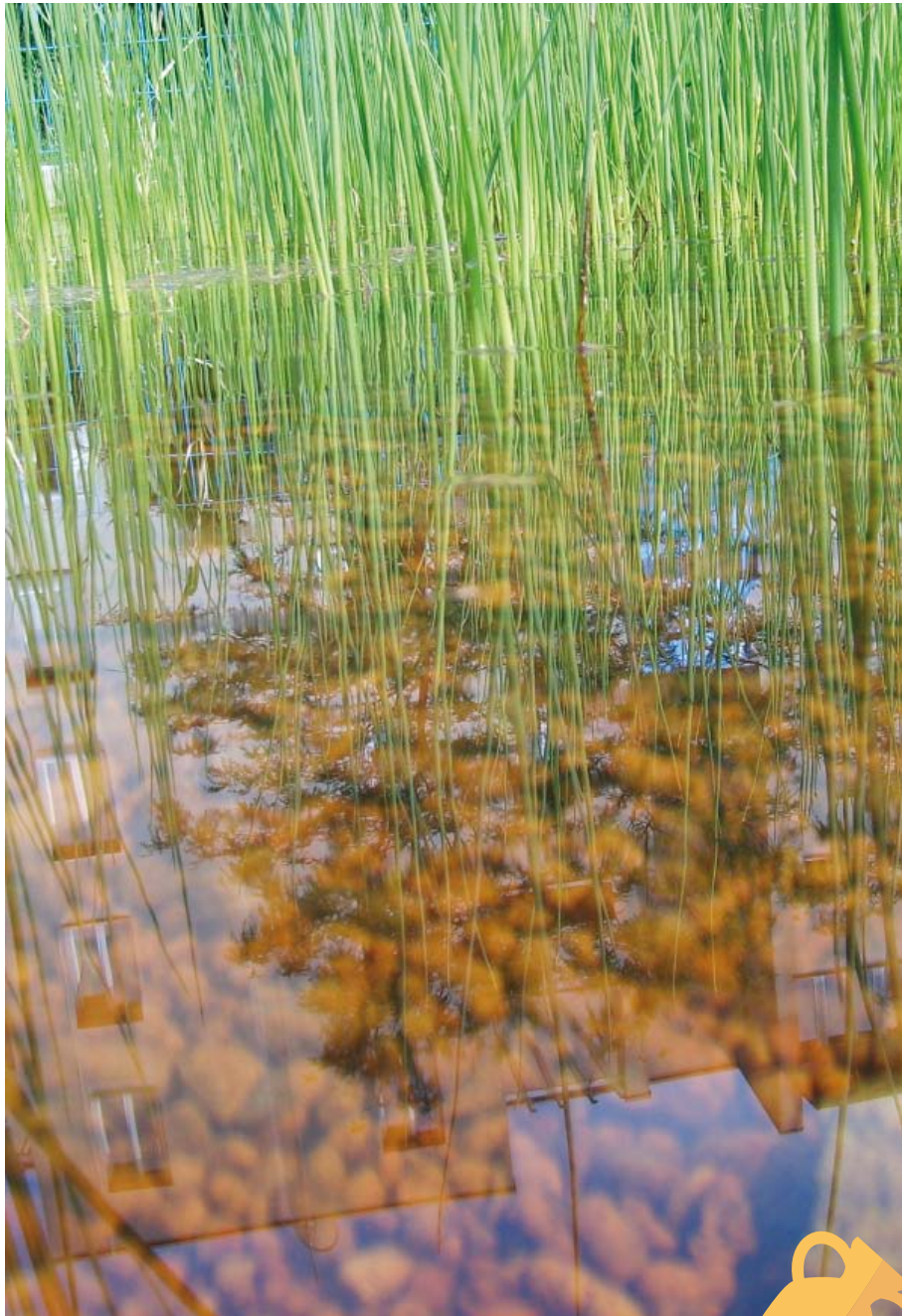




## THE EU MEDA WATER PROGRAMME



Picture Source: E. Nolde

The 40 million Euro MEDA Water programme has been an important step on the way to improving local water management in the Mediterranean. Much remains to be done to further develop and make sustainable all that was achieved in the MEDA Water Programme on a larger scale.



### THE WATER FOOTPRINT OF SPAIN



Picture Source: Martínez-Santos

In Spain, EU's most arid country, water resource management is an issue as important as controversial. Today most water resources experts admit that water conflicts are not caused by the physical water scarcity but mainly due to poor water management.

### CONSTRUCTED WETLAND IN EGYPT



A constructed wetland for the treatment and reuse of decentralized wastewater has been realized in Egypt: Field constructed for the treatment of sewage water and reuse for irrigation purpose.

### ZERO NET POTABLE WATER USE: A DESIGN OF URBAN RENEWAL IN SYDNEY (AUS)



Picture Source: Frasers Property

A number of former industrial sites in central Sydney are currently being redeveloped as entire new precincts, comprising residential, commercial and retail space. At one of these sites, the intention is to build a water system that uses zero net potable water from the mains supply.



**D**ue to an extension of the project Zer0-M it was possible to provide you with another issue of **SUSTAINABLE WATER MANAGEMENT** under the MEDA Water programme. I take the opportunity of this issue to reiterate the key concept of Zer0-M here. This concept was not developed by the project on its own, but furthered and adapted to new conditions and countries:

- The first step in a sustainable system is an effective water demand management;
- Rainwater is part of the available water resources and should be managed, not merely evacuated;
- The water supplied to a household remains a valuable resource even after its use;
- Nutrients contained in human excreta belong to agriculture and not into water bodies;
- Segregation of wastewater fractions at the source is one means to achieve these goals with an acceptable effort;

All this leads to a household centred approach to water management, where the first measures are set at the household level and only what cannot be handled at a smaller level is referred to the next larger one, from the household to the building to the neighbourhood and the town.

We hope that these lessons from Zer0-M can spread throughout the Mediterranean region, an area of a very old tradition of sustainable water management, which has to rely upon its own roots and develop new solutions based on traditional knowledge. If the EU further assists this development it may have the chance to acquire technologies which could prove valuable in Europe beyond the Mediterranean region, especially under the threat of yet unpredictable changes of climate patterns.

Stay tuned in to the homepage [www.zer0-m.org](http://www.zer0-m.org), which will be available for three more years (2011). Do not hesitate to contact any of the partners for issues of sustainable water management.

I thank here all authors who have contributed to this journal throughout the project and made it, hopefully, valuable to you.

Yours

*Martin Regelsberger*  
([m.regelsberger@aee.at](mailto:m.regelsberger@aee.at))

This journal, “Sustainable Water Management”, is an initiative of the project “Sustainable Concepts towards a Zero Outflow Municipality (Zer0-M). The project is part of the Euro-Mediterranean Regional Programme For Local Water Management (MEDA Water) of the European Union and the countries bordering the Mediterranean Sea.

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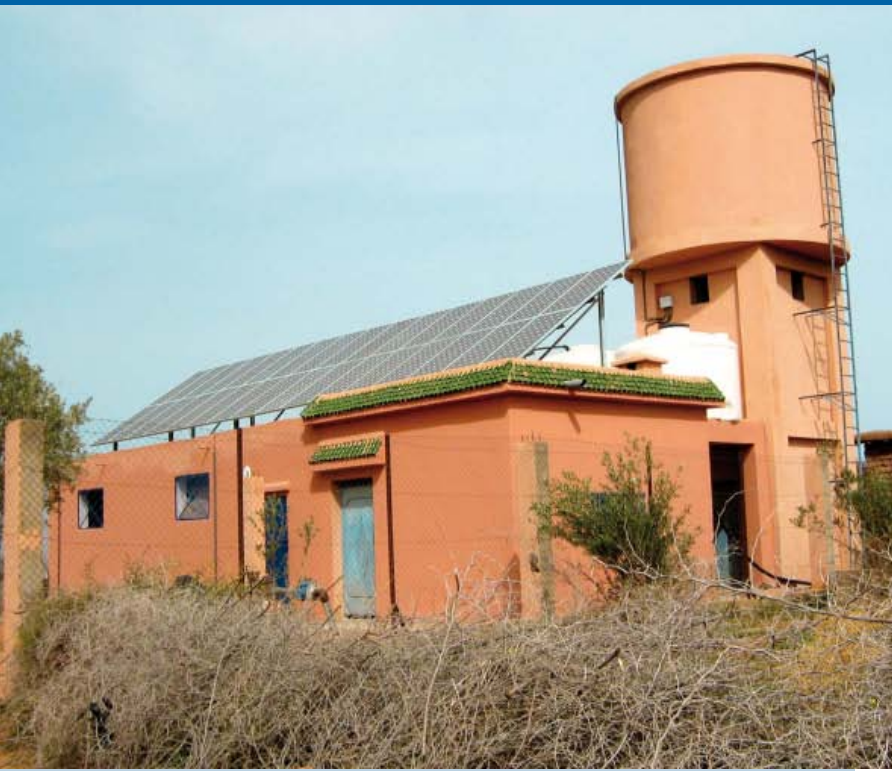
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# THE EU MEDA WATER PROGRAMME

By GERT SOER\*

The countries around the Mediterranean Sea, in particular those in the southern and Eastern part, are subjected to an extreme water scarcity, which is only made worse by the effect of global warming. The problems resulting from this water scarcity cannot be solved by large scale infrastructure measures alone. Much of the negative effects of water scarcity can be alleviated by improving the local management of water resources in the rural and peri-urban area.

## MEDA Water



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▲ *Figure 1:*  
**ADIRA SOLAR DESALINATION PILOT PLANT IN AITBENHSSAINE, MOROCCO**

Source: FM21

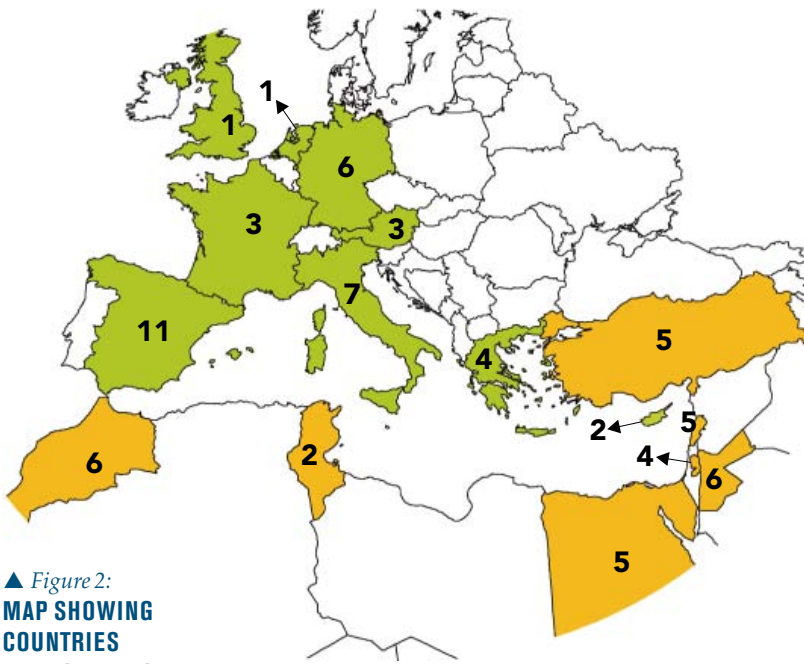
This fact was recognized by the last conference of the Euro-Mediterranean Water Ministers that took place in Turin in 1999. In this conference they launched, among other measures, the MEDA Water Programme with the full support of the European Union.

The MEDA Water Programme works in a number of action fields to improve local water management. These fields are the improvement of wastewater management and the reuse of wastewater in irrigation, the decentralization of water supply and sanitation, applying small scale affordable solutions, the involvement of water users in decision-making, the improvement of water use efficiency in irrigation, the mitigation of the effects of droughts and the reclaiming of brackish water resources by decentralized desalination.

The programme, made up of nine large regional projects and allocated 37 million EUROS, is one of the most important local water management exercises ever undertaken by the European Union in developing countries.

Encouraging results have been achieved in many fields. Farmers increasingly manage their water resources themselves; villages now plan the improvement of water availability and its use, and negotiate their investment needs with local, regional and national authorities; wastewater reuse is becoming more accepted as a result of clear guidelines and pilot projects.

Moreover, extensive North-South academic exchanges have taken place on drought management, wastewater treatment, wastewater reuse, autonomous



▲ **Figure 2:**  
MAP SHOWING COUNTRIES PARTICIPATING IN THE MW PROGRAMME. NUMBERS: QUANTITY OF NON-PROFIT ORGANISATIONS PER COUNTRY; GREEN: EU-COUNTRIES; ORANGE: MEDA-COUNTRIES  
Source: RMSU

▼ **Figure 3:**  
EMWATER PILOT WASTEWATER TREATMENT PLANT UNIVERSITY OF BALAMAND, LEBANON  
Source: RMSU

desalination, irrigation technology, dissemination technology and others. The capacity of MEDA countries to solve their problems has therefore increased.

## BACKGROUND INFORMATION

The Turin Conference of 1999 created four actions to improve local water management; These were (i) the establishment of local focal points (largely unsuccessful); the creation of EMWIS as an information platform for the Mediterranean area; (iii) the MEDA Water Programme for Local Water Management; and (iv) the Regional Monitoring and Support Unit (RMSU) for the MEDA Water Projects and the EU Water Initiative (vs. times schedule below). The EMWIS programme started right after the Turin Conference whereas the MEDA Water Programme for procedural reasons started more than three years later in April 2003. In October 2005, more than halfway through the Programme, the RMSU was created. Important milestones

in the policy development have since been the Water Director meetings and the three MEDA Water Regional Conferences organised by the RMSU.

The overall objective of the MEDA Water Programme is to improve the sustainable availability of water resources for the economic and social development of the Mediterranean region through the integrated management of water resources at the local level. The expected results of the MEDA Water Programme are (i) the assessment of the present situation (2003-2004) with regard to local water management; (ii) the reinforcement of regional co-operation, (iii) the improvement of the planning and management of water resources; and (iv) the increase of the availability of alternative water resources (desalination, wastewater reuse). Next to that, the MEDA Water Programme has worked on horizontal themes such as the transfer of knowledge, the increase of awareness and the improvement of institutional capacities.

In total 71 non-profit organisations (development corporations, research institutes, universities, NGOs and ministries of in altogether seven MEDA and nine EU countries participate in the MEDA Water Programme (see figure 2).

The Programme can be divided into five groups of projects which at times cover subjects that overlap with other groups. These are:

- the **treatment and reuse of wastewater**; the projects in this group are EMWATER and MEDAWARE;
- **non-conventional water supply** (autonomous desalination) and **ecosanitation**; the projects in this group are ADIRA and ZERO-M;
- **improvement of local governance** of water resources, supply and sanitation; the projects in this group are EMPOWERS and ISIIIMM;
- the **improvement of irrigation water management**; the projects in this group are IRWA and MEDWA; and
- the **improvement of drought management**; In this group there is only MEDROPLAN.

## TREATMENT AND REUSE OF WASTEWATER

The main task of the two projects in this group has been the inventory and assessment of wastewater treatment and reuse for irrigation in five of the seven target countries, the production of guidelines for wastewater treatment and wastewater reuse, the creation of computer supported decision support tools, knowledge transfer and training and awareness-raising. Next to this, innovative treatment methodologies have been tested at pilot scale in four countries.

The main outputs of this exercise have been country reports, guidelines, training manuals and five properly functioning demonstration, research and training pilot wastewater treatment facilities.

The developed methodologies, guidelines and support tools are ready to be implemented on a larger scale in all the Mediterranean countries.





## NON-CONVENTIONAL WATER SUPPLY

The group covers two rather different projects.

The **ADIRA project** is concerned with autonomous small desalination units driven by renewable energy. The project has made an inventory of the potential for such desalination systems in the four target countries where it is working, developed a handbook for the planning and design of such installations, supported by the AUDESSY computer-based decision support tool. Moreover, the project has implemented 10 pilot installations in three different countries. The technology has been proven to be cost-effective for water supply in remote areas and is ready to be implemented on a much larger scale.

The **Zer0-M project** is concerned with the ecosanitation and zero-outflow methodology of water and nutrients in the rural and peri-urban setup. The project has successfully raised awareness on alternative ecosanitation systems such as the separation of grey and black water, urine separation, the recycling of water and nutrients, etc. It has built demonstration and training centres in four different countries and pilot plants in three countries to test the developed technology in a real world situation. The technology needs to be further developed and tested for its social and economic viability, but is ready to be implemented and duplicated on a larger scale.

## IMPROVEMENT OF LOCAL WATER GOVERNANCE

The two projects in this group have both been working on governance issues. The **ISIIMM project** has been attacking this problem specifically for irrigation at all levels of society, including ministries, governorates, local authorities and water user associations. The analysis and recommendations for improving the governance structure have been tested in 11 pilot areas, in the MEDA region as well in EU countries. As a result, water user associations have been strengthened and rural living conditions improved.

The **EMPOWERS project** has mainly worked in the Middle East and introduced planning and participation concepts to small rural communities in order to improve their role in decision-making in water supply and sanitation. The methodology used by the project merits dissemination and use on a much larger scale and has the potential to become an indispensable tool in all rural development projects.

## IMPROVEMENT OF IRRIGATION MANAGEMENT

The two projects in this group have been mainly working in the Middle East region. They have rehabilitated water resources, implemented rainwater harvesting, improved the efficiency of water use on farms, improved the water quality for irrigation, introduced con-



◀ *Figure 4:*  
**FIELD VISIT AT THE  
ISIIMM PROJECT  
IN BAHERA, EGYPT**  
*Source: ISIIMM*

cepts for the reuse of wastewater and grey water and trained farmers in all aspects of irrigation water management on the farm. The projects have made an important contribution to the development of concepts that aim at improving irrigation water efficiency. They have also intensively worked together with farmers, set up functional extensions and established farmer associations where needed. Special attention has been paid to poor farmers and women.

