**Washouts in the Central and Northern Littoral of Rio Grande do Sul State, Brazil: Distribution and Implications**

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**ABSTRACT**


Washouts play an important role in the drainage of pluvial waters from the swamps located behind the frontal dunes systems of the RS coastal plain. The number and spatial distribution of these features varies along the coastline as a function of the seasonality, geology and geomorphology of the coastal plain. Eight years of monitoring allowed us to verify the main causes of its temporal and spatial distribution. The mean lowest and maximum values of washouts per kilometer were observed during the summer season (0.3 / Km) and at the winter time (0.8/ Km) respectively. During the Spring and fall intermeditated values were observed (0.6 to 0.8 / Km). As a function of urbanization processes, subsurface geology and topography high concentrations were respectively observed near Mar Grosso beach, Conceição and Mostardas Lighthouse. Due to the existence of coastal lagoons (Fish Lagoon and Estreito Lagoon), which receives the water from the lower adjacent areas, the number of washouts decreases around these lagoons. In the northern part of the littoral the existence of several pocket lagoons which can overflow during periods of high rainfall increases the number of washouts, generating features with dimensions over 300 m width. As already observed along the southern coast of RS, the washouts are the main agent responsible for the discontinuity of the foredunes systems. By carrying great amount of sand back to the surf zone they play an important role in the surf-zone sand nourishment. Its distribution patterns should be considered in any process related to the occupation of the coastal zone.

**ADDITIONAL INDEX WORDS:** Ephemeral creeks, beach drainage, foredunes.

**INTRODUCTION**

Along the 620 Km of the Rio Grande do Sul (RS) coastline a few fluvial discharges occur. However, the pluvial drainage in the form of washouts is intense. According to PEREIRA DA SILVA et al. (2003), processes related to erosion, transport and deposition of sediments throughout these creeks directly affect the region between the dune fields and the beach face. Washouts are the main agent interrupting the continuity of the foredunes ridges, by breaking down these ridges and transporting sand back to the surf-zone. The aim of this work is to describe the spatial and temporal distribution of the washouts on the central and northern littoral in relation to the influence of the meteorological forces, the associated geomorphology and anthropogenic influence due to urbanization processes.

**STUDY AREA**

The study area is the central and northern portion of the Rio Grande do Sul (RS) coastline which is located in the southernmost state of Brazil (Figure 1). The area is characterized by a continuous barrier island which is part of a wide and low laying coastal plain.

The predominant direction of waves that reach the RS coastline is from southeast. Waves from this quadrant have longer periods and lower steepness (swell). Waves from northeast are mostly sea waves characterized by higher steepness and lower period. The predominant wind direction is from northeast. Winds, however, are more susceptible to seasonal variation than the waves. Winds from N-NE, NE and E-NE are more frequent and stronger form September to April, being rare and weak from May to August. Winds from S and W are more frequent from May to October and rare from November to April.

Tides along the area are microtidal, however storm surges are important erosion events mainly during April and May when they occur in conjunction with spring tides (CALLIARI et al., 1988). Penetration of mid latitude frontal systems are responsible for most of the precipitation year around and do not display a well defined seasonal behavior. Evaporation rates are higher during the summer months (December to march). According to the morphodynamic sequences described by WRIGHT and SHORT (1984), beaches from RS are classified as intermediate and dissipative. Some changes in this pattern may occur as function of grain size variation, the presence of shell debris, in the region called Concheiros do Albardão, and close to Estreito Lighthouse where medium sand predominates. Differences in morphodynamic behavior between these regions are characterized by beach face steepness, frequency of secondary morphological features, erosion characteristics and associated hydrodynamics.

Figure 1. Study area. The central coast of Rio Grande do Sul, State, Brazil.
SIEGLE (1996) studying the area between Conceição and Chui Lighthouses, verified that fine sand dominate along this area, however at Concheiros do Albardão and near the Estreito Lighthouse medium sand was found. This variation on grain size is caused by geological inheritance, being the shoreface the source of sand. A region dominated by very fine sand under the influence of the lagoon discharge predominates on both sides near the mouth imprinting to these beaches the most dissipative characteristic of the entire barrier.

According to BARLETTA (1997), beaches between Solidão and Mar Grosso are classified mostly as intermediate and dissipative, displaying low and discontinuous foredunes. During summer months beaches near the Estreito Lighthouse can reach reflective conditions.

