# DUNE ENHANCEMENT TO SOLVE ENTRANCE INSTABILITY

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## Abstract

Mollymook Beach is an open-coast beach located north of Ulladulla on the Shoalhaven coast. Shoalhaven Council undertook coastal hazard mapping in 2009 for Mollymook Beach which indicated that the area north of Blackwater Creek, which contains significant public and private infrastructure, was at risk from coastal inundation due to the low dune crest levels, and dune erosion. The high coastal hazard in this area was considered to be a result of the propensity for the creek to break-out toward the north, significantly affecting the available volume of sand along the beach and limiting growth of the foredune.

Based on recommendations from Council's Draft Coastal Zone Management Plan, the dune on the northern side of Blackwater Creek was enhanced in April 2016 using sand sourced from Council's dredging program at Lake Conjola, in conjunction with a training wall at Blackwater Creek. The purpose of the works was to reduce the coastal erosion and inundation hazard for the area immediately north of the creek entrance, provide protection to essential sewer infrastructure and reduce the propensity for the creek to break out to the north, thus reducing the estuary entrance instability hazard for this area.

Advisian reviewed the coastal hazards and found that the works resulted in an additional 13 $m^3/m$ of dune sand available to feed the storm erosion demand. In addition, the crest level of the dune was raised to 5.5 m AHD which has reduced the wave inundation hazard, with the training wall enabling the creek to break out toward the south in a large storm event. This has eliminated the creek entrance instability hazard for the area immediately north of the creek entrance, providing additional reductions to the storm erosion demand.

Initially there was landowner concern about placing the sand in front of the properties, but now landowners have witnessed the benefit both with the revised hazard mapping and during a storm event. Shortly after the works were completed, the south coast experienced an east coast low storm event. Wave runup was observed over sections of the nourished dune but did not reach the sections of the natural dune or properties. In the two years since construction, the dune has been stabilised by native vegetation and the works remain encapsulated beneath the dune. Over this time, several storm events have occurred and the creek has tended to break-out toward the south, resulting in reduced risk to infrastructure. With the creek now breaking out toward the south, the foredune has continued to build up naturally due to onshore winds carrying sand from the beach berm onto the dune.

## Introduction

Mollymook Beach is approximately two kilometres long and is flanked by a rocky sandstone headland at Bannisters Point at the northern end and an intertidal rock shelf to the south. Two small creeks cross the beach, one towards the southern end and another near the northern end. The entire beach is flanked by urban development and in some areas, the frontal dune has been interfered with, reshaped and denuded of

natural vegetation, especially at the southern end where the Golf Club and Surf Club are located. Here, seawall structures have been constructed on the dune to protect property from erosion.

The natural foredune has been recently enhanced (April 2016) using sand sourced from dredging at Lake Conjola, on the northern side of Blackwater Creek, in conjunction with an entrance tripper wall, comprising a buried geobag and rock structure.

The presence of the works, as well as additional data collected since the 2009 coastal hazard assessment, have been taken into account in updating the hazard assessment for Mollymook Beach. Since 2009, additional data has become available, including photogrammetry data (dated 27/11/2014), LiDAR ground level information, bathymetric soundings dated December 2010 and ground survey of the dune dated March 2010, April 2013, March 2015 and December 2015. Further survey of the beach was undertaken following the East Coast Low of June 2016, allowing an assessment of storm erosion demand from that event. These additional data were used to update the hazard assessment for Mollymook.

## Creek Entrance Instability Hazard Estimation

Short term beach fluctuations can be enhanced at natural estuary entrances. Natural entrances tend to migrate along the beach in response to freshwater flooding and coastal storm effects (NSW Government, 1990). This phenomenon has been seen at some of the beaches in the Shoalhaven, including Mollymook, with the creek entrance location migrating in response to the severe coastal storms of May 1974.