The methodologies introduced by the two projects are ready to be implemented on a larger scale, also in other countries.

## IMPROVEMENT OF DROUGHT MANAGEMENT

The improvement of drought management has been the task of the MEDROPLAN project. The project has made an inventory of drought related problems in the Mediterranean area and introduced guidelines that in

### RÉSUMÉ :

#### LE PROGRAMME MEDA EAU DE L'UE

*Gert Soer*

Le programme MEDA Eau de 40 millions d'euros a pour but d'améliorer les conditions de gestion locale de l'eau à travers 9 projets régionaux qui visent cinq composants techniques : le traitement et la réutilisation de l'eau usée, les ressources d'eau alternatives, l'amélioration de la gouvernance locale, l'amélioration de la gestion de l'eau d'irrigation et l'amélioration de la gestion des sécheresses.

Des résultats encourageants ont été obtenus dans tous les secteurs mentionnés ci-dessus. Les agriculteurs gèrent de plus en plus eux-mêmes les ressources en eau ; la réutilisation de l'eau usée est de plus en plus acceptée ; l'utilisation de l'eau d'irrigation est devenue plus efficace et des concepts innovants ont été introduits pour la récupération et la gestion des ressources.

Des échanges extensifs nord-sud au niveau académique ont eu lieu concernant la gestion des sécheresses, le traitement et la réutilisation de l'eau usée, le dessalement autonome, les technologies d'irrigation, les techniques de vulgarisation etc. Ceci a augmenté la capacité des pays MEDA à résoudre leurs problèmes.

Le programme MEDA eau a constitué une étape importante en vue d'améliorer la gestion locale de l'eau en Méditerranée. Il reste cependant encore beaucoup à faire pour continuer à développer et rendre durable sur une plus grande échelle tout ce qui a été réalisé dans le programme MEDA Eau.



▲ *Figure 5:*  
**IRWA IRRIGATION  
WATER FILTERS  
IN KARAMEH,  
JORDAN**

*Source: RMSU*

a step-by-step approach help the user of the guidelines to prepare a drought management plan for the country or for a river basin or other region in that country.

The guidelines have been tested in a number of catchment areas. They are ready to be verified and implemented in all relevant MEDA countries, which should be the next step in their implementation.

The project has also established a network of institutions that have a function in the management of droughts. This network is a permanent mechanism that will outlive the duration of the MEDROPLAN project.

## JOINT PROCESS WATER FRAMEWORK DIRECTIVE - EU WATER INITIATIVE

The MEDA Water Programme has also financed activities within the framework of this Joint Process. These are: country studies on demand management, a workshop on demand management in 2006 in Zaragoza and two river basin pilot projects, Ec'Eau Sebou in Morocco (which studied the use of economic instruments in river basin management) and Litani River in Lebanon (which studies the optimal forms of organisation for river basin management in that country). The first pilot was successfully completed early in the year 2007 and the second will be completed in March 2009.

It is important to realize that much needs still to be done to further develop and make sustainable all that was achieved in the MEDA Water Programme on a larger scale. Countries in the Maghreb (Morocco, Algeria and Tunisia) are now ready to implement rural sanitation concepts on a much larger pilot scale, have announced to start using and further develop drought management methodology developed under the MEDA Water Programme and plan to use autonomous desalination as in the ADIRA concept. In the Middle

East, water demand management, wastewater reuse, drought management and desalination are increasingly important issues that have profited much from the results of the MEDA Water Programme. Moreover, irrigation water management, particularly increasing irrigation water efficiency and irrigation water quality received an important impulse from the MEDA Water Programme and follow-up projects are planned. Thanks in large measure to the MEDA Water Programme, water user participation is now recognized by most of the MEDA Governments as an important tool to improve water management. It is hoped that the much needed follow-up activities will receive the continuing support of governments and donor organisations alike.

**For more information**, please visit the website of the MEDA Water Programme

<http://www.medawater-rmsu.org> where links can also be found to the individual websites of the 9 MEDA Water projects and to the website of EMWIS.

**Photographs** by courtesy of the MEDA Water projects and the RMSU.

## ABSTRACT:

The 40 million Euro MEDA Water Programme intends to improve local water management conditions through nine regional projects that aim at five technical components: The treatment and reuse of wastewater, alternative water resources, the improvement of local governance, the improvement of irrigation water management and the improvement of drought management.

Encouraging results have been achieved in all of the sectors mentioned above. Farmers increasingly manage their water resources themselves, wastewater reuse is becoming more accepted, irrigation water use has become more efficient and innovative concepts have been introduced for the reclaiming and management of resources.

Extensive North-South academic exchanges have taken place on drought management, wastewater treatment, wastewater reuse, autonomous desalination, irrigation technology, dissemination technology and others. The capacity of MEDA countries to solve their problems has therefore increased.

The MEDA Water programme has been an important step on the way to improving local water management in the Mediterranean. Much remains to be done to further develop and make sustainable all that was achieved in the MEDA Water Programme on a larger scale.





# SOLAR WATER HEATING SYSTEM FOR A HAMMAM

## DESIGN AND IMPLEMENTATION FOR A PUBLIC BATH IN MOROCCO

By ALI HAJJI, BOUCHAIB EL HAMOURI, RUDI MOSCHIK and MARTIN REGELSBERGER\*

In hammams, wood is burned in very inefficient water heaters to produce hot water. Other “cheap combustibles” are also used sometimes such as waste rubber, vehicle lubricating car oil and vegetable waste leading to polluting smokes and unpleasant odours in densely populated areas. Water consumption of 150 L/person is also very high in these times of water scarcity.

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◀ Figure 1:  
FINISHED SOLAR COLLECTOR

The 5,000 hammams – 1,000 in Casablanca city alone – in use today in Morocco are the major wood consumers totalling a million tons of wood that is equivalent to 5,000 hectares of forests per year [1]!

### DESIGN ELEMENTS

The hammam Attaisir serves an average of 370 visitors per day. The daily profile of water usage was obtained through separate metering of hot and cold water and comparison to the hourly number of visitors (see figure 2 on p. 8).

It is seen that hot water is used since the first morning hours and this continues until late at night with three peaks around 11:00, 14:00 and 20:00 o'clock.

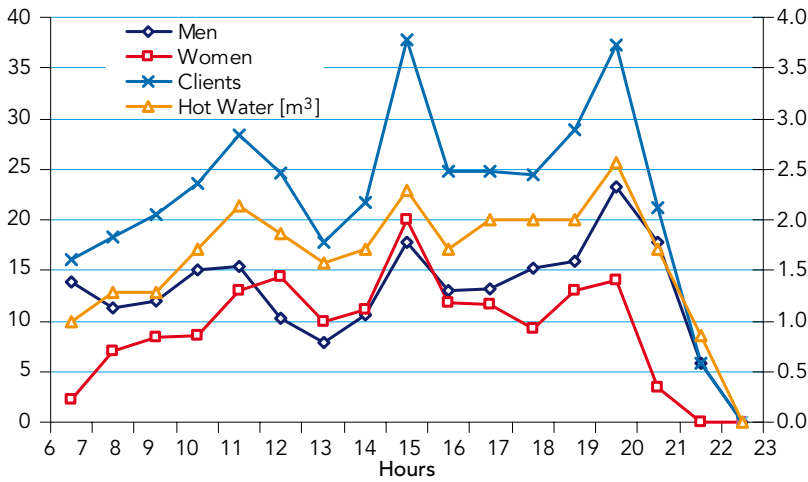
### RÉSUMÉ:

#### SYSTÈME DE CHAUFFAGE SOLAIRE POUR UN HAMMAM – CONCEPTION ET RÉALISATION POUR UN BAIN PUBLIC AU MAROC

*Ali Hajji, Bouchaib El Hamouri, Rudi Moschik et Martin Regelsberger*

L'approche du projet Zer0-M entre dans le cadre de la réduction de la demande de l'eau. Elle introduit la nécessité d'une utilisation rationnelle de l'eau urbaine comme le montre l'exemple de la ville d'El Attaouia (22.000 habitants), située à 80 km au nord-est de Marrakech. Cette ville est dotée depuis 2003 d'une station d'épuration recevant les eaux usées de la ville et d'un périmètre de réutilisation en agriculture d'environ 40 ha. A cette installation s'est ajouté, en mars 2008, dans le cadre d'un partenariat Zer0-M – Municipalité d'El Attaouia, un projet pilote “eaux grises de hammam Attaisir” consistant en la construction d'une station d'épuration des eaux grises. Entre 60 et 80 m<sup>3</sup> d'eaux grises sont épurées par jour et utilisés pour l'arrosage des espaces verts de la ville en remplacement de l'eau de très bonne qualité pompée à 50 m de profondeur (voir Zer0-M Journal 2-2008).

Cet article relate l'extension de l'approche Zer0-M à une gestion intégrée “eau-énergie”. Ainsi, Hammam Attaisir a été équipé une station solaire de 350 m<sup>2</sup> de collecteurs et de trois réservoirs métalliques de stockage des eaux chaudes totalisant une capacité de 20 m<sup>3</sup>. Les suivis effectués pendant les mois d'août et de septembre 2008 montrent que le système peut produire 20 m<sup>3</sup> d'eau chaude à plus de 60°C par jour et que l'économie de bois pouvant en résulter peut atteindre plus de 90% de la quantité normalement brûlée en l'absence du système de chauffage solaire. Un suivi des performances en saison froide sera effectué pour déterminer l'économie de bois qui sera réalisée en cette saison.



▲ Figure 2: HOURLY PROFILE OF HOT WATER CONSUMPTION IN A TYPICAL AVERAGE DAY

An analysis of the daily data (Table 1) shows peak values on Fridays of about 500 visitors and 72 m<sup>3</sup> of water. The specific water consumption is about 160 L/person and visit, 46% of which is hot water at 60 °C.

On the basis of the above data, two systems were implemented at the hammam: A greywater system, which collects the water from bathing, called greywater (see figure 5), separately and a solar heater for the production of hot water. The greywater is treated in a constructed wetland (see figure 6) and used for irrigation of green areas of the town. The system is described in the previous issue of this journal [1].

The solar thermal system was designed with the technical specifications of table 2.

It was decided that for this quite large system, it would be convenient to have three independent arrays. The lay out of the collectors on the roof terrace is shown in figures 3 and 4.

The collector surfaces of the three loops are: 90 m<sup>2</sup> for loop 1 (yellow) and 130 m<sup>2</sup> for loops 2 and 3 (grey and green).

Day	Number of Persons	Water consumption: Total [m <sup>3</sup> ]	Hot Water [m <sup>3</sup> ]	Hot Water Ratio	Litre per person
Monday	296	46.5	19.0	40.0%	157
Tuesday	329	51.7	23.0	40.0%	157
Wednesday	345	54.9	28.0	50.0%	159
Thursday	367	61.3	30.0	50.0%	167
Friday	488	72.6	35.0	50.0%	149
Saturday	357	62.2	30.0	50.0%	174
Sunday	448	71.9	30.0	40.0%	160
AVERAGE	376	60	28	46.3%	160

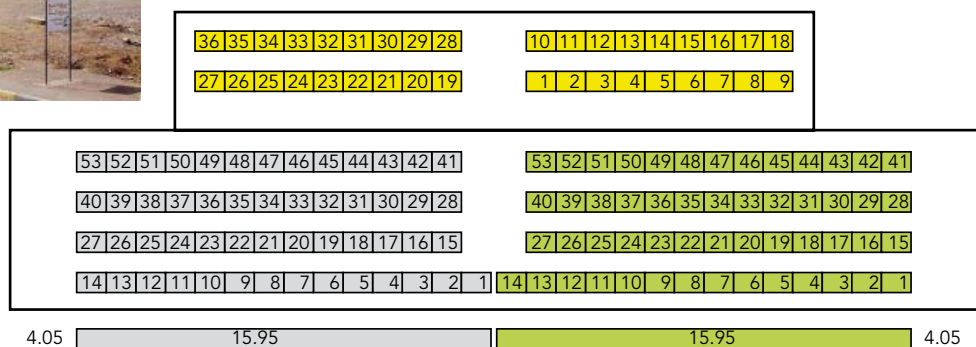
▲ Table 1: DAILY WATER CONSUMPTION DATA

▼ Table 2: DESIGN ELEMENTS OF THE SOLAR THERMAL SYSTEM

Description	Unit	Design data
<b>Cold/Hot water mixing ratio</b>		
Cold water temperature	°C	25
Warm water temperature	°C	41
Hot water temperature	°C	60
Volume of warm Water	m <sup>3</sup>	75.0
Volume of Hot Water	m <sup>3</sup>	34.3
Volume of Cold Water	m <sup>3</sup>	40.7
% of Hot water	%	45.7%
<b>Daily heating energy</b>		
Heating Energy	kWh	1393
<b>Wood consumption</b>		
Heating power	kcal/kg	2392
Boiler Efficiency	%	50%
Heating energy	kWh	1393
Wood consumption	kg	1003
<b>Water Usage</b>		
Number of persons	pers	450
Volume of hot water	m <sup>3</sup>	34.3
Specific consumption	Liter/pers	76.2
<b>Collector surface</b>		
Solar Input	kWh/m <sup>2</sup>	4
Collector surface	m <sup>2</sup>	348
<b>Hot water storage</b>		
Volume	m <sup>3</sup>	20
Number of loops		3



▲ Figures 3 and 4: ROOF LAYOUT OF COLLECTORS



0.5  
1.8  
2  
1.8  
2  
0.5  
1.8  
2  
1.8  
2  
1.8  
2  
1.8





◀◀ *Figure 5:*  
**INLET OF RAW  
GREYWATER**



◀ *Figure 6:*  
**FINISHED  
CONSTRUCTED  
WETLAND,  
FIRST STAGE**

## PRELIMINARY PERFORMANCE

The hot water temperature reaches peak values of 90°C and the 20 m<sup>3</sup> tank heats up relatively quickly and remains at temperatures above 60°C all day long. During the first two months of operation (August and September 2008), the production of hot water was sufficient for the needs of the hammam. Wood consumption decreased substantially, only a very small quantity of wood was burned very early in the morning to heat the floor and walls of the hammam. Solar energy for the floor is being considered by the hammam's owner, too, which would however need an adaptation of the existing intermediate floor heating.

## CONCLUSIONS

The pilot project implemented by Zer0-M in El Attaouia is a step forward toward sustainable concepts for integrated water and energy management in arid areas. All of the Zer0-M partners are satisfied: the municipality and the population of the city for greywater reuse and the hammam's owner for the solar thermal system.

The results clearly show that substantial water and energy savings could be achieved in order to act on the increasing demand for water and energy. Monitoring data also show that the greywater leaves the hammam with almost 40°C. Next implementations or newly erected hammams should certainly make use of this considerable amount of energy in order to further improve the energy efficiency of the system. The lessons learned, on the technical and institutional sides, are of importance and could help to generalise such an experience to areas of similar climatic and social conditions.

## ACKNOWLEDGEMENTS

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## ABSTRACT:

The approach of the project Zer0-M aims at reducing the domestic water demand. It introduces a rational use of water from the mains, as is demonstrated by the example at the town of El Attaouia (22.000 inhabitants), some 80 km North-East of Marrakech. The town has a wastewater treatment plant since 2003 and a perimeter for reuse of the treated water of 40 ha. These infrastructures were complemented by a pilot project "greywater of hammam Attaouia" in 2008 in a partnership between Zer0-M and the Municipality of El Attaouia. A daily volume of between 60 and 80 m<sup>3</sup> of greywater are treated and used for irrigation of the public green areas in town instead of groundwater pumped from a 50 m deep well [1].

The present paper deals with the extension of the Zer0-M approach to integrating the management of water and energy. The hammam Attaouia was provided with a solar system of 350 m<sup>2</sup> collector area and 3 hot water tanks with a total volume of 20 m<sup>3</sup>. The first monitoring results from August and September 2008 show that the system can produce more than 20 m<sup>3</sup> per day of hot water at 60°C resulting in a fire wood economy of more than 90% compared to the quantity consumed without the solar system. The performance of the system will be monitored throughout the cold season in order to determine the corresponding wood savings.



# CONSTRUCTED WETLAND IN EGYPT

## TREATMENT AND REUSE OF DECENTRALIZED WASTEWATER

By **HUSSEIN I. ABDEL-SHAFY**, **MARTIN REGELSBERGER**, **FABIO MASI**, **CHRISTIAN PLATZER** and **MOHAMED A. EL-KHATEEB\***

A main part of the pollutants contained in wastewater are nutrients that can be removed in wastewater treatment plants by reproducing natural self-purification processes. Conventional treatment plants, like activated sludge plants, enforce biological organisms with energy-intensive mechanical equipment to decompose complex compounds, to incorporate the nutrients in biomass and finally to separate that biomass from the purified water. Thus such plants are energy-intensive reactors with a relatively small area demand that are suitable for centralized wastewater treatment.

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◀ *Figure 1:*

### CONSTRUCTED WETLAND - THE REED STARTS TO GROW

**C**Ws principally use the same natural degradation processes and nutrient uptake but they act like “extensive systems” [1, 2]. The high degree of biodiversity present in these systems allows multiple and various degradation mechanisms for several classes of compounds, and therefore higher performances in comparison with the technological treatment plants in which only a few families of specialised bacteria are grown [3, 4]. The purifying processes take place without the input of “human produced” energy by, for instance, oxygenating pumps. Furthermore there is no excess sludge to be removed since there is a balance of biomass growth and decomposition in the constructed wetland system. To compensate for the low energy demand, there is a relatively large area demand. Accordingly CWs are usually suitable and cost-effective for small and medium size wastewater treatment.

