rainfall and the size of the dam.

While the long-run expected underground water flows are not exactly known, the annual rainfall is known and has been measured for this part of Cyprus for the past 81 years. Annual rainfall is approximately normally distributed with a mean of 488 mm and a standard deviation of 108 mm, or 22 per cent of the mean (Hatem-Moussallem *et al.* 1999, pp. 3–1, 3–2). Following standard practice, it is assumed that the annual underground water flow at the three sites will vary from year to year in a way that is proportional to the amount of rainfall for that year (Hatem-Moussallem *et al.* 1999, p. 3–3). Given that the expected annual groundwater flow at a particular site is equal to $\mu_f$, figure 3 shows the distribution of annual water flows caused by the annual variability in rainfall in Cyprus.

If a dam is built on the river with a maximum storage capacity of $Q_d$, then in some years when there is a low level of rainfall the annual flow of groundwater will be less than the dam's storage capacity. Hence, the water available for the distribution system will be less than $Q_d$. For years when the groundwater flow is greater than the dam capacity, the amount of the water collected will be just equal to the capacity of the dam. To find the expected value of water available for distribution over time, we apply the rule for estimating the expected value of a normal random variable that has mean $\mu_f$

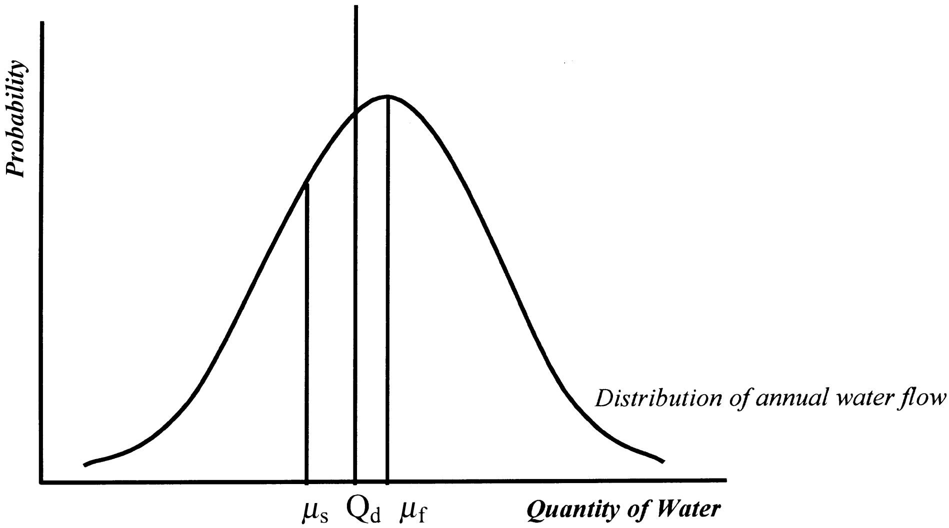


**Figure 3** Expected Water Flow and Storage

and standard deviation 0.221 $\mu_f$, and that is censored from above at $Q_d$. This censored distribution will have a mean supply of water of $\mu_s$, which is always less than either the capacity of the dam or the expected value of the annual groundwater flow.[4]

The mean value of the water stored can be calculated mathematically for dams with capacities of 6 200 000 $m^3$, 6 500 000 $m^3$, and 9 200 000 $m^3$, at sites I, II, and III respectively (Maddala 1983, p. 21). In the present paper, the expected values of the water available for distribution for these cases are estimated using a Monte Carlo simulation procedure.[5] The results are presented in table 2.[6]

By comparing the values in table 2 with those in table 1, and with the specified dam capacities, the expected values of quantities of water collected

[4] A further question that could be explored is whether a larger size of dam should be built to store water from the heavy rainfall years to be used in years of drought. Given the significantly larger area of rich agricultural land that would only be occasionally flooded it was decided at an early stage to not consider such a storage dam at this site. Other larger dams have been built in North Cyprus that have been designed to store water to meet the needs during drought years. However, if such a dam were to built it is likely that $Q_d$ in figure 3 would be to the right of $\mu_f$, hence raising the value of $\mu_s$ towards the value of $\mu_f$.

[5] The spreadsheets for the integrated financial-economic-stakeholder and risk analysis are available from the authors upon request.

[6] Crystal Ball User Manual 1998, Decisioneering Inc, Denver.

**Table 2** Expected values of quantities of water collected by dam site ($m^3$)

| | Site I | Site II | Site III |
|---|---|---|---|
| Dam capacity | 6 200 000 | 6 500 000 | 9 200 000 |
| Expected quantity | | | |
| Pessimistic | 5 442 978 | 5 673 349 | 7 744 068 |
| Base | 5 764 546 | 6 094 964 | 8 663 301 |
| Optimistic | 5 946 088 | 6 301 352 | 9 007 033 |

at each dam site are found to be significantly less than either the mean ground water flows or the dam capacities at these three sites. It is also important to note that the range of expected values of the quantity of water collected between the pessimistic and optimistic cases is significantly narrower than the range of the mean values for the groundwater flows. The reason is that the size of the dam puts a constraint on the upper limit of the range for the groundwater flow that can be collected within any given year. The base case no longer represents the mean of the potential outcomes.

