The water reclamation and reuse project of El Prat de Llobregat, Barcelona, Spain

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ABSTRACT

Water reclamation and reuse have become essential components of water resources management in the Metropolitan Area of Barcelona, by helping to develop additional water resources in the lower Llobregat River, one of its main sources of water supply. By generating a reliable flow of 300,000 m^3/day of high quality reclaimed water, the options available for integrated water resources management have widely expanded to allow in-stream river water substitution, restoration of natural wetland areas, agricultural irrigation, and supply to a seawater intrusion barrier. Those management options have been possible thanks to the implementation of an extensive water distribution system that allows distribution of reclaimed water to a point 15 km upstream of the reclamation facility, and to a seawater intrusion barrier within a few kilometres of the plant. The cost of producing reclaimed water using a physico-chemical process (0.05 €/m^3) and the investment required for such a facility (0.21 €/m^3 annual capacity) are very close to those of similar large scale projects in Spain. However, higher degrees of treatment, such as demineralization for agricultural irrigation and for injection into a seawater intrusion barrier, result in considerable increases of both water reclamation cost and investment costs.
Key words | integrated management, seawater intrusion barrier, water reclamation, water reuse,

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INTRODUCTION

Water supply in the Barcelona Metropolitan Area is provided by Aigües Ter Llobregat (ATLL), a wholesale Public Water Company of the Catalan Water Agency. The annual water volume provided by ATLL to associated water companies varies from 460 to 490 hm^3; of those, 180 hm^3 are transferred from the Ter River in a catchment area of Northern Catalonia, 120–150 hm^3 are abstracted from the Llobregat River, whose catchment area includes the Barcelona Metropolitan Area, and 160 hm^3 are extracted from several local aquifer systems within the ATLL influence area. The regional water distribution network was built progressively over the years, but has limited piping facilities to ensure adequate water transfers from the Ter River (entering the north of the Metropolitan area) to the Llobregat River (accessing from the south of the Metropolitan area) during the frequent water scarcity episodes experienced by the Metropolitan Area.

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The Barcelona Metropolitan Area covers 600 km^2 and includes more than thirty municipalities with a total population close to 3.5 million people, just about 50% of the total population of Catalonia (currently estimated at 7.4 million). It is the first industrial area in Spain, and the second in terms of population, workforce and income. Its economic structure is based on a solid industrial sector, well diversified and under an intense transformation process into the service sector, with a clear commitment to become an international social, cultural and economic metropolis. It has a high population density (5,800 inhab/km^2), with extensive urban areas along the central plains, the coastal stretches and the Llobregat and Besòs Rivers that cover 40% of its total surface area. Natural vegetation areas, mainly the Collserolla natural park in the north and the Garraf natural park in the south cover 38% of its territory.

Finally, the agricultural sector is located on the Delta and lower Llobregat valley and covers 16% of its territory.

The intensive exploitation of the Llobregat River as a water source for urban, industrial and agricultural uses, the high population density of the Metropolitan area, and the water quality deterioration of the Llobregat River due to agricultural runoff and disposal of industrial and urban treated effluents have resulted in quantitative and qualitative water deficits in most of the areas supplied from the Llobregat River. Two main actions are currently being implemented to correct the overall water scarcity: the construction of a seawater desalination facility (60 hm^3 per year) and the operation of a water reclamation and reuse project to provide 50 hm^3 annually of high quality water for a diversity of uses that include: in-stream river flow substitution, natural wetlands restoration, agricultural irrigation, and supply to a seawater intrusion barrier at the lower Llobregat Delta.

OBJECTIVES

The main objective of this paper is to present the basic elements of the water reclamation project of El Prat de Llobregat, and to discuss the strategies adopted for their implementation, the estimated and currently achieved benefits of the project, and the technical criteria and managerial options that could be applied in other areas with similar geographical and hydrological conditions. The paper describes the objectives of the project, the rationale behind them, the infrastructure required for its gradual implementation, and its economic and financial requirements.

