Dams and Reservoirs, Societies and Environment in the 21st Century – Berga et al (eds)
© 2006 Taylor & Francis Group, London, ISBN 0 415 40423 1

Azúa Valley Lake and integrated water resources management in Vitoria-Gasteiz

R. Mujeriego
Universidad Politécnica de Cataluña, Barcelona, Spain

J. López
Técnicas y Técnicos, S.A. (TYPSA), Vitoria-Gasteiz, Spain

ABSTRACT: The Azúa Valley Lake is the most emblematic element of the Integrated Water Reclamation and Reuse Plan for the Vitoria region that began in 1992. The off-stream lake has a capacity of 7 hm^3, satisfies the latest environmental requirements, and is located at 75 m above and 2 km distance from the surface water reservoirs supplying the regional areas of Bilbao and Vitoria. The lake will be able to store the winter-spring excess of reclaimed water produced at the Vitoria-Gasteiz water reclamation facility, so it can be used for agricultural and landscape irrigation during the summer, and also for in-stream ecological flow substitution. The use of reclaimed water will result in equivalent surface water flows available for urban water supply, improved protection against flooding, and an additional production of 2 million kWh annually of hydroelectric energy.

1 INTRODUCTION

The city of Vitoria-Gasteiz is the capital of both the Álava Foral Territory and the Regional Government of the Basque Country in Spain. With a population of 220,000 inhabitants, it includes a very diverse industrial activity that contributes about 30% of its wastewater flows. The city of Vitoria-Gasteiz shares its water supply system with the city and the regional area of Bilbao, with a population of 1 million inhabitants, through the conjunctive use of the water reservoirs of the Zadorra River, which have a total useful capacity of 180 hm^3.

The urban water supply requirements of Bilbao and Vitoria-Gasteiz have being exceeding the storage capacity of the existing reservoirs in a steady increasing manner during the last few decades. This situation has prompted the need for the current water users to provide additional water resources, particularly by Vitoria-Gasteiz, the user with the largest deficit. An Integrated Water Reclamation and Reuse (IWRR) Plan for Vitoria-Gasteiz was prepared by the Álava Regional Government in 1992 (Diputación Foral de Álava et al., 1995) as a coordinated response to the water demands of urban, industrial, and agricultural users in the Vitoria region. The main objectives of the plan were to improve water supply reliability, to decrease the risk of flooding, and to ensure the environmental protection of the tributary streams. The Azúa Valley Lake will become an essential component of the IWRR Plan, when it becomes operational by the end of 2006.

2 OBJECTIVES

The main objective of this paper is to assess the role of the Azúa Valley Lake as an essential component of the IWRR Plan of Vitoria-Gasteiz, with particular emphasis on: 1) the quality of the reclaimed water that will be stored in it, 2) the environmental and economic benefits that will be derived for the region, 3) the improvement in water supply reliability that will provide for the current water supply system, 4) the reduction of flooding risks associated with the current management policies of the surface water supply reservoirs, 5) the implementation of future strategies for using the reclaimed water stored in it, and 6) the definition of water quality management strategies to be followed for maintaining the aesthetic and environmental status of the reclaimed water stored in the lake.

3 WATER RESOURCES AND WATER USES

Table 1 summarizes the storage capacity of the Zadorra river reservoirs and the water demands of the surrounding populated areas. The water demands include urban and industrial supplies, and also the in-stream flows (ecological flows) that the reservoirs have to provide,

Table 1. Available water resources and water allocations from the Zadorra River reservoirs.

Reservoir capacity	
Urrunaga	67 hm^3
Ullibarri	139 hm^3
Total	206 hm^3
Authorized maximum volume	180 hm^3
Current allocations	
Water supply to Bilbao	145 hm^3
Water supply to Vitoria	25 hm^3
In-stream flows of the Zadorra y Santa Engracia Rivers	30 hm^3
Total	200 hm^3

downstream from the reservoirs, to the Zadorra River and its tributary the Santa Engracia River.

Table 1 clearly shows two basic and important facts: 1) the flows provided by the reservoirs are devoted exclusively to urban water supply and to preservation of the rivers environmental conditions, and 2) the annual water demands corresponding to those two uses exceed the useful capacity of the reservoirs.

