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Spatial Changes of Beach Profiles for a Small Tidal Inlet (Currumbin Creek, Australia)

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Abstract: *Many tidal inlets are actively monitored to investigate the change in flood or ebb shoals, as these sand deposits can have a major influence on the sediment budget of the adjacent coast. However, here it is hypothesized that the shores of the back barrier area can also act as a source of sediment to be considered in the sediment budget. Therefore, profile changes around Currumbin Creek tidal inlet were considered to identify the extent of such a contribution on the surrounding beach and the overall evolution of the inlet system. The results of 16 weeks survey showed that in general, the shores of the back barrier lagoon had a very marginal effect in the provision of material to the sand budget, although the gorge area is highly vulnerable and dynamic. Even an intense storm event and heavy rainfall during the data collection period, resulting in erosion of the surrounding beaches, showed no significant influence on the shore face of the lagoon.*

Keywords: *Beach Profile Evolution, Currumbin Creek, Small Tidal Inlet, Flood Shoal Dredging.*

1. INTRODUCTION

A tidal inlet is an opening within a beach face which is mostly controlled by tidal forces and exhibits periodic exchanges of water between an inland water body and the ocean. Apart from the entrance, the other most important features of a typical tidal inlet system are offshore (ebb delta) and/or inland (flood delta) sediment deposits (shoals). The excess sediment accumulation within these shoals, which may fully block the natural passage of water, is one of the common issues affecting a typical tidal inlet entrance. Different sources may contribute to these sediment deposits, such as littoral drift, material from beach washover and unsuccessful beach nourishment (Castelle, 2007). The aim of this paper is to distinguish the extent to which profile changes within the inlet itself can contribute to the overall coastal sediment transport budget. The results will be used to investigate alternative designs for dredging of the inlet or adjustment of the existing groynes.

2. STUDY AREA

This study is a part of a comprehensive study of Currumbin Creek tidal inlet system (28.127S, 153.484E-Figure 1) (Shaeri et al. 2013a,2014). Part of the results of the extensive field measurements are used to explore the dynamics of the creek. This area is a highly popular tourist attraction in South-East Queensland, Australia which also has a history of entrance maintenance operations. The inlet entrance is oriented in an east-west direction. At the immediate inland side of the entrance channel, a 15 hectare lagoon is situated with about 10% of this area comprising flood shoal deposits of marine sand. It is believed that this shoal greatly influences navigation safety (Strauss and Hughes, 2011).

Over the past 30 years, there have been annual dredging campaigns to keep the creek entrance open to mitigate the impacts of flooding upstream and to benefit water quality. Nevertheless, the entrance becomes shoaled again soon after each dredging campaign. This process is exacerbated by littoral drift and erosion of the adjacent beaches, suggested to be significant processes resulting in spatial changes to the ebb and flood shoals (D’Agata, 2002). The aim of this research is to investigate the effects of the shore face of the lagoon and the creek, in providing sediment supply for the shoals. Therefore, to provide an insight into the maintenance design, herein, changes in the beach profile around the creek are examined in detail.

Towards the end of the measurement period (in February 2013) there were a number of severe storm events with accompanying high waves and high rainfall prevailed throughout the study period. Based on recorded data available from the Australian Bureau of Meteorology (BOM, 2014) at the “Elanora Water Treatment Plant” station, the amount of rainfall during the measurement period was about 980 mm (55% of the total rainfall for 2012). Furthermore, the maximum significant wave height (Hs,max) and the longest storm period (defined as recorded significant wave height exceeding 3m) were 7.5m and 48hrs respectively (Shaeri et al. 2013a,2013b,2014).

Figure 1 Map and aerial photo of Currumbin Creek tidal inlet (with a red circle for its gorge) and location of profile lines

3. METHOD TO DEFINE PROFILE LINES

The aerial map (Figure 1) shows that the inlet entrance and the back-barrier lagoon are surrounded by sandy shores, which are prone to erosion. This erosion would appear to play a minor part in the deposition on the ebb/flood delta shoals when compared with marine infilling of the entrance. In order to investigate the evolution of these beaches a series of measurements were designed (Shaeri et al., 2013a, 2014).Surveys were conducted weekly for 16 weeks from 2nd December 2012 to 15th March 2013. The measurements were obtained from 141 specific survey lines over 5 km of the adjacent beaches. Continuous measurement was not possible with the limited resources available for this study.

