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Reports

# Transboundary River Basin Overview – La Plata

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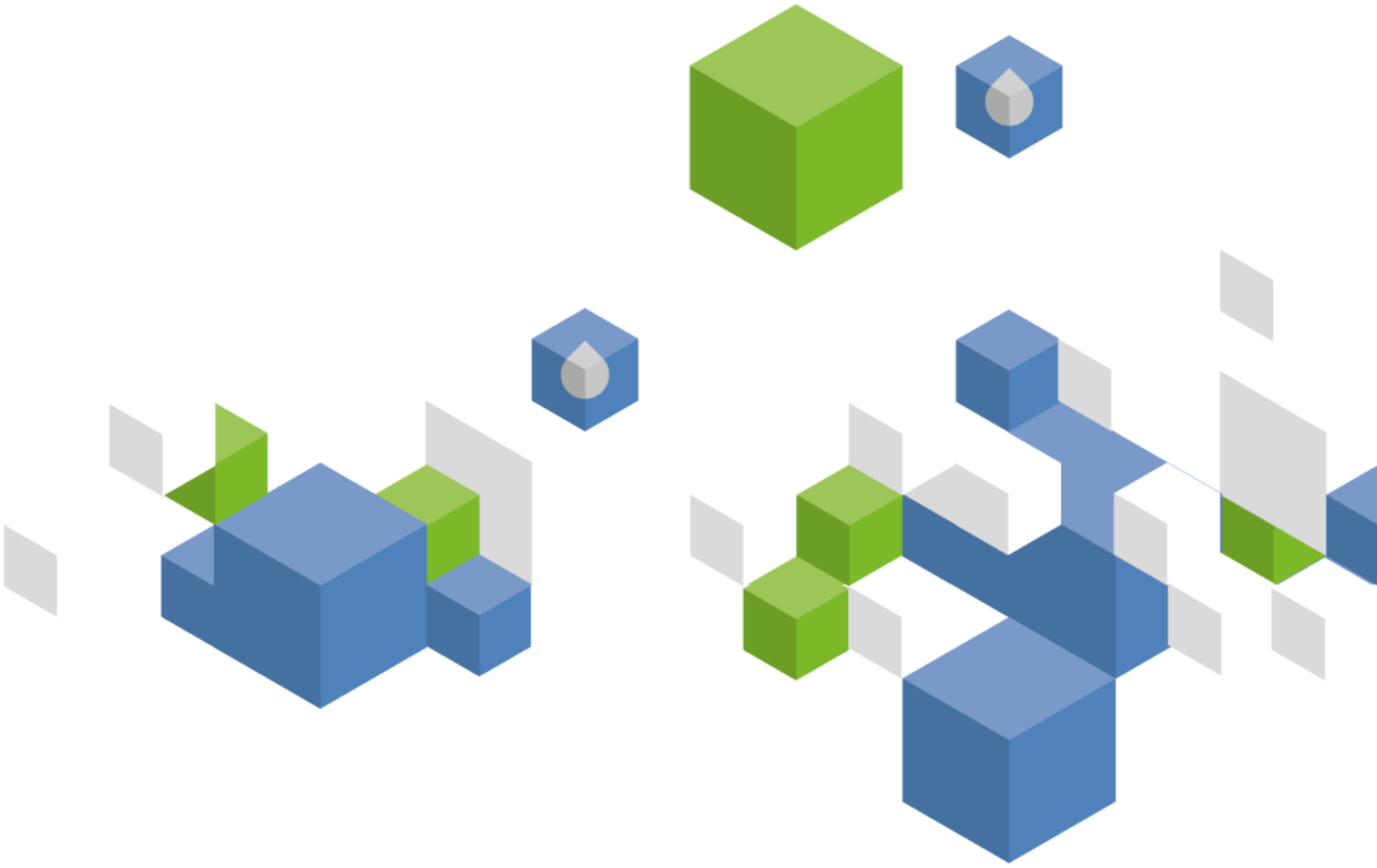

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# La Plata transboundary river basin

## GEOGRAPHY, CLIMATE AND POPULATION

### Geography

The La Plata basin is a transboundary river basin, situated between approximately 67°W and 43°W longitude and 15°S and 38°S latitude (CIC, 2016). It has a total area of about 3.1 million km² (VAMOS, 2001), distributed between Brazil (46 percent), Argentina (30 percent), Paraguay (13 percent), the Plurinational State of Bolivia (7 percent) and Uruguay (5 percent) (Table 1 and Basin map). It is bounded to the west by the Pampean ridges and the pre-mountain range of the Andes and to the northeast and the east by the Brazilian Plateaus and the Serra do Mar respectively. It is the fifth largest basin in the world and second only to the Amazon river basin in Southern America (Barros, Clarke and Silva Días, 2006; LPB ISG et al, 2005). The Amazon and La Plata river basins together cover more than half of the total area of Southern America. The principal sub-basins are the Parana, Paraguay and Uruguay river sub-basins (see Basin map).

The basin includes the entirety of Paraguay, 79 percent of Uruguay, 33 percent of Argentina, 19 percent of the Plurinational State of Bolivia and 17 percent of Brazil.

