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Characteristics of Tidal Channels in a Mesotidal Estuary of Argentina

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ABSTRACT

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Bahía Blanca Estuary is a complex network of tidal channels, extensive tidal flats, low marshes areas and islands. The lack of a large source of sediments either from river or the shelf results in that the tidal channels of this estuary controlling the dispersal of sediment into the system. A 3-year study of morphodynamic equilibrium has been carried out in the tidal channels of Bahía Blanca Estuary with the aim to investigate the evolution of the system. Detailed changes in the spatial bathymetry linked to the observed flow and sediment processes give a clearer indication of the tidal circulation in the channels. This paper discusses morphologic variability and processes of the erosion, deposition and transport of sediment, which determines the morphological evolution of the system.

Current measurements showed that channels appeared to be ebb- dominated with peak speeds of up to 1.2 m/s. Examination of current durations suggests that flood-time dominance is about 7 hr, while ebb period is 5 hr. The cross section bathymetry is usually bimodal with two channels separated by a shallow area. The deeper channel experiences ebb-directed net, while the shallower channel could be influenced by the net flood current. The net sediment transport into of these systems is shown to be governed more by the degree of tidal velocity asymmetry (ebb flow). In change the degree of time asymmetry (flood flow) governs the trends of erosion by the longer duration of tidal flood.

Channel migration causes a shift from degradation in the north sector to aggradation in the south side, during adjustment. As a consequence, the estimated rate of migration is on the order of 25 m yr^{-1}.

Comparing the migration pattern between tidal and fluvial channel, we can to say that in rivers, where the water flows only one way, all morphologic features tend to migrate downstream. In tidal channels, by contrast, the erosive features appear to migrate in opposed directions to the dominant sediment transport direction. It is the erosive processes at tidal channels, which are mainly associated with flood currents dominance.

ADDITIONAL INDEX WORDS: *Major tidal channels, morphodynamic equilibrium, erosion/deposition area, Bahia Blanca Estuary.*

INTRODUCTION

Extensive tidal flats, within estuarine zones, are often associated with major river discharges of sediments (*e.g.* tidal mudflats of the Huanghe, Amazon, and Mississippi Rivers, North Sea, Bay of Fundy). However, along the Argentina coast most tidal flats are well developed although the input of sediment associated with rivers is negligible. During the Holocene these rivers formed broad valleys that give an idea of their previous runoff. At the present time, river discharge is low due to several decades of low precipitation and the building of dams along their course (PICCOLO and PERILLO, 1999).

The Bahía Blanca Estuary is an example of extensive tidal flats where its tributary rivers are small and contributing small volumes of either water or sediment. It is located at the southern end of the Buenos Aires Province, Argentina (Figure 1). A system of NW-SE major channels, separated by extensive tidal flats, patches of low marshes and islands are the principal morphologic features.

The different types and dimensions of channels that occur within this system are large tidal channels, creeks and gullies. Usually smaller gullies or creeks, coming from the flats, flow into large tidal channel at right angles. The latter flow towards the main channel, through avulsion and entrenchment. They control the dispersal of sediment into the system, facilitating the exchange of sediments between tidal flats and open marine environment. In all channels, unconsolidated sand bodies occur as mouth shoals.

The Bahía Blanca Estuary has one large sinuous main channel (Principal Channel) (Figure 1), where the water depth is maintained by dredging to ensure the passage of ships to its harbor system (Ing. White, Galván, Belgrano and Rosales Harbors). Channels within this system can be meandering and/or straight. The straight channels occur predominantly in comparatively large tidal channels, while the smaller creeks and gullies are predominantly sinuous or meandering.

Marshes in the estuary correspond mostly to the low and

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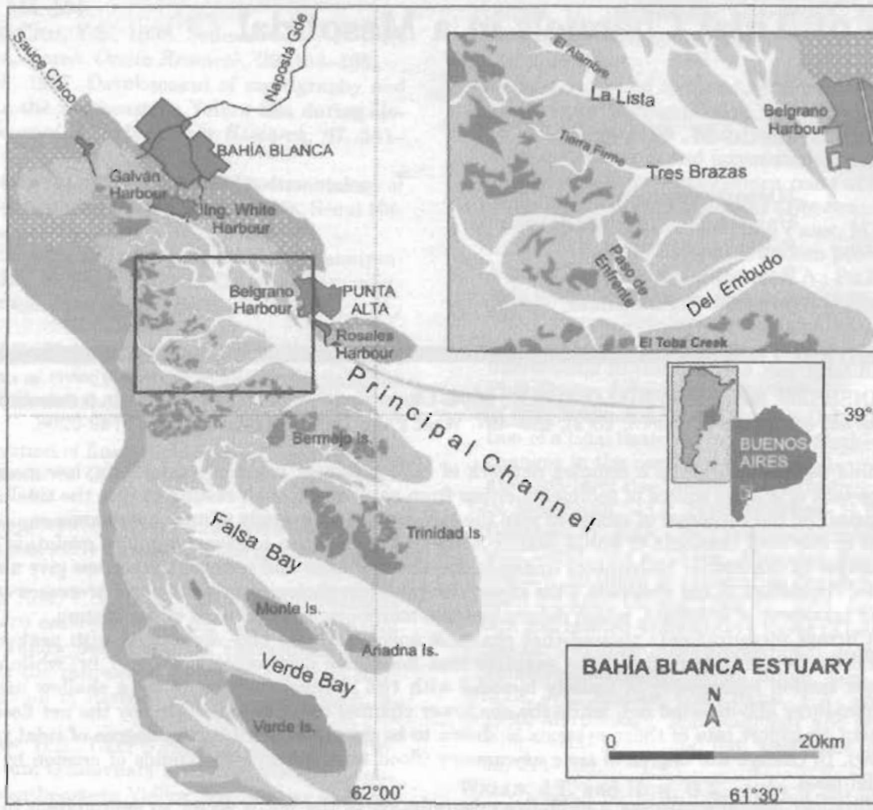