Within the last 20–30 years various types of CWs have been developed in different countries [5, 6]. There is a wide acceptance and interest within the population because of the following advantages:

- Less expensive to build than other treatment options
- Simple construction, operation and maintenance
- Low operation and maintenance cost
- High ability to tolerate fluctuations in flow and inlet quality
- High process stability (buffering effect)
- Sludge produced only by the primary treatment stage
- High pathogen removal – good water reuse and recycling options
- Optimal aesthetic appearance

Full scale CWs application in Egypt is not well known except in a few cases [6, 7, 8]. The present study focuses on implementing the constructed wetland in Egypt for the first time. The system is field constructed for the treatment of sewage water and reuse for irrigation purpose.

### OBJECTIVE OF THIS STUDY

The objective is to combine the European experience with the Egyptian practice to benefit from a clean environment, wastewater management and the reuse to irrigate timber plantations, protecting the groundwater as well as integrating the design, construction and management of a facility. Furthermore, the purpose is to implement an integrated model of wastewater management for peri-urban and deprived/remote regions for the purpose of saving and recycling the wastewater and making the effluent suitable, safe and appropriate for its intended re-use while protecting the environment.



Parameter	Unit	Inlet Value	Outlet Value	Removal %
Flow	m <sup>3</sup> /d	20		
BOD <sub>5</sub>	mg O <sub>2</sub> /L	750	20	97
Ammonia	mg/L	100	60	40
Nitrates	mg/L	0.5	1 to 2	97, considering the 40 mg/L of nitrified ammonia

▲ **Table 1: INPUT PARAMETERS AND THE TARGET OUTLET PARAMETERS FOR THE 200 m<sup>2</sup> HORIZONTAL FLOW CONSTRUCTED WETLAND**

### SITE DESCRIPTION FOR THE APPLICATIONS OF CWS

The area of the study is located in the east of Sharquiya Governorate 55 km north-east of Cairo. Thirty five years ago, this area was a desert without any agriculture activity. It is now a well known farm which depends on groundwater and rain to irrigate what they produce in terms of purely organic and pharmaceutical plants. One of the farm sewerage systems collects wastewater of schools and a boarding school, training workshops, offices, a laundry and a few houses. The farm is very well run and has a great interest in reusing its scarce resources of water, two strong guarantees for the good maintenance of a properly designed system. There was no access to the wastewater inlet in the existing septic tank (ST) for sampling. The wastewater characteristics correspond to similar domestic wastewater found and analysed by the project in Egypt.

The overall purpose is to treat the wastewater in a proper way, as well as saving the wastewater, to protect the environment and public health. The treated effluent is to be used to irrigate lumber trees. The irrigated land is sandy soil that is deprived of nutrient elements. The reuse of the treated wastewater could be in nutrient recycling as well as improving the soil characteristics. The work is to design and implement an integrated real scale model treatment of wastewater and reuse.

### MATERIALS AND METHODS

#### DESIGN AND OPERATION

The following are the characteristics of the raw wastewater that were used as the basis for the design and dimensioning of the plant (Table 1).

On the basis of the wastewater characteristics above,



◀ **Figure 2: OUTFLOW WELL OF THE TREATED WASTEWATER**

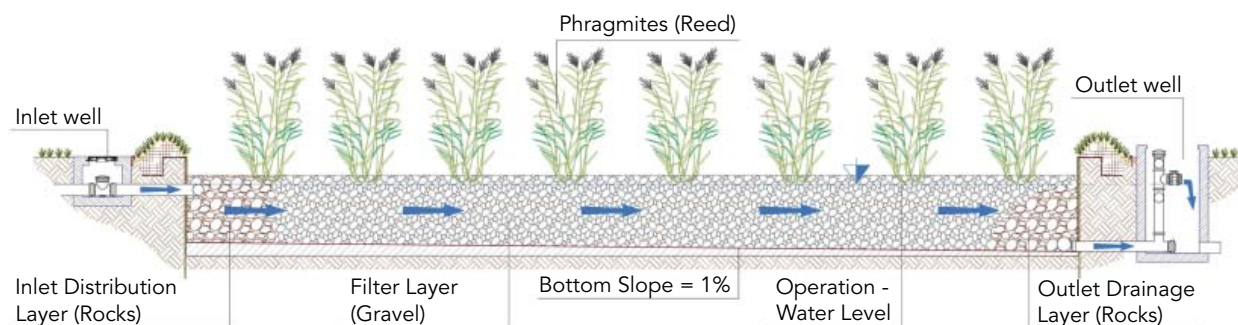
three chambers ST of 56 m<sup>3</sup> total volume were designed. The effluent was further treated by a constructed wetland of 200 m<sup>2</sup> horizontal flows and a depth of 1 m. The final treated wastewater flows via gravity without any energy input to a collection tank from which it is used to irrigate forest lumber trees.

### SAMPLING AND ANALYTICAL METHODS

An extensive program was designed to collect weekly samples of the raw wastewater, the outlet of the septic tank and the final effluent as outlet of the constructed wetland as well as the flow rate. The analyses covered pH, COD<sub>tot</sub>, COD<sub>col</sub>, COD<sub>settl</sub>, COD<sub>sol</sub>, BOD<sub>tot</sub>, BOD<sub>col</sub>, BOD<sub>settl</sub>, BOD<sub>sol</sub>, TKN, ammonia, nitrite, nitrate, phosphorus and total suspended solids (TSS). Determining the colloidal fraction was carried out by the filtration of the wastewater samples using filter paper with a pore size of 4.4 μm. The difference between the total value (without filtration) and the colloidal part is identified in this study for simplicity as settleable. However, it represents the settleable as well as the supra-colloidal fraction of the concerned parameter. The soluble fraction was determined in the filtrate of the membrane filter paper (0.45 μm). Physico-chemical analyses were carried out according to Standard Methods for the Examination of Water and Wastewater [9].

### RESULTS AND DISCUSSIONS

The physical and chemical characteristics of the raw wastewater, the outlet of the septic tank and the outlet of the constructed wetland are given in Table 2. Re-



◀ **Figure 3: CONSTRUCTED WETLAND FOR THE TREATMENT OF WASTEWATER AT THE STUDIED DECENTRALIZED AREA (CROSS SECTION)**



▲ **Figure 4:**  
**RAW WASTE-WATER AND OUTFLOW OF TREATED WASTEWATER**

removal efficiency of the successive treatment process as well as the overall removal was calculated and is shown in **Table 2**. The results showed that the pH was still between 6.8 and 8.3 and a remarkable improvement in the characteristics of the wastewater was obtained. The overall decrease in TSS, BOD, COD, TKN and oil & grease were from 136 to 12 mg/l, from 329 to 40 mg/l, from 588 to 74 mg/l, from 56 to 19.5 mg/l and from 85 to 17 mg/l respectively (**Fig. 5, 6, 7 and 8**).

For the ST, the removal rate for the TSS, BOD and COD was 59%, 46% and 41% respectively (**Figs. 5, 6 and 7**). The removal rate of TKN and oil & grease was 10% and 49%. No removal was achieved in terms of both the ammonia and the sulphides. This is mainly due to the anaerobic nature of the ST. The TDS showed a very slight increase of 1%. This may be attributed to the hydrolysis of the organic particulates in the ST.

Further removal was achieved by treating the efflu-

ent of the ST through the CW. The efficiency of the wetland reached 78%, 78%, 78%, 61.5%, and 61% for the COD, BOD, TSS, TKN and the oil & grease respectively. A slight improvement was realized with respect to the ammonia and sulphides. On the contrary, the TDS slightly increased from 1964 to 2030 mg/l due to the evapo-transpiration in the wetland (**Table 2**).

**RÉSUMÉ:**

**FILTRE PLANTÉ EN EGYPTE  
TRAITEMENT ET RÉUTILISATION  
DÉCENTRALISÉE D'EAUX USÉES**

*Hussein I. Abdel-Shafy, Martin Regelsberger, Fabio Masi, Christian Platzer et Mohamed A. El-Khateeb*

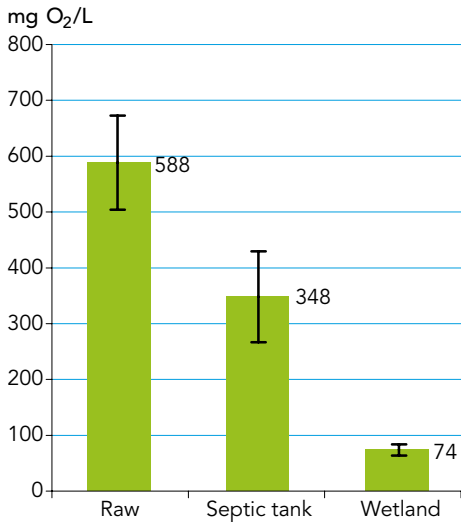
Beaucoup de stations de traitement des eaux usées de communes de petite et de moyenne taille dans le monde entier ne fonctionnent pas en raison de problèmes de gestion et des coûts d'exploitation et d'entretien élevés. D'autre part, les filtres plantés se sont avérés être l'une des meilleures technologies pour le traitement des eaux usées. Les avantages de ces filtres plantés résident dans le fait qu'ils allient un fonctionnement simple, fiable, à des coûts, des besoins en maintenance et en énergie modérés, une technologie durable et une bonne performance du traitement. L'application de filtres plantés à taille réelle en Egypte n'est pas très bien connue à l'exception de quelques cas. La présente étude examine pour la première fois en Egypte la mise en oeuvre de filtres plantés. Le système est construit sur place pour le traitement des eaux usées et leur réutilisation à des fins d'irrigation. La zone d'étude est située dans l'est du Sharquiya Governorate. Il y a trente ans, cette zone était un désert sans aucune activité agricole. Aujourd'hui, elle est connue pour des fermes dépendant des eaux souterraines et des pluies pour irriguer une production de plantes purement organiques et médicinales. L'un des systèmes d'évacuation des eaux usées des fermes draine une écoles et un internat, des ateliers de formation, des bureaux, une buanderie et quelques habitations. L'objectif de cette étude est la gestion de l'eau usée et sa réutilisation pour irriguer des plantations de bois, protéger les eaux souterraines et intégrer la conception et la réalisation en utilisant les matériaux locaux. De plus, il s'agit aussi de l'utilisation rationnelle de l'eau, de protéger l'environnement ainsi que la santé publique. Le travail consiste à concevoir et réaliser un système de traitement et de réutilisation des eaux usées intégré, à taille réelle et modèle pour les régions périurbaines et dévalorisées/éloignées. Une fosse septique à trois chambres de 56 m<sup>3</sup> de volume est suivie d'un filtre planté d'une superficie de 200 m<sup>2</sup> et d'une profondeur d'un mètre. Dans le présent article les caractéristiques de l'effluent sont données. La qualité de l'eau usée traitée satisfait les standards égyptiens. Il n'y a aucun problème au niveau des odeurs tandis que des méthodes de contrôle des moustiques dans un réservoir de stockage par moyens biologiques sont encore à la phase de test. Une amélioration de la production agricole est également attendue.

Parameter	Raw WW	ST effluent	% R of ST	CW effluent	% R of CW	T % R
pH	6.8-8.3	7.3-8.1	-	7.1-8.3	--	---
Turbidity	170	64	62	11	84	94
COD	588	348	41	74	78	87
BOD <sub>5</sub>	329	178	46	40	78	88
TKN	56	50	10	20	62	65
Ammonia	44	46	-3.6	18.5	59	58
TN	56.4	50.4	10.6	20.4	60	64
Organic N	12	4	66.7	1.5	62.5	87.5
Nitrates	0.33	0.31	6.1	0.27	12.9	18.2
Nitrites	0.089	0.058	-	0.12	-	-
TP	17	13	21	10	24	40
TSS	136	54	59	12	78	81
VSS	96	45	53	10	77.8	90
TDS	1949	1964	-1.0	2030	-3.4	-4.5
Oil & Grease	85	45	49	17	61	80
Sulphides	14.6	14.9	-2.2	3.5	76	76

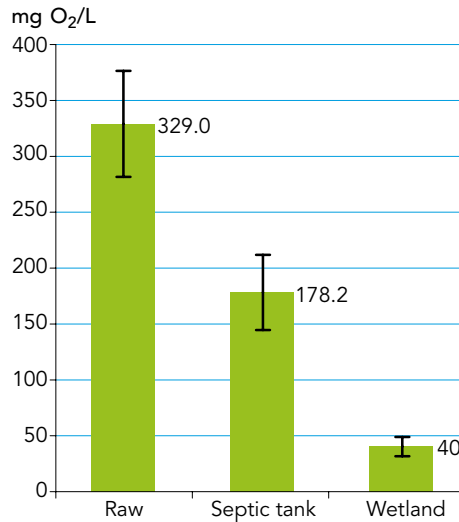
number of samples = 37, WW =wastewater

▲ **Table 2:**  
**CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE RAW MUNICIPAL WASTE-WATER, OUTLET OF THE SEPTIC TANK AND THE OUTLET OF THE CONSTRUCTED WETLAND AND THE CALCULATED REMOVAL EFFICIENCY OF EACH PROCESS (THE GIVEN RESULTS ARE THE AVERAGE OF 30 SUCCESSIVE SAMPLES)**

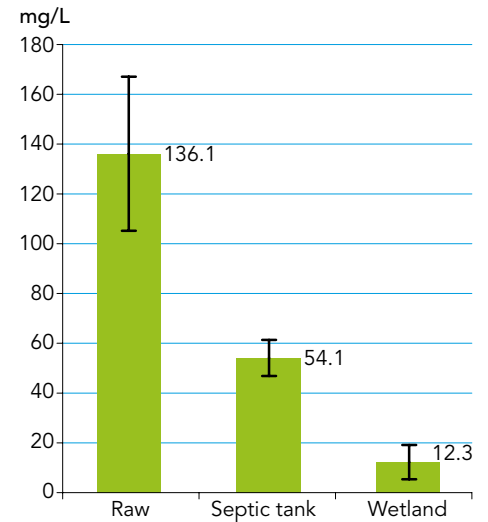




▲ **Figure 5:**  
THE AVERAGE LEVEL OF COD IN THE RAW WASTEWATER, EFFLUENT OF ST AND THE EFFLUENT OF THE WETLAND



▲ **Figure 6:**  
THE AVERAGE LEVEL OF BOD IN THE RAW WASTEWATER, EFFLUENT OF SEPTIC TANK AND THE EFFLUENT OF THE WETLAND

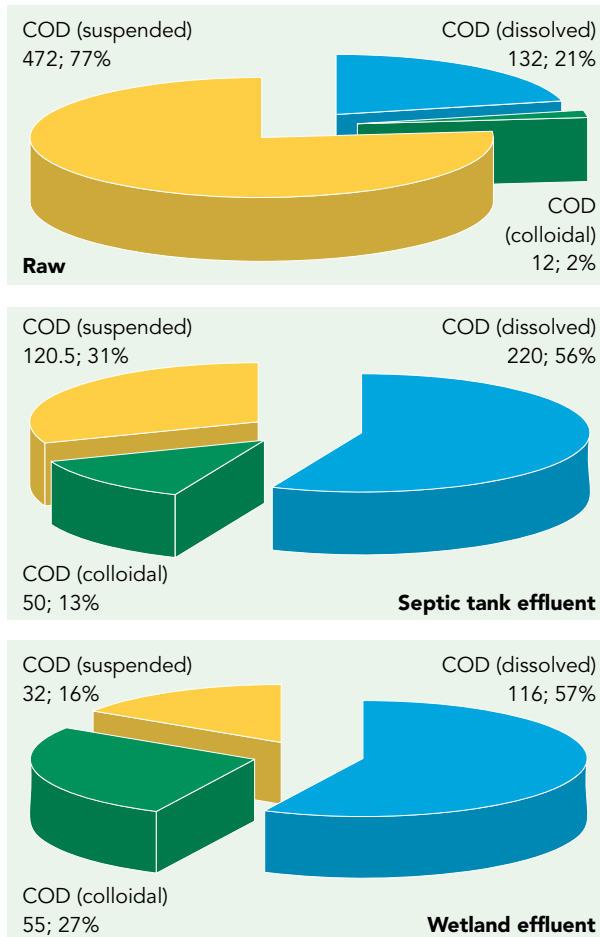


▲ **Figure 7:**  
THE AVERAGE LEVEL OF TSS IN THE RAW WASTEWATER, EFFLUENT OF SEPTIC TANK AND THE EFFLUENT OF THE WETLAND

The overall removal of the combined treatment systems was 65, 81 and 90% for the TKN, TSS and VSS (Table 2). The overall removal efficiency is 88% for the BOD<sub>5</sub> and 87% for the COD (Figs. 5 and 6). The turbidity and oil & grease decreased from 170 to 11 NTU and from 85 to 17 mg/l respectively. It is worth mentioning that the suspended COD decreased while the dissolved and colloidal COD increased as an indication of

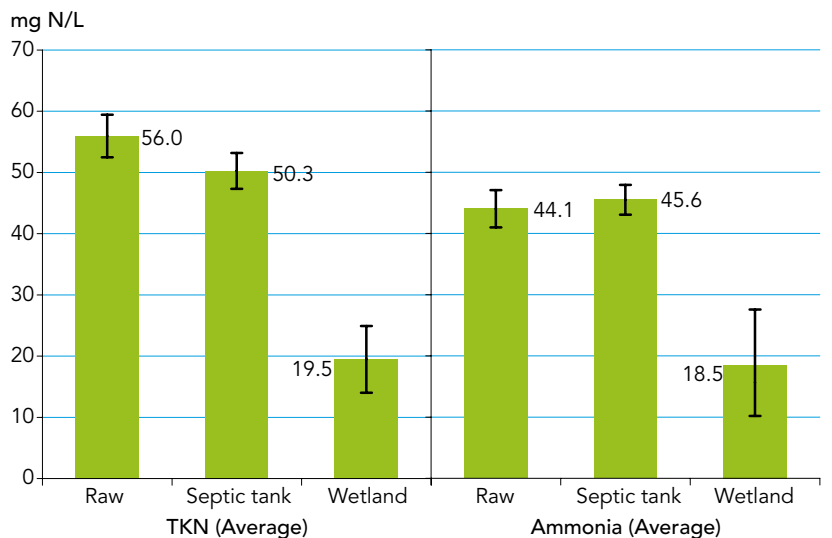
the efficiency of the combined treatment systems (Fig. 9). This finding was confirmed by other investigators [10].

