Innovative Groundwater Solutions

COLLECTION

Selection of managed aquifer recharge practices in Latin America

Case studies

Selection of managed aquifer recharge practices in Latin America

Selection prepared by:

Research Group INOWAS, Department of Hydrosciences, Faculty of Environmental Sciences, Technische Universität Dresden (TUD), Germany

Centre for Environmental Studies and Biodiversity (CEAB), Universidad del Valle de Guatemala (UVG), Guatemala

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About this report

The overall goal of the DIGIRES project ("Digitally-enabled green infrastructure for sustainable water resources management in Latin America and the Caribbean") is the development and utilisation of ICT-based tools, coupled with citizen science observations, for the design and implementation of managed aquifer recharge (MAR) as nature-inspired solution for sustainable water resources management in Latin America and the Caribbean (LAC). This technique is defined as a "*purposeful recharge of an aquifer for later recovery or environmental benefits*" and despite its well-known ability to viably and sustainably supply water in urban and peri-urban areas, its implementation is still very limited in many regions.

Photo: Valparaiso, Chile (Loïc Mermilliod, unsplash.com)

In fact, MAR is mostly recognised as a tool to improve the availability of water for agricultural productivity or drinking water provisioning. However, groundwater recharge can also help to achieve many other objectives such as supporting riparian habitats, mitigating floods, reducing runoff and erosion, controlling land subsidence, improving coastal water quality and increasing the minimum flow in rivers. With this perspective, MAR should be considered as an increasingly relevant non-conventional and innovative solution for future integrated water management planning in LAC with the goal of maintaining, enhancing and replenishing stressed groundwater systems and, at the same time, ensuring the maintenance of ecological processes to mitigate climate change and preserve biodiversity.

To this end, this report intends to demonstrate the potential of managed aquifer recharge through the identification and dissemination of several success stories throughout the LAC region, showing the great diversity of applications, water sources and MAR techniques involved.

Acknowledgement

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Read more: https://www.digires.inowas.com

Report compiled by

Catalin Stefan[1], Miguel Moreno Gómez[1], Catalina Zapata Barra[1], Margarita Alonso Asencio[2], Jackeline Brinker Palomo[2]

[1]Research Group INOWAS, Technische Universität Dresden (TUD), Germany; [2]Centre for Environmental Studies and Biodiversity (CEAB), Universidad del Valle de Guatemala (UVG), Guatemala

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Source photos: www.unsplash.com (if not others specified).

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Ecosystem Rural

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Social engagement to recharge the aquifer and to secure water supply in rural areas

- Groundwater over-abstraction
- **Water security / food security / livelihood**
- Groundwater quality / human health
- **Ecosystem degradation**
- **Salinity issues / intrusion**

> *How to benefit from social participation and local knowledge in the application of MAR strategies to secure water supply for endangered rural communities.*

MOTIVATION

The increasing demand for water supply (due to population growth and tourism) in the Manglaralto rural parish of Ecuador and the recent trend in rainfall shortages have put local communities under significant water stress. In this semi-arid coastal area, the only source of fresh water is the underlying aquifer, which is also at risk of seawater intrusion due to the ongoing depletion of the aquifer.

Dirt 'tape' in the Manglaralto river (photo: Niurka Alvarado Macancela).

APPROACH

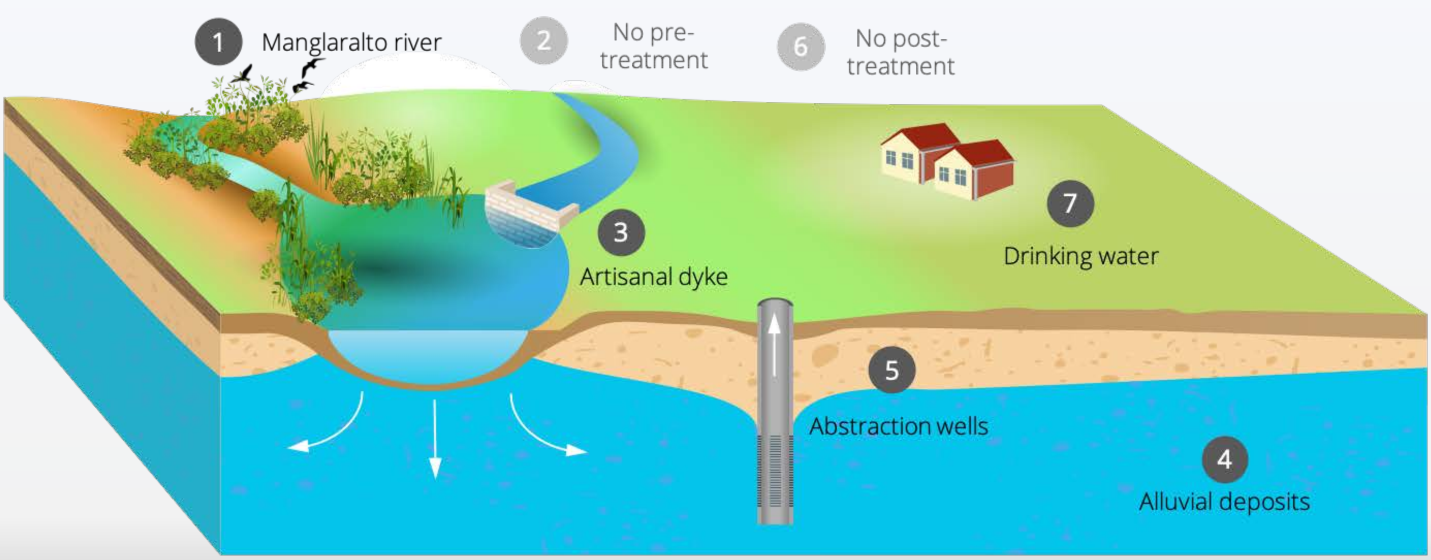
A Participatory Action Research (PAR) initiative between rural communities and water authorities was used to assess the problem and to develop actions for securing the water supply. The solutions included adaptations of ancient practices that use artisanal dikes to retain surface water and promote infiltration.

Since 2013, artisanal dykes (known locally as *tapes*) have been built following a trial-and-error method. The design of tapes in the Manglaralto river are constantly evolving, promoting additional groundwater recharge to secure supply and stop saline intrusion.

CHALLENGES

The trial-and-error method has brought dykes to failure during periods with high precipitation and seawater intrusion was difficult to contain during extreme dry seasons.

While there is a continuous increase of local water demand, the construction of more tapes would require more labour and a larger budget.



Managed aquifer recharge intervention

Capture zone	1	Manglaralto River
Pre-treatment	2	No pre-treatment
Recharge	3	Artisanal dykes
Subsurface	4	Alluvial deposits (gravel, sand and silt)
Recovery	5	Abstraction wells
Post-treatment	6	No post-treatment
End use	7	Drinking water supply / ecosystem

OUTCOMES

Groundwater piezometric levels in the extraction wells show an increasing tendency, which has also benefited the associated ecosystems.

Participatory actions of the community helped to improve the design of the dykes and to increase efficiency.

Bird habitat in the Manglaralto river (photo: Turismo Santa Elena).

WHAT'S NEXT?

For subsequent designs of the *tapes*, the use of floodgates in the spillways is projected in order to avoid dyke failure during extreme rainfall.

Construction phase of a concrete dike in the Manglaralto river (photo: I. Fajardo).