WATER RESOURCES IN THE LOWER LLOBREGAT

The lower Llobregat River is one of the main sources of water supply for the Metropolitan area of Barcelona: the water treatment plants of Abrera and Sant Joan Despí draw about 2.3 and 3.0 m^3/s of water from the river, respectively. Furthermore, the Catalan Water Agency, the regulatory agency, requires that a minimum water flow of 3.5 m^3/s be maintained in summer time just downstream of the Sant Joan Despí treatment plant and to the river discharge point into the Mediterranean Sea. Historical water rights for agricultural irrigation at the Right River Bank Irrigation District, just above the Sant Joan Despí water treatment plant, amounts to an additional 1.5 m^3/s. The irregular rain patterns of the Llobregat river catchment area have resulted in unreliable supplies to its upstream reservoirs of La Baells (109 hm^3), La Llosa del Cavall (80 hm^3) and Sant Ponç (24 hm^3). It has become more and more frequent over the last decades that the water level in the reservoirs goes well below its 50% capacity (as of July 2007, 48%, 35%, and 71% respectively), prompting the need for regional emergency water control measures such as diminished in-stream flows and seasonal limitations for irrigation water. The local Lower Llobregat Delta aquifer has been historically used by several urban, industrial and agricultural users as their main water supply source. Although water management strategies currently applied by the Lower Llobregat Delta Groundwater District are among the most advanced in Spain, they have not been able to recover the extensive seawater intrusion process experienced in some coastal zones of the aquifer during the last decades. Seasonal restrictions currently applied to river flows have further limited natural recharge of the aquifer with surface water flows. Water restrictions have also affected water rights for agricultural irrigation in the right bank of Llobregat River, and the supply to natural wetland systems located in the coastal periphery of the Delta.

WATER RECLAMATION AND REUSE PROJECT

The water reclamation and reuse project of El Prat de Llobregat, Barcelona, Spain (Depurbaix 2006; Infoenviro 2006) is a definite attempt to implement integrated water resources management in the Barcelona Metropolitan Area (Mujeriego 2004, 2005), offering a balanced solution to all the users affected by the restrictions on surface and groundwater resources for urban, industrial and agricultural uses. The project was initiated in 2002 with the objective of producing 50 hm^3/year of reclaimed water with quality levels suitable for different beneficial uses: (1) in-stream water flow substitution, (2) restoration of natural wetland areas, (3) alternative supply for agricultural irrigation, and (4) supply for injection into a seawater intrusion barrier. The Project had an initial budget of 102 M€; 85% of that amount has been covered by European Union Cohesion Funds, through the Spanish Ministry of the Environment, and the remaining 15% has been covered by the Catalan Water Agency.

Table 1 summarizes the water flows allocated to the different beneficial uses considered. All the water demands are seasonal, and will be thus satisfied on a regular basis during the summer period, except the demand associated to the seawater intrusion barrier that will be satisfied on a permanent basis throughout the year. The water reclamation plant has been designed to produce three different qualities of reclaimed water, with increasing physico-chemical and microbiological quality levels: (1) water for in-stream river flow substitution and restoration of wetland areas, (2) water for agricultural irrigation, and (3) water for supplying the seawater intrusion barrier. It is estimated that the volume of reclaimed water produced annually, during an average hydrological year, will be 50 hm^3; the reclamation plant, the piping system and the pumping stations have been designed for a maximum flow of 3.5 m^3/s. If the facilities would be ultimately operated on a permanent basis throughout the year, they would provide a flow of 100 hm^3/year, close to the annual flow of secondary effluent currently produced at El Prat de Llobregat wastewater treatment plant.

The wastewater treatment plant of El Prat de Llobregat has been operating since 2004 and has a capacity 420,000 m^3/day; it includes an activated sludge treatment process that was upgraded in 2006 to achieve nutrient removal, using biological nitrification-denitrification, plus biological and chemical phosphorus removal. The construction cost of the wastewater treatment plant expansion necessary to achieve nutrient removal was 15.6 M€.

Table 1 | Reclaimed water allocations for different beneficial uses of the water reclamation and reuse project of El Prat de Llobregat, Barcelona, Spain

Beneficial use	**Average flow** m^3**/day**	m^3**/s**
Substitution of in-stream river flows (seasonal)	175,000	2.00
Restoration of wetland areas (seasonal)	35,000	0.40
Substitution of irrigation water (seasonal)	65,000	0.75
Supply to seawater intrusion barrier, 1st phase (permanent)	5,000	0.06
Supply to seawater intrusion barrier, 2nd phase (permanent)	15,000	0.17

WATER RECLAMATION FACILITIES

Table 2 summarizes the water quality requirements for in-stream flow substitution, restoration of natural wetland areas and agricultural irrigation. Although Spain has no officially approved limits for reclaimed water quality, the Catalan Water Agency has been developing quality criteria for reclaimed water suitable to different uses (Catalan Water Agency 2006); those criteria cover a range of qualities including the limits established by Title 22 of the California Water Code (Asano *et al.* 1992; California State 2001), the water reuse criteria proposed by the US Environmental Protection Agency (2004), and the health guidelines recommended by the World Health Organization (1998).