Presently the treatment system is fully operating. The quality of the treated wastewater is within the permissible limits of the Egyptian standards. No problems with odour or insects exist. Biological control of the in-



◀ **Figure 8:**  
INCREASING OF BOTH COLLOIDAL AND DISSOLVED COD WHILE DECREASING THE SUSPENDED COD AS INDICATION OF TREATMENT EFFICIENCY

▼ **Figure 9:**  
THE AVERAGE LEVEL OF:  
a. THE TOTAL ORGANIC NITROGEN (TOTAL KYHDAL NITROGEN) TKN IN THE RAW WASTEWATER, EFFLUENT OF SEPTIC TANK AND THE EFFLUENT OF THE WETLAND  
b. THE TOTAL AMMONIA IN THE RAW WASTEWATER, EFFLUENT OF SEPTIC TANK AND THE EFFLUENT OF THE WETLAND



sects in a subsequent storage tank is still in a testing phase. A better agricultural production is expected.

## CONCLUSIONS

- CWs are important treatment systems for the decentralized areas.
- Employing the proper design of a CWs as well as the primary treatment system has improved the quality of the wastewater (WW) effluent.
- No problems with odour or insects exist. A better agricultural production is expected.
- The treated WW can be reused for irrigating the lumber forest trees.
- Indeed, the treated effluent can be safely used particularly on the sandy soil to improve the quality of the soil.
- It was possible to recycle the nutrient elements for agricultural purposes.
- Improvement of wastewater treatment is indeed an achievement towards better public health while protecting the environment.

## ACKNOWLEDGEMENTS

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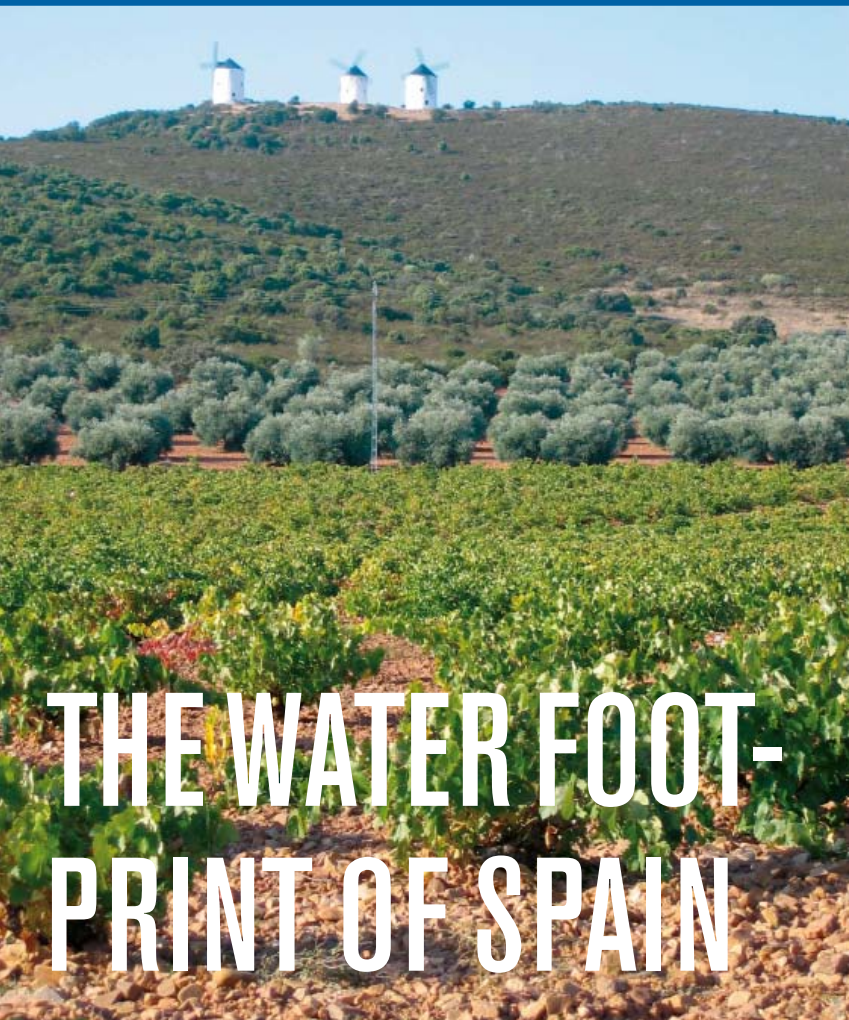
## ABSTRACT:

Many wastewater treatment plants of small and medium communities are out of operation worldwide due to management problems and high operation and maintenance costs. On the other hand, constructed wetlands (CWs) proved to be a very reliable technology for wastewater treatment. The advantages of CWs are that they combine simple, low-cost, low-maintenance, low energy, reliable operation, sustainable technology and high removal efficiency. Full scale CWs application in Egypt is not well known except for a few cases. The present study focuses on implementing a constructed wetland in Egypt for the first time. The system is field constructed for the treatment of sewage water and reuse for irrigation purpose. The area of the study is located in the East of Sharquiya Governorate. Thirty years ago, this area was a desert without any agriculture activity. It is now a well known farm which depends on groundwater and rains for irrigating the production of purely organic and pharmaceutical plants. One of the farm sewerage systems collects wastewater of schools and boarding school, training workshops, offices, laundry and a few houses. The objective of this study is wastewater management and reuse for irrigating timber plantations, protecting the groundwater as well as integrating the design and construction using local materials. In addition, the purpose is to save water, protect the environment as well as public health. The work is to design and implement integrated real systems of wastewater treatment and reuse for the peri-urban and deprived / remote regions. A three chambers septic tank of 56 m<sup>3</sup> was constructed, followed by a 200 m<sup>2</sup> CW with a depth of 1 m. The outlet characteristics are given below. The quality of the treated wastewater is within the permissible Egyptian standards. No problems with odour exist while biological ways to control insects in a buffer tank are tested. Better agricultural production is expected.

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# THE WATER FOOT- PRINT OF SPAIN

By MAITE MARTINEZ ALDAYA, A. GARRIDO, M.R. LLAMAS,  
C. VARELA-ORTEGA, P. NOVO and R. RODRÍGUEZ\*

In most arid and semi-arid countries, water resource management is both an important and controversial issue. Today most water resource experts admit that water conflicts are not caused by the physical scarcity but they are mainly due to poor water management. The scientific and technological advances that occurred in the last fifty years open new paths to solving many water-related conflicts, often with tools that a few decades ago seemed unthinkable [15, 16]. Along these lines, the estimation and analysis of the water footprint of Spain, both from a hydrological and economic perspective, is very useful to facilitate the efficient allocation of water and economic resources.

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**M. R. Llamas**, Complutense University of Madrid, Geodynamics Department, Madrid, Spain

◀ *Figure 1:*

## VINEYARDS AND OLIVE TREES IN LA MANCHA

Source: Zorrilla, 2008

This analysis can provide a transparent and multi-disciplinary framework for informing and optimising water policy decisions, contributing at the same time to the implementation of the EU Water Framework Directive (2000/60/EC), especially in its article 5 and for the preparation of the river basin management plans.

The water footprint (WF) is a consumption-based indicator of water use. The WF of an individual or community is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community. Closely linked to the concept of water footprint is the virtual water. The virtual water content of a product (a commodity, good or service) refers to the volume of water used in its production [11]. Building on this concept, virtual water 'trade' represents the amount of water embedded in traded products. International trade can save water globally if a water-intensive commodity is traded from an area where it is produced with high water productivity (resulting in products with low virtual-water content) to an area with lower water productivity. At national or regional level, a nation can preserve its domestic water resources by importing products instead of producing them domestically. This is particularly relevant to arid or semi-arid countries with scarce water resources such as is the case in Spain.

Apart from stressing its potential contribution to water savings, it is also important to establish whether the water used proceeds from rainwater evaporated during the production process (green water) or surface water and/or groundwater evaporated as a result of the

### RÉSUMÉ:

#### L'EMPREINTE SUR L'EAU DE L'ESPAGNE

*Maite Martinez Aldaya, A. Garrido, M. R. Llamas, C. Varela-Ortega, P. Novo et R. Rodríguez*

En Espagne, le pays le plus aride de l'Union Européenne, la gestion des ressources en eau constitue un problème aussi important que controversé. Aujourd'hui, la majorité des experts en ressources en eau admettent que les conflits relatifs à l'eau ne sont pas provoqués par la rareté physique de l'eau, mais qu'ils sont dus principalement à une mauvaise gestion de l'eau. Le concept d'eau virtuel, défini comme le volume d'eau utilisé dans la production d'une denrée, d'un bien ou d'un service ainsi que l'empreinte sur l'eau (volume d'eau utilisé pour produire les biens et services consommés par une personne ou une communauté), englobent conjointement une vaste gamme de secteurs et de problèmes, fournissant ainsi un cadre adéquat pour trouver des solutions potentielles et pour contribuer à une meilleure gestion des ressources en eau, notamment dans des pays arides ou semi-arides comme l'Espagne.



▲ *Figure 2:*  
**PIVOT IRRIGATION IN THE UPPER GUADIANA BASIN**

Source: NeWater

production of the product (blue water) [7]. Traditionally, emphasis has been given to the concept of blue water through the “miracle” of irrigation systems. However, an increasing number of authors highlight the importance of green water [3, 5, 8]. The economic and hydrological assessment of the water footprint and virtual water of both green and blue water (considering surface and groundwater) of the different economic sectors could facilitate a more efficient allocation and use of water resources, providing simultaneously a transparent interdisciplinary framework for policy formulation.

	Spain	Italy	US	India
Population (10 <sup>6</sup> )	40.5	57.7	280.3	1007.4
<b>Urban water supply</b>				
km <sup>3</sup> /year	4.2	8.0	60.8	38.6
m <sup>3</sup> /cap/year	105.0	136.0	217.0	38.0
<b>Crop evapotranspiration</b>				
National consumption (km <sup>3</sup> /year)	50.6	47.8	334.2	913.7
Idem (m <sup>3</sup> /cap/year)	1251.0	829.0	1192.0	907.0
For export (km <sup>3</sup> /year)	17.4	12.4	139.0	35.3
Idem (m <sup>3</sup> /cap/year)	430.0	214.0	495.0	35.0
<b>Industrial uses</b>				
National use (km <sup>3</sup> /year)	5.6	10.1	170.8	19.1
Idem (m <sup>3</sup> /cap/year)	138.0	176.0	609.0	14.0
For export (km <sup>3</sup> /year)	1.7	5.6	44.7	19.1
Idem (m <sup>3</sup> /cap/year)	42.0	97.0	159.0	6.0
<b>Virtual water ‘import’</b>				
Agricultural products (km <sup>3</sup> /year)	27.1	60.0	74.9	13.8
Idem (m <sup>3</sup> /cap/year)	671.0	1039.0	267.0	14.0
Industrial products (km <sup>3</sup> /year)	6.5	8.7	56.3	2.2
Idem (m <sup>3</sup> /cap/year)	1605.0	150.8	208.9	21.8
<b>Re-export of imported products</b>				
Idem (m <sup>3</sup> /cap/year)	281.0	351.0	163.0	1.0
<b>TOTAL WATER FOOTPRINT</b>				
km <sup>3</sup> /year	94.0	134.6	896.0	987.4
m <sup>3</sup> /cap/year	2300.0	2300.0	2500.0	980.0

## OVERVIEW OF SPAIN'S DIFFERENT SECTORS

Spain is the most arid country of the European Union and the one that devotes most water resources to irrigation [17]. According to **Chapagain and Hoekstra (2004)**, total water requirements (green and blue) by the different economic sectors in Spain are about 100 km<sup>3</sup>/year, that are distributed as follows:

According to **table 1**, **urban water supply** represents 5% of the total water used with a value of 4,200 million euros [17].

The **industrial sector** amounts to 15% of the total water use (from which more than a half corresponds to virtual water ‘imports’), 14% of the Gross Domestic Product (GDP) (123,000 million euros, [6]) and 16% of the economically active population (3,100,000 jobs, [6]) (**table 2**).

Urban water supply and industrial sector figures refer to blue water uses and are in line with the values given by official statistics [17]. Frequently the data from the MIMAM does not consider the consumptive uses, typical of agricultural, but the total water supplied; and usually a certain amount of this water returns downstream to the river basin and can available to downstream users.

The **agricultural sector**, considering green and blue crop consumption and livestock water use, represents about 80% of the total water use in line with [6] (2/3 with national water and 1/3 with ‘imported’ virtual water) (**table 1**) and [19]. The agricultural sector, however, just contributes with about 3% of the Gross Domestic Product (GDP) (about 26,000 million euros, including livestock and fisheries, according to [14]) and employs 5% of the economically active population (1,050,000 jobs, following [14]) (**table 2**). Special emphasis is given to this sector, as it is by far the main water user in Spain.

## WATER FOOTPRINT OF AGRICULTURE

Concerning the crop water consumptive use of agriculture in Spain, there are remarkable differences between the results of the different authors (**table 3**). Official numbers from the Spanish Ministry of the Environment are the lowest [17], probably due to the fact that official numbers do not take into account green water. Incorporating the concept of green water into the bigger picture makes it possible to understand water implications of land cover change and water scarcity problems of rain-fed agriculture [8]. In order to achieve an effective land use planning, green water analysis should be considered within an integrated land and water resource approach. Crop water consumptive use estimated by **Chapagain and Hoekstra (2004)** is higher than that of **Rodríguez (2008)** probably because of the greater detail of the latest study.

◀ *Table 1:*  
**VIRTUAL WATER FLOWS AND WATER FOOTPRINT OF SPAIN, ITALY, US AND INDIA (PERIOD 1997 – 2001)**  
Source: Modified from [3] in [7]



	Gross Domestic Product		Employment	
	Million €	%	Thousand jobs	%
Agriculture, livestock and fishing	26,473	3	1,033	5
Energy	20,415	2	149	1
Industry	122,844	14	3,130	16
Building industry	94,161	10	2,425	12
Services sector	546,929	60	13,324	66
Total	905,455	100	20,061	100

▲ **Table 2: GROSS DOMESTIC PRODUCT AND EMPLOYMENT IN SPAIN, YEAR 2005 AT CURRENT PRICES**

Source: Modified from Novo (2008), based on INE (2008) data [14]

Within the agricultural sector, irrigated agriculture uses about 80% of blue water resources [13, 17]. Concerning the economic aspects, however, irrigated agriculture is a vital component of the agricultural sector. Even if it just occupies about 20% of total crop area, it produces 60% of the total Gross Value Added (GVA) of agriculture [17]. This benefit is higher than the global average. Worldwide the gross value of rain-fed agriculture is 55% amounting to 72% of the world’s harvested cropland [5]. Along these lines, the economic productivity (EURO/ha) in irrigated agriculture in Spain is about five times higher than that of rain-fed agriculture [4, 10, 17].

### EFFICIENT ALLOCATION OF WATER RESOURCES

Spanish agriculture has comparative advantages as a result of its soil availability, sunshine hours, reasonable labour costs and location in relation to markets. Spain has no barriers to trade with other EU Member States. On the whole, Spain benefits from this advan-

Table 3: **ESTIMATED VALUES OF INTERNAL OR DOMESTIC WATER CONSUMPTIVE USE IN SPAIN’S AGRICULTURAL CROP PRODUCTION AFTER DIFFERENT SOURCES:**

	Agricultural water consumption <sup>1</sup> (Mm <sup>3</sup> )	Blue water consumption <sup>2</sup> (Mm <sup>3</sup> )	Green water consumption <sup>3</sup> (Mm <sup>3</sup> )
MIMAM (2007) <sup>4</sup>	-	11,897	-
Chapagain and Hoekstra (2004) <sup>5</sup>	50,570	-	-
Rodríguez (2008) <sup>6</sup>	26,824	15,645	11,177

- 1 Agricultural water consumption refers to the total crop water evapotranspiration.
- 2 Blue water consumption is the total amount of irrigation water evapotranspired by the crops.
- 3 Green water consumption represents the total amount of soil water evapotranspired by crops.
- 4 Average figures for the year 2001 (average rainfall year).
- 5 Average figures for the period 1997-2001
- 6 Average figures for the years 1998, 2001 and 2003.

