Final report

EU Water saving potential (Part 2 – Case Studies)

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1 Introduction

This document is the second part of the study on water saving potential in the EU. It contains four case studies from regions in four different European Member States which encounter increasing water stress. The case studies take the generic findings of the main synthesis report to more depth. The current and the projected situation in each river basin is first analyzed and possible measures to alleviate water deficit which were depicted in the synthesis report.

The **first case study** analyses the situation in the Guadalquivir river basin in southern Spain which focuses only on the analysis of water saving measures on irrigated agriculture. Guadalquivir is an example of an old and relatively well managed river basin that has reached the limit of sustainable water use. Any possibility to increase water supply is limited. The rising demand for irrigation water in this basin, coinciding with a series of dry years and reduced recharge, has increased the water deficit. As of 2006, the water deficit is estimated at 11% of the demand. The effect of technical, economic and social measures on water saving is therefore analysed in detail.

The **second case study** is that of the Ardèche river basin in France investigating costs and benefits of different measures and actions through qualitative and quantitative assessments for the five main water using sectors (household, tourism, agriculture, industry and energy). It explores potential savings versus maximal savings, temporal allocation, feasibility of measures (coherence, synergies, conflicts of interests, when available, the issues of wet and dry savings (savings that lead to effective environmental improvements), negative incentives that prevent from achieving this savings, water rights, etc), energy issues (cost benefits ratios of measures included in the Energy Action plan for energy savings and identify to what extent it can be extrapolated to the water sector), virtual Water in the context of water saving, role of the consumers in the context of water saving (water labelling, changes in consumption patterns), and values of environmental benefits (which value for additional water into the ecosystem -use and non-use values- avoided damages and investments).

Water scarcity is not only an issue in southern Europe. The **third case study** assesses water saving potential scenarios for South and South-East England (United-Kingdom). The South and Southeast of England are particularly cause for concern, with London rated as ‘very low’ by the World Resources Institute with regards to water resources. For the five sectors different water saving measures, including water labelling, metering and economic instruments are discussed.

The last and **forth case study** focuses on the Plastiras and Smokovo Reservoir in Greece. It discusses three different water saving scenarios based on hydrographical modelling and the related costs and benefits.

2 Guadalquivir river basin (Southern Spain)

This case study describes water use and water saving potential scenarios towards 2030 for irrigation sector in Guadalquivir river basin (Southern Spain).

2.1 Introduction

In the past 15 years, regions in the EU have faced drought events that are longer lasting, affect significantly more people and cause considerably more damage to the environment and the economy than in previous decades. Estimations of the overall economic impacts of droughts in the EU show that the annual average impact has doubled in the period of 1991-2006 compared to the prior 15 years[1]. Indeed, water scarcity, especially in the Mediterranean, is often caused by a lack of precipitation[2]. Water deficits occur as a result of a combination of factors, with overexploitation of water resources as a major contributor[3]. In Guadalquivir river basin in Southern Spain, as in most Mediterranean areas, water abstraction for irrigation purposes is the highest user among all uses. From the series of water balances since 1992[4], including the balance shown in the Drought Management Plan of this Basin[5], it can be observed that the pressures on water resources from the main consuming sectors (agriculture, industrial and urban/domestic) have not changed substantially. Water demand for industrial purposes represents 2% of total demand, for urban/domestic uses the demand reaches 13% of total demand and for agricultural use, mainly for irrigation, the level of demand grows up to 85%.

Nevertheless, establishing effective and efficient water saving measures for all consuming sectors is important; the repercussions of water saving measures on the irrigation sector will be greater on the whole basin management than saving measures applied to the urban or industrial sectors. Thus, applying saving measures that may reduce up to 10% of urban demand would mean 44 hm^3 (1.5% of current consumption) of savings on 2006 water balance (see **Table 1**). Similar reductions (up to 10%) on irrigation demand would provide water savings close to 290 hm^3 (more than six times the savings estimated for the urban sector and 8.5% of current consumption). Marginal water saving over current use in the urban sector has a much higher cost than similar savings in the irrigation sector. Taking into consideration the amount of water consumed and the marginal cost of savings, the following case study focuses only on the analysis of water saving measures on irrigated agriculture.

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1 European Environmental Agency (EEA) (2007): Climate change and water adaptation issues. EEA technical report no 2/2007.

2 Precipitation is the release of water from the atmosphere as rain, snow or hail.

3 Estrela, T.; Marcuello, C.; Dimas, M. (2000): Las aguas continentales en los países mediterráneos de la Unión Europea. Ed. Ministerio de Fomento y Ministerio de Medio Ambiente. Madrid.

4 Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (1995): Plan Hidrológico del Guadalquivir

5 Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

Gross added value (GVA) is estimated to be 6.5 times higher for irrigated than non-irrigated agriculture, and the net margin for irrigated agriculture in Spain is estimated to be on average 4.4 times higher than non-irrigated is[6]. Furthermore, the contribution one irrigated hectare has on employment in Guadalquivir is estimated to be 3.5 times higher than from one non-irrigated hectare[7]. Irrigated agriculture is thus a substantial wealth generator and is important for the region's rural based economy. However, in recent years it has become increasingly difficult to embark on new irrigation projects due to obstacles from the Basins Water Authority[8], water scarcity issues, and the lack of funds and support from international organisations and governments. The EU Water Framework Directive (WFD) (2000/60/EC of 23rd October), for example, has mandated that irrigated lands in southern Spain must subsist on a minimum level of economic assistance and obliges Member States to collect the full recovery cost of water supply from farmers[9].

Water resources are under huge pressures in most of the Mediterranean basins, and typically the overall water demand exceeds the amount of water resources available both for conventional and non-conventional water uses. In Guadalquivir, the exploitation of surface and ground water resources has reached its limit, and due to the current situation, almost none of the reservoirs can build up water supply. The basin is a typical inland basin though it does have a short shore line. Consequently, sea water desalination is not an alternative water supply option, as only a small increment of resources would be economically viable, insufficient to reduce water deficit in the basin. Hence, the only alternative for increasing water availability is to receive water from external basins.

As of 2006, the water deficit in the Guadalquivir river basin is estimated at 11% of the demand[10]. During the last decade, the irrigated surface are has grown significantly, thus leading to higher deficits. Therefore, efficiency measures should be tailored at improving actual water demand management rather than less productive efforts in increasing water availability.

2.2 Objectives

The objective of the case study of Guadalquivir river basin is, from an agricultural perspective, to focus on:

- Water allocation and water use in the Guadalquivir river basin; and

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6 Ministerio de Medio Ambiente (MIMAM) (2007): El Agua en la Economía Española: Situación y Perspectivas. Informe integrado del Análisis Económico de los Usos de Agua, Artículo 5 y Anejos II y III de la Directiva Marco de Agua. Madrid, January 2007: Ministry of the Environment.

7 Berbel, J; Gutiérrez, C. (2004): I Informe sobre la Sostenibilidad del Regadío. Edita Feragua.

8 Called Confederaciones Hidrográficas.

9 European Commission (2000): Pricing Policies for Enhancing the Sustainability of Water Resources. Communication from the Commission to the Council, the European Parliament, and the Economic and Social Committee (COM (2000) 477 final, European Commission, Brussels.

10 Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

- Cost and benefits of water saving measures in Guadalquivir basin.

2.3 Background

The Guadalquivir river basin in southern Spain has a surface of 57 527 Km^2 and a population more than 4.2 million people in 476 municipalities. The Hydrological Plan for Guadalquivir[11] outlines the general management of the basin and indicates that the average basin's renewable water resources (surface and groundwater) are more than 6 300 hm^3/year[12], while the gross consumption for 2002 was estimated at 3 583 hm^3/year. The basin is highly regulated, and supply is supplemented with reservoirs regulating 35% of natural superficial resources as well as the base flow and exploitation of aquifers reaching 49% of renewable water resources. The level of water abstracted is high (around 50% for a 'standard hydrological year') and rainfall fluctuates; therefore, the guarantee for accomplishing user's water allocation rights are low (Ibid). Agriculture is by far the biggest user of water (see 5.1), and the map below shows where the main irrigated areas are located (Figure 1).

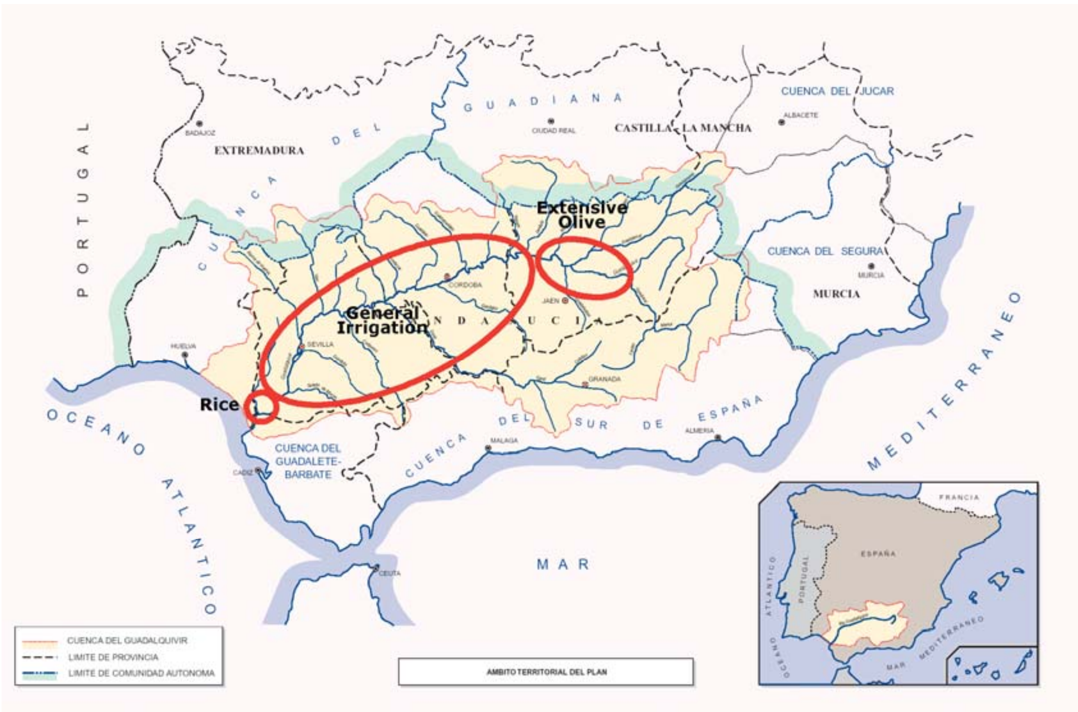

Figure 1: Schematic representation of irrigated areas in the Guadalquivir river basin. Source: Berbel and Gutierrez (2005) [13]

The Guadalquivir river basin has an estimated irrigated area of 715 000 ha[14], which represents 25.5% of the total cropped area. This irrigated-cropping area ratio is twice

[11] called Plan Hidrológico

[12] Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

[13] Berbel, J.; Gutierrez, C. (eds) (2005): Sustainability of European Agriculture under Water Framework Directive and Agenda 2000. European Commission, Brussels.

that for Spain as a whole (12.5%). The water sources used for irrigation are divided between surface water (80.9%), groundwater (18%) and wastewater (1.1%).

The main factors affecting the irrigation demand per surface unit are climate, soil, crop, and irrigation method. Hence, the main variable to obtain the aggregated irrigation demand at basin scale is the irrigated area. The increase in irrigated surface has been dramatic during the last century. Since 1900, the irrigated area in Guadalquivir has increased by 500%, from 142 900 ha in 1904 to 715 000 ha in 2004[15]. The increase has been particularly rapid in the last decade, around 60% from 1995 to 2004[16]. Due to this expansion, the demand for water has also increased considerably. As a consequence, there is now significant pressure on local water resources. The rising demand for irrigation water, coinciding with a series of dry years and reduced recharge, has undoubtedly increased this water deficit.

Irrigation water efficiency is another factor strongly related with agricultural water demand at basin scale. Due to concerns regarding long-term water scarcity, and in order to conserve available supplies, both water authorities and farmers have made great efforts to improve irrigation efficiency during the last few years. Today, some of the largest irrigation districts are still in the process of system modernisation. The old open channel networks are being replaced by 'on-demand' pressurised networks. The primary aim of these investments is to achieve more efficient conveyance and use of water. As a consequence, nearly half (45%) of the total irrigated area relies on micro (trickle) irrigation, which is now the most common application method in the basin. This tendency is in contrast to 15 years ago when surface irrigation was predominant (61%) whilst trickle (12%) was still regarded as a specialist technique. Consequently, the evolution of irrigation water demand per hectare since 1985 shows a strong tendency towards decreasing consumption. An in-depth analysis of a representative sample of 22 irrigation districts in Guadalquivir (30% of irrigated area) indicates that water consumption per unit of irrigated surface has decreased from an average of 7 000 m3/ha to 5 000 m^3/ha in 2004[17]. However, the continued rise in the area under irrigation has meant that the water assigned to each irrigation district has gradually been reduced in recent years, thus leading to an 'ad hoc' reassignment of resources, which will be discussed later.

Water scarcity in the river basin does, however, vary depending on the weather each year (Figure 2).

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[14] Aquavir (2005): Superficies de los cultivos de regadío y sus necesidades de riego, en la demarcación de la Confederación Hidrográfica del Guadalquivir. CHG. Spain.

[15] Camacho, E. (2005): Análisis de la eficiencia y el ahorro de agua en el regadío de la cuenca del Guadalquivir. Inversiones en la modernización de regadíos. FERAGUA. Spain.

[16] Parias, P. (2007): Perspectiva Del Regadio Andaluz Desde La Optica Del Regante Jornadas Sobre Recursos Hídricos De Andalucía: Evaluacion Y Uso Sostenible. Colegio Oficial De Ingenieros Agronomos De Andalucia. Sevilla, Enero.

[17] Camacho, E. (2005): Análisis de la eficiencia y el ahorro de agua en el regadío de la cuenca del Guadalquivir. Inversiones en la modernización de regadíos. FERAGUA. Spain.

The same study[18] shows that the average volume of water (m^3/ha) assigned by the authorities in these districts was severely reduced between 1992 and 1996 when Spain was in a protracted drought. Indeed, in 1995 farmers could not irrigate at all[19]. Furthermore, a new drought began in 2004 and is still affecting water allocation in the basin (e.g. Genil Cabra allocation for 2007 is 1 300m^3/ha, 30% of "normal allocation"[20]), and to cope with frequent scarcity periods, a drought management plan (DMP)[18] has been approved by Government this year.

Based on this, it can be interpreted that natural resources alone are not enough to satisfy the overall water demand every year, as they are not fully available for users. Figure 3 shows how only a fraction of natural resources are available for consumption[21]. Available sources are those stored in lakes and reservoirs and those extracted directly from wells, streams and rivers (dependent on climactic variability), minus several constraints imposed according to basin specific conditions, which are mainly related to environmental demand and safety storage in reservoirs.

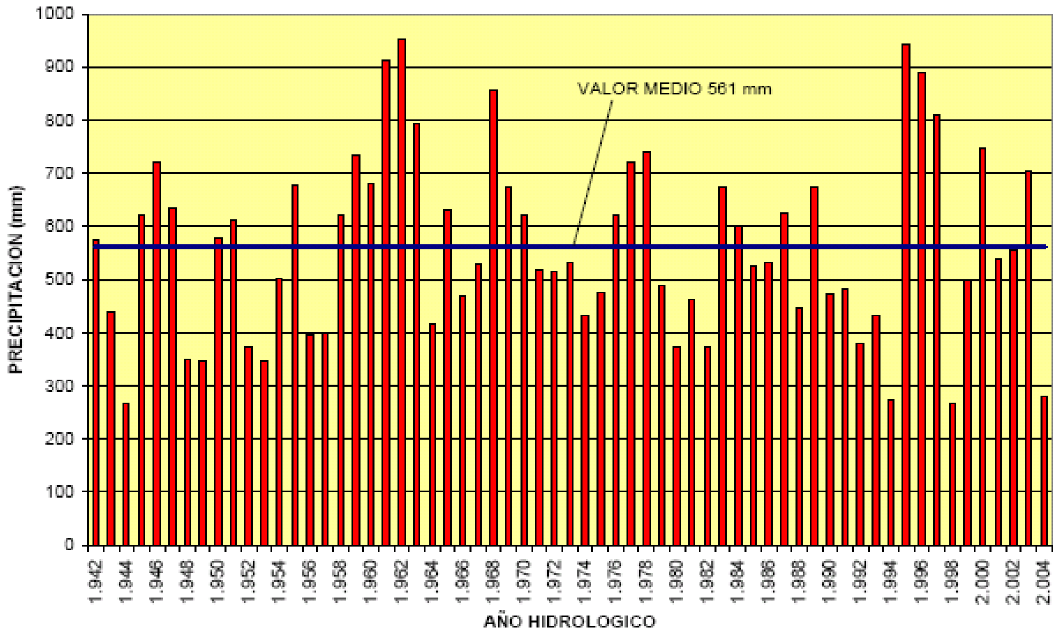

Figure 2: Average precipitations in Guadalquivir from 1942 to 2004[22].

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18 Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

19 Camacho, E. (2005): Análisis de la eficiencia y el ahorro de agua en el regadío de la cuenca del Guadalquivir. Inversiones en la modernización de regadíos. FERAGUA. Spain.

20 Personal communication from the Manager of the Genil Cabra Irrigation Community.

21 Ministerio de Medio Ambiente (MIMAM) (1998): Libro blanco del agua. Madrid.

22 Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

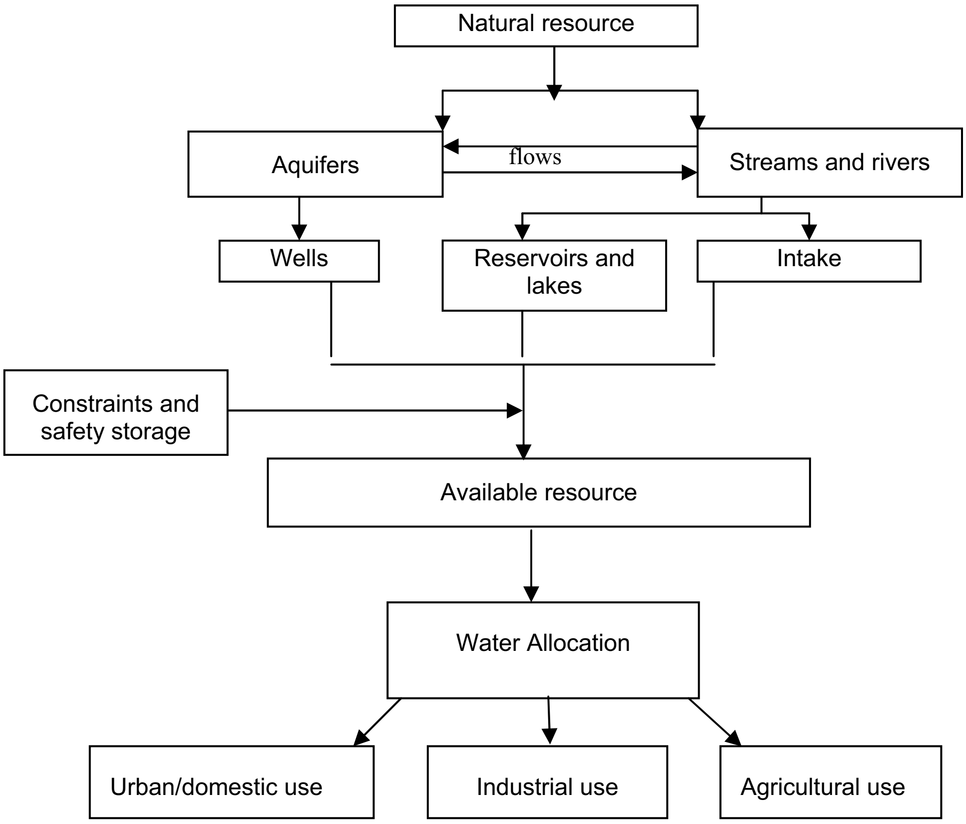

Figure 3: Conceptual flow diagram of the transformation from natural resource into available resources for use[23]

Using the previous flow diagram, for Guadalquivir, 6 300 hm3/year of natural water resources are transformed into 3 028 hm3/year available resources to be allocated among the users (urban, industries and agriculture).

Table 1 shows the average water balance for Guadalquivir river basin. The 3 028 hm^3 of available water are not enough to satisfy the net water allocation is estimated to a total of 3 105 hm^3/year, resulting in a negative administrative water balance. This table indicates that the total available water resources (previous to constraints consideration) in a standard year amounts to 3 287 hm^3, which comes from surface resources stored in reservoirs (2 321 hm3), underground sources (aquifers 621 hm^3), and the base flow near the river itself (345hm^3).

[23] Ministerio de Medio Ambiente (MIMAM) (1998): Libro blanco del agua. Madrid.

Table 1: Water balance in Guadalquivir[24]

Regulated resources (hm^3/year)			Mean allocated water (hm^3/year)		
Surface water	Groundwater	Base flow	Urban	Industrial	Irrigation
2 321	621	345	434	76	2 891
Total resources:		3 287	Total allocated water:		3 401
Constraints:		259	Returns		296
Total Resources – Constraints = Available resources (hm^3/year)		3 028	Total allocated water – Returns = Net water allocation (hm^3/year)		3 105
Administrative deficit = Available resources - Net water allocation = -77 hm^3/year					

When allocating water according to administrative rights (law) and by prioritised uses (domestic and urban uses come before agricultural uses followed by industry), it is observed that the mean overall allocated water is even higher than the average available resources, thus the basin is administratively "unbalanced". This difference is called 'Deficit hídrico' or water deficit. This deficit mainly affects irrigation water demand as for a standard hydrological year without allocation restrictions, its value reaches 3 857[25] hm^3, nearly 1 000 hm^3 more than the mean allocated water shown in **Table 1** above. The basin's water balance, shown in **Table 1**, is for an average year and leads us to think it is possible to increase the availability of water resources. It is assumed that the maximum resources available (potential) in a basin are its natural resources minus constraints and certain losses (it is technically impossible to transform all natural resources into available resources). Hence, the potential resources are estimated as 80% of average natural resources. The water exploitation index (WEI)[26] [27], for the Guadalquivir river basin, is the mean annual overall demand divided by the potential resources is, greater than 0.5. It means that in a standard year if the basin has reached it maximum capability of storage, the basin balance would be positive, but in a dry year the potential resources would be less and even smaller than the net demand. In this situation and frequently in Mediterranean basins, it is necessary to reduce user's water allocation according to their priorities.

According to the hydrological basin plan[28], there are almost no possibilities to build new reservoirs[29]. The current reservoir capacity is close to 6 900 hm^3, and the available

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[24] Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

[25] Aquavir (2005): Superficies de los cultivos de regadío y sus necesidades de riego, en la demarcación de la Confederación Hidrográfica del Guadalquivir. CHG. Spain.

[26] Ministerio de Medio Ambiente (MIMAM) (1998): Libro blanco del agua. Madrid.

[27] Estrela, T.; Marcuello, C.; Dimas, M. (2000): Las aguas continentales en los países mediterráneos de la Unión Europea. Ed. Ministerio de Fomento y Ministerio de Medio Ambiente. Madrid.

[28] Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (1995): Plan Hidrológico del Guadalquivir.

[29] Three new reservoirs are currently being built, and no more are planned in the near future

mean surface renewable natural resources are 6 300 hm^3 [24]. It is quite infrequent that reservoirs achieve full capacity. Furthermore, use of base flow and aquifers are close to the limit of overexploitation and there are no other possibilities for further abstraction. In conclusion, the potential for increasing available resources is quite limited. It should be realised that the limit for sustainable water resources exploitation has been reach, with scarce possibilities of building new reservoirs. The use of additional groundwater resources can only serve to compensate the water deficits in drought periods but not to be used for hypothetical permanent increases in water demand.

2.4 Allocation and use of water

This section examines the current and future allocation and use of water in Guadalquivir.

Table 2 indicates the current water consumption by use in the basin and shows that primary sector (mainly agriculture) consumes around 87% of all water abstracted from Guadalquivir in a "standard hydrological year", followed by domestic and municipal consumption (11%) and industry (2%).

Table 2:Estimation of water uses Guadalquivir (2005)[30]

Origin (hm^3)	Domestic	Irrigation	Industry	Total
Surface	326.26	2 700.35	67.67	3 094.28
Groundwater	96.60	584.74	7.76	689.10
Total hm^3	**422.86**	**3 285.09**	**75.43**	**3 783.38**
%	11.18	86.83	1.99	100.00

Agriculture generates 6% of Gross Value Added (GVA) and provides only approximately 11% of the basin's employment. At the same time, the agro-industry constitutes the most important industrial sub-sector, with 22% of industrial employment and 30% of the industrial GVA.

30 Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (1995): Plan Hidrológico del Guadalquivir.

Table 3 shows the share of GVA compared with water demand by sector in the basin.

Table 3: Gross Value Added and water Demand by sector in Guadalquivir[31]

Sector	**GVA**(10^6 Euro)	%	**Employment**10^3	%	**Water consumption** hm^3	%
Agriculture	3 693 106	6%	190	11%	3 414(*)	86%
Industry	8 059 714	13%	207	12%	98	2%
Tourism	7 288 138	12%	200	12%	22	1%
Other sectors incl. domestic consumption	41 191 591	68%	1 121	65%	415	11%
TOTAL	**60 232 549**	**100%**	**1 718**	**100%**	**3 901**	**100%**

(*) This estimation is based upon municipal water demand and may differ from the Basin estimate in Table 1.

The total industrial activity in 2002 for Guadalquivir Basin amounted to 6 876 millions Euro (15% of basin GVA), with 177 000 employed and a consumption of 86 hm^3 (2%). For 2015, the estimated industrial demand is 111.5 hm^3 (3% of overall consumption and increasing by 30% with regard to 2002).

Pressure put on water resources by irrigation is subject to two drivers working in opposite directions. On one hand, the irrigated area has increased constantly around 1% yearly for the last decade mainly due to the use of ground water and the focus on olive tree cultivation. Olive trees are now the most cultivated crop, both for irrigated as well as for non-irrigated land in the Guadalquivir, and represent around 45% of area in both systems. Table 4 illustrates the extent of irrigated crops.

[31] Ministerio de Medio Ambiente (MIMAM); Confederación Hidrográfica del Guadalquivir (CHG) (2005): Art 5 Report Guadalquivir River

Table 4: Area, average allocated water for the main irrigated crops in the Guadalquivir river basin[32].