Profile lines were chosen to be good representatives of their surrounding area. Lines were more closely spaced in areas of strong shoreline curvature and more widely spaced along straighter parts. The distance between any two consecutive lines varied between 10 and 100m. The base point of each line was approximately 0.5m above the highest high water (HHW) mark. The distance between any two consecutive lines was also measured from the base point of those two lines. From the base point, each line was surveyed roughly perpendicular to the local shoreline, extending from the dry part of the beach to a depth (approximately) 0.5m lower than the lowest low water (LLW) mark. After defining the route of each line, every single line was also divided into a number of subsections and at each ends of these subsections, the coordinates (x and y) and elevation (z) were measured. The number of subdivisions of a line depended on the existence of any abrupt change in elevation along that profile. In the case of relatively flat profiles (with no abrupt change in elevation), the subdivision lengths were limited to 5-7m. In this way, the recordings consisted of about 54100 points in total.

4. Results and Discussion

Overall, a length of about 5 km along inlet’s surrounding beaches has been surveyed during 16 weeks which has covered a total length exceeding 134 km. For simplicity of presenting and discussing the results, the area is divided into five major sub-areas. With reference to Figure 1, these are: the inlet south (updrift) beach (lines 001 to 022); inlet north (downdrift) beach (lines 112 to 141); inlet channel shores (lines 023 to 047 and 109 to 111); and shores of the Lagoon south (lines 048 to 065), west (lines 067 to 080), north (lines 081 to 100), and east (lines 101 to 108). Important lines for each of these divisions and their profiles on weeks 1, 5, 10 and 16 (the last week) are discussed hereafter.

4.1. Inlet South Beach

From the inlet entrance towards the south (updrift), a distance of about 2.0 km of the beach south of inlet was considered for surveying profiles. This area (lines 001 to 022) has a fundamental role in the net alongshore sediment transport including sand bypassing of a small headland which occurs here. Therefore, the effect of any sediment accumulation or loss should be carefully considered. Figure 2 (panels A to C) shows a minor erosive trend from the beginning of surveying up to the end of week 12 in this area. However, the effect of the February 2013 storms is remarkable yet again.

4.2. Inlet North Beach

Similar to the updrift beach, a distance of about 2.5 km (lines 112 to 141) was considered for surveying profiles based on the downdrift potential influence on the inlet evolution. The centre of this area (between lines 130 and 131) is used annually for the discharge of dredging materials from the creek flood shoal. Therefore, the effect of such an artificial sediment source should be carefully taken into account. A general trend for the lines in this area can be inferred from Figure 2 (panels D to F). As shown in this figure, firstly, the beach faces encountered deposition until week 5 and then experienced erosion until week 10. From week 10, the beach profiles showed no significant change (although with a slight erosive trend). This trend continued up to week 12, when the area was affected by the February 2013 storms, and a big shift (erosion) in the beach profile volumes (between week 12 and week 16) can be clearly seen in all panels.

4.3. Inlet Channel Side-Beaches

The surveyed lines located within the inlet channel (lines 023 to 047 and 109 to 111) represent the most dynamic profiles of the inlet system. In particular, the southern and northern sections of the inlet channel, which are exposed to the incoming waves, tides and storm surge, encountered very significant changes throughout the surveying period (Figure 3). Contrary to the ocean beaches of the inlet updrift and downdrift, sediments started to deposit in this area from the early stages of surveying.

However, similar to the other profiles, the February 2013 storms removed a substantial amount of sediment from this area. The most interesting survey lines were those which were close to the inlet channel gorge (the red circle in Figure 1 and profiles in Figure 3-panels D to F). In contrast to the aforementioned trend of deposition in the south section of the channel, this area experienced substantial erosion from the early stages of surveying, followed by sudden deposition after the February 2013 storms. Therefore, at the beginning of the survey, the sediments migrated from the flood shoal towards the entrance, but then co-incident with the storm events and elevated sea level, the majority of the eroded sediments of the channel filled the gorge section.