READ MORE

Herrera-Franco, G., Carrión-Mero, P., Aguilar-Aguilar, M., Morante-Carballo, F., Jaya-Montalvo, M., & Morillo-Balsera, M. C. (2020). Groundwater Resilience Assessment in a Communal Coastal Aquifer System. The Case of Manglaralto in Santa Elena, Ecuador. Sustainability, 12(19), 8290. doi: 10.3390/su12198290.

Urban

Application of groundwater recharge to counteract aquifer salinization in Paraguay

Urban rainfall harvesting to recharge the aquifer and minimize water supply and quality problems

- Groundwater over-abstraction
- **Water security / food security / livelihood**
- **Groundwater quality / human health**
- Ecosystem degradation
- **Salinity issues / intrusion**

> *"How to increase groundwater storage and stop saline intrusion by maximizing infiltration in strategic locations."*

MOTIVATION

The climatic and topographic characteristics of the Central Chaco region in Paraguay produce high evaporation and lower precipitation, promoting a deficit in the regional water balance. Moreover, due to the absence of surface water streams, the only other water source in the area are layers of fresh groundwater (lenses) that float above saltwater. The ongoing depletion of these freshwater lenses has severe impacts on the overall groundwater quality such as the increasing salinization.

Tajamar "La aguada" in Filadelfia city (photo: M. Duerksen).

APPROACH

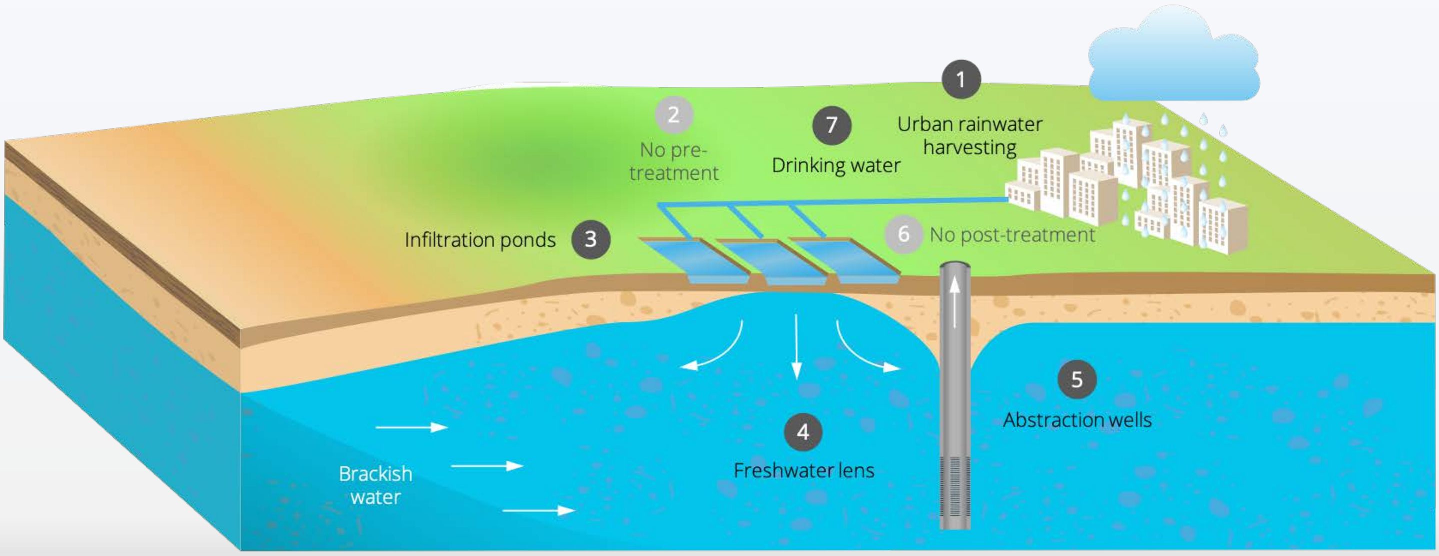
Given the characteristics of the region and drawing on the managed recharge experiences of the local indigenous people, who utilized recharge wells surrounded by infiltration rings, the selected MAR approach was the construction of *tajamares* (infiltration ponds). The water source for these ponds is precipitation.

Firstly, urban storm drains collect rainfall, redirecting the flow towards the infiltration ponds through lateral channels along the cities and towns. Then, the infiltration ponds promote a fast infiltration of the collected rainfall, minimizing losses by evaporation and augmenting freshwater volumes in the sub-surface, halting the ingress of brackish water in the water supply.

CHALLENGES

Lack of sufficient space in urban areas for the construction of new *tajamares*.

Given the lack of asphalt in many streets, fine sediments are carried by runoff forming layers at the bottom of the ponds. After some time, this affects the infiltration rates, making necessary corrective measures.



Managed aquifer recharge intervention

Capture zone	1	Urban rainwater harvesting
Pre-treatment	2	No pre-treatment
Recharge	3	Infiltration ponds
Subsurface	4	Sandy loams and sand
Recovery	5	Abstraction wells
Post-treatment	6	No post-treatment
End use	7	Urban water supply

OUTCOMES

Large volumes of water can be stored in the infiltration ponds. For example, *tajamar* Serenidad infiltrated 12,800 m^3 of water during 1990-1993.

Freshwater lenses of about 7 meters of thickness have been measured in the subsurface of infiltration ponds, pushing down brackish water.

Besides recharge, infiltration ponds can be regarded as multi-purpose interventions, also fulfilling tasks such as ecological support and livelihoods (fish farming) and urban landscape improvement (recreational parks).

Sediment removal in an infiltration pond (photo: E. Iglesias).

WHAT'S NEXT?

Optimize traditional infiltration ponds (increase infiltration volumes) in strategical sites to satisfy water demand during prolonged dry seasons.

READ MORE

Godoy, E., Garcia, D., & Fariña, S. (1994). Recarga artificial de acuífero freático en Filadelfia, Chaco Central paraguayo [Artificial recharge of phreatic aquifer in Filadelfia, Central Chaco Paraguay]. Águas Subterrâneas, 385-394.

Urban

Recovering groundwater levels in the Rimac aquifer, Peru

Implementing MAR to recover groundwater levels and secure water supply in urban areas

- **Groundwater over-abstraction**
- **Water security / food security / livelihood**
- Groundwater quality / human health
- Ecosystem degradation
- Salinity issues / intrusion

"How the inclusion of MAR, as part of integrated actions, helps to counteract groundwater overexploitation in rapidly growing regions."

MOTIVATION

The increasing water demand of the city of Lima due to population growth has been progressively depleting groundwater levels. The limited surface water and further decreasing infiltration, due to land use change given the constant urbanization, have created a water security problem in the Lima aquifer in terms of quantity and quality.

Interventions on the Rimac riverbed to improve infiltration to the aquifer (photo: Revista Perú Construye).

