Water pricing issues in countries with water deficit

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Dialogues on Mediterranean water challenges: Rational water use, water price versus value and lessons learned from the European Water Framework Directive

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Water pricing issues in countries with water deficit

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Abstract. In the Mediterranean countries water management is not only a matter of setting the price of water, but also of securing the availability of water. In Cyprus, water supply is based on rainfall that is becoming less and less with time. Water pricing should take into account covering the primary costs for the acquisition of water such as the cost of the distribution networks, running costs for pumps, and the intended use of the water (agriculture, industry, tourism, households and so on). Households have the right to be supplied with water of good quality at reasonably low prices. Water used for industry and other economic activities should be priced at its real cost, increased by an "availability factor" that takes into account the available water reserves of the country. A good water policy should promote issues such as: saving water in all sectors of economy and preventing irrational water use (through proper water pricing schemes, etc.); minimizing distribution network losses; safeguarding the quality of water reserves (during water production, distribution, storage, water treatment and reuse). All water resources in a country should be considered as a national resource and should be controlled by a single entity to achieve good coordination and management. This paper deals with a simplified method for water pricing, in cases of water scarcity as encountered in the Mediterranean countries.

Keywords. Water – Price policies – Water availability.

Prix de l'eau dans les pays exposés à la pénurie d'eau

Résumé. *La gestion de l'eau dans les pays méditerranéens ne se résume pas uniquement à la fixation de son prix, mais doit aussi assurer la disponibilité de l'eau. À Chypre, l'approvisionnement en eau est basé sur les précipitations qui diminuent progressivement. Le prix de l'eau doit tenir compte de la couverture des coûts primaires pour son acquisition, du coût des réseaux de distribution, des frais de fonctionnement des pompes et de l'utilisation prévue de l'eau (pour l'agriculture, l'industrie, le tourisme, la consommation des ménages, etc.). Les ménages ont tous le droit d'avoir accès à l'eau de bonne qualité, à des prix relativement bas. L'eau utilisée pour les secteurs industriels et les autres activités économiques devrait être évaluée à son coût réel, majoré d'un « facteur de disponibilité » qui prend en compte les réserves d'eau disponibles dans le pays. Une bonne politique de l'eau doit promouvoir les questions concernant les économies de l'eau dans tous les secteurs d'activités et la lutte contre le gaspillage inutile de l'eau (à travers l'application de tarifications adéquates) ; elle doit veiller à minimiser les pertes du réseau de distribution de l'eau, à protéger la qualité des réserves d'eau (tout au long de la production, de la distribution, du stockage, du traitement de l'eau et de sa réutilisation). Toutes les ressources en eau dans un pays doivent être considérées comme des ressources nationales et doivent être contrôlées par une entité unique pour assurer une bonne coordination et une bonne gestion. L'article présente une méthode simplifiée pour le prix de l'eau, en cas de pénurie d'eau, souvent constatée dans les pays méditerranéens.*

Mots-clés. *Eau – Fixation des prix – Eau disponible.*

I – Introduction

In Cyprus, water supply is based on rainfall that is becoming less and less with time. In 2008, due to a prolonged draught, there was no water available for agriculture! Climate changes negatively affect the Mediterranean basin in terms of temperature increase and rainfall decrease. Water policy is no longer only concerned with water collection, purification, distribution, quality control and safeguarding, waste treatment and reuse and so on. Since the water balance in countries like Cyprus depends on rainfall, water policies have to deal with the resulting water scarcity that

leads to a water budget deficit of the national water reserves. Water policies have to provide good resource management so that the limited available water is properly distributed among the economic sectors of the country. Decisions have to take into account the priorities and the importance of each sector in the national economy.