The Yeşilırmak Valley and surrounding communities contain some of the premier fruit growing areas of North Cyprus. Hence, the water demand for agricultural purposes is substantial. At the present time, the villagers and farmers are able to extract water from wells in the area at only the costs of pumping. Due to political sensitivities, the most likely situation is that if a dam is built in the Valley, some provision will have to be made to provide high quality water to the local villagers for their household consumption, plus sufficient water to irrigate their farmland. At a later date it might be possible to persuade the farmers to sell their water rights to the water authority but at the present time this is only a remote possibility.[7] Projecting from current consumption patterns, approximately 25 940 $m^3$ will be required annually for the purpose of household consumption in the village and an additional 1.5 million $m^3$ will be needed for agricultural irrigation purposes, even if modern irrigation methods are employed. When these volumes are deducted from the expected quantities of water collected, as reported in table 2, we obtain the annual amounts of water that can be delivered to the main water distribution system for the rest of North Cyprus (located at Kumkoy). These quantities are reported in table 3.

[7] The government is now actively pursuing the idea of importing water from Turkey. When it starts to pay for such water purchases on a continuous basis, the use of prices and markets to allocate water within the country will likely become increasingly attractive.

**Table 3** Distribution of accumulated water ($m^3$)

| | Site I | Site II | Site III |
|---|---|---|---|
| Yeşilırmak | | | |
| Use of water for drinking purposes | 25 940 | 25 940 | 25 940 |
| Use of water for agricultural purposes | 1 500 000 | 1 500 000 | 1 500 000 |
| Total | 1 525 940 | 1 525 940 | 1 525 940 |
| Kumkoy (distribution to rest of North Cyprus) | | | |
| Pessimistic | 3 917 038 | 4 147 409 | 6 218 128 |
| Base | 4 238 606 | 4 569 024 | 7 137 361 |
| Optimistic | 4 420 148 | 4 775 412 | 7 481 093 |

## 2.2 Investment costs of alternative dam sites

Costs associated with the three dam sites are given in table 4, excluding the amount of compensation paid for the land used. Differences in the technical specifications of the dams are reflected in the different investment and operating costs.

Building a dam in the Yeşilırmak Valley requires that a treatment plant for water be situated in the Yeşilırmak village, with related pipelines. The capacity of the treatment plant will vary between 13 000 $m^3$ and 21 000 $m^3$ per day, depending on which site the dam is built. The cost of the appropriate size of water treatment plant is included as part of the cost of each project.

The investment costs (in year 2000 prices) for the dam plus the water treatment plant, but excluding land costs, for the first, second and third sites are approximately US$17 800 000, $23 800 000 and $28 000 000, respectively.

The appropriate level of compensation that the government should provide to the owners of the land that will be flooded at the respective dam sites is a highly controversial and non-transparent issue. At the present time, the villagers are not willing to sell their land at the prices at which they expect to be compensated.[8] From the examination of recent land sales in the Valley, the transactions price for agricultural land is in the range of $35 000 to $45 000 per hectare. However, these few transaction prices do not necessarily reflect the average price at which the rest of the owners would be willing to

[8] In North Cyprus the government has not always compensated the land owners for properties obtained through its eminent domain powers at full market prices. This has resulted in a number of eminent domains disputes. The price of $50 000 per hectare used in the base case financial analysis represents a land price that is slightly above any reported sales of agricultural land in the area. A range of alternative levels of compensation is also provided.

**Table 4** Investment costs (US$ in year 2000 prices)

| | Site I | Site II | Site III |
|---|---|---|---|
| Yeşilırmak dam cost ($) | 5 334 791 | 11 407 500 | 13 913 000 |
| Treatment plant | | | |
| Daily capacity ($m^3$) | 13 000 | 14 000 | 21 000 |
| Total cost ($) | 2 600 000 | 2 800 000 | 4 200 000 |
| Reservoir in Yeşilırmak | | | |
| Capacity ($m^3$) | 1000 | 1000 | 1500 |
| Total cost ($) | 60 000 | 60 000 | 90 000 |
| Yeşilırmak–Kumkoy pipeline | | | |
| Length of pipeline (km) | 26.0 | 25.3 | 25.0 |
| Total cost ($) | 7 800 000 | 7 575 000 | 7 500 000 |
| Reservoir in Kumkoy | | | |
| Capacity ($m^3$) | 10 000 | 10 000 | 15 000 |
| Total cost ($) | 600 000 | 600 000 | 900 000 |
| Yeşilırmak water distribution system | | | |
| Length of pipeline (km) | 7 | 7 | 7 |
| Total cost ($) | 1 400 000 | 1 400 000 | 1 400 000 |
| Total investment cost (excluding land) | 17 794 791 | 23 842 500 | 28 003 000 |

sell. The area is rich in history, culture and community relations that many residents of the Valley value highly. These features would be irreversibly altered by the construction of a dam in the Valley. These costs are largely borne by the local community and should be considered when determining the appropriate level of land compensation. At the same time there are some villagers who will also be hurt by the change in the natural environment as a consequence of the dam, yet because their land would not be flooded, they would not receive any compensation via the government land compensation scheme. The loss of land in this valley will also impose use and non-use environmental losses on others living in Cyprus and elsewhere.

