Paper 109 – The Paraguayan Stretch of the Paraguay – Paraná Waterway: An Update

LÓPEZ LABORDE, J. & SANCHEZ MARTRES, W.
CSI Ingenieros SA, Soriano 1180 - Montevideo, Uruguay

Email (1st author): jllaborde@csi-ing.com

ABSTRACT: On year 2013 the Republic of Paraguay approved Law N° 5,102 related to "Investment promotion in public infrastructure, expansion and improvement of goods and services provided by the State". According to Article 3, the public – private partnership contracts may include infrastructure and service management projects regarding – among others – with waterway projects as well as with projects for dredging and maintaining the navigability of rivers. Consequently – according to meetings and consultations with captains of the main transport companies, with members of the captains and pilots societies and with authorities, technicians and staff of the Public Works and Communications Ministry (MOPC) and of the National Administration of Shipping and Ports (ANNP) – an update of the current state of the Paraguay River stretch under Paraguayan own and shared jurisdiction is presented.

1 INTRODUCTION

Many studies have been conducted in order to develop or to improve the navigability of the Paraguay – Paraná Waterway (Conarsud SA, 1989; Internave Engenharia SC, 1992; Hidroservice – Louis Berger – EIH, 1996; Hidroservice – Louis Berger – EIH, 1996a & b; Taylor – Golder – Consular – Connal, 1997; Consorcio Integración Hidroviaria, 2004).

Considering that the natural migration of sand banks and the temporal variations of hydraulic forces determines the spatial variation of the "critical stretches" ("malos pasos") and – consequently – of the navigation channel, during studies conducted on the years 2009 – 2010 (CSI Ingenieros SA, 2010) a particular effort in order to characterize the current state of the Paraguay River stretch under Paraguayan own and shared jurisdiction was made.

The present paper describes and summarizes the main results obtained during such studies.

2 PARAGUAY – PARANA WATERWAY PROGRAM

The Río de la Plata fluvial system formed by the Paraguay – Paraná and Uruguay rivers, covers an area of approximately 3,170,000 km^2 extending over the territories of Argentine, Bolivia, Brazil, Paraguay and Uruguay (Table 1 & 2, Figure 1).

Basin	Surface (km²)	Annual Precipitation (mm)	River discharge (m³/s)
Rio Paraguay	1.103.000	1.027	4.506
Rio Paraná Superior	975.375	1.523	11.780
Rio Paraná Inferior	704.815	776	1.078
Subtotal Paraguay – Paraná	**2.783.190**	**– – –**	**17.364**
Río Uruguay	350.250	1.385	5.033
Río de la Plata	36.560	962	198
TOTAL	**3.170.000**	**1.163**	**– – –**

Table 1: Río de la Plata basin – Main parameters (Tossini, 1959)

River	% of the territory				
	Argentine	Bolivia	Brazil	Paraguay	Uruguay
Paraguay	15,0	18,7	33,9	32,4	– – –
Paraná	37,5	– – –	59,0	3,5	– – –
Uruguay	16,4	– – –	42,5	– – –	41,1
TOTAL	**29,7**	**6,6**	**45,7**	**13,2**	**4,8**

Table 2: Río de la Plata basin – % per country (OEA, 1969)

Figure 1: Paraguay – Paraná Waterway in the general context of the Río de la Plata fluvial system

Particularly, Paraguay and Lower Paraná rivers forms the so–called Paraguay – Paraná Waterway representing the main artery of the Río de la Plata hydrographic system and the main mean for river transport to the countries sharing such river system.

On this basis, in 1969, the five countries (Argentine, Bolivia, Brazil, Paraguay and Uruguay) signed the so-called "Treaty of the Río de la Plata Basin" by which it was agreed to "promote programs, studies and works at common areas as well as for inland navigation improvement".

Later, in 1989, it was agreed to "promote, at the highest political level, the Paraguay – Paraná Waterway Program" as a "basin integration factor" aimed "to ensure continuous navigation throughout the whole day and the whole year in order to allow the transport of regional products through long distances and with the lowest possible cost".

From the beginning, it was an agreement involving a waterway of 3,442 km length extending between Puerto Cáceres (Brazil) and Nueva Palmira (Uruguay). Later, in order not to affect the Pantanal – a natural resource of worldwide concern – it was reformulated to a length of 2,770 km from Corumba (Brazil), through the ports located on the Paraguay River (Paraguay) and the ones located on the Lower Paraná River (Argentine), to Nueva Palmira (Uruguay).