TABLE 1
**Country areas in the La Plata River Basin**

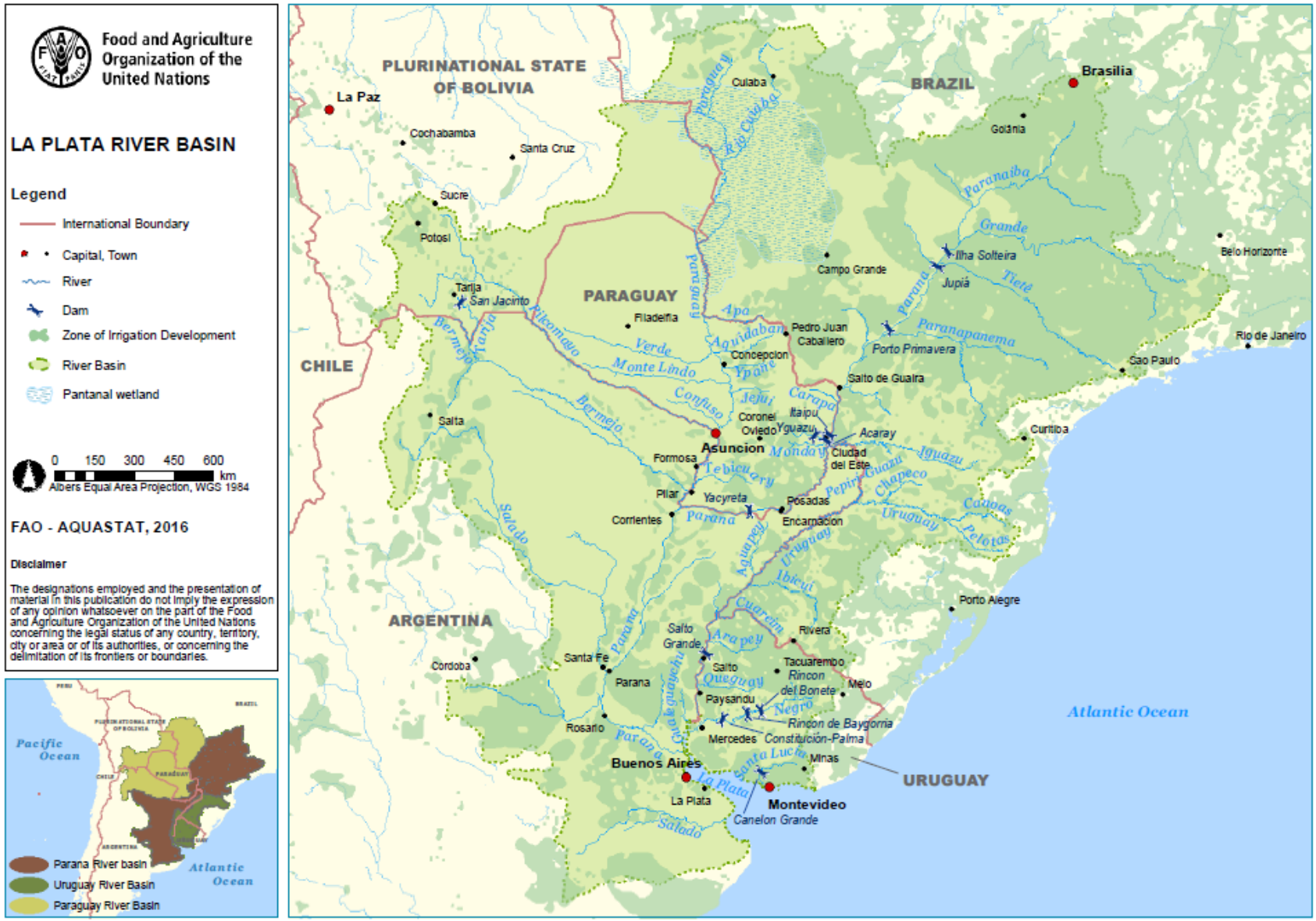
| Basin | Area | | Countries included | Area of country in the basin (km²) | As % of total area of the basin | As % of total area of the country |
|---|---|---|---|---|---|---|
| | km² | % of Southern America | | | | |
| Total | 3 086 000 | 17 | Argentina | 920 000 | 30 | 33 |
| | | | Bolivia (Plurinational State of) | 205 000 | 7 | 19 |
| | | | Brazil | 1 415 000 | 46 | 17 |
| | | | Paraguay | 406 800 | 13 | 100 |
| | | | Uruguay | 139 200 | 5 | 79 |

*Note: Compiled by AQUASTAT based on: Barros, Clarke and Silva Días, 2006; CIC, 2016; UN-HABITAT, NOLASCO, 2016*

The La Plata Basin contains several important and varied ecosystems (CIC, 2016; Flinker, 2012, Barros, Clarke and Silva Días, 2006; OAS):

- The Pantanal is one of the world's largest wetlands with an area that can be as large as 140 000 km² (VAMOS, 2001). It is located in the upper part of the basin of the Paraguay river and shared by Brazil, the Plurinational State of Bolivia and Paraguay. It has an enormous biological wealth and works as regulator of the hydrological system of the basin. A large wetland corridor links the Pantanal with the Delta del Parana.

Figure 1
**La Plata River Basin**



- The Chaco is the second largest biome of South America. It corresponds to an alluvial area located east from the Andes mountain range, formed by the deposit of sediments, mainly from the Bermejo and Pilcomayo rivers. The Bermejo river, which has its source in the Andes mountains, constitutes a natural ecological corridor among the puna ecosystems in the mountain, the yungas forest and the dry and humid areas of the Chaco plains.
- The Pampas's plain is the third ecosystem of global importance. It has the most fertile soils in the La Plata basin and agricultural production has settled since long in the area.
- The Cerrado, located in the north of the basin in Brazil, has a wide biological diversity. It is a mixture of shrubs and pastures. About 45 percent of the area is cultivated.
- The Atlantic forest or Mata Atlantica, to the northeast, is at present characterized mainly by a strong deforestation of its original forests that have been reduced to 4 percent.
- The Delta del Parana covers an area of 14 000 km² in Argentina, starting between the cities of Santa Fe and Rosario, where the Parana river splits into several arms, creating a network of islands and wetlands.

The basin includes a large number, variety, and high degree of endemism in fish species, located in the Paraguay river sub-basin, and the highest number of native birds, located in the Parana river sub-basin.

Plains are predominant in the La Plata basin. Altitudes vary from 1 500 m above sea level (asl) in the Sea Ridge, 1 000-4 000 m asl in the Andes, to less than 2 m asl in the most downstream part of the basin (CIC, 2016; Barros, Clarke and Silva Días, 2006).

The La Plata basin is considered to have lands with high agricultural production capacity (CIC, 2016). The basin is rich in mineral resources, forests, and soil fertility that favour economic development and make the La Plata basin a region that is attractive to population.

The economies of Argentina, Brazil and Uruguay have a strong agriculture and cattle component, but also include a significant level of industrial and service production. Paraguay maintains an agriculture-based economy. The Plurinational State of Bolivia's economy is mainly based in mining, oil and gas, but also agriculture represents an important source of income.

### Climate

The annual mean total precipitation in the La Plata basin is estimated at 1 100 mm; it tends to decrease both from north to south and from east to west. Average precipitation oscillates from 2 000 mm in the northeast of Argentina and in the Serra do Mar and 1 800 mm in the maritime uplands along the Brazilian coast to 200 mm along the western boundary of the basin. Rainfall is high in the upper reaches of the Paraguay and Parana river basins. The northern part of the basin has a well-defined annual cycle with maximum precipitation during summer (December-February). The central region, that includes northeast Argentina and southern Brazil, has a more uniform seasonal distribution, with maxima during spring and autumn.

