WATER MUSEUMS GLOBAL NETWORK

unesco Intergovernmental Hydrological Programme

Valuing Ancient Water Cultures

An Inspiring Source of Innovations for Sustainable Groundwater Management

Learning from past practices and knowledge to make the invisible visible: from Indian stepwells to Omani *aflaj*, Moroccan *khettaras*, Algerian oases, Chilean *socavones*, Mexican *tecuates*, and Mediterranean cisterns and wells

THE EXHIBITION

Learning from history and involving local communities in managing and monitoring groundwater quality and quantity are prerequisites for enlightened water use that supports the UN's Sustainable Development Goals.

In conjunction with the UN-Water Summit on Groundwater, the Global Network of Water Museums curated an exhibition with eight selected case studies from different parts of the world to illustrate how ancient water cultures can be an inspiring source of innovations for sustainable groundwater management.

Ancient water cultures and management practices are based on holistic knowledge and approaches. They can help to achieve the SDGs in ways that are more effective than those based solely on modern technological 'fixes' and increasingly powerful technologies. Shifting from a cultural paradigm of 'dominion over nature' to one of 'ecosystem sustainability' requires persistence in engagement, training, and education.

However, a commitment to shifting attitudes and behaviors in this way is vitally necessary now to secure humanity's future and global water security. Society must move on beyond paradigms that consider that water management for development can take place only through energy-intensive, ecosystem-altering major hydraulic infrastructures and technologies that have major ecological footprints and other negative environmental impacts.

Water museums display some of the most outstanding features of water heritage and human knowledge worldwide. They actively promote water heritage of all kinds - whether natural, cultural, tangible, or intangible - linked to the precious, life-giving element of water. Simultaneously, museums also excel in using innovative approaches for reconnecting people and communities to the values associated with water, and far-sighted ancestral practices of co-existence with nature.

This educational perspective is crucial, since multiple water assets have too often been obliterated by corporate consumerist treatments of the resource as simply an unlimited commodity.

In this context, museums must be recognized for the role they play in raising awareness about groundwater vulnerability, 'making the invisible visible' and building a 'new culture of water' through education and knowledge sharing across national borders and sectoral boundaries. Through concrete activities, museums show how traditional water knowledge and ancient management practices promote new holistic ideas for future resilience planning.

Canal-bridge to allow water overtaking a depression in a valley (*wadi bani kharous*). © University of Nizwra.

www.watermuseums.net/campaigns/valuing-ancient-water-cultures

Steps to Water: The Forgotten Stepwells of India

NEGOTIATING SPACE AND DESIGNING WATER: EMERGENCE AND DECLINE OF THE HISTORICAL ARCHITECTURE OF INDIAN STEPWELLS

There are more than 3,000 stepwells built between the 7th and 19th centuries which dot the semi-arid landscape of Gujarat and Rajasthan, in western India. They all extend along the trade routes that carry into Central Asia. These elaborate architectural wonders, usually from three to nine levels deep (20 to 25 metres), mark the invisible landscape of underground water, providing cool shade, life and sustenance to villagers, communities, and weary travellers.

The gift of water in India is considered a pious act. Consequently, many stepwells were funded by women and men of wealth – kings, queens and merchants – often to honour a deceased relative or a deity (typically, a female goddess). Indeed, water is largely associated with the feminine in India. Stepwells were special spaces for women - to fetch water, meet friends and spend time away from home and domestic work.

Stepwells draw water from an underground aquifer. They are filled through a process of seepage wherein rainwater, caught in a depression, percolates and is filtered through fine silt. With its deep vertical shape, the stepwell protects people from sun and hot winds, maintaining water at a constant temperature of approximately 13° Celsius.

Over the last century, the development of piped water systems and notions of public health have led to the disregard of these ancient structures. Yet, there are small signs of redemption. In the old city of Jodhpur, the recently restored *Toorji ka Jhalra* lies at the centre of the aptly named Stepwell Square - a popular meeting place with cafes, galleries and shops. Restoration work excavated to a depth of 60 metres and discovered intricate carvings, waterspouts and even the remnants of an old Persian hydraulic wheel. Built by a queen from the Marwar region in 1740, this stepwell is a clear example of the role of women in hydro-philanthropy.