RESULTS AND DISCUSSIONS

Seasonal Behavior (1991-2001)

Maximum and minimum values of washouts per Km are observed during the winter and summer respectively (Figure 3). This pattern is directly related to the meteorological parameters: evaporation and precipitation. Although there is a lack of a well defined seasonality in the precipitation pattern, the higher evaporation rates during the summer reduces the number of washouts. After analyzing the annual mean values of washout and its relationship with the evaporation and precipitation patterns during the respective years, it was found that the seasonal distribution is mainly dependent of the evaporation rates.

It should be pointed out that although the values displayed by Figures 2 and 3 are mean annual values, the number of washouts per Km actually can be as high as 3.2 /Km. Higher absolute values were also verified shortly after periods of high rainfall when the number of washouts increases abruptly, reaching more than 4 washouts/Km.

Spatial Distribution

From figure 2 which displays the mean values of the number of washouts per 10 Km registered during six years of monitoring some patterns emerge. Higher concentrations were observed near the jetty (Km 10) at Mar Grosso Beach, Conceição Lighthouse (Km 70) and near the Mostardas Lighthouse (Km 150). Lower values occur at Estreito Lighthouse (Km 40) and at the Fish Lagoon inlet (Km 120).

Barrier geomorphology is certainly the main control affecting the washouts spatial distribution. The presence of coastal lagoons such as Fish and Estreito Lagoon, which are located on the rear of the beach system explain the low frequency of washouts in this area. By being areas of low topography, all the adjacent drainage is directly landwards to the lagoonal body and the number of washouts decreases along these beach sectors (Figure 2). To the north, between São Simão and Tramandaí, the opposite effect is noticed. The existence of several pocket lagoons very close to the beach which generally overflow during periods of high rainfall increases the number of washouts along the beach. In this area, washout width and depth can reach over 300 m and 0.5 m respectively.

Washouts play also a major role in foredune erosion being the main factor controlling the discontinuity of high foredune ridges along the coast. This is evident around the Dunas Altas locality where the foredunes reach more than 10 m high.

Adjacent to Conceição Lighthouse, high values of washouts are common. Geological factors represented by subsurface peat deposits which occur behind the foredunes and on the backshore along tenths of kilometers, as well as, the presence of sandstone deposits of Pleistocene age (BUCHMANN and TOMAZELLI, 2003), on the beach face my contribute for this increase by reducing the beach permeability.

Close to the Fish Lagoon, few develop dunes are observed, what could facilitate the traffic of the washouts to the beach increasing the number of washouts in this area, however the number of washouts is reduced because of the presence of the lagoon.

Near Mostardas Lighthouse, dunes are well developed and the number of washouts per km is also high. Evidences from aerial photos show the presence of swamps and areas of low relief located in the deflation plains between the transverse dunes. Such morphology contributes for the storage of pluvial water that sustains the washouts. Through aerial photos, close to Mostardas Lighthouse, the washouts are located in the deflation plains between the transverse dunes. The morphology and dune orientation facilitate the washout arrival to the beach. The morphodynamic relationship between washouts and the dune field is complex and interdependent. The presence of washouts

Figure 2. Mean annual values of washouts from 1991 to 2003.
Figure 3. Geomorphological patterns of washouts along the coast.

3a - Near Fish Lagoon
3b - Bujuru
3c - Near Conceição Lighthouse
3d - Close to the Jetties
is independent of the foredunes development; however it can be related to the orientation and general morphology of the dune field.

Beach morphodynamic characteristics such as berm height and permeability which are controlled by grain size also affect washout distribution. In this sense, a decreases in the number and residence of washouts was identified near the Estreito Lighthouse were medium sand dominates imprinting intermediate characteristics to the beach profile.

In other places, fine and very fine well sorted sand with less permeability and porosity allow the pluvial water to flow quickly generating washouts. This is the case for Mar Grosso Beach, Conceição and Mostardas Lighthouse where fine sands and dissipative beaches predominate.

The existence of Pine plantations located near the dune fields along some sectors of the coast may reduce the number of ephemeral and intermittent washouts. However the number of bigger permanent washouts artificially built in order to drain the area to initiate the plantation increases. These artificial channels can be observed especially near Bujuru (90 Km north of the Patos Lagoon mouth).