However, negative opinions regarding the potential socio – environmental impacts of the project and an increasing international pressure discouraged the interest of the international organizations to financing the project; consequently, it was not possible to implement the Paraguay – Paraná Waterway Program as it was intended.

This is how the Paraguay – Paraná Waterway, as an unique project, was replaced by national projects developed on the jurisdiction of each country:

- Since 1993, Argentine has been developing a continuous improvement of the Lower Paraná River navigability. Firstly, covering the stretch between progressive km 584 (outer section of the access to Santa Fe Port) and the natural deepwater areas at the Outer Río de la Plata (progressive km 205.3 of the Punta Indio channel through Emilio Mitre channel) and, most recently, extending to progressive km 1,238 of the Lower Paraná River (Paraguay – Paraná rivers confluence) and even to the stretch of shared waters with Paraguay (progressive km 1,630, near Asuncion city).
- More recently, Paraguay has begun the studies in order to conduct a concession of the Paraguay River areas within its own or shared jurisdiction (between the confluences with Apa and Paraná rivers).

3 PARAGUAY RIVER

3.1 *General characteristics*

The Paraguay River is a meandering river with Northern – Southern runoff, an annual average flow of about 4,500 m^3/s and a length of about 2,625 km. The stretch comprised between the Apa and Pilcomayo river mouths (554 km length) corresponds to the exclusive jurisdiction of Paraguay Republic and the one between the Pilcomayo and Paraná river mouths (385 km length) to the shared jurisdiction between Paraguay and Argentine Republics.

North of the Apa river, depth varies between 4.0 and 10.0 m (except for the "critical stretches" where it decrease up to 1.50 m), river width varies between 120 and 600 m (except for the "Pantanal" area where width is even lower: 40 to 200 m) and floodplain width varies between 1.0 and 15.0 km.

At the stretch comprised between Apa river and Asuncion city, the river widens considerably and the floodplain reaches a width varying between 5.0 and 15.0 km (affecting only the right riverside) being a relatively deep river (with areas up to 8.0 m) but with significant presence of shoals and rocky outcrops (which are major obstacles to navigation).

South of Asuncion city (to the confluence with the Paraná River), is a meandering river (consisting of a single main channel accompanied by a series of adjacent "lakes"), the average river width is 700 m (although it varies between 260 and 2,700 m) and the floodplain width varies between 10.0 and 15.0 km (covering both sides).

Commercial navigation had its beginning on 1870 with the export of tannin by Mihanovich Company ships, subsequently the cement industry products (Vallemí SA) were added as well as the supply to the populations located to the north (Bahía Negra,

Corumbá and Cuyabá) and the commercial traffic between Asuncion and Buenos Aires cities.

In its current condition, coinciding with an alternating period of high and low waters, occurred between 1911 and 1961, navigation began at the mid of the 50's with the exploitation of iron ore deposits located at Mutúm and Urucúm (Corumbá and Puerto Quijarro surroundings) being interrupted during the low water period developed between 1962 – 1973. Later, since 1974, taking advantage of a new high water period, both navigation and cargo activities were restarted. Recently, since 1998, a new period of low water has started but retaining the high interannual variability (Figure 2 & 3).

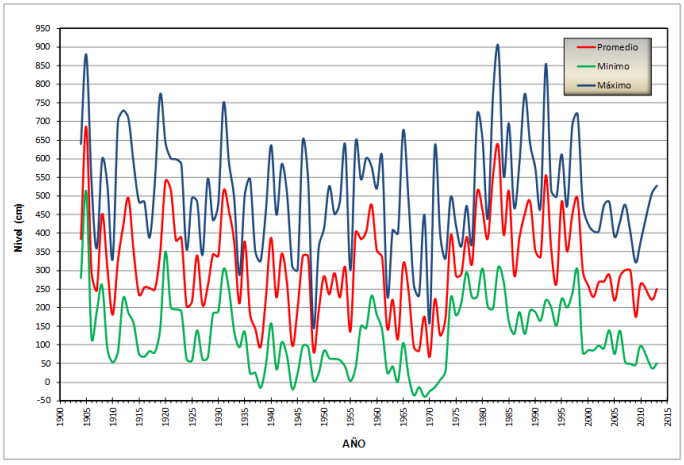

Figure 2: Asunción city – Mean annual water level (1904 – 2013)