Crop	Area (ha)	Area %	Average allocated water (m^3/ha)	Water %
Alfalfa	6 588	0.9	5 907	1.8
Cotton	74 499	10.4	6 049	16.6
Almond tree	5 752	0.8	4 946	0.5
Rice	36 078	5.1	14 000	12.3
Winter cereals	55 851	7.8	1 500	5.8
Citruses	20 039	2.8	5 501	2.5
Winter fodder	4 991	0.7	1 500	0.5
Strawberry	2 285	0.3	4 315	0.3
Fruit trees	21 993	3.1	5 386	2.2
Sunflower	18 034	2.5	1 500	2.3
Vegetables	44 519	6.2	6 196	6.9
Legume Grain	14 172	2.0	1 500	0.8
Maize	44 975	6.3	6 621	10.3
Olive tree	322 257	45.1	2 282	30.6
Potato main season	6 664	0.9	6 342	1.5
Early potato	11 165	1.6	5 142	0.8
Sugar beat	20 036	2.8	3 730	3.5
Tobacco	4 117	0.6	6 875	0.8
TOTAL	**714 015**	**100.0**		**100.0**

It can be observed that the six main crops represent 81% of irrigated area and 82% of water demand, with olive tree representing 45% of area and 31% of water demand. Cotton is 10% of area and 17% in water demand; rice 5% of area and 12% of water demand; maize 6% of area and 10% of water demand; vegetables 6% of area and 7% of water demand; and winter cereals (mainly wheat) 8% of area with 6% of water demand.

On the other hand, the current policy in the basin is to improve farm irrigation systems, (changing to trickle irrigation) and also improve the distribution system level (pressurized networks). The problem is that some farms have used the improved irrigation systems to change to more water intensive crops (horticulture, fruit trees) and

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32 Based on data from Aquavir (2005): Superficies de los cultivos de regadío y sus necesidades de riego, en la demarcación de la Confederación Hidrográfica del Guadalquivir. CHG. Spain.

therefore the achieved water savings by improvement is countered by the expansion of irrigated area and switch to more water demanding crops (orchards). This observation is based on the experience of University of Cordoba with the recently 'improved' irrigation districts, where an important number of farms have planted new crops, such as citrus (mainly orange), that are irrigated all the year around and on average have a greater demand for water than the crops they replaced.

Each farmer receives an amount of water assigned by the water authority as a 'water right' or concession. Water concessions are usually assigned for a 'standard year' at 6 000 m^3/ha; however, in the Guadalquivir they rarely receive the full right and are often allowed to use only a much smaller allocation. It should be noted that 6 000 m^3/ha is an average from the different administrative allocations that varies according to both area and crops (e.g. rice receives around 12 000 m^3/ha meanwhile some olive cultivation areas receive 2 500 m^3/ha). Figure 4 illustrates how the evolution of allocated water for irrigation has evolved during the last 20 years on the basis of data from a standard hydrologic year.

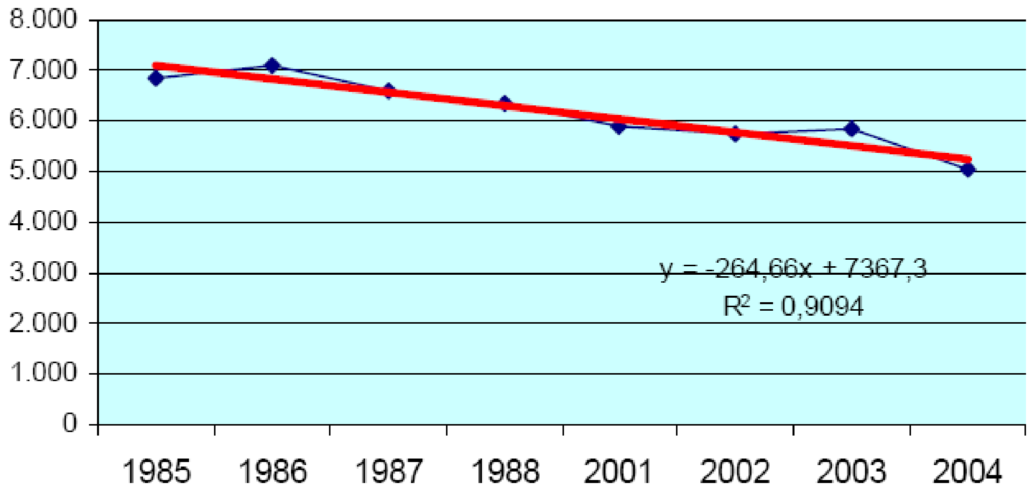

Figure 4: Average actual water allocated (m^3/ha) in representative irrigation districts in Guadalquivir[33])

The Response of farmers to reduction in right based allocation has been to change crop plans and irrigation systems.

The water use tendency scenario for 2015 has been estimated at 3 788 hm^3 (52.4% of renewable resources). If this tendency continues, we should expect water use in the basin to reach 4 044 hm^3 (55%) by year 2030 (no-change scenario). Table 5 summarises scenarios for 2002 and 2015, as reported in Art 5 report[34], and the scenario for 2030 is based upon our calculations assuming that the tendencies of 2002 to 2015 will continue with a similar growth rate.

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[33] Based on: Camacho, E. (2005): Análisis de la eficiencia y el ahorro de agua en el regadío de la cuenca del Guadalquivir. Inversiones en la modernización de regadíos. FERAGUA. Spain.

[34] Ministerio de Medio Ambiente (MIMAM) (2005): Confederación Hidrográfica del Guadalquivir: Informe arts. 5 y 6 DMA. Available online at: www.chguadalquivir.es.

Table 5: Possible future scenarios in water consumption in Guadalquivir[35]

Water uses (hm^3)	*2002	*2015	**2030
Agriculture[1]	3 143	3 213	3 284
Domestic	345	444	571
Industry and Tourism	95	132	189
Total uses	3 583	3 788	4 044
% over Renewable[2]	51%	54%	58%

[1]*Figure for agriculture and livestock are from 2001)*

[2]*Estimated in 7 000hm*^{3}

For the 2030 scenario, changes in crop pattern or improved crop varieties, changes in average water demand for irrigation, or the most critical point were no further increases in irrigated area takes place have not been considered. Changes due to Common Agriculture Policy (CAP) decoupled payments, as a policy measure, should also be studied, but this is outside the scope of this case study. Also, increases in industry and domestic use are projection based on the 2002 to 2015 increase (taking into account population growth and industrial projections by OECD/Spanish Government forecasts).

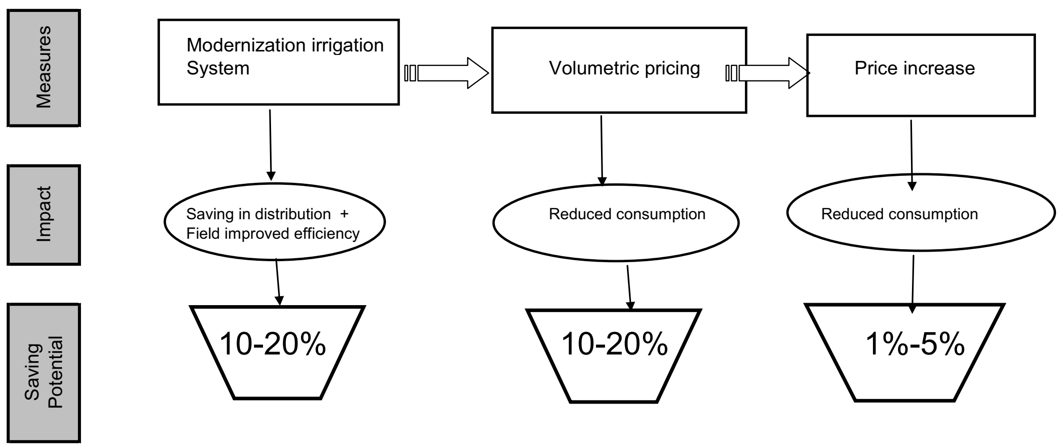

Figure 5: Measures, impacts and saving potential for Guadalquivir[36]

2.5 Water saving measure scenarios

In this section, we will focus on the following measures:

i) Water pricing with and without metering

ii) The drought management plan for Guadalquivir

iii) Temporarily re-allocation

[35] Ministerio de Medio Ambiente (MIMAM), Confederación Hidrográfica del Guadalquivir (CHG) (2005): Art 5 Report Guadalquivir River and Estimations by University of Cordoba.

[36] Estimations by University of Cordoba.

2.5.1 Water pricing and volumetric billing

There is a wide range of water pricing schemes in Europe. Most of these cases are a flat on-area basis tariff, but there are also some examples of binomial tariff (i.e. a fixed component covering ‘fixed cost’ of the system and a variable part of the tariff depending on actual consumption).

Figure 5 illustrates the relationship between technical and economic measures. We assume that an increase in the price of water should be implemented by a volumetric system of payment and never by a flat-rate on-area-basis system.

The first saving measure, modernisation of irrigation systems, consists of:

- Changing open channels for pressurised networks.
- On farm substitution of surface irrigation (furrow, etc.) for more efficient systems, such as trickle and sprinkler
- Normally in this transformation water metering devices are always included.

Table 6 shows the present level of adoption of improved distribution network and field system change. Subsidies as incentives (around 50% of distribution network total investment, and no subsidies for field irrigation system) have been given by different government agencies, such as central and regional government, and others institutions. The level of adoption has been satisfactory.

Figure 6 illustrates the investment in irrigation system improvements by public (pública) and private (privada) investments.

The Spanish National Irrigation Plan for 2008 predicts an improvement of 200 000 irrigated hectares for Guadalquivir (2008); however, this target has been reached already, and the allocated budget for this activity has been spent. The estimation of the irrigated area (2005) still needs to be improved. The basis for efficiency estimations both in the current year and 2030 are found in Table 6.

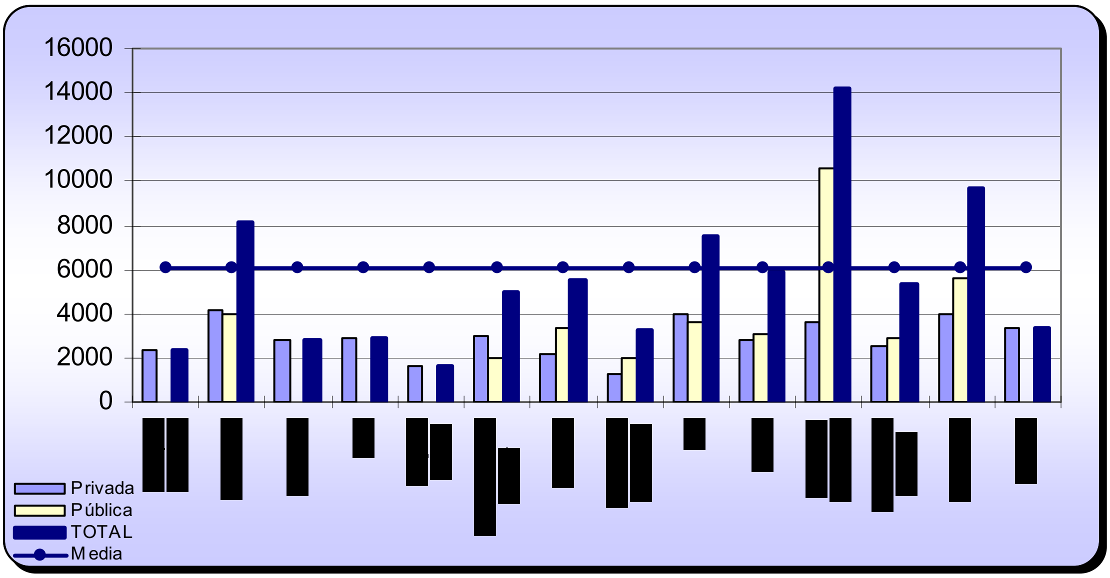

Figure 6: Investments in irrigation system improvements (in Euro)[37]

As we can see average investment was 6 000 Euro/ha at the time the figure was done (data accumulated to 2002) as priority was given to older and larger systems. Nevertheless, the figure to be used for this analysis will be reduced to 5 000 Euro/ha as an estimation of average for the global basin in the coming years.

Table 6: Current and future scenarios for efficiency[38]

Concept	2005		2030	
Irrigated area total	715 000	ha	715 000	ha
Irrigated by open channel	357 500	ha	357 500	ha
Efficiency distribution	**Efficiency**	**% Area**	**Efficiency**	**% Area**
Open channel main network	70%	50%	70%	5%
Pressurized	90%	32%	90%	77%
Underground	100%	18%	100%	18%
Average distribution efficiency	82%	100%	90%	100%
Efficiency field	**Efficiency**	**% Area**	**Efficiency**	**% Area**
Surface irrigation	55%	39%	55%	5%
Sprinkler	75%	18%	75%	18%
Drip	90%	43%	90%	77%
Average field efficiency	**74%**	**100%**	**86%**	**100%**

37 Berbel, J.; Gutierrez, C. (eds) (2005): Sustainability of European Agriculture under Water Framework Directive and Agenda 2000. European Commission, Brussels.

38 Estimated by University of Cordoba.

The current situation (2005) is that around 50% of Guadalquivir's irrigated area still needs to improve the main distribution network, and we assume that all networks will be pressurised by 2030. Regarding irrigation at the farm level, the current 39% of the open channels (furrow, etc.) will be reduced to only 5%, if we consider that rice will remain as a 'environmental buffer' around Doñana National Park and as a salinity buffer against marine intrusion into the river.

Figure 7 illustrates the impact of technical measures. Once the saving potential for pure-technical measures is exhausted, volumetric billing at current level of cost recovery (which is considered to be 90% of abstraction charges according WFD Art 5 reports) is considered the first step in the implementing water pricing. The illustration shows a comparison between the actual situation and a possible no-change scenario for 2030 in Guadalquivir river basin. The hypothesis is that irrigated surface and the average water assignation are maintained at the same level as of today. Therefore, all water saving is due to improved irrigation field system and distribution efficiencies. The difference between wet and dry saving are the return flows, which are considered not to exist in 2030 because of the absence of water losses related to lower efficiencies. Wet savings can only be achieved if the saved water is not used by any other sector, an example is the market for water created with savings by improvement of irrigation systems, which are sold to urban users or other higher value agricultural producers.

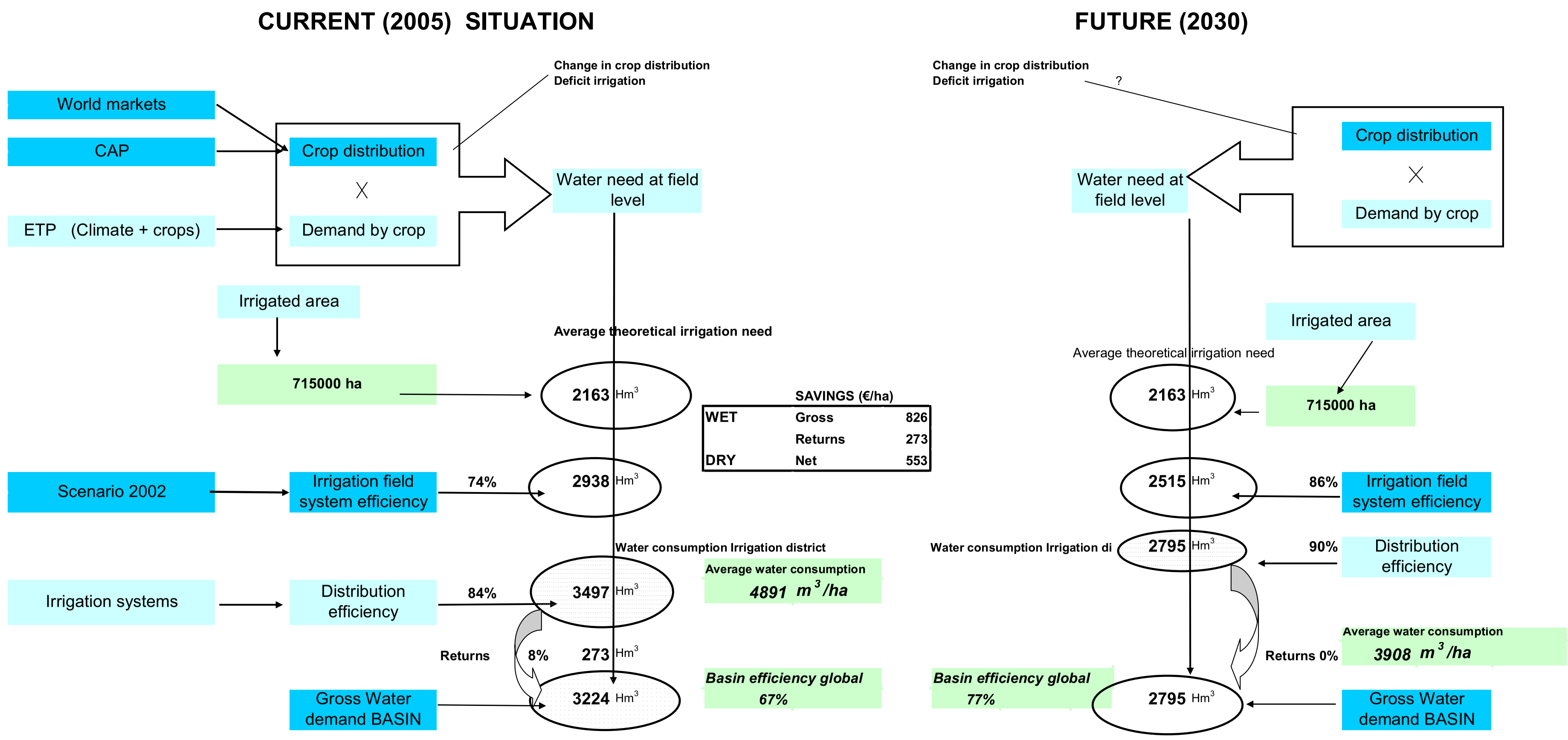

Figure 7: Technical 'Wet' and 'dry' savings for a 2030 scenario keeping irrigated land surface and average volume 'status quo

As mentioned above, the water saving in Figure 7 does not include volumetric billing, as it is only considering technical improvements. Estimation of water saving potential of volumetric billing is based on previous analysis[39], and the analysis supports the hypothesis that districts in which users pay for water a flat-rate, on-area-basis (i.e. per unit of irrigated area) are usually the largest consumers of water per hectare (Figure 8). In contrast, in districts with a pressurised irrigation network, where revenues are partly collected per cubic metre consumed measured with metering devices, consumption is significantly lower.

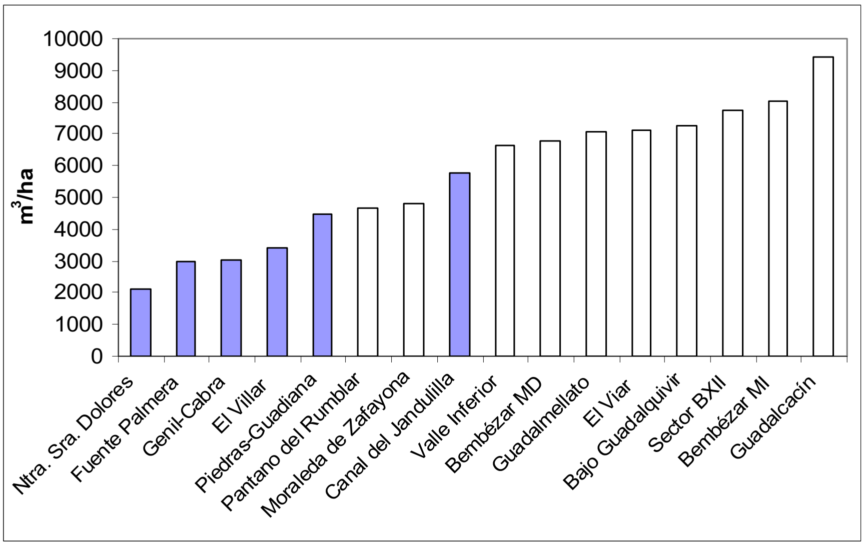

Figure 8: Annual irrigation water supply per unit irrigated area (Districts charging per unit of water are shaded)[40].

Hence, in the case of Guadalquivir, metering implies lower consumption and consequently improvement in surface water quality due to both smaller abstraction from the sources and smaller returns. Based on observations in Guadalquivir, it is reasonable to assume that 20%[41] of the water consumed can be reduced by introduction of volumetric billing. Hence, water pollution is also reduced and the environment directly benefits from this measure.

[39] Rodríguez Díaz, J.A. (2004): Estudio de la gestión del agua de riego y aplicación de las técnicas de benchmarking a las zonas regables de Andalucía. PhD Thesis. University of Córdoba. Spain.

[40] Rodríguez Díaz, J.A. (2004): Estudio de la gestión del agua de riego y aplicación de las técnicas de benchmarking a las zonas regables de Andalucía. PhD Thesis. University of Córdoba. Spain

[41] Rodríguez Díaz, J.A. (2004): Estudio de la gestión del agua de riego y aplicación de las técnicas de benchmarking a las zonas regables de Andalucía. PhD Thesis. University of Córdoba. Spain.

Once volumetric billing is implemented at present levels of cost recovery, the next step is to increase water price for full cost recover. Table 7 shows the percentage for water cost recovery for Spain on average[42]:

Table 7: Average Cost Recovery for Spain[34]

% Cost recovery	Abstraction and transport (surface)	Ground water	Urban uses	Irrigation
Spanish average	50-99%	99%	57-96%	85-98%
Guadalquivir basin (*)	90.45%	100%	n/a	100%

(*) Guadalquivir irrigation water is 80% surface, 20% groundwater.

The third and final step in the implementation of water pricing is the full cost recovery including environmental and resource costs. A rate of 35 Euro/year per household is used, according to estimates of the costs[43], which in the case of Guadalquivir (4.2 million inhabitants) will imply around 0.010 Euro/m^{3,} a very provisional estimates subject to further revision and to be paid by all uses (domestic, industrial, agriculture).

For agriculture, if full cost recovery at "abstraction charge" is applied, which implies going from 90.45% to 100% in the “canon del agua”[44], a increase in the canon of 0.0012 Euro/m^3 is assumed. A combination of both full financial cost recovery plus the above estimates of environmental and resource cost at ‘abstraction level’ will accumulate to an additional 0.012 Euro/m^3 over present level, which in combination to previous increase is an increase close to 100% over present levels of ‘canon del agua’ (according to cost recovery report of MIMAM (2007)[45]).

To analyse the impact in the water demand, the demand curve for Guadalquivir is used, where only ‘short term’ adaptation is considered. In this case, given the low elasticity for water demand, the impact is translated only to farmers by increasing cost and reducing

[42] Ministerio de Medio Ambiente (MIMAM) (2007): El Agua en la Economía Española: Situación y Perspectivas. Informe integrado del Análisis Económico de los Usos de Agua, Artículo 5 y Anejos II y III de la Directiva Marco de Agua. Madrid, January 2007: Ministry of the Environment.

[43] Two documents were reviewed to obtain the information: Martín-Ortega, J.; Berbel, J.; Brouwer, R. (2007): Beneficios y costes ambientales del uso del agua Una estimación en aplicación de la Directiva Marco del Agua al Guadalquivir. Working paper. European Commission - VITO (2007): Cost Benefit Analysis on the implementation of the Water Framework Directive including a specific focus on agriculture: Final Report. Draft 2 April 2007. The review in both documents show a wide range of estimations, we select 30Euro/person as a provisional estimation of WTP for an increase of water quality from present situation to desired level.

[44] Canon del agua is the name for Water Authority Costs in Spain, it comprises infrastructure depretiation (at historical cost), plus O&M cost. This is a general tariff paid by all users (urban and agriculture), and additionally the Basin Authority also uses an additional tariff for some single users when some infrastructure are not for global but for devoted use (e.g. an irrigation scheme).

[45] Ministerio de Medio Ambiente (MIMAM) (2007): Precios y Costes de los servicios de agua en España. Informe integrado Art 5 y Anexo III DMA. Madrid..

profitability. In the long term, there is also the possibility for shifts towards fruit trees where water productivity is higher, but the impact on water demand is not clear, since the impact of consumption is unpredictable even if the irrigated area is kept unchanged.

Figure 9 illustrates three irrigation water demand curves including other European basins for comparison.

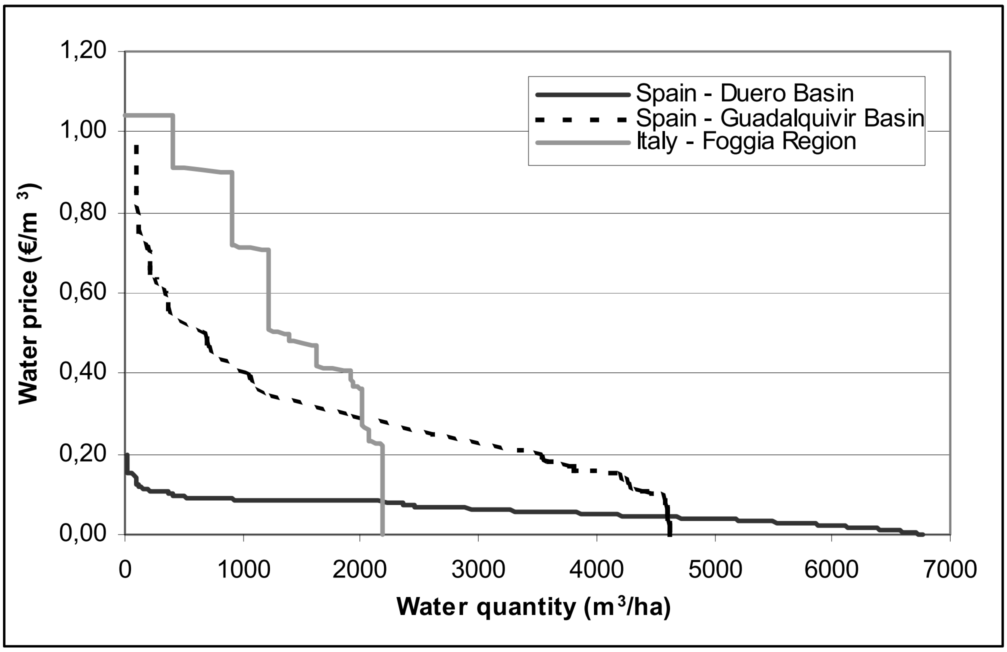

Figure 9: Demand curve for irrigation in Guadalquivir, Duero and Foggia.

