| COOPERACIÓ INTERNACIONAL |

BARCELONA METROPOLITAN AREA:

Local Water Managment, International and Regional Cooperation in the context of new demands

AMB Àrea Metropolitana de Barcelona

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PRESENTATION

The powers granted to the Metropolitan Area of Barcelona (AMB) by Article 14 of Law 31/2010 include the management of the integrated water cycle, which includes the following functions::

(1) The supply of domestic drinking water, or the mains water supply.

(2) Direct or indirect management of water.

(3) Regulation of water rates.

(4) The public sewage system and wastewater treatment.

(5) Regeneration of wastewater for other uses.

(6) Coordination of the municipal sanitation systems and, in particular, planning and integrated management of the evacuation of rainwater and wastewater and the sewer networks.¡

The main international event on water, the multi-stakeholder World Water Forum, co-hosted by the World Water Council and the city of Bali, is being held in Indonesia in May. The forum has been held every three years since 1997 and brings together participants from all levels and fields, including multilateral institutions, the academic world, civil society and the private sector, who will share knowledge, experiences and practices on a wide range of water-related topics.

In the current context of drought that has for three years severely affected the internal basins of Catalonia, which supply water to the metropolitan area, the management of the supply and distribution of water has become a priority for the metropolitan government constituted in July 2023. For this reason, the Metropolitan Action Plan for the 2023-2027 mandate, initially approved by the Metropolitan Council on 30 April 2024, pays special attention to the need for investment in water cycle facilities and, in particular, those intended for reclamation.

In April 2024 the AMB participated in the Mediterranean Water Forum, one of the four regional preparatory forums for the World Water Forum, and it met twice with the president of the Mediterranean Water Institute, Alain Meyssonnier.

The long-term analysis of the rainfall series of Barcelona reveals a general trend towards an increase in annual rainfall and especially winter rainfall. However, this perhaps unexpected finding is based above all on the very dry first half of the 19th century. The period between 1808 and 1840 showed a predominance of dry years that has been unprecedented in the instrumental era. The detailed causes of this atypical period are still unknown but probably involved a combination of solar and volcanic activity.

Through its membership of United Cities and Local Governments, the AMB has participated in the institutional declaration that the network will present to the World Water Forum and has also coordinated with MedCities for a joint participation, as an activity provided for in the collaboration agreement between the two entities.

Apart from the participation through these networks of cities and metropolitan areas, the AMB will present two policy briefs: one on the challenges and demand for water in the Barcelona metropolitan area with a view to 2050, written by the agronomist Jesús María Paniagua and jointly supervised by the Directorate of Water Cycle Services and the cooperation service of the AMB; and one on the international cooperation strategy in projects linked to water management.

SUMMARY

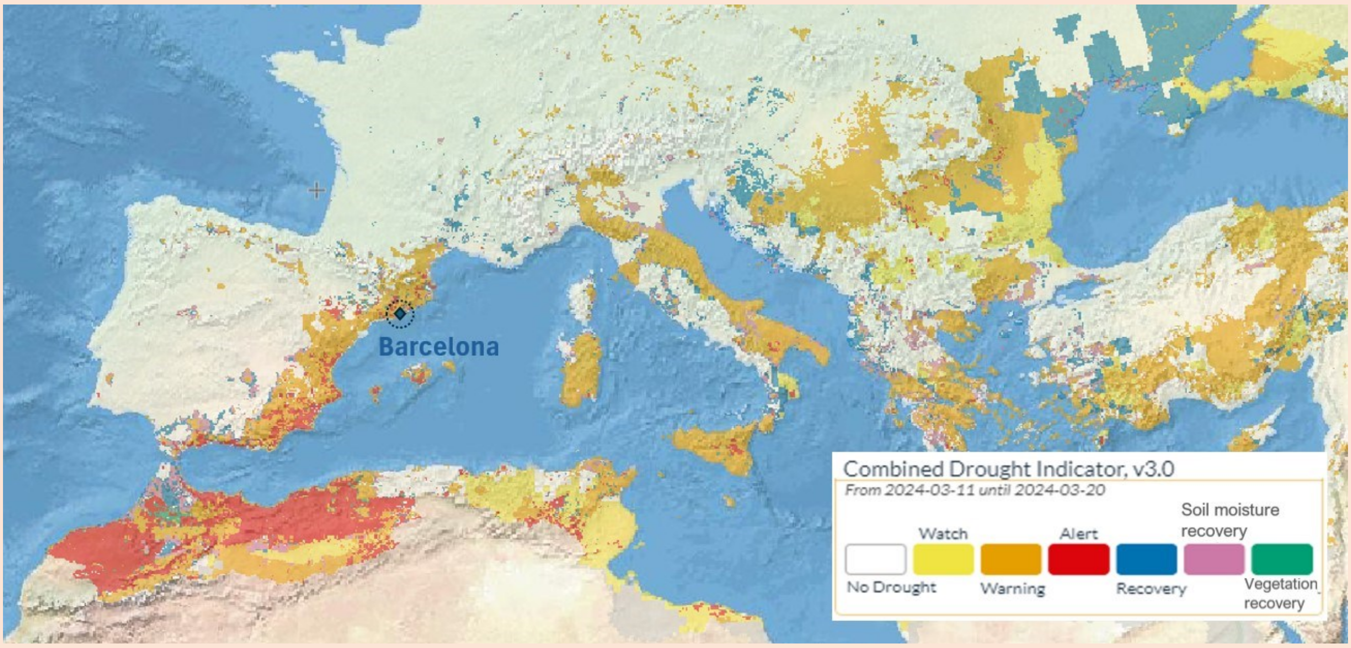
CHALLENGES FOR SUPPLYING THE BARCELONA METROPOLITAN AREA TO MEET THE NEEDS OF 2050

The 2020-2024 drought in Barcelona and its context

A dry period began in the western Mediterranean in late 2020 and has lasted for almost four years. The drought was widespread in Europe in 2022 but has been more persistent in some Spanish coastal areas of the Mediterranean. It has become especially acute in the inland basins of Catalonia, where it has seriously affected the water reserves for supplying the Barcelona metropolitan area, one of the most populated in Europe with a total of 3.3 million inhabitants.

Because of its location with respect to the general circulation of the atmosphere, the Mediterranean area is naturally prone to droughts, so water scarcity is a matter or particular concern there. To understand its patterns and reconstruct rainfall variability and climate change at a regional scale, it is vital to have reliable climate data. Fortunately, an observatory in Barcelona has maintained an uninterrupted instrumental precipitation series of 108 years dating back to 1916. Also available are much longer reconstructed and homogenized climate series dating back 237 years and monthly data from no less than 1787, two years before the French Revolution. This is an invaluable source of information.

Fig. 1. Drought situation in southern Europe in March 2024.

