

Argentina



Obelisk of Buenos Aires, historic monument and icon of icon of that city, located in Plaza de la Republica, Buenos Aires, Argentina. Photo credit ©iStock.com/dolphinphoto.



“Despite its vast territory, humid regions in Argentina only occupy a quarter of its surface and are inhabited by over two thirds of its inhabitants. Arid zones account for 60% of the area of the country, and are home to just 6% of the population. This ratio between water and population is exactly the opposite to that of the majority of Latin American countries”

Urban Water on the American Continent: the case of Argentina

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Summary

This chapter characterizes the availability and distribution of water resources, with an emphasis on their uneven spatial distribution. It analyzes population growth in recent years, noting that over 90% of the total live in urban areas. It describes the various catchment for water supply and studies the current level of coverage in the country's main cities. Although there are high percentages of drinking water coverage, over 90% in the principal cities, the level of sanitation is uneven, with indices varying between 35% and 80%. The chapter also mentions the organization of the provision of drinking water service, where there is a federal regime that implies the existence of specific norms and regulations for each province, which multiplies the number of providers in the country, bringing the total to 1,830.

The chapter also undertakes an analysis of the existing situation in the urban conglomerate of Greater Buenos Aires, home to over 12 million persons, with high levels of coverage. It focuses on the treatment and the level of reuse of wastewater. Lastly, it specifically analyzes two significant impacts linked to water resource management and rising water tables, and the impact of excess precipitation on urban centers.

Figure 2 is a map of the principal water basins and hydrographic groups. Both maps are taken from the 2010 *Atlas, Surface water basins and regions of Argentina*, by the National Water Institute, Under-Secretariat of Water Resources.

Wetlands occupy 24% of the area of the country, but are home to approximately 70% of the country's total inhabitants, whereas arid zones account for 61% of the territory, yet only contain 6% of its inhabitants. This water/population ratio is exactly the opposite of the majority of Latin American countries.

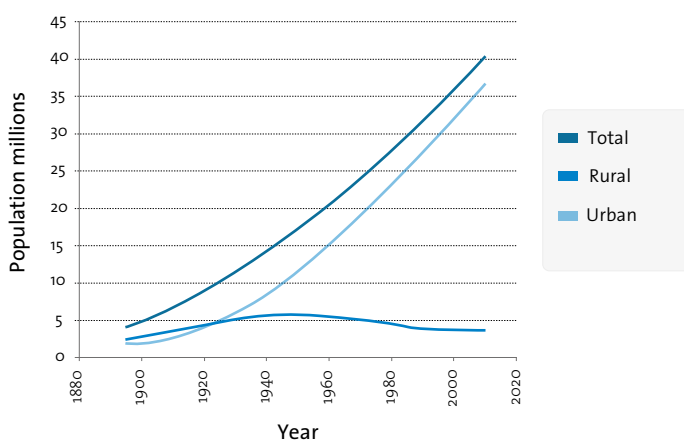
Though groundwater resources are of crucial importance in the arid and semiarid regions of the country, there is insufficient information regarding these resources nationwide. Available information refers to local aquifers, particularly in the areas of Cuyo, the North East and the Pampas region (Aquastat, 2000). The recently-created National Federal Plan for Groundwater at the Under-Secretariat for Water Resources (SSRH, 2012) will undoubtedly contribute to creating the information required for the integrated management of this key resource. Argentina possesses a broad distribution of aquifers with diverse characteristics throughout its territory, which enables water to be supplied for human consumption, particularly in most of the towns in the interior of the country. However, most of the water consumed is for irrigating agricultural production.

The Plan stipulates that sustainable underwater management is crucial to preventing a decrease in stored volumes or a reduction in wetlands areas, maintaining the useful life of boreholes, ensuring the quantity and temperature of thermal exploitations and preventing modifications in the surface of the land, among other undesirable effects of non-sustainable use. This National Plan is currently undergoing its first phase of implementation, which involves creating a hydrogeological database, continuing studies on the Guaraní Aquifer System in Argentina, and various forms of participation in actions involving trans-border aquifers and inter-jurisdictional basins.

The uncontrolled increase in the use of surface and groundwater, in both the industrial and productive sphere, with discharges of untreated effluent and the haphazard development of extensive marginal population settlements, meant that by the early 21st century, water resources had significantly deteriorated as a result of inadequate exploitation and the dumping and infiltration of polluting substances. This resulted in problems in the development of aquatic life, the emergence or increase in water-borne diseases, the deterioration of conditions for various leisure activities and an increase in water purification costs.

2. Some Notes on Urban Population

Figure 3. Evolution of Argentina's population



The population in Argentina's major urban centers grew far more rapidly than the country's total population. Figure 3 shows that in recent years, urban concentration has maintained a positive growth rate, with a marked decrease in the rural population.

According to information from the National Institute of Statistics and Censes, INDEC, (2011), Argentina's population data can be summarized as follows:

- Total population: 40,117,096 inhabitants (49% male)
- Annual population growth rate: 1.036%
- Birth rate: 18.6%
- Mortality rate: 7.6%
- Life expectancy: 76.8 years.

- Urban population in centers with over 2,000 inhabitants: 89.31% (48.27% male)
- Rural population in centers with fewer than 2,000 inhabitants: 3.40% (50.81% male)
- Scattered rural population: 7.28% (54.02% male)

The information from INDEC indicates that the total population estimated on July 1, 2014 was 42,669,500 inhabitants, 48.9% of whom were male, with an annual growth rate in the order of 1%.

According to the same source, Argentina's ten largest urban centers were home to a total of 21,050,797 inhabitants; that is, 52.47% (over half) of the country's total population.

As regards large urban agglomerations, there is debate surrounding the effective definition of "Greater Buenos Aires." Consequently, in 2003, INDEC proposed that the urban conglomerate be considered to comprise the city of Buenos Aires in addition to 24 surrounding districts belonging to the province of Buenos Aires.

However, the name "Greater Buenos Aires Agglomeration" has been given to a combination of the city and 30 districts in the province of Buenos Aires, which, whether totally or partially, comprise the "population belt" composing the agglomeration (INDEC, 2003). If one considers only Greater Buenos Aires and Greater La Plata, the Greater Buenos Aires "agglomeration" represents 35.85% of the total Argentinian population.

Though there is a lack of accurate information on this issue, it is clear that demographic growth in cities with the highest number of inhabitants – particularly Greater Buenos Aires – has taken place in suburban zones, generally as a result of internal migration or immigration from neighboring countries that form settlements, some of which experience severe problems of drinking water, sewerage and the risk of excess water. Figures 4 and 5 show a satellite image and a plan of the districts in the Buenos Aires agglomeration.

3. Types of Water Supply Sources

As a result of its extensive geographical distribution, seasonal and inter-annual stability and the high flexibility permitting its exploitation, groundwater

is used extensively in all socio-economic sectors. Indeed, its use ranges from small household wells for the domestic requirements of families in the suburbs of Buenos Aires to the battery of 118 irrigation wells for the Valley of Tulum (Province of San Juan), capable of providing a flow of 24 m³/s, through the wells that capture the Paraná aquifer, with highly saline waters yet suitable for industrial use.