To test the sensitivity of the break-even price of the water to the financial compensation given the present owners of the land to be flooded, compensation levels of US$50 000, $100 000, $150 000 and $200 000 per hectare are considered here. Given the areas to be covered by the water contained by each of the dams, table 5 shows the alternative total land compensation payments that are part of the financial investment costs of building each of the respective dams.

Given the levels of initial investment for the three sites, and using a price of land of $50 000 per hectare, it is found that the construction of the dam at

**Table 5** Land costs by site and level of compensation (US$ in year 2000 prices)

| | Site I | Site II | Site III |
|---|---|---|---|
| Total land lost (ha) | 6.25 | 17.67 | 32.80 |
| Total land cost at $50 000/ha | 312 500 | 883 500 | 1 640 000 |
| Total land cost at $100 000/ha | 625 000 | 1 767 000 | 3 280 000 |
| Total land cost at $150 000/ha | 937 500 | 2 650 500 | 4 920 000 |
| Total land cost at $200 000/ha | 1 250 000 | 3 534 000 | 6 560 000 |

Source: Engineering Division, Water Works Department, Ministry of the Interior, Government of North Cyprus, Nicosia 2000.

site II, rather than at site I, entails an additional investment of $6 618 709. Assuming the base case levels of ground water flows, site II yields only 330 000 $m^3$ additional water per year. On the other hand, choosing site III instead of site II implies some $4 917 000 in extra costs and yields 2 570 000 $m^3$ of additional water per year. If site III substitutes for site I, the additional costs will be $11 535 709 and 2 900 000 $m^3$ more water per year would be obtained.

## 3. Financial analysis

### 3.1 Break-even prices of water per cubic meter

The key question is what will be the real price (break-even price) of water that will allow the water authority to recover its investment and operating costs?[9] Evaluating the three investment alternatives allows one to consider the trade-offs that are being made between the marginal cost of water at the different sites and the socio-political issues that are present at the various sites.[10]

The average financial costs per $m^3$ are estimated using a cash-flow model for each of the three sites by finding the break-even price (i.e., the price at which the net present value (NPV) of the discounted net cash flows from the

[9] Leakages in the water distribution system are not taken into consideration, as the point of sale of the water from the dam is the entrance to the distribution system (Kumkoy).

[10] Discounted net cash flow models of the dam and their net present values (NPV) are used in evaluating the financial costs and revenues of the three alternative sites. The methodology employed can be found in Jenkins and Harberger (2000). The average financial cost of water per cubic metre for each site is calculated by setting the present values of the projected stream of annual net cash flows of each alternative site to zero. The average financial cost of water is the break-even price of the water where the required rate of return is satisfied. In order to measure the impact of different variables on the net present value of the cash flows, a sensitivity analysis is carried out as well. The detailed Excel spreadsheet model is available from the authors.

owner's perspective is equal to zero).[11] It is assumed that about 80 per cent of the investment cost will be financed initially by foreign sourced dollar-denominated debt at a 10.2 per cent real interest rate.[12] The remaining 20 per cent should be met by equity from the North Cyprus government at a real opportunity cost of 12 per cent. The draw down of debt and equity funds would occur on a pro rata basis. The construction plan covers 4 years (2001–2004).

The quantity of the water considered is the quantity delivered to Kumkoy for distribution to the rest of North Cyprus. An unknown variable at this point is the price that will be charged to the local residents of Yeşilırmak for the water they receive. It is likely that the price will be equal to or less than their current pumping costs of \$0.07 per $m^3$. In table 6 the estimates of the break-even cubic metre prices of water are presented in year 2000 prices for the three sites assuming also that the Yeşilırmak residents could be charged \$0.07, \$0.035 or zero for the water they receive. The estimates also are made for land compensation levels of \$50 000, \$100 000, \$150 000 and \$200 000. The base case level of water flow is assumed in all situations.

The break-even price of water is found to be lowest for site III (at \$0.59 per $m^3$) under the assumption that the local residents would be charged \$0.07 per $m^3$ and they only receive \$50 000 compensation per hectare for their land. Under these assumptions, site I has a break-even price of \$0.60 per $m^3$ and the break-even price at site II is \$0.77 per $m^3$. If the financial price of land is raised to \$200 000 per hectare, the lowest financial break-even price is now \$0.64 at site I, followed by site III at \$0.71 and highest at site II at \$0.86 per $m^3$. The switching of the lowest cost site arises because site III uses relatively much more land than site I for the amount of water collected.