The physical and economic environment are quite different in the three basins: Duero is extensively based on sugar beet and cereals; Foggia is based on fruits for Italy and export; and Guadalquivir is an intermediate case. Nevertheless, before an efficient water pricing mechanism, a technical investment is needed in order to make volumetric measure of water used by farmers possible. Thus, volumetric billing requires installation of proper water metering devices at every hydrant taking continuous measures of water consumption at every farm by enabling an automatic data collection process. However, this is not technically feasible in old open channels networks (Table 8).

[46] Berbel, J.; Gutierrez, C. (eds) (2005): Sustainability of European Agriculture under Water Framework Directive and Agenda 2000. European Commission, Brussels.

Table 8: Water saving potential of technical and institutional measures[47]

	Measure	Current situation	% Saving
Technical	Main network improvement	3 224	13%
Technical	Field irrigation system improvement		
Economic	Change to volumetric billing (*over 2 732 hm^3)	3 224	20%
Economic	Increase 100% of abstraction charges (i.e. 0.012 Euro/m^3) (**)	3 224	5%
Social	Advisory services	3 224	1%
	Total cumulative		**35%**

(*) This is only possible if technical measures are performed previously.

(**) current abstraction charges are 0.012 Euro/m3, we suppose a 100% increase by Water Authority

The detailed assumption for cost analysis is shown in Table 9. It is important to note that volumetric billing by itself compared to area payments implies a significant reduction of water demand, as this basin has the potential to recover an estimated 90% of financial costs for irrigation at 'abstraction level' and almost full recovery for distribution and field level irrigation costs. Once this phase (volumetric billing) is implemented, an additional price increase implies a minor reduction on water demand (estimated to 5%). However, it is assumed that water pricing is only effective if it is applied by a volumetric system.

Table 9 also presents the benefits of the proposed measures, namely the improvement of stream and rivers water quality due to the reduction of abstraction and polluted returns; and the volume of water saved may be kept in reservoirs and aquifers as safety stock to minimise the negative effect of drought periods that are fairly frequent in this area[48].

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[47] Source: University of Cordoba.

[48] Rodríguez Díaz, J.A. (2004): Estudio de la gestión del agua de riego y aplicación de las técnicas de benchmarking a las zonas regables de Andalucía. PhD Thesis. University of Córdoba. Spain.

Table 9: Water saving for irrigation Cost-benefit[49].

Measure	Marginal cost Euro x 10^6	Benefit = Net saving hm^3 per year	Basis for calculation	Equivalent Cost/m^3 per year	Source
Main network improvement	investment 1 875 Euro = 133,04 Euro/year	429	375 000 ha x 5 000 Euro/ha	0.31	Berbel and Gutiérrez, (2004)[50]; Camacho (2005)[51]
Field irrigation system improvement	investment 834 Euro = 29.17 Euro/year		278 000 ha x 3 000 Euro/ha	0.14	Berbel and Gutiérrez, (2004); Camacho (2005)
Change to volumetric billing (administration 3 Euro/ha)	2	559	Administrative cost estimated in 0.001 Euro/m^3	0.00	Camacho (2005)
PARTIAL: Cumulative technical + volumetric billing	164	988	(weighted average basic measures)	0.17	
Increasing water price (+0.012 Euro/m^3 increase Water Agency abstraction charge[1])	33	136	Farmers payment to Water Agency. Saving 5% x 2712hm^3	0.24	Berbel and Gutiérrez, (2004). Cost net saving is (2576 hm^3*0.012 Euro/m^3 /136 hm^3)
Advisory services 6 Euro/ha x715000 ha	4	27	Estimated per year	0.15	
Total cumulative saving measures	199	1 052	(weighted average)	0.17	

(*) This is only possible if technical measures are performed previously

Regarding cost for the measures implemented, those are considered the cost of investment, except in the case of volumetric billing, which is only a small administrative cost. For full cost recovery pricing, the payment by farmers for consumption after technical measures are implemented (i.e. 0.012 Euro/m^3 x 2.732 hm^3) is considered.

A negative effect of modernisation for farmers is the increase in management costs, as they are higher in pressurised networks due to energy costs in pumping stations,

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[49] Source: University of Cordoba.

[50] Berbel, J; Gutiérrez, C. (2004): I Informe sobre la Sostenibilidad del Regadío. Edita Feragua.

[51] Camacho, E. (2005): Análisis de la eficiencia y el ahorro de agua en el regadío de la cuenca del Guadalquivir. Inversiones en la modernización de regadíos. FERAGUA. Spain.

amortisation of equipments and maintenance. For example, in irrigation districts with pressurised networks, farmers devote an average of 10.5% of their gross income to satisfy water costs, while in traditional areas with open channels networks this ratio drops to approximately 4%.

2.5.2 Drought management plan for Guadalquivir

The objective of the Drought Management Plan of Guadalquivir is to minimise the environmental, economic and social impacts of incidental drought situations. Up to now water resources management was based on the Basin Hydrological Plan (BHP)[52]. This document stated the concept of supply warranty for each user according to its priority. Supply warranty is defined as the probability of demand to be satisfied and it is not accomplished when full water rights are not fulfilled. This is a key concept in water resources systems exploitation. Particularly, the BHP considers that the irrigation demand is satisfied if the supplied water varies from 100% down to 75% of the full water right.

The BHP recommendations to assure irrigation demand are:

- Maximum annual deficit between 20-40% of full water rights
- Maximum two years aggregated deficit between 30-60% of full water rights
- Maximum ten years aggregated deficit between 40-80% of full water rights

As the concern of frequent droughts in Mediterranean areas is increasing, a new management tool has been developed: the Drought Management Plan for the Guadalquivir river basin[53]. The DMP considers that the basin is in hydrological drought conditions when the whole water rights cannot be satisfied according the supply warranty consigned in the BHP.

Using various indicators related to availability and quality of water resources (reservoir storage, river flows, groundwater levels, rainfall and water quality), the DMP establishes several management rules to minimise drought impact on the basin. The most important indicator is the water volume stored in the reservoirs as surface water, which is the main source of supply in Guadalquivir.

According to the values of the previous indicators, several alert thresholds are established per each resources management unit in the basin. For reservoirs assigned for both urban and irrigation supply the thresholds are:

- Pre-alert: urban supply for 3 years and 3 irrigation seasons (1 year with full water rights and 2 consecutive years with 80%) are not assured.

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[52] Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (1995): Plan Hidrológico del Guadalquivir.

[53] Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

- Alert: urban supply for 2 consecutive years and 2 consecutive irrigation seasons (80% of nominal full water right) are not assured.
- Emergency: resources for urban supply only assure 1 year and next irrigation season (at 60% of nominal full water right) are not assured.

Table 10 shows the management rules when the different thresholds are reached.

Table 10: Percentage of reduction of full water rights[54]

Threshold	Use	
	Urban/Industrial	Irrigation
Prealert	1.5	5
Alert	5	30
Emergency	10	70
Strategic reserves		100

The DMP represents a strong movement towards the decrease of irrigation demand to increase guarantees for household and industries. As has been seen, the irrigation supply guarantee has in some irrigation districts never been fully satisfied. As a result, negative economic effects on agricultural production can be expected. In Table 11 below, the economic impacts on crops production due to reduction on water available for irrigation are evaluated.

[54] Confederación Hidrográfica del Guadalquivir (CHG); Ministerio de Medio Ambiente (MIMAM) (2006): Plan Especial Sequia. Draft.

Table 11: Predicted impacts of Drought Management Plan's actions on crops production[55]

DMP - Actions	Supply as % of irrigation need	Degree of influence on crops	Reductions in gross value of production									
			Olive tree		Citrus		Cotton		Corn		Sunflowers	
			Euro/ha	%	Euro/ha	%	Euro/ha	%	Euro/ha	%	Euro/ha	%
Prealert	95	Low	11.56	0	109.25	3	77.90	2	41.52	4	10.97	2
	80		46.88	2	441.82	11	327.90	10	174.01	15	47.18	8
Alert	70	Médium	70.73	3	665.92	17	498.47	16	264.39	23	72.00	12
	60		94.82	4	891.86	22	672.03	21	356.37	31	97.37	16
Emer-gency	30	High	156.74	6	1464.35	37	1 117.68	36	593.71	52	163.05	27
Strategic services	0	Very high	244.39	10	2 284.40	57	1 757.77	56	935.76	81	258.16	43
Percentage of total irrigated surface			45.13		2.80		10.40		6.20		2.50	

The DMP is a real time management tool for water authorities, and the costs of the plan itself involved are of administrative character. Obviously once the drought measure starts operating (according to the protocol alert), the cost are shared by all the users. Its aim is to re-allocate water according to water user priorities to minimize economic impacts.

2.5.3 Temporarily re-allocation

i) Explicit temporary re-allocation

In years of drought with different levels of severity, temporary re-allocations have been implemented. A current example (2007) - with moderate drought- the following water management measures have been approved by the Water Authority:

- Water transfer from agriculture to urban uses: In Seville City the public water company Emasesa has reached an agreement to buy 9 hm^3 of water from farmers in the irrigation district of 'El Viar'. This implies that farmers will be compensated by Emasesa according to the scale of the losses.
- Inter-agriculture sales: the irrigation district of 'Cuevas de Almazora', in the region of Almeria out of Guadalquivir river basin, has reached an agreement to buy 10 hm^3 from ´Comunidad de Regantes Bembezar' (irrigation district) at a market price of approximately 18 cent/m^3. This is a market operation that is subject to

55 Source: University of Cordoba.

approval by the Water Authority (as it implies exporting water resources from the Guadalquivir basin).

- 'Trasvase Negratín-Almanzora' is a publicly managed mechanism of water transfer that is designed to export a maximum of 40 hm^3 of water, but due to usual scarcity of resources, it is only handling 10 hm^3 to 18 hm^3 of water from Guadalquivir to Almeria area.

ii) Permanent re-allocation

The temporarily re-allocations, which were described above, need to be approved every year by the Water Authorities. An example of a more permanent allocation in the basin is from 2005, when 'Cuevas de Almazora' (Almeria) Comunidad de Regantes bought land devoted to rice production (located in the saline marshland area near the estuary) and asked for water transfer to Almeria by using the Negratin-Almazora channel. The character of this transfer is 'conceptually' permanent and given the price of land, this operation has an 'implicit price of water' (capitalised) of 4.31 Euro/m^3'. The Water Agency has approved the operation subject to the constraint that 50% of water must remain as an environmental buffer 'in situ' for 'salinity control', as rice is cultivated in these marshlands with tidal influence. However, year 2007 due to the drought and limited rice irrigation from Guadalquivir, this transfer of water out of the basin will not be allowed.

iii) Implicit 'ad hoc' temporary re-allocation in agriculture

In times of water scarcity the assigned water to farmers can be reduced below the original concession. **Error! Reference source not found.** shows the overall reductions in water allocated to selected irrigation districts over the last 22 irrigation seasons. In only 8 of 22 years (36%) have farmers actually received their full water rights. In most years, the water assigned was considerably lower, with adverse impacts on crop production. In 5 years (23%) the assigned water was reported at a third or less of the concession[56].

[56] Camacho, E. (2005): Análisis de la eficiencia y el ahorro de agua en el regadío de la cuenca del Guadalquivir. Inversiones en la modernización de regadíos. FERAGUA. Spain.

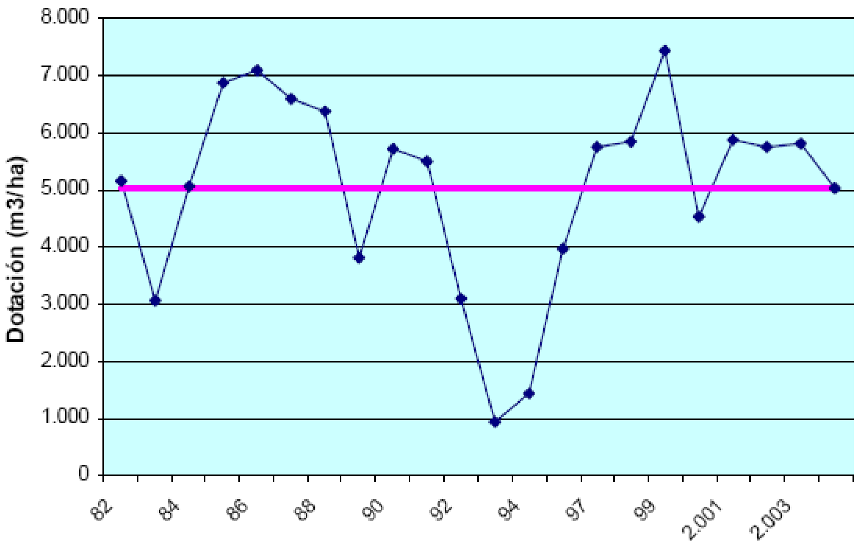

Figure 10: Water consumption in a sample of 22 irrigation districts (30% Guadalquivir irrigated area)[57]

User associations in Spain are mostly collective organizations, irrespective of whether they are served with public water rights (either surface water or groundwater) or from private groundwater rights.

Figure 10 shows that during the last years the reduction in water supply to irrigated areas, based on surface water with old customary rights, implies that the 'standard 6 000 m^3/ha' assigned water cannot be supplied; therefore, the Water Authority gives decreasing water supply to all farmers in general. The current year, as there is a moderate drought in the basin, all irrigators will receive 50% of 'standard allocation´. The farmers' response will be to use water on the most profitable crops. The consequence of diminishing water allocation is the gradual diminishing use of the most water demanding crops (maize and rice), and farmers will concentrate the water use on higher valued crops (orchards, cotton, olive trees, sugar beet, etc.). A proof of this trend is that in 2006 and 2007 there was a reduction in the planted area of rice (55% below 'average for 2000 to 2005) and maize (45% below average 2000 to 2005).

Finally, a starting point in the drought management plan is examined to look at the value of water for agriculture in the Guadalquivir in order to study temporary reallocation. In economic theory, the value of water can be treated as an 'economic rent', i.e. it may be considered an input factor similar to land. There are different methods for estimating water value, among them the residual method, which is one of the most widely used ones. In agronomic and hydrologic publications, the use of value of as an 'ad hoc'

[57] Camacho, E. (2005): Análisis de la eficiencia y el ahorro de agua en el regadío de la cuenca del Guadalquivir. Inversiones en la modernización de regadíos. FERAGUA. Spain.

concept of 'water productivity' is often defined as the ratio of economic turnover divided by water consumption.

Table 12 illustrates this concept for 2005 data for the main crops of the Guadalquivir (85% both in area and water consumption), where one can see the ratio of 'apparent productivity of water' is obtained by dividing 'total sales per hectare' or 'gross margin per hectare' by water consumption. Additionally, the 'residual value of water'[58] is also indicated, which is the value of water remaining once all other factors are paid, i.e. cash payment to factors (the difference between sales and gross margin) and also opportunity cost of land (rain fed value), family unpaid labour, interest on material capital, etc.

The use of the concept of 'residual value of water is important for economic rationality and may also be used to explain farmers' actual behaviour. A current example (2007) is useful to explain the water authorities' decision that water for irrigation will be around 50% of a normal year.

Table 12: Economic index and value of water (2005)[59]

Crop	Economic result per ha Total sales	Gross Margin	Water Consumption	Apparent productivity Sales/water	G.Margin/water	Value of water
	Euro/ha	Euro/ha	m^3	Euro/m^3	Euro/m^3	Euro/m^3
Citrus	6 584	3 609	5 501	1,.197	0.656	0.344
Olive	2 546	1 521	2 282	1.116	0.667	0.330
Sugar beet	3 799	1 664	3 730	1,.018	0.446	0.274
Cotton	4 429	1 973	6 049	0.732	0.326	0.215
Wheat	1 319	666	1 500	0.879	0.444	0.083
Maize	2 332	1 019	6 621	0.352	0.154	0.067
Rice	3 044	1 192	14 000	0.217	0.085	0.043
Sunflower	913	534	1 500	0.609	0.356	0.004

Figure 11 shows the differences between the ratio "sales value/water consumed" and the residual value of water.

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[58] Young, R.A. (2005): Determining the economic value of water: concepts and methods. Washington, D.C: Resources for the Future. Residual value is the most widely used method to estimate agricultural value of water in the analysis of irrigation projects.

[59] Source: University of Cordoba

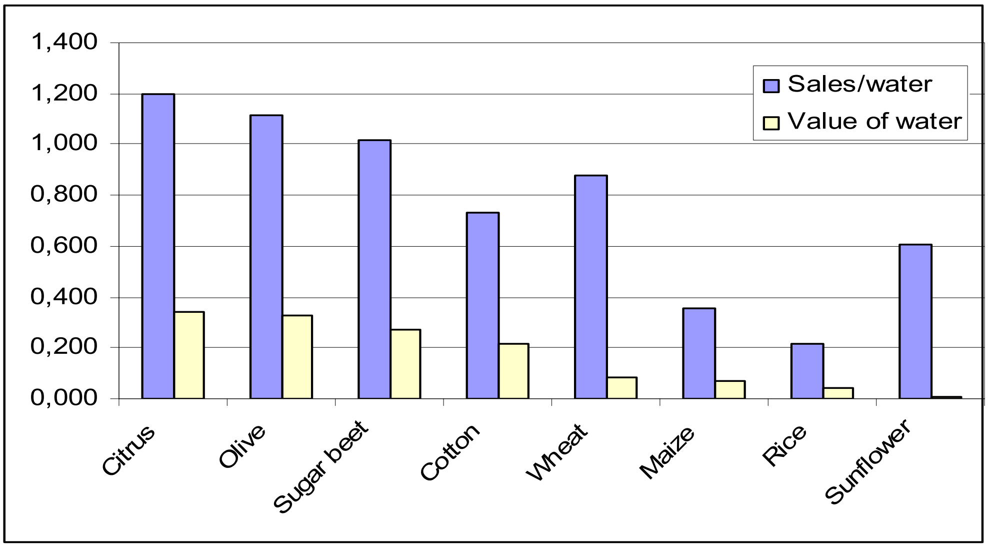

Figure 11: Comparison between sales over water consumption in Euro/m^3 and residual value of water in Euro/m^3 for main irrigated crops in Guadalquivir (2005)[60]

It is important to analyse the crops separately as agronomic systems need different crops to optimise resources as a whole, and if irrigated sunflower is considered alone, one can conclude that the value of water is almost zero and that sunflower should not be irrigated at all; however, sunflower is usually used for 'excess water' once all other main

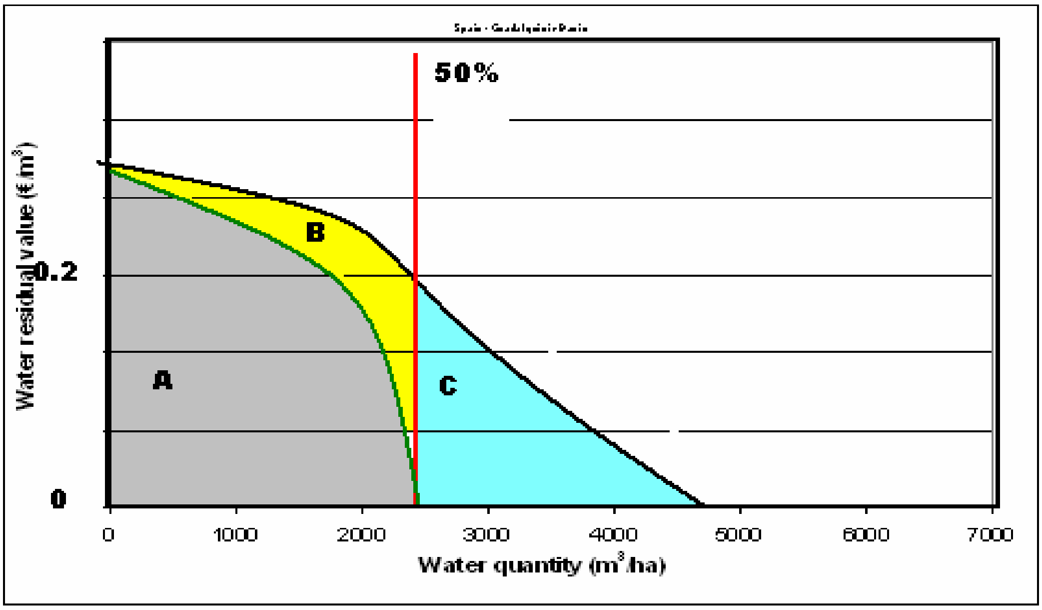

Figure 12: Illustration of impact of 50% reduction in water for irrigation (Guadalquivir)[61]

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[60] Source: University of Cordoba.

crops are fully irrigated. We must keep in mind that sowing decisions are taken when the available water for irrigation is not fully known. Therefore, sunflower plays a role in the crop rotation as the user of the excess water (if any) after all crops are irrigated. Figure 12 illustrates the impact of drought by the value of water for the basin. The vertical line shows the current (2007) irrigation water that is available (around 50% of a ´normal year´). If a virtual basin is imagined as a single decision making unit, the optimal solution is to irrigate all crops with residual value left of the vertical line and below the curve (areas A +B) and lose the 'C' area (low valued crops) But the Guadalquivir basin cannot be managed as a virtual single entity basin, as only some allocations and transfers are technically possible, and water allocation is a local decision with real transfers not available for 100% of the basin.

The 'market price' would be around 0.22 Euro/m^3, but the feasible solution implies that certain crops with water value this price of 0.22 Euro/m^3 will be irrigated (e.g. wheat, sunflower, maize etc.) due to transaction costs and technical barriers. It is interesting to note, for example,. the behaviour of the ´Irrigation community of Bembezar¨ mentioned in the 'temporal allocation' section, as this community uses 85% of the available water to irrigate the corps and is selling 15% of water at the price of 0.18 Euro/m^3 to other users that gets a higher value, so that they can concentrate locally the water in crops with a value higher to a contractual market price (mainly orchards and citrus). Unfortunately, the opportunity to sell water is not available for most users in the basin and therefore less profitable crops such as maize are irrigated (with area cultivated being 40% of 'normal' year area).

Thus, because of the transaction costs, the basin solution will be to maximise the value of water used subject to feasible water reallocation. Only area 'A' will be the value of irrigated crops, losing both the area 'C' for water scarcity and the area 'B' for transaction cost problems.

Finally, this 'equalitarian' allocation (i.e. all users 50% reduction) during drought years is rejected by some irrigators with old user rights. They claim it damages their administrative rights as the current allocation is not respecting allocation rights in a chronological order (i.e. older rights get a priority in allocation). As a consequence, new irrigated areas (most of them olive trees in the upper valley) have equal priority than 50 year old irrigation areas (most of them in the medium and low valley). These territorial and sectoral conflicts have not been a public issue yet. Irrigators have tried to solve this allocation problem internally, but the issue may rise in a near future and consequently result in a legal and economic debate.

iv) Implicit 'ad hoc' temporary re-allocation between agriculture and municipalities

In addition to the previously mentioned temporal contract between Seville City and 'Irrigation Community of El Viar', it should be mentioned that the Drought Management

[61] Source: University of Cordoba.

Plan is considering a 'implicit' allocation by increasing the years of guaranteed allocation to urban uses. Each year the water to be used depends upon quantity stores in reservoirs, priority uses and supply guarantee granted. This year (2007) and in the Drought Management Plan increasing the supply guarantee for urban uses from three to four or five years has been considered. The consequence is that available water to be distributed from the reservoir is reduced and is given to municipalities as priority. The increase of water guarantee to municipalities from three to five years implies that farmers suffer a reduction in water available for irrigation of 500 hm^3, which is a proposed 15% reduction now under discussion.

2.5.4 Additional measures for water saving

Finally, it should be mentioned that a full set of water saving measures for Guadalquivir is currently being analysed for their cost-efficiency in order to implement the Programme of Measure under the WFD[62]. Table 13 illustrates the selected measured with the 'a priori' largest impact[63] that has been included in this study and a set of 'additional' measures to be implemented after the first round is already working.

Table 13: Quantitative and qualitative measures for water saving in agriculture (Guadalquivir)[64]

Measures for water saving in agriculture (Guadalquivir)	Type of measure	Objective
Included in this case-study		
Change open conductions into pressurised	First stage	Quantity
Improvement of pipeline net conduction efficiency	Second stage	Quantity
Repair of open conductions covering	Second stage	Quantity
Replace sprinkler irrigation with whilst trickle	First stage	Quantity
Replace surface irrigation with sprinkler	First stage	Quantity
Replace surface irrigation with whilst trickle	First stage	Quantity
Updating tariff frameworks for irrigation uses (VOLUMETRIC BILLING)	First stage	Quantity
Full cost recovery-price increase	Second stage	Quantity
Spreading of irrigation farmers advising	First stage	Quantity

62 European Commission (2000): Pricing Policies for Enhancing the Sustainability of Water Resources. Communication from the Commission to the Council, the European Parliament, and the Economic and Social Committee (COM (2000) 477 final, European Commission, Brussels.

63 We have only provided information on the most cost-efficient measures ´a priori´ based on two sources: Local expert information and Ministerio de Medio Ambiente (MIMAM); Gobierno de Navarra (2002): Estudio Piloto de la Aplicación del Análisis Económico en la Cuenca del Cidacos.

64 CEDEX-MIMAM and elaboration by University of Cordoba

Additional measures not-included in this case-study		
Increase of available resources by civil regulation works	First stage	Quantity
Constitution of subterranean water users communities, or use on the whole to a better use of resources	Second stage	Quantity
Transaction of water use rights	Second stage	Neutral
Definition of basic criteria for subterranean water protection against marine intrusion	Second stage	Quantity
Economic compensation to land abandon and concession rescue	First stage	Quantity
Establishing criteria for concessions audit	Second stage	Quantity
Establishing norms for extractions and subterranean water concessions grant	First stage	Quantity
Increase of agricultural use available resources by mean of reuse treatment	Second stage	Quality/ quantity
introducing conditionality on the process for obtaining public subsidies at farming	First stage	Quality quantity
Improvement of draining system at irrigated areas	Second stage	Quantity
Public offer for concession rights acquisition by hydraulic administration	First stage	Quantity

2.6 Concluding remarks

Guadalquivir is an example of an old and relatively well managed river basin that has reached the limit of sustainable water use. Any possibility to increase water supply is limited (almost no possibilities for additional reservoirs nor additional groundwater resources), and simultaneously the water demand is increasing because of: a) competitive agriculture; b) increase in population c) economic development and d) increasing demand for environmental protection, including water quality and quantity available for environmental uses.