The extent of this hazard was quantified empirically based on historical photogrammetric data in the SMEC 2011 and Advisian 2016 coastal hazard mapping. The extent of the creek entrance instability hazard was estimated using an empirical method based on the photogrammetric data. The creek entrance instability hazard, where applicable, has been added to the short term erosion hazard. The combined hazard has been applied using the same protocol that was used for the design storm erosion (Nielsen et. al. 1992).

## Previous coastal hazard assessment and recommendations

Prior to the most recently adopted coastal hazard mapping being completed for Mollymook and prior to the dune enhancement works undertaken in April 2016, the coastal hazard assessment identified that the area immediately north of Blackwater Creek was subject to coastal erosion and inundation risk, as indicated in Figure 1.

Up to seven private properties were identified by SMEC in 2011 as being within the Immediate coastal hazard area, subject to the coastal hazards of immediate wave impact, slope adjustment, reduced foundation capacity and coastal inundation in a design coastal storm event equivalent to a 100 year ARI storm event. In addition to these private properties, Council sewer assets including a Shoalhaven Water sewer pumping station were identified as being subject to an extreme immediate risk from coastal hazards.

During the earlier phases of Council's development of the certified Shoalhaven Coastal Zone Management Plan, Council had commissioned a Site Specific Emergency Action Plan in 2010 which recommended that works be carried out to address the immediate risks. In particular, works were recommended for the area north of Blackwater Creek.

The dune height in front of the dwellings located directly north of the creek entrance was identified in SMEC 2011 as being low, due to the presence of the creek entrance and lateral movement of the creek entrance along the beach, in particular, the tendency for the creek to break out toward the north. A wave runup assessment of the beach found that the dune would be likely to be overtopped in a design storm event, leading to a risk of inundation to infrastructure. A possible solution for this issue was identified, which was the creation of a geotextile tripper wall along the entrance as illustrated in Figure 3. Such a tripper wall would reduce the impact of the creek flow on the dune and allow a building up of the dune north of the wall. Once protected by the tripper wall, it was suggested that the dune height be reshaped to reach a 6 m height to prevent wave run-up from overtopping the dune, allowing the dune to naturally build up over time. Beach scraping or Nature Assisted Beach Enhancement (NABE) could assist in this process. The dune could then be stabilised by planting vegetation and fenced. The reasoning behind this was to provide better protection to the houses located north of the creek entrance and hazard lines would move seaward as sand store builds up in this area.


**Figure 1 – Previous coastal hazard mapping for immediate timeframe area north of Blackwater Creek (SMEC 2011)**


**Figure 2 – Area subject to coastal inundation north of Blackwater Creek prior to construction of tripper wall (SMEC 2011)**


**Figure 3 – Suggested alignment for buried tripper wall north of Blackwater Creek showing location of Sewage Pumping Station (SMEC 2011)**

## Works Commissioned

Shoalhaven Council adopted the previous Draft Coastal Zone Management Plan in 2012 and following this, began to implement the recommendations of the Plan.

In 2015, Council commissioned a design of an engineered tripper wall structure, similar to what was envisaged in the Draft Coastal Zone Management Plan but with the dual purpose of providing coastal protection to the sewage pumping station. The tripper wall structure comprised a buried revetment along the northern foreshore of the creek fronting the sewage pumping station to provide erosion protection, linked with a buried geotextile container structure designed to reduce the likelihood of Blackwater Creek breaking out toward the north.

During the course of this design, Council was concurrently undertaking a dredging program for nearby estuaries, including at Lake Conjola. From this dredging campaign, suitable sand had been made available for use as beach nourishment or dune enhancement, with this sand having a suitable grain-size distribution for beach dune enhancement based on a grain size analysis carried out for the Review of Environmental Factors for the Lake Conjola dredging (Royal Haskoning, 2015). There was an opportunity to use this sand to locally raise the height of the dune at Mollymook to a level high enough to reduce the risk of wave overtopping onto the dune, as per the recommendations of the draft Coastal Zone Management Plan.