Good water policies should incorporate issues such as:

- saving water in all sectors of economy and preventing irrational water use (through proper water pricing schemes, etc.);
- minimizing distribution network losses;
- safeguarding the quality of water reserves (during water production, distribution, storage, water treatment and reuse)
- protecting aquifers from pollution or sea water intrusion
- safeguarding uninterrupted water supply to the consumers by exploiting technological means in finding new water resources (desalination plants, etc.) and
- proper allocation of limited water resources to the different sectors (industry, agriculture, households, tourism, landscaping, etc.), in case of severe water shortage.

The “value” and importance of each sector is different from country to country according to its economical structure. The best situation, under these circumstances, would be that all water resources in a country are considered as a national resource and thus controlled by a single entity so that good coordination and management is achieved. In Cyprus, an effort is made to position water management under the authority of a “Commission for Integrated Water Management”, a part of the Water Development Department of the Ministry of Agriculture, Natural Resources and Environment of the Cyprus Republic.

For the design and implementation of a good water pricing policy, it is essential that certain statistical data are available regarding the water consuming habits of water users (Environment Canada, 2007; Organization for Economic Co-operation and Development, 1999; Tate and Lacelle, 1995). A good overview of all necessary data to be collected for water charging in irrigated agriculture, is given in the FAO Water Report 28, 2004. The existing European legislation, the Water Framework Directive (2000/60/EC), establishes a framework for sustainable water management and protection of the water resources. The prevention of further deterioration of all water resources and the achievement of a good water status in Europe by the end of 2015 is considered to be the main purpose of this Directive.

A simplified water balance model is shown in Figure 1. Rain and sea water are the primary water resources for Cyprus. Rain water is collected behind dams and contributes to the aquifer recharge, the provision of drinking water and to irrigation. Sea water is desalinated to produce drinking water. Its high cost does not allow its use in agriculture. Treated waste water is an emerging water source for irrigation purposes. In crisis situations, as was the case in Cyprus in 2008, water cut-offs have to be made, so that drinking water can be supplied to the consumers and the most important economic activities, such as tourism, are kept alive.