Samerth, the NGO based in Gujarat, in 2018-19 revived four small stepwells with community participation in the semi-arid region of Kutch, providing water for domestic and livelihood purposes to 400 rural families. The wells are maintained by local youth groups and water committees, also involving women. Despite many obstacles, today a growing number of female water leaders are ensuring that their voices are heard in community water governance.

Recognising the importance of ancient water management systems, the Indian Ministry of Water Resources has also made recent investments to recharge aquifers.

However, successful restoration of stepwells is a complex process which requires a trans-disciplinary approach involving engineers, conservation architects, hydrologists, and also local associations and the civil society.

The octagonal structure of Bai Hari ni Vav, a stepwell commissioned in 1485 by the homonymous woman. Ahmedabad, Gujarat. © Somya Parikh, 2019 - Living Waters Museum.

The *Aflaj* Water Supply System in Oman: Sustainable Water Management through Millennia

THE FALAJ: ANCIENT KNOWLEDGE SYSTEM AND PEOPLE'S AWARENESS OF SUSTAINABLE WATER

The *falaj* (plural: *aflaj*) is a gently sloping subterranean tunnel that drains out groundwater and valley runoffs and brings it to farmlands in rural Oman. As such, the *falaj* is an extended hydraulic system that may stretch several kilometers, spanning different areas with various geological and botanical conditions that require specific knowledge and know-how for its management.

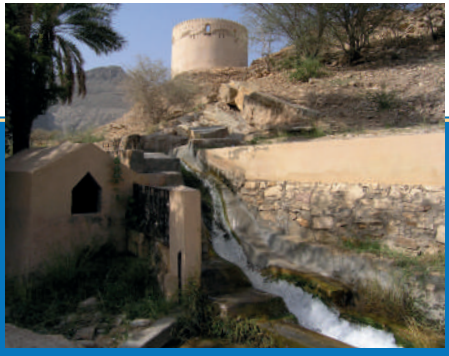
Relying on such hydraulic models, over the centuries local communities came across different issues in terms of water quality, ownership, and social management of a scarce resource. Such challenges have been solved thanks to empirical and technical know-how rooted in thorough environmental knowledge.

This traditional water mining system has proved to be the most crucial water source in many parts of Oman over the past millennia. It's most likely that the *falaj* system came into existence as a collective social response to climate change in the late Bronze Age when Oman experienced a dramatic decline in precipitations. Many communities shifted accordingly their water management practices from disappearing surface streams to groundwater.
In this period, the emergence of the cut-and-cover tunnels bears witness to an overall decrease in water resources, which led the local communities adopting such a technique to tap water at lower levels. Around 2,450 BC, when the region's precipitation had a downward trend, the first tunnels of this kind came into existence.

What marks out the *falaj* as a unique heritage is not only its role for sustainable water supply in a desertic region, but also its contribution to the social and cultural fabric of Oman. Centuries of local people's endeavor to find solutions to a variety of problems faced while digging and maintaining their *aflaj*, enabled them to better adapt to drier and harsher environments. Indeed, the construction and maintenance of these tunnels demand a high level of knowledge that has been shaped over the centuries and handed down from generation to generation.

This know-how paved the way for local communities to develop a special awareness towards their natural environment and heritage of water. The *aflaj* system highlights a high level of social consensus and convergence which are manifest in every aspect of people's life in traditional communities. For this reason, the potential loss of the *falaj* systems also undermines social cohesion and may cause potential massive migration from rural to urban areas.

The *aflaj* irrigation system of Oman is a World Heritage site since 2006, composed of five individual *falaj* in the north of Oman: *falaj* Al Jeela, *falaj* Muyasser, *falaj* Daris, *falaj* Malki and *falaj* Khatmein.