Figure 4. Buenos Aires agglomeration. Satellite Image



Figure 5. Buenos Aires agglomeration. Physical delimitation and districts. (INDEC, 2003)



Table 1 estimates the various consumptive uses of water extracted in Argentina between 1993 and 1997 (Calcagno et al., 2000).

The national average for the contribution of groundwater to the total demand coverage, of approximately 30%, does not reflect the importance of the role of these resources. Thus, in the irrigation sector, groundwater ensures multiannual regulation, which during periods of drought, such as the one that lasted from 1967 to 1972, offset the lack of surface resources.

The distribution and occurrence of the aquifer systems in Argentina's mainland territory is conditioned by the geological structure and climatic and hydrographic factors. Four broad hydrogeological regions can be distinguished (INCYTH, 1991): intermountain valleys, the Pampa Chaco plain, the Missionary tableland and Patagonian tablelands.

According to the specific bibliography (World Bank, 2000), the essential characteristic of the intermountain valley region, which includes the Andes mountain range and pre-mountain range region, is its extensive clastic sedimentary deposits that constitute aquifer systems with high permeability at the foothills and medium to low permeability in the center of valleys and at a depth. This region mainly encompasses the north east and Cuyo region (provinces of Jujuy, Salta, Tucumán, Catamarca, La Rioja, San Juan, San Luis and Mendoza), with an arid and semi-arid climate. The working of the aquifer systems is closely linked to the hydrology of the rivers, whose runoffs constitute the main natural recharge of these systems. There are aquifers that discharge into endorheic basins, such as those of Puna, the Tucuman alluvial fan and the valleys of Catamarca and Tunuyán and aquifer systems that discharge

into the floodplain that tends to flow into the Atlantic Ocean, such as those in the valleys and alluvial fans of the Mendoza, Atuel, Diamante and San Juan rivers.

The La Pampa Chaco plain has aquifers in clastic sediments throughout the region. The predominant morphology is plains, ranging from undulating to depressed and high. One part is located in the coastal and Mesopotamian zone, which corresponds to the provinces of Formosa, Chaco, Corrientes, Santa Fe and Entre Ríos; the so-called central zone or Pampa Gringa comprising the provinces of Santiago del Estero, Córdoba and La Pampa, and the other contains the province of Buenos Aires and the Buenos Aires agglomeration. In a predominantly humid climate, aquifer systems, are mainly recharged by rainfall infiltration. The groundwater resources in the region are mainly derived from the extensive aquifer system called Puelches, which includes three overlapping, interlinked aquifers: Epipuelches or Pampean, Puelches and Hipopuelches or Paraná.

The Missionary Plateau Region includes the provinces of Misiones and part of that of Corrientes. The aquifers comprise low permeability basalts and the sandstones of the Misiones Formation. The latter belong to a mega-aquifer, known as the Guaraní Aquifer, with an area of 1,500,000 km², occupying part of Brazil, Paraguay, Uruguay and Argentina.

The Patagonian Tablelands Region features an arid climate, with little or no rainfall. This region stretches from Tierra del Fuego to the Colorado river, including the provinces of Neuquén, Río Negro, Chubut, Santa Cruz and Tierra del Fuego. The aquifer systems include the formation of Patagonian pebbles, basalt plateaus and above all the floodplains of the rivers that rise in the south of the Andes mountain range.

Table 1. Extraction of water, by use and source, between 1993 and 1997

Use	Surface water		Groundwater		Total	
	10 ⁶ m ³ / year	% of the total water used	10 ⁶ m ³ / year	% of the total water used	10 ⁶ m ³ / year	% of use in relation to total extracted
Irrigation	18,000	75	6,000	25	24,000	71
Livestock	1,000	34	2,000	66	3,000	9
Municipal	3,500	78	1,000	22	4,500	13
Industry	1,500	60	1,000	40	2,500	7
Total	24,000	---	10,000	---	34,000	100

Source: Calcagno et al., 2000.

Figure 6. Physical and political map of the Province of Buenos Aires (INA, 2010)



In particular, the province of Buenos Aires is characterized by belonging to a vast plain occupying approximately 270,000 km² and is home to over a third of the country's population. The largest slopes are located in the Tandil and Ventana mountain ranges, which occupy around 10% of this area. Figure 6 shows a map of the province of Buenos Aires (INA, 2006).

The rest of the province mainly features very flat topography, with slopes in the order of one per thousand, just above sea level. This characteristic means that rain water has a limited ability to flow over the surface of the land, as a result of which most of this water returns to the atmosphere through evaporation and plant transpiration, while the remainder filters into the soil and recharges the aquifers. During the rainy season, the excess water feeds the aquifers, thus increasing the groundwater level. The water often rises to ground level, creating large surface lagoons characteristic of the heavy semi-permanent flooding that has affected this region on numerous occasions. The subsoil of the Province of Buenos Aires therefore contains an enormous amount of groundwater levels that can easily be exploited (Bonorino et al., 2009).

However, nowadays, the country's major urban centers are recharged by surface water resources. In particular, the large centers on the Paraná and La Plata rivers supply their riverside population through river water intakes with large-scale purification systems.

4. Drinking Water and Basic Sanitation in Argentina's Cities

80% of Argentina's population have a home connection to a drinking water network, and 53% have a home connection to a sewerage network, rising to 90% when improved sanitation systems are also included.

The 32 urban agglomerations, comprising over 70% of the national urban population, have an average drinking water coverage by network of 96% of inhabitants and sewerage coverage by network of 68% of inhabitants. The Buenos Aires agglomeration is below this average (83% and 58%, respectively).

In Argentina, the national average of water production per inhabitant served is estimated at 380 liters a day, with figures varying widely between the various provinces, from a maximum of 654 liters a day per inhabitant in the Province of San Juan to a minimum of 168 liters a day in the Province of La Pampa. Non-revenue water is one of the main efficiency problems encountered in drinking water services. It is calculated that losses in the network, sub-invoicing through clandestine connections and failure to update users' registries account for between 35% and 45% of the water produced, meaning that the average supply in Argentina is approximately 250 liters a day per inhabitant. This high level of consumption, compared to that recorded in numerous countries worldwide and in Latin America, can partly be explained by the low level of micro-measurement of consumption that prevails in Argentina's systems, particularly in the majority of services in large cities, where users are invoiced on the basis of "open faucet" tariff regimes. In this regard, based on international antecedents, the average consumption recorded by systems that operate using micro-measurement is in the order of 80 liters a day per inhabitant (PAHO, 1999).

Significant disparities across regions and provinces, and between urban and rural areas, can be observed in both drinking water and sewerage coverage. In the case of drinking water, coverage through house connections has increased by 10% in the past five years. This increase in coverage shows that other forms of supply have been replaced by house connections. In the case of sewerage service, coverage through a house connection has remained constant in recent years, suggesting that coverage has increased at the same rate as the population. On the other hand, the population without coverage has decreased in favor of types of provision other than house connections. In Argentina, the greatest environmental problem linked to water is due to the limited treatment of effluents and the heavy legacy of the lack of adequate urban planning. In the periphery of Buenos Aires, the occupation of the flood valleys of the Matanza-Riachuelo and Reconquista rivers, and of streams and tributaries, is closely linked to the pollution of the coastal strip of the Río de la Plata and part of the Paraná Delta. The factories installed in these valleys, which involve

complex controls, do not usually have a history of treating these effluents. Moreover, irregular settlements (known as “villas” here) do not all have adequate services for water supply and sanitation, which contributes to pollution. The emblematic case of the Matanza-Riachuelo basin suffers from several water and environmental problems: flooding of residential and industrial areas, drains in settlements without sanitation services, garbage collection and processing with techniques that fail to comply with hygiene, safety and health standards, and a certain informality in industrial activities. The National Government, the Government of the City of Buenos Aires, the Province of Buenos Aires and various municipalities of the province share jurisdiction over the basin. The creation of the Matanza-Riachuelo Basin Authority (ACUMAR) has significantly facilitated the coordination of the actions of various organisms, in an attempt to reach a consensus on a single joint strategy, without which it would be impossible to reverse the urban and environmental degradation.