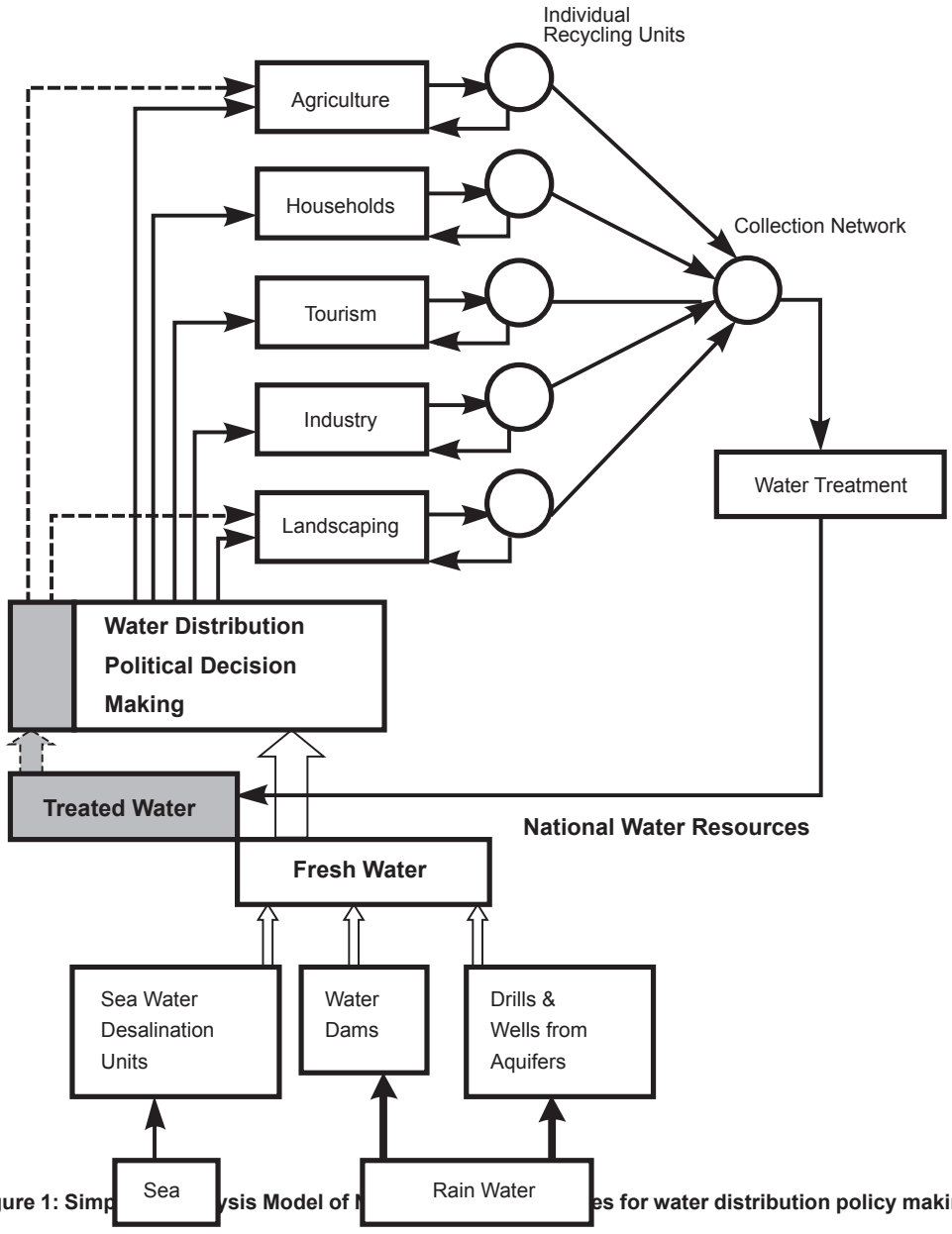

Figure 1: Simp ysis Model of N es for water distribution policy making.

A series of simulation models have been suggested worldwide, as useful policy making tools, trying to forecast the behavior of water consumers in relation to the water price levels and to evaluate the effect of different policies on water saving. Non-volumetric methods and a great

variety of volumetric charges and pricing methods based on tradable water rights could be applied (Cornish *et al.*, 2004) even among territories within a country itself (Markantonis *et al.*, 2004).

A simple dynamic model showing the influence of changing water prices within a year, according to the available water resources allocated to households, was examined in the present work.

II – Methods

1. Software tools used

In order to describe the behavior of the influence on water consumption of decreasing water reserves during the year, in combination with water pricing policy, a model was designed and applied using SIMULINK©, a control package of MATLAB©, version 7.6.0 (R2008a).

2. Model structure and design

The model simulates the behaviour of a model household that is assumed to follow a typical consumer behaviour, within a model of national action to adjust the price of water continuously according to the available water reserves. The water reserves are limited and decrease with time as water consumption proceeds.

3. Model parameters and boundary conditions

The model uses measured or simulated data. It considers a basic water consumption of 150 liters per person per day that is provided by the water supply authorities at a base price (€ 0.90/ m^3), covering all primary water costs. Consumption exceeding this amount is charged more to motivate the reduction of irrational water use. For the simulation, a population of 800,000 people was assumed and the initial available water reserves were assumed to be 90 million cubic meters.

An estimated daily water consumption per person without any price-related measures to limit consumption, other than those usually applied by water providing authorities (i.e. simple volumetric charges), C_{wn}, was considered to be as shown in Figure 2.