Figure 1. Location map of Bahía Blanca Estuary, Argentina. The research area is located in the box study area.

medium marsh level and occupy relatively small areas, at approximately the level of mean high tide. The dominant species of halophytic plants are *Salicornia ambigua, Spartina alterniflora, Hetterostachys ritteriana* and *Allenrolfea patagonica*.

The circulation in the estuary is dominated by a semidiurnal, quasi-stationary tidal wave (PERILLO and PICCOLO, 1991). Mean tidal ranges for spring and neap tides at the middle reach of the Canal Principal are 3.42 m and 2.5 m, respectively. However, mean range varies from 2 m to 4 m from the mouth to the head of the estuary (PERILLO and PICCOLO, 1999). The Sauce Chico River and the Napostá Grande Creek (Figure 1) provide most of the fresh water inflow. Annual mean runoffs are 1.9 and 0.8 $m^3.s^{-1}$, respectively (PERILLO *et al.*, 1987).

Tidal channels are key features of the estuarine environment because they are subject to intense human activity, allowing the development of harbors and shipping channels. They also contain areas of important ecological value, which are extremely sensitive to changes caused either by natural factors or human interference. This motivates increasing attention to the understanding of the complex processes that shape tidal channels, controlling sediment distribution as well as transport of pollutants and biological species. In this way, physical and sedimentological processes in North American and Europe tidal channels have been studied by a number of researchers (*i.e.,* FREY and BASAN, 1978; BOON, 1978; SETTLEMYRE and GARDNER, 1977; ZANG GUODONG *et al.*, 1987; VILAS and NOMBELA, 1985). However, studies on tidal channel dynamics on the Argentina coast have not received adequate attention, particularly as compared to those countries.

In an attempt to know the processes of sediment transport that occur in the tidal channels of the Bahía Blanca Estuary and influence their morphological evolution, a study was done in three tidal channels. The different types of tidal channels have been relatively little studied compared to the extensive research that has been made and is ongoing on the main navigation channel (*i.e.,* ALIOTTA and PERILLO, 1987; PERILLO and CUADRADO, 1991; GÓMEZ and PERILLO, 1992; PERILLO and SEQUEIRA, 1989; GÓMEZ *et al.*, 2000; CUADRADO *et al.*, 2001). ANGELES (2001), based in geographic information systems (GIS) investigated the fractal geometry and carried out a hierarchical analysis of tidal-channel systems. Fractal analysis of tidal channels, studied by PERILLO *et al.* (1996) and ANGELES *et al.* (in press), reveal that the tidal channel system in the Bahía Blanca Estuary can be regarded as statistical self-similar fractal.

Insight into the sedimentary processes associated in tidal channel flow is obtained from the erosional/depositional features associated with strength of currents such as the developments large bedforms, sediment waves, crevasse splays, and slump scars. These features have been used to make inferences about the hydrodynamics of tidal currents, and can be employed as sources of information about net sediment transport and long-term circulation.

Therefore, our specific objectives were to describe the morphology of tidal channels, and determine the dynamic processes in the major tidal channels that serve as arteries from the intertidal zone to Principal Channel. Furthermore, this paper describes the morphodynamic changes both qualitatively and quantitatively. The study was conducted at the La Lista, Tres Brazas and Del Embudo channels of Bahía Blanca Estuary (Figure 1), which are believed to be important ways to deliver sediment into the navigation channel. We also discuss the processes affecting their dynamics and the behavior of the shoals located at their mouths.

METHODS

Tidal channels changes in the study area were determined from a variety of sedimentologic, geomorphologic, and current velocity data that were collected in the channels studied. Detailed soundings taken in the La Lista, Tres Brazas and Del Embudo channels made it possible to define the morphological changes that took place over 3-year period. The sounding covered from the channel mouth up to approximately 10-km headward. Bathymetric profiles were made using a 208-kHz Raytheon echosounder. The transducer was calibrated before each working day. A microwave ranging device (Trisponder Del Norte Tech) was used as a navigation system. This instrument provides simultaneous measurement of the distance from the survey boat to two slave antennae whose absolute positions were known to high precision with an estimated error less than 3 m. Both antennae were located onshore less than 500 m from the water. The difference in microwave propagation over land and water is considered minimum. On each survey track, fixes were recorded every minute and the fix marks were automatically recorded on the echosounder.

Depth values measured from the echosounder records were corrected to Datum Plane for the area employing the tidal record from Puerto Belgrano Tidal Station. For this area, the Datum Plane is located 2.44 m below mean sea level. All maps were made using a Gauss-Kruger projection.