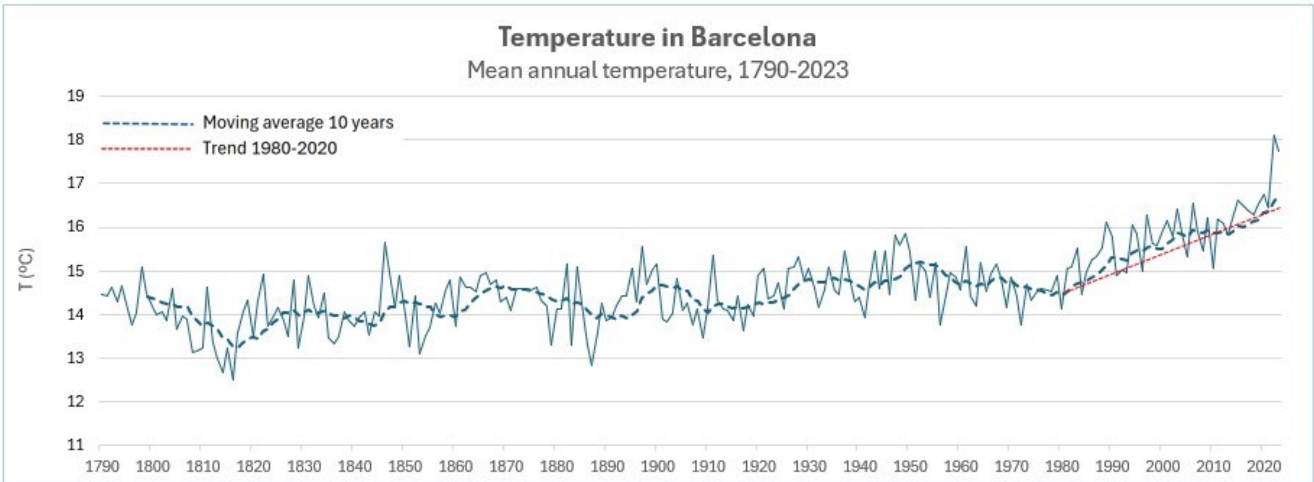


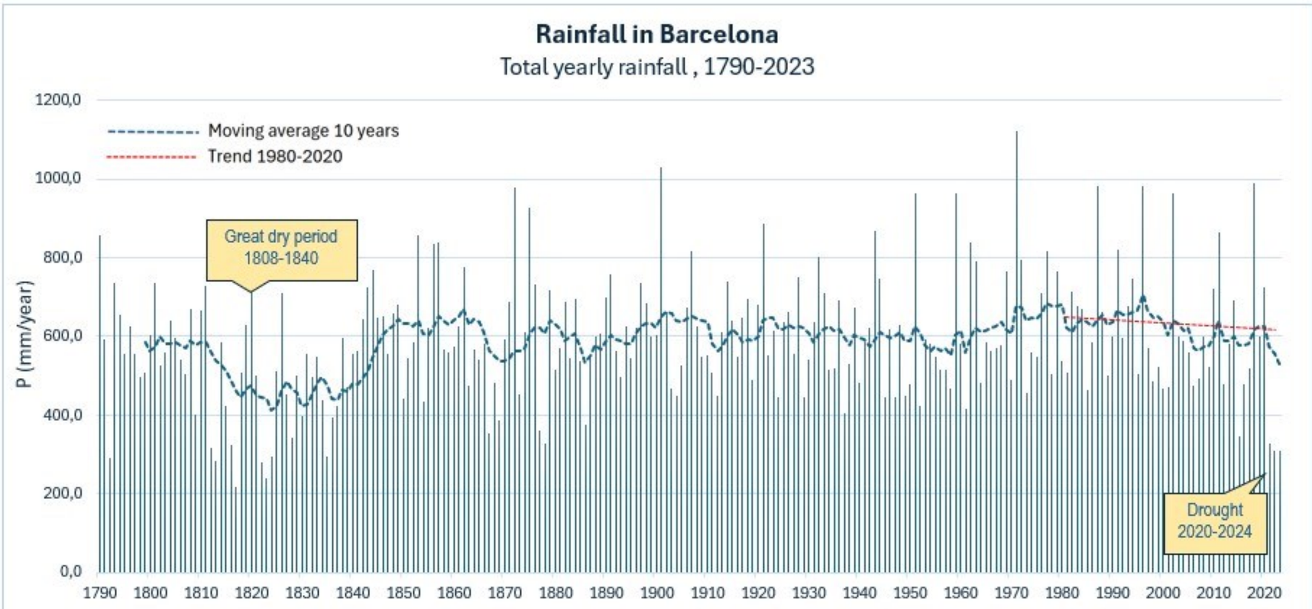
(Data: European Drought Observatory)

The long-term analysis of the rainfall series of Barcelona reveals a general trend towards an increase in annual rainfall and especially winter rainfall. However, this perhaps unexpected finding is based above all on the very dry first half of the 19th century. The period between 1808 and 1840 showed a predominance of dry years that has been unprecedented in the instrumental era. The detailed causes of this atypical period are still unknown but probably involved a combination of solar and volcanic activity.

However, a closer analysis in time shows other very marked, and quite different, trends in the last 40 years. First, temperatures showed a slight upward trend during the 20th century, with an intensification after 1980. The average annual temperature has increased since then by a total of 1.5 ºC, with decadal means rising from 14.7 to 16.2 ºC. Second, mean annual rainfall has shown a slight downward trend, falling by approximately -1.8% over the last 40 years to a current monthly mean of 627 mm, though this fall is of little statistical significanceen.

Fig. 2 Climate trends in Catalonia in the period 1790-2023



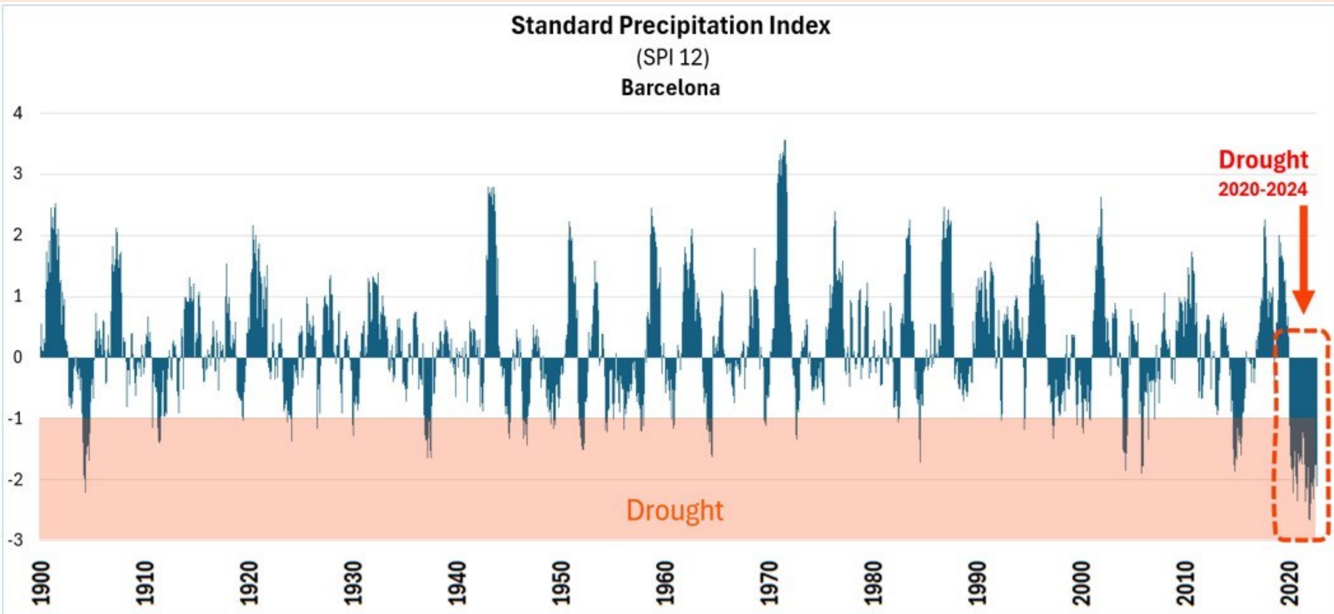


(Data: Meteorological Service of Catalonia)

In this region extreme phenomena such as droughts do not yet show a clear long-term trend either way in terms of duration, intensity or frequency. However, the drought of the last four years has been extraordinary and especially harsh, and in many aspects it is the worst of the period covered by instrumental data: the last century.

The clearest parameter for quantifying a drought is the standardized precipitation index (SPI-12 months), which clearly defines its intensity and duration. Data from the last century show that droughts, defined as periods of two to five years with an SPI lower than -1, are relatively frequent and recur every 10 to 15 years. However, Figure 2 shows that the drought that began in 2020 has reached peaks of intensity greater than any other recorded, and also continuously. As an extreme value, precipitation in 2022 was 308 mm, only 49% of the average value. To find such poor values we must go back in history to those estimated in the great dry period of 1808-1840. Only the drought of 1905 reached similar intensities, but with a much shorter duration, and the drought of 2020-24 (still ongoing) is only surpassed in intensity and duration by the extraordinary event of the early 19th century.

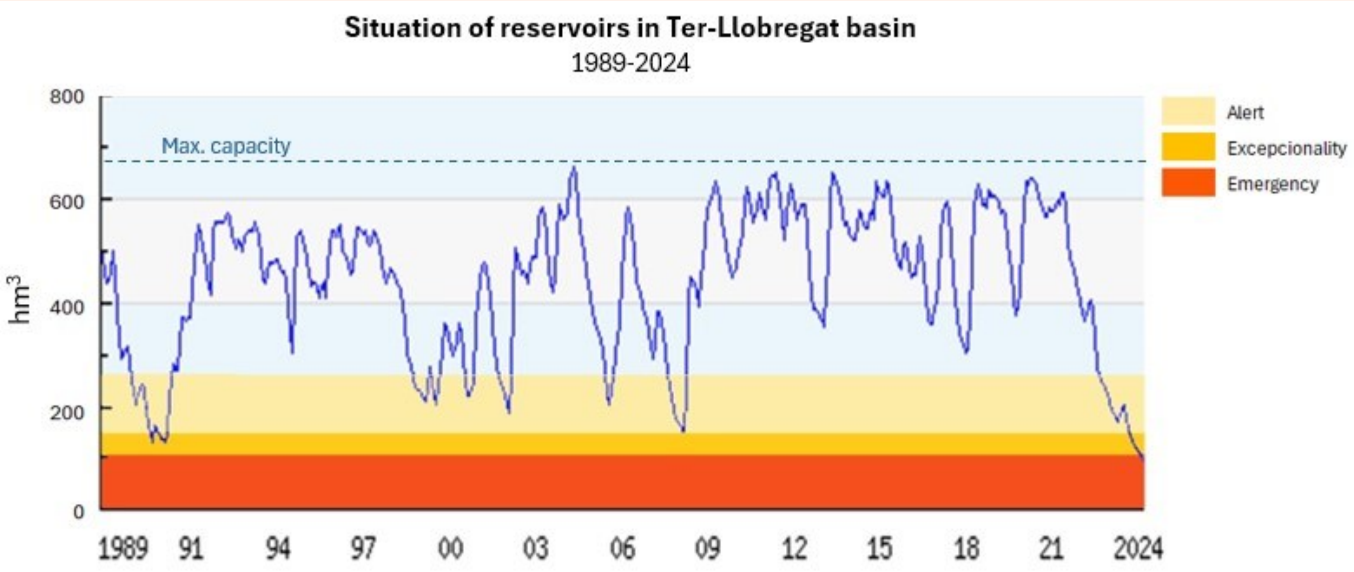
Fig. 3. 12-month standardized precipitation index for the period 1900-2023



(Data: Meteorological Service of Catalonia)

The consequences of this persistent lack of rain have not been long in coming. The flow of the region's rivers has been in continuous decline for three years. Consequently, the reservoirs of the Ter -Llobregat basin, from which most of the water to supply the Barcelona metropolitan area are obtained, have also reached historic lows. This has led to the declaration of states of alert, exceptional circumstances and finally the state of maximum severity: drought emergency. The state of drought emergency, applied when reserves fall below 100 hm3 (16% of total capacity), was declared on 1 February 2024.