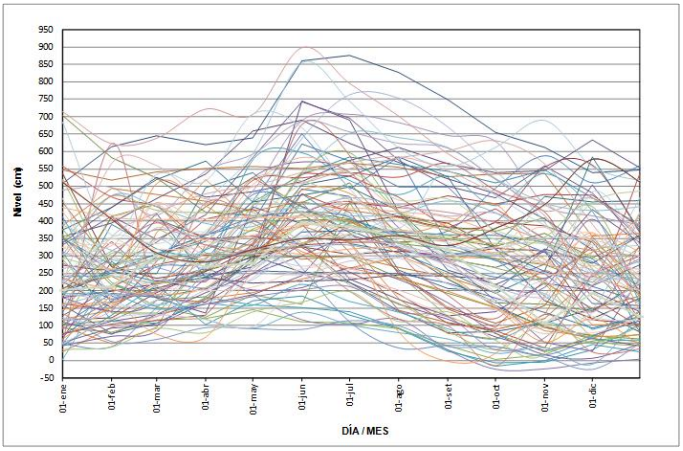

Figure 3: Asunción city – Mean daily water level (1904 – 2013)

Currently, the Paraguay River waterway is mostly operated by barge convoys carrying solid bulk (soybeans and soy products, wheat, iron ore and manganese, clinker, limestone materials, cement) and liquids (petroleum and its derivatives) between ports of South Western Brazil (Corumbá and Ladario), Western Bolivian (Terminal Aguirre) and Paraguay (Vallemí and other minor ports) to ports in Argentine, Uruguay and Paraguay (Villeta).

Recent studies (CSI Ingenieros SA, 2010), based on the analysis of the vessels registered at the Merchant Marine General Directorate (DGMM) from the Ministry of Public Works and Communications (MOPC) – Republic of Paraguay, allowed to characterize the Paraguay River fleet.

Such registry, corresponding to year 2010, includes a total of 2,591 vessels of which 1,730 (67%) were barges, 349 (13%) were boats of various nature, 159 (6%) were tugboats, 94 (4%) were merchant ships and 256 (10%) were non classified ones (grouped as "others").

Within barges (1,730): 1,487 (86%) were for bulk transport, 156 (9%) for liquid fuels, 37 (2%) for general cargo, 29 (1.7%) for containers transport, 7 (0.4%) for mineral transport, 3 (0.2%) for gas transport, 2 (0.1%) for sand transport and 2 (0.1%) for livestock transport.

Particularly, the analysis of the data corresponding to bulk cargo barges (1,487) showed that 1,120 (75.3%) had Paraguayan flag, 218 (14.7%) had Argentinean flag, 94 (6.3%) had Bolivian flag, 37 (2.5%) had Brazilian flag, 13 (0.9%) had Uruguayan flag and 2 (0.1%) had Panamanian flag.

Most barges had similar dimensions with lengths comprised between 59 and 61 m (80.4%), sleeve comprised between 10 and 12 m (83.4%) and moulded depth comprised between 3.0 and 4.0 m (92.6%).

In fact, barges correspond to two (2) basic designs: a) the so–called "Mississippi barges" with 60 m long, 10.66 m wide, 10 feet (3.05 m) draft and 1,500 tons of load capacity; and b) the so–called "Jumbo widened barges" with 60 m long, 16.67 m wide, 10 feet (3.05 m) draft and 2,600 tons of load capacity.

Such barges navigate forming "convoys" or "barge trains" driven by a unique unit (tugboat) which concentrates both the operating and propulsion systems and the crew.

At the Paraguay River due to the "Regulation on Maximum Dimensions for Convoys at the Paraguay – Paraná Waterway" (June, 1996) and an Argentinean – Paraguayan Bilateral Act (April, 2000), convoys reach a maximum of 319 m length and 60 m wide.

Such convoy sails downstream, loaded according to the draft permitted by river level and at a velocity rate that, on average terms, ranges from 6.0 to 8.0 km/h on curves and 10 km/h on the straights stretches (upstream navigation is mostly with downloaded convoys).

Regarding to dredging works, at the Paraguay River they have been relatively minor and irregular. Volumes had been highly variable since the completion of the works not only depends of the

waterway morphological and hydrological conditions but also from various aspects related to the availability of dredging equipment and financial resources. According to the information obtained, during the period 1999 – 2013 it has been dredged a total volume of 3,514,588 m^3 with annual variation between 21,402 m^3 (2008) to 514 890 m^3 (2000).