Another environmental water problem affecting urban zones in Argentina is groundwater pollution. In most of the country, groundwater management has been ineffective, meaning that only partial quantitative information is available to assess the current state of aquifers and the water quality trends in each of them. The responsibility for groundwater management lies with the provincial governments, which do not generally have the financial and human support to manage a resource that is much less visible than surface water.

According to INDEC, in the last trimester of 2006 (EPH–IV Trimester 2006, INDEC), coverage in the 32 urban agglomerations, whose urban population is equivalent to 70% of the national total, had average

access to drinking water through a network of 96%, with sewerage coverage for 68% of its inhabitants.

Table 2 shows that the lowest coverage of drinking water service corresponds to Greater Buenos Aires (83%), since although the federal capital zone has almost total coverage, as mentioned before it includes suburban zones with a high population density and low income. Though Greater Buenos Aires has a lower figure for domestic sanitation service (58%), the lowest level is registered in the city of Córdoba (35%).

Sanitation supply in Argentina has historically been lower than drinking water coverage through a network. A comparison of the districts shows that this gap between drinking water and sanitation services has varied. It is measured using the quotient of water users per sanitation service user, whereby the highest number expresses the highest asymmetry.

Marginal urban areas experience difficulties linked to the expansion of drinking water and effluent collection and disposal services, and improving the intermittent supply and disinfection.

5. Organization of Service Provision

The current distribution of water and sewerage services in Argentina mirrors the structure of the country. Indeed, each province has the power to establish its own jurisdictional norms for the institutional organization of drinking water and sewerage. This implies that each province has its own regulatory framework, which is basically structured as a control agency and a private or state

Table 2. Urban drinking water coverage in Argentina.

Urban center	Drinking Water %	Sanitation %
Greater Buenos Aires	83	58
Córdoba	96	35
Rosario	99	61
Mendoza	96	80
La Plata	92	68

Source: INDEC-EPH IV Trimester 2006

operator responsible for the local urban services of the province. In many cases, small urban centers have small, generally public providers, and a rural structure managed by the state.

Drinking water supply installations appeared in Argentina as a preventive measure implemented by the State following the cholera epidemics that devastated the city of Buenos Aires in the late 19th century. Over the course of 75 years, from 1912 to 1980, the national government was responsible for investment and supply through the state company Obras Sanitarias de la Nación (OSN), the only body in charge of designing, constructing and operating these installations.

In 1964, a new body, SNAP (National Drinking Water Service) was created to finance and facilitate service expansion in rural areas. This marked the beginning of a series of programs financed by the Inter-American Development Bank and the economic support of the Nation and the Provinces. Moreover, the foundations were laid for the creation of 1,500 cooperatives that assumed responsibility for supplying water in small- and medium-sized villages. In 1980, the National Government decentralized the OSN's services, transferring them to their respective provinces. The assets were transferred free of debt or charges, but the new companies were obliged to find an economic formula that would enable them to finance the operating costs and investments to renovate and expand the service.

Between 1989 and 1990, the State Reform Program was characterized by a generalized transformation of the organization of public services, which involved incorporating private

companies into the administration of these services, mainly in large cities, which had hitherto been operated by public companies and institutions. The organizational structure was completed by the creation of norms established in a regulatory framework, and of specialized and autonomous agencies for the regulation and control of service provision. Furthermore, at the government level, the National Body for Water Sanitation Works (ENHOSA) was created, with nationwide jurisdiction, designed to organize, manage and implement infrastructure programs derived from the national drinking water and sanitation services.

The most important concession to a private company was signed in 1993 for the metropolitan areas of Buenos Aires, with a consortium led by the French company Lyonnaise des Eaux-Suez, called Aguas Argentinas, S.A. During the period from 1991 to 2000, approximately 20 services were privatized in Argentina, including the largest cities, such as Santa Fe and Rosario (Aguas Provinciales de Santa Fe, S.A.), Córdoba (Aguas Cordobesas, S.A.), La Plata and Bahía Blanca (Azurix S.A.) and Tucumán (Aguas del Aconquija, S.A.). This model experienced its first crisis with a number of failed processes in 1997, when the contract concession in Tucumán was rescinded and subsequently in 2002, in the Province of Buenos Aires. In both cases, the state resumed responsibility for these services.

The macroeconomic crisis and the devaluation in 2002 was followed by a widespread process of renegotiating concession contracts for public services. Later on, contracts with the concessionary companies in Santa Fe (2006), the metropolitan

Table 3. Urban drinking water coverage in Argentina

Type of provider	National	Provincial	Municipal	Total
Public Company	1	8	0	9
State Company	0	3	2	5
Self-governing entity	0	1	10	11
Centralized body	0	4	377	381
Private company	0	7	10	17
Cooperative	0	0	639	639
Neighborhood association	0	0	768	768
Total	1	23	1,806	1,830

Source: ETOOS, 2003

areas of Buenos Aires (2006) and Catamarca (2008) were rescinded. As a result, the participation of private sanitation companies in Argentina fell from approximately 70% of users connected to a drinking water network in the mid-1990s to less than 30% at present. It is worth noting that this participation had only been 13% before privatization, largely due to the presence of cooperatives and neighborhood associations.

Melina Tobías (2012), having analyzed the results obtained following a decade of private service supply, observes a large disparity between the goals originally set and effectively achieved. The data available for 2001 show that Aguas Argentinas, S.A. barely contributed 19.2% of the investment agreed to (Azpiazu, 2010). The drinking water coverage goals, which were supposed to achieve 88%, only totalled 79%. As regards sanitation drainage, 63% coverage was achieved, though the objective established was 74%. The worst results linked to primary wastewater treatment as the concession contract set a goal of 74% but only attained 7% (ETOSS, 2003).

It is interesting to note that nowadays, it is estimated that there are 1,830 drinking water service providers, of which 365 also provide basic sanitation services. Table 3 shows the classification by legal nature of the provider and the level of decision or jurisdiction.

6. Water and Sanitation Service in Greater Buenos Aires

For various reasons, there has been a delay in the implementation of important expansion and infrastructure works, and the achievement of coverage levels in the concession area. In response to this situation, the management of the state company AySA, with the support of the national government, proposed to design and implement a Master Plan to reduce the deficit and achieve the objective of universalizing services, thereby complying with Millennium Development Goals set by the United Nations (UN).