A fraction of the secondary effluent flow goes into a 2-compartment equalization tank (15,600 m^3 in total) before it is pumped to the water reclamation process, at the rates requested by water users. The water reclamation plant has a 300,000 m^3/day (3.5 m^3/s) capacity and includes: (1) ballasted coagulation-flocculation and lamella settling, using three lines of Actiflo process, with addition of coagulant, 130–150 μm sand particles, and polyelectrolyte, (2) filtration through 10 μm pore size microscreening using two lines of 5 Hydrotech filters each, operated at 10–14 m/h filtration rate, and (3) UV light disinfection, using four parallel channels, each with two banks of 200 lamps, making a total of 1,600 UV lamps; the disinfection system was designed for applying a dose of 55 mJ/cm^2 to reclaimed water with a SS concentration below 5 mg/l, and a UV light transmittance of 60%. Oxygen supplied from a cryogenic tank

Table 2 | Quality requirements for reclaimed water used for in-stream flow substitution, restoration of natural wetland areas and agricultural irrigation

Parameter	**Limit**
Biochemical oxygen demand, BOD_5	$\leq$ 10 mg/l
Suspended solids, SS	$\leq$ 5 mg/l
Turbidity	$\leq$ 5 NTU
Faecal coliforms	$<$ 10 CFU/100 ml
Intestinal helminth eggs	$<$ 1 Ut/1000 ml
Residual chlorine	$\geq$ 0.6 mg/l
Dissolved oxygen, O_2	$\geq$ 7.5 mg/l
Electrical conductivity (for agricultural irrigation)	$\leq$ 1,400 μS/cm

is injected into the pipelines conveying reclaimed water flows for environmental uses, to ensure that its dissolved oxygen concentration is above 7.4 mg/l. The construction cost for the water reclamation facility was 23 M€.

Irrigation water

The regular use of reclaimed water, as a partial (50%) substitution of surface water allocations from the Llobregat River, has been traditionally opposed by the Right River Bank Irrigation District. The main reasons for rejection have been the high electrical conductivity levels of reclaimed water, particularly during the summer season when it may reach values close to 3,000 μS/cm, and also the widespread fear that produce markets, particularly in EU countries, may reject crops irrigated with reclaimed water. As of July 2007, the electrical conductivity of Llobregat River water ranges from 2,800 to 3,000 μS/cm, at lower values than those historically recorded just a decade ago, before a brine terrestrial outfall was built to convey the salt mine brines and the salty industrial effluents discharged at the time into the upper watershed of the Llobregat River. Although there are no European regulations addressing irrigation of food crops with reclaimed water, the alleged market rejection is commonly presented as a reason to oppose or postpone agricultural irrigation with reclaimed water, even of the best quality internationally recognized.

To overcome the electrical conductivity limitation and promote the use of reclaimed water for agricultural irrigation, the decision was taken by Depurbaix and the Catalan Water Agency to build an additional water reclamation process able to lower the electrical conductivity of the already available reclaimed water. To remove excess dissolved solids from reclaimed water, a 2-phase electrodialysis reversal plant is being built with a capacity to produce 55,000 m^3/day, an 85% fraction of the total flow assigned to agricultural irrigation. The demineralized effluent will be mixed with the remaining flow of reclaimed water to achieve irrigation water with an overall electrical conductivity lower than 1,400 μS/cm, a limit determined necessary for the agricultural crops commonly grown at the lower Llobregat Delta. The construction cost for the demineralization plant is 15.9 M€, and the O&M costs are estimated at 0.23 €/m^3.