Differences in depth were taken between the overlapping portions of both surveys, for each channel, at all intersections of a common rectangular grid 50 m on the side, to assess the distribution and volume of sediment erosion and deposition. Because of the error in determining exact depths from the echosounder record, differences smaller than 0.20 m, whether erosional or depositional, were excluded from the comparison and areas on the chart corresponding to such small differences were left blank.

Bottom sediments were obtained on both surveys by a Shipek grab sampler. A dredge was employed for those sites where bedrocks were present. Samples were collected along transverse lines to the channel. Nine of the lines were made in Del Embudo Channel, and in Tres Brazas and La Lista Channels seven and six lines, respectively were made. Four samples were taken at each transect. Sediments grain-size was analyzed in the laboratory by standard procedures (Folk, 1974).

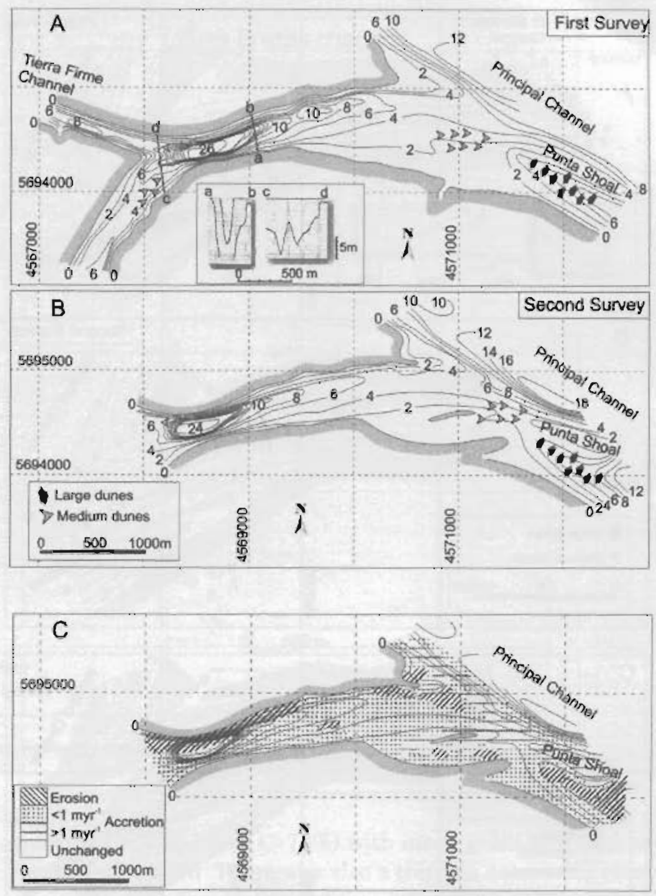

Figure 2. Bathymetry of the Tres Brazas channel in (A) 1986 and (B) 1989, represented in the Gauss Kruger system of coordinates in metres. Note in (A) the bimodal cross-sections with shallower channel on north side (profiles ab and cd). (C) Morphological changes in Tres Brazas channel over the three years.

Current measurements were undertaken in the Tres Brazas and Tierra Firme channels using an Endeco 110 direct reading currentmeter. The tidal current velocities were determined at three stations. The data were collected hourly for 13 hr during spring conditions. Two stations were located at Tres Brazas Channel, and the third station was positioned at Tierra Firme Channel.

RESULTS

Morphologic and Sedimentologic Characteristics

Contour maps of the analyzed reaches indicate that Tres Brazas, La Lista and Del Embudo channels (Figures 2, 3 and 4) have undergone considerable shape change in the study period. The morphology of the three channels is characterized in plane view by a funnel shape. Channel widths increase from about 300 m at their inner reaches to nearly 2 km at their mouths while mean depths are about 10 m (Table 1). Their bathymetries are characterized by bimodal channel cross-sections (Figures 2A, 3A and 4A) being mostly asym-