The Al-Khutmain in Birkat al-Mouz *falaj* is connected to a historical tank built for charity goals and to quench thirsty travelers. © University of Nizwra.

Managing Groundwater in Venice: The Cistern-System from the 12th Century to Today

FUNCTIONALITY AND DEVELOPMENT: PAST, PRESENT AND FUTURE

The entire saltwater lagoon where the city of Venice stands had through the centuries one major problem: how to obtain fresh water? As the city's chronicler Marin Sanudo wrote (1490): "Everything abounds except fresh water … Venice is in water - and yet, it has no water". The solution was a dense network of underground rainwater cisterns - eventually numbering close to 6,000 - located under squares and courtyards, buildings and streets.

Venice's famous wells, with their characteristic ornate well-heads, are typically located in the middle of a public square or private courtyard. They are actually complex devices for capturing, filtering and storing rainwater underground.

By the 16th century much of Venice's open space was dedicated to water capture in order to supply these cisterns. As the city's population increased, new cisterns were built to meet growing demands.

Venice itself had become a sophisticated machine for harvesting and storing rainwater. Nowhere in Europe was the approach to rainwater capture so systematic and widespread, the city concerned so populous, the technology so sophisticated, and the management so carefully regulated as in Venice.

The actual cistern-system occupied most of the area underneath each square. It consisted of a large basin, dug to a depth of 3-4 metres below the normal high-tide level, and filled with sand.

Surrounding the well-head was the stone-paved area of the square, sloping down slightly on all sides to let water drain in underground galleries. The cistern's walls and floor were covered by impermeable clay to prevent the rainwater from flowing away (and saltwater from flowing in).

In 1500, the volume of water provided by the cistern-system has been calculated at a potential 6 litres per person per day. This is a reasonable amount by early modern standards - compared to Paris's 4 litres. When the supply of rainwater was not sufficient, the *acquaroli* ('watermen') were responsible for bringing in fresh water. Using special flat-bottomed barges, known as *burchi*, the watermen would take on water from the River Brenta and transport it across the lagoon to pour it eventually into cisterns.

Following construction of Venice's aqueduct in 1884, the entire cistern-system was slowly decommissioned. Wells are now strictly ornamental. Some plans were recently made to put some of the cisterns back into use - providing water to flush toilets, supply fire hydrants and gardens - but nothing came of them. And yet there are small signs of renewed interest: the new student residence of Ca' Foscari University of Venice is equipped with a system for re-using rainwater.

Venice and its lagoon are a World Heritage site since 1987.

Well-head in the courtyard of the ducal palace, in a picture postcard of 1870. Source: Wikipedia.

The Heritage of Roman Aqueducts and Groundwater Conservation in Naples

ORIGINS OF THE AUGUSTAN AQUEDUCT AND THE STORYTELLING OF A THOUSAND-YEAR-OLD WATER HISTORY

The Augustan aqueduct is one of the longest hydraulic artifacts built in the ancient world. The work was commissioned by the Emperor Augustus in the Augustan age (27 BC - 14 AD) and completed under the reign of Emperor Claudius (14 - 37 AD). Its impressive structure spanned over 96 km long and ran from the Serino spring, in the Apennines, to the *Piscina Mirabilis* ('marvellous pool') - a large cistern with a capacity of 12,600 cubic meters serving the ancient Roman military ships stationed in the naval port of Misenum.

The function of this impressive cistern was both military and civilian. Indeed the aqueduct also supplied water to the main towns in the region before delivering the precious liquid element to the Roman naval fleet. Also, it supplied numerous rural villas along the sea and several spas, before reaching the terminal pools of the *Piscina Mirabilis.*

Exploiting only the gravity force, the aqueduct ran halfway along the mountaineous and the hilly land of the Appenines, both on the surface and for several stretches also underground. For its operation, the large size of the waterworks required frequent ordinary and extraordinary maintenance. However, the aqueduct suffered severe damage from the eruption of Vesuvius (79 AD). Its operation finally ceased in 410 AD, when the Visigoth army sacked Rome and Naples, severely damaging the hydraulic structure.