The dune enhancement works were commissioned and constructed in April 2016. A total of 3,680 $m^3$ of sand was placed at the crest of the dune along the beach for a distance of 280 m north from Blackwater Creek, to achieve a dune crest level of 5.5 m AHD.

The conceptual layout of the works at Blackwater Creek is illustrated in Figure 4.

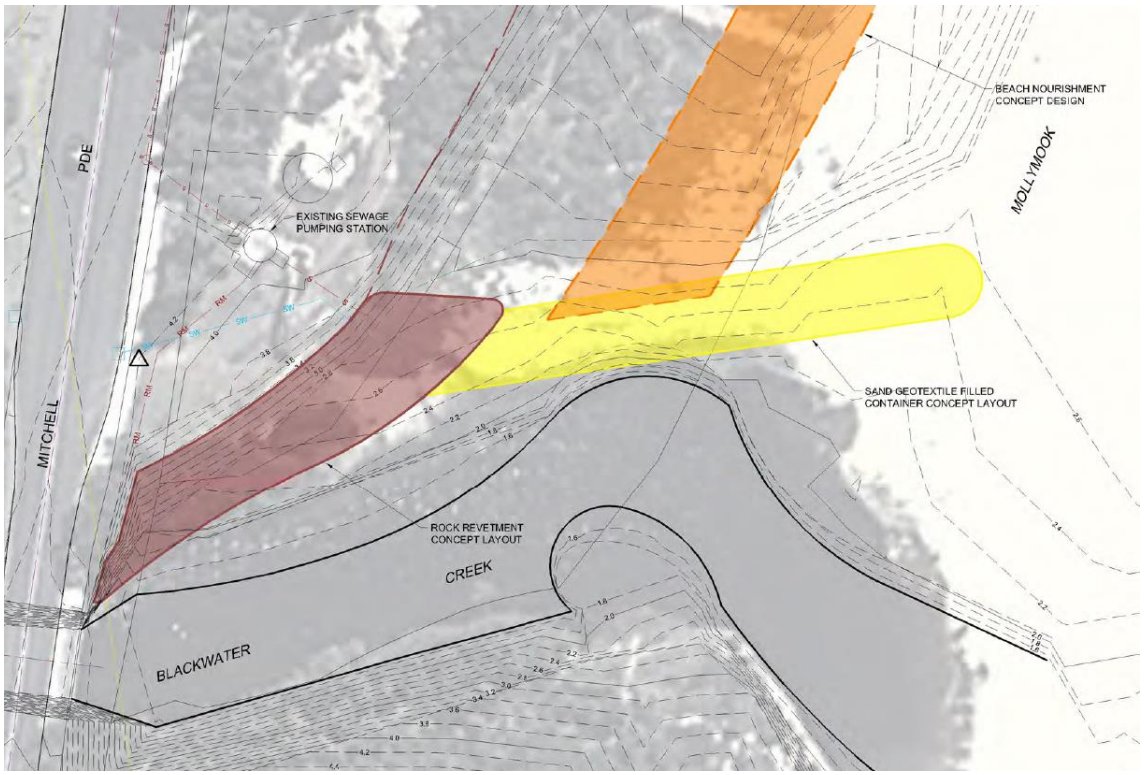


**Figure 4 – Conceptual layout of works at Blackwater Creek (Haskoning Australia, 2015)**

## Impact of Dune Enhancement

Natural dune building occurs when the wind is onshore and exceeds a critical threshold to mobilise a given sand grain size (Carley *et al.* 2010). With the creek breakout occurring toward the north from time to time, the ability for the dune to naturally rebuild was limited due to scour of the beach berm by the creek and a lack of available sand on the beach to feed dune growth.