Fig. 4. Situation of the reservoirs in the internal basins of Catalonia (Ter-Llobregat), 1989-2024



(Data: Catalan Water Agency)

Resource and demand forecasts until 2050

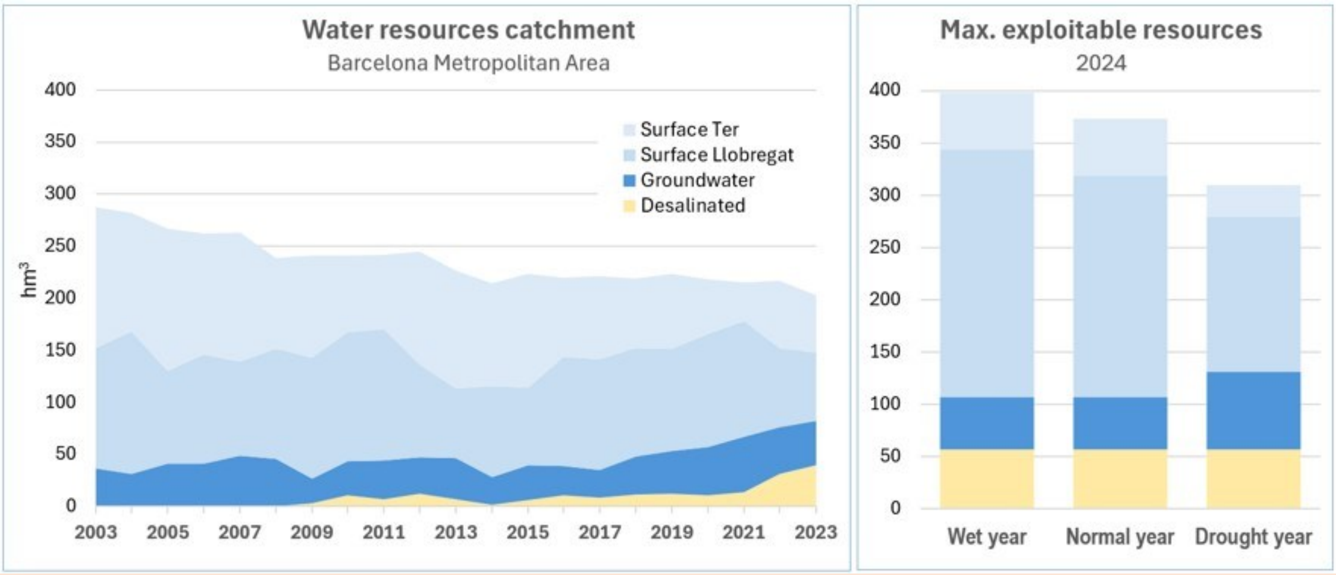
The Barcelona metropolitan area (AMB), with 3.3 million inhabitants (5.2 million including the outer area of the second metropolitan zone) requires an average water supply of 230 hm3/year. Unsurprisingly it is deficient in water resources. As in many large agglomerations, its large population and industrial activity consume more water than the physical environment it occupies can offer. Its supply is obtained mainly from surface water, most of which comes from the Ter and Llobregat rivers, with several catchments located outside the metropolitan area. In fact, unlike the Llobregat, which flows south of the city, the Ter runs completely outside the area.

Part of the supply is also taken from groundwater (10%–25% of the total, depending on the year), with more than 60 wells located in the aquifers of the Llobregat valley and delta, the Barcelona plain and the Besòs River. The aquifers of the Llobregat are the largest reservoir of groundwater in the area and are also used for irrigation in the delta area of the river. However, some of the aquifers have high salinity because of marine intrusion, which is a major limitation to current and future use.

Another resource that has been increasing in importance is desalinated seawater. It was first used in 2009 after the opening of the Llobregat seawater treatment facility (STF)[1], the largest in Europe with a capacity to supply 60 hm3/year. In 2011, the expansion of the Tordera STF provided an additional 20 hm3/year. These facilities form a support and guarantee system, especially for dry years. In fact, desalinated water accounts for no more than 3% to 5% of the available water supply in normal years, but in the current drought situation it has reached 19%.

[1] Abbreviations used: STF, seawater treatment facility; DWTP, drinking water treatment plant; WWTP, waste water treatment plant; WRP, water reclamation plant.

Fig 5. Evolution of the origin of water resources in the Barcelona metropolitan area (2003-2023) and maximum exploitable resources in a wet, normal and drought year.



(Data: Metropolitan Area of Barcelona)

The maximum exploitable resources currently range between 398 hm3 in a wet year and 303 hm3 in a drought year. “Maximum exploitable resources” are considered those that can be treated by drinking water treatment plants (DWTPs) and STFs, plus those that are exploited sustainably from groundwater, with the current capacities. Reclaimed waters are not included in this concept because they are reused rather than raw resources.

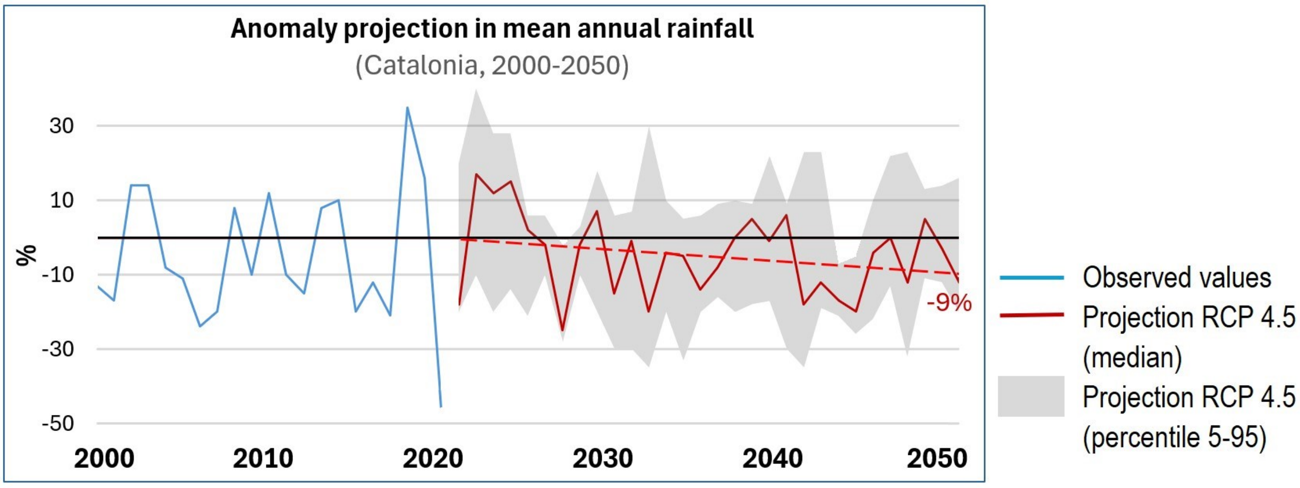
A limitation in the collection of surface water from the Ter must be taken into account: since 2017 there has been an agreement to limit the flows that the metropolitan area can draw from the river in order to maintain the ecological flows and irrigation of Girona downstream, so only an average of 54 hm3/year can be used from the Ter. On the other hand, in periods of drought it is accepted that aquifers can be exploited temporarily in excess of the renewable recharge. Therefore, in very dry years the available groundwater supply is greater, although not permanently. The overall result is that in a normal year 57% of the maximum exploitable supply is used for drinking, but in drought years it can reach 70%, placing the system under considerable stress.

The forecasts for the future, in scenarios of 2050 and 2100, are largely marked by climate change. It is true that the IPCC global models predict a global increase in average rainfall, but in the Mediterranean basin the general trend is precisely the opposite: a moderate long-term reduction (-9% in the area we are considering for the intermediate scenarios of the Intergovernmental Panel on Climate Change).

In addition to climate change, another unexpected factor is responsible for the reduction in river flows: the increase in forest mass in recent decades. In the last 40 years, forests have gained ground and the tree mass of river basins in the area has increased by 6% to 8%.

With more trees and higher temperatures, water evaporation increases and the river flow is reduced, as has been measured at the entrances to the Sau reservoir on the Ter River and the La Baells reservoir on the Llobregat River.

Fig. 6. Projection of anomalies in the mean annual rainfall, according to the RCP 4.5 projection.