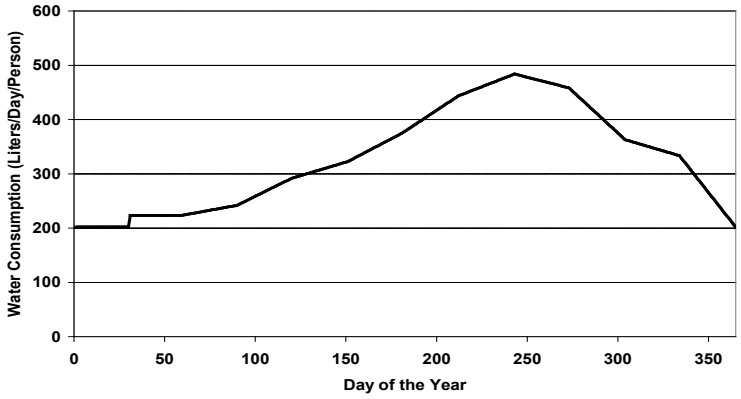

Figure 2: Estimated daily water consumption per person without any price-related measures limiting consumption, other than those usually applied by water providing authorities (i.e. simple volumetric charges).

The influence of water price, P_w, on water consumption, C_w, is shown by the Price Related Consumption Index, I_{pv}, shown in Figure 3, for the elastic case. The relation is given by the equation:

$$C_w = I_{pv} \times C_{wn} \quad (1)$$

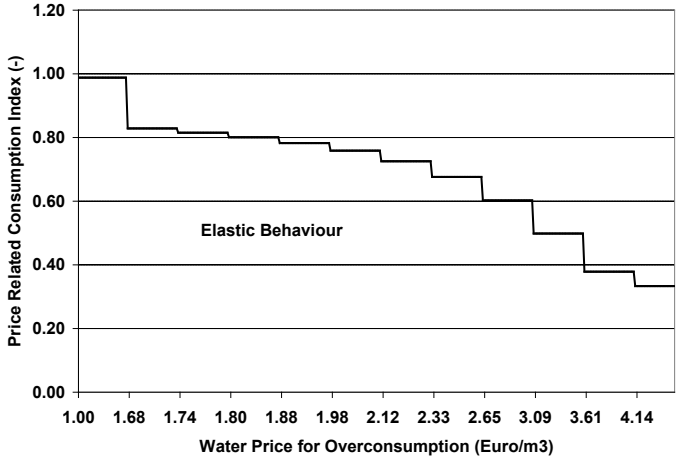

Figure 3: Estimated variation of Price Related Consumption Index according to the cost of water for the elastic case of influencing water consumption.

Water pricing should take into account the recovery of primary costs for the acquisition of water and the amortization of the whole system (e.g. desalination, filtering, purification, cost of the distribution network, running costs for pumps, etc.) and the intended use of the water (used for agricultural purposes, industry, tourism, households, etc.).

Households have a right to be supplied with water of good quality at reasonably low prices. Water used for industry and other economic activities should be priced at its real cost, increased by an "availability factor" that takes into account the available water reserves of the country. Water is in this case considered to be a primary material for the production of goods and the extra costs would be eventually transferred to the end product.

Water should be properly valued so that consumers avoid irrational use and make a conscious effort to save water. Water pricing policy may want to take into account certain social aspects, for instance the buying power of the people, the number of persons in the family, whether a household consists of pensioners. The water price should also take into account the water availability in the time period in question. The scarcer the water becomes, the more expensive it is, as an incentive to reduce consumption. The availability of water is changing with time within the year and is affected in a loop by the effectiveness of the water saving measures taken by the Water Authority.

The Water Availability Index is defined as $f_1 = A_w/(A_w - W_c)$ (2)

A_w, is the Available National Water Reserves at the beginning of the year (MCM),

W_c, is the cumulative Water Consumption during the year (MCM)

f_1, takes into account the availability of the water to be supplied to the households in the time period in question. The Available National Water Reserves at the beginning of the Year comprise of the water quantities stored behind the dams, allocated for drinking water, the water quantities pumped from wells and the desalinated water.