Lowering the tariff charged to the Yeşilırmak residents to \$0.035 reduces the break-even price by just \$0.013 per $m^3$ for site I, \$0.012 per $m^3$ for site II and \$0.007 per $m^3$ for site III. For the case where the Yeşilırmak residents do not have to pay anything for the water they receive, and its landowners receive \$200 000 for the land flooded by the dam, the break-even price is lowest at site I at \$0.66 per $m^3$, the next lowest is site III at \$0.72 and the highest is at site II at \$0.88 per $m^3$.

[11] The project life for the dam is assumed to be 50 years, and it is considered to have no salvage value. It is also assumed that the nominal tariff rate per $m^3$ of water expressed in Turkish Lira is increased at the rate of inflation for each period, which is assumed to be 60 per cent. As the project will be undertaken by the Water Works Department of the Ministry of Interior of the Government of North Cyprus, the project is exempt from corporate income tax.

[12] It is most likely that this loan financing will come from the Turkish government. The nominal rate of borrowing on the US dollar denominated loan and the rate of inflation for the USA are taken at 13.5 per cent and 3.0 per cent, respectively. Hence, the real rate of interest is calculated as $(13.5 - 3.0) / (1 + 0.03)$, giving a rate of 10.2 per cent.

**Table 6** Break-even price of water per $m^3$ delivered to Kumkoy (US$/$m^3$). Base case volumes

| | Site I | Site II | Site III |
|---|---|---|---|
| Price of water to Yeşilırmak residents = $0.07 | | | |
| Land price 50 000/ha | 0.599 | 0.765 | 0.594 |
| Land price 100 000/ha | 0.611 | 0.796 | 0.632 |
| Land price 150 000/ha | 0.623 | 0.828 | 0.670 |
| Land price 200 000/ha | 0.635 | 0.860 | 0.708 |
| Price of water to Yeşilırmak residents = $0.035 | | | |
| Land price 50 000/ha | 0.612 | 0.776 | 0.602 |
| Land price 100 000/ha | 0.624 | 0.808 | 0.640 |
| Land price 150 000/ha | 0.636 | 0.840 | 0.678 |
| Land price 200 000/ha | 0.648 | 0.872 | 0.715 |
| Price of water to Yeşilırmak residents = $0.00 | | | |
| Land price 50 000/ha | 0.624 | 0.788 | 0.609 |
| Land price 100 000/ha | 0.636 | 0.820 | 0.647 |
| Land price 150 000/ha | 0.648 | 0.852 | 0.685 |
| Land price 200 000/ha | 0.661 | 0.883 | 0.723 |

The impact of raising the price of land with the base case water flows from $50 000 to $200 000 is to add approximately $0.036 per $m^3$ to the break-even price for site I, $0.095 per $m^3$ at site II and $0.114 per $m^3$ at site III.

The values in table 6 were calculated using the base case assumptions for the volume of groundwater flowing down the Valley. If one were to assume the worst case scenario, with a land compensation of $50 000 per hectare and free distribution of water to the local residents, then the break-even price for site I is raised to $0.67, for site II it becomes $0.87 and at site III it is $0.70 per $m^3$. If instead the land compensation is raised to $200 000, the break-even prices are raised further to $0.71, $0.97 and $0.83 per $m^3$, for sites I, II and III respectively.

Alternatively, if one were to assume the best case scenario for the volume of water flows, and land compensation of only $50 000 per hectare with free distribution of water to the local residents, then the lowest break-even price for site I is approximately $0.60, for site II it is $0.76 and for Site III it is $0.58 per $m^3$. Again when the price of land is raised to $200 000, the break-even prices are raised to $0.63, $0.85 and $0.69 per $m^3$ for sites I, II and III, respectively.

From the financial analysis it appears that site I is the least expensive source of water, but for international political reasons it is likely to be impossible to build at that site. If site I is ruled out, then under the best possible financial circumstances,[13] the break-even price is at least $0.73 per $m^3$ for site II and $0.57 per $m^3$ for site III.

[13] In this case optimistic water flows are realised, the low price of $5000 is paid for the land, and the residents are charged $0.07 per $m^3$ for the water they use.

For the most pessimistic water flow case,[14] it is found that the financial break-even price of water from site II is between \$0.87 and \$0.97 per $m^3$, and at site III it is between \$0.70 and \$0.83 per $m^3$. Although site III is financially the second most attractive of the dam sites, due to the protests of the local villagers it might be difficult to build it there. Hence, the range of possible break-even prices for site II ranges from approximately \$0.73 to \$0.97 per $m^3$.

The water system of North Cyprus would still be subject to the cost of coping with the year-to-year fluctuations in water availability from the dam due to the variability of the annual rainfall. These costs are not present to the same extent when a tanker, a pipeline, or a desalinisation plant supplies water. When the availability of water suddenly drops due to low rainfall, either rationing must take place, which imposes a cost on the consumers directly, or alternative sources of supply need to be available. It can be assumed that in the future additional supplies of water will be imported on a continuous basis from Turkey via tanker, as the infrastructure for such water transportation is already being built. In such a situation the relevant costs of making up for the shortfalls in supply from the dam will be the financial cost of transporting additional water to North Cyprus via tanker. Assuming constant marginal costs of supply of water imported by tankers, the break-even prices calculated for water from the dam will require little or no further adjustment.