The mean annual temperature in the basin varies from around 15°C in the south to more than 25°C in the northwest. Most locations east of the Andes have a mean annual temperature of less than 20°C. The higher altitudes in the eastern part of the Brazilian states of São Paulo, Parana and Santa Catarina are substantially cooler than their surroundings. The warm season is from October to April and the cold season from May to September. In January, the maximum mean temperatures are over 28°C in the Chaco and western Argentina, while they are less than 23°C in the coastal areas of southern Brazil, Uruguay and the province of Buenos Aires. In winter, monthly-mean temperatures have a clear north-south gradient. In July, for example, the mean temperature over the northwest part of the basin is more than 20°C, while that in the province of Buenos Aires is around 10°C cooler. In summer the gradient is more zonal reacting to the land ocean distribution (Barros, Clarke and Silva Días, 2006; Mechoso et al, 2001; VAMOS, 2001).

The hydrologic cycle of the La Plata basin is influenced by the South Atlantic High semi-permanent pressure system, which reaches greater intensity near the continent during winter. This system is responsible for the atmospheric moisture flow from the Atlantic Ocean over the coastal ridges of Brazil where the sources of the most important tributaries of La Plata, with the exception of Paraguay river, are located.

Some studies indicate that the interannual variability of the precipitation over the La Plata basin is influenced by El Niño Southern Oscillation (ENSO). This influence varies along each of the ENSO phases, but is particularly strong during the spring (Barros, Clarke and Silva Días, 2006).

The summer circulation over South America is dominated by the South American monsoon system (SAMS). A major seasonal feature of the monsoonal circulation is the Southern Atlantic Convergence Zone (SACZ), which extends south-eastward along the north-eastern boundary of the La Plata basin during the summer season. The SACZ plays an important role in the variability of precipitation in the basin (Mechoso et al, 2001).

### Population

The population of the basin grew from 61 million inhabitants in 1968 to 116 million inhabitants in 1994 (Barros, Clarke and Silva Días, 2006). In 2015, the basin population is estimated at approximately 160 million inhabitants, of which 69 percent in Brazil, 22 percent in Argentina, 4 percent in Paraguay, 3 percent in the Plurinational State of Bolivia and 2 percent in Uruguay. This represents about 60 percent of the combined population of the five countries of the basin, varying from 100 percent of the total population in Paraguay, 88 percent in Uruguay, and 82 percent in Argentina to 54 percent in Brazil and 44 percent in the Plurinational State of Bolivia.

The La Plata basin counts 57 cities with more than 100 000 inhabitants—including São Paulo, the largest city in South America, and four capital cities: Buenos Aires in Argentina, Brasilia in Brazil, Asunción in Paraguay, and Montevideo in Uruguay. Only the capital city of the Plurinational State of Bolivia, La Paz, is not located in the La Plata basin.

While no data are available at the basin-level, at country-level in 2015 access to improved water sources varied from 90 percent in the Plurinational State of Bolivia to 100 percent in Uruguay (Table 2).

TABLE 2
**Access to improved water sources** (Source: JMP, 2015)

| Country | Access to improved water sources (% of population) | | |
|---|---|---|---|
| | National | Urban | Rural |
| Argentina | 99 | 99 | 100 |
| Bolivia (Plurinational State of) | 90 | 97 | 76 |
| Brazil | 98 | 100 | 87 |
| Paraguay | 98 | 100 | 95 |
| Uruguay | 100 | 100 | 94 |

## WATER RESOURCES

### Surface water

The La Plata basin is basically composed of three large sub-basins, corresponding to the Parana, Paraguay and Uruguay rivers. The Paraguay river flows into the Parana river and when the Parana river and the Uruguay river join it becomes the La Plata river near Buenos Aires, flowing into the Atlantic Ocean:

- The Parana river sub-basin: The Parana river has its source at the confluence of the Paranaiba and Grande rivers in southeast Brazil. It has a total length of 2 570 km from the confluence onwards, or 3 740 km if the Paranaiba river upstream of the confluence is also counted. The Parana flows mainly through the plains of Paraguay and Argentina before joining the Uruguay

river. The Parana's main tributary is the Paraguay river, which is described as a separate sub-basin below. The basin has a total area of 1.5 million km² (without the basin of the Paraguay river). The poor natural drainage of the region through which the Paraguay river flows has created the Pantanal wetlands. The Parana river is usually divided into Upper Parana, from its source up to the city of Corrientes in Argentina (close to the border with Paraguay), and Low Parana, from Corrientes up to its outlet in the La Plata river. In the Upper sub-basin, characterized by a quick runoff, it receives the contribution of numerous tributaries, among which the Paranapanema, the Iguazu and the Tietê rivers. The main tributaries of the Parana river flowing from Paraguay are the Acaray, Monday, Piratiy and Carapa river. In the Low Parana the course extends with a very slight decline to the La Plata river. This sector presents very low coasts, especially on its right bank, so that the very high discharges cause severe floods. Stretches of the river mark the boundary between Paraguay and Brazil, and between Paraguay and Argentina (Barros, Clarke and Silva Días, 2006; CIC, 2016; VAMOS, 2001).

- The Paraguay river sub-basin: The Paraguay river has its source in the central region of the Brazilian State of Mato Grosso, not far from the Plurinational State of Bolivia, on the oriental slope of the "Chapada do Parecis" and ends in the Parana river in the south of Paraguay at the border with Argentina, running along 2 550 km. Its basin area is 1.1 million km². The sub-basin of the Paraguay river is mainly in a great plain and, with few exceptions, has a small and uniform slope. Its elevation rarely exceeds 70 m above sea level. The sub-basin can be subdivided in four areas: Pantanal, High Paraguay, Middle Paraguay and Low Paraguay. The main tributaries of the Paraguay river are Pilcomayo river, originating in the Plurinational State of Bolivia and forming the border between Paraguay and Argentina, and Bermejo river, flowing through Argentina and reaching the Paraguay river not far upstream from the point where the Paraguay river flows into the Parana river. Other important tributaries of the Parana river are the Cuiaba, the Apa, Aquidaban, Ypane, Jejui, Tebicuary, Verde, Monte Lindo and Confuso rivers (Barros, Clarke and Silva Días, 2006; CIC, 2016).