Pumping station

Reclaimed water for in-stream flow substitution, agricultural irrigation and restoration of natural wetland areas is delivered by 2 pumping stations located in a single building, each with four submersible pumps (3 active and one spare). A pumping station with a capacity of 2.75 m^3/s provides 0.75 m^3/s for agricultural irrigation and 2.00 m^3/s for in-stream flow substitution, and a second pumping station with a capacity of 0.40 m^3/s delivers reclaimed water for restoration of natural wetland areas, which are located within a kilometre of the reclamation facility. Oxygen is injected in both water flows before leaving the plant, so as to maintain a dissolved oxygen concentration of 7.4 mg O_2/l at their discharge points. The water distribution network has 18.8 km of main pipes, most of them made of steel reinforced concrete and 1,600 mm diameter. Reclaimed water for agricultural irrigation is delivered into an equalization pond, to dissociate production rates of reclaimed water from water reuse rates for agricultural irrigation. The electrodialysis reversal plant, to lower the electrical conductivity of irrigation water, will be located in the proximity of the equalization pond in order to closely adjust its operation schedule with water reuse rates for agricultural irrigation. The construction cost of the pumping and distribution network was 66.8 M€.

Seawater intrusion barrier

Hydrogeological studies conducted at the lower Llobregat Delta indicate that the maximum recharge capacity of the aquifer is close to 15,000 m^3/day. A seawater intrusion barrier project was designed based on the experience from the Orange County Water District (2006) GWRS project and

Table 3 | Quality requirements for reclaimed water used for injection into the seawater intrusion barrier

Parameter	Limit
Suspended solids	≤ 1 mg/l
Turbidity	≤ 0.1 NTU
Faecal coliforms	< 10 CFU/100 ml
Electrical conductivity	≤ 150 μS/cm

other recharge projects in Spain. Table 3 summarizes the basic water quality requirements established for the water to be injected into the seawater intrusion barrier. To ensure optimum operation of the artificial recharge project, while preventing water quality deterioration of the affected potable water aquifer, an additional reclamation process has been built including a 500 μm microscreening process, an ultrafiltration step, an intermediate storage, a reverse osmosis step, and a UV light disinfection step. Treated water is further mixed on a 1:1 ratio with potable water taken from the local domestic water supply network (water extracted from the potable aquifer, passed through a water treatment plant, and then pumped into the distribution system), before it is directed to the injection wells using a 500 mm diameter distribution pipe. This operational strategy was adopted in accordance with OCWD traditional approach, to ensure approval from regulatory agencies (water resources protection and public health) and also to gain acceptance from the public at large. The seawater intrusion barrier is considered a demonstration project for both the water treatment and injection techniques adopted.

An ultrafiltration plus reverse osmosis and UV light disinfection facility has been built to produce 5,000 m^3/day during the first phase of the project; that capacity will be expanded with an additional capacity of 10,000 m^3/day during the second phase of the project. Four injection wells have been built, able to accept each an average flow of 50 m^3/h; the design process for the second phase of the project provides for the construction of 10–12 additional wells. The wells serve as injection points into the deep aquifer system, at an average depth of 55 metres.

The first phase of the seawater injection barrier was completed in January 2007 and has been under continuous operation since March 2007. Two wells are currently in operation, one routinely accepting 90 m^3/h (2,200 m^3/day) and other currently operating (July 2007) at an injection rate of 12 m^3/h (300 m^3/day), with a steady increase of 3 m^3/week. Those figures illustrate the variability of aquifer permeability and the need to follow a steady process for developing the optimum injection potential of each well. The other two wells will be put in operation subsequently. The water injected and the aquifer system are systematically monitored by the plant construction company (first year of operation) and also by the technical services of the Lower Llobregat Aquifer District and the Catalan Water Agency. The seawater intrusion barrier system will operate continuously, aside from maintenance and cleaning periods. The construction cost of the seawater intrusion barrier system (first phase) has been 6.9 M€, and its estimated O&M costs are 0.36 €/m^3.

Economic analysis

Table 4 summarizes the investment and operation and maintenance costs of the different components of the water reclamation and reuse project of El Prat de Llobregat. Based on those figures, the following economic indicators can be estimated for the project:

1. Water reclamation (basic treatment):
   Reclaimed water index (no capital cost): 0.05 €/m^3 annual capacity (2007).
   Reclamation investment index: 0.21 €/m^3 annual capacity (3.5 m^3/s) (2007).
2. Water reclamation for agricultural irrigation (demineralization):
   Reclaimed water index (no capital cost): 0.23 €/m^3 capacity (estimated).
   Reclamation investment index: 0.70 €/m^3 annual capacity (1995).
3. Water reuse for in-stream flow, restoration of wetlands and agricultural irrigation:

Table 4 | Construction costs and operation and maintenance costs of the water reclamation facilities included in the El Prat de Llobregat project

Item	Construction cost, M€	O&M costs, €/m^3
Nutrient removal	15.6	–
Water reclamation plant	23.0	0.05
Water distribution network	66.8	–
Reversal electrodialysis plant	15.9	0.23
Seawater intrusion barrier (first phase)	6.90	0.36
Seawater intrusion barrier (second phase)	14.0 (estimated)	–

Reuse investment index: 0.60 €/m^3 annual capacity (3.5 m^3/s).