4.4. Lagoon Beaches

In particular, many of the inner lagoon profiles (lines 048 to 108) showed no significant contribution to the overall sediment transformations of the inlet system. Moreover, there is no evidence of significant profile change, either related to the February 2013 storm tides or the inundation caused by the heavy rainfall discharge during the storms. However, the lines of the lagoon south beach (Figure 4) show a slight contribution to the sediment budget, with a relatively smaller amount of sediment volume commensurate with the channel shores lines. There is also a special case for the east side of the lagoon. In this area there was a nourishment activity between weeks 10 and 12, which resulted in change of profile. Following that activity and concurrent with the February 2013 storms, the beach here displayed a slight depositional trend.

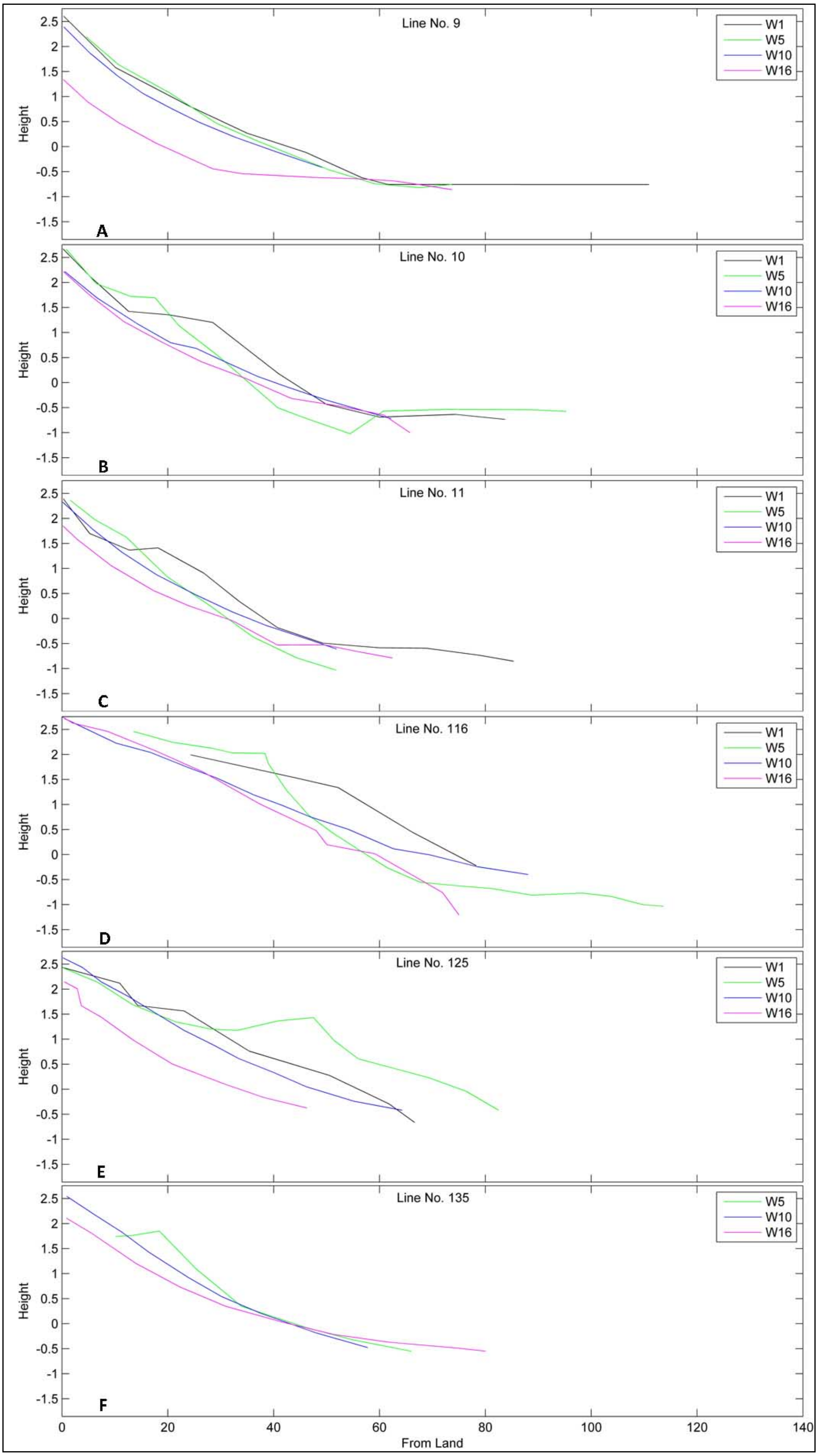

Figure 2 Lines of the updrift (A to C) and downdrift (D to F) beaches

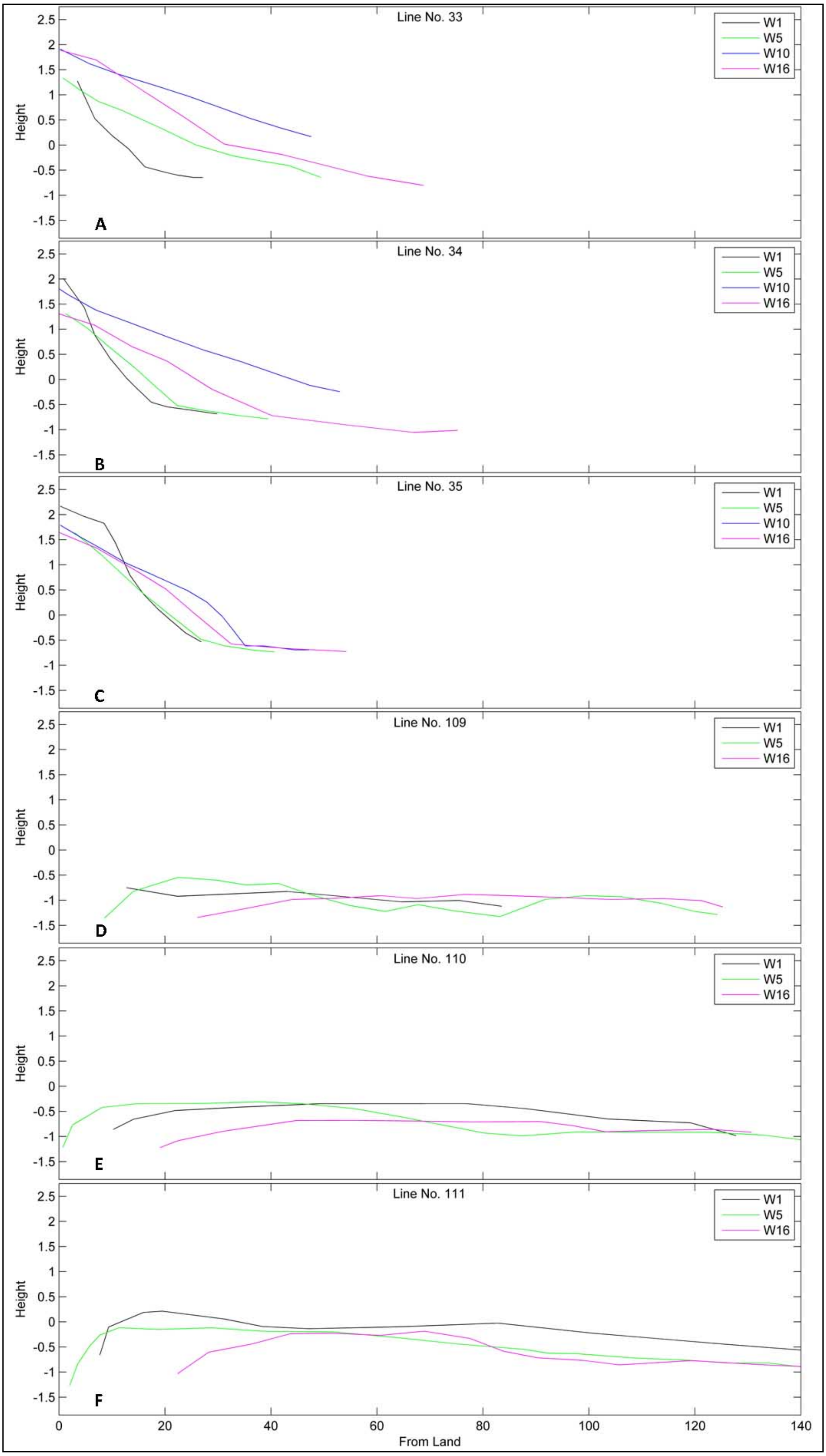

Figure 3 Lines of the Inlet channel south (A to C) and north (D to F) side-beaches