APPROACH

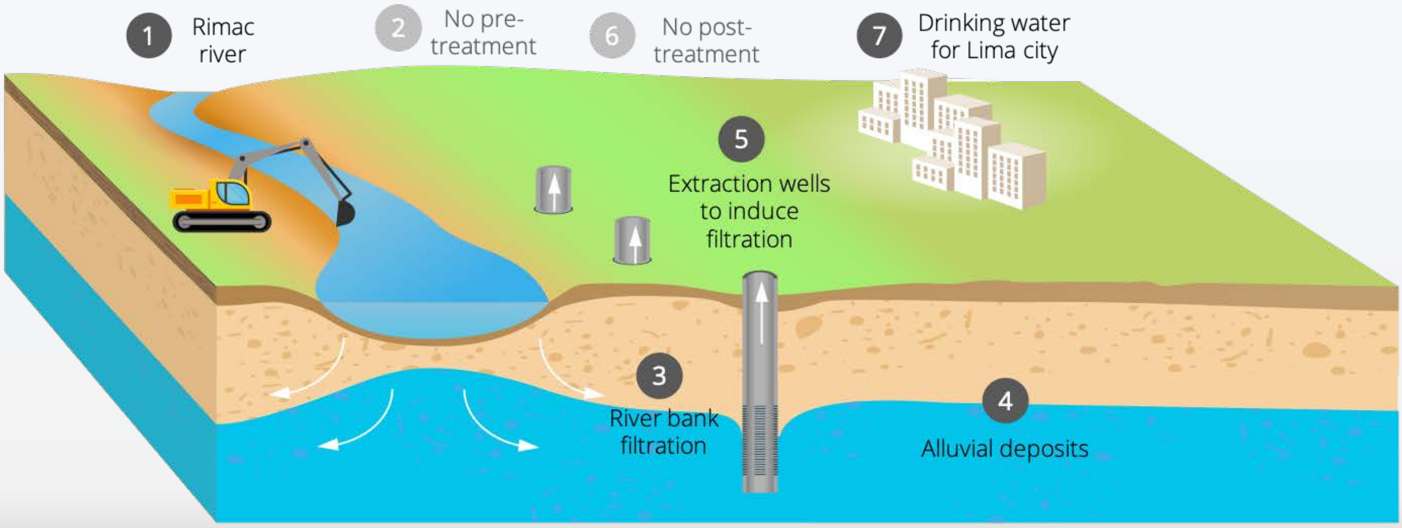
During periods of flooding in the Rimac River, there is a surplus of up to 400 Mm^3 of water per year. This volume of water is used in the ongoing induced recharge project, which consists of increasing the rate at which the aquifer is fed from the riverbed.

The project included the adaptation of 22 km of the riverbed to improve infiltration conditions and the construction of wells along the river with the objectives of extracting good quality groundwater for public water supply, and to create the necessary conditions to guarantee the immediate replenishment of the aquifer, without negatively affecting the existing reserves. The riverbank infiltration works are also integrated with other measures like monitoring campaigns and conjunctive use of water.

CHALLENGES

Strategies are necessary to keep the upstream part of the river free of suspended sediments that can be carried by the flow.

The hydraulic connection between the river and the phreatic level is not optimal. The water table is very low under the riverbed.



Managed aquifer recharge intervention

Capture zone	1	The Rimac river
Pre-treatment	2	No pre-treatment
Recharge	3	River bank filtration
Subsurface	4	Alluvial deposits (gravels, sands and clay)
Recovery	5	Extraction wells used to induce infiltration
Post-treatment	6	No post-treatment
End use	7	Drinking water for Lima city

OUTCOMES

In a lapse of five years, the groundwater level has recovered between 1 and 15 m (approx. 2 m/y) in most sections of the aquifer. However, there are some areas with a downward trend but with lesser intensity.

During the first three operational years, a recharge volume of 10.8 Mm^3 was estimated.

The current abstraction rate is 9 m^3/s, 1 m^3/s more than the estimated maximum sustainable extraction rate. This deficit could be progressively eliminated by the continuation of the projects.

Monitoring of the piezometer network of the Lima aquifer (photo: SEDAPAL S.A.).

WHAT'S NEXT?

Evaluate and apply further measures to stop groundwater depletion in critical sections of the aquifer, such as continuing and strengthening monitoring and promoting other conjunctive water use projects.

READ MORE

Quintana Albalat, J., Tovar Pacheco, J. 2002. Evaluación del acuífero de Lima (Perú) y medidas correctoras para contrarrestar la sobreexplotación [Evaluation of the Lima aquifer (Peru) and corrective actions to counteract overexploitation]. Boletín Geológico y Minero, 113 (3): 303-312. ISSN: 0366-0176.

Ecosystem Urban

Managed aquifer recharge as an economically suitable and sustainable solution for the disposal of treated wastewater

Successful MAR scheme in Mexico to counteract aquifer depletion and river contamination

- **Groundwater over-abstraction**
- Water security / food security / livelihood
- **Groundwater quality / human health**
- **Ecosystem degradation**
- Salinity issues / intrusion

> *How wastewater treatment together with groundwater recharge minimize riparian pollution and maintain groundwater budgets in semi-arid regions.*

MOTIVATION

The overexploitation of the aquifer in the semi-arid region of the San Luis Rio Colorado (SLRC) city required urgent measures to maintain its water budget. Traditionally, urban sewage was directly discharged into the rivers, polluting the area.

The construction and operation of a wastewater treatment plant solved that issue but still large volumes of treated wastewater required a sustainable and economic approach for its reuse.

Operational infiltration basins of 0.014 km² each. Total infrastructure cost of approximately USD 660,000 (photo: H. Hernandez).

APPROACH

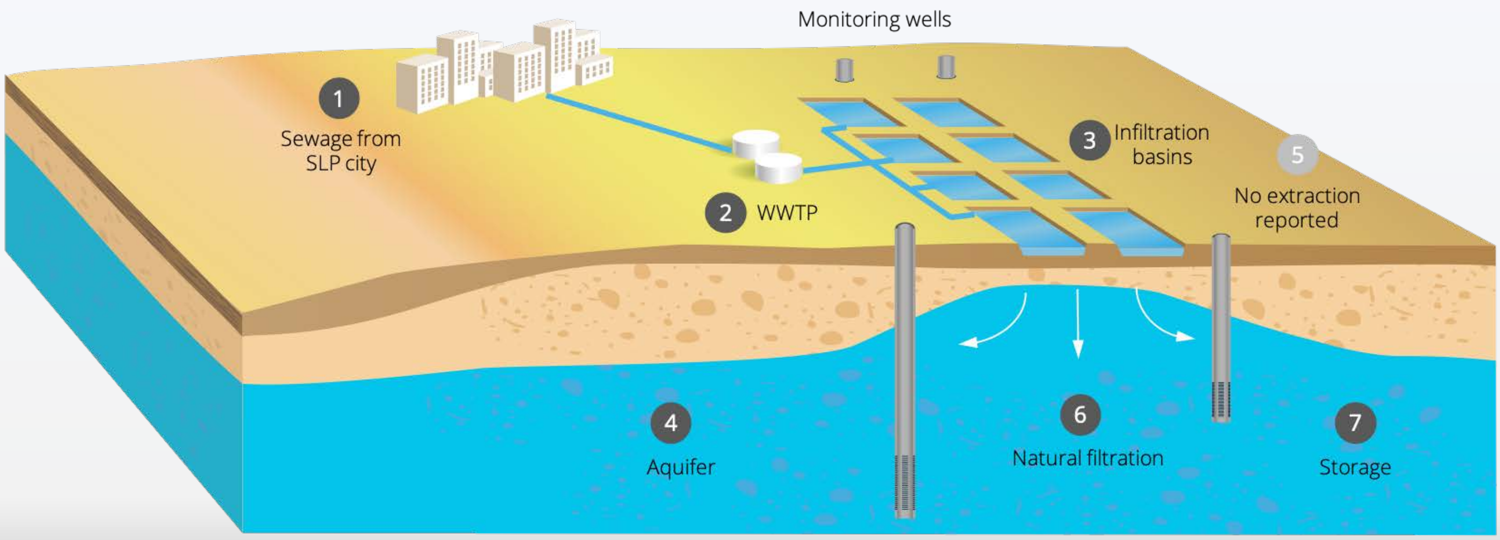
After economic and hydrological studies, the infiltration of the treated wastewater proved to be the most suitable solution in this area, as opposed to using it directly for irrigation.