Water laws and directives are applied by the Water Authorities (Confederación Hidrografica del Guadalquivir) and have to take into consideration priority use, such as environmental use and municipal uses, before agriculture water for municipals uses amounts to approximately 15% of water uses in an 'average year', and the remaining 85% is 'theoretically' assigned to agriculture (constrained by environmental uses). Therefore, agriculture is the main user a 'normal year', but in the last 20 years water for irrigation has been frequently reduced.

The climate of the Mediterranean is characterised by fluctuating rainfall, limited possibilities for further abstraction of water, water transfers, reuse and desalination of water, which makes it crucial to manage water resources in a sustainable manner. The problem is that the trade-offs between environment and irrigation are not fully understood and conflicts are likely to appear in the near future during the implementation of the WFD[65] and increasing social awareness. Therefore, agriculture is the key to save water in the basin, and it has been identified as the best way to ensure water availability in the future.

This case study has presented both technical and economic that should be combined in a complementary way. Volumetric billing and full cost recovery with increasing prices can be applied only after technical measures are implemented. In conclusion, measures are interrelated and therefore converting “flat-rate on-area-based” water payments to volumetric billing is the most cost-efficient systems to save water in the basin, as it simultaneously implies improvement in distribution networks and field irrigation system.

The change of crop pattern has not been considered as future scenarios are quite uncertain. However, even with a drastic CAP reform that changes the profitability of current crops, the role of irrigation in Mediterranean in river basins, such as Guadalquivir, always will play a key role. Furthermore, the underlying hypothesis for the sustainability of Guadalquivir basin is that water saving through technical and economic measures should imply no increase in irrigation area in order to sustainable use the water saved.

[65] European Commission (2000): Pricing Policies for Enhancing the Sustainability of Water Resources. Communication from the Commission to the Council, the European Parliament, and the Economic and Social Committee (COM (2000) 477 final, European Commission, Brussels.

3 Ardèche river basin (France)

3.1 Objectives and methodology

This case study is aimed at illustrating all the information provided in the synthesis report. The main objective is to investigate the costs & benefits of different measures and actions through qualitative and quantitative assessments.

The case study will also explore in depth potential savings versus maximal savings, temporal allocation, feasibility of measures (coherence, synergies, conflicts of interests, when available, the issues of wet and dry savings (savings that lead to effective environmental improvements), negative incentives that prevent from achieving this savings, water rights, etc), energy issues (cost benefits ratios of measures included in the Energy Action plan for energy savings and identify to what extent it can be extrapolated to the water sector), virtual Water in the context of water saving, role of the consumers in the context of water saving (water labelling, changes in consumption patterns), and values of environmental benefits (which value for additional water into the ecosystem -use and non-use values- avoided damages and investments).

The sectors taken into account are:

- Household
- Tourism
- Agriculture
- Industry and energy

In the Ardèche case study, the following will be presented:

- First, a description of the river basin's environmental, social and economic settings in order to identify the issues at stake and the reasons for water scarcity in the river basin.
- Second, the river basin district management plans, the Ardèche river basin and proposition from technical studies will be analysed, and a selection of measures to save water and applicable to the river basin will be identified. The relevance of these measures to the river basin will be presented.
- Third, an analysis of saving potentials and costs of selected measures will be explored for each sector. A further measure, temporal allocation of water, will be discussed.
- Fourth, the benefits of the measures for each sector and for the wider society/environment will be derived
- Finally, a discussion integrating the different results

3.2 Description of the case-study

3.2.1 Geographical scope and issues

The Ardèche river basin is situated in the south-east of France, on the eastern side of the Massif Central. The Ardèche river flows into the second biggest river in France, the Rhône, which itself flows into the Mediterranean sea. The Ardèche river basin covers 2 500 km^2; the average altitude is around 1 000 m, with a peak at 1 700 m. Topography ranges from low lying plains in the east, to valleys plains and plateaus in the centre of the river basin and in the western side Figure 13.

The river basin is inhabited by 112 000 inhabitants[66]. It has low population density (50 people/km^2 on average), although the central area is denser (about 100 people/km^2) with most of the industrial activities. Tourism is very important in the region.

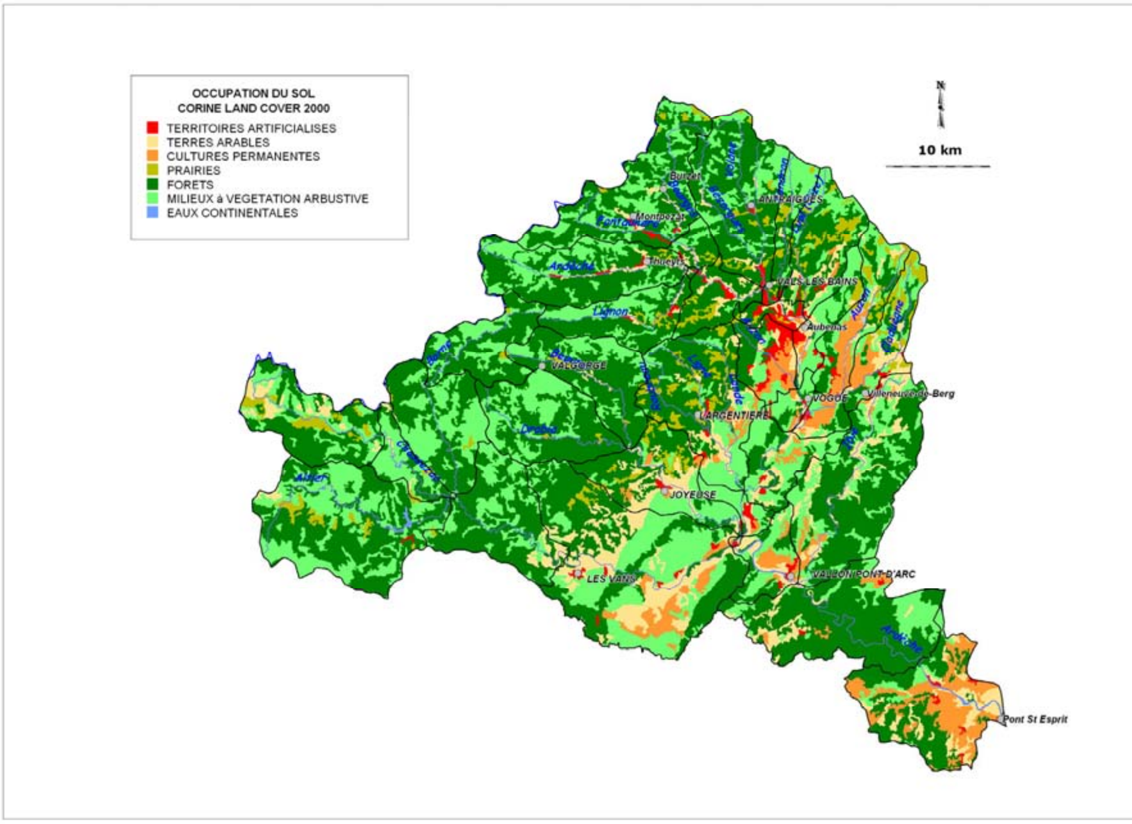

Figure 13 Land use of the Ardèche river basin[67]

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[66] www.insee.fr Statistical data from 1999

[67] Corin Land Cover 2000

Precipitation and temperature[68]

The climate of the river basin is very varied. The upper lands may be very cold (continental weather) and receive high rain and snow falls. Summer can, however, be very dry and hot,. Storms are frequent, particularly in the end of the summer in the western mountainous areas. About 900 mm up to 2 000 mm of rain falls on the river basin, which is the upper range of French averages (1 000 mm).

Surface resource[69]

The local geology is mainly made of cristalline rocks, which do not hold water, and alluvial deposits, which is characterised by karstic losses. The geology of the river basin provides little buffering, making the basin both prone to floods and droughts and to long and strong low flows.

Historically, inhabitants have tried to bridge this seasonal inequality by capturing water through all available means. Two large reservoirs exist upstream from the Ardèche river and of its main tributary, the Chassezac. One of the reservoirs, the Pont de Veyrières, receives water from the nearby Loire river basin. This water is used both for sustaining water flow in summer but also for hydropower production in winter.

Several small reservoirs exist for agriculture to stock the resource in the winter season and for use during low flow periods.

Groundwater resource

Little information is available. Groundwater is mainly located in karstic aquifers but seems to be very large. About 372 Mm^3 of stocks with about 169 Mm^3 is available (annual renewal).

3.2.2 Water uses

Household and tourism[70]

The permanent population in the river basin was 112 000 inhabitants in 1999. An increase of 5% was observed between 1990 and 1999. Similar increases can be expected in future years. The population is concentrated in the middle and lowland regions, as well as all economic activities.

To estimate the total volume consumed by the population in the river basin, the following information is needed:

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68 See: www.meteo-mc.fr

69 See: http://www.gorgesdelardeche.fr/patrimoine-physiques.php.

70 Source: www.insee.fr Statsitical data from 1999; Etat des lieux du district Rhône – Méditerranée, http://195.167.226.100/DCE/RM/RM_etat-des-lieux.htm, http://www.ardeche.fr/developpement-local-economie/environnement/eau/alimentation-eau-potable; http://www.memoire-ardeche.com/libre_acces/seba.pdf.

- There 158 councils within the river basin district. 80 councils are connected to a unique drinking water network, which is managed by a public company called SEBA, but not all end-users are under SEBA control.
- Abstraction for this network represents about 6 Mm^3, of which 2.5 Mm^3 is associated with end-users of the SEBA network.
- The drinking water network has an efficiency of around 70%, thus the water necessary to meet the demand by the end users in the SEBA network is around 3.6 Mm^3.
- The volume that is distributed from the SEBA network to other distributing companies is the difference between the volume of water abstracted (6 Mm^3) and the volume needed to meet the demand of the SEBA, thus around 2.4 Mm^3.
- Considering similar network efficiency (70%), about 1.7 Mm^3 is consumed by these end-users.
- Using these numbers to extrapolate over the whole river basin, total abstraction in the river basin for the collective drinking water network can be estimated at about 12 Mm^3 and total consumption to about 8.4 Mm^3.

Consumption has been rising rapidly in recent years, in particular because tourism has increased dramatically in the river basin (tourists tend to use more water).

Agriculture and irrigation[71]

The Ardèche river basin has about 66 000 ha of agriculture land, about 27% of the river basin area. Most of the land is for grassland (69%), followed by arable land (18%), vineyards (9%) and orchards (5%).

Irrigated lands covers about 1 600 ha. There has been a net decrease in the total irrigated areas in the river basin since 1979 due to changes in the structure of agricultural subsidies, from 2 672 ha in 1979 to 2 720 in 1988 and 1 600 in 2000.

Data was not available on the type of cultures present in the Ardèche river basin. An adapted share of cultures was adapted from average values at district level:

- Orchards are the most important cultures in terms of surface and can be irrigated using micro-aspersion or aspersion techniques;
- Vineyards is important in the river basin but irrigation is limited for this culture (most water is used to prevent frost);

[71] Source: Recensement Général Agricole http://www.agreste.agriculture.gouv.fr/ data from 2000; http://www.ardeche.chambagri.fr/Tout%20public/Chiffres-Cles/memento%2007pro.html, Etat des lieux du district Rhône – Méditerranée, http://195.167.226.100/DCE/RM/RM_etat-des-lieux.htm, donnée Agence de l'Eau Rhône-Méditerranée-Corse; Chohin-Kuper, A.; Gleyses, G.; Rieu, T.; Tauber, M. (2001): Impact économique de la modification de la redevance pour les irrigants, Série Irrigation Rapport, 893

- Cereals and maize are present in the lower lands and are usually irrigated using aspersion techniques;
- Truck farming using micro-aspersion and aspersion techniques;
- Some irrigated surfaces are chestnuts, small fruits, olive trees, gardens.

Collective irrigation is well developed in the river basin, with some systems composed of canalisations and pumps, and some with distributing canals. On the field, irrigation is mostly through sprinkling irrigation. Localised irrigation is also developed. Surface irrigation is minor.

Considering an average crop water demand of 2 000 m^3/ha, crop water demand in the river basin amounts to about 3.2 Mm^3. With an efficiency of 80% in the distribution system and field spraying system, about 4Mm^3 per year should be abstracted per year.

Industries[72]

Industrial activity in the river basin is very limited. About 0.3 Mm^3 is abstracted per year, and most returns to the aquatic environment since it is mainly used for processing.

Energy production[73]

In terms of energy production, the river basin has two main hydroelectric power plants, which have significant impact on the water flow, and 35 micro-hydroelectric power plant. The Puylaurent reservoir has a capacity of 12 Mm^3 and produces 18 MkWh per year.

Synthesis of water demand, and the reason for water scarcity in the river basin[74]

The domestic and agriculture sectors are the main abstractors of water, respectively with 12 Mm^3 and 4 Mm^3 of water abstracted.

Some of the abstracted water used in drinking water networks is returned through the wastewater system. The drinking water network distributes water to a wide range of activities, including households, businesses connected to the collective drinking water system, and activities linked to tourism (hotels, secondary houses, camping sites etc).

Water that is abstracted by agriculture, on the other hand, rarely comes back to the river. It is either consumed by the plant, evaporates or it percolates to the groundwater. Hence, this water is “lost” for the river, unlike water abstracted for the drinking water network.

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72 http://195.167.226.100/DCE/RM/RM_etat-des-lieux.htm, donnée Agence de l’Eau Rhône-Méditerranée-Corse, donnée Agence de l’Eau Rhône-Méditerranée-Corse

73 http://www.inbo-news.org/divers/megeve/eau_montagne_2002/Pdf/castaing.pdf.

74 http://www.inbo-news.org/divers/megeve/eau_montagne_2002/Pdf/castaing.pdf; http://www.rhone-alpes.ecologie.gouv.fr/hydro/qmna5/pdf/qmna5-07.pdf.; http://www.rdbrmc-travaux.com/spge/site_v2/IMG/pdf/qmna5-l8.pdf; http://www.languedoc-roussillon.ecologie.gouv.fr/zi/hydrogeomorphologie/ceze/rapport/fonctionnement.pdf.

There are very diverse situations across the river basin:

- The particularity of the Ardèche river basin is that water availability is very high but high seasonal variations in rain rainfall and temperatures as well as a specific geology means that water is much less present in summer.
- Some specific areas may naturally dry for several kilometres, for example because of karstic infiltrations
- Sometimes abstraction points were installed on small rivers (e.g. Volane). Seasonal fluctuations in the natural flow of these small rivers mean that abstraction may impact the river severely but not the overall river basin.

The volume stored by the reservoir in the end of spring is used to sustain water flow during summer. Since the capacity of the Puylaurent reservoir is 10 Mm^3, there is potentially 10 Mm^3 available for sustaining water flow in summer. This compares to 60 Mm^3 stored in reservoirs along the same river.

Reasons for water scarcity range from:

- High pressure from water services abstracting water in the river. Sometimes the best resource is not selected, and other types of resource could be exploited (e.g. deep groundwater)
- High pressure from consumptive water uses due to intensive activity, considering the available local resource. In such cases, measures should focus, for example, on increasing water use efficiency.

3.2.3 Current management plan[75]

The Ardèche river basin is in the Rhône-Méditerranée district, which has a specific district level management plan called SDAGE[76]. The following presents measures proposed in the current management plan as well as the future management plan starting 2009 (draft proposals of measures):

- Abstraction should be limited to available water, potentially provided by low flow support schemed (dams);
- Abstraction should be licensed;
- A short term drought management plan should be set up, listing user's demand, priorities, and specific rules governing restrictions when water flow reaches crisis levels. The local state representative should lead the process;
- Increase knowledge base of abstraction level for all water uses;
- Increase public awareness and education;

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75 Source: www.eaurmc.fr.

76 SDAGE: Schéma Directeur d'Aménagement et de Gestion de l'Eau.

- Promote water efficient technologies and water efficient process water use;
- Establish management plans for effective water allocation.

3.2.4 Measures explored in this case study

The following section will present the different type of measures and how they can be applied to the Ardèche river basin. The sectors considered are (i) household and tourism connected to the drinking water supply network, (ii) the agriculture sector, in particular irrigation, and (iii) the energy sector. Technical measures, such as improving the efficiency of networks, short term restrictions, and water pricing, are analysed. The use of water allocation measures for water stored in dams will then be considered separately.

Technical measures

Technical measures include all measures that aim to improve the efficiency of water infrastructure, including new infrastructure, and reduce losses in order to improve efficiency of distribution systems or change the kind of resource abstracted.

For households, improving the efficiency of drinking water supply network, installing water efficient techniques in homes (devices, etc), or constructing rainwater harvesting systems around houses can be technical solutions to water savings.

For the agriculture sector, increasing the efficiency of distribution systems such as canals, increasing the efficiency of spraying techniques, or using less water intensive crops can be considered “technical” solutions. These measures can be promoted by subsidising or encouraging users to do the necessary action. Households may also decide to install new infrastructures when they see an advantage to do so e.g. when their water bill is too high. Thus technical measures can be the end result of pricing policies.

Short term restrictions[77]

From the draft Annex to the Communication on Water Scarcity and Droughts[78], quotas (short term temporal restrictions) are included in the measure called “drought management plan”. Indeed, this measure is mainly targeted to exceptional situations, since long term management addressing long term imbalances should be addressed in WFD related activities. Quotas are used to limit abstraction levels in times of very low flows and quantity deficits in the river.

The cost for setting up the measure are administrative (i.e. technical study, setting up the management plan, implementation). The impacts of such measure are 1)

[77] Source: http://www.ardeche.pref.gouv.fr (last checked on 13.07.2007).

[78] European Commission (2007): Communication on Water Scarcity and Droughts- Annex 2 (to be published)

environmental (i.e. increase water flow thanks to lower abstraction level), 2) economic (i.e. activities limited by the volumes they can use and activities that profit from the increased water flow) and 3) social (i.e. consequences of the impact on economic activity and on environment). The level of measures' costs and costs/benefits of impacts is dependent on the level of ambition and extent (i.e. geographical scope).

A system of quotas is now in place in the Ardèche river basin. The drought management plan, applied by district and not to at river basin scale, described here is in the district that covers most of the river basin. It defines three homogeneous zones for implementing measures, based on hydrological characteristics. For agriculture, three more sub-zones are defined. Four levels of emergency are defined, each of which has a set of measures. Measures are increasingly restrictive as the situation becomes more severe.

During severe drought events, the local state representative is legally allowed to restrict water uses. Drinking water distribution is never forbidden (priority use). The first level does not actually restrict use, but is rather aimed at raising awareness of water scarcity issues. The second level forbids washing personal cars and roads, filling public fountains, artificial lakes and canals. It restricts watering gardens, sport venues and filling of private swimming pools. The third level, in addition to the activities forbidden in level two, restricts industrial and wastewater uses to strict necessity. The fourth level is the most restrictive and forbids any abstraction of water except for human consumption, safety purposes, and those strictly necessary for specific uses such as industries, public swimming pools etc..

In terms of restrictions on the agriculture sector, the different levels are also progressive. Level 2 starts to forbids irrigation by aspersion (allowed from 6h to 20h), and users are only allowed to irrigate four times per week for 10 hours. Irrigation by aspersion is more restricted than micro-aspersion (allowed from 10h to 18h), "goutte à goutte" (allowed from 18h to 10h) or "immersion" (10h to 18h). Reducing irrigation for collective associations and individuals can lower consumption by 30%. Water for animals is not restricted as well water abstracted from reservoirs. Level 3 restricts aspersion irrigation for 12h (allowed from 22h to 6h), and each user is allowed to irrigate 3 times per week for eight hours. Micro-aspersion (allowed from 6h to 20h) and "goute-à-goutte" (allowed from 18h to 10h) irrigation techniques are less restricted. These restrictions on collective associations and individuals will lower consumption by 50%. Irrigation by immersion is restricted (allowed from 8h to 23h). Water for animals is not restricted as well water abstracted from reservoirs. Level 4 is the most restrictive and forbids any irrigation. Water for animals is not restricted as well water abstracted from reservoirs.

Several arrangements are made to accommodate administrative issues (warning letters, water police, weather warning system, and planning). The minimum implementation time is one week.

Restrictions have been introduced every year for the last four years. They were targeted first at households, forbidding the use of water for gardening and swimming pools, and then at agriculture. Industries were not targeted. Priority was always given to drinking water supply, and some derogation was allowed for agriculture in 2006. Some sub-basins are more targeted than others: first the Ligne sub-basin, then the Beaume, Drobie and Volane. These sub-basins do not have a low flow support system made of reservoirs. The Chassezac and the Ardèche sub-basins are equipped with several reservoirs and are prone to fewer restrictions.

Water pricing[79]

Water pricing is aimed at compelling water users to reduce water consumption water by charging water through the volume (or flow) used. Two main variables control the price of water:

- The total cost to pay: cost may only include cost of infrastructure or may also include environmental and resource cost – this refers to the recovery of cost of water services.
- The total cost burden can be placed on water users or can be partly subsidised by the public sector. The polluter pays principle favours situations where water users pay the water bill in full.

Water pricing may be an incentive in terms of reducing water use when the water bill increases with volumes used, for example when the price is not flat. The draft Annex 2 to the Communication on Water Scarcity and Droughts[80] document refers to various situations in New Zealand, Italy, California and south eastern Europe where water pricing policies have led to water savings due to changes in 1) habits, 2) activities, 3) crop patterns and 4) technologies used.

In the Ardèche river basin, water pricing has not been historically used for water saving purposes. The water bill is already very high in most of the river basin (one of the highest in France), which is due to high infrastructure costs in the main drinking water supply company. The territory has had problems where people did not pay their water bill and the price of water was controlled by the state to avoid over-pricing. Water uses within the drinking water networks are not differentiated. Households, industries (including SMEs), tourism and agriculture (cattle) pay the same price for water (for both fixed and variable parts). Tourism is a main user of water in summer, since the population in the Ardèche river basin doubles during the dry period. Thus, Tourism does not pay for the real cost of water, including the additional infrastructure costs to provide enough water at peak times, as well as environmental and resource costs, which are potentially high during

[79] CEMAGREF (2002): Les outils économique pour la gestion de la demande en eau en Méditerranée, Tarification eau en Méditerranée. Série Irrigation Rapport, 1001; www.eaurmc.fr; http://www.ccomptes.fr/CRC24/documents/ROD/RAR200320.pdf; http://www.brl.fr/brli/francais/produits/produit.php?produits=1.

[80] European Commission (2007): Communication on Water Scarcity and Droughts- Annex 2 (to be published)

this period of low flow. Incentive pricing based on the true cost of activities impacting water resources could thus target these specific users.

In France water costs are on average 2.65 Euro/m^3. The water price in the river basin district averages around 2.79 Euro/m^3. For about 45 collectives, the price of water is around 5 Euro/m^3 due to the specific situation of the organisation managing the distribution of water within this network.

Pricing in irrigation is based on a recovery of initial investment costs (minus subsidies from the public sector and the water agency), operation and maintenance costs and taxes perceived by the state and the water agency.

Water pricing in the Ardèche river basin is not available in any literature. BRL, a territorial equipment company, manages an irrigation network in the south of the river basin. Prices applied are based on a binomial pricing system. Characteristics of irrigation water pricing are given in Table 14. This pricing system tends to incite irrigation use to consume less water. Distribution systems made of canals usually use flat tariffs. By changing these systems into systems in which water use can be measured, and volumetric pricing can be applied, making water savings possible.

Several studies referenced the savings potential of pricing instruments. In France, savings are observed when the price of water is as low as 0.02 Euro/m ^{3}. Raising the variable part of binomial pricing systems may thus lead to further savings.

Table 14 Pricing in one irrigation system in the Ardèche river basin, and on average in France

Pricing -Average	Pricing –Minimum	Pricing -Maximum	Average France
Fixed: 45 Euro per m^3/h	Fixed : 32 Euro/ha	Fxed : 138 Euro/ha	Fixed: 41 Euro/m^3
Variable: 0.13 Euro/m^3	Variable : 0.0732 Euro/m^3	Variable : 0.1045 Euro/m^3	Variable : 0.051 Euro/m^3

Temporal allocation of water[81]

Temporal allocation of water refers to the re-allocation of available resources, for example in reservoirs, between users. In the case of the Ardèche river basin, such changes would be possible in the two main dams that were designed to sustain a minimum flow of water in the river during summer. These reservoirs were, however, built for other purposes as well. In winter, the national electric company EDF uses the water

[81] http://www.inbo-news.org/divers/megeve/eau_montagne_2002/Pdf/castaing.pdf; http://www.rhone-alpes.ecologie.gouv.fr/hydro/qmna5/pdf/qmna5-07.pdf; http://www.rdbrmc-travaux.com/spge/site_v2/IMG/pdf/qmna5-l8.pdf; http://www.languedoc-roussillon.ecologie.gouv.fr/zi/hydrogeomorphologie/ceze/rapport/fonctionnement.pdf,

to produce electricity. This season usually corresponds to peak demand, thus increasing benefits to the company.

Currently, conventions regulate the share of the water stored in the reservoirs. For example, EDF is obliged to fill reservoirs before summer and sustain a minimum flow in the river from the 15 June to 15 September. The date at which reservoirs needs to be recharged, the rate at which it should be recharged and the minimum stock that should be available at the beginning of the low flow seasons are strictly specified and have to be met at the expense of electricity production during these periods.

Currently, however, severe low flows have occurred in the last years, and the availability of water is restricted for both the environment and the uses that are dependent on the resources, namely drinking water supply, tourism (ex. angling, canoeing, kayaking, etc) and irrigation activities.

The objective of re-allocation measures in the reservoirs are to:

- Extend the length of time during which the electricity company needs to liberate enough water to sustain water flow in the river. This would restrain the water available to produce electricity in the winter; and
- Increase the minimum flow requirements during the low flow season in order to meet any demand downstream.

The mean to achieve these objectives are:

- To change the convention of the reservoirs recharge, for example by starting recharge earlier in the year, and to prioritise low flow support earlier in the year; and
- To require higher volumes of water to be available in the reservoirs at the beginning of the low flow season, so that higher flows can be secured during the whole season.

These measures would impact the production of electricity, because the company would be more restricted in the volumes of water they can use from the reservoir.