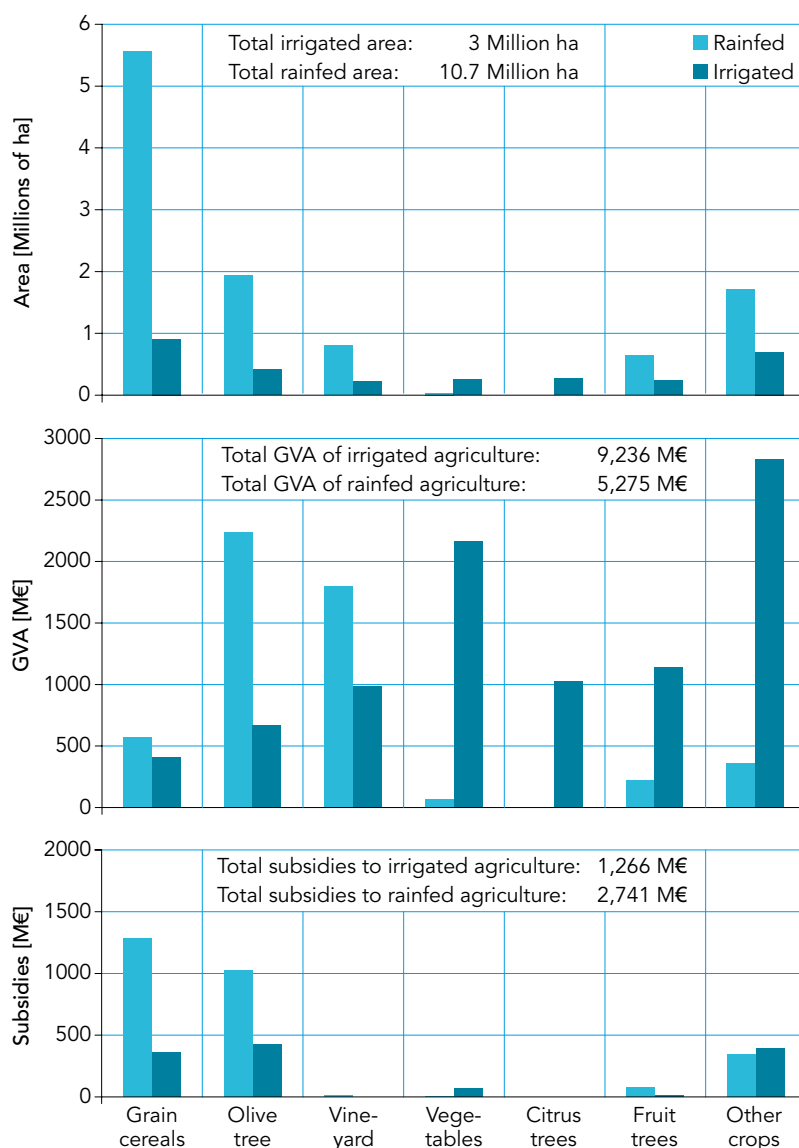
tage producing high value crops adapted to the Mediterranean climate, such as vegetables, citrus trees, vineyards and olive trees (figure 3).

First of all, it has to be highlighted that rain-fed grain cereals in Spain occupy more than 5 million hectares as shown in figure 3. In the year 2001, grain cereals were the main land and water users in Spain, utilizing the 47% of total arable land and 32% of blue water resources (figures 3 and 5) [17]. In economic terms, however, they generated the lowest GVA value, which was about 6% GVA of irrigated agriculture according to MIMAM data [17]. Nevertheless, we cannot just focus on economic aspects and forget the importance of agricultural multi-functionality (economic, social and environmental).

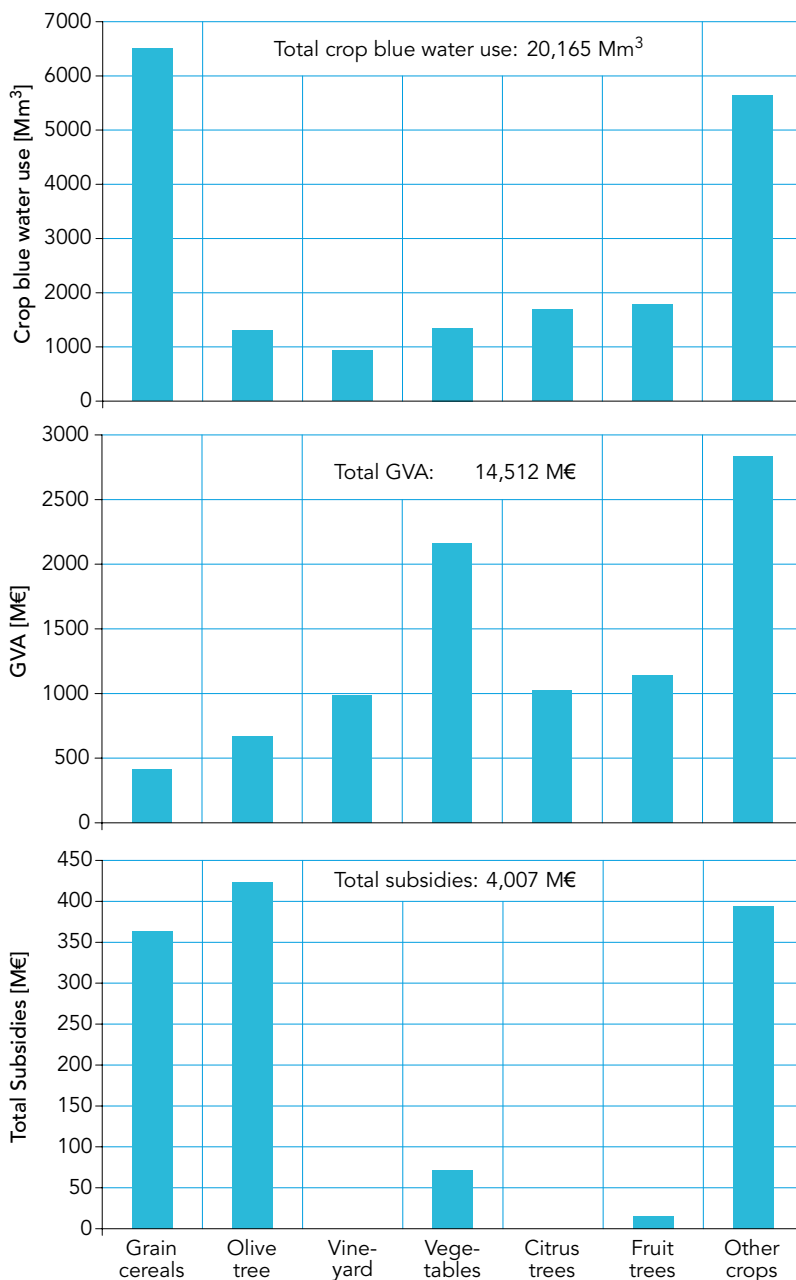
On the other hand, vegetables, citrus trees and fruit trees are very productive in economic terms and require a relatively small amount of land and water. These are, however, mainly grown with blue water resources. The best opportunities and economic yields are obtained when these are grown in areas where blue water resources are less abundant. In addition, carbon-intensive agro-chemical doses used in irrigated agriculture are higher than those used in rain-fed agriculture, with the corresponding ecologic impact [17]. Blue wa-

▼ **Figure 3: TOTAL AREA (ha) PER CROP (Mha), TOTAL GROSS VALUE ADDED (GVA) (M€) AND TOTAL SUBSIDIES (M€) COMPARING RAIN-FED AND IRRIGATED AGRICULTURE IN SPAIN FOR THE YEAR 2001.**

Source: based on data from the Spanish Ministry for the Environment [17]



► **Figure 4:**  
**PEÑARROYA DAM**  
**IN CIUDAD REAL**  
Source: Zorrila



▲ **Figure 5:**  
**CROP BLUE WATER SUPPLY (Mm<sup>3</sup>), TOTAL GROSS VALUE ADDED (GVA) (M€) AND TOTAL SUBSIDIES (M€) TO IRRIGATED AGRICULTURE IN SPAIN FOR THE YEAR 2001.**

Source: based on MIMAM data [17]

ter use in Spain, thus, has generally a higher opportunity cost and greater negative environmental externalities than green water use.

The water apparent productivity analysis can be very useful in order to identify possible water uses not justified in economic efficiency terms and achieve an efficient allocation of water resources. According to MIMAM (2007), average productivity of blue water used in irrigated agriculture is about 0.44 €/m<sup>3</sup>. When looking at the productivity per crop type (figure 6), greenhouse crops (horticultural, flowers and ornamental plants) present the highest Gross Value Added per water unit (with a minimum 4.87 €/m<sup>3</sup> and a maximum 17.52 €/m<sup>3</sup>). With lower values vegetables, vineyards and temperate climate trees show intermediate values. Finally, with remarkably lower values, grain cereals display an average productivity of just 0.06 €/m<sup>3</sup>. Accordingly, the apparent productivity of greenhouse crops is about one hundred times higher than that of cereals.

Figure 7 shows that a mere 4% of all blue water used in irrigated agriculture accounts for 66% of the total value added. Conversely, close to 60% of the water used in this sector produces a slight 5% of total value added in agriculture. Along these lines, even if Spain has already achieved a good degree of the policy “more crops and jobs per drop”, it struggles to obtain “more cash and nature per drop” [2].

Even if not considered in the study of [17], most probably high value crops are watered with groundwater resources or a combination of ground and surface water [9, 15]. This difference can be attributed to several causes: the greater control and supply guarantee that groundwater provides, which in turn allows farmers to introduce more efficient irrigation techniques and more profitable crops; the greater dynamism that has characterized the farmer that has sought out his own sources of water and bears the full costs of drilling, pumping and distribution; and the fact that the higher financial costs farmers bear motivates them to look for more profitable crops that will allow them to maximize their return on investments [9]. Surface and groundwater distinction, therefore, should be taken into account in order to achieve an efficient allocation of water resources.

## VIRTUAL WATER ‘TRADE’ IN SPAIN

Agricultural commodity trade in relation to water is an issue that has rarely been dealt with. It is important to take into account that Spain is a net virtual water ‘importer’ concerning agricultural commodities. According to Chapagain and Hoekstra (2004) Spain ‘imports’ about 27 km<sup>3</sup>/year and ‘exports’ 17 km<sup>3</sup>/year, resulting in a negative balance of 10 km<sup>3</sup>/year. Spain exports high economic value and low virtual water content crops, such as citrus fruits, vegetables or olive oil, while it exports virtual water intensive and low-economic value crops, such as cereals [18, 19]. This not only has a huge potential for relieving local hydrologic, economic and political stress in Spain but it is also very relevant for the national economy and water balance. Cereal grains



can thus be crucial commodities in terms of importance for food security to water-scarce importing and developing countries [21]. Spain's cereals production is only 5% of the total EU's, so Spanish demand would always be supplied by other EU producers or security stocks. This, however, does not imply that importing food is the only response the water-scarce countries and regions should and can take [22]. Furthermore, in the real world, even if the potential of trade to 'save' water at national level is substantial, most international food trade occurs for reasons not related to water resources [5]. International trade in agricultural commodities mainly depends on factors such as the availability of land, labour, technology, the costs of engaging in trade, freight costs, national food policies and international trade agreements [1, 12].

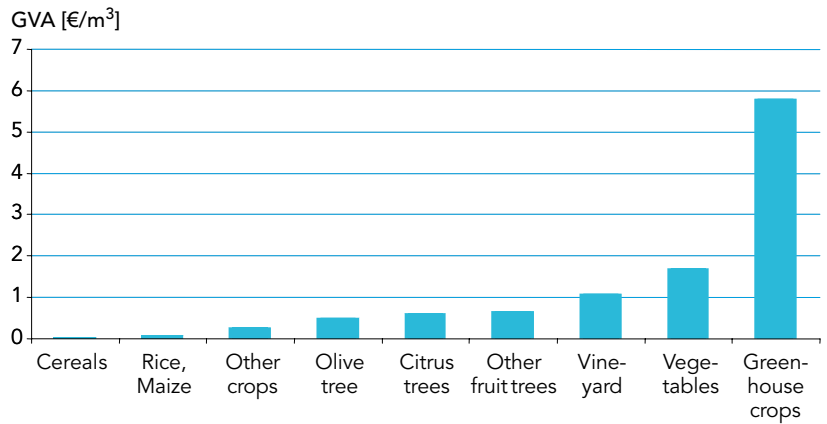
Spain's cereal imports make up about 70% of all water agricultural imports, whereas livestock exports represent 55% [19]. Both are obviously linked and respond to Spanish natural endowments, land and climate, and its intimate integration in the EU economy. Water scarcity as such does not explain why Spain 'exports' virtual water through livestock products. Lesser enforcement of environmental legislation, more empty territory and a great deal of economic integration do more to explain it. However, clearly without the option to import cereals and feedstock, the livestock sector would not have grown to the extent it did in the last 10 years.

### CONCLUSION

In conclusion, water scarcity in Spain is mainly due to the inefficient allocation of water resources and mismanagement in the agricultural sector, such as the use of large amounts of blue water in virtual water intensive but low economic value crops. Nevertheless, the Spanish water footprint should be analysed in time and from the point of view of sectorial and geographical standpoints. Furthermore, we cannot forget the multifunctionality of agriculture.

On the whole, there seems to be enough water to satisfy the Spanish agricultural sector needs, but a necessary condition is to achieve an efficient allocation and management of water resources. This will take some time since crop distribution in Spain is determined by several factors such as the CAP or the WTO regulations. The mentioned transition will require the action of the Spanish Government by embracing transparency and encouraging an active and effective public participation. This is already happening in Spain on the occasion of the application of the WFD.

The water footprint analysis, both hydrological and economic, at a river basin level facilitates the efficient allocation of water resources to the different economic and ecologic demands. There is no blueprint. The Spanish context is characterized by regional differences on green and blue water resource availability. Along these lines, virtual water studies, taking into account not only green and blue (ground and surface) water systems but also trade policies, can contribute to the better integrated management of water resources.



Finally, this analysis, in industrialized countries such as Spain can help to move from a policy of 'more crops and jobs per drop' towards 'more cash and nature per drop'. Achieving, thus, the preservation of the environment without damaging the agricultural sector economy.

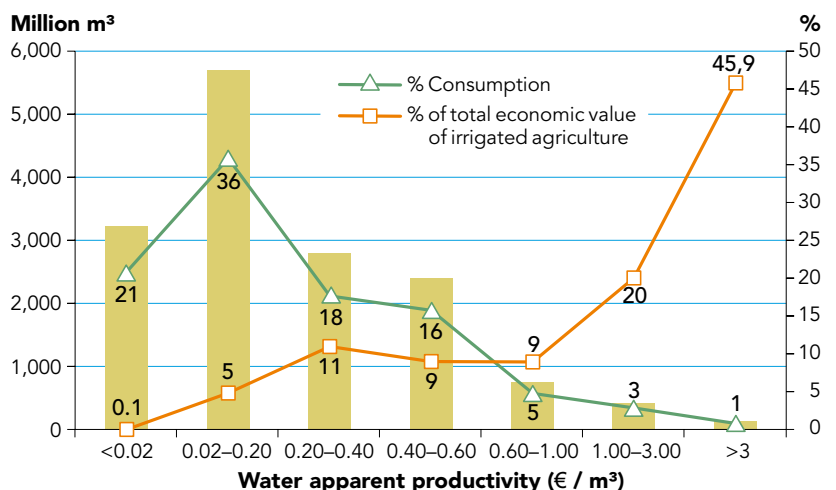
▲ Figure 6: WATER APPARENT PRODUCTIVITY (GROSS VALUE ADDED PER CUBIC METRE - GVA/m³) PER CROP IN IRRIGATED AGRICULTURE IN SPAIN FOR THE YEAR 2001 - 2002. DATA FOR 78% OF THE IRRIGATED AREA. Source: based on MIMAM data [17]

**ABSTRACT:**

As the most arid country in the European Union, water resource management in Spain is an issue as important as controversial. Today most water resources experts admit that water conflicts are not caused by the physical water scarcity but they are mainly due to poor water management. The virtual water concept, defined as the volume of water used in the production of a commodity, good or service, together with the water footprint (water volume used to produce the goods and services consumed by a person or community), link a large range of sectors and issues, providing an appropriate framework to find potential solutions and contribute to a better management of water resources, particularly in arid or semi-arid countries such as Spain.

▼ Figure 7: TOTAL WATER USE IN AGRICULTURE BY CROP PRODUCTIVITY RANGE AS PERCENT OF VOLUME AND VALUE ADDED (BASED ON 78% OF TOTAL IRRIGATION IN SPAIN) (2001-2002).

Source: Varela-Ortega (2008), based on data of [17]



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▲ **Figure 8: TABLAS DE DAIMIEL NATIONAL PARK IN THE SOUTH-CENTRAL SPAIN**  
Source: Martínez-Santos, 2008

The Tablas de Daimiel National Park, located in south-central Spain, is a wetland on the list of the Ramsar Convention and part of the Mancha Húmeda Biosphere reserve. Today, however, this wetland that used to receive the natural discharge from the Occidental Mancha aquifer, survive artificially, in a kind of “ecological coma”, thanks to the water transfers that come from the Tagus-Segura Aqueduct and to the artificial pumpage of groundwater.

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# THE SPRINGS PRESERVE: A WORLD-CLASS MODEL OF SUSTAINABILITY

By RICHARD B. HOLMES\*

Within the arid southwest United States lies a shimmering oasis: Las Vegas. Known as the “Entertainment Capital of the World,” Las Vegas features an abundance of the world’s most outstanding restaurants, performances and attractions. This cutting-edge city has produced yet another world-class venue, the Springs Preserve.