- The Uruguay river sub-basin: The Uruguay river has its source in the State of Santa Catarina in Brazil in the convergence of the Pelotas and Canoas rivers, which have their origin in the Serra do Mar and Geral, at almost 2 000 m above sea level. The river has a total length of 1 600 km (Flinker, 2012) and the basin has a total area of 0.4 million km². The hydrological regime of the Uruguay river is very irregular due to irregular precipitation. The Uruguay river is the only large river of the La Plata system that is not a tributary of the Parana. Two of the tributaries of Uruguay river, the Cuareim river and the Pepiri-Guazu river, form a portion of the international border between Brazil and Uruguay and between Brazil and Argentina respectively. After receiving the flow of the Pepiri-Guazu river, the Uruguay river forms the border between Argentina and Brazil until its convergence with the Cuareim river where it becomes the border between Argentina and Uruguay. After the confluence with Negro river, its major tributary with 850 km and 71 000 km², the Uruguay river becomes wider and an extension of the Plata river. (Barros, Clarke and Silva Días, 2006; CIC, 2016; VAMOS, 2001). Other important tributaries of the Uruguay river are the Chapecó (248 km) and Ibicuí (290 km) in Brazil, the Aguapey (310 km) and Gualeguaychu (268 km) in Argentina and the Arapey (240 km) and Queguay (280 km) in Uruguay.

- The La Plata river sub-basin: The La Plata river is formed by the confluence of the Uruguay and the Parana rivers. The river is about 290 km long, and it widens from about 2 km at the confluence to about 250 km at its mouth between San Antonio cape in Argentina and Santa Maria cape in Uruguay, where it empties into the Atlantic Ocean. La Plata river sub-basin covers approximately 0.1 km². It forms part of the border between Argentina and Uruguay, with the major ports and capital cities of Buenos Aires and Montevideo on its western and northern shores, respectively. The coasts of La Plata are the most densely populated areas of Argentina and Uruguay.

Information on the average discharge of the La Plata river into the Atlantic Ocean varies from 23 000 to 28 000 m³/s. Table 3 below shows the contribution by country and by sub-basin to the annual discharge of the La Plata basin.

TABLE 3
**Mean annual runoff in the La Plata River Basin (by country) (km³/year)**

| Country | Sub-basin | | | Total La Plata basin | |
|---|---|---|---|---|---|
| | Paraguay | Parana | Uruguay | (km³/year) | (%) |
| Argentina | 23 | 77 | 16 | 116 | 13 |
| Bolivia (Plurinational State of) | 16 | 0 | 0 | 16 | 2 |
| Brazil | 74 | 360 | 129 | 564 | 64 |
| Paraguay | 76 | 41 | 0 | 117 | 13 |
| Uruguay | 0 | 0 | 71 | 71 | 8 |
| **La Plata basin** | **189** | **478** | **217** | **884** | **100** |

*Notes:*
- *The distribution of runoff between the Paraguay, Parana and Uruguay sub-basins in Argentina has been estimated by AQUASTAT based on "World Water Vision, 2000".*
- *The distribution of runoff between the Paraguay and Parana sub-basins in Paraguay has been estimated by AQUASTAT based on "CIC, 2004".*
- *Total maximum flow in the basin is estimated at 28 000 m3/s, or 883.6 km3/year, by "UN-HABITAT, NOLASCO, 2016".*

The contribution of Argentina to the La Plata basin is estimated by AQUASTAT at 115.98 km³, of which to the Paraguay river sub-basin 22.74 km³, to the Parana river sub-basin 77.00 km³ and to the Uruguay river sub-basin 16.24 km³. Inflow in Argentina from other countries in the La Plata basin accounts for 513.13 km³, of which 10.10 km³/year from the Plurinational State of Bolivia (Bermejo river in the Paraguay river sub-basin), 377.45 km³/year from Brazil (326.40 km³/year through Parana river and 51.05 km³/year through Iguazu river in the Parana river sub-basin); 125.58 km³/year from Paraguay (73.27 km³/year through Paraguay river and 52.31 km³/year through Parana river). The accounted flow of border rivers is estimated at 67.96 km³/year, of which 2.96 km³ (5.92/2) correspond to Pilcomayo river in the Paraguay river sub-basin, border river with Argentina, and 65.00 km³ (130.00/2) correspond to Uruguay river, border river with Brazil. The outflow to Brazil is estimated at 50 percent of the 20.00 km³ of the flow of Uruguay river generated in Argentina.

The contribution of the Plurinational State of Bolivia to the La Plata basin is only through the Paraguay river sub-basin with 16.02 km³/year, of which 10.10 km³ flow to Argentina through Bermejo river and 5.92 km³ to Argentina through Pilcomayo river, which comes from the Plurinational State of Bolivia to become the border between Argentina and Paraguay. Paraguay river borders the Plurinational State of Bolivia for about 35 km, but is not accounted for since such a short distance.

The contribution of Brazil to the La Plata basin is as follows: to the Paraguay river sub-basin 74.40 km³, to the Parana river sub-basin is 359.90 km³ and to the Uruguay river sub-basin 129.40 km³. The outflow from Brazil to other countries in the basin is: 70.00 km³/year to Uruguay (Negro river in the Uruguay river sub-basin and Uruguay river, which comes from Brazil to become the border between Argentina and Uruguay), 442.45 km³/year to Argentina (Iguazu river in the Parana river sub-basin, Parana river and Uruguay river, which comes from Brazil to become the border between Argentina and Uruguay), 73.27 km³/year to Paraguay (Paraguay river). The Paraguay river does border Plurinational State of Bolivia only over a very short distance (35 km) and therefore is not counted as flowing from Brazil to the Plurinational State of Bolivia.

The contribution of Paraguay to the La Plata basin is 117.00 km³, of which to the Paraguay river sub-basin 76.05 km³ and to the Parana river sub-basin 40.95 km³. The inflow from other countries in Paraguay is estimated at 73.27 km³/year, which corresponds to Paraguay river from Brazil. The accounted flow of border rivers accounts for 197.53 km³: (i) 50 percent of the total flow of Parana river (border between Paraguay and Brazil and between Paraguay and Argentina): 163.20 km³; (ii) 50 percent of Iguazu river in the Parana river sub-basin, at the confluence with Parana river: 25.53 km³; (iii) 50 percent of Pilcomayo river in the Paraguay river sub-basin, border river with Argentina: 2.96 km³; (iv) 50 percent of Bermejo river in the Paraguay river sub-basin, at the confluence with Paraguay river:

5.84 km³. The outflow to Argentina is estimated at 125.58 km³/year, of which 52.31 km³/year through Parana river and 73.27 km³/year through Paraguay river.

The contribution of Uruguay to the La Plata basin is 70.90 km³, of which Uruguay river accounts for 21.90 km³, Negro river in the Uruguay river sub-basin for 40.30 km³, Santa Lucia river in the Uruguay river sub-basin for 5.50 km³ and La Plata river for 3.20 km³. The inflow from other countries in Uruguay is estimated at 80.00 km³, of which Negro river from Brazil accounts for 5.00 km³, and Uruguay river accounts for 75 km³ or 50 percent of the total flow of 150 km³ (border river with Argentina).