(Data: Meteorological Service of Catalonia)

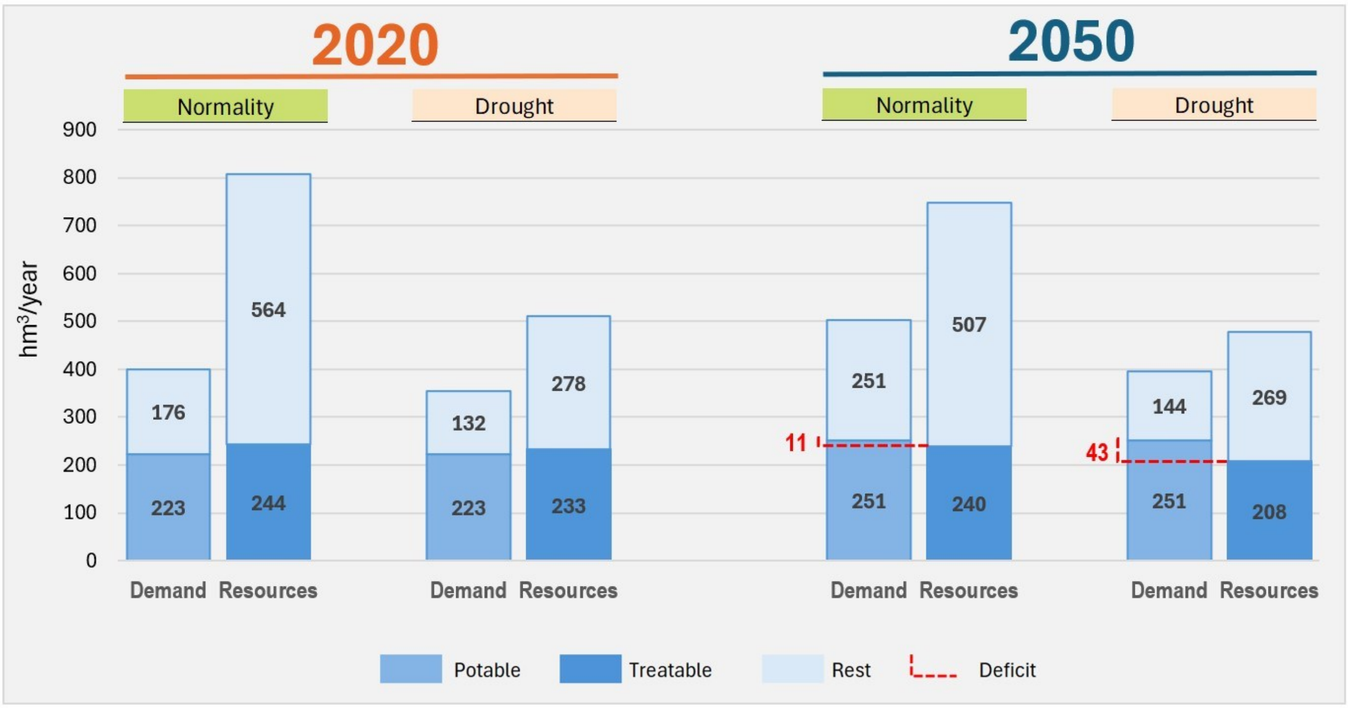
As a consequence of these scenarios, it is estimated that contributions to the headwaters of the rivers will decrease by between 5% and 15% in the course of this century. This means that, in drought years, the maximum availability for the metropolitan area would decrease between 3% and 9%, assuming the same capacity for using groundwater (always below that of renewable resources) and desalination plants. According to a study (CEDEX, 2011), the streamflows of the internal Catalan basins will suffer a reduction of 4% by 2070 compared with the period 1961-1990. This would especially affect the Ter basin, which is an essential part of the supply system of the Barcelona metropolitan area (its reserves are two thirds of the total Ter-Llobregat system). Overall, this means that by 2050 an average of 18 hm3 less would be available in drought years than in a current drought situation.

On the demand side, the forecast is for a moderate increase. According to the PECIA[2], discounting agricultural consumption, an increase in demand of 32 hm3/year (around 15%) is expected by 2050, and this increase will rise to 49 hm3 per year by 2100.

The total resources available to the metropolitan territory (including water that can be treated to make it potable and non-usable water) will in theory be sufficient to deal with the difference of 50 hm3 per year arising from greater demand and lower availability by 2050. But if we consider only the demand for drinking water compared with the resources that can be treated to make it potable, the forecasts for 2050 show that if no action is taken, a deficit situation will arise. The deficit would reach 11 hm3 in years of normal weather and 43 hm3 in drought years. This is a dangerously high value that unquestionably requires planning solutions to reduce the level of risk.

[2] PECIA: Strategic Plan for the Integrated Water Cycle of the Barcelona Metropolitan Area (2023)

Fig. 7. Expected evolution of the relationship between demand for potable water and water that can be treated to make it potable.



(Data: PECIA, Metropolitan Area of Barcelona)

Acting on available resources

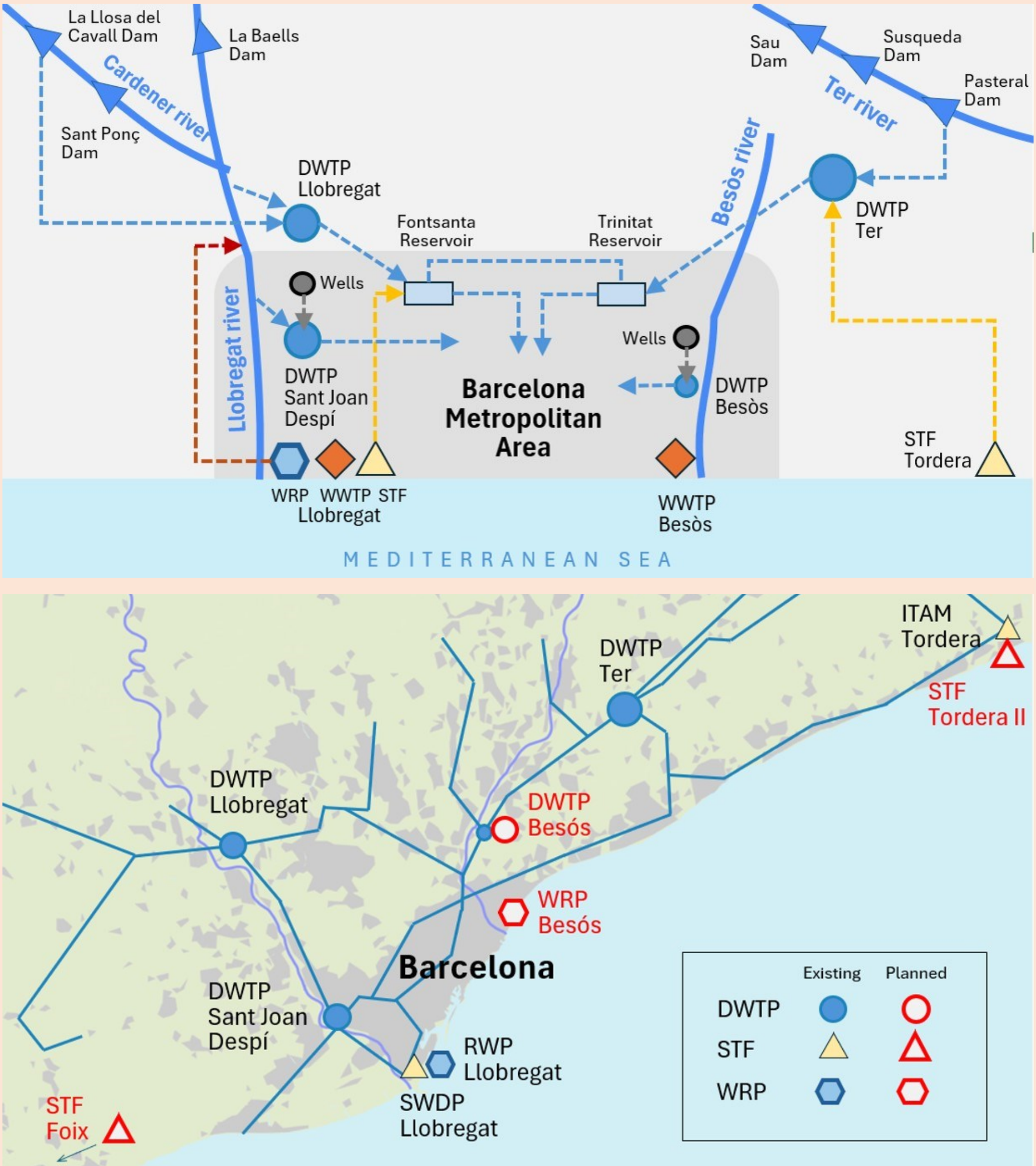
The drinking water system of the Barcelona metropolitan area is supported by five DWTPs, three of them with a large capacity, plus two STFs. Water from the Ter River is abstracted in the Pasteral reservoir, downstream of the Sau and Susqueda reservoirs and fed to the Ter (or Cardedeu) DWTP at a rate of 8 m3/s. On the Llobregat River there are two intakes: one at the Llobregat (or Abrera) DWTP, with a capacity of 3.2 m3/s and one at the Sant Joan Despí DWTP with a capacity of 6.3 m3/s. These are the main drinking water sources, and they are supported by the Cardener DWTP (0.35 m3/s), which takes water from the Cardener River (a tributary of the Llobregat) in the La Llosa del Cavall reservoir. In total, surface water represents 75% of the supply to the Barcelona metropolitan area under normal conditions. The Sant Joan Despí DWTP is the one that contributes the most to this supply, 40% of the total, followed by the Ter DWTP, which contributes 30%.

It is important to highlight that not all the water that is made potable at the Ter and Llobregat DWTPs is destined for the Barcelona metropolitan area. These plants, which are managed by the Ter-Llobregat Water Supply Agency, also supply the counties of the second metropolitan zone, which together with the 3.3 million inhabitants of the Barcelona metropolitan add up to a total of 5.2 million. Only 60% of the production of the Ter DWTP is destined for the Barcelona metropolitan area, while the ETAP Abreda has contributed 10% in recent years.