3.3 Potential maximum savings and cost assessment in each sector

3.3.1 Household and tourism[82]

This chapter will explore the potential savings in the collective drinking water supply system. Household and tourism are thus grouped together since they are both use the same distributing network.

[82] http://www.ccomptes.fr/CRC24/documents/ROD/RAR200320.pdf; www.jeconomiseleau.org/gen_particuliers.html, www.eaurmc.fr.

Potential savings

If one assumes a current efficiency of 70%, increasing drinking network efficiency up to 90% could save 2.4 Mm^3.

Furthermore, potential savings by increasing the efficiency of networks and water devices in each houses could lead to an overall average saving of 30% of household consumption (8.2 Mm^3). Potential savings would be thus around 2.46 Mm^3.

Restrictions on household would forbid washing cars, watering gardens and filling swimming pools. Considering water use to wash cars and water gardens takes about 10% of household summer water use (6 months of the year), and considering that summer consumption is 50% of annual water use, restrictions could thus save about 0.41 Mm^3. It was not possible to evaluate the savings from restrictions on swimming pools altogether.

Increasing the water price for households may have mixed effects. In the area where water costs about 5 Euro/m^3, past increases in price has to lead to people not paying their bill; therefore, no elasticity exists. In areas where water is not distributed from the SEBA system (which has financial difficulties), the price is likely to be lower so some elasticity may apply within those collectives. Table 15 indicates the water saving potential:

Table 15 Water saving potential in the drinking water network using pricing instruments

	SEBA 80 -44 collectivities	Other collectivities -114 collectivities
Water price (Euro/m^3)	5	2.79
Volume consumed (Mm^3)	2.5	5.9
% from the average price of water in France	201%	95%
Elasticity[83]	-	-0.31
Volumes saved for 10% increase in price	-	0.18
Volumes saved for 20% increase in price	-	0.37

Evaluating costs of measures

A recent survey identified that the main cause for water losses in the drinking water supply network is due to the age of the network. The following section will thus assume that to increase the efficiency of the network, all pipes will be renewed. The average cost

[83] Pouquet and Ragot, (1997- unpublished), taken in Montginoul and Alexandre, Le Prix de l'Eau Potable en France. An elasticity of about -0.31.

of renewal is 100 Euro/m[84]. SEBA has 1 100 km of pipelines. If we multiply this length by the ratio of consumer volume between SEBA and the rest of the river basin, about 2 300 km has to be updates, with a total cost of around 0.23M Euro.

Improving the efficiency of devices within houses would cost about 70 Euro per household for a saving of 60 m^3; total costs would be around 1.51M Euro Additional costs could arise from (i) the buying of more efficient washing machines and dishwashers and (ii) carrying out an audit of the house network and reducing losses.

The use of restrictions implies administrative and operation costs as well. Administrative and operation costs include the preparation of the restriction act during the low flow period and the control by the water police, who verify on a day-to-day basis whether people respect the restriction in place. The restriction procedure is usually accompanied by technical studies, an alarm system and a management plan. These costs are difficult to evaluate, particularly since such activities have other objectives, for example the preparation of an integrated management plan as in the case of the Ardèche river basin (SAGE). These costs should be compared to the benefits that arise from the development of the integrated management plan, beyond the scope of this study. Restrictions can also lead to costs to the household sector. Restrictions on watering affects the pleasure of people to have a green lawn, a clean car or the use of a swimming pools. An area prone to restrictions may also become less attractive, which can negatively affect housing prices.

3.3.2 Agriculture[85]

This chapter will explore the savings and costs associated with the identified measures in the agricultural sector.

Evaluating potential savings

Crop water demand per year is about 3.2 Mm^3. If it is assumed that 10% of irrigated surface receives water from canals, a rough estimation shows that the water demand from these surfaces amounts to 0.32 Mm^3. It is also assumed that all the water in the canals is used for surface irrigation. The efficiency of surface irrigation is 60%, thus the water demand from the start is around 0.53 Mm^3. The conveyance efficiency of canals is 76%. The total abstraction needed to meet water demand of the crops is thus 0.70 Mm^3; the loss in the canals amounts to 0.17 Mm^3.

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[84] Office International de l'Eau (2002): Inventaire et scenario de renouvellement du patrimoine d'infrastructure d'eau potable et d'assainissement.

[85] CEMAGREF (2002): Les outils économique pour la gestion de la demande en eau en Méditerranée, Tarification eau en Méditerranée. Série Irrigation Rapport, 1001; Chohin-Kuper, A.; Gleyses, G.; Rieu, T.; Tauber, M. (2001): Impact économique de la modification de la redevance pour les irrigants, Série Irrigation Rapport, 893.

Table 16 shows that by assuming that (i) the length of each type of canals is equal), and (ii) all irrigation systems are transformed into pipeline-based distributing systems, potential savings can amount to 0.11 Mm^3.

Table 16 Potential savings by changing irrigation systems

Type of canal	Length (%)	Volumes in canals (Mm^3)[86]	Current efficiency[87] (%)	Potential efficiency[88] (%)	Potential improvements (%)	Potential savings (Mm^3)
Concrete	30	0.21	85	95	10	0.02
Rocks	30	0.21	75	95	20	0.04
Earthen	30	0.21	70	95	25	0.05
Total	100	0.70	76	95	20	0.11

Further savings can be achieved by increasing the efficiency of spraying techniques. It is assumed that aspersion is used in 60% of irrigated surface, micro-aspersion 30% of irrigated surface and surface irrigation 10%. Assuming micro-aspersion could replace aspersion and be potentially used in 60% of irrigated areas, and that surface irrigation could be changed into aspersion irrigation, Table 17 shows the volume of water potentially saved, which amounts to 0.62 Mm^3:

Table 17 Saving potential by changing the type of irrigation

Type of irrigation	Current consumed volumes (Mm^3)	Efficiency of spraying technique (%)	Change in efficiency (%)	Change in surface surface (%)	Potentially saved volumes by considering type of culture and most efficient irrigation technique (Mm^3)
Surface	0.32	60	15	100	0.48
Aspersion	1.92	75	15	50	0.14
Micro-aspersion	0.96	90	0	0	-
Total	3.20	-	100	100	0.62

Other measures can target the type of cultures cultivated in the area. For example, cultures such as maize may be changed into vineyards. Assuming maize represents 20% of irrigated surface (320 ha), savings can reach up to 0.35 Mm^3[89].

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[86] Assuming that volumes of water distributed through canals are proportional to the irrigated surface considered.

[87] Karamanos, A.; Aggelides S.; Londra, P. (2005): Water use Efficiency and water productivity in Greece

[88] Efficiency of lined channels, in Karamanos, A.; Aggelides S.; Londra, P. (2005): Water use Efficiency and water productivity in Greece

[89] Irrigated maize uses 3100m^3/ha. Water demand for irrigated grassland is 2000 m^3/ha.

Water saving through water pricing can be estimated using elasticity ratios. Using an elasticity ratio of 0.03, as found in many studies, potential savings for an increase in the price of 10% and 20% in systems currently equipped with aspersion and micro-aspersion techniques would be between 0.09 and 0.17 Mm^3. It is impossible to calculate the change in consumption from surface irrigation to an aspersion irrigation system and apply pricing instruments on such consumption. Qualitatively, the change will be marginal since water use through surface irrigation is also marginal.

Evaluating costs of measures

Changing a surface/canal distribution system into a pipeline based irrigation system costs on average 4 000 Euro/ha, with an additional 2 000 Euro for the pumping station. Total cost for the 76 ha currently irrigated by surface irrigation and the 10 irrigation system concerned would be around 330 000 Euro.

Installing micro-aspersion techniques usually costs about 1500 Euro/ha[90]. About 435 ha would be changed into micro-aspersion, thus costing 652 500 Euro. The change from surface irrigation into aspersion irrigation would cost about 600 Euro/ha[91]. The cost for changing the 87 ha of surface irrigation would be about 52 200 Euro. Total cost of this measure would be 704 700 Euro.

Changing the nature of culture would change the income of the farmer and its management and commercial strategies. Estimating the cost of these is difficult, and several studies have tried to evaluate the total costs of such changes[92],by examining the change in production and the cost on the market[93].

Increasing the variable price per m^3 of the water bill by 6% would increase the cost of water for the farmer. The average cost of water is 0.064 Euro/m^3; the increase would increase the price of water by 0.04 Euro/m^3. The average water consumption per ha in the river basin is 2 130 m^3 per ha[94], thus an increase of 6% in the price of water would cost 85 Euro per ha. Since the average size of irrigated land per farm in the river basin is 3.41 ha[95], the average cost of increased water bill by farms would be 465 Euro. The total cost over the river basin would be136 000 Euro for 1 600 ha.

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90 Personal communication from Vincent Kulesza.

91 http://www.economie.eaufrance.fr:80/rubrique.php3?id_rubrique=44.

92 Chohin-Kuper, A.; Gleyses, G.; Rieu, T.; Tauber, M. (2001): Impact économique de la modification de la redevance pour les irrigants, Série Irrigation Rapport, 893.

93 If the production of one good increases, it is possible that market price will fall, thus lowering potential costs/benefits.

94 Irrigated surface amounts to 1600ha and water use by irrigation is 3.2Mm^3, thus the cost of water.

95 Recensement Général Agricole http://www.agreste.agriculture.gouv.fr/ data from 2000.

3.3.3 Temporal allocation of water: low flow and hydro-electricity

Evaluating potential savings for water scarcity[96]

Currently, the two systems of reservoirs in place to sustain water flow in the Ardèche and Chassezac sub-basins are composed of several reservoirs. Looking at the Chassezac sub-basin, about 60 Mm^3 is stored, of which 9.6 Mm^3 is available through conventions to sustain water flow. This volume can deliver an average flow of 1.7 m^3/s during the whole low flow period.

The objective here will is to assess what it would cost to (i) extend the length of support up to one month earlier in order to meet potential demand and limit damage from early droughts, and (ii) an increase of 50% in the water flow during the whole period:

(i) The extra volume needed to sustain the flow one month more is the average volume used in one month during the low flow season (9.6/3=3.2 Mm^3)
(ii) The extra volume needed is 50% more, thus 4.8 Mm^3

The power plant produces 18 MWh over the whole year, including 16.5 MWh during the winter (high season). 1.5 MWh is thus produced during the low flow season. The average production of 1m^3 in the low flow season, considering only the volumes released in the summer through conventions, is 0.16 MWh per m^3 or 160 000 MWh per Mm^3.

The loss to the electricity company is proportional to the difference of the price between summer and winter rates on the market. We will take the price of electricity between low periods (64.4 Euro/MWh) compared to the price for high periods (105.7 Euro/MWh)[97].

The loss to the electricity company is:

(i) For one month extension: 3.2*160*(105.7-64.4)=21.145M Euro
(ii) For an 50% increase in the water flow during the low flow season: 4.8*160*(105.7-64.4)=31.718M Euro

3.4 Evaluating benefits

The measures explored in the previous chapters can benefit (Table 18):

- Sectors such as households, tourism and agriculture
- The wider society
- The environment

Lower consumption through technical measures (e.g. improve efficiency of household devises or spraying techniques) can lower households bills by between 6.96 and 12.3M

[96] http://ftp.sandre.eaufrance.fr/public/brgm/bsh_brgm_01_5.pdf, and Le barrage de Puylaurent, EDF, http://www.inbo-news.org/divers/megeve/eau_montagne_2002/Pdf/castaing.pdf.

[97] Please note that the hydroelectric value of water is difference between 'daily peak price' and average cost by alternative (e.g. nuclear) power plants

Euro/year, or 113 Euro/inhabitant/year, and 94 900 Euro/year for agriculture (59 Euro/irrigated ha).

While it is difficult to evaluate benefits to society and the environment because no evaluation studies were carried out in the river basin, worth mentioning are the benefits for tourism. Indeed, tourism in the river basin is strongly linked to the quality of the environment (water-based activities). The river basin doubles its population during the summer. Most tourists are based in the Ardèche sub-basin, particularly in the most downstream part near the site of special interest, Georges de l'Ardèche.

Table 18 Identified benefits of the previous measures

Measure	Benefit	Who?
Efficiency of drinking water supply network	Lower abstraction demand, secure uses in time of scarcity	Uses connected to drinking water network
Installation of water efficient techniques in homes (devices, etc)	Lower consumption lowers the water bill	Uses connected to drinking water network
Improve efficiency in canals	Decrease in water bill when bill is based on volumes abstracted	Agriculture
Improve efficiency of spraying techniques	Decrease in water bill. Lower bills can lead to an increase in irrigated areas, (and so no water savings)	Agriculture
All measures that save water in surface water	Increase water flow to sustain leisure and sporting activities such as bathing, kayak	Tourism
All measures that save water in surface or groundwater	Can profit future generations (ex. savings that reduce pressure on aquifers), intrinsic value of nature	Wider society
All measures that save water in surface and, indirectly, groundwater	Limit impacts of severe low flows and droughts, increase biodiversity	Environment

3.5 Discussion and synthesis

The previous exercise has tried to evaluate total potential water savings for different kind of measures. Total potential savings can not be calculated because water pricing policies may include some technical changes.

Table 19 Potential savings in the Ardèche river basin (Mm^3)

Potential Savings		
Measure	**Household/tourism**	**Agriculture**
Technical (including changing crop)	4.86	0.67
Short term restrictions	0.41	-
Water pricing	0.37	0.17
Abstraction		
Annual abstraction	12	4

The evaluation was based on data at river basin scale and does not take into account the diversity of situations in the river basin. It also uses estimations and transfer data from other studies (mentioned along the text) when direct data is not available. The volumes abstracted and consumed by agriculture are particularly difficult to evaluate.

The report does not take into account questions of acceptability[98], implementation burden, and non-compliance (to restrictions for example) issues. Acceptability of measures to limit water use faces the challenge of key sectors for the local economy. Restrictions on tourism, for example, by forbidding the filling of swimming pools, could lower the willingness of people to come in the Ardèche river basin for their summer holidays. The impacts of restrictions or low flows in the river on tourism are difficult to estimate, but there are potentially some direct connections. The issue of attractiveness is an important one for the local population for which tourism is an important source of revenue.

Restrictions on agriculture are difficult to enforce (ex. multiplication of abstraction points, difficulty to monitor, etc). It is thus difficult to assess the effectiveness of measures.

Some other measures were not considered although they could be relevant for specific areas. For example, switching the origin of water for households/tourism and agriculture from surface water to groundwater during the dry season could lower the pressure on surface water during the summer. The technical capacity and the presence of aquifers will define the level at which this measure could be applied to save water within rivers and thus improve the issue of water scarcity during summer.

[98] Except for the use of elasticities on water use.

4 South and South-East England (United-Kingdom)

4.1 Introduction

The UK is often perceived as having an abundant supply of water to meet its needs. Yet water resources in England and Wales are categorized as low in the rating scale produced by the World Resources Institute. The South and Southeast of England are particularly cause for concern, with London rated as 'very low'. Southeast is under the most pressure from increased demand accompanied by low rainfall. The Thames and South East River Basin Districts map closely onto the Thames and Southern regions of the Environment Agency, the body which manages the resources. For the purpose of this case study, both areas will be referred to as River Basin Districts

Combined, these River Basin Districts cover an area of approximately 23 800 km^2, with a total population of 17 400 000. Specifically, the Thames RBD has a total land area of some 13 000 km^2, the Southeast RBD has a total land area of some 10 800 km^2.

Average figures for the Southeast and Thames RBD's from 1995-2003 indicate that the domestic sector (public water supply, including tourism) % of volume abstracted was 5 452 Ml/day. Industries were responsible for 739 Ml/d; Energy (cooling of power plants) was responsible for 5 059 Ml/d, and Irrigation was responsible for 51 Ml/d. Abstraction charges are levied in all licensed abstractors. Charges reflect environmental impacts: use; location and seasonal impacts Tariffs vary from 1.4 Euro to 140 Euro/mio litres[99].

4.2 Water Saving Dynamics in Thames and Southeast RDBs

4.2.1 Household Demand

Water companies in the Southeast expect household demand in the region to increase by about one fifth by 2030. Nearly three quarters of this additional demand is from new housing, but the amount of water each person uses is also expected to rise. Household numbers have increased with smaller households of two persons. At the moment people use about 150 litres of water every day, but in some parts of Southeast this could increase to as much as 200 litres by 2030. It is estimated that 550 000 new houses will be built in the southeast of England by 2016, suggesting that household demand for water is set to increase significantly unless mitigation measures are put in place. Presently, unmeasured charges are based on property rateable values, many of which

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[99] UK Environment Agency (2001a): Water Resources for the Future. Summary Strategy for Thames Region; UK Environment Agency (2001b): Water Resources for the Future. Summary Strategy for Southern Region; UK Environment Agency (2001c): Water Resources for the Future. Summary Strategy for England and Wales; UK Environment Agency (2007b): Identifying areas of water stress. Consultation Document.

have not been reviewed since 1973. No similar data is available for the Thames RBD. The difficulty of metering of flats remains a key constraint in London and environs.

Water Stress is defined as an area where the current household demand for water is a high proportion of the current effective rainfall or, the future household demand for water is likely to be a high proportion of the effective rainfall available to meet that demand. In areas of serious stress, water abstraction is already close to or above acceptable limits. Clearly, the highest levels of water efficiency activities should take place in the areas of serious water stress. The Thames and South East regions are critical (see Figure 14) areas of water stress.

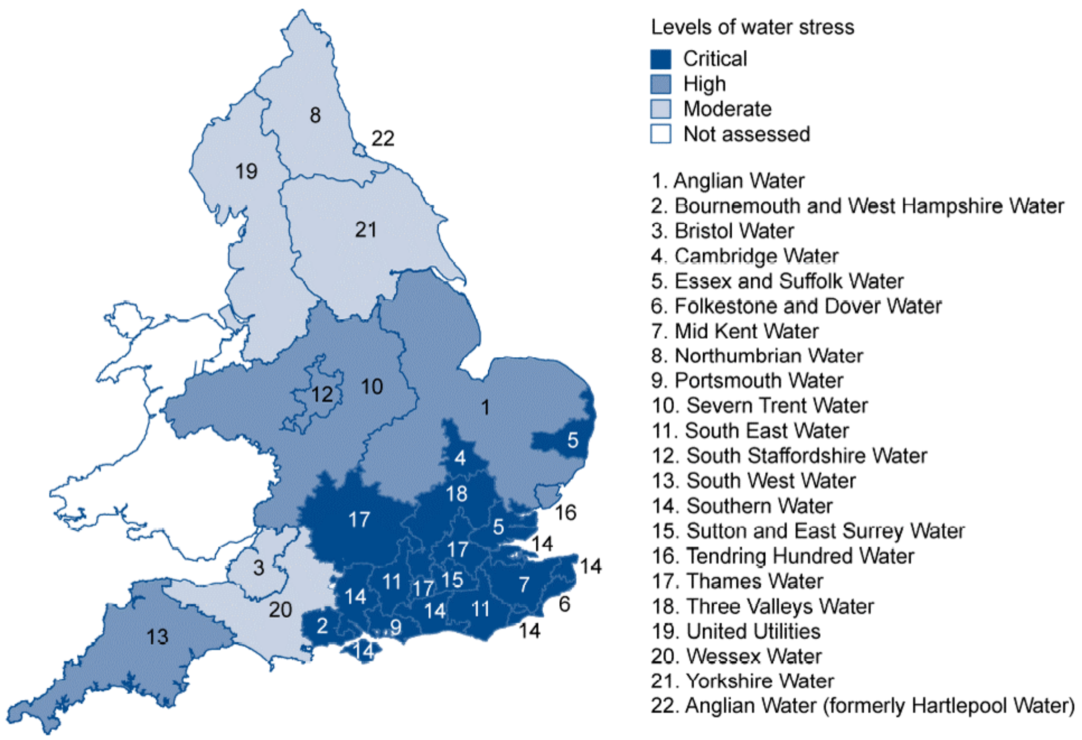

Figure 14: Levels of water stress in different regions of England[100]

The water industry is now taking account of the very latest information on the scale and location of future housing developments, particularly in the Southeast, as well as the most up-to-date information on climate change. The 25 year water resource management plans that all companies prepare will become statutory from 2007. By accelerated metering in seriously water stressed regions such as the Southeast and Thames RBDs, it is estimated that a 10% cut in water consumption is feasible. Smarter charges and innovative tariffs could lead to further savings. A recently set up Water Saving Group have devised an action plan includes targeted action for increasing

[100] UK Environment Agency (2007b): Identifying areas of water stress. Consultation Document.

metering in water stressed areas, and improving the understanding and delivery of metering generally[101].

The group has adopted an action plan covering customer perceptions and awareness, best practice in promoting water efficiency, information gaps, priorities and funding, the policy and regulatory framework; and measuring success, including targets.

Recently the House of Lords Science and Technology select committee recommended making it easier for water companies in water stressed areas to obtain water scarcity status, giving the companies the right to impose compulsory metering[102]. The Environment Agency has previously recommended area-wide metering in the Southeast. Deficiency between supply and demand is not grounds for specifying an area as being water scarce. Water companies also need to show that they had taken steps to meet the deficiency, such as effective leakage management and promoting water efficiency. Water companies have legislative powers to compulsorily meter customers, providing companies to apply for all or part of its supply area to be designated as an area of water scarcity. This designation allows a company to charge customers in that area according to the quantity of water that they use, i.e. to compulsorily meter its customers. To-date only one company, Folkestone and Dover Water Services Limited, has applied for and been granted area of water scarcity status (for 10 years form April 2006). This means that Folkestone and Dover Water are able to compulsorily meter its customers. They expect to meter 90% of their domestic customers by 2015, with the remaining 10% having their bills based on an assessed charge. Other companies have indicated that they administrative burden and the uncertainty associated with the process have been barriers to any applications.

The Water Saving Group's view is that a compulsory change to universal metering is not justified on water resource grounds. Its proposal is that in water stressed areas, companies would be expected to include in their draft water resource management plans a business case for the possible contribution to demand management from compulsory metering. The Environment Agency would identify the areas of water stress. This proposal would incorporate the current provisions allowing compulsory metering in 'water scarce areas' into the water companies' resource management plans.

4.2.2 Metering to reduce demand

Metering significantly reduces people's demand for water by making them aware of the amount they use and pay for. Metered households use 10 to 15 per cent less water than non-metered houses and variable (or sliding scale) tariffs can lead to an extra 10 per cent saving. It is not just new houses that need to be more efficient. Up to 40 per cent of

[101] www.defra.gov.uk/environment/water/conserve/wsg/index.htm

[102] http://www.publications.parliament.uk/pa/ld200607/ldselect/ldsctech/21/2106.htm.

the extra water needed for growth in the Southeast could be supplied from the water saved by installing meters and water efficient fittings in existing housing.

When a customer requests that a meter be installed they have the right to have it installed at no additional costs to themselves, where it is practicable to meter that property. This is known as the ‘free meter option’. The costs associated with fitting the meter are met by the generality of customers. The vast majority of meters have been installed for those opting for a meter or in new homes.

Public perceptions to water metering are increasingly sympathic partly due to the drought in the Southeast that started in 2004 and the impact of which continues into 2007. However, detailed attitudes to metering are mixed. It is popular with households who use relatively low amounts of water, particularly where the unmeasured alternative (if it exists) is expensive. Single people or couples without children in properties with relatively high rateable values tend to find metering an attractive financial option, which those that use large amounts of water, such as those with large families and large gardens might not.

Metering Costs/Benefits

The cost of fitting meters in the Southeast is higher than the national average (£194 for optional metering in England and Wales) due to higher wage costs and greater density of more ‘complex’ fits (e.g. flats or properties with shared supply pipes). Companies in the Southeast tend to fit mainly external meters. External meters are generally more expensive to fit, as they involve the creation of an external meter space (‘boundary box’), but they are generally seen as cheaper to read on an ongoing basis. There is no distinguishing between compulsory metering and metering on change of occupancy – they both considered to be ‘selective’ metering. For ‘selective’ metering, average reported costs are £237 outside the Southeast with an average of around £251 in the Southeast[103]. According to Baker (2006)[104] mart meters and tariffs will have the largest benefit-cost potential in the Southeast, during peak hours/seasons and during droughts. If metering rates are to be rapidly progressed, government, water companies, the regulators and consumer groups need to fully evaluate and communicate the net benefits of introducing smart meters as a matter of urgency. The water sector should also work with other utility sectors to share understanding of how meters can best influence the consumption behaviour of consumers and how best to exploit the potential opportunities for multiutility smart metering.

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[103] OFWAT (2005): Information on water metering, water efficiency and water infrastructure costs. www.ofwat.gov.uk/aptrix/ofwat/publish.nsf/AttachmentsByTitle/meteringcosts030405.doc/$FILE/metering costs030405.doc.

[104] Baker, W. (2006): Smart tariffs and smart metering: The economic view. Presentation given to the Global Smart Metering Summit, London, 30 June. Available at http://www.nera.com/image/EVT_WaterSummit_1247.pps

Meter installation costs are the largest component of costs. Installation costs can be reduced through economies of scale derived from installing the boundary box during the mains rehabilitation process. Intelligent/smart meters can reduce reading costs and facilitate greater water savings. The asset life of meters is specified by each water company in their data returns and the asset life of the boundary boxes is assumed to be 30 years. Meters have to be replaced at periodic intervals. Currently the UK water industry utilizes predominately mechanical rotary piston meters[105].

4.2.3 Water appliance labeling and related systems to reduce demand

Water appliance labelling and tax incentives on water efficient goods will also play a part in household demand management. Nevertheless, there is a lack of standardized labelling systems for water. Low awareness and interest in water conservation, particularly since rainfall is perceived to be plentiful, is also prevalent. In some cases, the purchasing decision chain maybe a factor, with plumbers rather than householders playing the key role in selecting household appliances and household fittings – this suggests a wider set of actors, rather than householders alone should be consider when designing schemes.

Installing grey water and rainwater systems requires a certain level of behavioral change to adapt to these new systems. Whilst these are suitable for new build, such systems are less feasible for existing buildings due to the cost and difficulties of retrofitting. There appears to be little data available on consumption and savings potential in existing households in relation to water, it is therefore difficult to establish an overall level of savings. Although in-house recycling of domestic greywater from baths, showers and washbasins for toilet flushing has been identified as a potential way to reduce household water demand, nevertheless, there are few, fully tested examples.