The main actions of the plan involve developing basic infrastructure, expanding existing installations and renovating and rehabilitating

networks. The central works to supply drinking water are the construction of the “Paraná de las Palmas” water purification plant, with an investment of over 17 millions Argentinian pesos, to serve two million persons in the Tigre district and lasting until 2020; and the creation of the “Virrey del Pino” inverse osmosis plant in the La Matanza district, which has a high density of low-income inhabitants. As regards sewage systems, the AySA plan is considering creating a new effluent removal plant in the Berazategui district, to significantly improve the quality of the water supplied to the city of Buenos Aires and its conurbation.

To extend the sewage network, AySA plans to modify the current distribution of the network, by building a large underground collector that will run parallel to the left bank of the Riachuelo and intercept a large part of the effluents currently received by the Berazategui basin through the main sewers. This work is essential to increasing coverage levels in the southern metropolitan area of Buenos Aires, as the new collector will relieve the flows of the Berazategui basin, whose capacity is currently saturated, thus giving it a greater capacity to receive new effluents from the zones to be incorporated into the network (AySA, 2010, “User Report”).

While the region with the highest income per capita and the greatest urban consolidation has full service coverage, the districts of Greater Buenos Aires have levels far below those of the capital city (Merlinsky et al., 2011).

These large infrastructure works promoted by AySA are designed to solve the problem of coverage in the medium and long term. However, the critical sanitary situation of certain regions in the Greater Buenos Aires area, compounded by the negative effects of poverty on inhabitants’ living conditions, made it necessary for the company to undertake local actions to expand water and sewerage services in low-income neighborhoods.

To this end, AySA employed two strategies: the Participative Management Model and the so-called “Water+Work” plan and “Sewage+Work” plan, designed to increase the interaction of the company, as the main source of financing, with neighbors - who provided labor - and the municipality - responsible for providing certain material inputs and the technical management of the works. In the case

of these plans, the following players are involved: the AySA company, responsible for designing the project and the financing and technical supervision of the works; neighborhood cooperatives, which provide the labor for undertaking the works; the municipalities, the players directing the projects and the entities implementing the works, other state organizations such as the Institute of Third-Sector Activities and Social Economy (INAES), which provides technical and legal assistance for the creation of the cooperatives and organizations such as the Greater Buenos Aires Union of Sanitation Worker (SGBATOS), which provides training for cooperative members (AySA, 2011).

Six years after the state began to manage service provision, drinking water coverage within the concession area has benefited 8.1 million inhabitants, while 5.7 million persons have sewerage service (AySA, 2010). According to data provided by the company, in late 2010 a total of 1,021,825 inhabitants were beneficiaries of the “Water+Work” and “Sewerage+Work” plans, with the former accounting for over 90%.

At the same time, during the first five-year revision of tariffs, in 2001, the concept of social tariff was introduced, with a fund of 4 million Argentinian pesos a year being established for its financing. This was made possible by a subsidy contributed by all the users of the concession, for the low-income residential users who were not able to pay their bills (Lentini, 2007).

7. Wastewater and Reuse

A first approximation of the volume of municipal wastewater discharged into the sewerage networks can be made, given that according to the National Population, Household and Housing Census of 2010 Argentina had a population of 40,117,096 inhabitants, 48.8% of private homes had a sewage drain, there were 11,317,507 private homes, 12,171,675 households, an average of 3.3 inhabitants per household, and 12.2% of households shared housing (INDEC, 2012). Consequently, applying an average supply for the country of 0.3 m³/(inhabitants.day) and a reduction

factor of 0.8 (80% of the water supplied and used is discharged into the sewerage network), the volume of wastewater discharged into the sewerage network can be estimated at approximately 1.596 x 10⁶ m³/year.

Information from the early 21st century indicates that only 10% of the total volume of domestic effluent collected in the sewerage drain systems was treated by a purification system (Calcagno *et al.*, 2000). The country's main obstacles to treating wastewater were the priorities established for the sector and the economic and financial resources available, particularly in view of the commitments made by Argentina when it signed the Millennium Development Goals (MDGs) in 2000.

Thus, the MDG regulation 8, “Ensure a sustainable environment” set the following global objectives, among others:

- Reduce the proportion of the population without access to drinking water between 1990 and 2015 by two thirds.
- Reduce the proportion of the population without access to sewerage drains between 1990 and 2015.

In this respect, between 2000 and 2009 Argentina almost tripled social investment in the area of “drinking water and sewerage”, which rose from 0.9% of the total in 2000 to 2.3% in 2009 (MDG Argentina, 2010).

As for the destination of the wastewater, including agricultural reuse, the country still lacks regulations establishing the minimum budgets applicable in all jurisdictions. In this regard, the National Congress is studying several projects, but has yet to achieve the consensus required for their approval. One of these is the draft National Law for the Reuse of Wastewater (Sartor *et al.*, 2012).

The province of Mendoza has specific regulations for agricultural reuse of treated waste liquids (DGI, 2003). Several municipalities are advancing in the regulation of the reuse of liquid waste treated for specific purposes, including Puerto Madryn, in the Patagonian province of Chubut, through Ordinance N° 6.301/2006, “Reuse of treated sewerage effluents” (municipality of Puerto Madryn, 2006a) and Appendix I of the Regulation (Municipality of Puerto Madryn, 2006b).

8. Urban Impact due to the Rise of Groundwater

It is important to note that specific regulations are not yet in place for the quality control of the products irrigated with wastewater. The implementation of the Strategic Agro-Food Plan by the Under-Secretariat of Water Resources (PEA2 SsRH) will promote the adoption of tools to improve the use of water, including its reuse, for food production.

According to the 2002 National Agricultural Census (INDEC, 2002), the total area used for agricultural purposes in Argentina was 33,491,480 hectares (approximately 19% of the total area), of which only 1,355,601 hectares were effectively irrigated (approximately 4% of the total). Mendoza is the province with the largest irrigated area (267,889 hectares), which equivalent to approximately 19.8% of the total irrigated area in Argentina.

The main treatment plants in the province of Mendoza are those of Campo Espejo and El Paramillo. They process almost 80% of the domestic liquid waste treated in the province. Both use systems with stabilization ponds. The Campo Espejo purification plant treats approximately 140,000 m³/day (1.7 m³/s), which are used to irrigate approximately 2,000 hectares through direct reuse (Fasciolo *et al.*, 1998), and which eventually indirectly irrigate over 10,000 hectares through the Jocoli canal (Barbeito Anzorena, 2001). The El Paramillo purification plant treats approximately 91,000 m³/day (1 m³/s), which are used to irrigate around 1,800 hectares in summer (Álvarez *et al.*, 2008).

According to the information available (Fasciolo *et al.*, 1998; Barbeito Anzorena, 2001; Álvarez *et al.*, 2008) and the total surface irrigated in the province of Mendoza (INDEC, 2007), less than 2% of this surface is irrigated through the direct reuse of treated wastewater.

Chapter 12 of Resolution N° 400/2003 of the General Irrigation Department of the Province of Mendoza specifies the irrigation methods permitted by the Special Restricted Cultivation Area Regulations (ACRE): seedbeds without a slope, furrows without sewers at the base, subsurface irrigation and localized irrigation, and expressly prohibits irrigation by sprinkler, pivot or similar methods that project effluent into the atmosphere.