Groundwater, which normally contributes less than 20% of the total, is extracted mainly from the aquifers of the Llobregat basin and is purified in the Sant Joan Despí DWTP. The contribution from the Besòs River aquifer requires treatment through nanofiltration and reverse osmosis at the small Besòs DWTP because of the high salt content and the presence of organic contamination.

The two desalination plants collect water directly from the Mediterranean Sea and transform it into potable water. Once purified, the water of the Llobregat STF (60 hm3/year) is sent to the Fontsanta storage tanks located in Sant Joan Despí. That of the Tordera STF (20 hm3/year) is distributed among the municipalities of the coastal counties of La Selva and Maresme outside the Barcelona metropolitan area, and also to the storage tanks of the Ter DWTP.

Fig. 8. Diagram of supply to the Barcelona metropolitan area



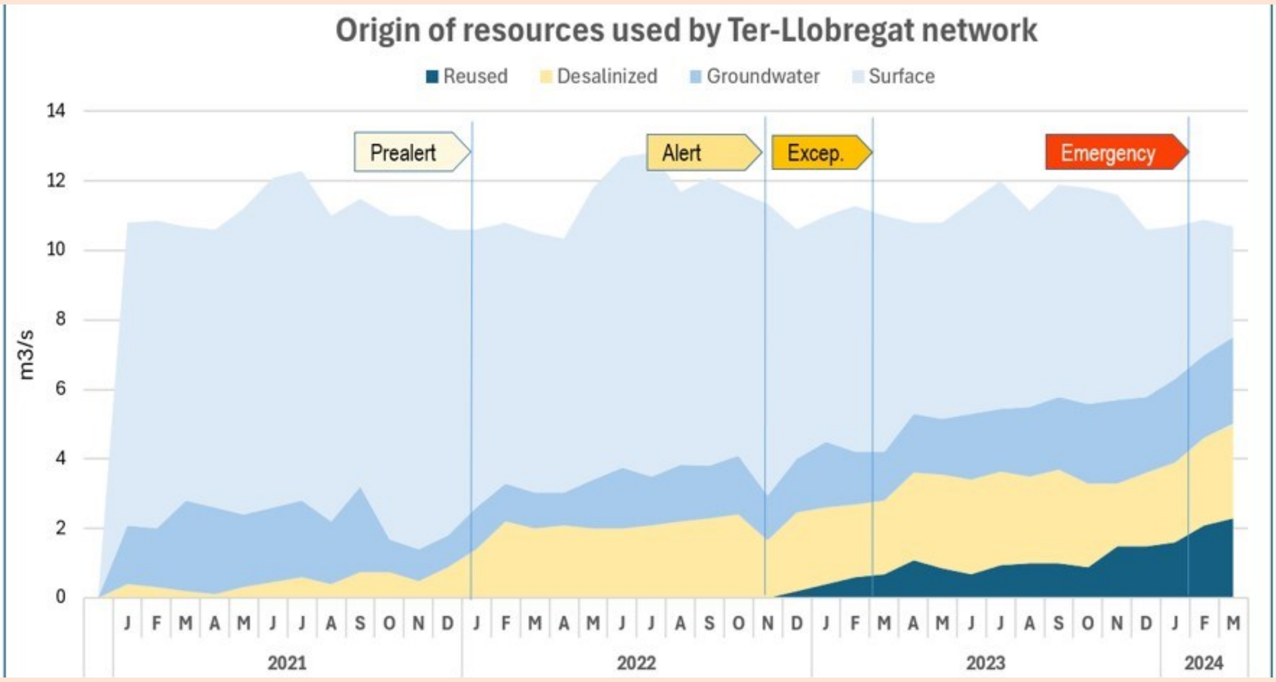
(Above, diagram of the current situation; below, map of the current situation and planned facilities)

In addition to these raw water sources, there are a series of treated water reclamation plants (WRPs). These have become a key tool for the security of the system. The most important one (the Llobregat WRP) is installed in the Llobregat wastewater treatment plant (WWTP). It has a capacity of up to 110 hm³/year, although it is limited by the flow rate of the WWTP, currently about 85 hm³. The reclamation process is advanced, including physical-chemical processes, filtration and UV disinfection, and was put into service in 2005. In a normal situation, the reclaimed water is used to maintain the ecological flows of the Llobregat, but it can also be pumped as pretreated water to the Molins de Rei weir, 8 km upstream from the Sant Joan Despí DWTP. Additionally, with a complementary treatment of ultrafiltration and osmosis, it is also used for injection into the aquifer of the Llobregat delta to block the wedge of saline intrusion caused by overexploitation. Other smaller WRPs (especially Gavà–Viladecans and Sant Feliu de Llobregat) are also used to regenerate the delta and for agriculture.

However, in drought conditions this reclaimed water system provides decisive security. It can be used to increase the amount of pretreated water that is pumped back to the Llobregat, which can be collected again by the DWTP and reintegrated into the urban cycle. The reclaimed water can thus be used indirectly for drinking.

In this general scheme, the drought situation of 2020-24 has intensified the use of non-conventional resources (desalinated and reclaimed water), taking into account the outlook for 2050. These resources will reduce the tension between demand and resources, which is expected to increase. These two resources are considered irreplaceable, especially in the scenario of future droughts.

Fig. 9. Origin of the resources used in the Ter-Llobregat network during the 2020-2024 drought.
A substantial increase in non-conventional resources (desalinated and reclaimed water) is observed.



(Data: Metropolitan Area of Barcelona)

A series of future actions will focus (but not exclusively) on non-conventional resources:

- **Desalination:** It is planned to expand the Tordera STF with an extra capacity of 60 hm^3/year (up to a total of 80 hm^3) and to build the new Foix STF to the south of the metropolitan area with a capacity for another 30 hm^3/year. Both desalination plants would also supply other towns outside the metropolitan area but, together with the Llobregat plant, they would provide an estimated maximum flow of desalinated water of 130 hm^3/year in the Barcelona metropolitan area in cases of drought.
- **Use of the Besòs River:** The surface waters of this river, which is the second major metropolitan river, are of lower quality than those of the Llobregat and are not currently used. However, it is planned to expand the Besòs DWTP, which now processes only groundwater, to also treat surface water up to a capacity of 30 hm^3/year. This project is linked to that of a new WRP in the Besòs WWTP to reclaim water from the river.
- **Reclaimed water:** The solution of using pretreated reclaimed water has worked with considerable success in the Llobregat River. Therefore, it is intended to extend the model to the Besòs River, which is currently little exploited. It is planned to equip the Besòs WWTP with a WRP with a capacity of 30 hm^3/year, which, according to the model, would be pumped back into the river upstream of the new, expanded plant. This new reclaimed water would also replace water used for agricultural and industrial purposes and ecological flows of the river. A new WRP is also planned in Sant Feliu de Llobregat. With the incorporation of these projects, almost 50% of the wastewater generated in the metropolitan area would be reclaimed, in total about 120 hm^3/year, in a circular solution of extraordinary scope.

  It is also important to increase the use of reclaimed water for other purposes, such as industrial use or garden irrigation, for which it is not necessary to use potable water. For example, there is a future project for a reclaimed water distribution network for purposes that do not require potable water. It would serve the Zona Franca industrial estate in the Marina del Prat Vermell neighbourhood and would also supply the municipalities of Sant Cugat and Cerdanyola.

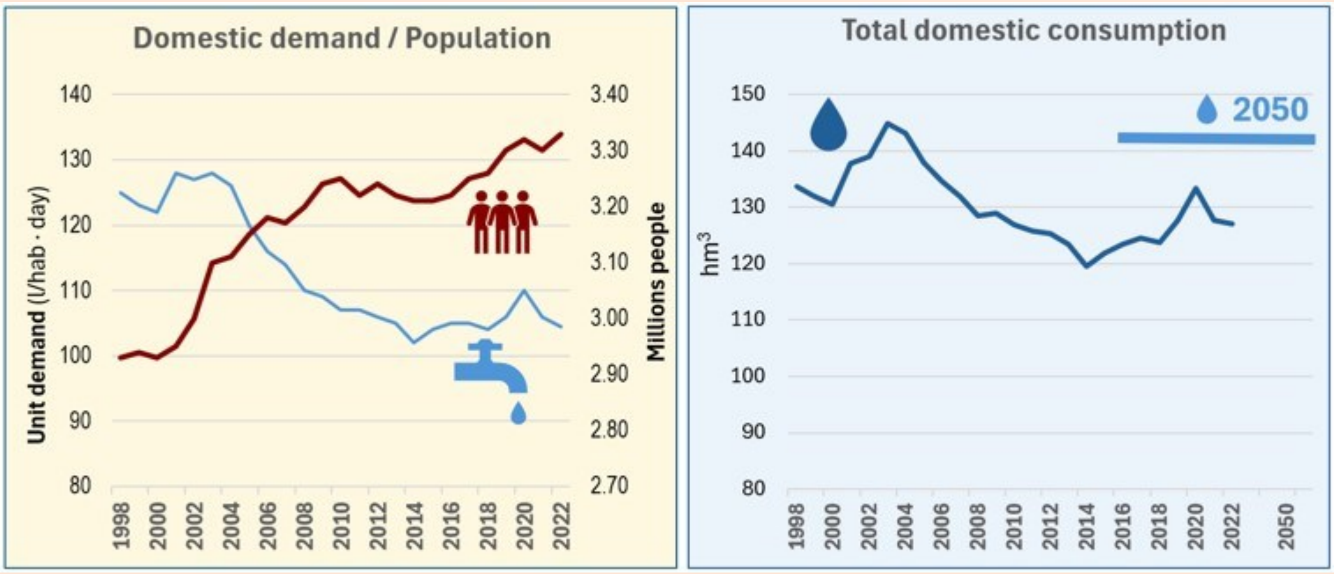
With the implementation of all these solutions (desalination, reclaimed water and the surface water of the Besòs), a total flow of 250 hm^3/year would be reached. This amount would be enough to cover the total demand for drinking water in the event of a drought, and even 90% to 100% in a normal year. These figures indicate a very high security of supply, especially in such a densely populated metropolitan area.