Finally, regarding to navigational aids, the system currently in force along the Paraguay – Paraná Waterway is based on a unified regulation (1994) which states that "countries should adopt the IALA system (Region B) adapted for inland navigation or the signaling system of ´actions to be taken´, or both".

At Paraguay River stretch comprised between the confluence with Apa and Paraná rivers, most of the marginal signs are damaged, covered by vegetation and, generally, are not easily visualized (because they don´t have good light reflection).

3.2 *Common practices applied for inland navigation*

At Paraguay River of the Paraguay – Paraná Waterway, the navigation channel responds – basically – to its natural morphological and sedimentological conditions so it can be assumed that there is a balance between water flow, the sediment carried by the river and the bed materials size and grading.

Thus, virtually along all the Paraguay River extension, river morphology follows the laws of meandering river hydraulics:

- When the river course has long straight sections, the "thalweg" appears as indefinite being developed within rapidly evolving sandbars and shallow depths.
- When the course meanders along the channel, the "thalweg" approaches to the concave part of the curves and cross the river at the inflection areas within opposing curves (where sand banks are formed).
- When, during the flood, a natural channel cuts a curve, an island is formed between the new and the old channel and, as the new channel is steeper and more erosive, its section increases meanwhile the old channel is gradually closed. Consequently, on a large number of curves appear islands near to curve apex (with the "thalweg" on the innermost channel).

At the Paraguay River stretch, navigation is basically of visual character (based on knowledge of the river and on crew experience). In fact, knowledge of the rivers is essential and irreplaceable, being an element always present in river navigation.

The crew knows "by memory" the specific conditions of the river including navigation directions, shallow areas and navigation channel locations as well as bed characteristics.

Such knowledge – which includes not only the restrictive elements to navigation but also insights regarding winds and currents behavior as well as vessels responses to maneuvers – is learned over time and continuous navigation; the latter element is essential (whatever the size of the vessel).

Usually navigation is helped by simple sketches made by the own mariners. Additionally, echo and radar are essential instruments; in fact, the great barge trains use a combined system consisting of two echo sounders and two radars. The skipper, sitting in the wheelhouse, has, on each side, a radar and, in the front, two echo sounders, one for each band, with the sensors located on the front of the convoy (about 300 m below).

A common practice, consist of sending, ahead of the vessel, a boat with the elements necessary to verify the deep and to signalize the deepest area. This makes possible to cross the "critical stretches" ("malos pasos") with minimal water margins.

Moreover, due to the precision currently achieved by global positioning systems (GPS) another common practice is to use a combined system: river signaling and record the track on the GPS memory (safety water positions). Such information is used for subsequent navigations; however, in the difficult sections ("critical stretches" – "malos pasos") mariners continue checking depths and, whenever necessary, new tracks are registered.

4 RECENT STUDIES: MAIN RESULTS

The stretch of the Paraguay – Paraná Waterway corresponding to the Paraguay River is particularly important. In fact: a) for Brazil is the main means of transport for one of the most important iron ore deposits of the world, b) for Bolivia, represents an alternative allowing a considerable part of its foreign trade with countries of the region and of the rest of the world, and c) for Paraguay due to the magnitude of cargo movements (mainly cement, fuel and trades) from main production centers to the cities located at the northern part of the river.

Studies conducted by Hidroservice – Louis Berger – EIH (1996a & b) identified – at the section comprised between the cities of Santa Fe (Lower Paraná River, progressive km 590) and Corumbá (Paraguay River, progressive km 2,770), about 250 "critical stretches" ("malos pasos"). Of these, about 111 were included between the confluence with Apa and Paraná rivers and, of these, 51 were identified as impediments for a continuous navigation.

It must be noted that, although there is a tendency to maintain, over time, the location of major "critical stretches" ("malos pasos"), the natural migration of sand banks and the temporal variations

of hydraulic forces determines a certain spatial variation of such "critical stretches" ("malos pasos") and – consequently – of the navigation channel.