Considering that the average rainfall intensity for the area is close to 800 mm/year, the contributing watershed has a surface area close to 400 km^2, and the water fraction infiltrating in the soil can be estimated at 30%, the average annual water contribution of the Zadorra river watershed to the storage reservoirs can be estimated at 220 hm^3. This estimate does not have into account the agricultural practices applied in the surface area of the watershed above the reservoirs, which could further reduce the water volume actually collected. It is evident that an average annual contribution of 220 hm^3 of surface water cannot provide, during years of below-average rainfall, a volume of stored water sufficient to provide the 200 hm^3 of water necessary to supply the Bilbao and Vitoria regions.

This inadequate water supply reliability, historically estimated as a minimum deficit of 20 hm^3 per year, has resulted in serious difficulties over the last few decades for the Inter-regional Watershed Agency (Confederación Hidrográfica del Ebro, CHE), the Regional Governments of Álava y Vizcaya, the City Councils affected, and the Irrigation Districts in the area. Those difficulties usually reach a particularly critical point at the time of establishing the operational water level conditions of the reservoirs that ensure a reliable water supply to the Bilbao regional area, while taking into account the upper protection water levels in the reservoirs necessary to prevent the flooding episodes that periodically affect the urban, industrial, and agricultural activities in the lower areas of the Vitoria region. Water levels adequate to satisfy the water supply needs of the Bilbao region have resulted in the past in inadequate water levels to accommodate the large water volumes generated in the upstream watershed during heavy rains, or sudden snow melting episodes.

4 PLANNED WATER REUSE AND INTEGRATED MANAGEMENT PROGRAM

In contrast to the traditionally proposed solutions, such as dam's height increase, or expansion of the Zadorra river bed so it can accommodate up to 150 m^3/s, (9 times larger than its current maximum flow rate), the Irrigation Districts affected, in cooperation with the CHE and the Álava Regional Government, have been implementing since 1996 an Integrated Water Reclamation and Reuse Plan, with the following main objectives:

1 To use reclaimed water for irrigation of 10,000 ha of several food crops, including orchards and raw eaten vegetables. Irrigation started in 1996, and covered initially a surface area of 4,000 ha. The additional 6,000 ha began irrigation with surface water during the summer of 2005, waiting for the corresponding volumes of reclaimed water that will be stored in the Azúa Valley Lake, by the end of 2006.
2 To replace a fraction of the in-stream ecological flows currently provided from the surface water reservoirs by the corresponding flows of reclaimed water, with the quality level required for supporting fish life, namely salmonid and cyprinid waters (European Council, 1978). Those replacement flows would be introduced just below the water supply dams, using the pumping stations and the pipelines of the existing irrigation network.

By replacing a fraction of the water flows discharged from the surface water reservoirs by equivalent flows of reclaimed water, three main objectives will be reached: 1) to increase surface water availability for supplying the Bilbao region, 2) to produce a additional amount of hydroelectric energy, taking into account the decrease in elevation experienced by surface water when traveling to Bilbao, and 3) to lower down the upper protection water level of the surface water reservoirs, and consequently offering a larger capacity for retaining the high flows that can be produced by the Zadorra watershed areas, and thus preventing the potential flooding episodes in the lower areas of the Vitoria region.

In-stream water flows replacement in the Zadorra River will begin in early 2006, by providing reclaimed water flows equivalent to a 20% fraction of the in-stream water flows customarily provided from surface water reservoirs. This fraction will be gradually increased until it reaches a 50% of the total in-stream flow of 1 m^3/s established by regulatory requirements.

Table 2. Surface water consumption for urban water supply and landscape irrigation in the city of Vitoria-Gasteiz.

Year	Landscape area, ha	Urban supply, hm^3	Urban irrigation, hm^3 (% total use)
2003	460	24,6	3,1 (13)
2002	437	24,6	2,5 (10)
2001	402	25,2	2,8 (11)
2000	402	24,8	2,5 (10)
1999	400	24,5	2,4 (10)
1998	380	25,3	2,0 (7,9)

3 To use reclaimed water for landscape irrigation of parks and public gardens in the city of Vitoria-Gasteiz. Table 2 shows that landscape irrigation in Vitoria-Gasteiz represents more than 10% of the city's surface water supply. When the currently proposed new landscape areas become operational in the forthcoming years, that fraction will reach an estimated 15% value.