Acting on demand

Three types of demand are considered: potable water, non-potable water and environmental water. Non-potable water is used for irrigation, industrial uses and urban uses such as garden irrigation, water surfaces and washing. The environmental uses correspond to maintenance of river flows and injection of water into aquifers. All uses are interconnected, so in years of scarcity the lower general availability of the resource also affects the purification capacity.

The demand for domestic drinking water in the metropolitan area has fluctuated in the last decade between 120 and 130 hm3/year. Fortunately, the individual provision in litres per inhabitant per day has decreased considerably to 105 L/ inhabitant day at present. This reduction is attributed to more conscious consumer habits and the progressive introduction of more efficient devices in homes. Even so, there was a striking (though isolated) peak in demand in 2020, the year of the COVID pandemic. Furthermore, the area's population has increased by almost 15% in the last 25 years, and intermediate projections suggest that it will reach 3.7 million by 2050. Consequently, domestic consumption is expected to grow to 142 hm3 by then.

Fig. 10. Evolution of population and domestic demand in the Barcelona metropolitan area



(Data: Metropolitan Area of Barcelona, Catalan Water Agency)

Several actions would affect demand, so the supply per inhabitant remains consistently contained, or total losses are reduced:

- **Efficiency in non-revenue water:** Although the use of purified water in the metropolitan area is highly efficient (84% on average), there is some room for improvement. Total losses are currently estimated at about 36 hm3/year. Of this total volume, a part is due to losses caused by leaks in the network, but the rest is due to measurement errors in meters, fraudulent consumption and consumption that is authorized but not billed. The estimated leaks are around 3.2%. The growing use of digital meters and network monitoring help identify the sectors most suitable for these improvements, in a continuous process of network updating. A medium-term savings potential of 1.2% is estimated, which would result in additional resources of 2.9 hm3/year.
- **Regulation of pressures in the network:** During the drought emergency phase, pressure reduction trials have been carried out in 15 of the 180 sectors into which the network is divided, leading to no incidents in the wa-

ter supply and achieving savings of 7.6%. This experience allows us to consider future adjustments of the average pressure of the network, with its different pressure levels, taking into account that a normal supply pressure is around 30 m.w.c. The installation of home pressure regulators has also been studied and would allow the pressure in each home to be adjusted to around this value. With a measure like this, and with an estimated adoption for 2050 in about 100,000 properties, in an average scenario an additional saving of around 5.1 hm3/year could be achieved.

- **Domestic demand reduction mechanisms:** A series of measures to achieve significant savings in the home have been studied, though their level of adoption varies:

  a) *Aerators for domestic taps*: aerators reduce the flow by introducing air, saving 40%–60% of the water without the user perceiving a lower-quality experience. Many of the five million taps in the metropolitan area already have them, but there is still room for progress in this regard.

  b) *Domestic hot water recirculation systems*: wastage while users wait for hot water to come out of the tap could be avoided. Recirculation systems allow 100% of that water to be used and could be installed progressively.

  c) *Use of grey water*: using grey water from showers, bathtubs, washbasins and sinks would allow it to be reused for flushing toilets after a light treatment. At present this use is very limited. It requires a specific infrastructure but would be economically viable in buildings with more than 20 dwellings or in hotels with more than 100 beds.

  d) *Reuse of swimming pool filter rinsing water*: This is a viable use in many buildings in suburban areas, especially for garden irrigation.

  e) *Use of rainwater for irrigation*: Given the irregularity of rainfall, this use would only be possible in special situations: public buildings with green areas, housing estates, sports facilities, and other places with large catchment areas and space to build tanks. The same can be said of sustainable urban drainage systems.

These measures will have to be implemented progressively, in many cases as buildings are renovated or new ones are built. Altogether, with an average adoption of all of them, it is estimated that by 2050 an overall saving of 13.5 hm^3/year could be achieved.

In total, actions on demand could lead to savings over current forecasts of up to 21 hm^3/year. Combined with actions on supply, it would be possible to guarantee supply to the Barcelona metropolitan area in 2050 in any climatic conditions.

Action on facilities in the medium and long term

Actions on supply and demand are largely essential to guarantee sufficient resources in 2050, even in the drought conditions that will undoubtedly return. The structural water deficit, which is evident in the driest years, will be more pronounced in the future. To deal with this problem, we must improve processes, change ways of thinking and above all invest in facilities.

The necessary investments have been included in the 2022-2027 Management Plan for the River Basin District of Catalonia of the Catalan Water Agency. The actions laid out in the plan will increase the availability of water from new sources by around 30% and will guarantee the supply of the metropolitan area in the long term. In addition, other investments are planned to improve the quality of water masses and environmental flows in rivers and their ecosystems, and to carry out other sanitation measures.

The investment plan has a special impact on non-conventional resources: desalination, reclaimed water and improvement of water abstraction and purification.

Improvements in desalination, purification and reuse: New resources will generate 182 hm3/year for consumption: 80 hm3/year will come from desalination, 56 hm3/year from reuse and improvements in DWTPS, and 25 hm3/year from intensifying the use of the Besòs River. To this will be added 6 hm3/year from network efficiency improvements and 15 hm3/year from new groundwater collection.

Fig. 11. Investments planned to guarantee long-term water resources in the Barcelona metropolitan area, according to the 2022-2027 Management Plan for the River Basin District of Catalonia

Actions on desalination	**370,000,000 €**
Expansion of STF Tordera	220,000,000 €
Construction of the STF Foix	150,000,000 €
Actions on reclaimed water	**173,000,000 €**
Construction of RWP at the Besòs WWTP and transport network	93,000,000 €
Improvement of the WRP in Sant Feliu de Llobregat and other municipalities	14,000,000 €
Connection of reclaimed water from the Besòs basin to the Llobregat basin	31,000,000 €
Reclaimed water distribution network in high-demand locations	35,000,000 €
Actions on purification	**260,000,000 €**
Construction of the new Besòs DWTP	39,000,000 €
Capacity improvement and quality optimisation of the Ter DWTP	72,000,000 €
Capacity improvement and quality optimisation of the Llobregat DWTP	107,000,000 €
New underground catchment field at the Llobregat DWTP	3,000,000 €
New underground catchment field at the Sant Joan Despí DWTP	12,000,000 €
Expansion and new underground catchment field at the Besós DWTP	27,000,000 €
Actions to improve efficiency	**681,700,000 €**
Improvement of municipal high capacity water supplies	175,700,000 €
Improvement and reinforcement of supra-municipal supplies	58,000,000 €
Improvement of the Ter-Llobregat network operated by ATL	388,000,000 €
New connections to the Ter Llobregat network	28,000,000 €
Extensions of the transport network in supra-municipal systems	5,000,000 €
Modernization of irrigation systems	27,000,000 €
	1,484,700,000 €

(Data: Catalan Water Agency)

Increased regeneration: In Catalonia as a whole, the current 24 WRPs will be increased to a total of 40, with which the regeneration capacity will reach 120 hm3/year, 50 hm3 more than today. For the metropolitan territory, a total regeneration capacity of 120 hm3/year will be achieved. This means that almost 50% of all treated water can be reused.

The total planned investments come to around €2,400 million, which will initially be provided by the Catalan Water Agency (58%) and the Spanish Ministry of the Environment (42%). Of this total, investments to guarantee the water supply to the Barcelona metropolitan area amount to around €1,485 million according to the details shown in Fig. 11. It is important to note that the metropolitan area, including the second zone, accounts for 65% of the total population of Catalonia.

Digitizing water management: sensorization and digital twins

The water supply systems of an area the size of the Barcelona metropolitan area are complicated and changing. They include industrial elements of great complexity and geographically very extensive networks. Digitization, understood as the digital modelling of physical elements and the collection and integration of millions of data for management, is an essential tool for managing this infrastructure. It is not totally new because supervisory control and data acquisition and sensorization of plants or networks have been evolving for years. But much more powerful and capable tools are already in application, including digital twins, artificial intelligence applied to decision-making, management and processing of huge amounts of data, and advanced mathematical models with machine learning.