The infiltration system comprises a delivery channel from the treatment plant, 12 infiltration ponds (four of which are only used in extreme events) and monitoring wells. The ponds are filled to different heights in summer and winter depending on the evaporation rates.

The ponds are wetted in pairs and alternated to prevent the infiltration delay caused by increased moisture in the subsoil. Maintenance is carried out once the ponds have been taken out of operation and dried, and it consists in the removal of the crust formed by algae at the floor of the infiltrations basins.

CHALLENGES

A better control for the concentration of suspended solids in the inflow and on the operation and maintenance protocols to delay the clogging process.



Managed aquifer recharge intervention

Capture zone	1	Domestic sewage from SLRC city
Pre-treatment	2	WWTP (anaerobic processes)
Recharge	3	Infiltration ponds
Subsurface	4	Sands with discontinuous lenses of silt and clay
Recovery	5	Not reported
Post-treatment	6	Natural filtration
End use	7	Storage

OUTCOMES

The infiltration rate of 8.2 Mm^3/y of the MAR infrastructure surpasses the yearly aquifer abstraction volume of 7.5 Mm^3.

The infiltrated treated wastewater showed a considerable decrease in the microbiological content after 20 m of transit through the vadose zone.

After 10 years of operation, the amount of contaminants removed remains stable; however, there has been a considerable decrease in the infiltration rate.

Ecological benefits arise since wastewater is no longer discharged into the riverbed, minimizing the health risk for downstream consumers and negative ecological impacts.

Clogging of infiltration pond soil, causing reduced infiltration and loss of surface smoothness (photo: Humberto et al., 2018).

WHAT'S NEXT?

Despite the infiltration process complies with the Mexican standards, a continuous monitoring process is necessary to identify water quality variations that could affect the inherent groundwater composition.

The ponds need to be scraped after two to three wet-drying periods to restore the infiltration rate.

READ MORE

Humberto, H. A. M., Raúl, C. C., Lorenzo, V. V., & Jorge, R. H. (2018). Aquifer recharge with treated municipal wastewater: long-term experience at San Luis Rio Colorado, Sonora. Sustainable Water Resources Management, 4(2), 251-260. doi: 10.1007/s40899-017-0196-2.

Agriculture Rural

Groundwater recharge to increase water availability for irrigation in rural areas of Brazil

The benefits of maximizing groundwater storage to improve food production

- Groundwater over-abstraction
- **Water security / food security / livelihood**
- Groundwater quality / human health
- Ecosystem degradation
- Salinity issues / intrusion

> *How MAR benefits rural and poor areas by supporting irrigation and increasing food production as a measure to counteract hunger and poverty.*

MOTIVATION

The shortages of precipitation in the Brazilian semi-arid regions and ever-increasing demand represent a threat for rural communities who are dependent upon agriculture. Periods of droughts severely affect not just the overall production, but food security and livelihood of these rural communities, making simple, low-cost, and easily applicable technologies a priority.

Underground dam after a rain event in Ouricuri, state of Pernambuco (photos: João Mello).

APPROACH

In several communities from the states of Pernambuco, Paraíba, Bahia, Ceará, and Rio Grande do Norte, subsurface dams across streams and valleys have been constructed to maximize groundwater storage. They allow rainwater to be stored underground during the rainy season with an impermeable transverse wall in order to raise the groundwater table. Then, the water is recovered during the dry season.

Although easy to apply, the construction has to comply with some technical requirements. For example, the sediments must be predominantly sandy to enhance infiltration, and when built on a stream, the construction site must be at the narrowest part of the riverbed, to maximize water capture and minimize costs.

CHALLENGES

In some cases, depending on the influent water or on the local conditions, the stored water might become unsuitable for irrigation due to high salinity. The interventions in natural groundwater flow might have a negative impact on downstream areas. The effort in water quality monitoring also varied from site to site.

The costs of building underground dams can be up to USD 1,300 if using heavy machinery.

Managed aquifer recharge intervention

Capture zone	1	Rainwater
Pre-treatment	2	No pre-treatment
Recharge	3	Sub-surface dams
Subsurface	4	Variable
Recovery	5	Abstraction wells
Post-treatment	6	No post-treatment
End use	7	Irrigation

OUTCOMES

The production of maize, beans and rice has increased where this technique has been applied. In some areas, harvesting was even possible during the dry season.

The increased production has secured food for the families, improving also their incomes after selling the surplus of production. In addition, the owners reported a better quality of the fruits and a better food security for their animals.

The underground dams also promoted environmental benefits such as soil conservation/restoration, headwaters recovery and groundwater replenishment.

Construction of a sub-surface dam in Campina Grande, state of Paraíba (photo: R. Diniz).

WHAT'S NEXT?

Given the multiple conditions of the sites where this MAR technique is applied, monitoring strategies need to be adequate to maintain the efficiency of the dams.

Constant communication between water authorities and farmers is necessary to highlight ongoing problems and to develop sustainable solutions.

READ MORE

Shubo, T., Fernandes, L., & Montenegro, S. G. (2020). An Overview of Managed Aquifer Recharge in Brazil. Water, 12(4), 1072. doi:10.3390/w12041072.

Urban

Application of managed recharge to boost infiltration and prevent urban flooding in San Luis Potosi, Mexico

The integration of MAR to recover aquifer levels and minimize damage by intense precipitation events

- **Groundwater over-abstraction**
- **Water security / food security / livelihood**
- **Groundwater quality / human health**
- Ecosystem degradation
- Salinity issues / intrusion

> *How integration of MAR in urban areas helps to counteract aquifer depletion and prevent urban flooding.*

MOTIVATION

In central Mexico, the aquifer supplying the San Luis Potosi (SLP) valley has been overexploited to fulfil the multiple regional water requirements. This area has been experiencing extreme precipitation events due to the changing climate, but urbanization and impermeable surfaces do not allow a natural infiltration to occur, affecting the natural aquifer recovery.

Additionally, intense precipitation and steep topography affect populated areas with flooding, damaging properties, which in turn diminish welfare and impair the economy.

APPROACH

The measures developed include flood protection for the San Luis Potosi city together with groundwater recharge to counteract the ongoing depletion of the aquifer.