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◀ Figure 1:

**LOCATED AT THE SPRINGS PRESERVE, THE LEED PLATINUM RATED DESERT LIVING CENTER UTILIZES TECHNOLOGIES SUCH AS COOLING TOWERS, STRAW BALE INSULATION AND RAMMED EARTH WALLS TO DEMONSTRATE SUSTAINABLE DESIGN PRINCIPLES AND BENEFITS**

Just off the resort corridor, the Springs Preserve stands amidst the rugged desert landscape as a model of sustainability, designed to reshape our thinking and inspire us to change our behavior for the benefit of the communities in which we live. This new 180-acre attraction creates a space for both visitor and nature and allows all to explore, discover and learn. The Preserve enables visitors to gain a better appreciation for the world around them, as well as the limited natural resources it contains. While visiting the Preserve, one can imagine the possibilities for a more sustainable future through a series of state-of-the-art museums, colorful botanical gardens, walking trails, and restored historic structures. More than just a museum, the Springs Preserve is an experience which combines natural open spaces with man-made elements that demonstrate both sustainable form and function.

## VISION

Known as the birthplace of Las Vegas, the site of the Springs Preserve was once home to bubbling springs that were a source of water for Native Americans thousands of years ago. It also sustained travelers of the Old Spanish Trail and pioneers who came to settle in the

## RÉSUMÉ:

### LA «SPRINGS PRESERVE»: UN MODÈLE DE DURABILITÉ D'ORDRE MONDIAL

*Richard Holmes*

Au sein du paysage austère et sauvage du désert des Mojaves, le site du «Springs Preserve» à Las Vegas, au Nevada, représente un modèle durable, conçu pour influencer notre façon de penser et pour nous inspirer à modifier nos comportements vis-à-vis des nombreux défis qui sont reliés au développement durable de nos communautés. Le Springs Preserve éveille chez ses visiteurs une nouvelle appréciation du monde qui les entoure ainsi que de ses ressources limitées. En visitant le site du Springs Preserve, la perspective d'un futur plus durable et de ses possibilités est facilitée par de nombreux musées modernes, des jardins botaniques colorés, des sentiers de marche, des structures historiques remises en état. Bien plus qu'un simple musée, le Springs Preserve constitue une expérience hors du commun combinant de vastes espaces verts aux éléments artificiels (construit) qui démontrent simultanément forme et fonction durables.

► *Figure 2:*  
RAIN HARVESTING  
SYSTEMS, CATCH  
RAIN WATER AND  
RELEASE IT SLOWLY  
TO PREVENT FLOOD-  
ING, EROSION,  
AND SURFACE  
DISTURBANCE



West. Early ranchers, farmers and the San Pedro, Los Angeles and Salt Lake Railroads (later known as Union Pacific), utilized the flowing waters to establish Las Vegas as a new settlement. As the main source of water for the emerging town, the land was protected from encroaching development because of its value as a functioning well field for the railroad and then the Las Vegas Valley Water District.

Under the National Historic Preservation Act of 1966, the Las Vegas Springs were designated an archaeological site and listed on the National Register of Historic Places in 1978. To further preserve the historic site, the Las Vegas Valley Water District Board of Directors approved a plan in 1997 to develop a preserve to protect and manage the site's cultural, natural and water resources. Following a decade of planning and construction, the Springs Preserve opened in June 2007.

Since its opening, the Preserve has attracted over 200,000 visitors in addition to more than 25,000 school children. The Springs Preserve stands as a cultural and historical attraction designed to commemorate Las Vegas' dynamic history and to provide a vision for a sustainable future. Its message reaches out to the entire world and invites people everywhere to examine the

way they live and make necessary changes for all of our future.

## DESIGN

The facility is the first of its kind in the United States to earn two Platinum LEED® (Leadership in Energy and Environmental Design) ratings on the same site.

The Springs Preserve demonstrates water efficiency, green building and environmental design on a level rarely seen in public spaces. Two buildings totaling more than 3,800-square-metres make the Springs Preserve the largest commercial straw bale construction project in the United States. Straw is five times more efficient than standard insulation with an R-value of over R-50. The straw used at the Preserve came from nearby California; it was considered waste material and otherwise would have been burned or disposed of in a landfill.

All water used on site is filtered by plants and microbes below the soil surface as it travels through created wetlands. The water is then reused to irrigate plants and flush toilets at the Springs Preserve. Many of the buildings feature waterless urinals and rain harvesting systems. Butterfly roofs on a few of the buildings help collect storm water for reuse. While Las Vegas only receives approximately 10 centimeters of precipitation a year, much of that occurs during brief and sometimes violent storms. Rain systems on the site help retain water and release it slowly to prevent flooding, erosion, and surface disturbance. These innovative systems minimize the effects of the storms on hardscapes and allow rainwater to percolate into the soil.

Designers positioned buildings at the Preserve to utilize natural lighting and collect solar power to radiantly heat floors and water. The buildings contain only Low E (energy) windows which face north and south. Photovoltaic panels create covered parking for visitors and generate enough solar energy to power approximately 70 percent of the attraction. Structures were also designed to take advantage of natural ventilation; several make use of entryway, overhangs and patio microclimates. Wide roof eaves restrict summer sun from warming south-facing walls, but allow the benefits of light and heat during the winter. While eaves protect the buildings from the sun's heat, light shelves have been positioned to bounce light into the building, reducing the need for electrical lighting. Also, deciduous trees were planted along the southern walls to shade the buildings with their leaves during the summer heat, but allow light and warmth inside during the winter when the trees drop their leaves.

## USED MATERIAL

Throughout the project, locally sourced materials, such as caliche (a naturally occurring concrete) and rammed earth have been used as primary building elements. Caliche rock that was removed from the ground during construction was reused throughout the site as

► *Figure 3:*  
PHOTOVOLTAIC PANELS CREATE  
COVERED PARKING FOR VISITORS AND  
GENERATE ENOUGH SOLAR ENERGY TO  
POWER APPROXIMATELY 70 PERCENT  
OF THE SPRINGS PRESERVE





retainer walls, erosion control, and barriers. Using the rock on site reduced the energy that would have been required to load and transport this material and no landfill space was used. Rammed earth walls were created by mixing local soils with 4 to 10 percent cement. Rammed earth may be crumbled back into aggregate soil, if ever needed, to avoid landfill waste. Also, the thermal mass of the rammed earth walls allows heat collected during winter months to be released into the buildings, thereby reducing energy demands.

## HEATING AND COOLING

Heating and cooling systems at the Springs Preserve combine ancient technologies with some modern improvements. With radiant heat technology, water is first warmed by the sun and then circulated through the concrete slab floors. This way of heating is very efficient since it heats the room, not the air, from the ground up. To cool the buildings, designers employed ancient technology from the desert Middle East. Cooling towers were positioned at each end of the buildings. As water cascades over mats, it cools the air and provides humidification for comfort. The towers work in conjunction with motorized upper windows that vent warmer air and help move the cooler air through the structure.

Other sustainable products utilized at the Springs Preserve include: carpet made from recycled plastic bottles and corn husks; certified sustainable lumber; low volatile organic compound paints, furniture, fabrics and wood composite; furnishings made of recycled sunflower seed husks and countertops made from recycled paper and reclaimed steel and glass.

Outside, the Gardens at the Springs Preserve create an innovative learning environment for visitors to explore native and non-native desert-adapted plant life. More than 400 mature trees and plants, some 20 years old and over 30 feet tall, were transplanted to the site from an existing garden. The Gardens at the Springs Preserve is a public space in the best tradition of the term, serving as a learning experience, a social experience, and an inspirational space for the community. Spanning eight acres, the Gardens are a place for visitors to come enjoy themselves, and take valuable lessons with them to put into practice in their homes.

## EXPERIENCE

Once home to ancient Native American tribes and a resting place for weary Spanish explorers, the Springs Preserve invites visitors to learn about the history of the Las Vegas Valley as well as methods to maintain a sustainable lifestyle in their environments. The structures, the landscapes and the experiences at the Springs Preserve engage visitors to learn more about the value of sustainable living. Visitors learn through both passive and hands-on exhibits, which provide a well-balanced approach to education.



## THE ORIGEN EXPERIENCE

The 180-acre complex is comprised of the ORIGEN Experience, the Desert Living Center, the Gardens at the Springs Preserve, numerous walking trails, and a cienega or desert wetlands. In 2009, it will also help celebrate the opening of the Nevada State Museum, which is currently under construction. All of these components, combined with other outdoor amenities, such as a 2,000 seat amphitheater, create a rich and diverse experience for visitors. Also in 2009, the Water Works interpretive facility will open to the public allowing visitors to see how a functioning reservoir and pump station work.

As the interpretive focal point for history at the Springs Preserve, the ORIGEN Experience is comprised of three galleries featuring more than 75 exhibits, an indoor theater and traveling exhibit space. The name ORIGEN was derived from two words: original and generations. The ORIGEN Experience captures the essence of the land, the early inhabitants and the many possibilities for Las Vegas' future.

In the ORIGEN Experience, visitors uncover the geological and biological history of the Las Vegas Valley and Mojave Desert. They can experience the thunderous and powerful roar of a simulated flash flood, or wander through the outdoor wildlife habitat. Visitors can also learn how to positively impact the environment in a fun and creative way through a globally-connected arcade filled with games and activities that celebrate the cultural highlights of Las Vegas. Other activities include multi-player games and game show experiences, an interactive multi-media attraction, and an animated show set displaying visitors' messages and game scores.

## THE DESERT LIVING CENTER

The Desert Living Center (DLC) is the "green" jewel in the crown of the Springs Preserve. The DLC buildings, along with the Guest Services building, are the

▲ *Figure 4:*  
**STUDENTS INTER-  
ACT WITH  
EXHIBITS IN THE  
SUSTAINABILITY  
GALLERY**

► *Figure 5:*  
**VISITORS TO THE  
 GARDENS AT THE  
 SPRINGS PRESERVE  
 LEARN ABOUT  
 SUSTAINABLE  
 LANDSCAPING  
 TECHNIQUES AND  
 PRACTICES**



only platinum LEED® buildings in the Mojave Desert. These buildings embody the Preserve's message of sustainability. Visitors to the DLC learn ways to protect the valuable environmental resources of our global community, while enhancing their quality of life. The DLC campus has five buildings featuring 43 interactive exhibits, classroom and meeting space and gardens that explore sustainable solutions to current and future environmental issues.

The eight-acre botanical Gardens at the Springs Preserve feature a wide range of desert landscapes and demonstrate native and non-native desert plant life with interpretive stations and hands-on activities. Unique features of the garden include the Watering Can Theater for irrigation instruction; the Tool Shed Theater, a children's theater featuring molded mush-

room-shaped chairs; a weather station with real-time weather data; the Enabling Garden, which demonstrates options for people who have physical challenges; and the Frame House, a 70-seat kitchen area for outdoor cooking demonstrations.

Visitors to the Preserve may also walk or hike through four uniquely-themed trails that encompass approximately 3 kilometers of picturesque landscapes leading to a cienega, an important feature of this National Historic Site. The walking trails border the cienega which serves as a tranquil home for hundreds of native plant, bird and animal species.

## CONTINUING THE VISION

Las Vegas, located within the Mojave Desert, exists in one of the hottest and driest climates on earth. This desert environment is a world of extremes with blistering temperatures during the summer days and with winter nights that dip well below freezing. Yet, somehow in this harsh climate, plants and animals have found a way to adapt and survive. Design elements within the Springs Preserve draw from nature to help visitors find a way to live more in harmony with the environment.

The increasing demands placed on our planet require us to choose a better, more sustainable way. The people of today and those who will follow depend on us, individually and collectively, to make the right decisions that will ensure the long term availability of our fragile and limited resources. The Springs Preserve stands as a model of what can be accomplished and provides a framework for visitors to take action. It is up to all of us to work together for a sustainable future, and the Springs Preserve provides a vision and the tools to help us.

### ABSTRACT:

In the austere and wild landscape of the Mojave desert the Springs Preserve at Las Vegas, Nevada, represents a sustainable model meant to influence our way of thinking and inspire us to modify our behaviour towards the numerous challenges linked to the sustainable development of our communities. The Springs Preserve incites its visitors to a new appreciation of the world and its limited resources. The Spring Preserve with its numerous modern museums, its colourful botanic gardens, its hiking trails and its rehabilitated historical structures opens a new perspective on a sustainable future and its potential. The Springs Preserve is much more than a simple museum, its an extraordinary experience combining wide, green areas with artificial (built) elements which together show sustainable form and function.





◀ Figure 1:

### RAINWATER EVAPORATION AND INFILTRATION IN THE INTEGRATED WATER CONCEPT IN BLOCK 6 IN THE CENTRE OF BERLIN, GERMANY

Today, as discussions over climate change and water scarcity are taking place worldwide and the high-quality but limited drinking water resources, which are already variably polluted, are being wasted down the drain, the urge to act has tremendously increased. As long as households are bound to have only a single water supply network, sooner or later it has to be accepted that only water of non-drinking quality will flow out of the household tap. Under these conditions, consumers can resort to available technologies such as reverse osmosis to produce their own chemically pure water, at the same time their “non-viable drinking water”.

For reasons of water and resource protection, there is an urgent need today to separate the different water flows in households, as is already the case in many industrial sectors. Only a separate collection of greywater and blackwater will make the recycling of plant nutrients, energy and water from household wastewater possible. Therefore, the treatment of household wastewater will have to shift in the future more to greywater treatment, which can take place in comparatively small decentralised systems.

### A RETROSPECTIVE REVIEW

Similar to nutrient recycling, greywater utilisation is nothing new. During the period of rapid economic growth in Germany, the idea was pushed aside for over 40 years. At that time, the multiple reuse of the warm bath water among the family members was a common

# ESTABLISHING GREY-WATER RECYCLING

## ON ITS WAY TO HOUSING TECHNOLOGY

By ERWIN NOLDE\*

**Why Greywater Recycling? — Basically, water in drinking water quality is not required for every application and also not available everywhere. With little expenditure and great benefit, it is possible to supply water from greywater recycling systems for toilet flushing, washing machines, gardening, etc. without any hygienic risk or loss of comfort.**

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### RÉSUMÉ:

#### ÉTABLIR LE RECYCLAGE DES EAUX GRISES COMME TECHNOLOGIE DU BÂTIMENT

*Erwin Nolde*

Le recyclage des eaux grises est la clef pour le succès d'une gestion écologique de l'eau. Le concept intégré avec recyclage des substances nutritives et de l'énergie affirmera sa position au cours des prochaines années face aux technologies end-of-pipe. La technologie pour le recyclage des eaux grises est disponible; toutefois, cela en soit ne suffit pas sans la coopération de tous les acteurs. Ce document présente un bref historique du développement autour des eaux grises au cours des 20 dernières années en Allemagne et le rôle important des différents groupes d'intérêt et du législateur pour faire avancer le recyclage des eaux grises comme un moyen de fermer la boucle de l'eau.

► *Figure 2:*  
**INTEGRATED  
 WATER CONCEPT  
 IN BLOCK 6 IN THE  
 CENTRE OF BERLIN:  
 GREYWATER RE-  
 CYCLING OF HIGH-  
 LOAD GREYWATER  
 INCLUDING  
 KITCHEN AND  
 WASHING  
 MACHINES  
 (10 m<sup>3</sup>/d; 250 PERS.)  
 THE GREYWATER  
 VESSELS SERVE  
 TO HEAT THE  
 OPERATION ROOM  
 DURING WINTER**



event, with the subsequent use of the untreated greywater for irrigation. The household water consumption amounted in the 60s to about 60–75 Liters per day (L/d). In the 70s and 80s, the consumption of 200 to 250 L/d was predicted for the year 2010 in connection with the evolution of luxurious bathrooms.

Already at that time, German water experts realised that the rise in the individual's water consumption cannot be solely covered by high-grade resources, namely well-protected groundwater resources. Instead of taking appropriate measures to reduce water consumption, or even better to reduce the wastewater generation, the principles of the centralised water supply (defined in DIN 2000) have been fundamentally modified in the face of fears centering around "water scarcity".

Although the standard formulation "Drinking water should be palatable dependent on its origin and should encourage consumption dependent on its external properties. It should be colourless, clear, cool, odourless and of good taste", offered a positive definition, this was modified in 1973 with the result that the most important aspect, namely that "drinking water should be palatable dependent on its origin" has been deleted without replacement. Still hope (of the engineers) remained in the form of the development of a technology, which should process water that is clean and palatable from partly highly contaminated rivers.

In the meantime, more than 10,000 new organic substances can be found on the market, many of which are toxicologically relevant (e.g. pharmaceuticals) and detected at critical concentrations in water. This knowledge makes many consumers insecure. Many companies benefit from this by filling tap water into bottles and selling it at exorbitant prices. The conveyance, filling and transport activities related to this business will cause further environmental damage. While water suppliers expected increasing water consumption rates and consequently a high turnover, consumers reduced the flow rate in their bathroom fittings and minimised

their toilet water demand by placing bricks in the flushing tanks.

Some environmental activists reinvented rainwater harvesting, while others laboriously bucketed their bath water to flush their toilets. The industry optimised water closets by producing flushing tanks where a 6 or 3 L flushing volume can be variably used instead of 12 L. Water efficient fittings and washing machines have also been developed which require only 50 L per cycle in connection with new washing agents instead of 180 L.

Today, the German household water consumption of about 90–140 L/d lies far below the predicted 200–250 L/d. Where water recycling is practiced, water consumption equals approximately 60 L/d.

The "water business" is the strongest force hindering technical progress in the field of decentralised water technologies. There, where water suppliers failed to provoke citizens to increase their water consumption, attempts are being made to introduce a kind of flat rate (a significant monthly basic charge and a low tariff for the metered water) with the feeble argument that fixed costs make up 80 to 90% of the total costs. Other attempts to hinder rainwater harvesting and greywater recycling have been also undertaken. Apparently, the aim of the water suppliers is to financially penalise environmentally-conscious and economical consumers. These arguments can be countered by the fact that the current high water price for drinking and wastewater of about 5 €/m<sup>3</sup> at fixed costs of 80–90%, is definite evidence that the centralised water system has also failed from the economic point of view.