Prior to enhancement of the dune and construction of the tripper works, the following mechanisms were responsible for the magnitude of the coastal hazard observed in this zone:

- Breakout of Blackwater Creek toward the north, leading to scour of sand on the beach berm and undermining of the dune, limiting the volume of sand available to supply the storm erosion demand for this area.
- The reduced volume of sand on the beach meant that the natural dune height along this stretch of beach was limited, as insufficient sand was available to feed the natural dune recovery process.
- In addition, the limited height of the dune meant that there was less uplift of sand particles by onshore winds, reducing the ability of the dune to grow.
- Overtopping of the dune on a regular basis may also have led to periodic damage to dune vegetation, further reducing the height of the onshore wind field, therefore further restricting the build-up of the dune in this area.

The above mechanisms acted as a feedback and resulted in a reduction in dune growth in the area affected by estuary entrance instability.

The installed works and dune enhancement have acted to break this feedback loop and reduce the coastal hazards for the area north of the creek, via the following mechanisms:

- Breakout of the creek now tends to occur toward the south (Figure 5), with sand available on the beach berm to contribute to natural dune growth on the northern side of the creek entrance
- Overtopping of the dune is now less likely to occur, allowing the dune vegetation to become established, therefore contributing to natural dune-building by modifying the onshore wind field
- The additional sand volume on the beach, both from the placement of beach nourishment sand and natural build-up of the beach berm due to the creek now breaking out toward the south is now directly available to satisfy the storm erosion demand
- The higher dune has reduced the extent of wave runup along this section of the beach.

Comparison of the works immediately following construction (but prior to the 2016 East Coast Low) is provided in Figure 6. This comparison shows that the dune vegetation has become well established and visually, the area of the works is indistinguishable from the surrounding natural foredune.

The dune enhancement works have therefore acted in a similar way to the concept behind beach scraping, or NABE to enhance the natural dune building process. Considerations for the timing of this type of dune enhancement would include the seasonal occurrence of onshore winds to provide the maximum benefit for dune building. The works could be combined with NABE if there is sufficient sand available on the beach berm. The timing of NABE works is best carried out when low wave energy is expected to occur, during the spring tidal phase, outside the breeding/nesting

seasons, at times of low beach/surfzone access requirements and during the planting season to provide the best opportunity for post NABE foredune stabilisation (Carley *et al* 2010).

**Figure 5 – Photo showing creek breakout along dune toward south**

**Figure 6 – Left – Enhanced dune, 30 May 2016. Right – Enhanced Dune, 17 May 2018**

## Performance of works in June 2016 East Coast Low

The East Coast Low event of June 2016 occurred less than two months after installation of the works. This event was particularly damaging for the east and north-east facing beaches in the Shoalhaven, due to the storm approach direction.

The east-northeast approach direction of the June 2016 East Coast Low made that event particularly significant for the southern ends of the open-coast beaches, and for the section of Mollymook Beach near Blackwater Creek, due to the approach direction, that storm event appears to have led to a similar volume of storm erosion when compared with the May-June 1974 storm event (Figure 7).

At the Botany Bay offshore Waverider buoy, which provides wave data representative of the region, offshore significant wave heights reached a maximum of 7.2 m, from the east during the June 2016 event. The 6-hour duration offshore significant wave height was 6.15 m, with an offshore direction of 87°TN. From Table 1, the 100 year ARI significant wave height for waves from the East is 7.0 m – this means that the June 2016 East Coast Low is in excess of a 1 in 100 year ARI event for storms from the easterly direction. The storm coincided with the maximum spring tide of the year, making this storm particularly damaging for beaches worst affected by swells from the east.

The dune suffered minor damage due to the storm, as indicated in Figure 8. Shoalhaven Council undertook an assessment of the performance of the works immediately following the storm and provided the following observations:

- The original beachfront was substantially washed out leaving a cutting up to the foredune of 1-1.5 metres.
- The new dune works have remained mostly intact with some damage to the front of the new dune along the northern half. Areas at the southern end which had a greater quantity and mix of vegetation on the old foredune have remained intact.
- There is evidence of storm wave action overtopping the dune including beach sand washed in to the scrub behind the dune, erosion caused by water running down the back of the dune in quantity and tide marks on the top surface of the dune.
- Given the additional height provided by the dune works it is highly likely that the placement of the dune provided protection to the houses on Mitchell Parade, stopping the majority of the wave action from impacting the area behind the dune. The continued establishment of the vegetation works on the dune to stabilise the sand will further strengthen that protection.
- Blackwater Creek has departed from its southern creep along the beach and has broken out directly to the ocean. The revegetation works in the Blackwater Creek area have remained intact.