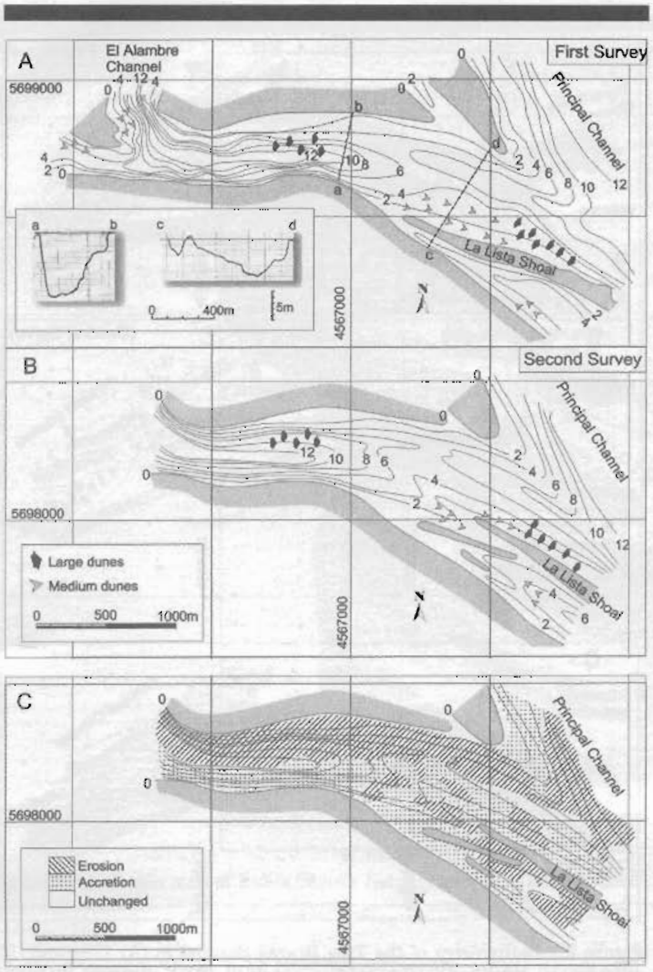

Figure 3. Bathymetry of the La Lista channel in (A) 1986 and (B) 1989, represented in the Gauss Kruger system of coordinates in metres. Note in (A) the bimodal cross-sections with shallower channel on north side (profiles ab and cd). (C) Morphological changes in La Lista channel over the three years.

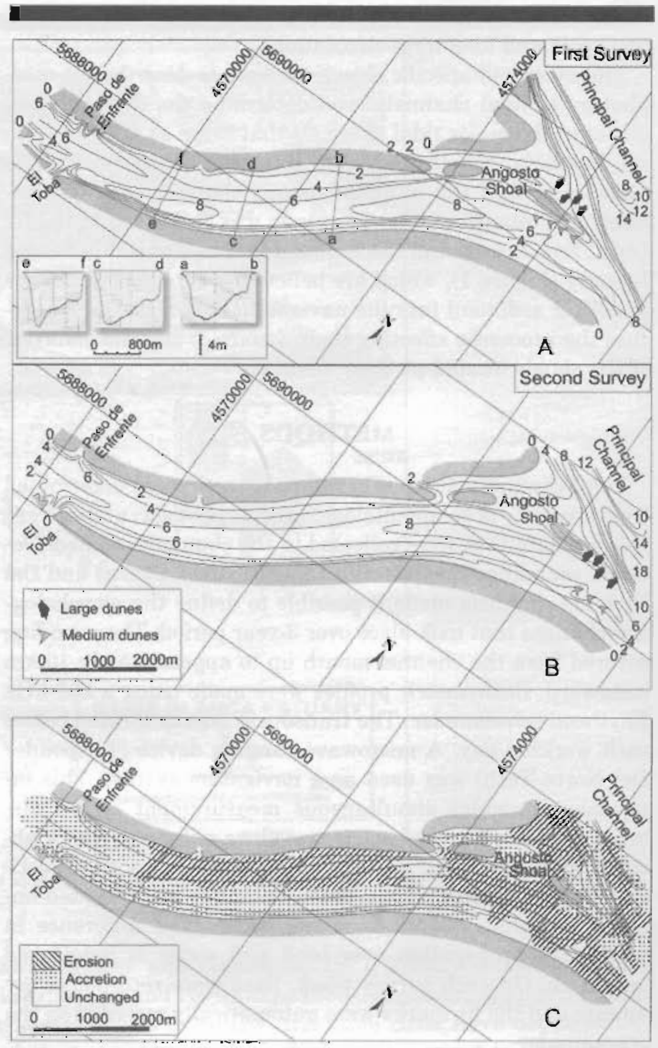

Figure 4. Bathymetry of the Del Embudo channel in (A) 1986 and (B) 1989, represented in the Gauss Kruger system of coordinates in metres. Note in (A) the bimodal cross-sections with shallower channel on north side (profiles ab, cd and ef). (C) Morphological changes in Del Embudo channel over the three years.

metrical, with the thalweg close to the southern bank. The marginal channel is narrower and shallower and it is often found on the northern side of cross sections close to the high water level.

Acoustic records have shown bedforms, which are predominantly asymmetrical dunes. These bedforms have been used to make inferences about the hydrodynamics processes and current circulation. According to ASHLEY's (1990) classification, almost all bedforms are medium to large 3D dunes, being in general, ebb-oriented with wavelengths varying from 10 to 25 m and maximum height of 1 m (Figures 2A and B; 3A and B and 4A and B). These bedforms were observed during both surveys.

Small sand shoals present at all three channel mouths are aligned parallel to the general direction of the strongest tidal currents. We named the shoals as Punta Shoal at Tres Brazas Channel (Figure 2A), La Lista Shoal at La Lista Channel (Figure 3A) and Angosto Shoal at Del Embudo Channel (Figure 4A) as they did not have previous denomination. They have an elongated shape, being the Angosto Shoal the largest and La Lista Shoal the narrowest. They are submerged during high tide and exposed from mid-tide down. In plan view, the shoals are curvilinear and have asymmetrical cross-sections. Large and medium 3D dunes are present all over the shoals. These bedforms are asymmetrical, being flood-oriented along the northern flank and ebb-oriented along the south-

Table 1. *Channels dimensions for study reach of Bahia Blanca Estuary.*

Channels	Length of reach study km	Maximum width km	Minimum width km	Maximum depth m
La Lista	5	0.95	0.25	12
Tres Brazas	6	1.75	0.30	24
Del Embudo	11.5	2.60	0.90	8