## PUBLIC ACCEPTANCE

Greywater recycling and the avoidance of wastewater is the key to a more secure and resource-friendly water management. Surveys have shown that



the consumer is remarkably open to new water concepts. He expects that drinking water should have a high quality and wishes/accepts other applications with a lower water quality, which does not stringently fulfil the requirements of the drinking water ordinance. Through the use of non-drinking water, there should be no hygienic risk or comfort loss. Furthermore, he expects that service water will be offered at a more favourable price than drinking water.

### CURRENT STATE OF RESEARCH AND DEVELOPMENT

Greywater recycling includes both wastewater treatment and water supply. The technology of greywater recycling is basically not different from the already established treatment methods, which are usually applied in the field of drinking water and wastewater treatment.

Since many years, several technologies (e.g. greywater recycling using constructed wetlands, trickling filter) have proved their reliability in Germany as well as in other countries (see Training and Demonstration Centres (TDC) in the Zer0-M project). With regard to the water quality, the different technologies are equally efficient as long as they are properly designed, operated and maintained. Novel systems based on the fluidised-bed or membrane reactor have been also developed. For the user, the major decision criteria include the purchase price, the required space and design. However, other aspects such as the energy consumption and maintenance requirements, as well as system durability, are also very important.

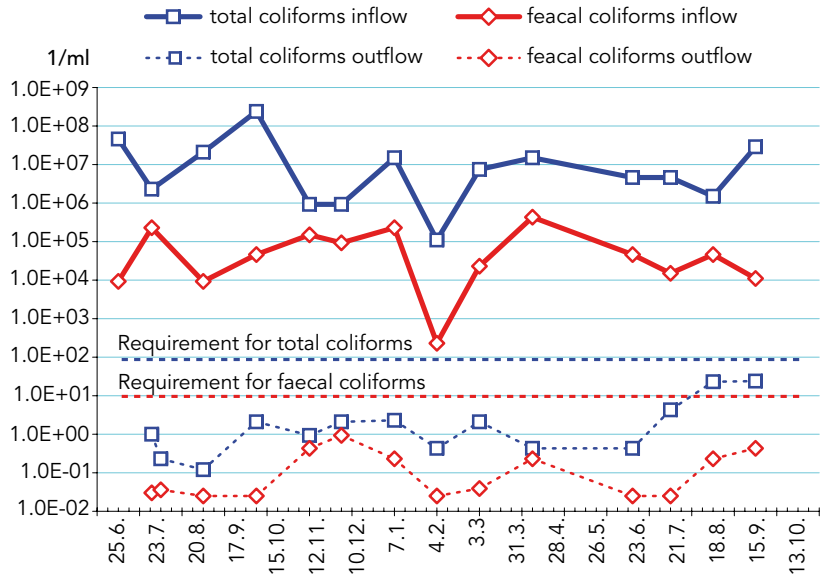
The research and development fields are well advised to orient themselves to the needs and expectations of the users and to promote technologies, which are more energy and resource-efficient compared to the conventional ones. If more energy or chemicals are required for the same water services, this should be critically questioned. Furthermore, a prognosis of the demographic development and climate change should be included in the assessment.

### GREYwater RECYCLING IN MODERN HOUSING

Today, the integration of greywater recycling in housing technology is a mission that should be properly undertaken by architects and planers together with plumbers and system manufacturers.

Although drinking water is available in many places in adequate amounts and pressure at the property line for all application purposes, and wastewater

► **Figure 4:**  
**A GREYwater RECYCLING PLANT IN A RESTAURANT IN SOUTH AFRICA TREATING WATER FROM THE HAND WASHBASINS FOR REUSE IN TOILET FLUSHING. THE AMOUNTS OF WATER SAVED ARE DISPLAYED VISUALLY**



▲ **Figure 3:**  
**WATER QUALITY OF THE INFLUENT AND EFFLUENT OF THE GREYwater RECYCLING PLANT IN BLOCK 6, BERLIN (INFLUENT COD: 600-800 mg/L; EFFLUENT COD < 30 mg/L; BOD<sub>7</sub> < 5 mg/L; TURBIDITY < 1 NTU)**

and rainwater are drained in the sewer, architects and planers still have to deal with additional aspects. They have to select a system but lack the required knowledge and experience on issues such as the amount of generated greywater, wastewater load and the amount of service water needed in the short, middle and long-term. From the manufacturer's documents it is not always clear, what operational expenditure is involved or what service life can be expected or guaranteed. Therefore, a broad and independent monitoring programme of systems already in operation is urgently needed, associated with advanced training and data publication to offer support to planers.

A novel aspect which will be increasingly considered in the future mainly in the northern hemisphere is heat recovery from greywater. In this case, the choice of the proper site for system installation is of considerable importance, not only for the capital costs but also for the future operation and maintenance costs (second pipe network, pumps and lifting station). For example, if the recycling system is installed in the hobby cellar,



the radiant heat from the warm greywater can be used for room heating with no additional costs. One kWh of heat energy can be saved per cubic metre of generated greywater and 1 K difference in temperature. Energy, which is required to heat the drinking water, can be withdrawn from the warm greywater by means of a heat exchanger. This is more economical to install outdoors on a frost-proof site, however, the heat recovery will be less efficient. These advantages and disadvantages should be weighed against each other.

Furthermore, the choice of the greywater sources is of importance. If the sole aim is to recycle 30 to 60% of the slightly polluted greywater from showers and bath tubs, then the system technology would be much simpler than when nutrient recycling is additionally practiced or high-load greywater sources are included, such as from kitchen or washing machines.

## THE ROLE OF MANUFACTURERS AND PLUMBERS

Today manufacturers are able to supply high-quality greywater system components and make sure that plant installation and operations are properly carried out. Some systems can be easily connected with the planned infrastructure (greywater influent, service water network, power supply, mains back-up system), so that operation can take place within a short time period.

German plumbers are also still waiting in vain for the industry to produce a standardised, coloured service water pipe with the inscription "Service Water", which will make the network installation and labelling of the second pipe network easier. Moreover, product certification can establish additional trust between suppliers and users and the first certificates have already been made available.

As with the introduction of rainwater harvesting systems, manufacturer-dependent and independent training courses for planners and plumbers have proved to be very effective.

Manufacturers and plumbers should also be able to offer maintenance contracts, since not every person is technically qualified to operate a greywater recycling plant. For larger systems such as for hotels and residential buildings, low-interest credits or leasing agreements as well as operator contracts can be a strong incentive for greywater propagation.

## REGULATORY FRAMEWORK

Although the first greywater recycling plants, such as the one installed in 1995 in the four-star Arabella Sheraton Hotel (with 400 beds) in Offenburg/Germany, are still operating successfully today and new large ones are constantly being planned, in addition to more than 1,000 operating smaller units, the regulatory associations have failed to incorporate greywater recycling in their body of rules and standards.

Also the German State did not take it upon itself to establish clear conditions, and today there is still no regulatory framework for greywater recycling. For many years manufacturers, planners and operators have been demanding more legal security and assurance.

The former Berlin Senate Department for Construction and Housing took the challenge in 1993 to establish quality standards for non-drinking water in buildings in cooperation with hygiene experts, scientists, planners and specialist companies, offering assistance in the planning, construction and operation of these plants. A document on these requirements was published in 1995 and updated in 2003. Due to the wide international interest, the document is also available in an abridged form in the English language on the internet ([http://www.stadtentwicklung.berlin.de/-bauen/oekologisches\\_bauen/de/downloads/betriebswasser\\_englisch2007.pdf](http://www.stadtentwicklung.berlin.de/-bauen/oekologisches_bauen/de/downloads/betriebswasser_englisch2007.pdf)).

The Berlin quality standards are oriented towards the EU guidelines for bathing water with respect to the hygienic/microbiological parameters which offer adequate safety for the use of greywater in buildings. These standards can be achieved even without the addition of chemicals as long as the greywater is extensively treated ( $BOD_7 < 5 \text{ mg/L}$ ).

The Association for Rainwater Harvesting and Water Utilisation (fbr e.V.) worked out in 2003 the fbr Information Sheet H 201 offering guidelines on the planning and operation of greywater recycling systems. Due to the technical progress in this field, the document will soon be updated. It is also available in the English language on the internet ([http://www.fbr.de/fileadmin/user\\_upload/files/Englische\\_Seite/H201\\_fbr-Information\\_Sheet\\_Greywater-Recycling\\_neu.pdf](http://www.fbr.de/fileadmin/user_upload/files/Englische_Seite/H201_fbr-Information_Sheet_Greywater-Recycling_neu.pdf)).

## AMORTISATION AND FUNDING

Although larger greywater systems amortise within a few years in places with high water and wastewater costs, this is not always and everywhere the case. Especially in locations where drinking water is still subsidised, wastewater inadequately treated or the infrastructure of the centralised water supply and wastewater discharge systems is subsidised, and the consequential costs of an erroneous water policy remain unconsidered, a calculation of amortisation on the basis of the individually saved water costs is not always encouraging.

More and more greywater recycling systems are in operation in hotels where water is not available in sufficient quantities. Without water recycling, these hotels cannot work with full occupancy. In this case the amortisation period will not be the deciding factor for greywater recycling.

As long as no adequate planning fundamentals are available for plant design, the planner will tend to oversize rather than undersize the system and this will be associated with additional, unnecessary capital and operation costs.

As has been successfully practiced in the field of regenerative energy, greywater recycling plants should



be also funded over a certain period of time. Such an approach requires technical innovations which will lead to the quick integration of these systems as a standard in the housing technology.

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## ABSTRACT:

Greywater recycling is the access to a successful ecological water management. The integrated concept with nutrient and energy recycling will assert its position in the next few years against the end-of-the-pipe technologies. The technology for greywater recycling is available, however, this alone is not sufficient without the co-operation of the different stakeholders. This paper presents a short history of greywater development during the past 20 years in Germany and the important role of the different interest groups and legislators in bringing forward greywater recycling as one means to close the water loop.

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▼ *Figure 5:*  
**DRAGON-FLY**  
*Source: E. Nolde*





# DESIGNING FOR ZERO NET POTABLE WATER USE

## A CASE OF URBAN RENEWAL IN SYDNEY, AUSTRALIA

By **MONIQUE RETAMAL, STUART WHITE** and **SIMON FANE\***

Increasing demand for housing and office space as well as the drive for urban consolidation have led to the renewal or planned renewal of several large former industrial sites in central Sydney. Public concern regarding the need to reduce water and energy consumption has risen, spurred by a decade of drought, water restrictions and an increased awareness of climate change.

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◀ *Figure 1:*

**AN ARTIST'S IMPRESSION OF THE NEW FRASERS BROADWAY PRECINCT CURRENTLY BEING BUILT. ARCHITECTS: FOSTER & PARTNERS, ATELIER JEAN NOUVEL**  
*Source: Frasers Property (used with permission)*

**G**overnment regulations require new houses and buildings to make significant reductions in water and energy use and in addition, commercial tenants are increasingly seeking office space with high credentials in terms of sustainability. These drivers have led to significant changes in building industry practices and the redevelopment of entire urban precincts is providing opportunities for innovation in the design of integrated, precinct-wide water, energy and waste systems.

At one such location in Sydney, a new precinct is currently being built on a former industrial site. The site occupies nearly six hectares on the edge of Sydney's central business district and is set to be a mixed use precinct, with an assumed gross floor area of 235,000 m<sup>2</sup> comprising new residential, commercial and retail space which has been designed to meet with high targets for sustainability. Located within a highly urbanised area, the site is surrounded by an existing service infrastructure, including ageing sewers and drains dating from the early period of Sydney's development. The possibility of using local 'waste' resources and developing decentralised systems for the site were envi-

### RÉSUMÉ:

#### CONCEPT VERS UNE DEMANDE ZÉRO D'EAU POTABLE – UN CAS DE RÉAMÉNAGEMENT URBAINE À SYDNEY, AUSTRALIE

*Monique Retamal, Stuart White et Simon Fane*

Un certain nombre d'anciens sites industriels du centre de Sydney sont en cours de re-développement sous forme de concepts entièrement nouveaux, comprenant des espaces résidentiels, affaires et commerciaux. Sur l'un de ces sites, il a été décidé de construire un système d'eau qui n'utilise absolument pas d'eau potable venant du réseau. Cette étude de cas souligne le processus utilisé pour concevoir ce système et les principes qui ont présidé à l'approche comme «la primauté de l'efficacité» et «une approche systémique». Les études ont montré que plus de 50% de la consommation d'eau pouvaient être économisés par l'amélioration de l'efficacité et que les sources d'eau locales comme l'eau de pluie, les eaux d'orage et l'eau usée pouvaient être réutilisées et ainsi permettre une réduction de la consommation d'eau du réseau atteignant jusqu'à 90%. Les cycles d'eau décentralisés et intégrés, examinés dans cette étude, se sont avérés avoir la plus faible consommation en énergie et les plus faibles émissions correspondantes en dioxyde de carbone.





▲ *Figure 2:*  
**AN ARTIST'S IMPRESSION OF THE NEW URBAN PRECINCT  
 LOCATED NEAR SYDNEY'S CENTRAL STATION, ARCHITECTS:  
 FOSTER & PARTNERS, ATELIER JEAN NOUVEL**

Source: Frasers Property (used with permission)

sioned early in the planning process. The possibility of creating a site which, during operation would have net zero potable water consumption was investigated and is detailed here as a case study.

The investigation had the following objectives:

- 1 Model the expected water demand using end-use modelling;
- 2 Determine the potential for water efficiency and the use of alternative water sources such as on-site collection and reuse of rainwater, stormwater and wastewater;
- 3 Identify the potential contribution of these water management options to the achievement of a zero net water development for the site;
- 4 Examine the feasibility and practical implications of the range of water cycle options.

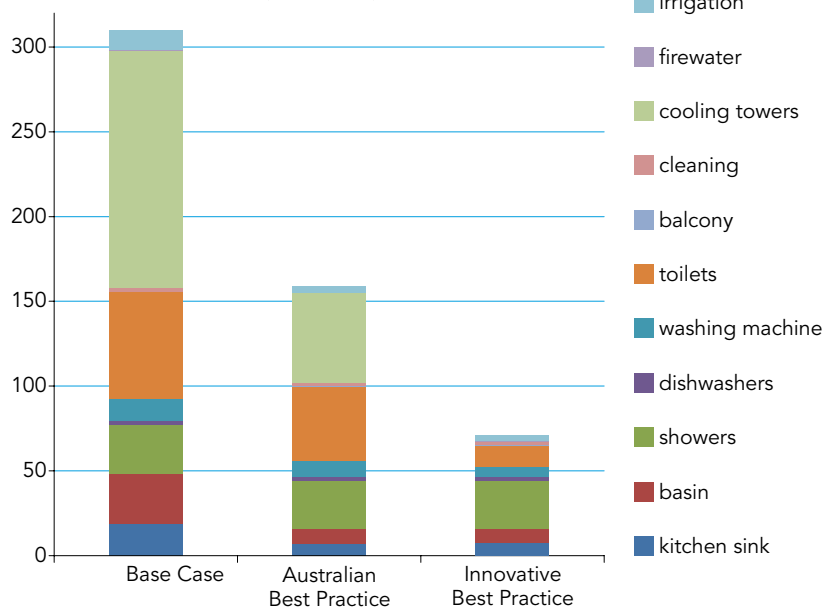
Sustainability principles such as applying efficiency first and systems thinking underpinned the approach to this investigation. Water efficiency and conservation is the first step in the 'reduce, reuse, recycle' hierarchy. Systems thinking is an approach that aims to maximise the integration of water cycle elements and develop synergies between water and other systems such as energy and waste.

The term 'end-use' refers to where the water is used and what it is used for (for example showering, cooling towers etc.). An end-use model disaggregates water demand into sector types and individual uses and uses empirical findings from end-use analysis (water use surveys or sub-metering) to enable the forecasting of water demand. Taking an end-use approach can reveal different ways of providing the same service, such as with a different quality or quantity of water [1].

## DETERMINING DEMAND AT VARIOUS LEVELS OF EFFICIENCY

End-use modelling was used to estimate water demand at the site across the residential, commercial and retail sectors for three target levels of water efficiency. Firstly, a base case for water demand was configured to

Annual Site Water Demand (ML/annum)



▲ *Figure 3:*  
**TOTAL ANNUAL SITE  
 WATER DEMAND  
 WITH END-USE  
 BREAKDOWN**

meet with state regulations for efficiency in residential water use and to correspond to the average water use for existing commercial buildings.

The second target level of water efficiency was aimed at achieving 'Australian Best Practice'. This means using the most efficient appliances and fittings currently available in Australia including 4.5/3 L dual flush toilets, waterless urinals and using drip irrigation as well as super efficient cooling towers for air-conditioning. The third target level of water efficiency aimed to improve on Australian best practice by using innovative technology to increase the site's overall sustainability. This level involves the elimination of cooling towers in favour of cooling via geothermal heat exchange and the use of high efficiency urine diverting toilets.

The annual site water demand as modelled for the three target levels of efficiency is depicted in the graph in [figure 3](#). These results have been disaggregated to show the breakdown of water demand according to end-use. This figure shows that the water demand for cooling towers and toilets represents the largest proportion of the overall water demand for the base case and the Australian best practice case. Demand for these end-uses can be significantly reduced through the use of innovative technology as shown in the third scenario. It is evident from this graph that considerable water savings are possible through the use of built in water efficient fixtures and appliances.