The irrigation water demands for the agricultural areas of the Vitoria region and the landscape urban areas of the city of Vitoria-Gasteiz become a reality mainly during the summer season, from early June to late September or even October, depending on the spring rainfall pattern. Usually, the rainfall received from October to June is sufficient to cover the water requirements of the agricultural crops grown in the area, as well as the basic maintenance of the city's landscape areas. Similarly, the water requirements for in-stream flows in the Zadorra River become especially necessary during the summer season.

5 WATER RECALAMATION PLANT

The water reclamation facility of Vitoria-Gasteiz began operating in 1995, and has a capacity of 35,000 m^3/day, equivalent to 12 hm^3/year. That water volume is sufficient to irrigate 10,000 ha of agricultural land during the summer season. The edaphic characteristics of the agricultural areas of the Vitoria region render summer irrigation a recommended practice under a schedule of once every three consecutive years. This practical requirement results in an agricultural surface area actually irrigated during a summer season close to 3,300 ha, just about one third of the 10,000 ha available to the Irrigation Districts.

The water reclamation plant of Vitoria-Gasteiz was designed according to the quality criteria for reclaimed water required by the Title 22 of the California Water Code (Asano, 1998, Asano et al. 1991). Planned water reuse for agricultural irrigation was designed according to the guidelines and technical criteria included in the Guidance Manual prepared by the California State Water Resources Control Board (Mujeriego, 1990).

Table 3. Integrated water reclamation and reuse plan for Vitoria-Gasteiz.

Capacity and uses	Objectives
Reclamation capacity (2003)	12,00 hm^3/year
Agricultural uses (2003)	2,40 hm^3/year
Agricultural uses (2006)	7,00 hm^3/year
Storage capacity	7,00 hm^3/year
Existing irrigation network	350 km pipelines

Table 4. Physico-chemical quality of reclaimed water produced at the water reclamation plant of Vitoria-Gasteiz, from 1996 to 2006.

Turbidity	<2 NTU	Boron	<1,50 mg/l
Electrical conductivity	<1,000 µS/cm	Cadmium	ND
Ammonia nitrogen	1,5–19 mg N/l	Chromium	<0,02 mg/l
BOD_5	<5 mg/l	Copper	<0,05 mg/l
NO_3	2–15 mg/l	Mercury	ND
COD	<20 mg/l	Nickel	<0,40 mg/l
Oxygen demand	<7 mg/l	Lead	ND
		Selenium	ND
		Zinc	<0,40 mg/l

ND: non detectable, lower than 0,01 mg/l

The optimal operation of the water reclamation plant was limited by the ability of the system to store the reclaimed water produced during the fall-winter-spring seasons. The flow capacity of the water reclamation plant allows irrigation of a maximum of 4,000 ha (1,300 ha effective) under a continuous operation regime during the summer season. However, storing the reclaimed water produced during the rest of the year would provide enough water supply to irrigate up to 10,000 ha (3,300 ha effective). To achieve that objective, the IWRR Plan of Vitoria-Gasteiz included the construction of an off-stream reservoir, where reclaimed water could be stored during the fall-winter-spring season, and subsequently used for irrigation during the summer season. Table 3 summarizes the water flow provisions included in the IWRR Plan of Vitoria-Gasteiz.

Tables 4, 5 and 6 show the water quality achieved by the water reclamation plant of Vitoria-Gasteiz since 1996, when it became operational. The reclaimed water produced satisfies the quality criteria specified in the Title 22 of the California Water Code (Asano et al. 1991), the health guidelines recommended by the World Health Organization (1998) y and the water reuse criteria proposed by the US Environmental Protection Agency (2004).

Table 5. Organic and microbiological quality of reclaimed water produced at the water reclamation plant of Vitoria-Gasteiz, from 1996 to 2006.