From the mid-15th century, a renewed interest to redeem the ancient Roman aqueduct infrastructure was manifested by the popes who were concerned with the building of new and impressive fountains in Rome. In Campania, new interest in supplying quality drinking water began with the Spanish Viceroyalty, when the Augustan aqueduct was renovated and reused to improve water service to the city of Naples. From 1560, much of the ancient route that was abandoned after the fall of the Roman empire was patiently rebuilt. Then, a final main branch was completed in 1885, to transfer to Naples the hydropotable flows needed to supply the growing demands of a population increased to over 500,000 inhabitants.

This last new branch of the aqueduct testifies the continuity of historical management of drinking water and groundwater throughout over 2,000 years. In its first phase of set up, the newly established Water Museum of Naples features the history of the Serino aqueduct with its unique ancient heritage. The public waterworks of Naples, ABC, runs the water museum.

An exceptional underground route along the *Roman Decumanus* - a road that runs through the underground of Naples - illustrates several fascinating hydraulic artefacts that make visible a millennial history of water.

The Piscina Mirabilis ('marvellous pool') is the monumental cistern built 2,000 years ago to supply the Roman military ships at the port of Misenum. Source: *piscinamirabilisbacoli.it*

Re-adapting the Circular Irrigation System of Oases in the M'zab Valley, Algeria

THE OASIS: A PARADIGMATIC MODEL FOR SUSTAINABLE IRRIGATION AND AGRICULTURE

The emergence and sustainability of life in the desert oases, which have undergone many changes over time, have always been closely associated with careful management of water resources. In this respect, the M'zab valley represents an exceptional case - as it was inscribed on the UNESCO List of World Heritage in 1982.

The pioneers of the Ibadite faith, one of the currents of Islam practiced by a minority of Muslims, gradually settled in the wadi of the M'zab Valley in the 11th century. Here they built five fortified cities (*ksour*) along the M'zab *wadi*.
To make the best use of scarce water resources, they conceived and built an ingenious water recharge system aimed to capture surface water from the hydrological cycle (up to 3 annual flash floods) and divert it in local loops.
The circularity of such an ingenious practice is materialized by a set of hydraulic structures for transport (canals and tunnels), sharing (distributors, dikes, water intakes), and storage of surface water in the aquifer (dams and catchment wells). However, the circularity of the oasis system is not only limited to water. It also permeates the organization of other activities such as agricultural production, waste and energy management.

On the outskirts of the ancient oases, from the 1980s new agricultural lands were created by the state to favor an entrepreneurial agriculture inspired by the agro-industrial model, groundwater exploitation and use of chemicals. These practices are developed by investors not originating from the region and whose main interest is economic profit.
The native farmers, being aware that the new agriculture is incompatible with the traditional agro-systems, have been forced to develop a different farming model. They are now combining a variety of practices, inspired both by the ancient know-how and most recent technological innovations. For instance, they applied the concepts of permaculture and agro-ecology and have also introduced water-saving irrigation techniques, such as drip irrigation and exogenous crops with low water consumption. Like their ancestors, today's oases farmers try to respect the fragile balance between human needs and nature.

The development of new agro-industrial practices created a competition over water. The main challenge for the future is the sharing of water between upstream farmers (the modern extensions) and downstream (the ancient oasis). At first glance, this is an unequal battle. Upstream farmers have the priority in access to water, while the ancient palm groves have suffered from urbanization, land fragmentation, and social disruption.

And yet, the system based on the ancestral water culture highlights a good practice that should be promoted further to foster a more farsighted development paradigm and face desertification and climate change.

The ancestral dyke built downstream of the Ben Isguen palm grove is functional to stop flood waters and recharge the aquifer. © Farah Hamamouche.