In the upper Parana river and Paraguay river sub-basins, the rainy season occurs during summer. In the Uruguay river sub-basin, on the other hand, high-flow season occurs during winter (VAMOS, 2001).

### Groundwater

The basin also encompasses the Guarani aquifer, one of the world's largest groundwater reservoirs, with an estimated area of 1.2 million km², the majority beneath Brazilian territory (71 percent of the total area of the aquifer), followed by Argentina (20 percent), Paraguay (6 percent) and Uruguay (3 percent). The aquifer's depth varies between 50 m and 1 800 m. The total volume of the aquifer is estimated at 45 000 km³. However, the exploitable volume corresponds to the natural recharge calculated at approximately 166 km³/year (CIC, 2016).

Another important groundwater system is the Yrenda-Toba-Tarijeño (SAYTT) Aquifer System, entirely contained within La Plata basin in the semiarid Chaco of Argentina, the Plurinational State of Bolivia and Paraguay. The annual recharge for this aquifer in the territory of Paraguay is 2 460 km³ (Monte Domecq y Báez Benítez, 2007).

The Patiño aquifer in the central area of Paraguay is also an important aquifer in the basin. However, it is overexploited. According to the 2005 water balance, the aquifer has an annual recharge of 0.175 km³ while total annual withdrawal is 0.249 km³ (Monte Domecq y Báez Benítez, 2007).

In Uruguay, besides the Guarani aquifer, the main aquifers in the La Plata basin are Raigon, Salto and Mercedes. The Raigon aquifer, with a total area of 1 800 km², is located in the Santa Lucia river basin and is strategic due to its use for water supply for Montevideo and for irrigation and livestock. The Salto aquifer, in the north-west of the country, is mainly used for irrigation of vegetables. The Mercedes aquifer, of approximately 20 000 km$^2$, is located to the west of the Uruguay river and is mainly used for water supply.

## WATER-RELATED DEVELOPMENTS IN THE BASIN

### Water use

Agriculture and livestock account for the largest withdrawals of water in the La Plata basin. The basin also provides the water for the households in the region, which is the most populated of South America. Rivers are natural waterways and the volume transported over rivers has greatly increased in the last decades. The navigation historically led to the development of important urban centres along the rivers in the basin. The basin accounts for the generation of most of the electricity of the countries. Around 70 percent of the total Gross Domestic Product (GDP) of the five countries of the basin is produced in the area of the basin (Barros, Clarke and Silva Días, 2006; Flinker, 2012; LPB ISG et al, 2005; VAMOS, 2001). Mining is also an important economic activity in the region (CIC, 2016).

In Paraguay, which is entirely located in the basin, total water withdrawal in 2012 was an estimated 2 413 million m³ of which 79 percent for agriculture, 15 percent for municipalities and 6 percent for industry. Surface water withdrawal accounts for 82 percent and groundwater withdrawal for 18 percent.

Irrigation uses mainly surface water, while drinking water supply uses mainly groundwater. Direct use of treated wastewater also takes place in some areas of the basin, but no data is available.

In Brazil, the water withdrawal in the La Plata basin in 2006 was an estimated 21 140 million m³, which represents 36 percent of the total withdrawal of the country, equal to 26 percent in the Parana basin, 8 percent in the Uruguay basin and 2 percent in the Paraguay basin. Agriculture and livestock accounted for 44 percent of the total water withdrawal in the basin, municipalities for 31 percent and industry for 25 percent. Parana sub-basin was responsible for 27 percent of the total withdrawal of the country, while it has only 6 percent of the water resources of the country. Water availability is at a critical level in the Parana sub-basin due to the high population density, while it is at a critical level in the Uruguay sub-basin due to the high demand for irrigation (ANA, 2009).

In the Upper Parana river, above the confluence with the Iguazu river at the border point with Paraguay and Argentina, main issues are the use and operation of the huge hydropower production and the change in land use from natural forest to cropping systems based on soybean production. In the lower courses of the Paraguay and Parana rivers, main issues of hydrological concern are navigation and flood control (VAMOS, 2001).

### Dams and hydropower

There are approximately 75 dams in the La Plata basin (Flinker, 2012). Table 4 shows the main dams by country in the basin.

The Parana river and its tributaries account for the largest number of dams in the basin.

The Itaipu reservoir in the Parana river, not far from Iguaçu Falls, is shared between Brazil and Paraguay. It is the largest dam in the basin with a total capacity of 29 000 million m³ and has the largest hydroelectric plant in the world with a total installed capacity of 14 000 MW and an average production of 12 600 MW.

The Furnas hydroelectric dam on the Grande river in Brazil is the second largest dam in the basin with a reservoir capacity of 22 950 million m³, followed by the Ilha Solteira dam on the Parana river in Brazil with 21 046 million m³.

The Yacyreta hydroelectric dam, on the Parana river, is located on the border between Argentina and Paraguay. The total capacity of the dam is 21 000 million m³. The hydropower generated by this dam, which has a total capacity of 3 200 MW, is mainly used by Argentina.

The Salto Grande dam, on the Uruguay river, is located on the border between Argentina and Uruguay, and has a capacity of 5 500 million m³. The power plant has a total capacity of 1 890 MW, which covers 6 percent of the power demand of Argentina and 50 percent of the power demand of Uruguay.

Other important dams on the main course of the Parana river in Brazil are the Porto Primavera with a total dam capacity of 20 320 million m³ and the Jupia dam with 3 354 million m³.

The main dams in Paraguay in the basin are, besides the Itaipu dam shared with Brazil and the Yacyreta dam shared with Argentina, the Yguazu and Acaray dam with 8 473 million $m^3$ and 56 million m³ respectively. The main purpose of these dams is hydropower generation, but it is also used for irrigation and water supply.

In Uruguay the main dams in the basin are, besides the Salto Grande dam shared with Argentina, the Rincon del Bonete dam, with a total capacity of 8 850 million m³, the Constitucion dam, with 2 850 million $m^3$, and the Rincon de Baygorria, with 570 million m³, all of them hydroelectric dams located in the Negro river.