Numerous towns in the metropolitan area of Buenos Aires have experienced the progressive rise of water tables, and have discussed the origins of the phenomenon, the individual relevance of its causes and emerging responsibilities. Moreover, the water that emerges has serious quality problems. In short, the uncontrolled rise of water has caused the following problems: the flooding of basements even in zones on high ground, foundation problems in various types of structure, upwelling of water in low zones with flooded land, slump of blind wells, polluted water in contact with the population, destruction of pavements, in short, a serious decline in the quality of life (Bianchi and Lopardo, 2003).

According to certain preliminary explanations, the phenomenon could result from an increase in rainfall and climate factors. Others say that it is caused by anthropic actions such as the lack of sewers in the affected zones, the importation of water through drinking water pipelines from sources outside the basin, the sharp decrease in water supply through domestic wells, the elimination of the provision of industrial water through local wells and the systematic retraction of the public supply of drinking water from underground sources.

A specific study has been carried out in a region in a “water emergency” state in the Lomas de Zamora district in the southern zone of Greater Buenos Aires, with an area of approximately 88 km² and a high population density, which rose from 574,330 in 1991 to 627,806 in 2003. Lomas de Zamora is located in a low region of the basin of the Matanza river, which is very inefficient in comparison with the natural drainage network into the Matanza-Riachuelo system, and makes the district more vulnerable than medium and large areas in regions in the Buenos Aires metropolitan area.

Since high population growth has not been accompanied by a rise in basic sanitation infrastructure, anthropic causes also interfere negatively with natural ones, such as the increase in rainfall. In 1991, the drinking water network served 69.9% of the population of the Lomas de Zamora district, while the sewerage network covered only 22.7%. The drinking water network currently supplies 90%, but uses surface water,

imported through large-sized pipes from treatment plants in Río de la Plata. On the other hand, the sewerage network has been omitted from the concession's work plan, remaining in a service that only serves 33% of the district's population. Other anthropic factors specific to the district must be taken into consideration, such as deforestation, the dismantling of the industrial belt (which requires much less pumped water) and the aforementioned change in the drinking water supply source, which has a double impact. Indeed, when pumping from the aquifer ceases the pressures on it increase, and when water is incorporated into the region without associated sewage and rainwater drainage works, more water is absorbed into the ground.

Exploitation of the "Puelches" aquifer began in 1920. The expansion of its use for public and industrial supply caused an extraction rate far above its natural recharge, and produced cones of depression that reached apices of -35 m and -40 m in 1975 (Santa Cruz, 2000). The area with the highest exploitation of the aquifer was the one with the thickest aquifer. The most significant development of the cones of depression took place in the south east of the district, where the public supply wells were located, and in the south zone, the most industrially developed area. This overexploitation of the aquifer and the decline in quality (due to an increase in nitrate concentration), led to the progressive abandonment of the supply of groundwater for domestic use. When this supply service was abandoned, the number of active wells fell from 114 in 1990 to just 13 in 2001. Moreover, industries drastically reduced their extractions due to the economic crisis of that era, causing a recovery of the piezometric levels, and a change in the size and location of the cones.

The decrease or suspension of domestic primarily affected the north-east zone. In this zone, in the period from 1991 to 1995, pumping was 16.1 Hm³ and in the period from 1996 to 2000, pumping had dropped to 7.5 Hm³, equivalent to only 34% of the volumes obtained through anthropic means. This decrease in discharge capacity was a result of the change in supply source. In short, the variations in the phreatic level had different causes and degrees of affectation, according to their geographical location.

Moreover, by associating the behavior of the phreatic level with these locations, various patterns of functioning were distinguished according to the topographic characteristics, degree of urbanization, deactivation of perforations (for both drinking water and industry), water imports, and the development and age of the drinking water, sewage and rainwater networks. These characteristics gave rise to a new concept, making it possible to manage the treatment of the problem, defined as "homogenous zones" (Bianchi et al., 2005). This determined the areas or zones in which the vertical movements (recharge or discharge) of the phreatic surface are produced from the predominance of a specific factor, whether natural or anthropic. It is thought that due to the low slopes of the metropolitan area, vertical movements prevailed over horizontal ones.

This experience demonstrated the need for in-depth studies on the natural and anthropic influence before making changes in the supply sources of drinking water in zones with incomplete sanitation.

9. Problems Associated with Surplus Water in Major Urban Centers

Undoubtedly, the main challenge faced by Argentina as regards water is to provide the entire population with integral drinking water and sanitation coverage, principally in the urban center of Buenos Aires and its conurbation. However, this urban conglomerate presents another equally significant obstacle linked to excess water management.

The numerous recent floods in various cities in the metropolitan area in particular, as well as the province of Buenos Aires have highlighted a challenge as significant as drinking water management and distribution. This challenge is linked to the capacity to conduct an integral analysis of the causes, effects and solutions associated with growing urban development, whereby the essence of the problem is the unplanned occupation of the flood valleys of rivers and streams.

Structural Vulnerability of Urban Centers

This progressive advance of the urban area provides the backdrop to a structural vulnerability that even the construction of large sanitation works has failed to eliminate.

Indeed, although for years the natural features of typical fluvial systems have coexisted with the uses and customs of the population, the pursuit of progress in the late 19th century and early 20th centuries fostered the rapid advance of urbanization on waterways, which resulted in the creation of piping or specific interventions on the original waterways, which attempted to conceal the natural traits of the system in order to develop neighborhoods, infrastructure and services. The dilemma of the occupation of land close to river courses (typically flood plains) has been a known fact since ancient times. The presence of a nearby waterway provides benefits for the development of a population, despite the damage floods are known to cause (Aradas and Bacchiega, 2012).

A clear example of this indiscriminate advance is given in Figure 7, which shows the gradual expansion of the metropolitan area of the city of Buenos Aires from 1750 to the present. It shows how waterways were progressively occupied by the urban infrastructure that invaded not only the flood valley, but also led to the occupation though piping of the courses themselves.

This uncontrolled growth has been identified in most of Argentina's riverside cities, where catastrophic floods have occurred at least once in the past 50 years. Example of this include Buenos Aires itself, La Plata, Villa Elisa, Luján, San Antonio de Areco, Arrecifes, Pergamino and Santa Fe, all of which have populations of between 30,000 and 3 million inhabitants.

The Influence of Climatic Variability

Beyond the structural vulnerability to flooding of many of Argentina's urban centers, complementary aspects exist that become parallel causes to the increase in recorded cases of urban flooding. Climatic variability and the main meteorological

Figure 7. Evolution of the urban area of Buenos Aires

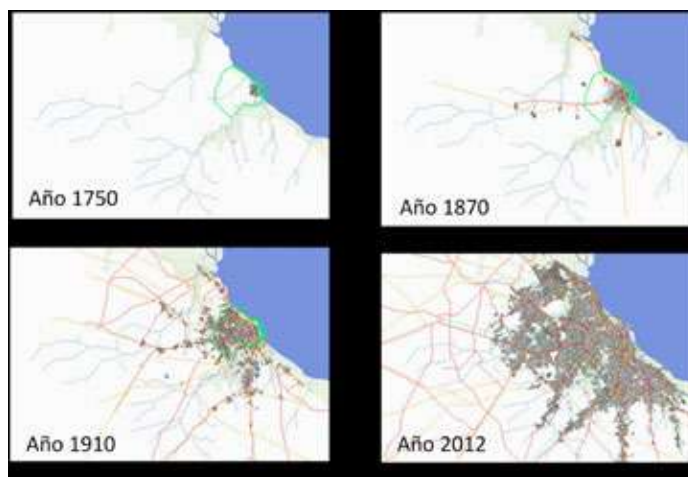
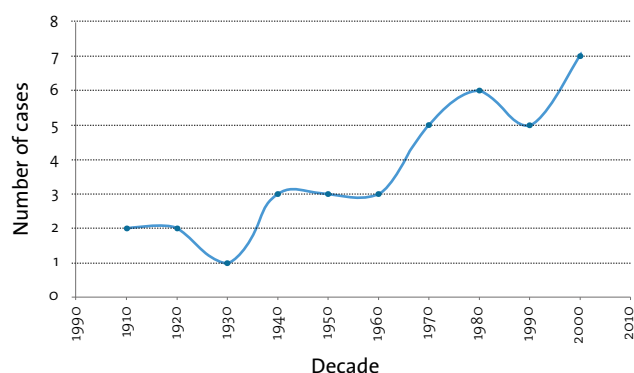