The effect of the number of people in the family N_p, on water price, is considered by the index

$f_2 = 1$ for household members $N_p < 5$ and $f_2 = -0.05xN_p+1$ for $N_p>5$ (3)

The social policy of most countries is to support large families so as to counter lowering birth rates. The function of f_2 for multi-person families can be adjusted by policy makers according to the family relief measures they want to apply. The measures should be such that social policies are promoted, but motivation for water saving remains.

The support of pensioners and low income families is given by the Household Status Index, f_3. The respective values given in Table 1, can be varied according to the aims of the policy makers.

Table 1: Variation of the Household status index, according to the household social situation.

Household status Index , f_3		
Pensioners	**Low Income**	**Normal**
0.5	0.2	1

In an attempt to reduce the inequality of water prices among the European countries, the purchasing power of the people is taken into account. This is done, by considering the National Per Capita Volume Index of the country, compared to the average European Index that is set to the value EU27=100 (Svennebye, 2008).

The Gross National Product Per Capita Index, f_4, is calculated as the ratio of the National Per Capita Volume Index of the country divided by the mean European value that is set to 100. The per capita volume index represents the real volume of Gross Domestic Product (GDP) in per capita terms. “Real volumes” means that the figures have been adjusted for price level differences across countries, using purchasing power parities. They are expressed in relation to the European Union average (EU27=100). When the per capita GDP index of a certain country is higher than 100, that signifies that the GDP per capita of that country is higher than that of the EU27 as a whole. Cyprus with a GDP per capita index of 91 (2007), stands about 10% below the average.

$$f_4 = \frac{\text{National Per Capita Volume Index}}{100}$$

It is evident from the above that the structure of the households, their income and social status should be known so as to adjust water pricing according to the individual conditions. This requires good cooperation among governmental departments that posses this information. These departments will, however, have to take into consideration the laws for the protection of personal data.

Regarding the consumption in households, a basic water volume should be allowed according to the number of persons in the family that is priced at a lower rate. In case that the water consumption exceeds this volume, a penalty price is to be charged for the extra consumption.

The calculated water price, P, in €/m^3 that the household consumer has to pay for the water consumption over the basic consumption, P_{wB}, of 150 liters/day/person is then calculated by the following equation:

$$P=P_{wB} \times (1 + f_1 \times f_2 \times f_3) \times f_4 \quad (5)$$

The basic water consumption is priced at 0.9 €/m^3.

III – Results and discussion

In order to take into account all the parameters involved, it is necessary to define some indices, as explained above, that quantify their influence. The process for the evaluation of the water price to household consumers, using the simple water pricing model, is explained by means of the following example:

The base water price (Euro/m^3), (production, distribution, running costs, etc.), is P_{wB}= 0.9.

The available national water reserves in the year (million cubic meters: MCM), A_w = 90 (53 MCM from desalination plants, 30 MCM from dams and 7 MCM from wells).

Yearly water requirements (in MCM), Y_w = 96 (Usual water consumption without the suggested corrective measures). This means that the available water, in the example, is less than the yearly required amount.

For this case the variation of the Water Availability Index, f_1, during the year, is shown in Figure 4. Index f_1 increases with time, as the available national water reserves are exhausted.

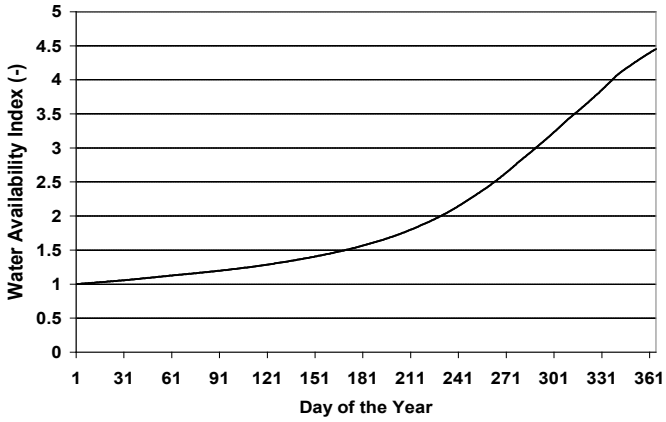

Figure 4: Variation of the Water Availability Index, f1, during the year.