Bromodichloromethane	<5 μg/cm
Bromoform	1 μg/l
Chloroform	<30 μg/l
Dibromochloromethane	<1, 0 μg/l
Chlorophenols	Non detectable
Total coliforms	Absence
Nematode eggs	Absence
Giardia lamblia	Absence
Cryptosporidium	Absence
Legionella	Absence
Salmonella	Absence

Table 6. Quality of the water produced at the water reclamation plant of Vitoria-Gasteiz, during the summer of 2006.

Turbidity	<0,5 NTU
Electrical conductivity	<900 μS/cm
Ammonia nitrogen	<1,5 mg/l
NO_3	<7 mg/l
Phosphorous	<1 mg/l
BOD_5	<5 mg/l de O_2
COD	<10 mg/l de O_2
Permanganate oxygen demand	<5 mg/l de O_2
Metals	<0,1 mg/l
Trihalomethanes	<15 mg/l
Chlorophenols	Absence
Microbiology	Absence of microorganisms analyzed (see Table 5)

6 AZÚA VALLEY LAKE

The Azúa Valley Lake is the last significant construction included in the IWRR Plan of Vitoria-Gasteiz. Is it an off-stream storage reservoir, formed by two earth dams that result in an artificial lake with a capacity of 7 hm^3. The lake has been designed and built considering the environmental requirements applicable to a high value natural landscape environment. The lake is located 75 m over the water level of the nearby surface water reservoirs of the Zadorra River, and just about 2 km from them. This topographic situation offers a unique condition to contemplate the possibility for future water contributions from the Azúa Valley Lake to the Ullibarri reservoir, after applying the water purification processes that may be considered necessary at that time. Figure 1 shows an air view of Azúa Valley Lake during the construction process in 2004. The Ullibarri reservoir appears in the background.

Synthetic membranes for ultrafiltration, nanofiltration, and reverse osmosis offer the technical means to contemplate at the present time the possibility for decreasing the salinity concentration of the available reclaimed water well below 500 μS/cm. This represents

Figure 1. Air view of Azúa Valley Lake during construction in 2004. The Ullibarri surface water reservoir appears in the background.

a water quality equal or better than that of the surface water reaching the reservoirs through runoff from its natural, urban and agricultural watershed. The introduction of highly treated reclaimed water flows into the surface water reservoirs, currently used for urban water supply, would offer a possibility to partially close the water cycle at the regional level, in the terms, with the scope, and the schedule that may be considered appropriate in the future.

Construction of the Azúa Valley Lake was completed by late 2004, pending the implementation of the compressed air diffuser system and the photovoltaic panels necessary to generate the electric energy for driving them. The regulatory approval process for Emergency Plans and the Filling Protocols are being completed during first semester of 2006.

The Azúa Valley Lake is an essential component of the IWRR Plan of Vitoria-Gasteiz, for the following reasons:

1 It provides the reclaimed water volumes required for in-stream flow substitution in the Zadorra River, in case of a prolonged failure of the biological treatment processes of the municipal wastewater treatment plant of Vitoria-Gasteiz, or the physico-chemical processes of the water reclamation facility of Vitoria-Gasteiz.
2 It ensures the water flows necessary for agricultural and landscape irrigation of the regional and the urban areas of Vitoria-Gasteiz during the summer season.
3 It provides a mechanism for nutrients removal from the reclaimed water stored in the lake, by alternating anoxic and aerobic conditions in the water column, and the addition of atmospheric oxygen through a deep aeration system, using compressed air that will be generated by photovoltaic energy panels located in inland slopes of the earth dams.

Table 7 summarizes the main characteristics of the earth dams forming the Azúa Valley Lake.

Table 7. Main characteristics of the earth dams forming the Azúa Valley Lake.