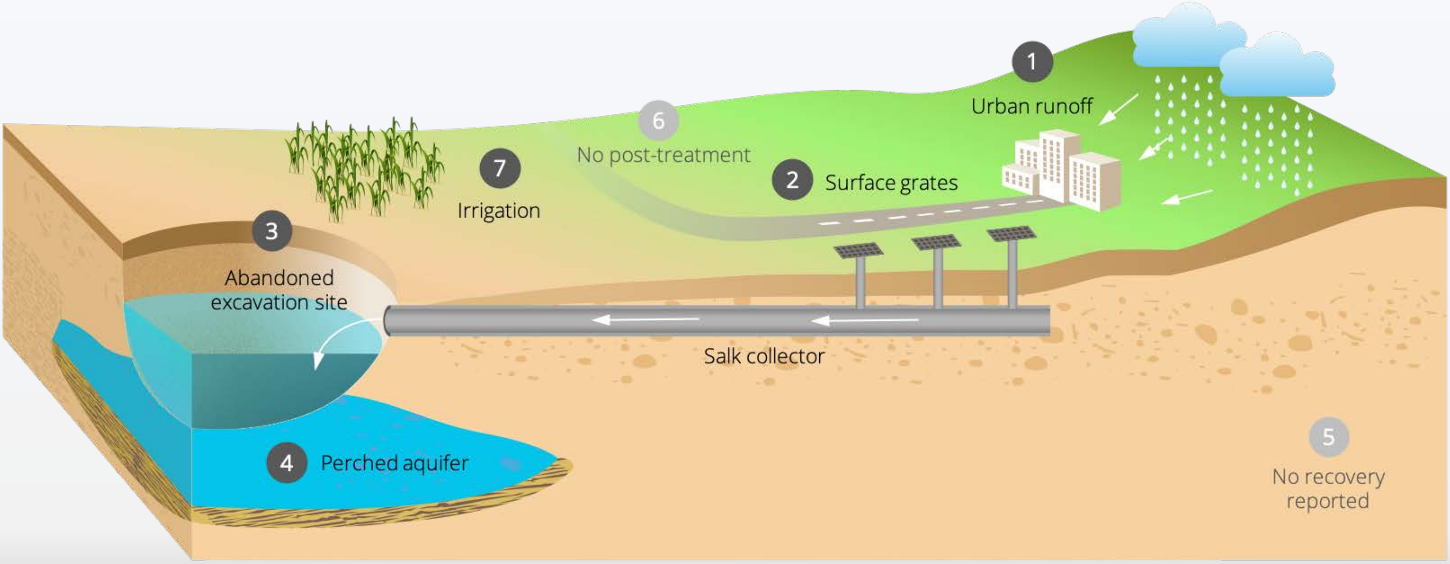
The proposal consisted of the construction of new dams for flood control in the upper part of the basin, the creation of a protected area for the collection of rainwater runoff, as well as interceptors and collectors for stormwater in the conurbation area.

The *Salk* collector collects the rainwater and stormwater runoff generated in a basin with a surface of 8.2 km^2 and conveys it 1.4 km to an old excavation site that is used as catchment area to allow infiltration into the aquifer.

CHALLENGES

The lack of social awareness regarding the functioning of the collector results in waste accumulation in the streets. This is a common problem since waste entering into the collector minimize its transport capacity, making frequent cleaning works necessary.

Construction of storm drains to divert rainwater and prevent flooding and waterlogging (photo: El Sol de San Luis, 27.02.2021).



Managed aquifer recharge intervention

Capture zone	1	Urban runoff
Pre-treatment	2	Grids to remove solids
Recharge	3	Abandoned excavation site
Subsurface	4	Perched aquifer above compact fine sands
Recovery	5	Not reported
Post-treatment	6	No post-treatment
End use	7	Multiple purposes

OUTCOMES

The *Salk* collector can drain 22 m^3/s, redirecting captured water towards an area with a storage capacity of 1,140,000 m^3.

The grates on the streets above the collector effectively separate solids and debris larger than one inch.

The abandoned excavation site provides a natural sedimentation process.

The *Salk* collector has decreased the flooding risk of the southwest area of San Luis Potosi and enhanced the replenishment of the aquifer.

WHAT'S NEXT?

The construction of observation wells would allow the determination of recharge rates and hydrodynamic parameters to support the development of simulation models and to determine the chemical interactions that could be generated within the aquifer by the quality of the injected water. However, the recharge system was designed so that it is of a similar quality to that abstracted for drinking water supply purposes.

Further steps include studying other areas of the city prone to flooding and evaluating the possibility of constructing additional collectors.

Recharge area (abandoned excavation site) to the SLP valley aquifer (photo: Google Earth, May 2019).

READ MORE

Briceño-Ruiz et al. 2017. Infiltración de agua de tormenta al acuífero de San Luis Potosí, México: colector Salk [Infiltration of stormwater in the Aquifer of San Luis Potosi, Mexico: Salk collector]. In "Manejo de la recarga de acuíferos: un enfoque hacia Latinoamérica". Pag: 159-186.

Agriculture Urban

Application of groundwater recharge to recover aquifer levels in the Ica Valley, Peru

Implementing MAR to help overcome water depletion caused by extensive irrigation

- **Groundwater over-abstraction**
- **Water security / food security / livelihood**
- Groundwater quality / human health
- Ecosystem degradation
- Salinity issues / intrusion

> *MAR technique as an important tool to recover exploited aquifers and maintain equilibrium in areas under high anthropogenic pressure.*

MOTIVATION

The intense groundwater extraction to irrigate the approximately 35,000 ha of high-income export agriculture in the Ica Valley in Peru has put significant pressure on the groundwater resources (75% of farmers do not have sufficient water). Other factors affecting the sustainability of the resource are land use changes for irrigated agriculture and the growing population.

This situation has prompted the authorities and private enterprises to seek ways to improve water resources management, such as promoting managed aquifer recharge, among others.

Expansion of the frontier of irrigated agriculture onto desert land (photo: Enrique Fernández-Escalante).

APPROACH

The excess flow of the Ica river between 2013–2017 accounted for about 183 Mm^3, which corresponds to the presumed maximum volume to be captured by a MAR scheme. Currently, water is detained in the river during the Andean rainy season by dams, later retained in sedimentation ponds, and then diverted to infiltration ponds (*pozas*) spread across the valley.

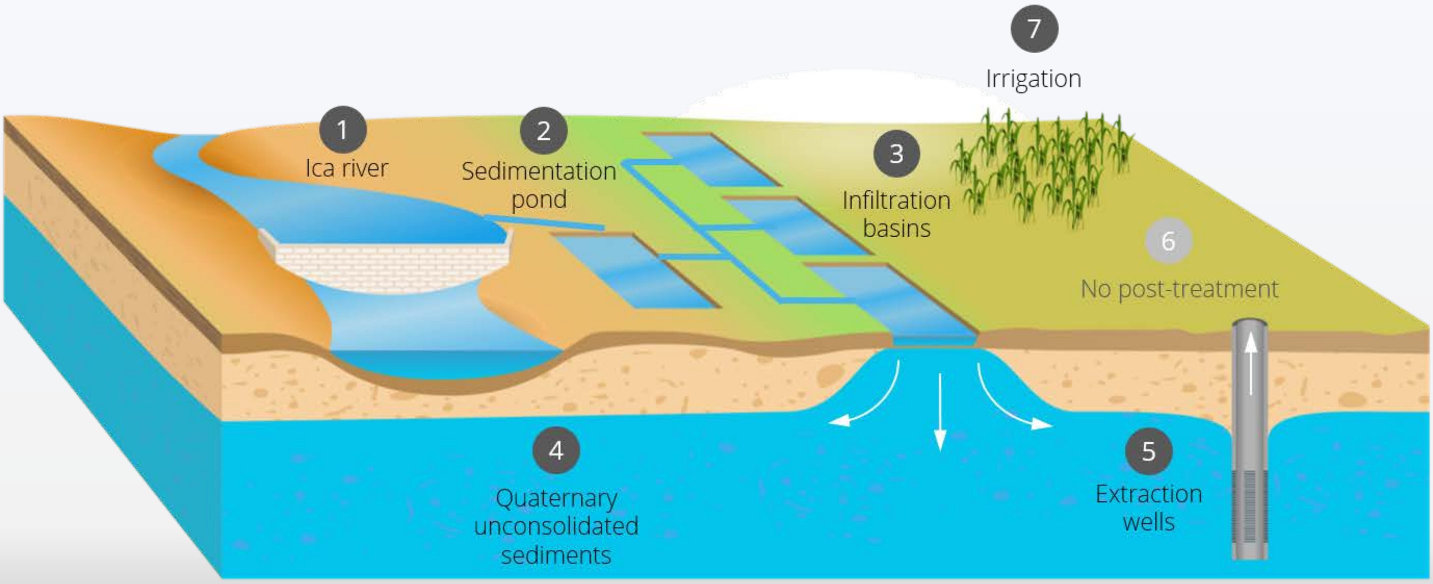
The land where the ponds are located was borrowed from private land-owners, who were informed about how the increase of groundwater storage will favour the productivity of their wells used for agricultural irrigation.