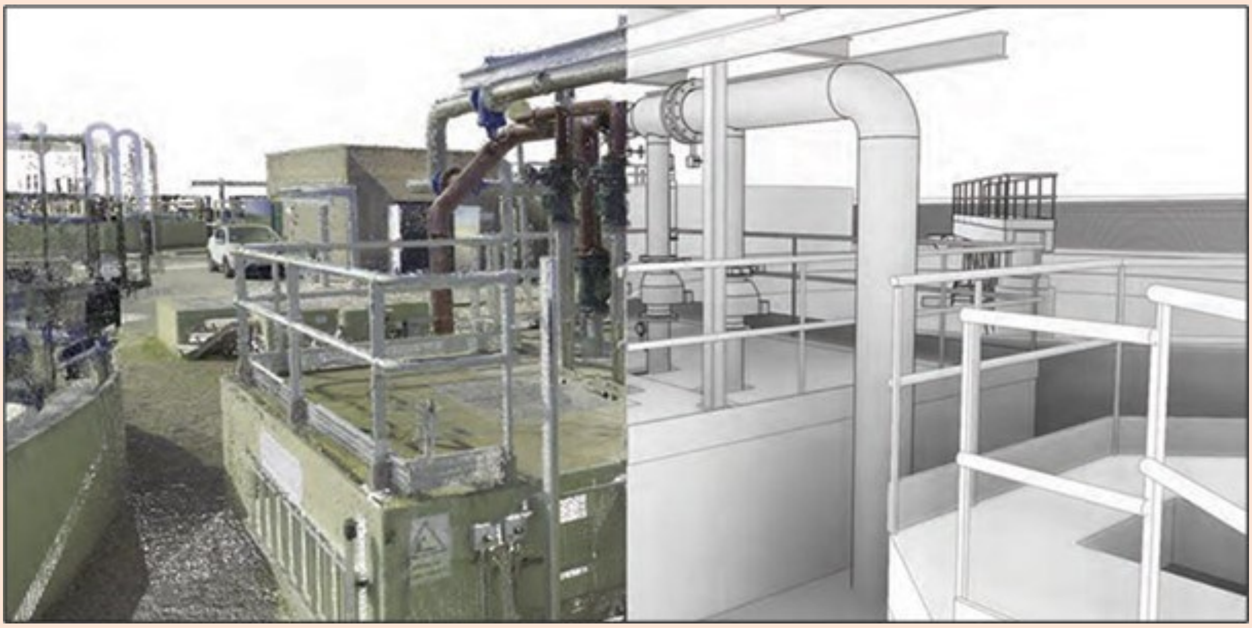
With all of them, many critical aspects can be improved: a) the hydraulic and energy efficiency of the supply, including the reduction of losses; b) the operation and maintenance of major facilities through digital twins; c) real-time monitoring of flows, pressures, qualities and all network parameters; d) promotion of responsible use of water through remote reading systems; and e) generation of aquifer models and their integration into geographic information systems (GIS), with data collection for control and management forecasts. Furthermore, this data control and analysis allows key information to be incorporated from the various systems and shared by all major actors to improve management, governance and transparency.

A good example of these tools is the ongoing implementation of digital twins with building information modelling. This is a system for modelling and simulating facilities that allows advanced control, optimizes decision-making and minimizes management problems. It is especially useful for large facilities (DWTPs, WWTPs and STFs) but also for elements such as networks, wells, tanks and pumping stations.

Digital twins are replicas of a physical asset in the digital world and are used for management, monitoring, simulation and analysis. They are developed from real data of the facilities captured with point cloud systems, which capture each element with millimetre precision. These data are replicated in the digital model as built, integrating information from all the equipment and elements (pumps, screens, blowers, valves, etc.) with sensor data and all the design and maintenance information. In addition, the digital twins of a system (all plants, pumping stations, tanks, etc.) can be interconnected for management through GIS. A digital twin makes it possible to optimize decision-making and even act predictively, allowing future changes in the system to be modelled. Thanks to this flow of information, water losses can be minimized, quality optimized and energy consumption adjusted.

In addition, digital twins are used for operation and maintenance and are incorporated in computer-aided maintenance management systems. Building information modelling of the plant enables visualization of maintenance operations and can also include predictive analytics. This allows for faster, more informed decisions and improved efficiency. It also allows problems to be anticipated and marks a change from corrective to predictive maintenance.

Fig. 12. Development of the digital twin of the Caldes de Montbui WWTP



(Source: Besòs-Tordera Consortium)

Techniques such as augmented reality can also be introduced, giving operators all the information necessary for their actions on the plant flexibly and visually, normally through a tablet or just a smartphone.

Another substantial part of digitalization is the sensorization of facilities to acquire and correlate information from remote devices. For example, the deployment of smart meters (already 70% of the meters, allowing measurements every hour) improves the service, saves water and provides detailed information on the operation of the networks. It also reduces management costs and offers a better service to users.

Digitization using GIS is also applied to control groundwater through mathematical aquifer models. An example of an application is the advanced monitoring of the recharge of the Llobregat delta aquifer.

[3]Strategic Project for Economic Recovery and Transformation (PERTE), the name given in Spain to the tools for the European Union's Next Generation funds. They are tools for public-private collaboration to improve economic competitiveness and employment.

In this regard, the Metropolitan Area of Barcelona, together with the Aigües de Barcelona utility and the Catalan Water Agency, is developing an extensive digitalization programme applied to hydraulic systems. To achieve this, the first action plan has a budget of €20 million, of which 50% comes from the European Next Generation funds within the framework of the Strategic Project[3] for the digitalization of the water cycle.

Conclusions

Solving the water shortage in the Barcelona metropolitan area to meet the needs of 2050 must involve a combination of solutions. First, it is imperative to further optimize networks and contain per capita consumption on a continuous basis. The next step is to continue expanding the infrastructure for regenerating treated water with the aim of progressively approaching the target of 100% of reclaimed water. Qualities must be adapted to uses, and drinking water must be replaced whenever possible. Finally, the capacity of the desalination plants must be increased, to guarantee sufficient supply. The cost of desalinated water (around €0.60/m3) is greater than that of reclaimed water (€0.35-0.50/m3), as is its environmental cost, but it is an essential solution in situations of scarcity. It is an unlimited resource that allows us to guarantee the water supply regardless of the climate.

The future of supply to the Barcelona metropolitan area will therefore be a mix of raw, reclaimed and desalinated water whose composition will vary depending on the climatic conditions each year. It is essential to protect water resources and preserve water as a natural resource, in addition to adapting water management to climate change forecasts. Therefore, having the option of water from non-conventional sources is critical to avoid the problems of future droughts, which will undoubtedly return again and again, and probably with increasing frequency. Fortunately, the technology is already ready for these solutions. Work is underway to provide the infrastructure necessary to complete the system by 2030 and is a vital priority for the Barcelona metropolitan area.

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THE INTERNATIONAL COOPERATION STRATEGY OF THE AMB: THE RIGHT TO WATER

International agendas

The AMB takes as its starting point the recognition by the United Nations that safe and clean drinking water and sanitation is a human right essential to the full enjoyment of life and all other human rights (United Nations General Assembly, 28 July 2010). The Committee on Economic, Social and Cultural Rights of the Economic and Social Council of the United Nations (ECOSOC) defined the human right to water as follows:

> "The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses. An adequate amount of safe water is necessary to prevent death from dehydration, to reduce the risk of water-related disease and to provide for consumption, cooking, personal and domestic hygienic requirements."

- This involves guaranteeing the following:
- The availability of sufficient water for personal and domestic use.
- Physical and economic accessibility.
- Adequate water quality through the development and implementation of water sanitation and potability policies.

The 2030 Agenda underlines the importance of the right to drinking water and sanitation as an essential component for sustainable development, the eradication of poverty and the promotion of equity and human rights. This right is specifically addressed in Sustainable Development Goal 6, which focuses on "Clean water and sanitation". Goal 6 aims to ensure the availability and sustainable management of water and sanitation for all people by 2030 and establishes a number of targets related to access to drinking water and sanitation, water use efficiency, protection and restoration of water-related ecosystems, community participation and international cooperation in water management.

Water management has also been incorporated in the New Urban Agenda, which defends the need for sustainable towns with integral management of high-quality water to guarantee the rights of everyone.

Management of the water cycle and local authorities

According to UN-Habitat (2022), approximately 60% of the global population lives in urban areas, and this trend is expected to increase in the coming years, especially in some regions of the Global South. In addition, climate change causes severe droughts and heavy rains that have a great impact on the soil, affecting water forecasting and management.

According to the UN, 17% of the population does not have access to water service, 60% do not have safe sanitation, and 80% of waste water is dumped untreated into rivers, seas and lakes. The most vulnerable people, especially women, children, older people and people with illnesses, are the most affected by the infringement of the right to water.

The supply of drinking water and sanitation is often the responsibility of local authorities.
In many urban centres, the main challenge is the lack of access to basic services, good-quality drinking water and an adequate sanitation system, especially in spontaneous human settlements.

Another indispensable element, especially in the context of the climate emergency, is the management of water resources, which requires multi-level and multi-actor cooperation, alignment and complementarity.

Faced with the current major challenges of water management, it is necessary to reflect on water governance at the local level and to include strategic actors such as municipalities and metropolises. The AMB promotes reflection on metropolitan water governance as a solution that enhances effectiveness, efficiency and equity, and enables a quality service to be provided in the complete cycle. Furthermore, because water does not recognize geographic boundaries, coordination must extend widely beyond municipalities, regions and borders.

The water cycle and the AMB's cooperation strategy

Since 2015, the AMB has maintained a strong commitment to international cooperation with the countries of the Mediterranean, Africa and Latin America. It has made a commitment to dedicate 0.7% of its own resources to this cooperation, as recommended by the UN. This commitment is reflected in the Metropolitan Action Plan, the public policy that establishes the mandate plan every four years, and in the International Cooperation Master Plan, which establishes the cooperation model, the priorities and the strategies that will be carried out.

The metropolitan administration has established a model of work focused on decentralized cooperation between metropolises. We work directly with actors from similar territories based on a process of mutual knowledge and technical cooperation. This fosters platforms for exchange of experiences, actions and joint reflection based on a decolonial perspective that recognizes the territory and relates to it from a horizontal standpoint. This work methodology makes it possible to get to know the contexts, challenges and priorities of each territory and to promote transformative processes that help guarantee the rights of all the people who live there.