Figure 8. Number of cases per decade with rainfall of over 100 mm/day



parameters' tendency to change are undoubtedly aspects to be considered.

Changes in average global temperatures can be a leading cause of the increasing rainfall observed in many regions of the world. In this context, records indicate that in the past 150 years the average temperature of the earth's surface has increased, and that the global temperature has risen by 0.74°C over the past 100 years and around 0.4°C in the past 25 years, the period with the most reliable observations (Camillón, AABA, 2010).

Together with the variation in the temperature recorded globally, in Argentina in general and Greater Buenos Aires in particular, annual and daily rainfall have increased considerably. Figure 8 shows the increase in cases in various decades in which rainfall above 100 mm in a single day was recorded. This number has almost doubled in the past 50 years.

Likewise, changes in other variables linked to climatic variability have been recorded. Río de la Plata is experiencing an increase of its average level (Figure 9), driven mainly by the increase in the average sea level. The total increase was approximately 17 cm in the 20th century, of which approximately 50% took place in the past three decades (Barros and Menéndez, 2005).

In this context of climate change and vulnerability, floods have taken place in major Argentinian cities driven by varying amounts of

rainfall. Table 4 and Figures 10a and 10b show some of the cities affected by severe flooding in recent years, within a radius of approximately 500 km around the city of Buenos Aires.

Each of the storms reported were analyzed separately, as extraordinary events with return periods of above 500 to 1,000 years. However, past records demonstrate that there has been at least one increase in the frequency of occurrence over the past 20 years. Some of the urban centers indicated have suffered more than one catastrophic flood during this period, while in others, such as the city of La Plata, several events have been recorded in a short period, such as those of Buenos Aires and the nearby town of Villa Elisa.

The aforementioned situation is a background to the concept of extreme and extraordinary events mentioned every time a catastrophic event takes place. Likewise, it is important to determine the level of vulnerability of each urban center in the face of rainfall events that, though considerable, are not beyond the probability of occurrence in each city.

Figure 9. Variation in the average level of Río de la Plata
(Barros et al., 2005)

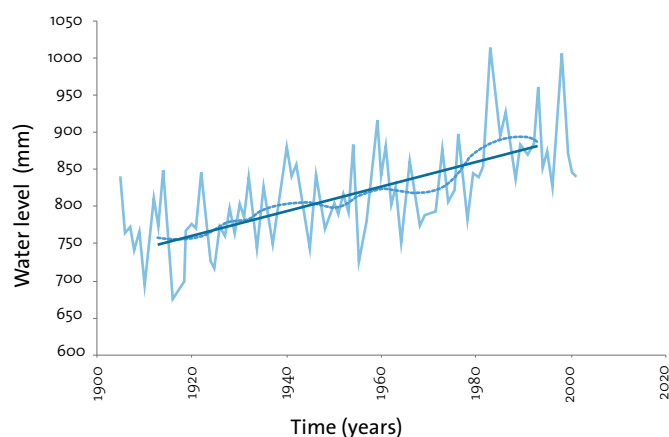


Table 4. Cities close to Buenos Aires with severe flooding

City	Precipitation (mm)	Year of Occurrence
Buenos Aires	100-200	1984-1995-2000 2001-2010-2013
Pergamino	200-436	1995-2009-2011
Santa Fe	400-500	2003-2007
S.A de Areco	250	2009-2011
Villa Elisa	240	2008
La Plata	390	2013

Source: ETOOS, 2003

Flooding in Major Urban Centers

The cities mentioned in which flooding was recorded have heterogeneous populations, which range between 30,000 and 3 million persons, and

Figure 10a. Cities affected by flooding



Figure 10b. Flooding in urban centers in the Pampa region (Bacchiega, 2012)

sizes. However, their common denominator is that they are located in flood valleys of natural channels, making them intrinsically vulnerable.

A common factor of all these centers, particularly the cities of Buenos Aires and La Plata, recently affected by catastrophic events, is their progressive development alongside various natural water ways. These urban development schemes are repeated in all the cases in which water logging processes have been recorded in recent years, meaning that images like those below are the inevitable consequence of the relative location of the cities, regardless of the amount of rainfall they may receive.

It can therefore be argued that in the majority of cases, the likelihood of floods reflects cities' basic vulnerability and the struggle between urban development and the natural geological courses of the natural sewage network. Buenos Aires is a clear example of this combination of effects, since over the decades it has grown in 11 basins that originally drained their surplus into natural riverbeds that are now piped and heavily urbanized. Figure 11 below shows the main hydrographic basins in the urban area of the city of Buenos Aires.

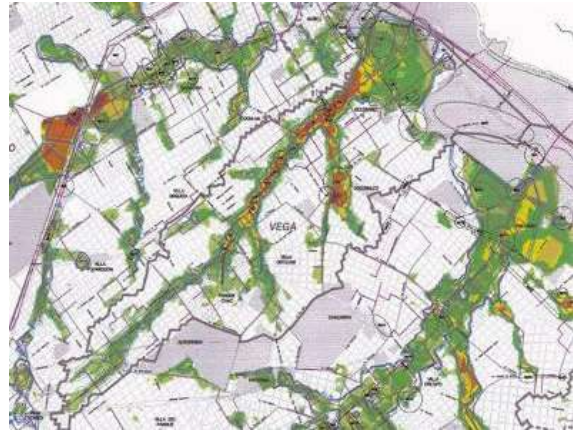
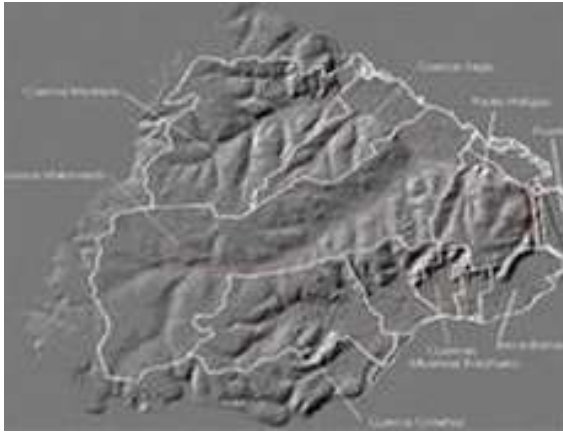
Of the basins indicated, those of Medrano, Vega and Maldonado streams are the most vulnerable as a result of the population density and urban infrastructure. The risk areas and the extent of the floods recorded reflect natural geomorphological characteristics.