CHALLENGES

The monthly and annual variability of the river flow is a challenge for water management. Moreover, the annual average flow that could be recovered during 2013–2017 was 36.5 m^3/y, much lower than the current rate of groundwater overexploitation of 52 Mm^3/y.

In consequence, another 120 ha of ponds are required to achieve groundwater balance but there is a lack of available land and in dry years the diminished river flow entails a lower infiltration volume.

Also, poor ecological river conditions give rise to large sediment load, affecting pond functioning.



Managed aquifer recharge intervention

Capture zone	1	Ica River
Pre-treatment	2	Sedimentation ponds
Recharge	3	Infiltration ponds
Subsurface	4	Quaternary unconsolidated fluvial-alluvial sediments
Recovery	5	Extraction wells
Post-treatment	6	No post-treatment
End use	7	Irrigation

OUTCOMES

Given the numerous benefits of MAR, in a period of five years (2012-2015) the total area designed for infiltration increased from 22,000 to 300,000 m^2.

In 2017, an artificial recharge of 17.6 Mm^3 was possible from 864 ponds occupying an area of 295 ha.

Annual cleaning and maintenance of both canals and ponds has maintained an effective groundwater resource augmentation.

WHAT'S NEXT?

The lack of suitable land for the construction of more ponds makes necessary to consider other techniques such as infiltration wells or galleries.

Further hydrological and geological studies are necessary to determine groundwater flow and therefore to optimize the location of future infiltration sites.

Given the still ongoing groundwater depletion, other techniques are required in addition to ongoing MAR applications. For example, licensing and metering of existing waterwells, and a reduction in the cultivated land area. All these measures require proactive dissemination and awareness-raising in order to be successful.

Full (top) and empty (bottom) infiltration ponds (photo: Enrique Fernández-Escalante).

READ MORE

Fernández-Escalante, E., Foster, S., & Navarro-Benegas, R. (2020). Evolution and sustainability of groundwater use from the Ica aquifers for the most profitable agriculture in Peru. Hydrogeology Journal, 28, 2601–2612. doi: 10.1007/s10040-020-02203-0.

Managed aquifer recharge as a measure to lower production costs of drinking water in Valparaiso, Chile

MAR techniques to boost natural infiltration

- Groundwater over-abstraction
- **Water security / food security / livelihood**
- Groundwater quality / human health
- Ecosystem degradation
- Salinity issues / intrusion

> *Groundwater recharge as a suitable cost-effective solution to guarantee drinking water production.*

MOTIVATION

In Chile, water companies are legally obliged to acquire sufficient water rights to meet the demand of the population at all times. However, in many cases, new rights cannot be granted and the cost of acquiring rights from third parties can be extremely high.

It was therefore necessary to look for alternatives that allowed an increment of the available water for the drinking water treatment plant Las Vegas in Valparaiso region in order to lower operational costs and increase water security for the served population.

Aerial view of the Aconcagua river, infiltration ponds and water treatment plant. The location of Las Vegas drain is highlighted in red (photo: Google Earth, 2021).

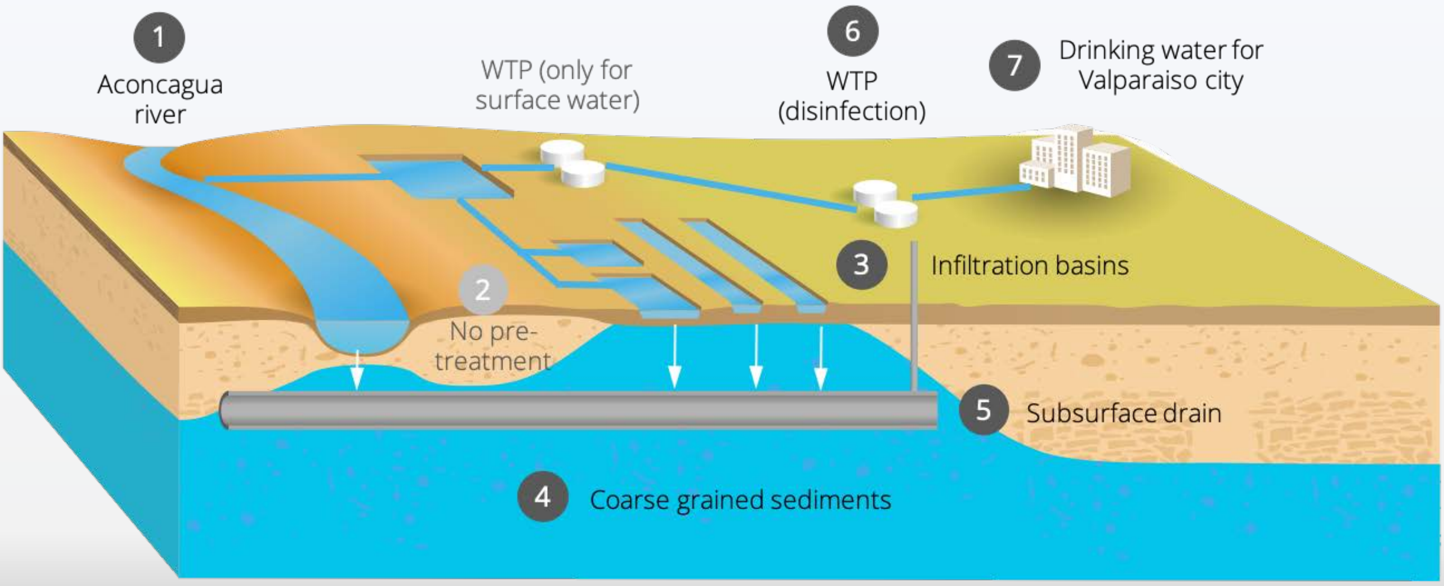
APPROACH

The Las Vegas drinking water system has two processes to capture water: on the surface, two lateral intakes derive water from the Aconcagua river, which undergoes initial treatment processes; and underground, the drain Las Vegas, a subsurface structure (30-40m below surface) perpendicular to the river axis, capturing groundwater of very low turbidity. Both water sources are redirected towards a joint aqueduct leading to the final disinfection stage.

The project goal was to increase the uptake of the subsurface drain to increase the overall system resilience and decrease the direct use of surface water that requires more treatment and is therefore more costly. To this end, several infiltration ponds were created that collect the excess water from surface intakes that could not be treated by the plant. Then this water flows to the drain where is collected for further use.

CHALLENGES

Maintenance of the infiltration ponds must be optimal to minimize clogging and to keep an acceptable infiltration capacity. Clogging can also affect the drain and given its location, its maintenance can drive additional operational costs.