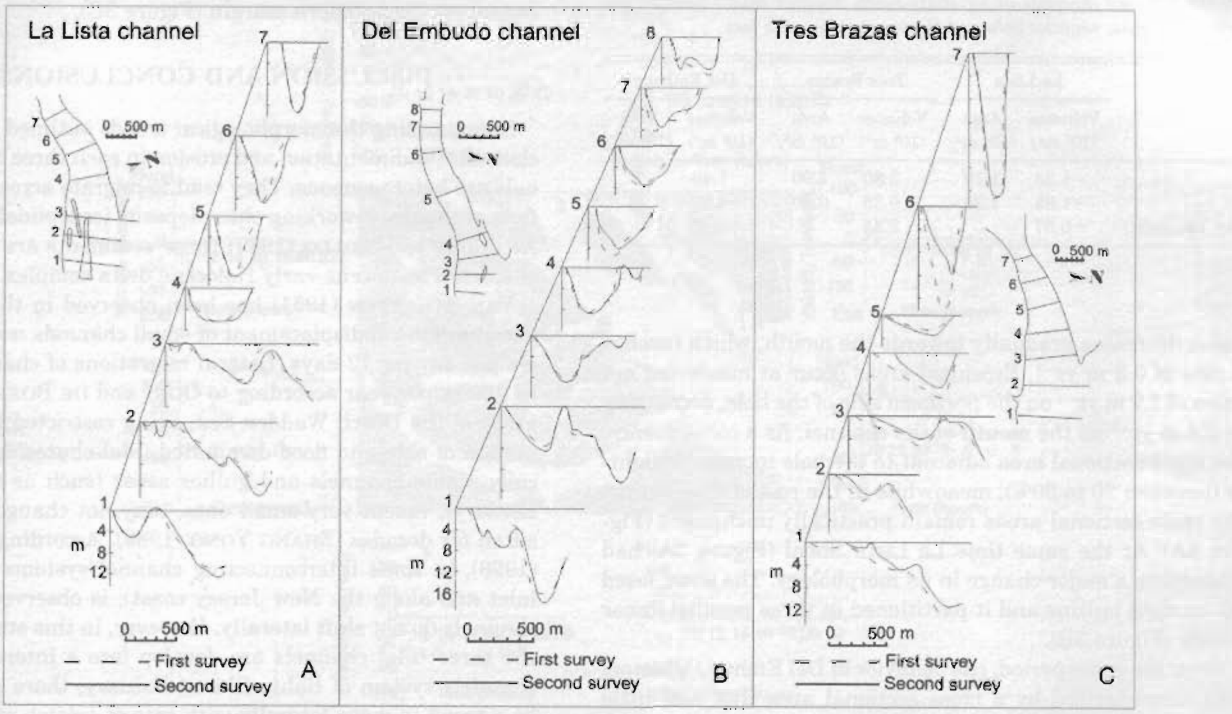

Figure 5. Cross sectional changes in the sector of the study area between both surveys, for the three channels.

ern flank. Their heights are less than 1 m and their wavelengths vary between 6 and 18 m.

The steeper slopes of La Lista and Angosto shoals (Figures 3A and B and 4A and B) are bordered by a flood sinus, whereas one is observed on the southern flank of Punta Shoal (Figures 2A and B). Within the sinuses medium 2D and large 3D dunes have been observed, having a pronounced asymmetry towards the dominant flood current. They have wavelengths between 6 and 20 m.

Deep-scour holes were recognized at junctions of Tres Brazas and La Lista channels with their tributaries (GINSBERG and PERILLO, 1999). These branches are Tierra Firme (Figure 2) and El Alambre channels (Figure 3), respectively. The holes have depths between 12–27 m to Datum Plane (2–17 m relative relief with respect to the channel bottom). Their borders have steep scour sides (3.5°) at the mouth of each confluent channel and gentle sides (1.5°), corresponding to a depositional zone at the opposite downstream side. Bedforms localized along the gentler side are ebb oriented (Figures 2 and 3). The wavelengths were between 13 and 15 m and their heights varied from 0.80 to 1 m.

Surficial sediments in the studied channels are mostly silty clay with low percentages of sand, being also poorly sorted. The subtidal sediments include from 20% to 90% of mud. Lowest mud concentrations were in the deeper parts of the channels and on the shoals, whereas the highest concentrations were mostly on the channels banks.

The channel flanks have a very fine stratification of clayey-silt layers, 0.4 cm thick, separated by 0.1 cm thick layers of fine to very fine sand. Their sediments are composed primarily of silt and clay (>70%) with mean grain size (M_z) between 6 and 7 phi. There was also a trend in decreasing mean grain size with increasing distance laterally from the channel mouth.

The deeper parts of the channels contain coarser material (2.2 phi $< M_z <$ 4.8 phi), while mostly fine to medium sand found on the mouth shoals (1.8 phi $< M_z <$ 3 phi). Most of the sand material coincides with the large dunes. The percent sand in the deeper parts of the channels ranged from 65% to 95%, and greater than 90% in the shoal mouth. The sediment on the shoals is well sorted (0.3 phi–0.7 phi).

Morphological Changes

In order to investigate the morphological changes for each channel, the bathymetric maps have been compared. The morphology modifications in the tidal channels are shown as spatial distribution of erosion and deposition areas (Figures 2C, 3C and 4C). Likewise, amount and change in form can be derived from the comparison of the cross-sections (Figure 5).