4. Water reclamation for seawater intrusion barrier:
   Reclaimed water index (no capital cost): 0.36 €/m^3 (first phase).
   Reclamation investment index: 2.74 €/m^3 annual capacity (2,500 m^3/day demineralized).
5. Water reuse for seawater intrusion barrier:
   Reuse investment index: 2.40 €/m^3 annual capacity (5,000 m^3/day injected).

Three main conclusions emerge from the previous results. (1) The cost of water reclamation using a complete physico-chemical process (0.05 €/m3) and the investment cost required for constructing such a facility (0.21 €/m^3 annual capacity) are very similar to those observed in similar large scale projects in Spain. (2) Seasonal operation of the facilities (summer season), as is initially expected in the El Prat de Llobregat reclamation plant, affects directly the investment index, as the investment costs have to be distributed among the cubic metres of reclaimed water actually produced; the actual cost of producing reclaimed water is affected to a lesser degree by seasonal operation, due to reduced expenditures in chemicals, energy and labor. (3) Application of higher degrees of reclamation, such as demineralization for agricultural irrigation and for injection into a seawater intrusion barrier, result in a considerable increase in both the investment cost index and the cost of water reclamation, as compared to basic physico-chemical reclamation process, up to the point of bringing the corresponding figures three times higher in the partial desalination process (electrodialysis reversal) and upto ten times higher in the reverse osmosis case.

Those results further suggest two basic operational recommendations: (1) reclamation facilities should preferably be operated on a permanent basis along the year, so as to optimize the investment and achieve the highest beneficial effects for which they were proposed (water substitution for in-stream flows and agricultural irrigation, and flows for natural wetland restoration); and (2) source control measures should be systematically implemented throughout the sewer catchment area, so as to reduce diffuse salt contributions from urban and industrial discharges that are not altered during conventional wastewater treatment processes.

Current situation and future perspectives

As of July 2007, reclaimed water is being used for in-stream river water augmentation and natural wetland restoration, using the initially designed flows. Injection of reclaimed water at the seawater intrusion barrier is conducted at a rate of 2,500 m^3/day (50% of design capacity) and will be steadily brought to full capacity in the next months. Reclaimed water supply for substitution of agricultural irrigation water is pending construction of an electrodialysis reversal facility that will provide irrigation water with a final electrical conductivity of 1,400 μS/cm.

The reliability and quality level of reclaimed water for the three different beneficial uses considered will become apparent in the coming months. In addition to the already evident beneficial effects obtained from in-stream river flow substitution and restoration of wetland areas, by storing equivalent water volumes in upstream reservoirs, the systematic use of reclaimed water for agricultural irrigation should overcome the reservations of local farmers to use this water source, particularly due to the its higher reliability as compared with surface water supplies. The impending approval of reclaimed water quality regulations by Spanish government is expected to become an additional convincing factor for overcoming the alleged negative perception associated with the use of reclaimed water for produce crops cultivation. Finally the systematic follow-up of the seawater intrusion barrier should provide practical guidelines for expanding this type of strategy for groundwater quality management in other affected aquifers. By optimizing the operation and maintenance strategies of this type of demonstration projects, particularly when considering the scale-up factor, it is expected that realistic estimates for economic and financial costs of those techniques can be obtained.

CONCLUSIONS

Water reclamation and reuse have become essential components of water resources management in the Metropolitan Area of Barcelona, by helping to develop additional water resources in the lower Llobregat River, one of its main sources of water supply. By generating a reliable flow of 300,000 m^3/day of high quality reclaimed water, the options available for integrated water resources management have widely expanded as to allow consideration of in-stream river water substitution, agricultural irrigation, restoration of natural wetland areas and supply to a seawater intrusion barrier. The most evident beneficial effects derived have been the supply of 175,000 m^3/day for in-stream river flows substitution, downstream of current abstraction points for water supply, the supply of 35,000 m^3/day for natural wetland restoration, the provision of 65,000 m^3/day for agricultural irrigation, and the supply of 5,000 m^3/day (to be expanded up to 15,000 m^3/day) for injection into a seawater intrusion barrier. Those management options have been possible thanks to the implementation of an extensive water distribution system (the reuse component) that allows distribution of reclaimed water to a point 15 km upstream of the reclamation facility, and to a seawater intrusion barrier within a few kilometres of the plant.