The System of *Khettaras* in Morocco, from the 10th Century to the Present Day

PAST, PRESENT AND FUTURE OF AN ANCIENT SYSTEM OF GROUNDWATER MANAGEMENT

The *khettaras*, or draining galleries, have for centuries been ingenious systems for the most efficient and effective management of water resources in the arid regions of Morocco.
The technique is ancient, described as a Persian invention that dates to more than 2,500 years ago. It's a technique for extracting and collecting groundwater through a horizontal seeping tunnel that gathers groundwater upstream and, by gravity, facilitates its progressive flow to cultivated fields located at a lower level. The underground tunnels communicate with the surface through regularly dug and spaced wells that unmistakably mark the landscape desert and are clearly visible in aerial photographs.

This system of managing groundwater required both skilled labor and well-maintained infrastructure for its smooth operation. For that reason, its spread to wider regions was historically supported by the ingenious hydraulic science developed by the so-called Arab water school.

In Morocco, the establishment of *khettaras* in the 10th century is linked to the supply of drinking water to Marrakech during the Almoravid period. At the end of the 20th century, approx. 650 *khettaras* were efficiently working in the outskirts of the imperial city. The *khettara* system was also introduced to develop the plain of Haouz near Marrakech.

Here agro-pastoral activity had always been conducted in unfavorable climatic conditions, but thanks to constantly well-managed *khettaras* the local farmers have been able to use groundwater at any time to irrigate crops for over a thousand years. The management of *khettaras* is also related to key intangible values which have deep socio-cultural connotations. When collective memory is evoked, the mythical foundations of communities are attributed to the ancestral men who are today the head of important families' lineages.

Today, the traditional technique of collecting groundwater is subject to severe constraints due to the overexploitation of aquifers and the dramatic succession of several years of drought. In Marrakech, the level of the water table has fallen sharply and today the *khettaras* are almost vanished. Artificial recharging of the alluvial aquifers during flash floods is one of the possible solutions to maintain this heritage, which nowadays has also been recognized as a historical legacy to be protected and valorized further. To keep the ancient practice alive, the rehabilitation of the main *khettaras* systems is urgent and necessary. The sustainable development of arid and semi-arid areas affected by severe water stress seems to be inextricably linked to the rehabilitation of ancestral hydraulic systems.

Indeed, with the use of *khettaras,* water exploitation never exceeds the natural recharge of aquifers. This prevents desertification and shows remarkable affinities with the targets of the SDGs.

Evocative interior spaces of the *khettara* in Akdima, Oasis of Tinghir, Morocco. Picture from the documentary series 'Children of Water', by Joy Penroz & Sylvain Grain © 2022 Raki Films.

Indigenous Hydro-Technology and the *Tecuates* of the Tehuacan Valley, Mexico

ANCIENT TECHNOLOGY SOLUTIONS FOR FARSIGHTED GROUNDWATER MANAGEMENT IN ARID AREAS

The famous Tehuacan-Cuicatlan Valley of Mesoamerica is an invaluable heritage of humanity located in an arid and semi-arid zone of striking biodiversity. The struggle for water is the predominant theme throughout regional history and several hydraulic artefacts bear evidence of the innovative capacity and constant adaptation of humans to adverse natural conditions. Indigenous communities domesticated teosinte and created modern corn around 5,800 BC. Early development of crops allowed for the emergence of agricultural settlements. From the 2nd millennium BC, rainwater harvesting was also developed through a system of small dams and canals. Over the centuries, local communities built complex canal networks to convey spring water to the terraced agricultural plots by raising, leveling, and compacting the soil. Terraced farmlands also facilitated the recharge of the groundwater table.

With the continuous water flow in the canals, the mineral component of the liquid element encrusted the irrigation ditches and created an impressive, fossilized structure called *tecuates* - a name derived from the Nahuatl '*te-coatl*' (i.e. stone-snake). The evocative archaeological remains of these canals are still visible today. However, the indigenous water culture of *tecuates* was progressively disrupted by the Spanish colonist, who introduced another hydraulic technology: that of *galerias filtrantes* (seeping galleries) of Arab origins. Still today, local communities use the *galerias* brought by the Spaniards.