From these observations, the works were successful in providing protection to the area north of Blackwater Creek following the June 2016 East Coast Low event. The observations also highlight the importance of establishing vegetation on the dune to enhance the level of protection afforded by the dune.

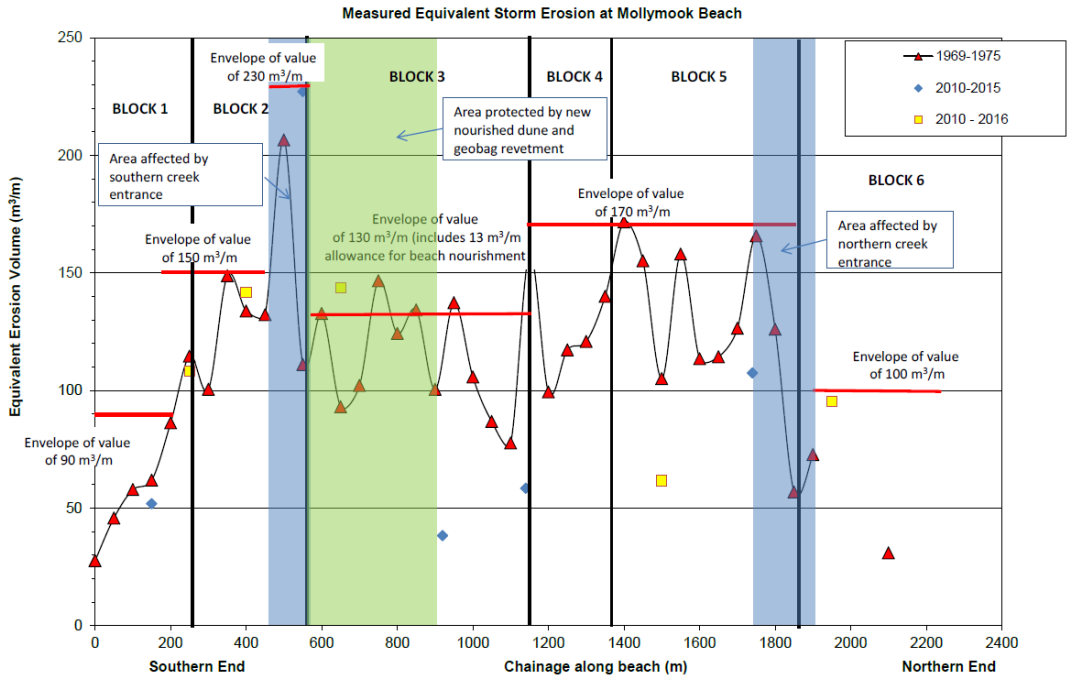


**Figure 7 – Storm erosion demand assessment for Mollymook (Advisian 2016). Note the assessment of storm erosion demand from the 2016 East Coast Low event (comparison between 2010 and 2016 photogrammetry) and the estuary entrance instability erosion demand measured in the 1974 storm event (comparison between 1969 and 1975 photogrammetry).**

**Table 1 – 100 Year ARI 1 hour Significant Wave Heights and Periods for Sydney**

| Direction | NE | ENE | E | ESE | SE | SSE | S | WSW |
|---|---|---|---|---|---|---|---|---|
| $H_s$ (m) | 4.4 | 6.0 | 7.0 | 7.3 | 8.5 | 9.3 | 8.8 | 5.5 |
| $T_p$ (s) | 9.2 | 10.7 | 11.6 | 11.8 | 12.7 | 13.3 | 13.0 | 10.2 |