Water recycling systems are currently too complicated and expensive for single houses, but commercial and community scale systems are becoming more cost effective. The potential for water efficiency savings within the existing housing stock in Southeast was examined and it concluded that around 65 Ml/d could be saved through large-scale water efficiency retrofit schemes. The amount of waste water that houses produce is largely determined by the amount of water used. Any water use efficiency measures, like grey water recycling and lower water consumption, will reduce the volume of water that foul sewers and Sewage Treatment works have to cope with, and save money. The pollutant load coming from each household would stay about the same.

Studies have shown that the highest water savings come from combined implementation strategies. Compulsory metering combined with fitting of variable flush retrofit devices and subsidising the end of life replacement of toilets with low flush models returns yields of 77.2 Ml/d (+/-25.3) for 136 p/m^3 (+/-39). The same scheme, but with metering on

[105] Goldley, A, Mobbs, P; Davey, A (2007): Cost benefit analysis of metering policies. Public Summary Report. WRc/Porfolio, Report No. P7381.

change of occupancy, can save 31.9 Ml/d (+/-10.5) for 115 p/m^3 (+/30). Savings from compulsory metering, combined with a range of low water use fittings, were just as high but cost more: 77.5 Ml/d (+/-25.8) for 162 p/m^3 (+/-49). Low use fittings combined with metering on change of occupancy is estimated to save 22.4 Ml/d (+/-6.6) for 150 p/m^3 (+/-42)[106].

Probabilistic modelling using a Monte Carlo simulation estimates that there is a 95 per cent chance of achieving savings of approximately 65 Ml/d from each of the combined schemes when implemented with compulsory metering and a 75 per cent chance of achieving approximately 70 Ml/d. The relatively high savings from these schemes are based on the assumption that households switching to a metered supply will be more interested in water efficiency. Metering on change of occupancy may be more likely as compulsory metering currently depends on applying for water scarcity status.

Improving water efficiency in existing homes can offset increased demand in growth areas like Ashford and the Thames Gateway. Increase in demand caused by these growth areas is predicted to be around 50 – 70 Ml/d, which is less than the potential demand management savings from implementation of combined strategies. The total increase in demand for the entire Southeast region is estimated to be approximately 160 Ml/d by 2015. So, introducing the combined strategy measures in existing homes could reduce this increased consumption by almost 50 per cent.

The results show that water savings increase significantly with only a small increase in cost if full subsidies and free installation are provided as part of the ‘package’. This is because greater incentives encourage more people to take up the schemes, which increase savings. Also, up front costs are discounted over the life of the scheme. The implementation of individual demand management measures at a local level is likely to achieve limited savings. However, compulsory metering is estimated to provide useful savings in water resource zones with limited available resources, particularly if combined with water efficiency measures such as low use fittings or toilet replacement/retrofit. The combined implementation schemes can also achieve significant savings even at resource zone level. Significant uncertainty remains around many of the inputs used for calculating scheme savings. This uncertainty will reduce as new and ongoing studies are completed creating higher confidence levels for the calculation of updated results.

Water appliance labeling and related systems Costs

A recent Southern Water trial WC replacement, calculated potential savings for a retrofit toilet program based on the following assumptions: 2.6 litres/flush saving x 5 flushes/person and day x 2.5 persons/property= 32.5 litres/property/day. Costs were calculated as £10 for the unit plus £10 for fitting based on 1 000 units. This seems optimistic but Southern Water's recent costing exercise came up with £20/WC based on

[106] Environment Agency (2007c): Water Efficiency in the Southeast of England.

66,000 properties. Multihead showers were previously aimed at the luxury market, low cost models are now available and manufacturers see this as a potential growth area[107].

Rainwater harvesting and conservation systems, for example add around £2 000 per unit for purchase and installation, depending on size. However manufacturers' literature suggests that this could readily be halved if implemented on a communal basis rather than individually. Operating costs are minimal, since maintenance simply requires the user to occasionally clean the filter. For a communal system manufacturers claim the annual maintenance and operation cost is unlikely to exceed £300 per year[108]. Additional UV treatment system costs are £200-1 600 per household. Greywater harvesting using waste water from sink, washing machine and baths costs £3 000 per household, for a 50% reduction in water uses for gardens, toilets, and washing machines[109]. An external water butt for garden use, saving approximately 1% of household water use costs around £20[110].

Behaviour and water saving

For domestic water conservation measures are to succeed, understanding the environmental behaviour and commitment of water users is critical. Researchers in the UK[111] analysed social, attitudinal and behavioural composition of water saving activities using a sample of 1 600 households from Devon. The major findings of their research were:

- Behavioural complexity: it is important to focus on whether an activity is based on consumption or habit.
- Behavioural grouping: based on environmental behaviour and commitment, four types of individuals were identified (committed environmentalist, mainstream environmentalist, occasional environmentalist, and non-environmentalist). These different attitudes should be taken into account when promoting policies. There are also differences between individual actions and actual groups that should be noted.

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107 UK Environment Agency (2003): The economics of water efficient products in the household. Prepared for the Environment Agency by Elemental Solutions.

108 Horton B, (2005): Sustainable homes – the financial and environmental benefits. Science Report SC040050/SR. Environment Agency, Bristol.

109 See WEB_HYDROL_17 Sustainable Solutions to UK water supply-demand issues. UK Groundwater Forum: www.groundwateruk.org.

110 Horton B, (2005): Sustainable homes – the financial and environmental benefits. Science Report SC040050/SR. Environment Agency, Bristol.

111 Gilg, A.; Barr, S. (2006): Behavioural attitudes towards water saving? : Evidence from a study of environmental actions. Ecological Economics. Vol. 57, no. 3, p. 400-414.

- Lifestyle types: analysis of the socio-demographic data and the reported attitudes revealed that social situation and attitudes play a very important role in determining behavioural commitment.

4.2.4 Increase capacity to meet demand

Seven large-scale water storage facilities are being considered for the Southeast, including five new reservoirs and increasing capacity at three existing reservoirs. It takes a long time for reservoirs to be built and they are expensive and are subject to environmental impact management. Clearly there remains significant scope for capturing and storing more water through reservoir development, particularly as winters become wetter. The WRSE report (2004)[112] identified five proposed PWS reservoirs in the Southeast:

- An Upper Thames Reservoir by 2019/20;
- Enlargement of Bewl Reservoir by 2014/15;
- Broad Oak Reservoir by 2019/20;
- Clay Hill Reservoir by 2014/15;
- Havant Thicket Reservoir by 2020/21;

The twin track approach is already being used, but more emphasis needs to be put on using water efficiency measures to reduce demand rather than relying on new supplies. This will mean that fewer large, new resource schemes will be needed, reducing both economic and environmental costs. About a third of the water we use in our homes does not need to be treated to drinking water standards because it is used for flushing toilets or in the garden.

Costs of increasing reservoir capacity

Each new reservoir cost approximately £500 million each[113], although this is a one off cost. The largest of the proposed reservoirs is Abington in Oxford with a cost of £1 billion, providing an estimated 150 Bl and 350 Ml/d[114]. Reservoirs provide a relatively reliable water resource, with relatively low operating costs. A major concern in reservoir planning is gaining the acceptance of local communities who can sometimes views reservoirs as a 'blight' on the landscape. RSPB estimates the avoided infrastructure costs of new water resource capacity (i.e. reservoir costs) by reduction in average water

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[112] WRSE Group (2004): A Contribution to Preparation of the South East Plan. Water Resources in the South East Group

[113] EFRAC (2004): Evidence given to the Environment, Food and Rural Affairs. Committee on Climate Change, Water Security and Flooding, Evidence 9, Question 19.

[114] See: WEB_HYDROL_17 Sustainable Solutions to UK water supply-demand issues. UK Groundwater Forum: www.groundwateruk.org (last checked on 13.07.2007).

consumption. Reduction in water use of 15% to 40%, gives the avoided infrastructure costs of between £111- 739 per household[115].

4.2.5 Businesses

What is lacking in the other sectors is at least part developed in the business sector, not least because most non-household customers are already on a meter. Envirowise offers free advice to UK businesses on ways to increase profitability and reduce environmental impact and has a programme on water efficiency. Envirowise is now working closely with around 100 companies to support them make savings that have already been identified and participants have reported reducing water consumption by as much as a third.

The Enhanced Capital Allowance (ECA) scheme offers tax relief for businesses to invest in products that save water or improve water quality. The ECA maintains a Water Technology List of products that qualify. Companies can claim 100 per cent tax relief for capital costs against taxable profits for the period of investment, providing an incentive to companies to invest in water saving technologies, and an incentive for manufacturers to develop more innovative products. The technologies that currently appear on the Water Technology List are as follows[116]:

- cleaning in place equipment;
- efficient showers;
- efficient taps;
- efficient toilets;
- efficient washing machines;
- flow controllers;
- leakage detection equipment;
- meters and monitoring equipment;
- rainwater harvesting equipment;
- small scale slurry and sludge dewatering equipment;
- efficient membrane filtration systems;

Key water saving can result from low cost changes to toilets, showers urinals etc. Potential savings at industrial sites are harder to estimate as they are process specific. Table 20 below shows the average that you can expect to save for different types of efficiency measures.

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[115] Dickie, I. (2005): Resource Savings and Ecohomes. RSPB Discussion Paper, September 2005

[116] See: www.eca-water.gov.uk (last checked on 13.07.2007).

Table 20: Water saving potential for different water efficiency measures in the industry sector[117]

Efficiency measure	Percentage of water saved
Closed loop recycling	90%
Closed loop recycling with treatment	60%
Automatic shut-off	15%
Countercurrent rinsing	40%
Spray/jet upgrades	20%
Reuse of wash water	50%
Scrapers	30%
Cleaning in place (CiP)	60%
Pressure Reduction	Variable
Cooling tower heat load reduction	Variable

A project commissioned by the BOC Foundation, Environment Agency, Corus Group plc and Wales Tourist Board, aimed to identify potential savings from water efficiency in the hotel industry and to provide practical assistance in reducing water consumption. The project sought to raise awareness of water efficiency in the hotel sector by providing a benchmark for water consumption. The project ran from June 2000 until April 2003. Eight hotels of various sizes were involved. Each hotel was sub-metered, with an average of 10 meters used in each establishment. These targeted specific activities such as kitchens and some individual appliances. Water -use and occupancy were monitored for 24 months.

Half way through the project, a package of water efficient devices was supplied and fitted at each hotel. This was done free of charge, thanks to grant funding from the Wales Tourist Board and a number of private sector sponsors. Devices included infra-red controls, waterless urinals and spray taps. To see how efficient the various devices were, they compared the use of water per year, per guest over the two-year period. Variables such as leak detection and increased amenity were taken into account.

Overall water use fell by between 15% and 58% per guest per year. This was based on a combination of water-saving measures, and saved up to £1 600. One hotel reduced its

[117] Envirowise (no year): Water Account Pocket Notebook.

total water-use by 33% following the installation of one type of water-efficient device. Another hotel saved 300m^3 per annum through leak detection and repair alone[118].

4.2.6 Power Generation and Energy

Power generation is a significant use of water in England and Wales, with water primarily used for cooling. New power stations generally use less water, with some being air cooled. Hydropower resources are generally concentrated outside of Southeast and Thames RBDs and therefore will not be covered here in detail. Afforestation or a major commitment to new crops for bio-fuel could also have implications for water resources management in the RBDs.

The process of abstracting, transporting, and treating water uses energy and thus produces carbon emissions. On average, 1 Ml of water requires 468 kWh to supply, producing 209 kg of CO2, while 1ML of wastewater requires 437 kWh to treat, producing 195 kg of CO2. These values will vary depending on the source of water and the amount of pumping and treatment involved.

4.2.7 Agriculture

The most significant use of water by the agricultural sector is spray irrigation. This is a highly consumptive use of water with virtually no return discharges to the river system. In some locations, peak day spray irrigation demand can exceed that for public water supplies. Because it is concentrated in summer months, and will be particularly high in periods of exceptionally low rainfall, the demand for water for irrigation can have a particular impact at a time of the year when flows are at their lowest.

Irrigation in England is concentrated in East Anglia, parts of the midlands and the Southeast. The most important irrigated crops are potatoes, sugar beet, root vegetables and fruit. Currently, about 30% of UK wheat is grown on drought-prone land and drought losses are on average 1-2 t ha-1, which costs £40 M per year. This means that even in years with ‘normal’ rainfall, potential yield and grain quality are affected by insufficient water at some time during crop development.

Unreliability of abstraction supply can have a significant impact on the quality and yield of the crop, with farmers potentially incurring significant reduction in crop value. Although this has a direct effect on the economic viability of the individual farm, the implications are more far-reaching with indirect impacts on rural employment and the national balance of trade.

In many parts of the country farmers are unable to obtain new spray irrigation licenses for summer abstraction, and are encouraged to invest in winter storage reservoirs. Over

[118] See: http://www.environment-agency.gov.uk/subjects/waterres/286587/1332197/746671/995746/?lang=_e# (last checked on 13.07.2007).

the past 15 years the number of winter abstraction licenses has increased, with many farmers investing in relatively low-cost reservoirs that take advantage of natural clay soils as linings. However, in other parts of the country, farmers have had to build bunded and lined reservoirs.

Supermarkets and food processing firms have extended their influence over all areas of on farm decision making, through development of farm assurance schemes and integrated crop management protocols. In this context, farmers have limited flexibility to incorporate water efficiency measures into their farm management practices.

Apart from spray irrigation there is a number of other uses of water on the farm, including animal watering, dilution of chemical sprays, vehicle washing, cleaning of yards and specialists diary equipment, and food preparation. Farmers draw on public supplies and direct abstraction from rivers and groundwater. To-date limited attention has been paid to quantifying these water uses.

Large-joint schemes requiring substantial pipework and pumping are unlikely to be economic; therefore agricultural demand for water will remain essentially a matter needing local solution. Much of the current demand for irrigation water is in parts of the country where local resources are stretched. Radical changes in cropping patterns as wall as adjustments between traditional food crops have also been proposed, but limited information is available on the resulting water savings.

Genetic improvement programmes aimed at identifying Quantitative Trait Loci (QTL) for improved drought tolerance will eventually facilitate the marker-assisted selection of new lines with improved water use efficiency. However, UK horticulture is unlikely to benefit from these advances for at least a decade. In the meantime, deficit irrigation techniques that improve the efficiency of water use in existing crops grown in areas where water resources are most threatened are an attractive management option. These techniques, which include Regulated Deficit Irrigation (RDI) and Partial Rootzone Drying (PRD), involve applying slightly less water than the plant needs so that mild soil water deficits develop. Roots exposed to the drying soil produce chemical signals that are transported to the shoots where they influence both vegetative and reproductive growth[119]. Agriculture must continue to use available water to best effect. Farmers should consider crop suitability and the possibility of increased winter storage. Future demand for water is volatile due to changes in economic growth and regional policies.

4.2.8 Transfers

Large scale water transfers across England and Wales using a national water grid has been proposed as a solution to the southeast's water shortages, but the Environment

[119] See: Defra Science Project (WU0110). Developing novel water-saving irrigation strategies to produce fruit with more consistent flavour and quality and an improved shelf-life. www.defra.gov.uk (last checked on 13.07.2007).

Agency conclude that there is no new evidence of a need for large-scale transfers of water to south east England from the north of England or from Wales. This would be an extremely costly option and damage the environment[120]. The Agency has estimated that constructing a pipeline to transfer water from the northern Pennines to London would cost at least four times more than the new and enlarged reservoirs planned in the south east. The capital cost of transferring water from a reservoir in the north of England to London would be about £2.4 to £11 million per Ml/day, more than the £1.6 million per Ml/day to provide the same resource from new reservoirs. Water companies' existing plans provide for water supply in south east England to 2025 without the need for large scale transfers. Suggested river transfers between the Severn and Thames' catchments would present significant environmental issues: the acidity of water in the Severn would be expected to be damaging to the ecology in the Thames[121].

The need to ensure adequate supplies of water in dry periods has led to the development of a wide variety of public water supply systems. Options such as icebergs or the transfer of water from overseas were considered but found to be unfeasible. Most feasible options are based on conjunctive use of abstractions from different types of resources. Water from reservoirs, direct abstractions and groundwater can be used at different times to give greater reliability. Larger systems often involve transfer of water, either by pipeline or aqueduct, or within rivers and canals. Many water companies supply water to or receive water from other companies. Such bulk transfers can be treated or untreated water. Concerns about availability at times of scarcity are handled through clear statements in company drought plans and by written clauses within the supply agreement.

Transfers of any type are limited by its effect on the receiving water, in terms of both its flow regime and quality. There are particular concerns associated with transferring water of different qualities, and with the movement of alien species and of plant, animal and fish diseases between different river habitats.

4.2.9 Leakage

Total industry leakage rates have risen over the last three years. In the Southeast, Thames water and Three Valleys Water have failed to reach their leakage targets. Leakage rates may actually be higher than reported, as unmetered per capita consumption may be disguising significant levels of leakage. Ofwat, the water regulator, regulates water companies' leakage through the use of the Economic Level of Leakage (ELL). All companies are required to operate at their ELL. Most companies have really

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[120] See: http://www.publications.parliament.uk/pa/ld200607/ldselect/ldsctech/21/2106.htm (last checked on 13.07.2007).

[121] UK Environment Agency (2001a): Water Resources for the Future. Summary Strategy for Thames Region; UK Environment Agency (2001b): Water Resources for the Future. Summary Strategy for Southern Region; UK Environment Agency (2001c): Water Resources for the Future. Summary Strategy for England and Wales.

increased their efforts and met their annual leakage targets. But some are failing to meet their targets in successive years. A review of how leakage targets are set is likely. For example, Thames Water reports a 1/3 of the water distributed is lost before tap. Thames Water has a reduction target of 725 ML/d by 2010, with £0.5 m/day expenditure.[122] After four years of rising leakage, from 662 Ml/d to 946 Ml/d, Thames achieved its first sizeable leakage reduction at a company level[123]. Water onlu company estimates of leakage in the Southeast (l/Prop/day)[124] for 2004-2005 is 116, down from 147 in 2000-2001. Leakage targets for Water companies only in the Southeast (Ml/d) is 69 each year up to 2009-2010[125]. Expenditure (£k) per Ml/d saved in the Greater Southeast is an average of 3 936[126].

4.3 Economic Instruments – in the case for raising abstraction charges

The UK government consulted/surveyed water users on economic instruments in April 2000[127]. They considered the case for raising abstraction charges above the cost recovery level, either to make abstractors bear the environmental costs of the effects of their abstraction, or to reduce the amount of water abstracted for economically low-value uses. It also considered the potential for trading of abstraction licenses as an effective means of achieving the optimal distribution of water resources within and between different sectors.

4.3.1 Industrial Abstractors

For industrial abstractors in particular, the cost of disposing of used water and effluent at the end of the manufacturing process renders abstraction charges almost insignificant in comparison. As such, an increase in abstraction charges will, generally, have less impact on industrial users than those abstracting for spray irrigation. Of these latter, the smaller farm operations are likely to be the most sensitive to any price increase, although even these users have the ability to absorb a significant price increase, largely due to the low current charging level.

[122] See: WEB_HYDROL_17: Sustainable Solutions to UK water supply-demand issues. UK Groundwater Forum: www.groundwateruk.org (last checked on 13.07.2007).

[123] OFWAT (2005-06): Security of Supply, leakage and the efficient use of water 2004-05 report.

[124] Total connected properties are used as the denominator in these calculations.

[125] OFWAT (2005-06): Security of Supply, leakage and the efficient use of water 2004-05 report.

[126] See: Appendix 2a (Calculations on water company activity on water efficiency), in Every and Foley (2005).

[127] Defra (2000): Economic Instruments in Relation to Water Abstraction. Research Report Prepared for DETR

4.3.2 Spray Irrigators

Modelling of spray irrigators responses to potential charge increases indicates that the price-elasticity of demand is more responsive for charges levied on authorised volumes than for charges levied on actual volumes. This is as might be expected as, in general, authorised volumes are greater than the actual volumes taken, so that reductions in authorised volumes are achievable at little cost. In addition, the response to any charge on authorised volumes will take into account both the productive value of irrigation water and the longer-term asset value which it yields to an agricultural holding. The elasticities found for increases in the price of authorised volumes ranged from 0.18 to 0.31 as prices increased by an effective 1 p/m^3 and 2p/m^3 respectively, while those for actual volumes abstracted ranged from 0.16 to 0.75 for price increases of 10 p/m^3 to 40 p/m^3 respectively. These figures are consistent with other data presented in the economics literature.

As can be seen from the above, large increases in charges are needed to give spray irrigators as a sector the incentive to reduce. Given the significant differences that currently exist between authorised and actual volumes, relatively few abstractors would reduce their licensed volumes below an increase in charges on authorised volumes of 100% (although it must be remembered that this relates only to an average increase in price of 2 p/m^3). Above 100%, 34% of all spray irrigators stated that they would reduce their authorisations. Some small reductions in actual volumes may be made through an increased charge of 5 p/m^3 over current charges, however, significant reductions would only occur at increases of 50 p/m^3 or more.

The types of measures that would be adopted in reaction to charge increases are reductions in the area of land under irrigation and investment in water saving measures. However, some spray irrigators indicated an inability to respond to changes in charge rates as they are constrained by the need to produce high quality products, have controls imposed on the timing and volumes of water that they apply to crops or, for sports clubs and racetracks, by the need to ensure safety.

Similarly, demand for amenity uses is greatest in the summer, with respondents indicating that they are unable to reduce water use either because water is essential (e.g. for fish ponds) or because water saving measures have already been introduced.

In summary, although spray irrigators (particularly small farmers) are likely to be more sensitive to relatively small increases in abstraction charges than, for example, industrial users and water supply companies, these latter categories of abstractors are on the whole unlikely to respond to increases in charges unless those increases are significantly higher than the current charge rates; however, a doubling of charges may eliminate some of the lowest value uses of abstractions.

4.3.3 Industry and Aggregates

The varying nature of industrial users is such that it is difficult to provide a summary for the sector as a whole. However, for most industry types, it is the need to reduce effluent discharges and associated treatment costs that is the driving force behind reductions in water consumption (and hence abstractions). In many cases, reductions have already been made with respondents indicating that further reductions are not currently possible due to the cost of additional investment or the production methods used. Some reductions may be possible, however, with the level of charge increase required being highly abstractor dependent.

4.3.4 Water Companies

There is little scope for reductions in either authorisations or actual volumes due to the need to ensure security of supply. Options that would reduce demand or result in more efficient use of water are under consideration, but these are currently considered too expensive. The water companies were unsure as to the effect increased charges would have on abstractions (authorised or actual), indicating that there may be no reductions or that predictions were too difficult to make. The method chosen for this sector for predicting the likely response is through consideration of long-run marginal costs and average incremental social costs of various supply/demand management options.

In summary, the high charge rates predicted as being necessary to provide abstractors with sufficient incentive to reduce abstractions in line with resource managers' objectives (for reducing authorised volumes and actual abstractions) would not only act as a very blunt regulatory instrument, but also have equity and distributional implications at the sectoral and catchment level. Given the monetary estimates of environmental damage costs calculated using existing methods, charging so as to internalise environmental externalities is unlikely to provide sufficient incentive to abstractors to significantly reduce levels of actual abstractions; thus, although damage costs would be internalised, little environmental improvement would result.

4.3.5 Potential for Trading

Fifty-five percent of respondents surveyed indicated an interest in trading, although most were unable to indicate the volumes or prices at which they would sell or buy. Spray irrigators were generally interested in temporary trading over a period of one year (or less than five years). The prices at which they would be willing to buy and sell water are compatible (between 5 and 10 p/m^3), with the overlap in price suggesting that the development of a market is possible.

Some of the industrial respondents also indicated an interest in trading, with the length of preferred trades being longer-term (1 to 5 years, or greater than 5 years). Prices demanded by industry when selling water are between 10 and 20 p/m^3. Water companies indicated that in some cases, their demand is not met through their existing authorisations and, in such cases, they expressed a desire to purchase additional authorised volumes to ensure continuity of supply. These water companies indicated a general willingness to pay between 5 and 10 p/m^3. Although many respondents were unsure as to their exact behaviour, indicating that the volume available for trade and the price expected depended on the nature of the market at the time of trading, the number of buyers and sellers and the prices that are being offered or demanded are such that markets could, feasibly, develop. The factors considered most important by the respondents in encouraging trading were help in finding a buyer/seller, rapid approval times by the regulating authority, the ability to trade with other sectors, and the reliability of the authorisation in terms of flow related conditions.

In summary, the creation of markets in transferable abstraction rights ought to be feasible in those catchments where there is currently an unmet demand. Rules would have to be developed, however, within a flexible approach to facilitate both very short-term (i.e. within season) trades as well as allowing more permanent longer-term trading; these rules would need to ensure protection against derogation and environmental damages. The report recommended that a mixed approach towards the allocation and of permits should be considered, where this includes examination of the combined use of an initial grandfathering of rights followed by auctioning, for example, or when finding buyers for an authorised quantity up for trade or when existing licenses expire.

4.4 Strategy for water savings per RBD

Key strategies for the Southeast and Thames RBDs in regard to water savings, allowing for resource developments, are summarised in Box 1 and Box 2 below.

Box 1. Presenting water saving strategies in the Southeast River Basin District

Water is a scarce and often over-committed resource in Southeast RBD. There is an aim to recover around 10 per cent of current abstraction across the region. In 1999, abstraction of water for the public supply amounted to some 1 400 million litres a day (Ml/d). Household use accounted for about 60 per cent of this, commercial use just over 20 per cent, and leakage from pipes nearly 20 per cent. In addition, some 600 Ml/d was abstracted directly by industries. Farmers also took around 30 Ml/d for spray irrigation, a relatively small amount but concentrated in the summer months, when river flows are at their lowest. Current and likely future demands in Southeast RBD are dominated by public water supply. Government planners suggest that provision be made for some 380 000 additional houses in the region by 2016. The Southeast region has a complex but less integrated water supply infrastructure than much of the rest of the England. There are some water transfers between these zones within individual water companies, and some supplies go from one company to another, with proposals for more included in our strategy. Some zones have surplus resources and others have existing or forecast deficits. Water companies in the Southeast are currently following their drought plans. Most have imposed hosepipe and sprinkler bans. The Secretary of State has granted Drought Orders to Mid Kent Water, Southern Water, and Sutton and East Surrey Water to further restrict non-essential uses of water. Only the latter has had to be implemented. People responded well to both hosepipe restrictions and the general media campaign to save water. Companies have reported a demand saving of between 5-15%. Drought Order powers if they need to be used, should be used sensitively and progressively. The public supply is there for domestic customers first and businesses second

Strategy for public water supply by 2010

Expected water savings of up to 74 Ml/d, allowing for resource developments of up to 115 Ml/d

- Demand management options including metering and water efficiency measures
- Progressive metering toward 2025 expectations
- Progressive leakage control toward 2025 expectations
- Enhancement of some local source outputs (50 Ml/d)
- Further integration of existing water supply systems (25 Ml/d)
- Bulk supplies and other resource sharing, including potential enhancement of storage by enlarging either Bewl of Darwell reservoirs (40 Ml/d)
- Determine the best use of Swanscombe quarry as an additional or alternative source.