## 4. Economic analysis

In this section the benefits and costs accruing during the course of the project from the perspective of the total economy are considered. It uses the economic values of all the inputs and outputs of the project, which are different from the market prices when market distortions are present.

A key economic price is the economic value of water. Two alternative approaches might be taken to estimate this variable. The first approach is to measure the value of water by the consumers' willingness to pay for it, after making an appropriate adjustment for distribution costs. The second approach measures the value of water by the value of the resource costs of alternative sources of supply that otherwise must be used to supply the water. Which approach to take depends on the facts and circumstances of the situation. The question is, will the additional water supplied by the dam expand the consumption of water, or will it reduce the amount supplied from other sources?

A study of the demand for water undertaken in North Cyprus has measured the willingness to pay (in year 2000 prices) for non-potable water to

[14] The assumption is that (the likely scenario of) free water is given to the local villagers.

be more than \$1.50 per $m^3$, while drinking water sold by vendors costs approximately \$25.00 per $m^3$.[15] However, there are alternative sources of raw water that are available to North Cyprus, including the mass importation of water from Turkey and the desalinisation of sea-water. Hence, in this study, the economic value of water from the Yeşilırmak Dam will be based on the resource costs saved by not having to import water from Turkey by a known technology (i.e., water tankers).

The economic value of \$0.79 per $m^3$ reflects the economic cost of obtaining untreated water via tanker from Manavgat (Turkey) (Bıçak and Jenkins 2000, p. 124). This price is the delivery price to Kumkoy, from where it is distributed to other parts of North Cyprus. The price includes all the costs of infrastructure to be developed on land and in the sea in North Cyprus, as well as port handling charges in Turkey, but excludes any payment for water to Turkey and the cost of treatment of the water in Cyprus. When these additional costs are added, then the economic cost of water by tanker would rise to approximately \$0.90 per $m^3$. Hence, in the analysis that follows, both \$0.79 and \$0.90 per $m^3$ are used as the economic value of water obtained from the alternative dams. Lower cost sources of water might become available in the future. For example it is reported that the estimated cost is \$0.84 per $m^3$ for water produced by the desalinisation facilities recently built in South Cyprus (Hatem-Moussallem *et al.* 1999, pp. 4–13). However, it is clear that this estimate does not price the cost of capital at its real economic opportunity cost, which would typically be higher than its real financial cost.

When considering the economic costs of the dam, estimates of the economic opportunity cost of inputs and outputs, including the economic value of the land that will be lost when the dam is built, are required.[16] From the sale prices of land in the area (\$30 000 to \$45 000 per hectare), it appears that the base case economic price of land of \$50 000 per hectare would be appropriate. The price does not include any additional perceived value that some residents might place on the land. The latter will be considered when the impact of higher economic values of land is considered.

The economic opportunity cost of capital is taken as 12 per cent in this study. This value has been used elsewhere and reflects the economic cost of

[15] Korman (2002). The valuation of drinking water at \$10.00 per $m^3$ does not include the cost of bottled water.

[16] In most countries, the market exchange rate does not reflect the economic cost of foreign exchange. In the case of North Cyprus (TRNC), because it uses the Turkish Lira (TL) – which is issued by Turkey and is convertible to any type of foreign exchange – there is no reason to include a premium for foreign exchange. TRNC is very small as compared to the Turkish economy. Hence, any external cost associated with conversion of the TL into foreign exchange to be used for buying imports will be borne largely by Turkey. As a consequence, there is no premium on foreign exchange from the perspective of the TRNC.

either not using capital resources elsewhere in the economy or the real cost to the Turkish Republic of Northern Cyprus (TRNC) of the foreign investment it receives from abroad (Özdemirağ *et al*. 1998, annex 23).

The economic analysis was carried out for a project life of 50 years. The economic benefits are the quantities of treated water supplied to the water utility valued at either $0.79/m$^3$ or $0.90/m$^3$ reflecting the appropriate cost of alternative water supplies. The economic value of the water supplied to the local villagers is measured by the economic value of the resources saved by the elimination of the pumping that would be done if the dam were not built. All the investment costs are corrected for the taxes and other distortions that create divergencies between their financial and economic values. The net benefits are then discounted to the year 2000 by the 12 per cent economic opportunity cost of funds.

The results of the economic analysis in table 7 are expressed in year 2000 prices. Using the base case water flows and a $0.79 economic value for water, site III is ranked first, with the highest economic NPV of $7 350 000. Site I, which has the lowest financial break-even price, is ranked second in terms of its NPV, with an economic NPV of $4 270 000 – or almost 40 per cent less than the NPV of site III. Site II has the lowest economic NPV of $610 000. Site III appears to be the most attractive economically, due to the relatively large amount of water captured by this site. When the water is valued more realistically at an economic price of $0.90 per m$^3$, the economic net present value of site III increases to $11 490 000, site I increases to $6 720 000 and site II increases to $3 260 000.