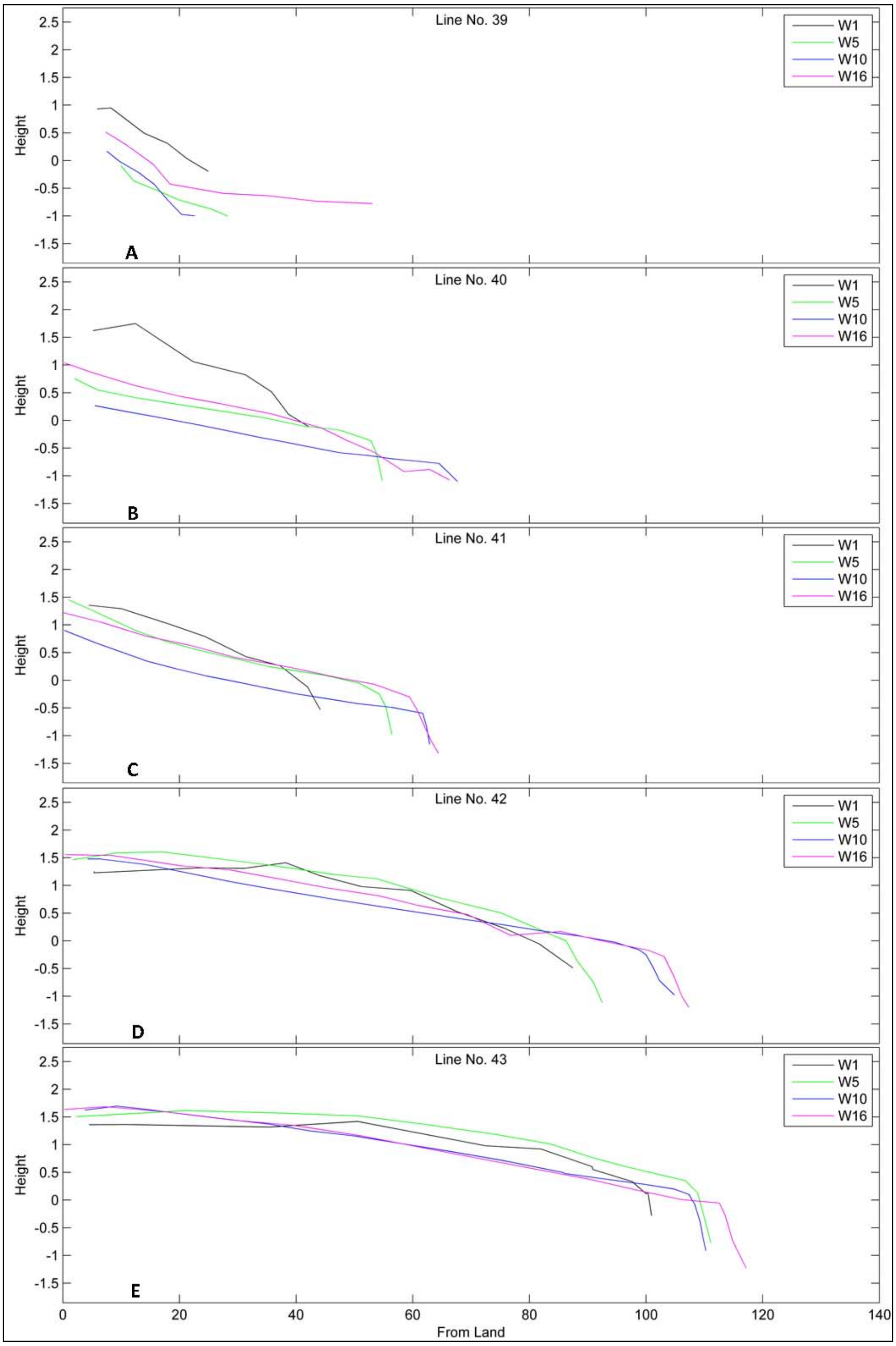

Figure 4 Lines of the Inlet Channel – West Section

4.5. Volumetric Changes

With further analyses of the profile changes, the (approximate) volumetric change of each line was also derived. Herein, it was assumed that each line was (at least) representative of a unit width of its surroundings. Therefore, relative to an arbitrarily baseline, it was possible to calculate the change of sediment volume at each line with respect to the first week data. Comparing these sediment volumes over the course of the surveys (Figure 5) provided the (approximate) amount of sediment accumulation (positive) or erosion (negative) for each line. It can be seen that the volume of profile line 001 increased initially until week 5 (by accretion), and then eroded until week 10 (Figure 5-panel A for the updrift beach). This line responded to the February 2013 storms by accumulating more sediment compared to the first week. For line 002 in the same panel there is increasing volume until week 10 with a net increase still evident at the end of the measurements. As for the graph in Figure 5-panel B (for the channel south beach) and the results described in section 4.3, although the overall trend of lines 033 and 034 were toward deposition, the intensive storm of February 2013 totally changed the shape of line 034. The volume in week 10 at line 034 was approximately twice the volume of the previous week.