Main purpose	To store reclaimed water produced at the Vitoria-Gasteiz water reclamation plant (Title 22 of California Water Code).
Beneficial uses	To irrigate 10,000 ha of food crops, urban landscape areas, and substitution of in-stream flows of the Zadorra River.
Watershed surface:	1 km^2
Lake surface area	50 ha
Storage capacity	7 hm^3
Dams height	Dam 1: 35 m; Dam 2: 29 m
Dam type	Earth dams with impermeable core.
Inlet and outlet systems	Through a pipeline installed in a tunnel with inlet-outlet under Dam 1, located 30 m below the dam's highest point.
Filling system	Pumping from the water reclamation plant, with 110 m of hydrostatic pressure
Other facilities (under design)	Deep aeration system for injection of compressed air produced by photovoltaic energy panels.
Construction costs	11,8 million € (1, 7 €/m^3)

6.1 *In-stream flows (ecological flows) and agricultural and landscape irrigation*

The substitution of the ecological flows currently discharged from the surface water reservoirs by future flows of reclaimed water must be based on a reliable water source, protected from the potential failures and shutdowns that can affect the wastewater treatment and water reclamation processes. Furthermore, the regulatory requirements applicable to the Zadorra River are those of fresh waters capable of supporting fish life, namely salmonid and cyprinid waters, as set forth by Council Directive 78/659/CEE (1978). Among the imperative limits established in that Directive, it has to be pointed out a dissolved oxygen level higher than 9 mg/l during 50% of the time, a non-ionized ammonia level lower than 0,025 mg/l, a total ammonia nitrogen level lower than 1 mg/l, and a total residual chlorine level lower than 0,005 mg HOCl/l. To satisfy those flow and quality requirements, it became necessary to have a water reservoir of adequate capacity, provided with the technical means to achieve and to maintain the required water quality levels, and also to ensure the availability of the water flows required by the Zadorra River and the agricultural and landscape irrigation systems.

The reclaimed water storage reservoir was considered a basic element of the IWRR Plan of Vitoria-Gasteiz, according to similar water resources management initiatives widely adopted in Southern California (Mujeriego, 2004, 2005). The Azúa Valley Lake promotes a more sustainable use of the hydroelectric energy generated with the surface water stored in the Zadorra river reservoirs, and also results in an overall lower generation of carbon dioxide (Sala & Serra, 2004, Mujeriego, 2005).

The water reclamation plant of Vitoria-Gasteiz has a design capacity of 12 hm^3 per year, which is sufficient to satisfy the water required for agricultural and landscape irrigation, and to contribute a flow of up to 0.4 m^3/s for substitution of the in-stream (ecological) flows discharged from the surface water reservoirs. That flow contribution represents just 40% of the 1 m^3/s in-stream flow currently established by regulatory requirements.

The indirect benefits of this flow substitution are: 1) the availability of the corresponding 0.4 m^3/s of surface water that can be diverted from the reservoirs and used for urban water supply in the Bilbao region, and 2) the production of an additional amount of hydroelectric energy, generated by that same flow when descending the 300 m altitude difference existing between the surface water reservoirs and the hydroelectric power station in the Bilbao region. The hydroelectric energy generated by those flows will be close to 2 million kWh annually.

In summary, by promoting the use of reclaimed water, the IWRR Plan of Vitoria-Gasteiz allows the substitution of in-stream flows in the Zadorra River during the summer, which represents a total water volume of 3,1 hm^3, and also the availability of 5 hm^3 of reclaimed water for agricultural and landscape irrigation in the Vitoria region during the summer season. Those irrigation water flows will be provided in equal amounts from the water stored in the Azúa Valley Lake and the reclaimed water produced at the water reclamation plant of Vitoria-Gasteiz.

6.2 *Deep aeration system*

The reclaimed water discharged into the Azúa Valley Lake will be of excellent physico-chemical and microbiological quality (see Tables 4, 5, and 6). However, it contains significant concentrations of nutrients (ammonia nitrogen, nitrates and phosphorous). Those nutrient concentrations need to be controlled, to prevent the development of anoxic conditions during ammonia nitrogen oxidation, and thus to ensure suitable biological and aesthetic conditions in the lake. An ammonia nitrogen limit of 0.5 mg N/l (equivalent to 2.3 mg/l of dissolved oxygen) has been adopted to ensure that the biological quality of the water in the reservoir and its potential to maintain aerobic conditions remain acceptable at all times in the lake.