The water reclamation and reuse project of El Prat de Llobregat was initially promoted by Depurbaix, an agency of the Ministry of the Environment, in cooperation with the Catalan Water Agency. Users perception has been diverse, posing the need for continuous promotion of reclaimed water among regulatory agencies before it becomes widely accepted by all users. The regular use of reclaimed water has been traditionally opposed by local farmers, mainly due to the high electrical conductivity levels of reclaimed water, particularly during the summer season when it may reach values close to 3,000 μS/cm, and also the widespread fear that produce markets, particularly in EU countries, may reject crops irrigated with reclaimed water. The higher reliability of reclaimed water supply has not been a convincing argument to irrigation districts, probably because the water supply restrictions brought about by meteorological conditions have not been severe enough until now.

The cost of water reclamation using a complete physico-chemical process (0.05 €/m^3) and the investment cost required for constructing such a facility (0.21 €/m^3 annual capacity) are very similar to those observed in similar large scale projects in Spain, while application of higher degrees of treatment, such as demineralization for agricultural irrigation and for injection into a seawater intrusion barrier, result in a considerable increase in both the cost of water reclamation and investment costs, bringing the corresponding figures 3 times higher in the partial desalination process (electrodialysis reversal) and to 10 times higher in the reverse osmosis case. That brings the need for reclamation facilities to be operated permanently along the year, and the implementation of a source control program to reduce diffuse salt contributions from urban and industrial discharges.

The reliability and quality level of reclaimed water will become apparent in the coming months, when the project goes into operation. In addition to the already evident beneficial effects from in-stream river flow substitution and restoration of wetland areas, the systematic use of reclaimed water for agricultural irrigation should overcome the reservations of local farmers to use this water source, particularly due to the its higher reliability. The impending approval of reclaimed water quality regulations by Spanish government should become a convincing factor for overcoming the negative perception associated to the use of reclaimed water for produce crops cultivation.

REFERENCES

Asano, T., Richard, D., Crites, R. W. & Tchobanoglous, G. 1992 Evolution of tertiary treatment requirements in California. *Water Environ. Technol.* **4**(2), 36–41.

California State Departament of Health Services 2001 *California Health Laws Related to Recycled Water "The Purple Book"*. June 2001 Edition. http://www.dhs.ca.gov/ps/ddwem/waterrecycling/PDFs/purplebookupdate6-01.PDF

Catalan Water Agency 2006 Criteris de qualitat de l'aigua regenerada segons diferents usos. *Reclaimed water quality criteria for different uses*. http://mediambient.gencat.net/aca/documents/ca/planificacio/criteris_tecnics/criteris_reutilitzacio_aigues_regenerades.pdf

Depuradora del Baix Llobregat (Depurbaix) 2006 Reutilización del efluente del Baix Llobregat, http://www.depurbaix.com/archivos/informes-estudios/Reutilizacion%20Baix%20Llobregat.pdf

Infoenviro 2006 Reutilización de las aguas residuales del Baix Llobregat. Reuse of wastewaters at the Lower Llobregat. An exclusive plant report, October 2006. http://www.infoenviro.es/inc/plantDescription.php?language = en

Mujeriego, R. 2005 La reutilización, la regulación y la desalación de agua. Water reuse, storage, and desalination. *Ingeniería y Territorio*, No. 72. ISSN: 1695–9647. Colegio de Ingenieros de Caminos, Canales y Puertos. Madrid. http://www.ciccp.es/revistait/portada/index.asp?id = 265

Mujeriego, R. 2004 La gestión del agua en el sur de California. Water management in Southern California. *Ambienta*, No. 38, pág. 31–38. ISSN: 1577–9491. Ministerio de Medio Ambiente. Madrid. http://www.mma.es/portal/secciones/biblioteca_publicacion/publicaciones/revista_ambienta/n38/index.htm

Orange County Water District (OCWD) 2006 The Groundwater Replenishment System (GWRS): Needs and Benefits. http://www.gwrsystem.com/about/overview.html

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.

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