TABLE 4
**Main dams in the La Plata River Basin**

| Country | Name of dam | Sub-basin | River | Year | Capacity (MW) | Reservoir capacity (million $m^3$) | Main use * |
|---|---|---|---|---|---|---|---|
| Argentina | Yacyreta ** | Parana | Parana | 1994 | 1 600 | 10 500 | H, F |
| | Salto Grande *** | Uruguay | Uruguay | 1979 | 945 | 2 750 | I, H, W |
| Bolivia (Plurinational State of) | San Jacinto | Paraguay | Tolomosa | 1986 | - | 50 | I, H |
| Brazil | Furnas | Parana | Grande | 1963 | 1 216 | 22 950 | H |
| | Ilha Solteira | Parana | Parana | 1973 | 3 444 | 21 046 | H |
| | Porto Primavera | Parana | Parana | 1999 | 1 540 | 20 320 | H |
| | Emborcação | Parana | Paranaiba | 1983 | 1 192 | 17 725 | H, F |
| | Itumbiara | Parana | Paranaiba | 1981 | 2 082 | 17 027 | H |
| | Itaipu **** | Parana | Parana | 1984 | 7 000 | 14 500 | H |
| | Três Irmãos | Parana | Tiete | 1999 | 808 | 13 371 | H |
| | São Simão | Parana | Paranaiba | 1979 | 1 710 | 12 540 | H |
| | Água Vermelha | Parana | Grande | 1979 | 1 396 | 11 025 | H |
| | Capivara | Parana | Parapanema | 1977 | 619 | 10 542 | H |
| | Chavantes | Parana | Paranapema | - | - | 8 795 | H |
| | Promissão | Parana | Tiete | - | - | 7 407 | H |
| | Manso | Paraguay | Manso | - | 210 | 7 337 | H |
| | Jurumirim | Parana | Paranapanema | - | 100 | 7 008 | H |
| | Salto Santiago | Parana | Iguazu | - | - | 6 776 | H |
| | Marimbondo | Parana | Grande | - | - | 6 150 | H |
| | Foz Do Areia | Parana | Iguazu | - | - | 5 779 | H |
| | Ita | Uruguay | Uruguay | - | 1 450 | 5 100 | H |
| | Boa Esperança | Parana | Paranaiba | - | 272 | 5 085 | H |
| | Mascarenhas De Moraes | Parana | - | - | - | 4 040 | H |
| | Salto Caxias | Parana | - | - | - | 3 573 | H |
| | Jupia | Parana | Parana | - | - | 3 354 | H |
| Paraguay | Itaipu **** | Parana | Parana | 1984 | 7 000 | 14 500 | H |
| | Yacyreta ** | Parana | Parana | 1994 | 1 600 | 10 500 | H, F |
| | Yguazu | Parana | Yguazu | 1977 | - | 8 473 | I, H, W |
| | Acaray | Parana | Acaray | 1977 | 210 | 56 | I, H, W |
| Uruguay | Rincon del Bonete | Uruguay | Negro | 1945 | 152 | 8 850 | H |
| | Constitucion | Uruguay | Negro | 1982 | 333 | 2 850 | I |
| | Salto Grande *** | Uruguay | Uruguay | 1979 | 945 | 2 750 | I, H, W |
| | Rincon De Baygorria | Uruguay | Negro | 1960 | 108 | 570 | H |
| | Canelon Grande | La Plata | Santa Lucia | - | - | 23 | I, W |

* *I = Irrigation; H = Hydropower; F = Flood control; W = Water supply*
** *Yacyreta dam is shared between Argentina and Paraguay. Total capacity: 3 200 MW and 21 000 million $m^3$*
*** *Salto Grande dam is shared between Argentina and Uruguay. Total capacity: 1 890 MW and 5 500 million $m^3$*
**** *Itaipu dam is shared between Paraguay and Brazil. Total capacity: 14 000 MW and 29 000 million $m^3$*

The most important dam of the Plurinational State of Bolivia in the basin is the San Jacinto dam, with a total capacity of 50 million $m^3$.

At the end of the 20th century, the restructuring of the power market within the MERCOSUR countries of Argentina, Brazil, Paraguay, and Uruguay was designed to make hydropower projects more attractive for private investors (VAMOS, 2001).

The basin accounts for the generation of most of the electricity of the countries of the basin (Barros, Clarke and Silva Días, 2006; LPB ISG et al, 2005). The hydroelectric potential in the basin is approximately 100 000 MW of which half is being utilized (Flinker, 2012).

### Agriculture

The La Plata basin is one of the largest food and crop producers in the world. Agriculture is the main economic activity in the basin, where soybean, maize and wheat are produced at large scale. Livestock and fishing are also important sources of food and income. The basin provides most of the food to the basin countries and accounts for most of the exports of these countries. Argentinean provinces in the basin produce more than 90 percent of the country's cereals and oil crops, and grow more than 85 percent of the country's bovines. Brazilian states in the basin produce more than 30 percent of the country's rice, soybeans, wheat, maize, and grow about 10 percent of the country's bovines. Uruguay produces its

entire cereals and oil crops and grows more than 80 percent of its livestock in the basin. The economy of Paraguay, entirely located within the basin, largely depends directly or indirectly on agricultural production, 90 percent of which corresponds to livestock. The main crops of the Plurinational State of Bolivia in the basin are cereals, cotton, sugarcane and soybean. Livestock is also important (Barros, Clarke and Silva Días, 2006; CIC, 2016; Flinker, 2012; Mechoso et al, 2001; VAMOS, 2001).

Agricultural production in the southern region of the La Plata basin primarily develops on the highly fertile soils of the Pampas. The Pampas extend over 75 million ha, of which 26 million ha were cultivated in 2006. The incorporation of updated technology and the revision of inadequate policies for the sector caused a considerable increment of grain production at the end of the 20$^{th}$ century. The cultivated area in the Pampas has increased in detriment of pastures during years with more favourable prices for grain crops compared with those for cattle. Such changes in land use require an intensification of production systems, higher input use, and result in increased risk of land degradation. The organic soil content in some locations was reduced to 50 percent of its value before agricultural practice at the beginning of the 20th century. For this reason and considering other economics aspects, direct seeding or minimum tilling is growing rapidly, driving to certain restoration of the arable area.

Agriculture in the southern Brazilian states of Rio Grande do Sul, Santa Catarina, and Parana is based on land that was originally part of the Atlantic Forest (Mata Atlantica) and the Meridional Forests and Grasslands ecosystems. More than 90 percent of this ecosystem has been gradually converted to agricultural uses since the early 1900s. Agricultural production in southern Brazil is highly mechanized with high crop yields, but has brought serious environmental problems such as soil compaction and erosion, water contamination, and vegetation devastation. The northern region of the La Plata basin includes parts of the Cerrados ecosystem, which is characterized by low fertility soils that are also being gradually converted to annual crops (soybeans, wheat, maize, etc.) (Mechoso et al, 2001; VAMOS, 2001).