The following figure shows the geomorphological formation of the city of Buenos Aires and the corresponding zones of greatest risk, based on the risk maps drawn in the Water Management Plan of the City of Buenos Aires (Consortium of Consultants, 2004).

These water logging and flooding processes have produced severe economic, social and environmental problems. Though these issues have been addressed for years by analyzing causes and solutions, the economic quantification of their effects has been limited.

Figure 11. The city of Buenos Aires. Hydrographic Basins (GCBA, 2013)

Figure 12. The city of Buenos Aires: Geomorphological characteristics and risk areas Medrano, Vega and Maldonado Basins



In the indiscriminate occupation of land and the modification of the flow pattern in water basins and the absorption of water from rainfall, the rainfall, hydrology and topography (with land above sea level that varies between approximately 4 and 24 m) were not taken into account. Social and economic aspects are frequently exacerbated by the pollution of the water flowing in from the districts in the province of Buenos Aires, which comprises large industrial areas. This pollution mainly comprises the flow of agrochemicals used in agriculture and liquid effluents from industrial establishments, and the degradation of the coasts and the water of the Río de la Plata. The total negative impacts have not yet been studied in depth.

One issue common to other urban centers as well as Buenos Aires is that the areas with the highest frequency of flooding are generally those with the highest poverty levels. This increases the vulnerability of the lowest-income sectors.

The city of La Plata, the capital of the province of Buenos Aires, is very similar to Buenos Aires. Located 60 km to the south of the capital, it was planned before its founding in 1882. It was built directly on the flood valleys of three streams whose geomorphology was responsible for the severe flooding recorded in April 2013.

Figure 13 shows the location of the Gato stream and the extent of the flood recorded, following its geomorphological pattern (Aradas and Bacchiega, 2013).

This flood affected over 2,500 inhabitants, and principally struck the valleys of the natural waterways, regardless of the distribution of roads, avenues and rain pipes.

As in Buenos Aires, the most socially vulnerable zones of the city of La Plata are the most severely affected, as the streams' conduction capacity is significantly limited by the progressive occupation of their banks.

Figures 14 and 15 below show the discharge zone of the Gato Stream and the vulnerable zones of the Maldonado Stream.

3 million inhabitants live in the 60 km stretch that separates Buenos Aires, in floodable zones that have not been waterlogged.

Figure 13. City of La Plata. Flooding in 2013

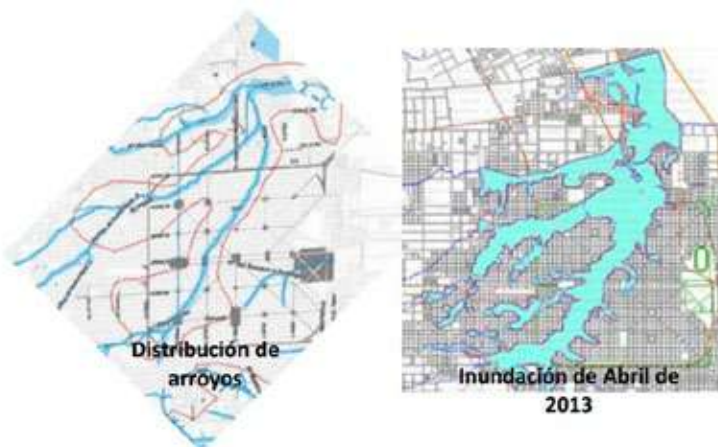


Figure 14. Structural vulnerability in the discharge of the Gato Stream – La Plata



Figure 15. Structural vulnerability in the discharge of the Maldonado Stream – La Plata



Figure 16 shows the existing water basins between the cities of Buenos Aires and La Plata, where a dense urban structure has developed, with high levels of vulnerability. If any of these had been affected by events such as those that occurred in the cities of Buenos Aires or La Plata in 2013, there would have been even more catastrophic consequences. Studies undertaken by the National Water Institute (2014) established the maximum extent of the floods that would have taken place in these basins, had there been 390 mm of rainfall, similar to that observed in La Plata. The figure below displays the highest-risk zones in the basins of the Sarandí, Santo Domingo and Jiménez rivers.

In response to these issues affecting many of Argentina's cities, the traditional procedure of imposing conduction and retention works as the only

solution should be replaced by new management and planning methods that include aspects linked to flood vulnerability, water risk and structural and non-structural action measures, to produce clear guidelines for an integrated management that understand that floods affect society as a whole (Aradas and Bacchiega, 2012).

Thus, the aforementioned intrinsic vulnerability of urban centers must be considered in the protection schemes implemented, risk analysis and therefore the rules for decision-making and defining integral analysis schemes that comprise an adequate combination of structural and non-structural measures. This aspect, which is difficult to implement in most cases, is the greatest obstacle to reducing risks associated with urban water surplus.

The Challenge of Integral Water Risk Management in Argentina's Urban Centers

The structural vulnerability faced by urban centers is the result of the relative position of the infrastructure with regard to the flood valleys of natural waterways that existed before the urbanization process. However, other environmental, socio-economic and political circumstances combine with this natural condition to determine the population's flood vulnerability. These elements, in addition to

the unpredictable rainfalls and high water levels that cause the problem, make it necessary to design the cities' protection levels through an integral risk analysis that links all the elements involved and determines the efficiency of various possible concrete actions.

The floods recorded in the majority of Argentina's riverside urban centers, and the resulting economic and human losses, highlight the need to address this problem comprehensively, giving water surpluses the same level of urgency as droughts.

Flood risk management proposes to mitigate flood risks to an acceptable or tolerable level, either by reducing the frequency of the flooding or its consequences, by decreasing exposure and/or vulnerability. In most cases, flood risk can be mitigated but rarely eliminated.

The aforementioned previous cases, particularly the city of Buenos Aires, have common factors in terms of protection levels before the flood and the measured reactions taken after the event.

- In all cases, the adaptation levels of water infrastructure were not completely implemented.
- Structural solutions that are projected and not always implemented with the planned degrees of protection, with rarely exceed five years of design recurrence, with the exception of the city of Buenos Aires, whose works were intended to be implemented within ten years.
- Low risk perception by the population living in the zones susceptible to flooding.
- Low or no implementation of non-structural measures.
- Low protection levels in actions during the emergency.
- Unplanned and non-contextualized structural actions after the emergency.

These characteristics of the solutions adopted until the present, with the exception of the Water Management Plan developed in the city of Buenos Aires, should help to design an integral approach to the problem of flooding that explicitly recognizes that human settlements and draining influence each other mutually, while acknowledging the fact that even works built with the highest protection level do not substantially change the structural vulnerability of urban centers liable to flooding.