The various hydraulic waterworks introduced in each period generated complex socio-technological systems that sometimes still coexist. Unlike other parts of the world, today the *galerias filtrantes* of Tehuacan are kept operational thanks to the hard work of farmers' water societies. Some 225 registered galleries are managed by well-structured water and canal societies and provide 170 million cubic metres of water for irrigation each year.

In 1980, with the belief that villagers had to cooperate more to solve their water needs - instead of waiting for government support - a civil association launched the program called *Agua para Siempre!* ('Water Forever!'). Since then, over 11,600 agroecological waterworks have been accomplished. In 1999, it was decided to also create the water museum *Agua para Siempre!* to promote indigenous water education and preserve the traditional knowledge of using natural resources. Today the museum is actively engaged in protecting groundwater by considering three basic principles: the empirical knowledge of agro-ecology; the regional socio-cultural organizational patterns; and the use of appropriate local technology for each tributary watershed.

The water heritage of the Tehuacan Valley illustrates the continuum paradigm of managing water through a combination of different hydro-technologies. Such a rich heritage of ancestral techniques and know-how illustrates well a key contribution to sustainable water management targeted by the UN's SDGs.

Traditional rock dams filter water and simultaneously allow infiltration. © Raúl Hernández Garciadiego.

The System of *Socavones* in the Oasis of Pica-Matilla, Atacama Desert, Chile

THE GROUNDWATER HERITAGE OF ARID AREAS: A SUSTAINABLE BUT FORGOTTEN LOW-COST WATER SUPPLY SYSTEM

Pica-Matilla is an oasis located in the hyper-arid Atacama Desert, at the foothill of the Andean Cordillera, in the North of Chile. It is one of the most arid areas on Earth.
The filtration galleries of Pica (called *socavones*; singular, *socavón*) are the most southern known of the Latin American continent. Their origin goes back to the middle of the 17th century. They were built to irrigate the vineyards and boost the vine industry, influenced by the proximity to the mines of Potosí. Indeed, the word *socavón* refers to an artificial underground gallery used for mining.

Filtration galleries are the traditional water management systems used to provide a reliable supply of water in arid and semi-arid climates. They consist of an underground and almost horizontal tunnel with vertical shaft wells, which tap and drain groundwater from the earth surface. Groundwater seeps into the wells and tunnels in the saturated part of the aquifer and flows downward by gravity, up to the exit point that supplies water for domestic purpose and irrigate downslope lands.

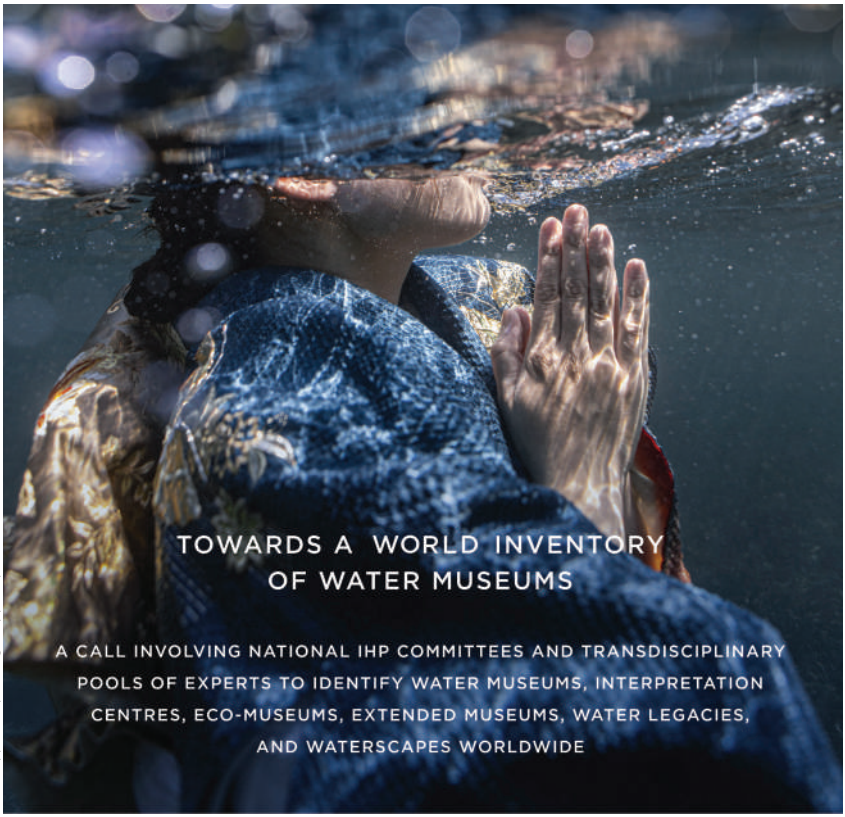
The origin of the filtration galleries dates back to the 1st millenium BC in ancient Persia, now Iran. It then spread to other cultures, China to the east and North Africa to the west.
When the Muslims conquered the Iberian Peninsula in the 8th century AD, they implemented these hydraulic works in all the peninsula. Later, the Spanish would take this technique to the Americas during the conquest, between the 16th and 17th centuries.