Strategy For public water supply by 2025

Expected water savings[1] of up to 123 Ml/d, allowing for resource developments of up to 47Ml/d

- Demand management options including leakage control, meterting and water efficiency measures for saving at least 30Ml/d
- Increased household metering
- Higher levels of metering in some areas where water is particularly scarce
- Further leakage control, for savings up to 45 Ml/d
- Further water company system integration, optimization and resource sharing

[1] Excludes water savings through maintaining current active leakage control targets

For agriculture, by 2025

- Individual and consortium winter storage reservoirs totaling 15 Ml/d

For industry and commerce, by 2025

- Water use minimization will be promoted

For the environment, by 2025

- Abstraction recovery of 80 Ml/d to 180 Ml/d across the region, where abstraction is damaging the environment

Other options under consideration

- Reuse of effluent currently discharged in to coastal waters
- Potential resource developments of new reservoirs
- Strategic transfer into the region from Thames Region
- Desalination

Other significant uncertainties

- Housing numbers and economic development proposals for the region
- Over abstraction

Box 2. Presenting water saving strategies in the Thames River Basin District

The Basins population density is three times the national average, which means that human needs impose significant pressures on water resources. An average of about 5 000 million litres of water per day (Ml/d) is abstracted from rivers, streams and aquifers within the Basin. Total abstraction in the region amounts to some 55 per cent of effective rainfall. Some 85% of this is for public water supply, and the remainder is abstracted directly by industry and agriculture. Household use accounts for half the water put in public supply, and industry and commerce a little less than a quarter. The rest of the water put into the public supply is largely lost through leakage from the distribution system, a major concern in the region.

Non-public water supply abstractions comprise 700 Ml/d for industry, commerce and agricultural use, including 20 Ml/d for spray irrigation. Principal uses in the region include cooling water for power generation and for manufacturing, process water, sand and gravel extraction, fish farming and cress growing. The quantity of water abstracted for spray irrigation is small, but demand for it is concentrated in summer months, when river flows are at their lowest. Current and likely future demands in Thames Basin are dominated by public water supply. The rate of growth predicted by government planners for the region could lead to 700 000 additional households and a population increase of 800 000 by 2025.

Strategy for public water supply by 2010

Expected water savings of up to 470 Ml/d, allowing for resource developments of up to 340 Ml/d

- Demand management options including metering and water efficiency measures
- Surface water yield improvements (within licence)
- Groundwater developments including London Rising Groundwater, and artificial recharge and recovery of London Basin groundwater
- Indirect effluent re-use for river support (River Lee)
- Infrastructure/outage improvements
- Full take up of bulk transfers.

For public water supply by 2025

Expected water savings[1] of up to 750 Ml/d, allowing for resource developments of up to 590 Ml/d

- Demand management options including leakage control, metering and water efficiency measures
- Combination of abstraction, bulk transfers, new reservoir storage, schemes to improve outage and deployable output, aquifer recharge and recovery.
- Excludes water savings through maintaining current active leakage control targets

For agriculture by 2025 • Promotion of winter storage and on-farm efficiencies
For industry and commerce, by 2025 • Water use minimization saving. Forecast trends across sectors indicate potential opportunities for licence review and re-allocation over the long term.
For the environment, by 2025 • Abstraction recovery of between 185 Ml/d to 350 Ml/d, principally impacting on the Thames (145 Ml/d) and Three Valleys (40 Ml/d)
Other options under consideration • Major new reservoirs • Desalination
Other significant uncertainties • Canal transfer scheme • Alternative reservoir scenarios requiring further investigations of site feasibility and environmental impacts etc. • Resource availability and operational viability of transfer schemes for the River Severn, including potential environmental impacts, in particular resulting from the Habitats Directive. • Increasing pollution risk to groundwater within the urban and fringe areas potentially bringing forward the need for water resource developments.

These two illustrations illustrate how the different river basins and regions of England & Wales have embarked actively on drought and water saving strategies. They also stress the need for integrating measures and sectors in strategies dealing with water scarcity and drought in a comprehensive manner – combining both demand-based management and some supply-based measures[128].

[128] UK Environment Agency (2001a): Water Resources for the Future. Summary Strategy for Thames Region; UK Environment Agency (2001b): Water Resources for the Future. Summary Strategy for Southern Region; UK Environment Agency (2001c): Water Resources for the Future; Summary Strategy for England and Wales. UK Environment Agency (2007b): Identifying areas of water stress. Consultation Document.

5 Plastiras and Smokovo Reservoir (Greece)

5.1 Objectives and Methodology

The case study considers an area with competitive uses of water: domestic water supply, irrigation of an important farm land, energy production and environmental uses all combined with the need to preserve the aesthetic value of two reservoirs.

It aims to illustrate the potential benefits and costs of water saving measures in the domestic and agricultural sector. The measures considered are technical and economic and their results are addressed in a qualitative and quantitative way, when data availability makes it possible.

The case study is structured as follows:

1. **General Context:** A description of the considered hydro-system, its natural characteristics, the existing water supply infrastructure, current water demand per sector and the relevant socio-economic factors.
2. **Water Balance Forecast.** The available previous research results (synthetic rainfall, runoff, evapotranspiration time series) are utilized to estimate the possibility of covering water demands up to the year 2030, demonstrating possible deficits and system failures.
3. **Alternative Water Saving Scenario Identification:** The possibility of implementation of water saving measures is assessed. Benefits and costs of measures are identified and their public acceptance is discussed.
4. **Results and Conclusions**.

5.2 Backround and Hydrosystem Definition

5.2.1 Location

The prefecture of Karditsa is in Central Greece, in the south-western part of the department of Thessaly. Two major reservoirs are found in the area: Plastiras and Smokovo. Their water basins occupy an area of 6 249 km^2. It is basically a rural area with a strong agricultural heritage and orientation.

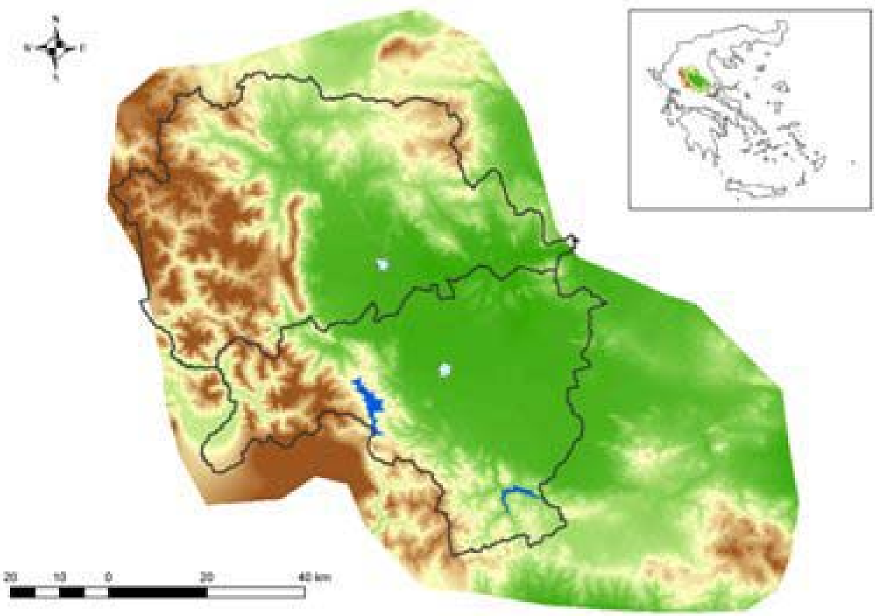

Figure 15: Western Thessaly DTM, Plastiras and Smokovo Reservoirs

5.2.2 Population and Regional Economy

The prefecture Karditsa, according to 2001 census data had 129 000 residents. The prefecture represents 1.2% of the national population and on the other hand 0.9% of the GDP. Between 1991-2001, the population had a small rate of increase, in the order 2.3%. In the area there are twenty Municipalities, with the Municipality Karditsa being the capital of Prefecture, with a population of 37 000 residents. The economy is basically rural, the primary sector accounting for 47.7% of the employment.

Census data for the period 1996-2001 Table 21 demonstrate that while cultivated land almost the same in area, the irrigated part is gradually decreasing (the area for 2001 is 87% of the one for 1996).

The respective agricultural production is given in Table 22, showing an increase in wheat and cotton.

Table 21: Development of cultivated irrigated land (in 1000 m2)

	1996	1997	1998	1999	2000	2001
Total	1 098 530	1 099 601	1 099 615	1 097 624	1 097 684	1 039 328
Irrigated	893 624	866 625	839 048	849 529	812 481	775 803

Table 22: Agricultural Production (tn)

	1996	1997	1998	1999	2000	2001
Tobacco	7 251	6 926	7 044	6 458	6 148	5 860
Cotton	134 799	193 443	186 605	179 154	179 950	194 066
Wheat	29 833	42 307	50 722	46 816	61 545	76 429
Apples	576	542	525	583	564	452
Peaches	139	173	159	78	66	67
Potatoes	4 775	4 657	4 891	4 604	4 707	4 193
Tomatoes	41 975	43 389	47 124	73 099	52 201	38 577
Meat	9 186	8 936	8 465	8 006	8 379	8 126
Milk	36 299	36 063	33 106	30 195	32 131	30 187
Cheese soft	1 822	2 025	1 984	1 968	1 831	1 695
Cheese hard	53	45	55	59	68	74
Eggs (k items)	17 469	18 377	18 178	22 808	21 018	20 201

5.2.3 Climatic conditions and water resources

In the area one can distinguish two types of climate:

- continental climate in the flat region;
- mountainous climate in the western mountainous region.

The medium annual temperature is between 16 and 17°C. Annual rainfall ranges from 550 mm (Station Tirnavos – law elevation) and 1 142 mm (station of Moyzaki – high elevation). The rainiest months are from October to January, while the driest are July and August.

The surface water potential for the region has three major components (simulated in Figure 17):

- an extensive stream and river network·(Peneos being the major river and Kaletzis Pamisos, Lithaios, Farsaliotis and Enipeas being the major streams);

- a combined system of artificial reservoirs: Plastiras and Smokovo;
- a complex network of irrigation and drainage canals.

The operational characteristics of the two reservoirs can be found in Table 23.

Table 23: Characteristics of Plastiras and Smokovo Reservoirs.

	Plastiras	Smokovo
Net Storage Capacity (hm^3)	286.3	209.2
Installed Power (MW)	129.9	15.0
Run off basin	161.3	376.5

Plastiras Dam was constructed in the 1956-62 period for the purpose of hydroelectric energy production and irrigation of Thessalian plain. Progressively, the energy character of Dam has been downgraded in favour of irrigation and drinking water supply. In the past few year there has been particular development in the amenity value of the reservoir.

Smokovo Reservoir has been recently has been completed (operation began in 2002). Its purpose is irrigation of 260 000 acres in the Prefectures of Karditsa, Fthiotida and Larissa, drinking water supply of settlements and groundwater recharge.

Groundwater is overexploited in the area (basically for irrigation) with adverse effects to its levels and quality (especially in the region of Sofades)

5.2.4 Water Uses

Drinking Water Supply

The main source of drinking water supply in the Prefecture Karditsa is Plastiras Reservoir. Water is treated and distributed through the following networks:

- Karditsa area network , length 8 200 m, which serves exclusively the city of Karditsa;
- Northern network, length 46 200 m, that serves 14 Municipal Departments;
- Eastern network, length 70 630 m, that serves 22 Municipal Departments.

The network is old (most of it was constructed 40 years ago). Water consumption is very high in the city of Karditsa, reaching 700 L/capita/day in the summer period. According to local authorities this is mainly attributed to:

- Extensive leaks;
- Bad irrigatory practices (in gardens etc) in the summer period.

Extensive network rehabilitation works are planned for the next 5 years.

Settlements not served by the aforementioned network use boreholes for water supply.

Groundwater quality is often found unsuitable due to high nitrate concentrations.

Irrigation

Irrigatory needs are covered by the two reservoirs and private boreholes:

- Roughly 150 000 acres of cultivated land are irrigated from Plastiras Reservoir.
- 7 000 private and 150 communal boreholes operate in the case study area.

The Smokovo Reservoir covers today the irrigation needs of 55 000 acres of cultivated land and in its full capacity it will serve 252 600 acres.

Production of energy

As already mentioned Plastiras' primary purpose was hydroelectric power generation. It produces 220 GWh annually. Water leaves the reservoir via a tunnel, 2 625 m in length and 3.5 m in diameter. After turbine exit, water is stored in an equilibrium lake of a 600 000 m^3 volume and from there distributed to users.

It should it is pointed out that the progressive change of purpose of the reservoir has resulted in a progressive change of the water abstraction monthly distribution: from uniform throughout the year to almost restricted in the summer period.

Environmental Considerations

When considering Water Management in the region one should keep in mind the following environmental restrictions:

Plastiras Reservoir:

- Water levels should be mantained over +782 –784 m (quality problems are identified under these levels);
- Water level should fluctuate as less as possible (aesthetic consideration);
- Smokovo Reservoir;
- A distinct minimal environmental flows must be maintained after the dam (Table 24).

Table 24: Minimal environmental flow after the dam in Sofaditikos River

Month	According to the EIA for the Project
April	0.36
May	1.76
June	2.43
July	2.93
August	1.84
September	0.71
Total	10.00

5.2.5 Consumption Needs

Irrigation Needs

Data from recent studies estimate the following irrigation water demands per agricultural area (node):

Table 25: Monthly irrigation needs per node (hm^3)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Xironeri	0	0	0	0	0.005	0.206	0.366	0.422	0.413	0	0	0
Mesenikolas	0	0	0	0	0.033	0.129	0.259	0.238	0.186			
Selana	0	0	0	0	0.012	7.714	13.057	15.337	13.930			
Triakala	0	0	0	0	0.141	11.180	19.546	20.604	17.825			
Karditsa	0	0	0	0	0.023	9.068	16.641	19.345	18.504			
Agiopighi	0	0	0	0	0.000	2.630	4.190	4.890	4.230			
Palamas	0	0	0	0	0.007	11.274	16.367	21.382	21.768			
Sofades	0	0	0	0	0.006	4.473	6.377	8.255	7.999			

Drinking water needs

Monthly drinking water needs covered by the Reservoir System are given in Table 26.

Table 26: Monthly drinking water needs (hm^3)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Karditsa Complex	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
East Karditsa Settlements	0.33	0.33	0.512	0.512	0.512	0.512	0.619	0.512	0.512	0.33	0.33	0.33

From the above it is evident that irrigation water demand accounts for 93% of the total yearly estimations, temporally dominating in the dry summer months (Figure 16).

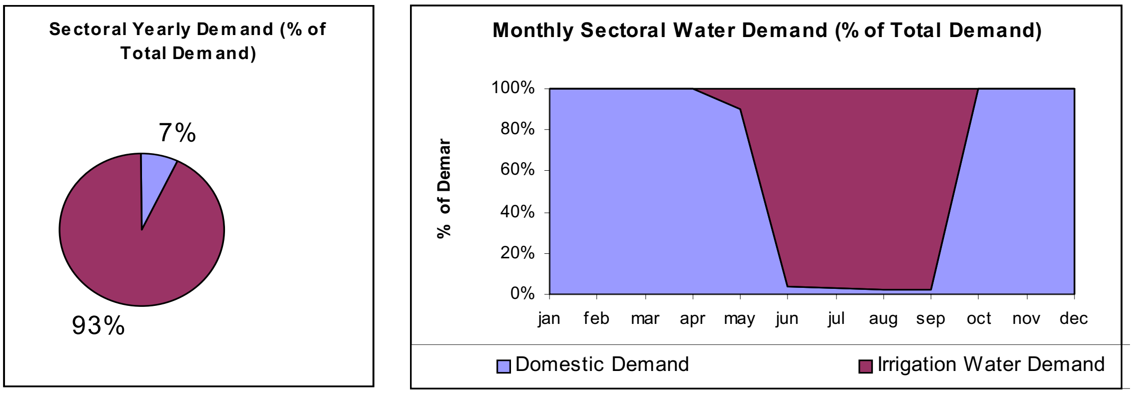

Figure 16: Domestic and irrigation water demand as percent of the total water demand per year (left) and per month (right)

5.3 Water Balance Projections –Business as usual Scenario

In order to estimate future water demand coverage by surface and groundwater sources in the case study area, the recently developed HYDRONOMEAS software was used (Hydrosystem Operational Optimisation). The simulation of the hydrosystem is given in Figure 17 where:

- The local hydrographic network is modelled as inlet nodes;
- Irrigation, drinking water consumption areas and environmental restrictions are modelled as outlet nodes and are given "coverage" priorities (Table 27) Available water volumes will first be used in priority 1 uses, then 2 and so on.

Table 27: Synopsis of hydrosystem objectives and restrictions

Targets	Category	Priority
Water supply Karditsa	Water supply	1 or 3
Ecological flow	Environmental flow	1
Irrigation Karditsa	Irrigation	2
Water supply East Karditsa	Water supply	3
Minimum Water Elevation in Plastiras resevoir	Environmental flow	3
Irrigation Xynoneri	Irrigation	5
Irrigation Agiopigi	Irrigation	5
Irrigation Mesenikolas	Irrigation	5
Irrigation Palama	Irrigation	5
Irrigation Sofadon	Irrigation	5
Irrigation Selana	Irrigation	5
Irrigation N. Trikalas	Irrigation	5
Irrigation Smokovo	Irrigation	5

In this first scenario, current water consumption needs are considered constant and the minimum water level of Plastiras Reservoir is set at +784 m but as a third priority.

Running the simulation up to the year 2030 gave the following results (Table 28):

Table 28: Business as usual up to 2030

Targets	Category	Priority	Yearly failure probability	Mean annual Water Deficit in hm3
Water supply Karditsa	Water supply	1	0.000	0 (0.332)
Sofaditikos Ecological flow	Environmental Restriction	1	0.000	0
Irrigation Karditsa	Irrigation	2	0.000	0 (2.666)
Water supply East Karditsa	Water supply	3	0.042	0.014 (0.014)
Minimum Water Elevation in Plastiras resevoir	Environmental Restriction	3 (1)	0.167	0.969 (0.375)
Irrigation Xynoneri	Irrigation	5	0	0
Irrigation Agiopigi	Irrigation	5	0	0
Irrigation Mesenikolas	Irrigation	5	0	0
Irrigation Palama	Irrigation	5	0	0
Irrigation Sofadon	Irrigation	5	0	0
Irrigation Selana	Irrigation	5	0	0
Irrigation N. Trikalas	Irrigation	5	0	0
Irrigation Smokovo	Irrigation	5	0.417	2.960 (2.960)

It is evident that future water demands, even under optimised operation conditions and with limited environmental considerations, cannot be fully covered, with significant target failures and water deficits that reach a mean annual value of 3.9 hm^3.

It is noted that if the system is operated in way that environmental targets are met (values in parenthesis), then water deficits for the remaining water supply and irrigation uses rise up to 6.3 hm^3 per year. Irrigation of Karditsa and Smokovo will suffer 5.6 hm^3 mean annual water deficit. Recent studies estimate an agricultural income of 0.06 – 0.15 Euro / m^3 of water. So system failures might be translated to a 7.8 – 18.5 M Euro loss of agricultural income for the projection period.

5.4 Water Saving Measures, Benefits and Costs

5.4.1 First Water Saving Scenario: Fulfilling Environmental Targets and Implementing Technical Water Saving Measures (conservative implementation)

In this first scenario the following are assumed:

- Minimum water level of Plastiras Reservoir is set at +786 m, as a 1st priority. This water level ensures a better water quality, since there is now strong scientific evidence that lower levels increase chlorophyll-a concentrations in the reservoir. At the same time, according to a recent public research undertaken in the area, it enhances its aesthetic value.
- Drinking water consumption is reduced by 20% as a result of leakage reduction (rehabilitation of aged network infrastructure) and partial implementation of household water saving devices (eg low flow toilet flushes). It is noted that for the municipality of Karditsa a significant gap of 8.3 hm^3 is noted between the yearly volume of water distributed and the volume of the water actually billed.
- Irrigation water demand is reduced by 20% as result of leakage reduction in conveyance systems

Running the simulation up to the year 2030 gave the following results (Table 29):

Table 29: Fulfilling environmental and water saving targets for up to the year 2030

Targets	Category	Priority	Yearly failure probability	Mean annual Water Deficit in hm3
Water supply Karditsa	Water supply	1	0.083	0.096
Sofaditikos Ecological flow	Environmental Restriction	1	0.000	0
Irrigation Karditsa	Irrigation	2	0.042	0.292
Water supply East Karditsa	Water supply	3	0.000	0
Minimum Water Elevation in Plastiras reservoir	Environmental Restriction	3	0.042	0.052
Irrigation Xynoneri	Irrigation	5	0	0
Irrigation Agiopigi	Irrigation	5	0	0
Irrigation Mesenikolas	Irrigation	5	0	0
Irrigation Palama	Irrigation	5	0	0
Irrigation Sofadon	Irrigation	5	0	0
Irrigation Selana	Irrigation	5	0	0
Irrigation N. Trikalas	Irrigation	5	0	0
Irrigation Smokovo	Irrigation	5	0.000	0

It is evident that a conservative implementation of technical water saving measures can significantly improve the water balance picture for the area, reducing possible water deficits to 0.44 hm^3 (93% reduction).

Possible Benefits and Costs

Benefits for domestic water users basically include a lower water bill when using water saving devices and appliances within the household. A conservative 10% reduction in their water demand will lead to 2.3 hm^3 of water saved per year and an average of 3.2M Euro of annual savings for the population. A lower energy bill can also be expected when low volume washers are used.

On the other hand, costs for domestic water users include the market costs for water saving devices or appliances. For example installing low flow toilet flush at a 150 Euro cost is expected to save up to 45 l/household/day, which can be easily translated to 22 Euro savings per year (with an expected payback period in the range of 7 – 8 years), considering current, average domestic water tariffs.

For the local water supply service benefits include:

- Reduction of water treatment costs, when environmental targets are met (better quality of raw water).
- Reduction of future capital costs for the capacity increase of the water supply infrastructure. For example the realigning of the Aspros stream in order to enhance flows into the Plastiras reservoir has been preliminary estimated with a cost of 39 M Euro.
- Reduction of abstraction and energy costs. As already mentioned aged pipes are the cause of extensive leakages. A recent study for network rehabilitation, control and extension in the city of Karditsa had an estimated investment cost for the company of 10 M Euro. However, if it is conservatively assumed that the leakage reduction program accounts for a 10% reduction of water demand (2.3 hm^3 per year when the reported gap between distributed water and billed water is 8.3 hm^3) then a ten year pay-back period can be expected, when summing up benefits from reduced abstraction, treatment and distribution costs (assumed to be 35% of the average water tariff).

The implementation of water saving measures in agricultural water conveyance networks will produce the obvious benefit of a lower failure probability, which is connected to lost productivity. When comparing the business as usual scenario and this first water saving scenario, the latter secures annually an average of 4.8 hm^3 for irrigation purposes. This could be translated to 0.3 M Euro to 0.7 M Euro yearly increase of income for cultivators. The project capital costs are related to the local irrigation/reclamation unions. Currently there are no case specific cost estimations for such an investment. When considering the 0.05 Euro/m^3 calculated for France it is noted that it is significantly less than the estimated agricultural income loss, that ranges from

0.06 to 0.15 Euro/m^3 for the case study area.

5.4.2 Second Water Saving Scenario: Fulfilling Environmental Targets and Implementing Technical and Economic Water Saving Measures

In this second scenario the following are assumed:

- Minimum water level of Plastiras Reservoir is set at +786 m as a first priority
- Drinking water consumption is reduced by 20% as a result of leakage reduction (rehabilitation of old network infrastructure) and partial implementation of household water saving devices (eg low flow toilet flushes).
- Drinking water consumption is reduced by another 10% as a result of water pricing as a demand management measure. The Municipality of Karditsa has a rising block tariff structure and there is considerable margin for a price increase. According to the available data of the Union of Greek Municipal Water Supply Companies, for Karditsa the average bill per m3 is estimated to be 1.35 Euro, below the calculated 1.58 Euro average in other Greek municipalities, with similar population. Meanwhile the average tariff per m3 for the nearby city complexes of Larissa and Volos is 1.65 Euro.
- Irrigation water demand is reduced by 20% as a result of leakage reduction in conveyance systems.
- Irrigation water demand is reduced by another 10% as a result of water pricing or a conservative shift from the cultivation of cotton to the cultivation of wheat or the implementation of water efficient irrigation techniques (eg shifting from furrow irrigation to pivot irrigation could save up to 30% of the water consumed). It is noted that a recent study in the nearby water basin of Peneos indicated that a 50% shift from the water consuming cultivation of cotton to the less consuming cultivation of wheat will lead to a 40% reduction of irrigation water demand.

Running the simulation up to the year 2030 gave the following results (Table 30).

Table 30: Implementing technical water saving measures up to the year 2030

Targets	Category	Priority	Yearly failure probability	Mean annual Water Deficit in hm^3
Water supply Karditsa	Water supply	1	0.042	0.031
Ecological flow	Environmental Restriction	1	0	0
Irrigation Karditsa	Irrigation	2	0	0
Water supply East Karditsa	Water supply	3	0	0
Minimum Water Elevation in Plastiras reservoir	Environmental Restriction	1	0	0
Irrigation Xynoneri	Irrigation	5	0	0
Irrigation Agiopigi	Irrigation	5	0	0
Irrigation Mesenikolas	Irrigation	5	0	0
Irrigation Palama	Irrigation	5	0	0
Irrigation Sofadon	Irrigation	5	0	0
Irrigation Selana	Irrigation	5	0	0
Irrigation N. Trikalas	Irrigation	5	0	0
Irrigation Smokovo	Irrigation	5	0	0

It is evident that a combined implementation of technical and economic water saving measures can improve even further the water balance picture for the case study area, reducing possible water deficits by 95%.