These results clearly illustrate that although site I has the lowest per unit cost, it does not create as much net wealth for North Cyprus as site III. The economic analysis also indicates that if site III cannot be built due to the protests of the local villagers, and instead site II is built, the country will lose

**Table 7** Economic NPV with Land Price at $ 50 000 per hectare (US$ millions, in year 2000 prices)

| | Site I | Site II | Site III |
|---|---|---|---|
| Pessimistic case | | | |
| Economic price of water set at $0.79 | 2.95 | −1.11 | 3.60 |
| Economic price of water set at $0.90 | 5.22 | 1.29 | 7.20 |
| Base case | | | |
| Economic price of water set at $0.79 | 4.27 | 0.61 | 7.35 |
| Economic price of water set at $0.90 | 6.72 | 3.26 | 11.49 |
| Optimistic case | | | |
| Economic price of water set at $0.79 | 5.00 | 1.45 | 8.76 |
| Economic price of water set at $0.90 | 7.57 | 4.22 | 13.10 |

(in this base case) between \$6 700 000 and \$8 200 000 compared with supplying water by tanker. In the pessimistic scenario, the dam should not be built at all at site II if the economic price were as low as \$0.79. If the water has an economic value of \$0.90, the economic NPV is positive (\$1 300 000) at this site. In this case the loss from not being able to build at site III would be between \$3 600 000 and \$5 900 000. For the optimistic case, the loss incurred from not being able to build at site III would range between \$7 300 000 and \$8 900 000.

Given that only about 25 farmers are involved in the land compensation problem, this will lead to an economic loss to the country of between US\$144 000 and US\$356 000 per land owner. If the dam is to be built at all, it would seem prudent to attempt to negotiate a politically acceptable settlement with these families and build the dam at site III. But such negotiations do not necessarily mean that the dam will be built.[17]

The compensation of the villagers for the land to be covered by water appears to be one of the main political problems to be solved before the project can be implemented, especially at site III. If that is not solved, there is little economic justification for building the dam at site II.

Considering that there is likely to be a price at which the villagers would be willing to overcome the perceived value they place on their land and would be willing to sell, a sensitivity analysis is carried out to find the break-even opportunity cost of land at various economic opportunity costs of water in North Cyprus. Table 8, shows that at an economic price of water of \$0.55 per $m^3$, none of the three sites could support an economic opportunity cost of land of zero. At an economic price of water of \$0.90 per $m^3$, the economic opportunity cost of land per hectare could be as high as \$1 290 510 at site I, \$262 670 at site II and \$454 050 at site III. At the economic opportunity cost of \$0.79 per cubic metre, the break-even cost of land per hectare is \$837 230 for site I, \$89 840 for site II and \$308 610 for site III. From the analysis, it is clear that the authorities need to have a good estimate of the economic opportunity cost of water before determining the acceptable range for land compensation, if the project is to benefit both the land owners as well as the consumers of the water.

## 5. Stakeholder – distributive analysis

In this section of the paper we measure who will bear the project's costs, who will benefit, and by how much. In essence, we allocate the net benefits/or losses to be generated by the project to the major shareholders of the project

[17] An illustrative case of Kito Dam in Japan by McCormack (1997, pp. 225–8).

**Table 8** Sensitivity analysis of the break-even economic opportunity cost of land ($/hectar) for different economic opportunity costs of water

| Economic opportunity cost of water $ | Site I | Site II | Site III |
|---|---|---|---|
| 0.55 | 0 | 0 | 0 |
| 0.60 | 54 290 | 0 | 57 400 |
| 0.65 | 260 320 | 0 | 123 510 |
| 0.70 | 466 360 | 0 | 189 620 |
| 0.75 | 672 400 | 27 000 | 255 730 |
| 0.79 | 837 230 | 89 840 | 308 610 |
| 0.80 | 878 430 | 105 550 | 321 840 |
| 0.85 | 1 084 470 | 184 110 | 387 950 |
| 0.90 | 1 290 510 | 262 670 | 454 050 |
| 0.95 | 1 496 540 | 341 230 | 520 160 |
| 1.00 | 1 702 580 | 419 780 | 586 270 |

(Jenkins 1999, pp. 87–96). The distribution of net benefits or costs of the project is estimated by subtracting the values found in the financial cash flow statement from the values found in the economic benefit/cost statement. In this way, the economic and financial values of inputs and outputs are reconciled. The NPV of the economic net benefits statement is equal to the NPV of the financial net cash flow plus the present value of the stakeholder impacts (SI) generated by the project, all discounted by the economic opportunity cost of capital. This relationship can be expressed as follows:

$$\mathrm{NPV}^{e}_{\mathrm{ECOK}} = \mathrm{NPV}^{f}_{\mathrm{ECOK}} + \sum \mathrm{PV}_{\mathrm{ECOK}}(\mathrm{SI}) \tag{1}$$

where $\mathrm{NPV}^{e}_{\mathrm{EOCK}}$ is the net present value of the economic benefits and costs, $\mathrm{NPV}^{f}_{\mathrm{EOCK}}$ is the net present value of the financial benefits and costs, and $\sum \mathrm{PV}_{\mathrm{EOCK}}$ (SI) is the sum of the present value of all the stakeholder impacts generated by the project, all discounted using the economic opportunity cost of capital (Jenkins 1999, pp. 87–96).