The system of *socavones* rely entirely on passive tapping of the available water by gravity. As such, the natural supply of water in a filtration gallery can never exceed the groundwater recharge. For this reason, *socavones* represent a truly sustainable and low-cost water supply system.
Unfortunately, despite the high value of such an ancient groundwater heritage to combat desertification, the *socavones* are neither protected nor valorized.
The owners of land with *socavones*, who used to enter in the galleries for their maintenance, nowadays do not dare to enter any more. They are falling into decay and slowly vanishing, both from memories and people's perceptions.

Today, only two out of more than twenty *socavones* of Pica and Matilla are still managed by farmers' collective associations. Water is distributed through a network of canals and according to strict regulations. But most of *socavones* are abandoned while groundwater extraction through shallow and deep wells increases, leading to aquifer drawdown and salinization. As it happens today in many other countries, unfortunately filtration galleries are abandoned and replaced by wasteful pumped wells and boreholes.

The narrow gallery of San Isidro still with flowing water despite the lowering of the aquifer level. © Fundación Carpe Science.

THE GLOBAL NETWORK OF WATER MUSEUMS



The Global Network of Water Museums (WAMU-NET) is an independent non-profit association aimed at fostering water awareness education and changing people's attitudes and behaviors towards water.

The mission of WAMU-NET is to re-connect individuals to all forms of water heritage (including both natural and cultural assets) and to highlight through a holistic perspective all the natural, social, cultural, artistic and spiritual dimensions related to water.

The Network has been granted the status of a 'flagship initiative' of UNESCO's Intergovernmental Hydrological Programme (UNESCO-IHP) in 2018 (Resolution n. XXIII-5). In 2019, another resolution of UNESCO-IHP (n. XXIV-7) highlighted the opportunity to implement a world inventory of water museums and heritage sites calling on Member States, universities and research centres.

Explore the toolkit for the world inventory implementation
www.watermuseums.net/activities/world-inventory

WATER AWARENESS EDUCATION PROMOTED THROUGH AN EXHIBITION AND SIDE EVENT AT THE UN-WATER SUMMIT ON GROUNDWATER

Today there is an urgent need to promote innovative, trans-disciplinary and holistic perspectives to overcome unduly narrow visions and approaches that have proved to be an inadequate response to the challenges of the global water crisis.

In this context, museums play a key role in paving the way for paradigm shifts and building a 'new culture of water'. Museums can foster richer perspectives and cultural approaches towards water, helping individuals and communities to properly value and not forget our watery past.

For this reason, WAMU-NET supports cooperation among museums, institutions and individuals to implement new actions aiming to repair our degraded relationship with the most precious element for life.

AN EXHIBITION AND SIDE EVENT SUPPORTED BY

IN COOPERATION WITH