The presence of the beach resorts modifies the natural concentration of washouts along the coast. As the resorts growth, edification and paving reduces the infiltration area and the number of washouts increases significantly. This can explain the high number of washouts at the Mar Grosso beach.

Washouts and Coastal Geomorphology

Based on digital aerial photography and field observations, six distinct morphologic patterns of washouts which are related to spatial changes in the geomorphologic of the beach and dune systems can be identified. (Figure 3).

Close to the jetty, near Mar Grosso beach, high number of ephemeral and intermittent washouts are observed, being the number of permanent ones very low (Figure 3a).

In the surroundings of the Estreito Lighthouse the washouts spread over the beach face cutting down very little the sand deposits. This morphological pattern is related the existence of a higher berm during the summer season when this beach sector display intermediate morphodynamic characteristics due to the higher content of medium quartz sand. The higher berm forces the washouts to migrate parallel to the shoreline. This behavior was already noticed by PEREIRA DA SILVA et al. (2003) at intermediate and reflective sectors of the southern RS beaches.

As a result of the artificial drainage imposed during the process of Pine plantation, the area adjacent to Bujuru is characterized by straight, deep and more permanent washouts (Figure 3b).

The Conceição Lighthouse area is characterized by higher washouts concentration, which can be due to the presence of impermeable layers of peat deposits on the back shore and dunes. Some of the washouts are very narrow and ephemeral, displaying low residence time at the beach face being mostly observed during high precipitation events. Permanent washouts which extend over long distances landward are also common in this area. Its presence can be linked to the existence of low relief areas on the landward dune field. (Figure 3c).

Near the Fish Lagoon, few washouts are observed (Figure 3d). Most of the pluvial drainage in this area is directed to this coastal lagoon which can display an ephemeral bar during the rainy season.

As we approach the Mostardas Lighthouse, the dimensions (width and depth) as well as the number of washouts increases being most of them intermittent. This pattern is controlled by the transverse dunes field which display a normal orientation related to the shoreline, directing the pluvial drainage towards the beach (Figure 4).

Washouts: Urbanization and Coastal Hazards

Urbanization processes visibly increases the washout concentration along the beach and dune field. This is mainly due to the reduction of the infiltration area and soil compaction which is caused by road pavement and any kind of edification (Figure 5).

At most of the beach resorts along the RS coastline this fact can lead to flash flood of the lower urbanized areas which has serious consequences on basic sanitation for both the urbanized areas and the water quality at the surf-zone since domestic waste is not treated. These problems have deep effects over tourism related activities. Additional problems are related to dune erosion, since there is an increase on the volume of water that is drained towards the beach. In the northern part of the barrier an increase in the number of washouts in more urbanized sections is well known and cause a deficit in the beach sedimentary budget.

Washouts also are a source of coastal hazards. The fact that fine sand predominates along the beaches provides good conditions for car traffic. However, after high precipitations, events beaches can hide great danger and cause accidents to the unaware users since deep washouts can be suddenly formed and be difficult to spot. Many accidents have been reported in such conditions, including car lost on quick sand along these ephemeral creeks.

When the washouts cut the dune field, high unstable scarps with a potential risk for collapse are formed. A fatality has been reported on November of 2001, in the Inhame locality, when eight years old boy, which was playing on the edge of the scarp, was buried by the sand of the collapsing dune.

Lost of property is also an issue when constructions are set on the course of washouts. This can happen when urbanization is done during the dry season, without any previous study of its seasonal behavior. All the above examples demonstrate the importance of understand several aspects of washouts related to coastal management. Urbanization problems and Hazards can be avoided if washout distribution and behavior is taking into account on the occupation plan. Special efforts should be concentrated on the acquisition of highly detailed topographic maps, which will be the first and important basic tool for a proper occupation.

It is also essential to understand the morphodynamic processes which control “the life cycle” (beginning, development and closing) of these ephemeral water courses, since they are part of the beach-dune interaction system. Additionally, the monitoring of its water characteristics will provide important clues regarding its role as a source of fresh water, organic matter and nutrients to the surf-zone.

The RS coastline will in a very near future experiment an intense occupation process due to the conclusion of the BR 101. This 400 Km long highway will facilitate the access and the rapid development of the central part of the barrier which is still in a pristine state. It would be very positive if the development of future “coastal resorts” could be planned considering all the environmental aspects related to washouts occurrence.
LITERATURE CITED


Figure 5. Increase in the number of washouts in the vicinity of a beach resort.