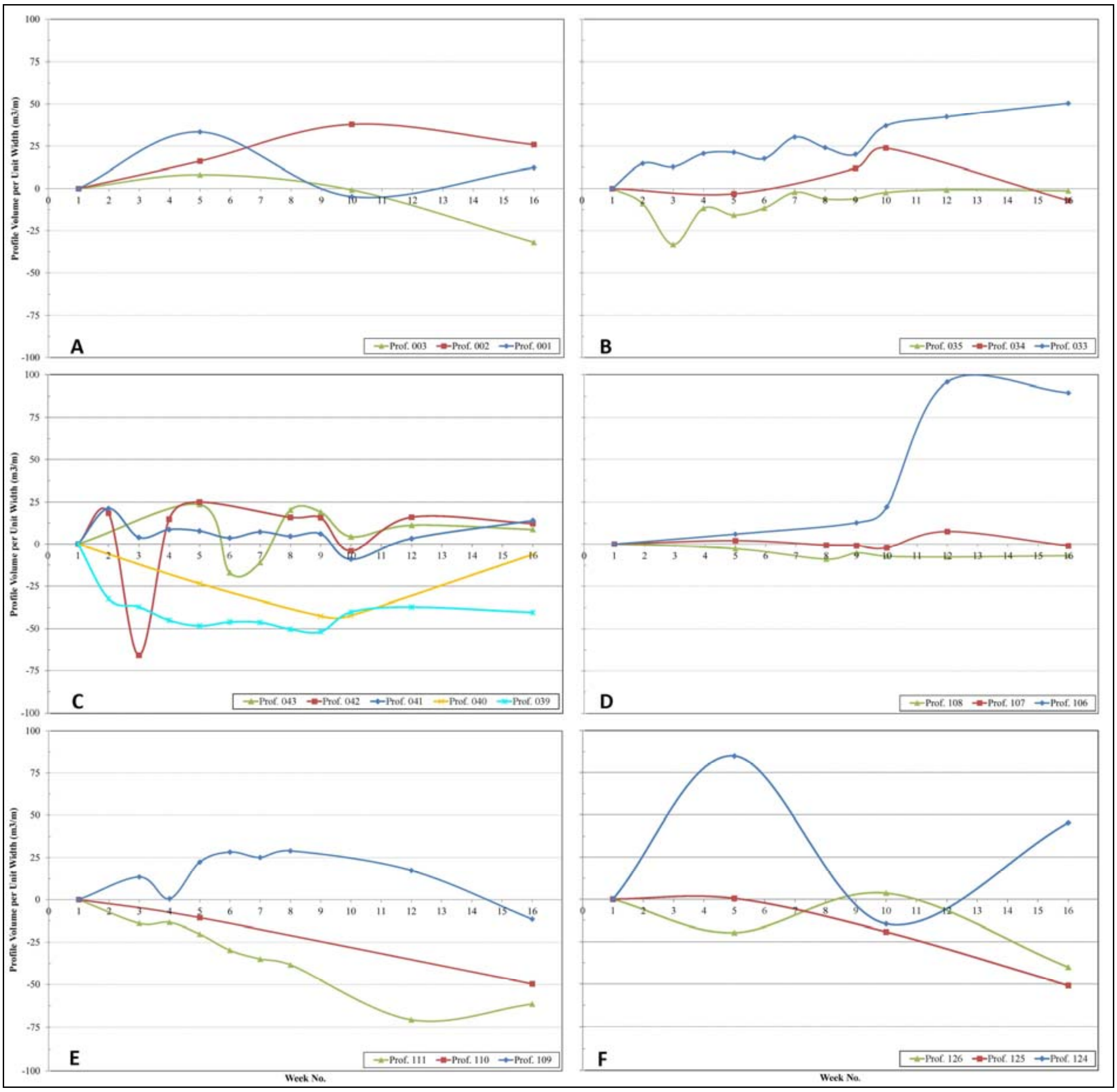

Figure 5 Changes of Profile Volume per Unit Width (cubic meter per meter)

The graph in Figure 5-panel C (for the gorge section) relates to the lines close to the inlet gorge. As discussed in section 4.3, for lines 039 and 040 there was highly significant erosion and also transportation of sediment toward the inlet entrance. However, the previously described effect of the February 2013 storms is noteworthy here as well, because the erosive trend changed sharply to deposition on profile 040. In addition to that, comparison between lines 042 and 043, clearly reveals the exchange of sediment between these lines over different weeks. As reflected in section 4.4, in large areas of the Lagoon beaches, the profiles had insignificant changes compared to other parts of the Lagoon. However, Figure 5-panels D (for the lagoon north beach) and E (for the channel north beach) clearly show the effect of nourishment on the changes in lines 106 and 109 and the erosion of lines 110 and 111. It should also be noticed that such erosion is mainly because of the change of the channel gorge. Unlike the updrift lines, many of the lines for the downdrift beaches (Figure 5- panel F) showed accretion, except lines 125 and 126. This irregularity should be investigated separately in detail in a future study.

5. CONCLUSION

Analyses of the profile changes of beaches and shores around an inlet entrance can provide a valuable insight regarding the importance and contribution of any individual part of the system, for the entire sediment transport and stability of the area. Since extensive changes occur in the Currumbin Creek flood shoal area, it has been hypothesized that the backbarrier shores contribute to the sediment budget. Therefore, an intensive field measurement exercise was conducted to collect periodical beach profiles to investigate beach changes. Many of the profiles of the updrift and downdrift beaches showed an expected trend of accretion until the occurrence of storms in February 2013. Following that there was a predominantly erosional trend observed at these beaches. In contrast, profiles of the Lagoon side had no significant change.

Therefore, the main outcome of this study is that the responses of the profile lines of the region adjacent to the channel and in particular the channel gorge are very dynamic and that this region has a significant effect on the evolution of the whole system. This area was only marginally affected by the February 2013 storms, but to a lesser extent compared to the natural trend of post-dredging profile evolution. For better interpretation of the observed changes for each profile, bathymetric survey of the area should also be conducted simultaneously, particularly for the channel gorge section. In addition, longer data sets, with data from different extreme (annual) tidal variations, may result in better explanations of the outcomes.

6. ACKNOWLEDGMENTS

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