Possible Benefits and Costs

When considering the cumulative effects of a 20% reduction of domestic water demand because of household water saving devices and increase in water tariffs assuming a 25% increase for the mean water tariff (from 1.35 Euro/m^3 to 1.68 Euro/m), the following are noted:

- 4.6 hm^3 are saved yearly because of reduced domestic consumption
- When compared to the «business as usual scenario», the domestic population covers its estimated consumption needs with no differential cost (31.5M Euro). For a more optimistic water saving assumption of 25% reduction in demand the population could save 2.0 M Euro per year. However if the economic measures have no significant result or no result the differential cost for the domestic population rises up to 4.0 M Euro per year.
- Installing a low flow toilet flush at a 150 Euro cost will have a payback period in the range of 6 years, considering increased domestic water tariffs.

An obvious additional benefit for the local water supply service is an increased income of 2.5 M Euro when comparing

- water production reduced only by 10% and sails with current tariffs

- water production reduced by 20% and sails with tariffs increased by 25%

When considering long standing agricultural water pricing methods in the area and in the country as a whole (pricing by size of irrigated parcel), the implementation of economic measures in addition to technical ones (e.g. metering and increase of agricultural water tariffs) is associated with costs for the users:

- Meter equipment costs
- Increased water bill costs
- Possible loss of productivity (because of a reduced consumption due to financial reasons)

This is a measure that is expected to have a very low public acceptability.

On the other hand if an improvement of application efficiency is considered (change from furrow irrigation to pivot irrigation) for almost 35% of the irrigated area (35 000 hectares) leading to a total 10% reduction of the irrigation demand the following are noted:

Assuming an average 250 Euro per hectare, 8.75 M Euro as a total cost is calculated. When compared to the 1st water saving scenario, each year 0.292 hm^3 are additionally left available for the farmers. This could be translated to a cost 1.32 Euro per cubic meter saved.

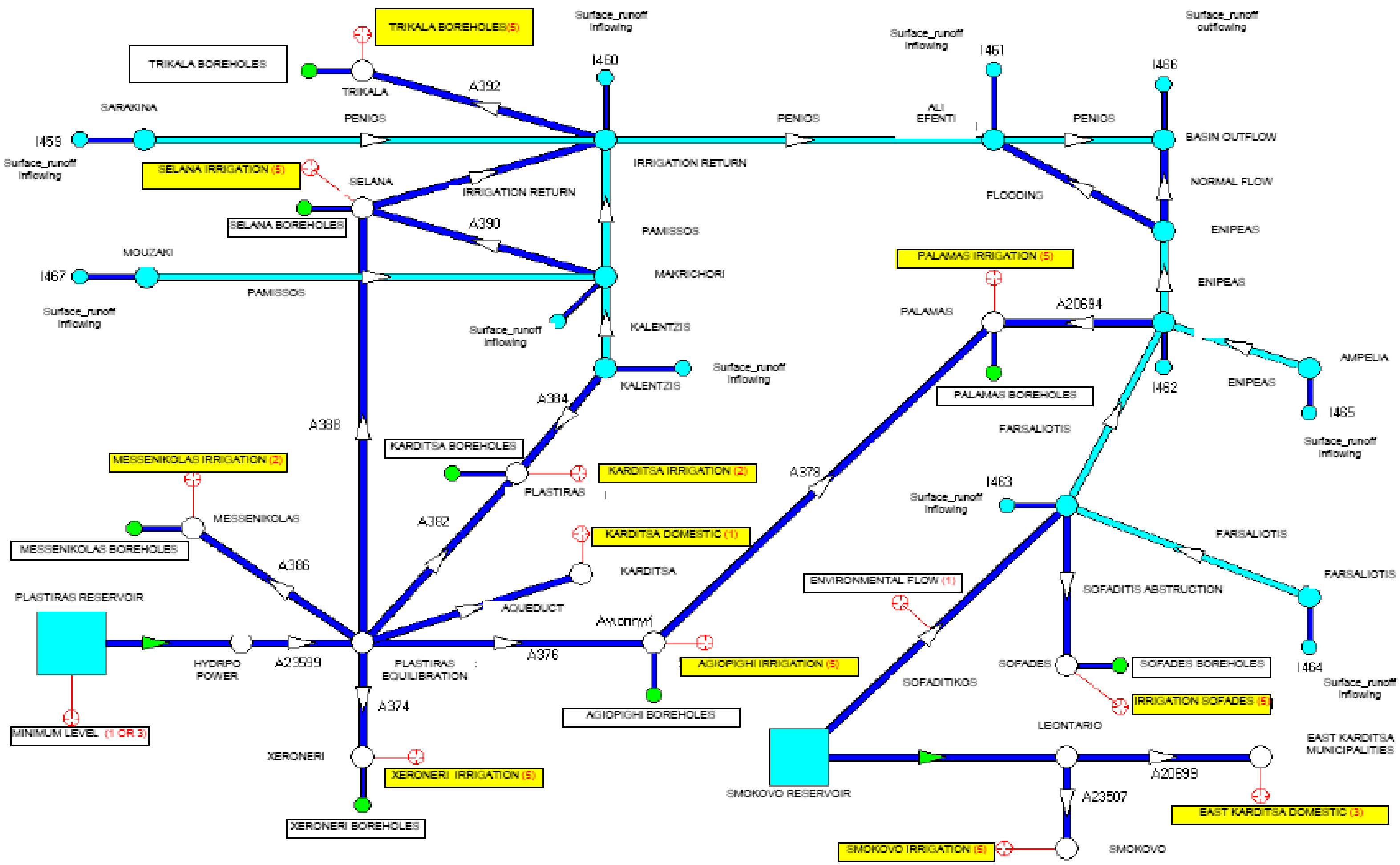

Figure 17: Schematic illustration of the HYDRONOMEAS software

5.5 Discussion of Results

The progressive improvement of the water balance picture for the area is given in the following table a graph in terms of mean annual water deficits and avoided mean annual water deficits (Table 31 and Figure 18):

Table 31: Progressive improvement of the water balance

hm^3/ annually	*Business as usual - limited environmental considerations*	*Business as usual - with environmental considerations - baseline*	*1st Water Saving Scenario*	*2nd Water Saving Scenario*
Possible Water Supply Deficits	0.014	0.346	0.096	0.031
Possible Irrigation Deficits	2.96	5.626	0.292	0
Possible Environmental Deficits	0.969	0.375	0.052	0
Possible Total Deficits	3.943	6.347	0.44	0.031

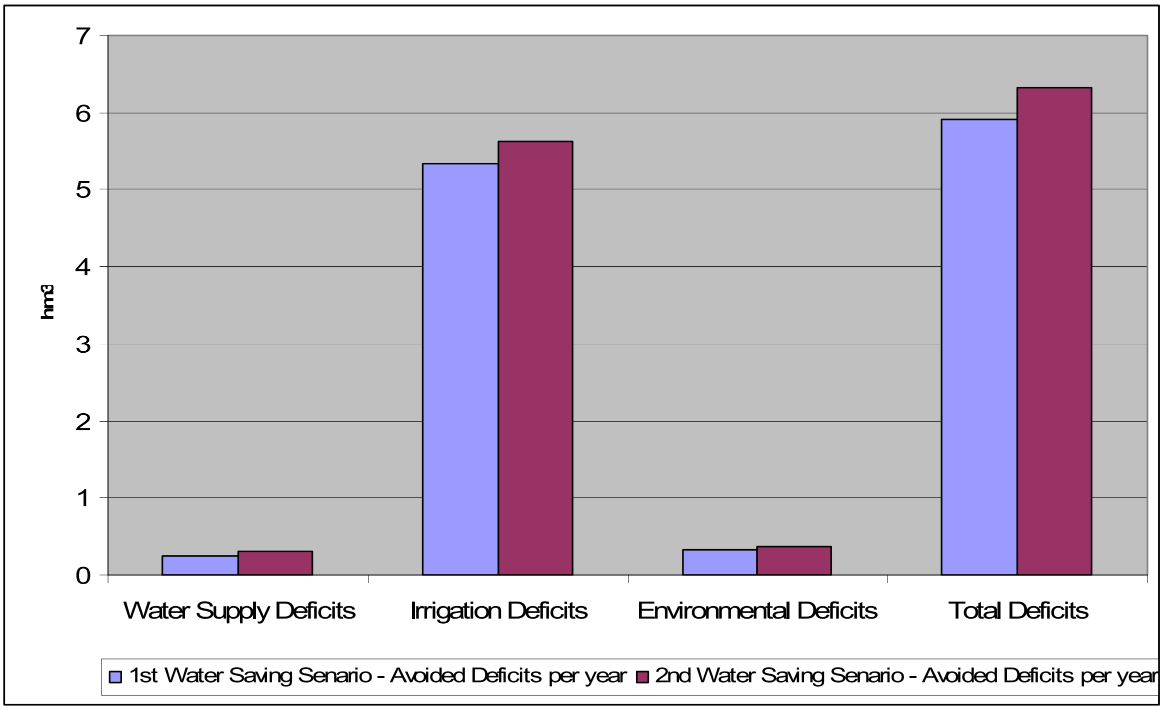

Figure 18: Progressive reduction of possible water deficits

Besides the obvious result of an improved water balance, the considered water saving scenarios results can be recapitulated as follows.

Firsts Scenario: Conservative implementation of Technical water saving measures while fulfilling environmental targets:

- A 10% domestic water demand reduction, because of household water saving devices, will lead to 2.3 hm^3 of water saved per year (which are reallocated to other users) and an average of 3.2 M Euro of annual savings for the population. Costs of devices have a payback period in the range of 7 – 8 years.

- Avoided future capital costs, for increasing water supply capacity can be significant (eg 39 M Euro for securing 8 hm^3).
- Leakage reduction projects conservatively leading to 2.3 hm^3 of water saved per year (not allocated to users) could have a ten year pay-back period.
- Improving the water conveyance infrastructure could secure annually an average of 4.8 hm^3 for irrigation purposes (with a cost of 0.05 Euro/m^3). This could be translated to a 0.3 M Euro to 0.7 M Euro yearly increase of income for cultivators.

Second Scenario: Implementation of Technical and Economic water saving measures while fulfilling environmental targets:

- 4.6 hm^3 could be saved yearly because of reduced domestic consumption (reallocated to other uses).
- When compared to the «business as usual scenario», the domestic population covers its estimated consumption needs with no differential cost. Cost of devices have a payback period in the range of 6 years.
- An increased income is expected for the local water supply service when considering a reduction in the water production of 20% and sails with tariffs increased by 25% as opposed to a reduction to the water production of 10% and no water tariff increase.
- Economic measures in the agricultural sector are associated with: meter equipment costs, increased water bill costs and possible loss of productivity (because of a reduced consumption due to financial reasons). This is a measure that is expected to have a very low public acceptability.
- An improvement of irrigation water application efficiency is considered (change from furrow irrigation to pivot irrigation) for 35% of the irrigated area will secure each year 0.292 hm^3, additionally (when compared to the 1st scenario) with a possible cost of 1.32 Euro per cubic meter saved.

As it was expected going from a 95% to a 98% reduction of possible water deficit could have a higher incremental cost.

6 Summary of presented case studies

BASIN	SUMMARY
Guadalquivir (Spain)	***Water Saving Measure Scenarios*** *Water Pricing and volumetric billing* ▪ Once potential for pure-technical measures is exhausted, volumetric billing at current level of costs recovery is considered the first step in implementing water pricing. ▪ Estimation of water saving potential of volumetric billing supports the hypothesis that districts in which users pay for water at a flat-rate, on area basis (i.e. per unit of irrigated area) are usually the largest consumers of water per hectare. ▪ In contrast, Districts with a pressurized irrigation network, where revenues are partly collected per cubic metre consumed measured with metering devices, consumption is significantly lower. ▪ Volumetric billing by itself compared to area payments implies a significant reduction of water demand, as this basin has the potential to recover an estimated 90% of financial costs for irrigation at ‘abstraction level’ and almost full recovery for distribution and field level irrigation costs. *Drought Management plan* ▪ Objective is to minimize the socio-economic impacts of incidental droughts – when hydrological drought conditions when the whole water rights cannot be satisfied according to the supply warranty consigned in the Basin Hydrological Plan. ▪ The most important indicator related to availability and quality of water resources is water volume stored in the reservoirs as surface water, which is the main source of supply in the Basin. Other indicators include river flows; groundwater levels; rainfall and water quality). ▪ Several alert thresholds are established per resources management unit in the Basin. *Temporal re-allocation* ▪ In years of drought with varying levels of severity, temporary re-allocations have been implemented. E.g. water transfers from agriculture to urban uses; inter-agricultural sales; water export due to scarcity. ▪ Permanent re-allocations – a conceptually permanent transfer and given the price of land, this operation has an ‘implicit price’ of water (capitalised) at 4.31 Euro/m³. *Additional measures* ▪ A full set of water saving measures for the Basin is currently being analysed for their cost-efficiency in order to implement the PoMs under WFD.

Adreche (France)	***Potential maximum savings and cost assessment in each sector*** *Household and tourism* ▪ Consumption has been rising rapidly in recent years, in particular because tourism has increased dramatically in the Basin (tourists tend to use more water) ▪ Potential savings at 2.46 Mm³. ▪ Improving efficiency of household devices cost about 70 Euro per households for a saving of 60m³; total costs would be around 1.51M Euro. Additional costs could arise from (i) buying more efficient washing machines and dishwashers and (ii) carrying out an audit of the housing network to reduce losses. *Agriculture and Industry* ▪ Considering an average crop water demand of 2 000 m³/ha , crop water demand in the Basin amounts to circa 3.2 Mm³. ▪ Industrial activity in the Basin is limited. About 0.3 Mm³ is abstracted per year, and most returns to the aquatic environment since it is mainly uses for processing. ▪ The Basin has two main hydroelectric plants, which impact significantly on water flow. ▪ Potential savings and costs associated with measures in the agricultural sector: assuming that (i) the length of each type of canal is equal) and (ii) all irrigation systems are transformed into pipeline-based distribution systems, potential savings can amount to 0.11Mm³. Further savings can be achieved by increasing the efficiency of spraying techniques – assuming micro-aspersion could replace aspersion and be potentially used in 60% of irrigated areas, and that surface irrigation could be changes into aspersion irrigation, the volume of water potentially saved amounts to 0.62Mm³. ▪ Changing a surface/canal distribution system into a pipeline based irrigation system costs an average 4 000 Euro/ha, with an additional 2 000 Euro for pumping station. Total cost for the 76 ha currently irrigated by surface irrigation and the 10 irrigation system concerned would be around 330 000 Euro. ▪ Installing micro-aspersion techniques usually costs about 1 500 Euro/ha. About 435ha would be changed into micro-aspersion, thus costing 652 500 Euro. The change from surface irrigation into aspersion irrigation would cost about 600 Euro/ha. The cost for changing the 87ha of surface irrigation would be about 52 200 Euro. Total cost of this measure would be 704 700 Euro. ▪ Changing the nature of culture would change the income of the farmer and its management and commercial strategies. Estimating the cost of these is difficult, and several studies have tried to evaluate the total costs of such changes, by examining the change in production and the cost on the market. ▪ Increasing the variable price per m^3 of the water bill by 6% would increase the cost of water for the farmer. The average cost of water is 0.064 Euro/m^3; the increase would increase the price of water by 0.04 Euro/m^3. The average water consumption per ha in the river basin is 2 130m^3 per ha, thus an increase of 6% in the price of water would cost 85 Euro per ha. Since the average size of irrigated

	land per farm in the river basin is 3.41ha, the average cost of increased water bill by farms would be 465 Euro. The total cost over the river basin would be136 000 Euro for 1 600ha. *Temporal allocation of water* ▪ Reservoirs have a dual purpose – electricity production and minimum water flow to support other users. Currently, severe flows have occurred, with the availability of water restricted for both environmental uses and drinking water supply, tourism and irrigation activities. Measures to improve reservoir recharge and to secure higher flows, impact on the production of electricity. ▪ What would it cost to (i) extend the length of support up to one month earlier in order to meet potential demand and limit damage from early droughts, and (ii) an increase of 50% in the water flow during the whole period: (i) The extra volume needed to sustain the flow one month more is the average volume used in one month during the low flow season (9.6/3=3.2Mm^3); (ii) The extra volume needed is 50% more, thus 4.8 Mm^3 The power plant produces 18MWh over the whole year, including 16.5MWh during the winter (high season). 1.5MWh is thus produced during the low flow season. The average production of 1m^3 in the low flow season, considering only the volumes released in the summer through conventions, is 0.16MWh per m^3 or 160 000MWh per Mm^3. The loss to the electricity company is proportional to the difference of the price between summer and winter rates on the market. We will take the price of electricity between low periods (64.4 Euro/MWh) compared to the price for high periods (105.7 Euro/MWh). The loss to the electricity company is: (i) For one month extension: 3.2*160*(105.7-64.4)=21.145M Euro (ii) For an 50% increase in the water flow during the low flow season: 4.8*160*(105.7-64.4)=31.718M Euro *Benefits* ▪ Lower consumption through technical measures (e.g. improve efficiency of household devises or spraying techniques) can lower households bills by between 6.96 and 12.3 M Euro/year, or 113 Euro/inhabitant/year, and 94 900 Euro/year for agriculture (59 Euro/irrigated ha). ▪ While it is difficult to evaluate benefits to society and the environment because no evaluation studies were carried out in the river basin, worth mentioning are the benefits for tourism. Indeed, tourism in the river basin is strongly linked to the quality of the environment (water-based activities). The river basin doubles its population during the summer. Most tourists are based in the Ardèche sub-basin, particularly in the most downstream part near the site of special interest, Georges de l'Ardèche.

South & Southeast (UK)	***Water Saving Dynamics in Thames and Southeast Basins*** *Water saving potential in the Southeast Basin.* ▪ Water is a scarce and often over-committed resource in Southeast RBD. There is an aim to recover around 10 per cent of current abstraction across the region. In 1999, abstraction of water for the public supply amounted to some 1,400 million litres a day (Ml/d). Household use accounted for about 60 per cent of this, commercial use just over 20 per cent, and leakage from pipes nearly 20 per cent. In addition, some 600 Ml/d was abstracted directly by industries. Farmers also took around 30 Ml/d for spray irrigation, a relatively small amount but concentrated in the summer months, when river flows are at their lowest. Current and likely future demands in Southeast RBD are dominated by public water supply. Government planners suggest that provision be made for some 380 000 additional houses in the region by 2016. The Southeast region has a complex but less integrated water supply infrastructure than much of the rest of the England. There are some water transfers between these zones within individual water companies, and some supplies go from one company to another, with proposals for more included in our strategy. Some zones have surplus resources and others have existing or forecast deficits. Water companies in the Southeast are currently following their drought plans. Most have imposed hosepipe and sprinkler bans. The Secretary of State has granted Drought Orders to Mid Kent Water, Southern Water, and Sutton and East Surrey Water to further restrict non-essential uses of water. Only the latter has had to be implemented. People responded well to both hosepipe restrictions and the general media campaign to save water. Companies have reported a demand saving of between 5-15%. Drought Order powers if they need to be used, should be used sensitively and progressively. The public supply is there for domestic customers first and businesses second. ▪ **Strategy for public water supply by 2010:** Expected water savings of up to 74/Ml/d, allowing for resource developments of up to 115 Ml/d. Demand management options including metering and water efficiency measures; Progressive metering toward 2025 expectations; Progressive leakage control toward 2025 expectations; Enhancement of some local source outputs (50 Ml/d); Further integration of existing water supply systems (25 Ml/d); Bulk supplies and other resource sharing, including potential enhancement of storage by enlarging either Bewl of Darwell reservoirs (40 Ml/d); Determine the best use of Swanscombe quarry as an additional or alternative source; ▪ **Strategy For public water supply by 2025:** Expected water savings[1] of up to 123 Ml/d, allowing for resource developments of up to 47Ml/d. Demand management options including leakage control, metering and water efficiency measures for saving at least 30Ml/d; Increased household metering; Higher levels of metering in some areas where water is particularly scarce; Further leakage control, for savings up to 45 Ml/d; Further water company system integration, optimization and resource sharing; Excludes water savings through maintaining current active leakage control targets. ▪ **For agriculture, by 2025:** Individual and consortium winter storage reservoirs totaling 15 Ml/d;

	▪ **For industry and commerce, by 2025:** Water use minimization will be promoted; ▪ **For the environment, by 2025:** Abstraction recovery of 80 Ml/d to 180 Ml/d across the region, where abstraction is damaging the environment; ▪ **Other options under consideration:** Reuse of effluent currently discharged in to coastal waters**;** Potential resource developments of new reservoirs; Strategic transfer into the region from Thames Region**;** Desalination; ▪ **Other significant uncertainties**: Housing numbers and economic development proposals for the region and over abstraction; *Water saving strategies in the Thames River Basin District* ▪ The Basin population density is three times the national average, which means that human needs impose significant pressures on water resources. An average of about 5,000 million litres of water per day (Ml/d) is abstracted from rivers, streams and aquifers within the Basin. Total abstraction in the region amounts to some 55 per cent of effective rainfall. Some 85% of this is for public water supply, and the remainder is abstracted directly by industry and agriculture. Household use accounts for half the water put in public supply, and industry and commerce a little less than a quarter. The rest of the water put into the public supply is largely lost through leakage from the distribution system, a major concern in the region. Non-public water supply abstractions comprise 700 Ml/d for industry, commerce and agricultural use, including 20 Ml/d for spray irrigation. Principal uses in the region include cooling water for power generation and for manufacturing, process water, sand and gravel extraction, fish farming and cress growing. The quantity of water abstracted for spray irrigation is small, but demand for it is concentrated in summer months, when river flows are at their lowest. Current and likely future demands in Thames Basin are dominated by public water supply. The rate of growth predicted by government planners for the region could lead to 700 000 additional households and a population increase of 800 000 by 2025. ▪ **Strategy for public water supply by 2010:** Expected water savings of up to 470/Ml/d, allowing for resource developments of up to 340 Ml/d. Demand management options including metering and water efficiency measures; Surface water yield improvements (within licence); Groundwater developments including London Rising Groundwater, and artificial recharge and recovery of London Basin groundwater; Indirect effluent re-use for river support (River Lee); Infrastructure/outage improvement; Full take up of bulk transfers. ▪ **For public water supply by 2025:** Expected water savings1 of up to 750 Ml/d, allowing for resource developments of up to 590Ml/d. Demand management options including leakage control, metering and water efficiency measures; Combination of abstraction, bulk transfers, new reservoir storage, schemes to improve outage and deployable output, aquifer recharge and recovery; excludes water savings through maintaining current active leakage control targets. ▪ **For agriculture by 2025:** Promotion of winter storage and on-farm efficiencies ▪ **For industry and commerce, by 2025:** Water use minimization saving. Forecast trends across sectors indicate potential opportunities for licence review and re-

	allocation over the long term. ▪ **For the environment, by 2025**: Abstraction recovery of between 185 Ml/d to 350 Ml/d, principally impacting on the Thames (145 Ml/d) and Three Valleys (40 Ml/d) ▪ **Other options under consideration**: Major new reservoirs and Desalination ▪ **Other significant uncertainties:** Canal transfer scheme; Alternative reservoir scenarios requiring further investigations of site feasibility and environmental impacts etc.; Resource availability and operational viability of transfer schemes for the River Severn, including potential environmental impacts, in particular resulting from the Habitats Directive; Increasing pollution risk to groundwater within the urban and fringe areas potentially bringing forward the need for water resource developments. These two illustrations illustrate how the different river basins and regions of England & Wales have embarked actively on drought and water saving strategies. They also stress the need for integrating measures and sectors in strategies dealing with water scarcity and drought in a comprehensive manner – combining both demand-based management and some supply-based measures. *Trading* ▪ The creation of markets in transferable abstraction rights ought to be feasible in those catchments where there is currently an unmet demand. Rules would have to be developed, however, within a flexible approach to facilitate both very short-term (i.e. within season) trades as well as allowing more permanent longer-term trading; these rules would need to ensure protection against derogation and environmental damages. The report recommended that a mixed approach towards the allocation and of permits should be considered, where this includes examination of the combined use of an initial grandfathering of rights followed by auctioning, for example, or when finding buyers for an authorised quantity up for trade or when existing licenses expire.
Plastiras & Smokovo (Greece)	***Fulfilling Conflicting Demands*** The case study area is basically a rural area with a strong agricultural heritage and orientation. Two major reservoirs are found in it: Plastiras and Smokovo and groundwater is overexploited. Even under optimised, temporal hydrosystem operation and water allocation (between the domestic, irrigation and energy use), water deficits are estimated to rise up to 4 – 6 hm^3 yearly. Water Saving Measures could improve significantly the problematic water balance picture. For a conservative implementation of Technical Water Saving Measures (95% reduction of water deficits): ▪ A 10% domestic water demand reduction, because of household water saving devices, will lead to 2.3 hm^3 of water saved per year and an average of 3.2 M Euro of annual savings for the population. Costs of devices have a payback period in the range of 7 – 8 years ▪ Avoided future capital costs, for increasing water supply capacity can be significant

	(e.g. 39 M Euro for securing some extra 8 hm^3) ▪ Leakage reduction projects conservatively leading to 2.3 hm^3 of water saved per year (not allocated to users) could have a ten year pay-back period. ▪ Improving the water conveyance infrastructure could secure annually an average of 4.8 hm^3 for irrigation purposes (with a cost of 0.05 Euro/m^3). This could be translated to a 0.3 M Euro to 0.7 M Euro yearly increase of income for cultivators. While with a relatively rigorous implementation of Technical and Economic Water Saving measures (98% reduction of water deficits): ▪ 4.6 hm^3 could be saved yearly because of reduced domestic consumption (reallocated to other uses), when considering household water saving devices and a conservative water tariff increase. The domestic population could cover its estimated consumption needs with no differential cost. Moderate costs for devices have a payback period in the range of 6 years. ▪ An increased income is possible for the local water supply service. ▪ Economic measures in the agricultural sector and the introduction of volumetric billing is expected to have a very low public acceptability. ▪ A partial improvement of irrigation water application efficiency could secure an additional 0.292 hm^3 of water each year, at a relatively high incremental cost of 1.32 Euro per cubic meter saved.

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