In all residual maps, areas of erosion are found primarily along the northern sector with much smaller sedimentation areas over the flank of the channels. Sediment deposition was evidenced over the southern and mouth sectors. Estimations of volumes of total erosion, deposition and volumetric changes for each channel are given in Table 2.

Analysis of the net erosional and depositional areas for La Lista Channel (Figure 3C) indicates an average accumulation rate of 0.8 m yr^{-1} in the southern sector of the hole. This

Table 2. *Volumes changes (in 10^6 m^3) of sediment and areas (in 10^6 m^2) for the different channels along study reach. Positive values indicate net volumetric gain; negative values indicate net volumetric loss.*

	La Lista		Tres Brazas		Del Embudo	
	Volumes (10^6 m^3)	Area (10^6 m^2)	Volumes (10^6 m^3)	Area (10^6 m^2)	Volumes (10^6 m^3)	Area (10^6 m^2)
	1.28	1.10	2.80	1.90	7.40	7
	−1.85	1.25	−0.35	0.30	−4.20	5
Net loss/gain	−0.57		2.45		3.20	

value decreases gradually towards the mouth, which reaches a rate of 0.3 m yr^{-1}. Erosional areas occur at maximum net rates of 1.2 m yr^{-1} on the northern side of the hole, decreasing to 0.4 m yr^{-1} on the mouth of the channel. As a consequence, the cross-sectional area adjacent to the hole increased slightly (between 20 to 30%), meanwhile in the rest of the channel the cross sectional areas remain practically unchanged (Figure 5A). At the same time La Lista Shoal (Figure 3A) had undergone a major change in its morphology. The shoal losed its straight outline and it partitioned in three parallel linear shoals (Figure 3B).

Over the same period, the behavior of Del Embudo Channel was characterized by a cross sectional area that had little changes (Figure 5B). Computation of the volumetric changes for various segments of the studied reach indicates that the rate of sedimentation and erosion were 0.4 m yr^{-1} and 0.3 m yr^{-1}, respectively. Net sedimentation areas occur in the southern and inner sector of the channel, while the erosional areas were localized at the central and northern portions and in the mouth (Figure 4C). The sedimentation that occurs in the inner sector of Del Embudo Channel may be due to the sediment input by two tributaries. They are El Toba and Paso de Enfrente channels (Figure 4C). Evidence for this sedimentation is a small spit formed at the mouth of El Toba Channel (Figure 4A). Sediment accumulation on the Angosto Shoal occurred at maximum rates of 0.4 m yr^{-1} while erosional average was 0.3 m yr^{-1}. The steeper northern and around the crestal portion had the largest deposition values.

Erosion and sedimentation rates related to depth of the Tres Brazas Channel (Figure 2C) indicates that the hole sector experienced erosion at its northern sector while sedimentation dominated at the southern sector. The average rates of erosion and sedimentation for each sector are 1.2 m yr^{-1} and 1.4 m yr^{-1}, respectively. In the mouth zone sedimentation occurs at maximum rates of 0.5 m yr^{-1} and average rates of erosion is 0.4 m yr^{-1}. As a consequence, the cross sectional area has decreased (between 30–50%), particularly at the mouth (Figure 5C). A sediment tongue originated by sediment deposition was developed across the mouth on the southern side (Figure 2C). Such accumulation originated a small bank, which then became attached to the coast and acquired an oblique orientation (Figure 2B). Sediment accumulation in this sector reached about 1.2 × 10^6 m^3 during the three years. The area of most intense erosion extends between Punta Shoal and the southern margin, where a total of 0.2 × 10^6 m^3 of sediment was removed in the same period. Also, a small erosion area, which has lost 10^5 m^3, can be observed on the northern margin (Figure 3C).

DISCUSSION AND CONCLUSIONS

Summarizing the morphological trends outlined above, it's clear that sedimentation and erosion in each three tidal channels are heterogeneous. They tend to migrate across the tidal flats gradually reworking older deposits (consolidated muds). According to PERILLO (1989) these sediments are remnants of a late Pleistocene-early Holocene delta complex.

VAN STRAATEN (1951) has been observed in the Wadden Sea that lateral displacement of small channels was up to 15 cm per day for 12 days. Lateral migrations of channels may be 100 m per year according to OOST and DE BOER (1994) in areas of the Dutch Wadden Sea, being restricted by the formation of ebb- and flood-dominated tidal chutes. In dynamically stable channels and gullies areas (such as the Dollar Estuary), except very small ones, may not change their position for decades (ZHANG YONG, 1988). According to EISMA (1998), in some interconnecting channel systems (in North inlet and along the New Jersey coast), is observed that the channels do not shift laterally. However, in this study, where the three tidal channels are develop into a interconnecting channels system of Bahía Blanca Estuary, there appears to be a trend to move laterally with rate of erosion of the order of 25 m per year. The lateral shifting is restricted to northern bank. A significant proportion of its sediment is derived by erosion of the channel bank and cutbank slumping. The total volume of sediment introduced to the channel by each slumping feature was estimated as 18-m^3 yr^{-1} (GINSBERG and PERILLO, 1990). Bahía Blanca Estuary contains only reworked sediment and is not augmented by fluvial derived sediment.