Managed aquifer recharge intervention

Capture zone	1	Aconcagua river
Pre-treatment	2	No pre-treatment
Recharge	3	Infiltration ponds
Subsurface	4	Coarse grained sediments with a sandy matrix
Recovery	5	Aqueduct
Post-treatment	6	Disinfection
End use	7	Distribution network of Gran Valparaiso area

OUTCOMES

Given the natural filtration properties of the aquifer, all the water coming from the drain needs less treatment, thus, overall operational costs are decreased.

The ponds in operation provide about 15% of the total flow captured by the Las Vegas underground drain and have increased its effectiveness by approximately 17% from 85,000 m^3/d to 101,000 m^3/d.

Despite the increased infiltration, the current pond scheme doesn't provide enough water to make the drain the main water source for the drinking water treatment plant.

WHAT'S NEXT?

Models have demonstrated that an infiltration area of about 17 hectares (30-70 infiltration ponds) would increase further the water volumes captured by the drain Las Vegas to the optimum of 1.3 m^3/s.

Future research topics include the analysis of infiltrated water quality and how it affects the aquifer, the accuracy of the data used and the degree of influence they have on the result, the feasibility of establishing a serious maintenance regime and its possible economic implications.

Surface intake diverting water from the Aconcagua river towards Las Vegas water treatment plant (photo: SISS, 2014).

READ MORE

Tobar Espinoza, E. A. (2009). Modelación del Efecto de la Recarga Artificial Sobre la Operación del Dren Las Vegas. Bachelor thesis, Universidad de Chile. Available in: http://repositorio.uchile.cl/handle/2250/103531.

Agriculture Urban

A gradual path towards groundwater recharge to face water-related problems in the Department of Sucre, Colombia

Artificial recharge as a viable solution to deal with groundwater overexploitation

- **Groundwater over-abstraction**
- **Water security / food security / livelihood**
- Groundwater quality / human health
- Ecosystem degradation
- Salinity issues / intrusion

> *How MAR pilot sites help to design sustainable strategies in regions facing aquifer depletion.*

MOTIVATION

In Colombia, causes for groundwater depletion are population growth, which implies the construction of new urban areas that leads to the waterproofing of soils and the alteration of natural cycles, diminishing the natural recharge of the aquifer; and the existence of many illegal extraction wells that lead to an indiscriminate exploitation of the resource, threatening the supply.

These problems have encouraged the analysis and test of MAR as a feasible solution to deal with the diminishing aquifer levels.

Infiltration trench (photo: José Luis Navarro, 2020).

APPROACH

The pilot scheme for managed aquifer recharge in the Morroa aquifer, department of Sucre, was built to test the feasibility of MAR at larger scale. It consists of a retaining wall that diverts surface runoff from the basin into the works.

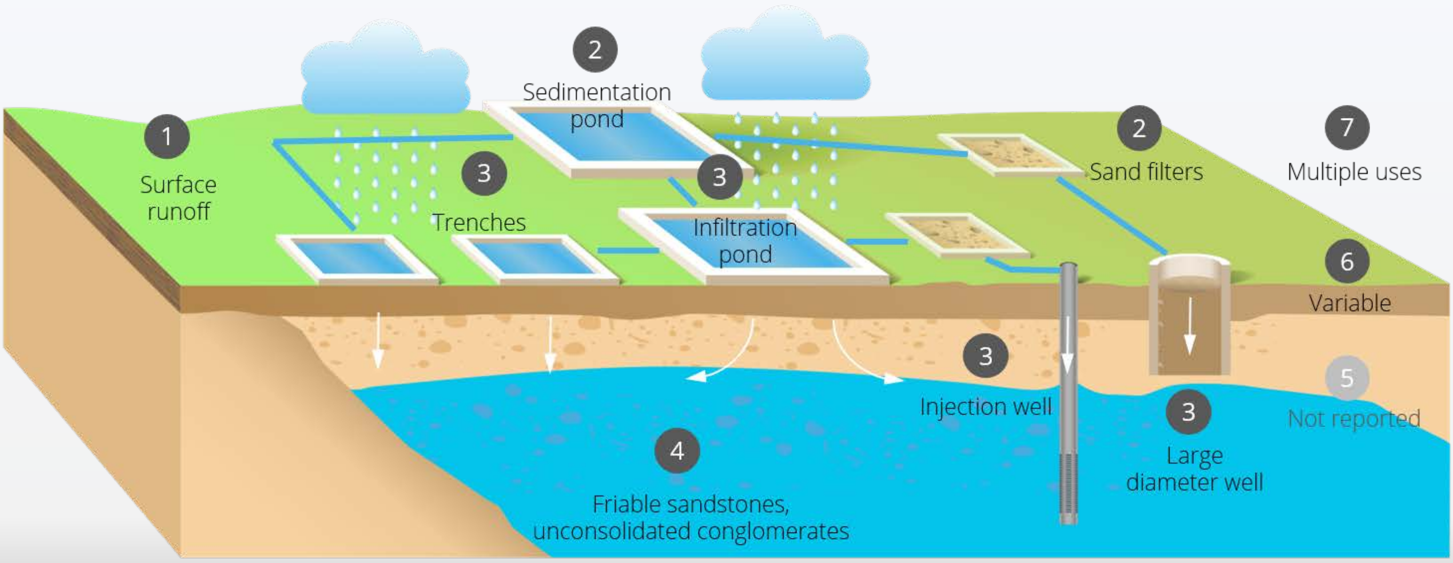
The water is firstly collected in a sedimentation pond before being discharged to the artificial recharge system consisting of infiltration trenches, large diameter wells and infiltration ponds.

Water that fails to infiltrate into the infiltration pond passes through filters before reaching a pool, where it is treated for injection into a gravity-fed well. Later, a second trench was built, which receives excess water from the infiltration pond.

CHALLENGES

The effects of certain processes such as evaporation are not well represented at pilot scale. For large scale applications, additional measurements and calculations are necessary.

The lack of environmental policies and culture greatly affect water bodies and future MAR applications.



Managed aquifer recharge intervention

Capture zone	1	Surface runoff
Pre-treatment	2	Sedimentation pond, sand filters
Recharge	3	Infiltration pond, trenches, wells
Subsurface	4	Friable sandstones, unconsolidated conglomerates
Recovery	5	Not reported
Post-treatment	6	Variable
End use	7	Multiple (drinking, agriculture, livestock....)

OUTCOMES

Infiltration ponds are the most suitable MAR technique for the region in terms of costs and infiltrated water volumes, which vary between 52 and 622 m^3/y.

The rest of the infiltration structures (large diameter well, trench N° 1 and N° 2) presented infiltration flow rates ranging from 0.2 to 70 m^3/y.

Despite this, the infiltration values are insignificant compared to the pumping regime subjected to the Morroa aquifer.

There is a relationship between rainfall and infiltration flow rates: The years with the highest and lowest flow rates are directly associated with wet and dry years.

Large diameter well (photo: José Luis Navarro, 2020).

WHAT'S NEXT?

The evaluation of these pilot systems has provided indispensable parameters for the design and development of recharge works on a larger scale (many of them currently under construction), which together with an adequate use of the resource and greater control can guarantee the future supply of the population in the department of Sucre.

READ MORE

Navarro Mercado, J. L. (2020). Monitoreo de las obras piloto de recarga artificial en el acuífero Morroa, departamento de Sucre, Colombia. Bachelor thesis, Universidad EAFIT.