So, during studies conducted on the years 2009 – 2010 (CSI Ingenieros SA, 2010) a particular effort aimed at the characterization of the current state of the Paraguay River stretch was made. Several meetings and consultations were made with captains of the main transport companies (Panchita G SA, Transbarge Navigation SA and UABL Paraguay SA), with members of the captains and pilots societies and with authorities, technicians and staff of the Public Works and Communications Ministry (MOPC) and of the National Administration of Shipping and Ports (ANNP).

Particularly, during interviews with mariners it was possible to access to charts and other technical documents (logs) where they settle the tracks as well as the location of the main navigation obstacles.

According to the information collected, it was possible to perform an update of the main obstacles to navigation ("critical stretches") during the dry season (Table 3) as well as the locations where it is necessary to fragment the barge convoy: progressives km 2,095 (in order to cross over the critical stretches named Aguirre – Palacio Cué, Guardia Cué and Romero Cué), km 1,958 (in order to cross over the critical stretches named Punta Yrigoyen, Itacurubí – Yaguareté and Saladillo as well as Mercedes, Isla del Medio – Concepción / Guggiari, Riacho Negro and Milagro), km 1,726 (in order to cross over the critical stretch Montero Cué), km 1,628 (in order to cross over the critical stretches named Itá Pita Punta, Cassacia, Medín, San Antonio, Villeta, Buey Muerto, Angostura, Itá Pyrú and Guayratí) and km 1,555 (in order to cross over the critical stretches names Santa Rosa, Lobato and Sepultura).

Progressive (km)	Critical Stretch	Bed material	Probable dredging length (m)
Lower Paraná River – Pilcomayo River (Paraguay – Argentine shared jurisdiction)			
1509	Sepultura	Sand	1000
1534	Lobato	Sand	1000
1558	Santa Rosa	Sand	1000
1581	Guyratí	Sand and hard material	800
1585	Ytá Pirú	Sand and hard material	800
1591	Buey Muerto	Sand	800
1595	Villeta	Sand and hard material	1000
1604	San Antonio	Sand	600
1605	Cortada San Antonio	Sand	1000
1608	Medín	Sand	300
Pilcomayo – Apa River (Paraguay own jurisdiction)			
1619	Casaccia	Sand	800
1626	Itá Pytá Punta	Sand and hard material	– – –
1645	Remanso Castillo	Sand and rock	– – –
1650	Travesía Confuso	Sand	500
1665	Tres Bocas Superior e Inferior	Sand	1000
1671	Arecutacuá	Sand	700
1688	Barbero	Sand	800
1707	Marina	Sand	1000
1719	Merzan	Sand	500
1723	Mortero Cué	Sand	1500
1740	Uruguaytá	Sand	600
1750	Travesía Elvira	Sand	300

Progressive (km)	Critical Stretch	Bed material	Probable dredging length (m)
1756	Diamela o Ybynayú	Sand	300
1762	Palmita	Sand	800
1765	Victoria	Sand	400
1776	Cortada Rosario	Sand	2000
1783	Pando	Sand	800
1794	Burro Yguá	Sand	300
1801	Almirón	Sand	800
1806	San José	Sand	800
1810	Juejuí	Sand	100
1856	Curuzú Juanita	Sand	300
1862	Monte Lindo	Sand	150
1879	Pedernal Superior, Medio e Inferior	Sand and hard material	600
1919	Asunción Superior	Sand	200
1928	Milagro	Sand	1000
1933	Santa Rita	Sand	1000
1940	Isla del Medio – Concepción – Guggiari	Sand and hard material	600
1943	Riacho Negro Superior	Sand	800
1943	Calaverita	Sand	1000
1947	Saladillo	Sand	800
1951	Itacutubí – Yaguareté	Sand and hard material	800
1963	Romero Cué	Sand and hard material	1500
1971	Toldo Cué	Sand	1000
1997	Alegre	Sand	800
2002	San Juan	Sand	2000
2011	Cooper	Sand	800
2014	Leonor Superior	Sand	1000
2017	Nancy	Sand	500
2032	Lenguas Inferior	Sand	600
2035	San Pablo	Sand	600
2038	San Salvador	Sand	800
2047	Arrecifes Superior y Medio	Sand, hard material and rock	1000
2056	Toba	Sand	500
2057	Cambá	Sand	1000
2059	Guardia Cué	Sand	1000
2065	Stanley	Sand	1000
2069	Cerro Lorito	Sand	1000
2073	Pinasco	Sand	1000
2087	Travesía Max	Sand	2000
2089	Saldivar	Sand	2000