In addition, the AMB has a model of cooperation with a metropolitan perspective that is people-centred, transformative and based on cross-cutting principles, adopting a local and global perspective. The cooperation focuses on the AMB's responsibilities, including the water cycle. The universal right to water is approached by improving the integrated management of the water cycle and protecting water resources. It is also a cross-cutting principle that must be incorporated in all lines of action and is linked to strategies for mitigating and adapting to climate change.

In this framework, the work follows four lines:

1. Protection of water resources
2. Water management in metropolitan areas
   - Water abstraction: extraction of water from rivers, lakes, aquifers, etc.
   - Drinking water: treatment of water to make it suitable for human consumption.
   - Supply: the system of pipes and channels that allow drinking water to be transported to points of consumption.
   - Sewers: the system of channels that transport wastewater to the point of treatment.
   - Treatment: The processing of wastewater to remove or reduce polluting substances before it is returned to the environment.
   - The regeneration and reuse of water: improved treatment of purified water to put it back into service.
3. Water governance
4. Reflection on the climate emergency, water and international cooperation

Among the above lines, the International Cooperation Service has promoted actions in the following areas: water governance in urban centres; protection of water resources; sustainable urban drainage systems and reclaimed water; the supply of good-quality drinking water and sanitation; climate emergency and water; and education for global citizenship.

All the actions have been carried out from a triple perspective: governance, technical solutions and social strategies. In particular, they are carried out through direct cooperation with other urban areas, with whom we work along two lines:

- Technical cooperation: an opportunity for exchange and collective construction between the technical staff of the areas involved, especially the staff dealing with the water cycle and public spaces.
- Implementation of transformative actions in the area linked to the strategies, methodologies and techniques prioritized in projects.

Work is also done in triangular cooperation, focusing on the exchange of experiences and the construction of knowledge collaboratively between various areas, and concerted cooperation with other actors in the field of international cooperation.

1. Protection of water resources

This topic has been worked on particularly in the Lempa river basin, in the transnational region of El Trifinio at the meeting point of three countries: El Salvador, Guatemala and Honduras. The river basin, with an extension of 17,926 km, has high rates of pollution caused by inadequate management of freshwater, solid waste and black water, poor management of mining, and excessive use of toxic agrochemicals. The Lempa River supplies water for 37%

of the inhabitants of the metropolitan area of San Salvador.

To achieve coordinated management, the Tri-National Border Federation of Río Lempa (MTFRL) was set up. This federation contributes to integrated, sustainable and shared water management in the region and enhances the protection of the river. The AMB has supported the federation in the promotion of integrated management of water resources, sustainable management of water recharge areas, and conservation of water sources that supply municipal drinking water systems.

2. **Water management in urban and metropolitan areas**

Several actions have been carried out in this line to address the priorities of each context, the local actors and the area where they are carried out.

In the area of the Lempa River bordering on El Salvador, Guatemala and Honduras, action has been taken on drinking water treatment plants and the canalization system, control of the recorded water volumes, and management to reduce supply cuts and guarantee daily water in homes and public facilities. We have also worked on door-to-door awareness campaigns in relation to consumption, cost, payment, protection and conservation of water resources. This is an area where drinking water coverage ranges from 29% to 44%, depending on the municipality. In areas of armed conflict, basic

Pic. 1 : AMB Project 'Trifinium', Guatemala

services such as water are severely damaged, hampering people's daily lives, and water resources are often used as a tool of war.

In **North and East Syria,** work has been done with local actors[1] to provide drinking water to the population and improve the essential facilities linked to drinking water and sanitation.

The Al-Shyokh water pumping station, the main source of drinking water supply in Kobani, which had been damaged in attacks and sabotage by jihadist groups during the siege of the city in 2014

[1] The AMB is working with Mezzaluna Rossa Kurdistan Italia, medico international, the Kurdish Red Crescent and local authorities in this region.

and 2015, has been rehabilitated. It has also been equipped with materials for water purification through chlorination. The municipality's water management capacities have been reinforced through the training of municipal staff and the development of protocols for the operation, supervision and maintenance of the pumping station.

- In Qamishli, water, sanitation and waste management systems (including sanitary systems) have been provided to the first prosthesis centre and the first oncology hospital of North and East Syria, and solar energy systems have been installed to ensure their autonomy. The staff have been trained in their maintenance to ensure sustainability. In the oncology hospital, a drinking water treatment plant has been installed for medical uses, as well as a liquid waste treatment plant for the chemicals used in chemotherapy.

Pic. 2: AMB Project 'Oncological Center', Qamishli, North and East Syria

- In the Shahba region, wells with integrated chlorination systems powered by solar panels have been built and equipped to ensure access to water for the population most affected by the earthquakes of 6 February 2023. The wells, each with a capacity to supply drinking water to 5,000 people, have been located near camps for displaced people and health centres. Training has also been given to strengthen local technical capacities for the proper use and maintenance of the installed systems in order to guarantee their functionality and sustainability.

In the **province of Aleppo**, Syria, the AMB works with UNHCR with the aim of facilitating access to drinking water services for displaced people and refugees. To help guarantee access to basic water services, work has been done on the following:

- Repair of existing water networks and replacement of damaged pipes in residential buildings. This action has had an impact on the lives of a hundred families, especially the most vulnerable ones in the province of Aleppo.
- Repair of drinking water abstraction systems in three rehabilitated community centres in the city of Aleppo used by approximately 2,250 returnees.

Priority has been given to families led by single females who have returned to their homes with children and disabled children in their care because they are the ones with the least access to safe, good-quality water.

In the western Mediterranean, work has been done in **Tunisia**, a country characterized by water shortages and floods, which will become increasingly frequent under the effect of climate change.

The AMB works with the **Gabès** City Council and the MedCities network, promoting innovative strategies to strengthen the municipality's capacities and reduce the impacts of climate change through effective and efficient water management.

The actions are carried out within the framework of

Pic. 3: AMB Project 'ValeEUr-Gabès', Gabès, Western Mediterranean

the project “ValEUr-Gabès: Valorization of urban water through innovative actions and instruments” with the co-financing of the European Union. The use of non-conventional water resources as an alternative to fresh water allows efficient management of water resources, improving the quality of aquifers and the maintenance of natural ecosystems.

One of the main lines of the project is the implementation of transformative proposals for the collection of uncontaminated water on roofs for municipal uses and the valorization of rainwater for groundwater recharge and reuse for municipal purposes.

In this context, the following solutions are identified and studied:

- Infiltration ponds and water retention tanks of approximately 10,000 m^3 for each project for flood mitigation, aquifer recharge and reuse.
- Collection and valorization of rainwater in a public building.
- Study of the sustainability of green roofs and their adaptability to the climate, and access to water in the region.
- Valorization of wastewater for domestic use.

An infiltration pond, a retention tank and a system for recovering rainwater and grey water from a public building have been installed.

Exchange of experiences and analysis of common challenges constitute a strategy for strengthening technical capacities for the integrated management of water in metropolitan areas. An example of this triangular way of working has been the proposal of exchange between three metropolises: **Bogotá, Mexico City and the AMB.** Challenges and strategies for transformation have been iden-

Pic. 3: AMB Project ‘Comprehensive Water Management for Adaptation to Climate Change in Metropolises

Bogotá, Colombia

tified to substantially change the integrated management of rainwater and grey water and water governance while minimizing disturbance to natural systems and contributing to the adaptation to climate change. Experiences and reflections are shared and systematized to improve practices in the metropolitan areas of Bogotá, Mexico City and Barcelona. This process creates a continuous opportunity to exchange and analyse specific policies and strategies for the integrated management of urban water, serving as a basis for new initiatives in the metropolis. This action has received the support of the Metropolis network of metropolitan areas and cities.

3. Water governance

An efficient, effective and high-quality water governance with a technical and social perspective is essential to guarantee the right to water for the population and the territory. For this reason, all the projects implemented have a line dedicated to reflection on and strengthening of water governance. The AMB draws on its metropolitan experience and municipal knowledge to promote a joint reflection with actors from other areas. Together they share and analyse policies, strategies and instruments in order to learn and identify new solutions that bring innovation and transformation in the areas in which they work.

We will give two examples of work in water governance. The first is the experience in Gabès, Tunisia, carried out with the city council, the MedCities network and the AMB. This project involved strengthening the municipal institution to improve urban water management, drafting the Integrated Urban Rainwater Management Plan, and designing mechanisms and instruments for its implementation. This process has been accompanied by training actions aimed at the public and private actors of the area that are involved in water management. The second is the work with the Tri-National Federation of 28 municipalities of three countries. With the federation we reflected on supra-municipal and tri-national governance of the Lempa river basin and the essential elements of water management at the municipal level, such as public, private and mixed water management and payment of the supply service.

4. Reflection on the climate emergency, water and international cooperation

Several actions have been taken to strengthen reflection and action on water and the climate emergency in cities in the field of international cooperation in both the Barcelona metropolitan area and areas on other continents. Actions of reflection, studies and work guides have been carried out in relation to international cooperation and management of the water cycle and the climate emergency in urban centres with the aim of placing their importance and urgency in the current context and on the agenda of urban centres in various areas of the world.

AMB Àrea Metropolitana de Barcelona