There is a large variability with the cross-sectional area change degree in the time, at each channel. As a result, three groups may by distinguished during migration: *i)* cross sectional areas decreasing with time, located at Tres Brazas Channel, *ii)* cross sectional areas increasing with time, located at La Lista Channel and *iii)* cross sectional areas unchanged with time located at Del Embudo Channel. This suggests that every channel behaves as a different morphological unit, whereas some channels have their areas temporally variable, in another channels their areas remained stable. This proves that sediment demand of the channels (the amount of sediment required to restore equilibrium) is reduced towards southern channels of the Bahía Blanca system and their migration continued landward.

The balance between erosion and deposition governs the channel maintenance. This balance is controlled by the hydrodynamics, being the resultant of the interaction of the tide with the morphology. The magnitude and direction of the net transport over a tidal cycle is mainly affected by tidal asymmetries favoring unequal duration and/or unequal magnitude of ebb and flood (DRONKERS, 1986). In particular, flow asymmetries characterized by shorter flood duration and higher flood current maximum (*i.e.*, flood dominance) induces a landward directed sediment transport (LANZONI and SEMINARA, 2002). Conversely, shorter fall periods and greater ebb current maximum (ebb dominance) cause a net outward sedi-

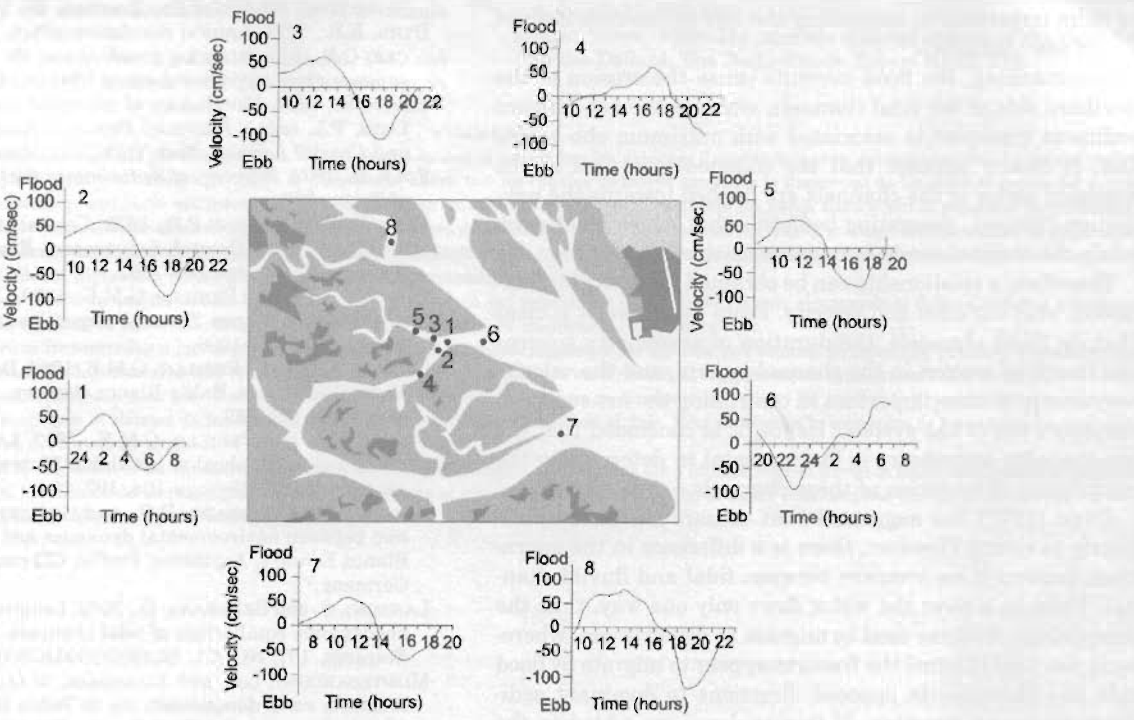

Figure 6. Mean velocity against time is compared for the study area. Current measurement at stations 4, 5, 6 and 8 were taken by MONTESARCHIO and LIZASOAIN (1981), and station 7 by NEDECO-ARCONSULT (1983).

ment transport. Current measurements taken at some tidal channels of Bahía Blanca Estuary by MONTESARCHIO and LIZASOAIN (1981) and by NEDECO-ARCONSULT (1983) and those that we carried out in the Tres Brazas and Tierra Firme channels indicate the existence of time-velocity asymmetry (Figure 6). These measurements suggested that ebb velocity dominance throughout the record, with maximum flood velocities of about 80 cm s^{-1} (+ve values) and maximum ebb velocities of about 120 cm s^{-1} (−ve values). Maximum flood velocities occur about 2.5 hr before high tide, whereas the maximum ebb velocity reach after the time of mid-tide. Examination of current duration indicates that flood time dominance is about 7 hr while ebb period is 5 hr.