Here, the same discount rate has been used for both the financial and economic analyses, and the financial prices were set so that the financial NPV is equal to zero. Hence, the present values of the stakeholder impacts will be exactly equal to the economic net present value of the project. For the base case of groundwater flow and an economic value of water of $0.90 per m$^3$, it is found that the net present values in year 2000 prices for the three sites are $6 720 000, $3 260 000 and $11 490 000, respectively.

When considering the allocation of the net benefits of the project, we find that the benefits accrue to the consumers of water in the rest of North Cyprus, the land owners of the dam site, other land owners who will use the water from the dam for irrigation purposes and the household consumers of water in Yeşilırmak village after the project is built. The allocation of the net

**Table 9a** Stakeholder impacts of Yeşilırmak dam base case water volumes (US$ millions in year 2000 prices). Worst case scenario for Yeşilırmak land compensation $50,000 per hectare. Water sold to villagers at $0.07

| | Water consumers | Landowners of site | Other landowners | Village consumers | Total |
|---|---|---|---|---|---|
| Site I | 6.72 | 0 | 0 | 0 | 6.72 |
| Site II | 3.26 | 0 | 0 | 0 | 3.26 |
| Site III | 11.49 | 0 | 0 | 0 | 11.49 |

**Table 9b** Best case scenario for Yeşilırmak land compensation $200,000 per hectare. Water sold to villagers at $0.00

| | Water consumers | Landowners of site | Other landowners | Village consumers | Total |
|---|---|---|---|---|---|
| Site I | 5.35 | 0.81 | 0.55 | 0.01 | 6.72 |
| Site II | 0.40 | 2.30 | 0.55 | 0.01 | 3.26 |
| Site III | 6.66 | 4.27 | 0.55 | 0.01 | 11.49 |

benefits by site, for two extreme levels of land compensation and prices charged for the water to be distributed in the village are shown in table 9.

In the first case, if the land owners just receive the financial opportunity cost of $50 000 per hectare, and the villagers and farmers have to pay $0.07 per $m^3$ for the water they obtain from the dam, then the residents and land owners of Yeşilırmak will receive no distributive or stakeholder benefit at all from the construction of the dam. They are made no worse off financially, but at the same time they are no better off. The entire benefit goes to the other consumers of water in North Cyprus. At site I consumers would potentially gain $6 720 000, from site II they would gain $3 260 000, and from site III they would gain $11.49 over the alternative of importing water from Turkey at a cost of $0.90 per $m^3$.

In table 9b the opposite case is given. In this situation the land owners of the dam site get paid compensation of $200 000 per hectare and the consumers of water in the village and the local farmers obtain water free of charge. In this case the total value of the stakeholder impacts are the same as before, but this time their distribution across the stakeholders is very different. In the case of site I the water consumers in North Cyprus would receive $5 350 000 or 79.6 per cent of the total net benefits. The land owners would receive $810 000 or 12.05 per cent, while the other farmers would receive $550 000 or 8.2 per cent, and the village water consumers would receive $10 000 or 0.15 per cent of the value of the net benefits. However, as it is highly unlikely that the authorities would ever allow a dam to be built on site I, it is sites II and III that are of greater practical importance.

A dam at site II would generate only \$3 260 000 of net benefits. With these parameters the water consumers of North Cyprus would only receive \$40 000 or 12.27 per cent of the total. The land owners of the dam site would gain \$2 300 000 or 70.55 per cent of the value of the net benefits. Other land owners would receive \$550 000 or 16.87 per cent of the available benefits, and village consumers would receive \$10 000 or 0.3 per cent of the benefits. In this case it is hardly worthwhile for the consumers of North Cyprus to pursue the option of building the dam at site II. They would end up in almost the same situation as they would be if they were to import water. The landowners, however, do quite well. At this site there are not more than 10 landowners and they get to share \$2 300 000, over and above receiving the financial opportunity cost of their land.

A most interesting situation arises if the dam is built at site III. In this case there are \$11 490 000 of distributive benefits to be allocated. Because of the large volume of water, the consumers of North Cyprus obtain a benefit of \$6 660 000 or 58 per cent of the value of the net benefits. The landowners of the dam site would obtain \$4 270 000, or 37 per cent of the total net benefits. On a per land owner basis, each of the 25 farmers would receive, on average, \$170 000 over and above the financial opportunity cost of their land. Again the other land owners would receive \$550 000 and the village consumers would receive \$10 000 through the savings in their current pumping costs.