Figure 16. Water Basins of the South Agglomeration of Buenos Aires

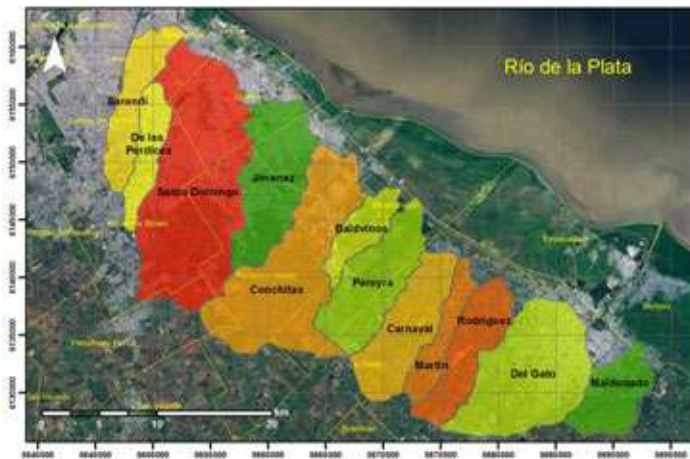
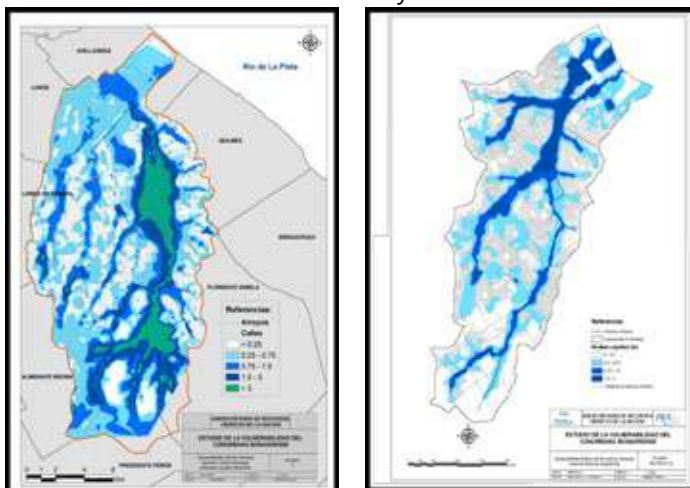


Figure 17. Extent of floods in the southern basins of the city of Buenos Aires



Basin of the Sarandí – Santo Domingo Streams

Basin of the Jiménez Stream

Figure 18. Construction of relief tunnels in the city of Buenos Aires



One example is this is the basin of the Maldonado Stream in the city of Buenos Aires, where two relief tunnels were recently built, with a diameter of 6.90 m and a length of 5 km, under the existing piping. These tunnels were built over 20 m below the surface of the city, and interconnected with the current piping. The high investment cost of this work is justified, to minimize the consequences of flooding caused by storms that recur every ten years. In this context, though the work has been finished, the effects of normal floods have been mitigated, but the intrinsic social and urban vulnerability has not changed, and will continue to exist for more frequent storms.

Based on the previous example, it can be argued that for many years classic project assessment made it possible to strike a balance between the statistical models to estimate the recurrence of extreme events and the technical economic analysis of mitigation works (structural measures), often required to support the financing feasibility of the associated investment amounts. This resulted in works with a recurrence rarely above 20 years. Nonetheless, this analysis model became more complex in response



to the more recurrent extreme events and the challenge of achieving a balance between a more economic model and a more social model that would drive an increase in protection standards.

The decision pattern must obviously prioritize non-structural measures over structural ones, without this minimizing their positive effects on the broad range of recurrence of intense events. It is therefore sensible to consider these

recommendations in the future development of action plans in centers susceptible to flooding in Argentina (Aradas and Bacchiega, 2013).

- Develop integral plans at the basin level where they do not already exist and then follow up on their implementation.
- Consider risk areas, by integrating areas of natural supply that view the basin as a minimum unit and the integration of regions, beyond jurisdictional or political divisions. Consider the formation of basin committees such as technical comptroller, analysis and supervision bodies for integral problems.
- Encourage the authorities to increase awareness of the risk of flooding, principally among the population at risk, by establishing the concept of structural vulnerability as a guiding principle for structural and non-structural solutions.
- Plan land use, giving the appropriate importance to the “security” provided by the works
- Design and check intervention strategies for a broad spectrum of events, to explicitly recognize the uncertainty inherent in meteorological processes.
- Consider existing antecedents in homogenous regions as antecedents characteristic of each urban center, in order to plan mitigation actions jointly.
- Adopt a criteria of “zero” additional runoff for all new urban developments, to preserve the existing infrastructure standard. That is, each new development must absorb and internally manage the excess runoff it causes.
- Implement meteorological records that allow correct interpretation of the temporal and spatial characteristics of the storms.
- Regularly review the measures proposed in the master plans to adapt to the evolution of the problem and the situation of the basin.
- Attempt to make the geomorphological traits of the sewerage system more visible.

10. Conclusions

The main challenge faced by Argentina for drinking water and sanitation is the universalization of these services. It is essential to supply millions of inhabitants currently lacking drinking water and sewerage services. Moreover, it is crucial that works be implemented to increase the treatment of waste water and raise awareness within the government and among professionals, technicians and all sectors of the population regarding the rational use of water and the protection of its quality.

This raises the following challenges: a) Designing and implementing socially and economically sustainable investment plans that prioritize the universalization of services and, where necessary, ensuring their financing by assigning the necessary funds in public bodies' budgets; b) improving the economic sustainability of the supply and achieving an improved rationalization of the tariff regime; c) increasing the efficiency levels of the management of operators and the efficient coordination between sector and jurisdictions; d) perfecting the information system for management and results; and e) promoting the participation of civil society and local authorities. To this end, the following actions are proposed:

- Foster and prioritize investment in the sector, taking into account the benefits resulting from their impact on public health, the environment and the general economy, the reduction of destitution and poverty and social cohesion.
- Establish explicit incentive mechanisms for the efficient management of operating companies and the rational use of services. Tariff regimes should comprise incentives to rationalize water use and supply, which could be achieved by significantly increasing the micro-measurement of the amounts consumed by users, and through investment to reduce losses in water networks.
- Strengthen regulation and control functions for service provision, to ensure the technical capacity and independence of action of the organizations responsible for these actions.
- Improve the legal and institutional mechanisms relating to the participation of

civil society and local authorities, and enhance the dissemination and communication of information on the performance of control operators and authorities, and, primarily in elementary and high schools, foster education actions on the issues associated with drinking water and sanitation and their importance in preserving public health and the environment.

In addition to the problems existing in the water and sanitation sector, Argentina faces significant challenges for the handling, control and management of surplus water in urban centers. The intense rainfall recorded in nearby areas, with periods of occurrence below 20 years proves that large floods are not uncommon problems. Moreover, the increasing urban progress towards rivers' and streams' flood valleys has increased vulnerability in the majority of riverside cities.

The city of Buenos Aires and other nearby cities experience severe problems in managing water surplus linked to urban growth. Numerous floods have been recorded in the past 30 years, with significant economic and human losses. As an example of the path to follow, the city of Buenos Aires has implemented a successful Water Management Plan, which made it possible to establish the principal causes and consequences of flooding processes, and set guidelines for conduction works that mitigate the effects of frequent flooding. However, these engineering works, with the application of advanced technologies, do not ensure total protection from future floods.

This is why the greatest challenge in surplus management is the integral analysis of the problem, with a proper balance of structural and non-structural measures. This is crucial in the agglomeration of Buenos Aires, home to over 10 million inhabitants, the majority of whom are unaware of the risk posed by future flooding.

In response to this problem, it is recommended that priority be given to structural and non-structural actions to mitigate the effects of excess water in densely populated urban ones, the rise in water tables and disasters caused by heavy rain.

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