Urban

Groundwater recharge as a tool to minimize flood risks and enhance infiltration in Natal, Brazil

Integration of detention and infiltration reservoirs into the urban drainage system

- Groundwater over-abstraction
- **Water security / food security / livelihood**
- **Groundwater quality / human health**
- Ecosystem degradation
- Salinity issues / intrusion

> *MAR as a feasible solution against urban floods and as a water source for multiple uses.*

MOTIVATION

Causes for flooding are manifold: soil sealing or channelization of runoff; real estate pressure around green and other areas of natural aquifer replenishment. All of them directly impact the hydrological cycle and bring negative consequences, such as serious problems for the safety of homes, property and human lives.

In particular, in the city of Natal, Brazil, several natural lagoons have disappeared to make way for squares and buildings, but often they re-emerge during rainy periods, causing frequent flooding. Furthermore, due to the absence of drainage plans in some areas of the city, there is a direct impact on sanitation systems, contributing to the spread of diseases and other public health issues.

Irregular discharge of untreated sewage into Lagoa da Tarauca (photo: MPRN - Informação Técnica nº 088/2018).

APPROACH

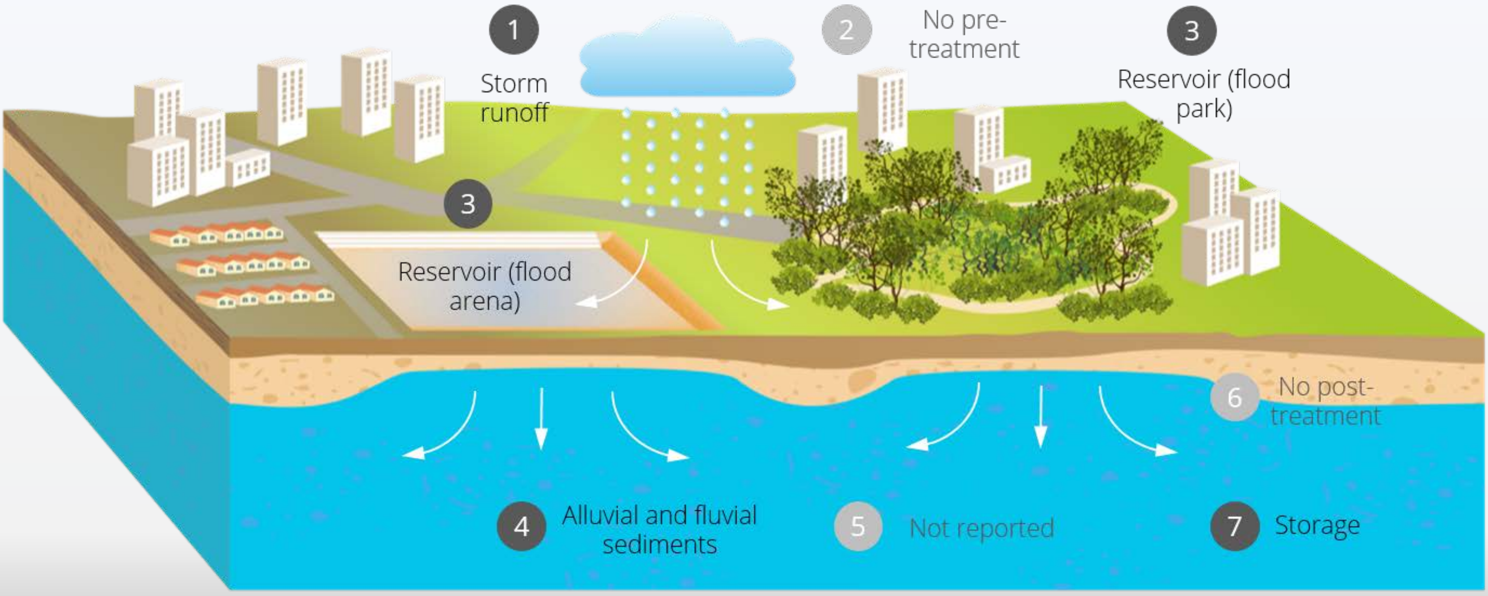
To counteract this situation and to augment aquifer storage, several detention and infiltration reservoirs were built in the city. They are structures for the temporary accumulation of rainwater. The construction in public places (streets or squares) help to avoid the formation of higher peaks of flow that may cause urban flooding. Their objective is to retain the water for a certain period of time, regulating the outflow to a desired value, and thus, promoting the damping of peak flows downstream.

Despite the stored water cannot be directly used for human consumption (poor quality), other areas take advantage from these storages such as ecological, industrial and recreational activities.

CHALLENGES

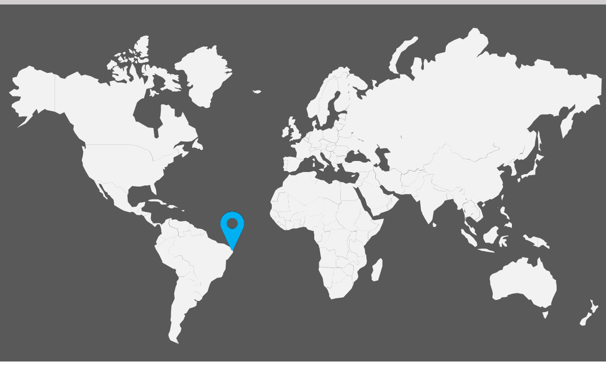
The construction of structures the size of a reservoir in the midst of a consolidated urban space may also cause problems related to urban impact, as well as higher costs resulting from expropriation, among others.

The absence of infrastructure maintenance and water quality monitoring directly impact the functioning of the reservoirs (reduced retention capacity, causing overflows onto the adjacent roads, excessive vegetation, presence of untreated sewage...).



Managed aquifer recharge intervention

Capture zone	1	Storm runoff
Pre-treatment	2	No pre-treatment
Recharge	3	Detention and infiltration reservoirs
Subsurface	4	Alluvial and fluvial sediments
Recovery	5	Not reported
Post-treatment	6	No post-treatment
End use	7	Storage



OUTCOMES

In 2011 a total of 35 urban detention and infiltration ponds were operational in Natal. They are regarded as essential equipment for the functioning of the urban drainage system of the city, being the main destination of rainwater, preventing flooding, as well as participating in the replenishment of the aquifer through infiltration.

Despite their widespread use, they often have structural problems, such as damaged slopes, accumulated sediments inside the lagoon and the irregular disposal of waste water.

Besides the enhanced infiltration and decreased flooding risks provided by the reservoirs, they are also used as water sources for other urban services like irrigation of green areas, construction, cooling systems, firefighting, etc.

WHAT'S NEXT?

The construction of a sewage pumping station is expected to diminish or stop the disposal of untreated sewage into the reservoirs.

Ongoing studies indicate the possibility to utilize the stored water for human consumption in the future. However, additional processes (pre- and post-treatments) are necessary given the current water quality indicators.

Mirassol Arena 'flooded' after 48 hours of rain. In dry periods the reservoir works as an arena for football, handball and beach volleyball (photo: Augusto Gomes/GloboEsporte.com).

READ MORE

Silva, Selma & Neto, Cícero & Ingunza, Maria. (2019). Potencialidade de uso não potável de água de lagoa de detenção. Engenharia Sanitaria e Ambiental. 24. 1061-1070. doi: 10.1590/s1413-41522019190821.

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