At site III there is a positive incentive for everyone to make a deal, and there are sufficient distributive benefits so that everyone involved can obtain a significant net financial benefit. It would appear that site III has the potential to make all parties better off, without making anyone worse off.

The analysis so far has not taken into consideration the social impact on the villagers caused by the aesthetic losses and the values they might place on the cultural and historical preservation of the Valley. It is clear that this green fertile Valley is almost unique to North Cyprus. Its preservation is likely to be valued most by the villagers themselves who own land that will be flooded by the dam, but also by those who live in the village and do not own land. Another important group includes the many relatives who live abroad (mostly in Australia and the UK). A significant number of these out-migrants still own land in the Valley and often have aspirations of returning to the village after their retirement. The level of compensation will serve to offset the net costs of the owners of the land. If not compensated they can refuse to sell. However, those people who are somehow connected to the Yeşilırmak Valley but do not obtain compensation through the sale of their land are likely to feel worse off if the dam is built. It is not surprising that this group, particularly the former villagers residing abroad, have been active in orchestrating political pressure to get the government to abandon the project.

## 6. Concluding remarks

The dam project represents just one among several different choices for supplying water to North Cyprus. Site III has the largest catchment area and initial investment cost, but also generates a significant economic and financial benefit for water consumers in North Cyprus. Unfortunately it covers a very fertile, and perhaps unique, area of North Cyprus that the local inhabitants are not prepared to give up at the level of compensation they now expect to receive. For such projects, reaching an agreement on land issues is critical. Left unsettled they may block the implementation of the project, or later cause severe economic, and social conflicts. This source of conflict must be dealt with at the beginning of the project in a way that all the stakeholders are willing to settle their differences. This paper illustrates a method of analysis for quantifying the distributive net benefits that are available, and provides a useful tool to aid negotiations.

An interesting question that is not fully addressed in this paper is the evaluation of the benefits and costs of postponing the project. The costs of postponement for a year can be estimated by multiplying the NPV of the alternative dams by the economic opportunity cost of capital. The benefits of postponement are more difficult to quantify. Of particular concern is the uncertainty surrounding the appropriate values to place on the cultural and historical aspects of the Yeşilırmak Valley that will be affected by the dam. Over time these values might become better known. The negotiations which need to take place to reach a settlement over land compensation may give the authorities a clearer sense of the intrinsic values that the residents of the Valley, their relatives, and other residents of North Cyprus place on these externalities. More time may also allow a better judgement to be made about the value of water in North Cyprus in future years.

The present paper also systematically considers the interaction between the expected quantity of the ground water and the annual variability of the water flows, and the capacities of the different dams that come together to determine the expected quantity of water available for consumption. It is found that the expected values of the quantities of water captured by the dams are significantly smaller than either the mean annual volume of underground water flows, or the design capacities of the dams.

## References

Bıçak, H. and Jenkins, G.P. 2000, 'Transporting Water by Tanker from Turkey to North Cyprus: Costs and Pricing Policies Related', in Brooks, D. and Mehmet, O. (eds), *Water Balances in the Eastern Mediterranean*, IDRC, Ottawa.

Dorcey, T., Steiner, A., Acreman, M. and Orlando, B. 1997, *Large Dams: Learning from the Past Looking at the Future*, World Bank and World Conservation Union Publications Service, Cambridge, UK.

Hatem-Moussallem, M., Gaffney, B., Cox, C. and Batho, M. 1999, *Solutions to Water Scarcity in Cyprus – a Proposal for Water Banking* (MA Thesis), Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Boston.

Jenkins, G.P. 1999, 'Stakeholder Impacts: Evaluation of Stakeholder Impacts in Cost Benefit Analysis', *Impact Assessment and Project Appraisal*, vol. 17(2), pp. 87–96.

Jenkins, G.P. and Harberger, A.C. 2000, *Cost-Benefit Analysis of Investment Decisions*, Cambridge Resources International, Cambridge, MA.

Korman, V. 2002, *The Willingness to Pay for Water Supply Improvement in Famagusta, North Cyprus* (Dissertation), Northeastern University, Boston.

Maddala, G.S. 1983, *Limited-Dependent and Qualitative Variables in Econometrics*, Cambridge University Press, Cambridge.

Maurer, H. 2000, 'As a Dam Forces Villagers Out', *Business Week* 16 October, McGraw-Hill, New York.

McCormack, G. 1997, 'Village vs. State', *The Ecologist* 27 November–December, pp. 225–228.

Özdemirağ, A., Shim, J. and Oteyza, S. 1998, *Water Supply by Sea Pipeline from Turkey to North Cyprus*, Investment Appraisal and Management Program, Harvard Institute for International Development, Harvard University, Cambridge.

Robbins, E. 1999, 'Damning Dams', *The Environmental Magazine*, vol. 10, pp. 14–15.

Wade, B. 1999, 'Finances vs. Fish: a Dam-Nable Debate', *American City and Country*, vol. 114(6), p. 28.