Rice represents the major consumer of water, since it is cultivated by the system of flooding and on average uses around 15 000 m/ha per year. Currently this crop extends over the south of Paraguay and in Brazil in the basin of the tributaries of the Uruguay river, Ibicui and Cuareim (Quarai) (Barros, Clarke and Silva Días, 2006).

In 2003, total irrigated area in the basin was an estimated at 3.85 million ha (Barros, Clarke and Silva Días, 2006), representing almost half of the total area equipped for irrigation in the five basin countries. In Paraguay, entirely located in the basin, the area equipped for irrigation is an estimated 136 170 ha in 2012, compared to 67 000 ha in 1998. In Brazil, the area equipped for irrigation in the basin in 2010 accounts for 2 336 000 ha or 43 percent of the total area equipped for irrigation in the country, of which the Parana sub-basin accounts for 34 percent, the Uruguay sub-basin for 8 percent and the Paraguay sub-basin for 1 percent (ANA, 2012). There is no information available on how the remaining 1.37 million ha equipped for irrigation in the basin is distributed amongst the other three countries of the basin: Argentina, Plurinational State of Bolivia and Uruguay.

The most important irrigated crops in the basin are rice, other cereals, soybean, sugarcane, fodder, vegetables and fruit trees.

The area equipped for irrigation in the basin is mainly irrigated by surface water. Groundwater is also used in some areas of the region such as for example in Uruguay where 50 percent of the area of vegetables and fruit trees are irrigated by groundwater. Direct use of treated wastewater is also used in some areas of the basin.

## ENVIRONMENT, WATER QUALITY AND HEALTH

The environmental quality of the La Plata basin is affected by the development reached in the region, namely by the loss of the vegetable cover, urban concentrations, intensive agricultural practices with high dependence of agrochemicals, population growth, highways, mining, dams, industry, river navigation and irrigation projects (Barros, Clarke and Silva Días, 2006; Flinker, 2012).

Deforestation and agriculture are intensive in the three sub-basins: Paraguay, Parana and Uruguay. Agricultural expansion from 1960 onwards particularly in Brazil has left some areas with only 5 percent of its original forest cover. In the Brazilian state of São Paulo the area of primary forest has decreased from 58 percent to 8 percent at the end of the 20th century and in the east of Paraguay the forest area has fallen from 55 percent in 1945 to only 15 percent in 1990. The increasing deposition of sediments appear to be a relevant issue at present as well.

Environmental degradation is also caused by intensive urbanization. Population is highly concentrated in cities in the La Plata basin and the capital cities of all basin countries, except the Plurinational State of Bolivia, are within the La Plata basin. Incomplete treatment of urban wastewater causes a deterioration of the quality of the water.

In the La Plata basin, water resources are already under pressure in certain zones and sectors as a result of the increasing demand.

Amongst the sub-continental regions of the world, Southern South America has shown the largest positive trend in precipitation during the last century. For example, in the west of Buenos Aires province and in part of the Argentina-Brazil border region, the mean annual precipitation increases with more than 200 mm. Increased precipitation has led to increased river discharge. The most adverse effect of this change is the higher frequency and severity of flooding, both at the river valleys and in extensive flat areas of the Pampas. In the alluvial valleys of the Parana, Uruguay and Paraguay sub-basins, floods have become more frequent since the mid-1970s. Floods are one of the major concerns in the La Plata basin due to the damage they cause in almost the whole basin, leading to losses of human lives and considerable damages to infrastructures and the economy, mainly in the urban areas. Most of the damage caused by this phenomenon affects the poorest people of the society that occupy precarious settlements in easily floodable areas. Provinces of north-eastern Argentina periodically have floods as a result of the overflow of the Parana, Uruguay and Paraguay rivers. The extensive deforested areas, the acceleration of flood frequency and the disordered riverside population's growth in the flood plains, increase the problem. Most rivers have long and wide flood plains, which have been settled and cultivated. Existent scientific literature indicates that the largest disastrous flood event characteristics are associated to the El Niño phenomenon (Barros, Clarke and Silva Días, 2006; Flinker, 2012; VAMOS, 2001).

Affected aquatic ecosystems deserve special attention in the whole La Plata basin, characterized as one of the basins of larger continental aquatic diversity of the world, in particular the sub-basins of the Parana and Paraguay rivers (Pantanal) and of its marine front. These ecosystems are constantly and mainly affected by, amongst others, increments of sediments, modifications in the contribution of nutrients to the waters, constructions of dams and reservoirs, pollution of water courses (Barros, Clarke and Silva Días, 2006).

Poor drinking water quality causes diarrheal diseases, which are one of the most important health problems for the population of the region, especially for children. Dengue and malaria are also important water-related diseases in the region.

## TRANSBOUNDARY WATER ISSUES

Before the 1960s, some relevant agreements dealing with water use in the basin already existed.

In 1967, during the First Meeting of Ministers of Foreign Affairs of the countries of the La Plata basin, the Intergovernmental Coordinating Committee (CIC) was established by the governments of Argentina, Bolivia, Brazil, Paraguay and Uruguay as the coordinating mechanism of the basin.

Two years later, in 1969, they signed the La Plata Basin Treaty which is the main legal instrument of the basin and worked for several years as a political interconnection between Argentina, Bolivia, Brazil, Paraguay and Uruguay. Its main objectives are: the wise use of water resources; regional development with preservation of flora and fauna; physical, fluvial and terrestrial integration; and promotion of greater knowledge of the basin, its resources and potential. The treaty can be considered as a precursor, in the preservation of the environment and the generation of infrastructure and communication, in line with what would be MERCOSUR over two decades later. The Treaty and the international instruments that resulted from it created and gave functions to the different bodies, such as the CIC which is the executive body of the System of the La Plata basin, responsible for promoting, coordinating and monitoring the progress of multinational actions for an integrated development of the La Plata basin. It consists of representatives from each of the member countries.

After this treaty, several other treaties were signed by two or more countries, as summarized below and in Table 5.

In 1971, Argentina and Paraguay signed the Convention to study the use of the Parana river's resources and created the Joint Commission of the Parana river.

In 1973, Argentina and Paraguay signed the Yacyreta Treaty, which deals with hydroelectricity, navigation and floods in the Parana river in the area close to the Yacyreta dam.

In 1973, Argentina and Uruguay signed the Salto Grande Joint Technical Commission Creation Treaty.