To achieve that objective, the Azúa Valley Lake design project incorporates a deep aeration system,

using compressed air diffusers located at 1 m above the bottom of the lake, with a capacity to maintain a minimum dissolved oxygen concentration of 3 mg/l. This aeration system includes an underground pipeline, which surrounds the lake along all its service road. Lateral conduits placed every 25 m will go into the water, reach the bottom of the corresponding area, and finalize in an air diffusers section. Each lateral conduit will be provided with an automatic electrical valve, to allow opening and closing of the air flow by remote action, depending of the dissolved oxygen concentration in the water and the protocols of aeration adopted.

The dissolved oxygen introduced by this network of bottom diffusers has a multiple objective: 1) to add the oxygen necessary for the oxidation of ammonia nitrogen to nitrates, 2) to satisfy the oxygen demand produced by the organic matter (BOD5 y COD) remaining in reclaimed water, and 3) to promote vertical mixing of the lake waters, preventing the detrimental effects that may be caused by common density stratification, or even light stratification due to algal blooms in the upper water layers.

By alternating aerobic phases, when ammonia nitrogen will be oxidized to nitrates, with anoxic phases, when nitrates will be reduced to nitrogen gas, the overall result will be a net reduction of the nitrogen content of the water. Opening and closing of the electrical valves will be programmed according to the continuous field measurements of dissolved oxygen concentration in strategic points of the lake, both in vertical profiles and also in different bottom locations.

The compressed air system has been designed with a capacity to provide the dissolved oxygen required daily by one of the 10 surface units of 5 ha each in which the 50 ha surface area of the lake has been divided. That strategy will allow continuous aeration of one surface unit for up to 24 hours daily, with a minimum frequency of once every 10 days. It has to be pointed our that the usual operation of the lake along its yearly cycle will result in water levels fluctuations from its highest level at the end of the spring season, to its lowest level (practically empty) at the end of the summer season. At that time, all the reclaimed water stored in the lake will be used, together with that produced by the water reclamation plant, for agricultural and landscape irrigation in the Vitoria region and for substitution of in-stream flows in the Zadorra River.

6.3 *Energy supply*

The considerable amount of compressed air that will be required to satisfy the oxygen demand of the lake water makes necessary to consider an inexpensive energy source, with a low carbon dioxide emission rate. Considering that the inside slopes of the earth dams face North and South, the most appropriate option was to incorporate a large surface area of photovoltaic plates, that will be installed on the inside slopes of the dams, preventing any undesirable aesthetic impact from the outside.

The top line of the earth dams has a length of 900 m, which allows for a total surface area of photovoltaic plates of 1,800 m^2, with a power capacity of up to 150 kW. The direct current produced by the plates will be stored and subsequently converted to alternate current, which will be used for running the air compressors.

This photovoltaic energy supply system has a lower aesthetic impact than a windmill energy system, and is more reliable than the latter one, as it ensures a minimum daily production of energy. Although maintenance of a photovoltaic power system is simpler that a windmill energy system, the operation cots are likely higher than those of the latter.

7 CONCLUSSIONS

The Azúa Valley Lake is the most emblematic element of the ambitious Integrated Water Reclamation and Reuse Plan of Vitoria-Gasteiz that began in 1992. The significant development experienced by the urban, industrial, agricultural, and landscape activities in the Vitoria region, with a population of 222,000 inhabitants in 2005, has resulted in a steady increase of water consumption in relation with the allocations established in 1957, when its population was only of 60,000 inhabitants. The increasing water supply deficits experienced by Vitoria-Gasteiz have been satisfied by additional withdrawals from the allocations to other users of the watershed, rising numerous and increasing difficulties for managing the overall water resources of the watershed.

Construction of the Azúa Valley Lake was completed in June 2004, and full operation is expected by late 2006, once the required safety and operation protocols are completed and approved. The off-stream lake has a capacity of 7 hm^3, satisfies the latest environmental requirements, and is located at 75 m above and 2 km distance from the surface water reservoirs supplying the regional areas of Bilbao and Vitoria. The lake has been designed to store the winter-spring excess of reclaimed water produced at the Vitoria-Gasteiz water reclamation plant, so it can be used for agricultural and landscape irrigation during the summer, and also for in-stream ecological flow substitution. The Azúa Valley Lake is a unique infrastructure in Spain, but similar to others built in Southern California and Israel to store reclaimed water for multiple uses.