## INTEGRATING THE WATER CYCLE

Following the end use analysis and demand estimations, further options for integrating the water cycle on the site were considered. Sources of alternative water supply include rainwater harvested from roofs, the recycling of wastewater from the site, stormwater mining from trunk stormwater drains and sewer mining from trunk sewers passing beneath the site. New state legislation has recently made these last two options more feasible as a business opportunity.

The *Water Industry Competition Act 2006* allows third parties (other than the monopoly water utility) to access public water infrastructure, recycle water and on-sell the product. The act establishes a licensing regime for private entrants to the water industry in New South Wales that seek to provide water (including drinking, recycled and other grades of water) or sewerage services. It also provides a comprehensive access regime to facilitate the negotiation of arrangements for the storage and transportation of water and sewage using existing water and sewerage networks. The two categories of licence that can be granted by the Minister under the Act are: a network operator's licence that authorises the holder to construct, maintain and operate specified water industry infrastructure and a retail supplier's licence that authorises the licence holder to supply water or provide sewerage services by means of water industry infrastructure [2]. This legislation was designed to introduce greater competition within the water industry and encourage new and innovative water recycling projects. This legislation provides an opportunity to offset the mains water consumed at the site by recycling more than is required and providing the additional supply to neighbouring sites.

### ALTERNATIVE WATER SOURCES

Health regulations in NSW require that the mains water supply be used for drinking in all areas where it is available [3]. Aside from drinking water, which makes up a small percentage of water use, there are significant opportunities for substituting potable water with alternative water sources, following the principles of the 'water quality cascade'. End-uses are sorted according to the quality of water required, with drinking water requiring the highest quality and water used for outdoor applications such as cleaning and irrigation requiring the lowest water quality. Alternative wa-

ter sources should be matched with end-uses according to the quality required. This concept is illustrated in **Figure 4**.

**Recycled wastewater in Australia** is currently only directly reused for non-potable end-uses such as irrigation, toilet flushing and occasionally for clothes washing. This is the case in the former Olympic village in Sydney [4]. Rainwater, once heated for hot water is generally considered acceptable for hot water applications.

**Rainwater** – The site will have a total roof area of 22,000 m<sup>2</sup> which can be used to collect rainwater for use both internally and externally. Filtered and disinfected rainwater can be used for hot water, washing machines and cooling towers, in addition to other non-potable end-uses such as for toilet flushing, and irrigation. The ability to use rainwater is usually limited by supply rather than applicable end-uses.

**Stormwater Mining** – Two trunk stormwater mains that pass beneath the site drain a 25 ha urban catchment. Stormwater collected from a trunk main will have a range of contaminants including organic matter, nutrients, inflow from sewers and oil, grease and heavy metals from roads. Consequently, harvested stormwater requires physical treatment and disinfection before it can be reused.

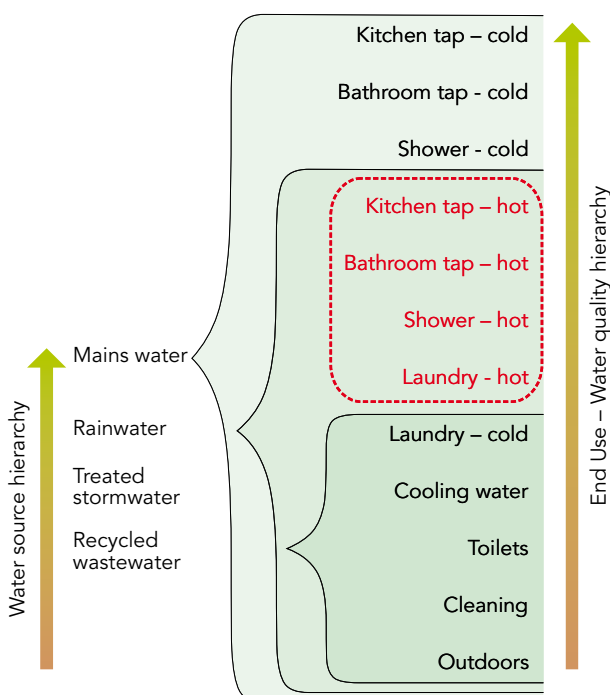
**On-Site Wastewater Recycling** – Greywater and blackwater produced on the site would require a similar high level of treatment to enable reuse; consequently it was decided not to separate these two streams. The additional cost of separating these streams at the source over such a large development would significantly add to reticulation costs, with several supply streams already planned.

**Sewer Mining** – There are two sewer mains passing beneath the site, one of which has a flow greater than 6 ML/day and is available for sewer mining.

### INTEGRATED WATER CYCLE OPTIONS

Four potential integrated water cycle options for the site were developed according to the principle of the

► **Figure 4:**  
**WATER QUALITY HIERARCHY – WATER SOURCES MATCHED TO END-USES**



◀ **Figure 5:**  
**CENTRAL SYDNEY (BACKGROUND) AND THE AREA TO BE REDEVELOPED OUTLINED IN RED**  
Source: Frasers Property (used with permission)



water quality cascade, with the practical issues of reticulation in mind. These options were modelled to determine the potential yield from each water source and the capacity to meet with set water demands. The four options were as follows.

*Option 1* – Rainwater used for all non-potable end-uses (outdoors, cooling towers, toilets and cold water in laundries). This option was set up to examine the potential yield from rainwater with varying storage capacities.

*Option 2* – Stormwater diverted from the drain used for all non-potable end-uses. Rainwater used in the hot water supply.

*Option 3* – Wastewater collected from the site and recycled for all non-potable end-uses. Rainwater used in the hot water supply.

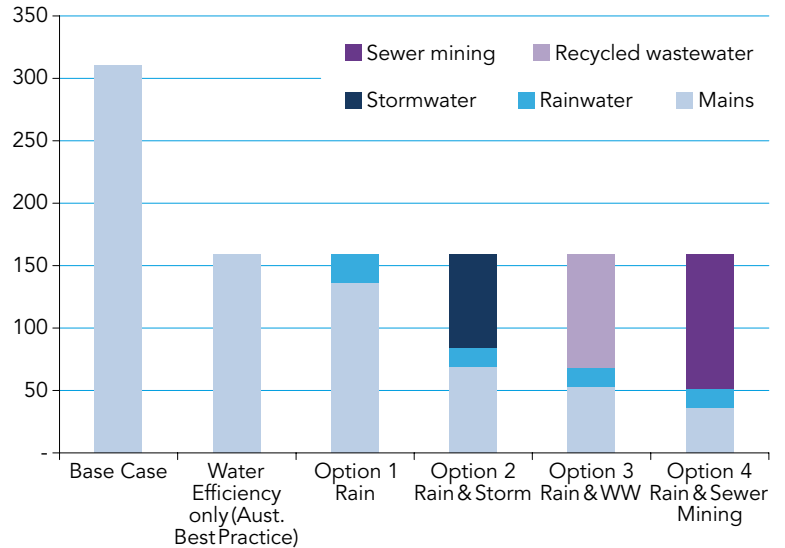
*Option 4* – Wastewater mined from the sewer recycled for all non-potable end-uses. Excess wastewater will be treated and sold to neighbouring sites as a secondary water supply. Rainwater used in the hot water supply.

Mains water is required to supply drinking water in all cases, consequently, only Option 4, which involves the on-selling of recycled wastewater, has the capacity to achieve a net zero mains water consumption by offsetting its water use. Options 2, 3 and 4 are also integrated with the energy system on the site, as the rainwater is used to cool the natural gas fuelled tri-generation plant and its heat is used for the hot water supply. Additionally, in Options 3 and 4, the biosolids extracted from the wastewater stream are converted to biogas through an anaerobic digester. The biogas is then used to help fuel the wastewater treatment plant.

## MODELLING

A water balance model was developed for this project, which integrates an end-use demand model and a supply model incorporating a daily time step rainwater/stormwater harvesting and wastewater recycling model. The ‘Australian Best Practice’ efficiency scenario was adopted for this phase of the modelling as it was considered the most likely scenario to be adopted. The modelling results for the four options are illustrated in **figure 6** alongside the calculated base case wa-

Site water consumption & alternative water yield (ML/annum)

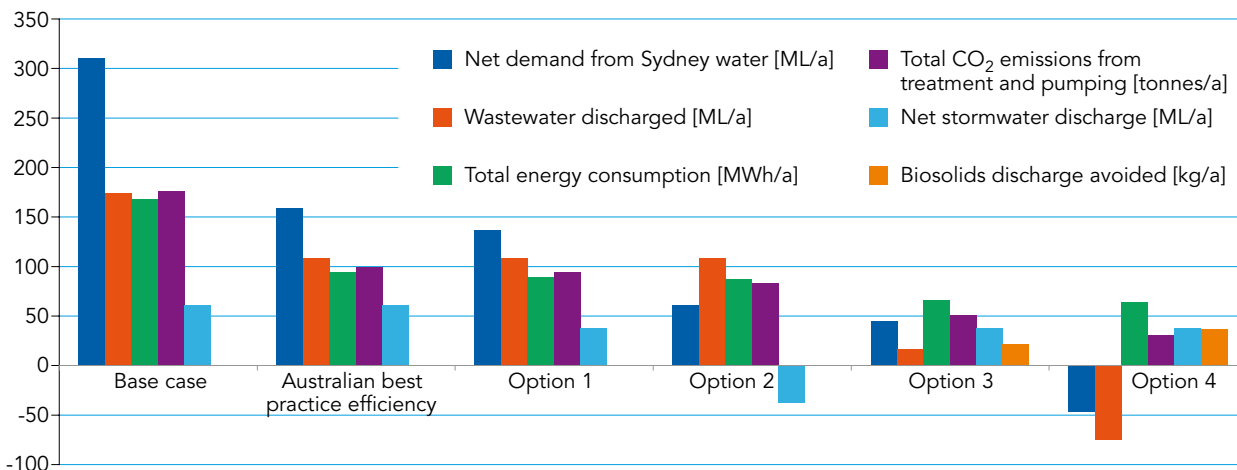


▲ *Figure 6:* INTEGRATED WATER CYCLE OPTIONS FOR THE SITE

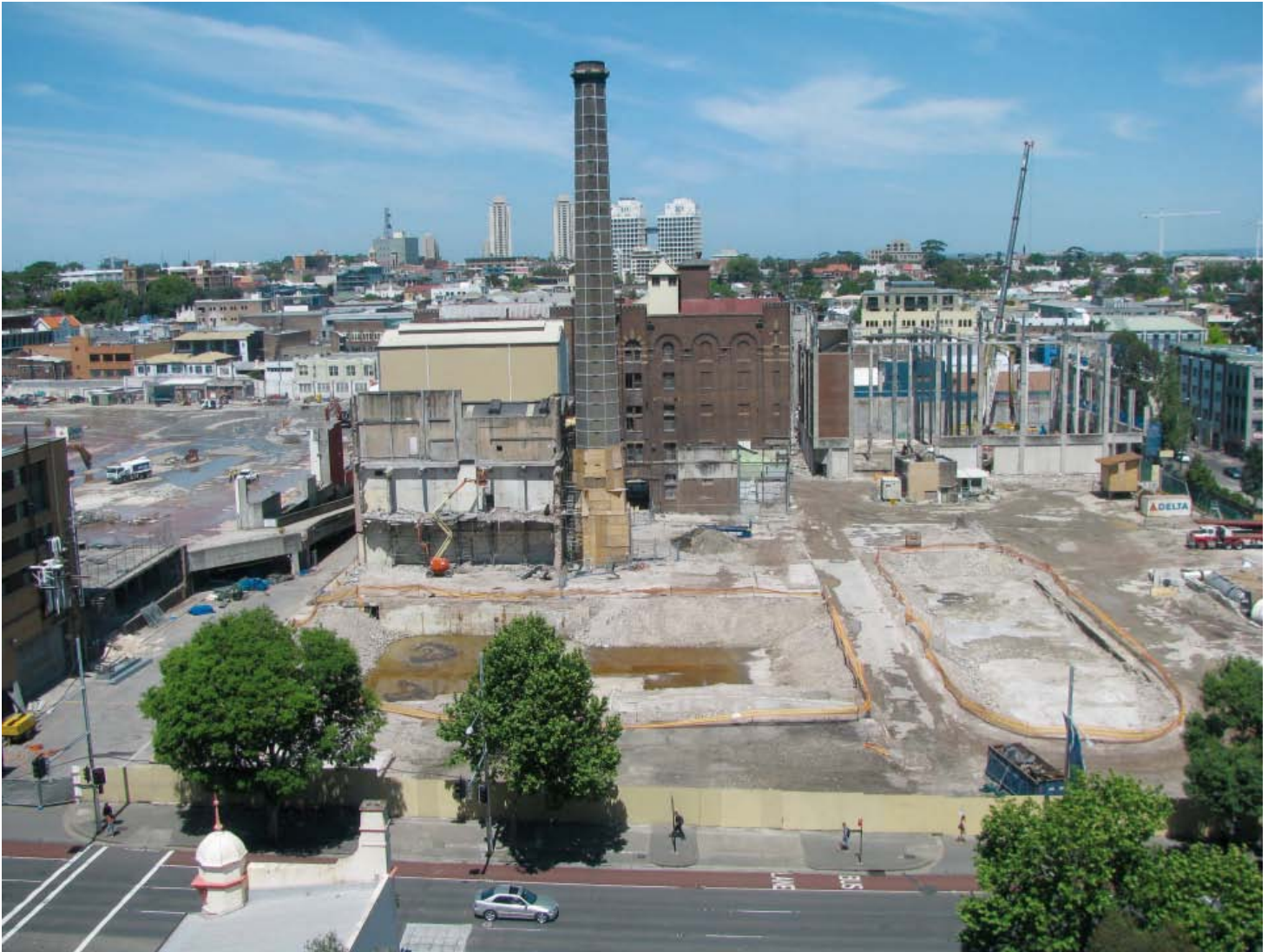
ter consumption and the ‘Australian Best Practice’ water efficiency scenario. This graph shows the capacity to meet demand at the site only; the excess water recycled in Option 4 is not shown in this graph.

These options have been further compared across a range of other criteria including the net mains water consumption, total energy consumption, CO<sub>2</sub> emissions, wastewater discharged, stormwater discharge and biosolids collected. The relative impact of these factors is illustrated in **figure 7** below. The total energy consumption shown in the graph includes the energy used to treat and pump the mains water supplies, the alternative water supplies (rain, storm, recycled wastewater) and the wastewater treatment and disposal. The carbon dioxide emissions calculations assume the on-site power supply to be natural gas (through an on-site tri-generation plant) and the external energy supply (used in pumping mains water) to be coal.

It can be seen in the graph that mains water consumption in Option 4 has been more than offset by the excess production and sale of recycled water. Energy consumption for the base case is the highest, as it uses only the centralised supply. Options 3 and 4 use the least energy as the water supplied in these options is primarily treated and used on-site with minimal pumping requirements. The energy intensity of the mains wa-



◀ *Figure 7:* COMPARISON OF OPTIONS AGAINST MULTIPLE CRITERIA



▲ **Figure 8:**  
**THE SIX HECTARE**  
**FORMER BREWERY**  
**WHICH IS**  
**CURRENTLY BEING**  
**REDEVELOPED INTO**  
**A NEW URBAN**  
**PRECINCT**

Source: Monique Retamal

ter supply in Sydney is estimated at approximately 300 kWh/ML, however this is an underestimation as it does not include treatment and pumping used in all parts of the supply network. The energy intensity of the treatment and disposal of wastewater is estimated to be around 450 kWh/ML [5, 6]. Overall, Option 4 had the most positive overall impacts based on the criteria that were analysed; specifically mains water use, sewage discharge and energy consumption.

## CONCLUSIONS

The investigation carried out at this site demonstrated that considerable savings in water consumption can be made through efficiency alone (over 50%) and how local water sources such as rainwater, stormwater and wastewater which are normally treated as “waste to be discharged” can be reclaimed and reused to further reduce mains water consumption. Up to 90% of mains water required under an efficient scenario can be substituted by alternative water sources in the Australian urban context. The options in this study which made greatest use of local water sources such as Options 2, 3 and 4 used the least mains water and the least

energy. Options 3 and 4 provide a significant opportunity to reduce wastewater flows and recover biosolids for conversion to biogas. The decentralised, integrated water cycles examined in this study were found to have greatly improved sustainability outcomes across water and energy consumption, resource efficiency (through linkages with other local systems such as energy) and reduced strain on the ageing infrastructure within the city. The construction of the new precinct and the detailed design of Option 4 is currently underway.

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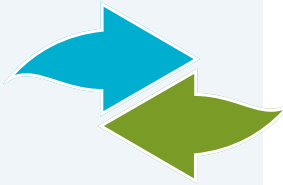
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### ABSTRACT:

A number of former industrial sites in central Sydney are currently being redeveloped as entire new precincts, comprising residential, commercial and retail space. At one of these sites, the intention is to build a water system that uses zero net potable water from the mains supply. This case study outlines the process used in designing this system and the principles that underpinned the approach, such as 'efficiency first' and 'systems thinking'. The investigation demonstrated that over 50% of water consumption can be saved through efficiency alone and that local water sources such as rainwater, stormwater and wastewater can be reused to further reduce mains water consumption by up to 90%. The decentralised, integrated water cycles examined in this study were found to have the lowest energy consumption and associated carbon dioxide emissions.



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**SUSTAINABLE CONCEPTS TOWARDS A ZERO OUTFLOW MUNICIPALITY**

CONTRACTING AUTHORITY

EUROPEAN COMMISSION / Delegation of the European Commission in Jordan

PROGRAMME

EURO-MEDITERRANEAN PARTNERSHIP

Euro-Mediterranean Regional Programme For Local Water Management

BUDGET LINE B7- 4100

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