In 1973, Argentina and Uruguay signed the La Plata River and the Corresponding Maritime Boundary Treaty that provides the geographic coordinates for the boundary points in the Rio de la Plata, affords the status of Martín Garcia Island and other islands in the La Plata river, designates Isla Martin Garcia as the seat of an Administrative Commission for the La Plata river, and regulates the adjacent maritime front.

In 1973, Brazil and Paraguay signed the Itaipú Treaty which created "Itaipú Binacional", the entity responsible for the creation of the Itaipú dam and its energy generation. This treaty generated several conflicts with Argentina, but they were finally resolved in 1979 with the Three Party Corpus and Itaipu Treaty between Argentina, Brazil and Paraguay.

In 1974, the governments of Argentina, Bolivia, Brazil, Paraguay and Uruguay signed the Financial Fund for the Development of the Countries of the La Plata basin (FONPLATA), an entity with international legal status, which was created to act as the financial body of the Treaty on the La Plata basin. Its mission is to give technical and financial support for studies, projects, programmes and initiatives, which work to promote the harmonious development and physical integration of the member countries of the La Plata basin.
In 1975, Argentina and Uruguay created the Administrative Commission of the Uruguay River (CARU), the main goal of which was to institutionalize a global management of the Uruguay river in the common stretch of the river.
In 1983, Argentina and Brazil signed the Uruguay river and Peperi Guazu river Treaty.

In 1989, Argentina, Bolivia, Brazil, Paraguay and Uruguay created the Intergovernmental Committee of the Paraguay-Parana Waterway which is in charge of navigation.

In 1992, Brazil and Uruguay signed the Quarei River Natural Resources Use and Development Cooperation agreement.

In 1993, Argentina and Paraguay signed the Pilcomayo River Binational Commission Creation Treaty.

In 1995, Argentina, Bolivia and Paraguay signed the Plicomayo River Trinational Commission Creation Treaty.

In 1995, Argentina and Bolivia signed the Bermejo River Binational Commission Creation Treaty.

In 2001, during the IV Inter-American Water Management Dialogue, the preparation of an Integrated Water Resources Management Programme in relation to climate change was agreed upon. At that meeting, the President of the CIC, Foreign Affairs representatives of the Basin countries, experts, technicians, and project personnel from the five countries, with GEF (Global Environment Facility) support, established the need to develop a Framework Programme for the La Plata basin in order to:

- Coordinate common interest projects for the La Plata basin countries
- Carry out projects in water resources management and select concrete prioritized actions
- Highlight the importance of flood and drought phenomena in the Basin, among others
- Define sustainable hydrology
- Promote regional initiatives

In 2003, given the importance of the Guarani aquifer in the region, shared between Argentina, Brazil, Paraguay and Uruguay, it was agreed to start the "Project for environmental protection and sustainable integrated management of the Guarani aquifer system" financed by the Global Environment Facility (GEF) with support from the World Bank and the Organization of American States (OAS) (IICA, 2010).

Table 5 lists the main historical events in the La Plata basin.

TABLE 5 **Chronology of major events in the La Plata River Basin**

| Year | Plans/projects/treaties/conflicts | Countries involved | Main aspects |
|---|---|---|---|
| **1967** | Intergovernmental Coordinating Committee (CIC) | Argentina, Bolivia, Brazil, Paraguay and Uruguay | Creation of the Intergovernmental Coordinating Committee (CIC) as the coordinating mechanism of the basin |
| **1969** | La Plata Basin Treaty | Argentina, Bolivia, Brazil, Paraguay and Uruguay | The treaty was signed which is the main legal instrument of the basin |
| **1971** | Convention to study the use of the Parana river's resources;<br>Joint Commission of the Parana river | Argentina and Paraguay | The Convention was signed to study the use of the Parana river's resources. The two countries created the Joint Commission of the Parana river |
| **1973** | Yacyreta Treaty | Argentina and Paraguay | The treaty was signed. It deals with hydroelectricity, navigation and floods in the Parana river in the area close to the Yacyreta dam |
| **1973** | Salto Grande Joint Technical Commission Creation Treaty. | Argentina and Uruguay | The treaty was signed |
| **1973** | La Plata River and the Corresponding Maritime Boundary Treaty | Argentina and Uruguay | The treaty was signed. It provides the geographic coordinates for the boundary points in the Rio de la Plata. |
| **1973** | Itaipú Treaty;<br>Creation of "Itaipú Binacional" | Brazil and Paraguay | The Itaipú Treaty was signed. It created the "Itaipú Binacional", entity responsible for the creation of the Itaipú dam and its energy generation. |
| **1974** | Financial fund for the development of the countries of the Plata river basin (FONPLATA) | Argentina, Bolivia, Brazil, Paraguay and Uruguay | The fund was signed. It is an entity with international legal status, which was created to act as the financial body of the Treaty on the Plata river basin. |
| **1975** | Administrative Commission of the Uruguay River (CARU) | Argentina and Uruguay | Creation of the CARU, which main goal was to institutionalize a global management of the Uruguay river in the common stretch of the river |
| **1979** | Three Party Corpus and Itaipu Treaty | Argentina, Brazil and Paraguay | The treaty was signed, resolving several conflicts created by the Itaipu Treaty (1973) |

TABLE 5 *(Continued)*
**Chronology of major events in the La Plata basin**

| Year | Plans/projects/treaties/conflicts | Countries involved | Main aspects |
|---|---|---|---|
| **1983** | Uruguay river and Peperi Guazu river Treaty | Argentina and Brazil | The treaty was signed |
| **1989** | Intergovernmental Committee of the Paraguay-Parana Waterway | Argentina, Bolivia, Brasil, Paraguay and Uruguay | The committee is in charge of navigation |
| **1992** | Quarei River Natural Resources Use and Development Cooperation agreement. | Brazil and Uruguay | The agreement was signed |
| **1993** | Pilcomayo River Binational Commission Creation Treaty | Argentina and Paraguay | The treaty was signed |
| **1995** | Plicomayo River Trinational Commission Creation Treaty | Argentina, Bolivia and Paraguay | The treaty was signed |
| **1995** | Bermejo River Binational Commission Creation Treaty | Argentina and Bolivia | The treaty was signed |
| **2001** | Integrated Water Resources Management Program in relation to climate change | Argentina, Bolivia, Brazil, Paraguay and Uruguay | The Program was agreed upon that established the need to develop a Framework Program for the La Plata Basin |
| **2003** | Project for environmental protection and sustainable integrated management of the Guarani aquifer system | Argentina, Brazil, Paraguay and Uruguay | It was agreed to start this project, given the importance of the Guarani aquifer in the region |

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