The variation of the Water Price that a household with a normal income has to pay according to the number of persons in the family, for a National per Capita Volume Index of 91 units is shown for the above example in the Figure 5.

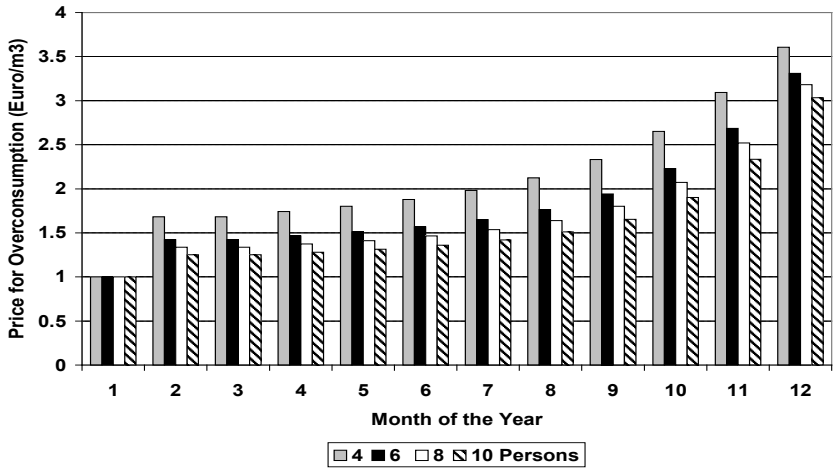

Figure 5: Variation of the water price a household with a normal income has to pay, according to the number of persons in the family, for a National per Capita Volume Index of 91 units.

The influence of the corrective measures, offered by the indices used, on water consumption in a household comprising of 4 persons and a normal income is shown in Figure 6, compared to the case that no measures are taken. Two consumer behaviour situations are compared: the elastic and inelastic relation between water consumption and water price. The consumption shown is the over consumption above the 150 litres per person per day that is considered as basic water consumption.

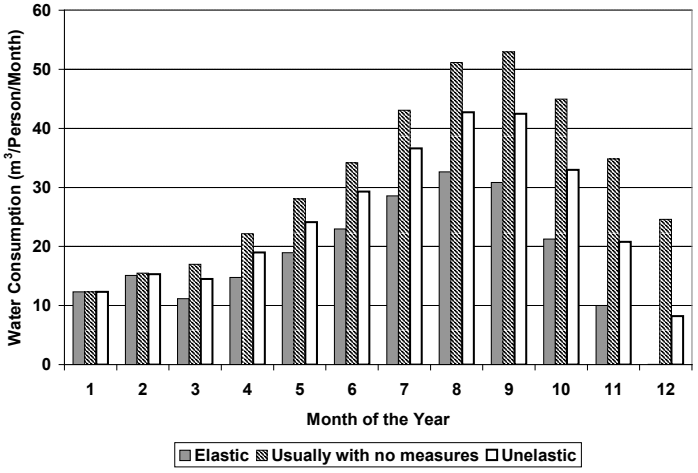

Figure 6: Variation of water consumption during the year, for a household with 4 persons and a normal income, for a National per Capita Volume Index of 91 units and an elastic and inelastic behaviour.

The variation of the price of the consumed water above base volume (over consumption), is shown in Figure 7 for the elastic and inelastic consumer behaviour. As the national water reserves are exhausted with time, the water price increases. The price charged in water bills is adjusted each month.