According to the bedform distribution and morphological features characteristics, it is possible to outline the bottom flow patterns on tidal channels. In the Bahía Blanca Estuary the larger channels, ebb and flood follow different sides of the channel. This suggests that within the same channel there is a flood-dominated side and an ebb-dominated one. For instance, during flood tide the water flowing through the mouth and tend to move on northern side of the tidal channel, whereas during low tide the ebb currents are mainly directed towards the deeper sectors. Thus, the depth that marginal channel is formed could indicate that it is developed mainly by flood currents due to their longer duration. In addition, where the Tres Brazas Channel is bifurcated (Figure 2A) appear two channels open in the flood direction (flood-dominated sinus), which is another evidence that suggests that maximum scour occurs during flood. Therefore, we can assume that the asymmetry (in flood direction) governs the long-term trend of erosion on these channels and their northward migration.

According to AUBREY and SPEER (1985), the morphological evolution of the estuary system is dependent of the net sediment transport. Although the dominance sense of flood/ebb determines whether sediments are being transported in or out of the system, more important is the magnitude of flood/ebb velocities, because it determines over long periods, the net volume of sediment transport. Sediment transport volumes are highly sensitive to tidal velocities as they are related through a cubic expression to each other (BAGNOLD, 1963). In addition, based on current data from all stations (Figure 6), is reveal that the currents at Tres Brazas Channel and its tributary (Tierra Firme Channel) are ebb dominated, with maximum flood velocities of about 0.60 m s^{-1} and maximum ebb velocities of about 0.85 m s^{-1} (Figure 6, stations 1, 2, 3, 4, 5). Ebb dominance is also observed at Del Embudo Channel with maximum flood velocities of about 0.40 m s^{-1} and maximum ebb velocities of about 0.80 m s^{-1} (Figure 6, station 8). At El Alambre Channel the maximum velocity was at ebb direction, which reach 1.20 m s^{-1}, while flood was about 0.80 m s^{-1} (Figure 6, station 7). Therefore, these measurements suggest that high volumes of sediment of Bahía Blanca Estuary are being transported out of the tidal channels. Another evidence for the movement of sediment towards the large tidal channels by the tributaries (creeks) is the fact that the small spit at the mouth of El Toba Creek in the Del Embudo Channel (Figure 4A), is oriented or elongated in an ebb direction. We then assume that velocity asymmetry (ebb) is more important in controlling the net sediment transport out of the channels.

Summarizing, the flood currents cause the erosion of the northern side of the tidal channels, whereas the net outward sediment transport is associated with maximum ebb velocities. It clearly appears that the sediments scoured in the northern sector of the channels are flushed towards the navigation channel, generating bedforms that migrate outward, while the channel tends to migrate northward.

Therefore, a relationship can be obtained for flood/ebb dominance with duration and velocity. From the above, it is clear that, in these channels, the duration of asymmetry governs the trends of erosion in the channel system, and the velocity asymmetry is more important in controlling the net sediment transport out of the system. Hence, it is concluded that the time/velocity asymmetry is instrumental in determining the morphological evolution of these channels.

DYER (1977) has suggested that estuaries behave analogously to rivers. However, there is a difference in the migrations pattern if we compare between tidal and fluvial channel. Thus, in a river the water flows only one way, thus the morphologic features tend to migrate at downstream, whereas in the tidal channel the features appear to migrate by flood tide and therefore in opposed directions to dominant sediment transport direction. If this evidence we added to the exposed in previous paragraphs, can assume that the erosive processes at tidal channels are mainly related to the flood currents dominance.

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☐ SUMMARY ☐

El estuario de Bahía Blanca esta formado por una compleja red de canales de marea mesomareales, extensas llanuras de marea, marismas e islas. La escasa cantidad de sedimento aportado por los ríos y el introducido desde la plataforma, hacen que los canales de marea controlen la dispersión de los mismos dentro del sistema. Un estudio de tres años sobre el equilibrio morfodinámco, fue realizado en los canales de marea del Estuario de Bahía Blanca con el propósito de investigar la evolución del sistema. Sobre la base de análisis de relevamientos batimétricos espaciados 3 años, observaciones del flujo y procesos sedimentarios, se determinó la circulación en los canales. Por lo tanto, este trabajo discute los cambios morfológicos y los procesos de erosión, sedimentación y transporte de sedimento en los canales de marea del Estuario de Bahía Blanca, los cuales determinan la evolución morfológica del sistema.

Las corrientes de marea muestran que los canales son dominados por el reflujo con velocidades máximas de 1.2 m/s, alcanzando el flujo velocidades máximas de 0.80 m/s. Exámenes de la duración de las corrientes sugieren que el flujo demora 7 hr mientras el reflujo dura 5 hr.

Las secciones batimétricas transversales a los canales son bimodales, con dos canales separados por un área mas somera. El canal más profundo experimenta una corriente neta en dirección al reflujo mientras que el canal mas somero la corriente neta es en dirección al flujo. Nosotros consideramos que el transporte neto de sedimento dentro del sistema es gobernado por el grado de asimetría en velocidad, el cual es en dirección del reflujo. En cambio la duración de las corrientes de flujo/reflujo gobierna la erosión en el sistema de los canales, siendo dicha asimetría en dirección al flujo. Esta provocaría la migración de los canales hacia el sector norte con una velocidad de erosión de 25 m/año.

Comparando el modelo de migración de los canales de marea con el de los ríos podemos observar que estos últimos migran corriente abajo, en dirección al transporte de sedimento. En cambio, los canales de marea migran en dirección opuesta al transporte de sedimento. Por lo tanto, consideramos que los procesos erosivos en los canales de marea están relacionados con las corrientes de flujo.