Progressive (km)	Critical Stretch	Bed material	Probable dredging length (m)
2092	Aguirre – Palacio Cué	Sand and hard material	2000
2115	Lamboné (Piedra Partidas)	Sand and hard material	2000
2120	San José	Sand	1000
2141	Casado Superior	Sand	1000
2146	Puerto Casado	Sand	600
2160	Casilda Superior e Inferior	Sand	400

Table 3: Critical stretches ("malos pasos") identified at the Paraguay River stretch comprised between the confluences of Apa and Paraná River (according to meetings and consultations with captains of the main transport companies, with members of the captains and pilots societies and with authorities, technicians and staff of the Public Works and Communications Ministry – MOPC and of the National Administration of Shipping and Ports – ANNP).

The presence of the critical stretches previously identified determines a complex stage determining that Paraguay River stretch of own and shared jurisdiction of the Republic of Paraguay is one of the most difficult of the whole Paraguay – Paraná Waterway. Main consequences are the following:

- Greater navigation times associated to:
  - The need to split the barge convoy in order to cross – during daylight hours – many of the critical stretches.
  - The delays associated with the time required to perform expeditious bathymetric survey and signaling of such critical stretches (which obviously require its implementation during daylight hours).
- Lower cargo volumes (many companies loads barges according to information on river level conditions and own estimates of the optimal navigational depth).
- Draft limitations imposed by Paraguayan Maritime Authority during the dry season (through Maritime Resolutions).

Such constraints imply an important overcost imposed to the economy of river transport companies and also to cargo producers; such overcost was estimated (CSI Ingenieros SA, 2010) in the order of US$ 200 million by year (or 15 US$/ton).

5 CONCLUSION

On year 2013 the Republic of Paraguay approved Law N° 5,102 related to "Investment promotion in public infrastructure, expansion and improvement of goods and services provided by the State" (regulated by Decree N° 1,350/2014).

According to Article 3, the public – private partnership contracts may include infrastructure and service management projects regarding – among others – with waterway projects as well as with projects for dredging and maintaining the navigability of rivers.

As a consequence of such scenery, the previous update of the current state of the Paraguay River stretch under Paraguayan own and shared jurisdiction becomes of particularly importance (mainly when all the previous studies have been based on the definitions made by Hidroservice – Louis Berger – EIH on 1996).

REFERENCES

Conarsud SA. 1989. Estudio de Prefactibilidad Técnico – Económico para el Mejoramiento de la Vía Fluvial de Navegación Paraná – Paraguay.

Consorcio Integración Hidroviaria, 2004. Estudio Institucional – Legal, de Ingeniería, Ambiental y Económico Complementario para el Desarrollo de las Obras en la Hidrovía Paraguay – Paraná entre Puerto Quijarro (Canal Tamengo), Corumbá y Santa Fe.

CSI Ingenieros SA. 2010. Estudios de la Viabilidad del Mejoramiento de las Condiciones de Navegación del río Paraguay a través del Sistema de Participación Público – Privada (Tramo Apa – Formosa). *Banco Mundial. Report Number 63033 – PY*

Hidroservice – Louis Berger – Estudio de Ingeniería Hidráulica (EIH). 1996a. Estudios de Ingeniería y Viabilidad Técnica y Económica del Mejoramiento de las Condiciones de Navegación de la Hidrovía Paraguay – Paraná: Tramo Santa Fe – Corumbá.

Hidroservice – Louis Berger – Estudio de Ingeniería Hidráulica (EIH). 1996b. Estudios de Ingeniería y Viabilidad Técnica y Económica del Mejoramiento de las Condiciones de Navegación de la Hidrovía Paraguay – Paraná: Tramo Puerto Cáceres – Puerto Nueva Palmira.

Internave Engenharia SC. 1992. Hidrovia Paraguai – Paraná: Estudo de viabilidade económica.

Organización de Estados Americanos (OEA). 1969. Cuenca del Plata: Estudio para su Planificación y Desarrollo.

Taylor – Golder – Consular – Connal. 1997. Evaluación del Impacto Ambiental del Mejoramiento de la Hidrovía Paraguay – Paraná.

Tossini, L. 1959. Sistema hidrográfico y cuenca del Río de la Plata. Contribución al estudio de su régimen hidrológico. *Anales de la Sociedad Científica Argentina, 167 (3–4): 4 –64*.