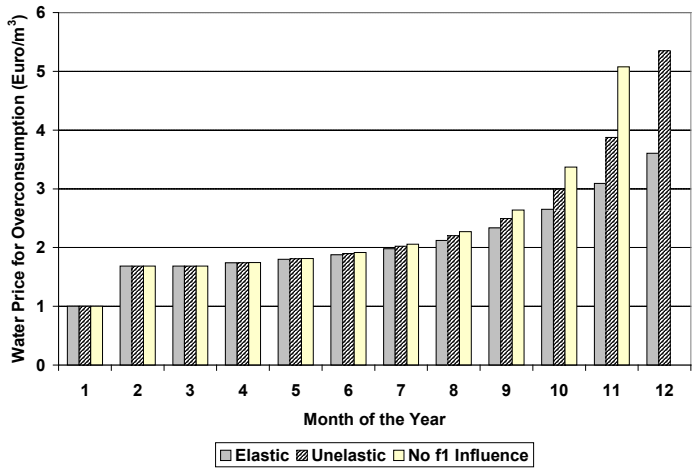

Figure 7: Variation of the price of the consumed water above base volume, for a 4 person-household with normal income, for the elastic and inelastic consumer behaviour, with time.

The cumulative estimated water consumption in households when pricing measures are applied, compared to the base consumption (150 liters/person/day) and the existing situation without the suggested measures, is shown in Figure 8. The objective of the pricing measures is to stimulate households to save water and adjust the consumption. In this way the national water resources, existing at the beginning of the year, satisfy the water demand up to the end of the year. This objective is fulfilled.

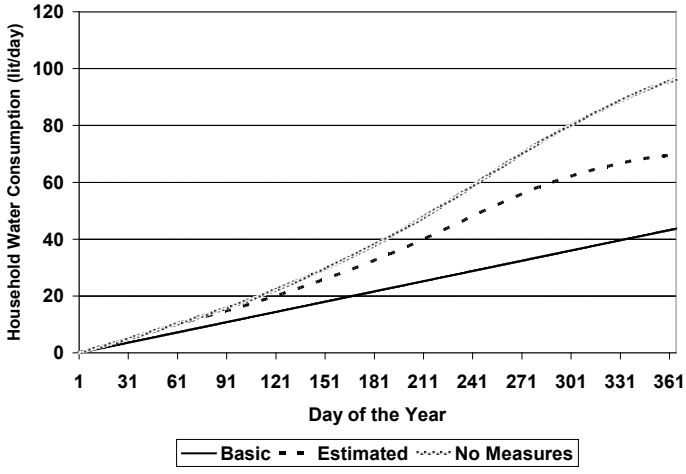

Figure 8: Different cumulative estimated water consumption patterns in households, the base consumption (based on 150 liters/person/day), the estimates based on the pricing model and the existing situation without the suggested measures, with time.

Similar considerations, with modified indices, could be followed for the pricing of the water supplied to industries or agriculture. In this case the local evapotranspiration, the crop type, the cultivated area, the farmer status (fulltime/ part-time), etc. should be taken into account.

IV – Conclusions

Water pricing is of huge importance for countries experiencing water shortage situations, since it represents a useful tool for water management policy to control consumption in crisis conditions. The modelling exercise demonstrates that water pricing can be a valuable policy instrument in stimulating households to reduce their water consumption.

Political, economic, social, environmental and other factors should be considered so as to match available water resources with demand and at the same time to keep economic activities going and minimize dissatisfaction by the public.

The water management authorities should keep records of the water demand and supply behaviour of the "market". Statistical data are very useful for long term planning of water policy. They give a measure of the elasticity of water demand to water pricing, so that better and more accurate models can be designed as a tool for handling water crisis situations. The data have to be regularly updated, since the situation in households and other water consumer groups (e.g. agriculture), changes year by year (i.e. number of persons in a household, income situation, cultivated land in agricultural units, crop type, etc.). The way consumers react to price changes is very important in policy making on water saving, i.e. elastic or inelastic behaviour. This could be influenced by educating and informing people adequately. This is a factor to be considered by the water providing authorities.

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