Operation of the Azúa Valley Lake will serve the following main objectives:

1 To provide the reclaimed water flows necessary for substitution of the in-stream (ecological) flows of

the Zadorra River, especially during the summer season.

2 To provide the reclaimed water flows necessary for agricultural and landscape irrigation in both the Vitoria region and the city of Vitoria-Gasteiz during the summer months.
3 To promote nutrient removal from the stored reclaimed water, mainly in the form of ammonia nitrogen and nitrates.
4 To provide a future option for complete recycling of a fraction of the reclaimed water produced by the city of Vitoria-Gasteiz. This could be achieved by applying an advanced treatment process to the water stored in the Azúa Valley Lake, and its controlled discharge and mixing with the water stored in the surface water reservoirs supplying the Vitoria and Bilbao regions. It is expected that water treatment systems using ultrafiltration and reverse osmosis membranes, together with other advanced treatment processes that may be considered necessary, will provide an effluent water of equal or better quality than that currently entering the water supply reservoirs from its natural watershed areas.

Furthermore, operation of the Azúa Valley Lake will satisfy the following secondary objectives:

1 To gradually restore the water allocations of the Bilbao region, which have been increasingly used for drinking water supply in the Vitoria region. Those returns will be generated by partial replacement of current in-stream flows of the Zadorra River with reclaimed water flows produced by the city of Vitoria-Gasteiz.
2 To allow for a more sensible management protocols for the water levels in the surface water reservoirs, as to ensure a higher protection level with respect to flooding episodes in the Vitoria region.
3 To produce an additional 2 million kWh annually of hydroelectric energy, by allowing larger surface water flows to be transferred to the Bilbao region, and using the 300 m altitude difference between the surface water reservoirs and the existing hydroelectric power station of the Bilbao region.

REFERENCES

Asano, T. (Editor) 1998. *Wastewater Reclamation and Reuse*. Water quality management library, Vol. 10. Technomic Publishing Co. Inc. Lancaster, PA, USA.

Asano, T., Richard, D., Crites, R.W. & Tchobanoglous, G. 1991. Evolution of tertiary treatment requirements in California. *Water Environment and Technology*. vol. 4, no. 2.

Council of the European Communities 1978. *Council Directive 78/659/EEC of 18 July 1978 on the quality of fresh waters needing protection or improvement in order to support fish life*. Official Journal L222, pp. 0001–0010.

Diputación Foral de Álava, Gobierno Vasco y Aguas Municipales de Vitoria 1995. *Plan de Recuperación y Reutilización Integral de las Aguas Residuales de Vitoria-Gasteiz*. Diputación Foral de Álava, Vitoria.

Mujeriego 2005. La reutilización, la regulación y la desalación de agua. *Ingeniería y Territorio*, No. 72. ISSN: 1695-9647. Spanish Civil Engineering Association. Madrid. www.ciccp.es/revistait/

Mujeriego, R. 2004. La gestión del agua en el sur de California. *Ambienta*, no. 38, pp. 31–38. Ministry of the Environment, Madrid. www.mma.es/publicacion/ambienta/

Mujeriego, R. (Editor) 1990. *Guidance Manual on Irrigation with Reclaimed Municipal Wastewater (in Spanish)*. Universidad Politécnica de Cataluña, Barcelona.

Sala, L. & Serra, M. 2004. Towards sustainability in water recycling, *Water Science and Technology*, vol. 50, no. 2, pp. 1–8.

United States Environmental Protection Agency (USEPA) and United States Agency for International Development (USAID) 2004. *Guidelines for Water Reuse*. EPA/625/R-04/108, September 2004. Office of Water, Washington, D.C., y Office of Research and Development, Cincinnati, Ohio.

World Health Organization (WHO)1989. *Health guidelines for the use of wastewater in agriculture and aquaculture*. Technical Report Series 778. Geneva, Switzerland.