**Figure 8 – Photo of enhanced dune damaged by East Coast Low, 7 June 2016**

## Reduction in Coastal Hazard Extent

Prior to installation of the works, the areas subject to coastal hazards north of Blackwater Creek for the immediate timeframe included:

- Fourteen residential lots and land surrounding Shoalhaven Water sewage pumping station subject to reduced foundation capacity
- Ten residential lots and section of Mitchell Parade subject to wave inundation due to overtopping of the frontal dune by wave runup
- Six lots subject to immediate risk of wave impact and slope adjustment
- A storm erosion demand of 170 $m^3/m$ for the area north of Blackwater Creek, and greater than 200 $m^3/m$ immediately adjacent to the creek entrance (measured from photogrammetry data between September 1971 and March 1975).

Advisian (2016) and SMEC (2006) found that at Blackwater Creek entrance, there were very large fluctuations in sub-aerial beach volumes which corresponded with fluctuations in the state of the estuary entrance. While the area north of the creek that was outside the zone of direct influence of the creek dynamics was found to be subject to a storm erosion demand of 170 $m^3/m$, the fluctuation in sand volume of the entrance area depending on the direction of the breakout of the creek was found to be much higher than this. The historical volume fluctuation of the beach profile at the entrance to Blackwater Creek is shown in Figure 9, with this fluctuation being highest closer to the creek entrance and not necessarily correlated with the occurrence of a coastal erosion event.

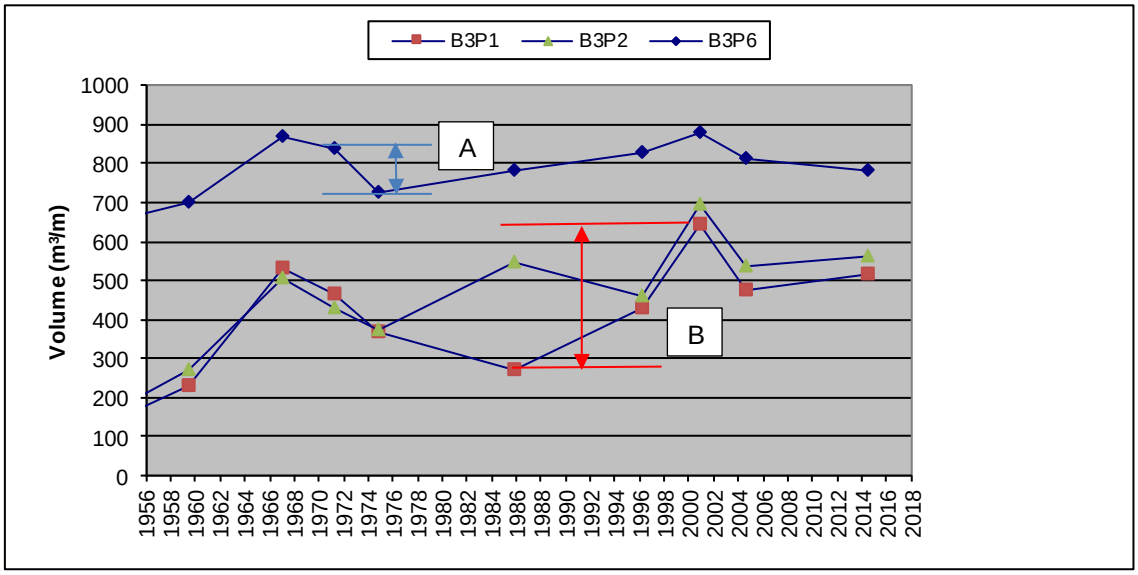


**Figure 9 – Beach berm volume fluctuations at Mollymook Beach north of Blackwater Creek. "A" – area outside of direct zone of influence of creek entrance, beach berm volume change ~150 $m^3/m$ from 1971 to 1975, indicative of storm erosion demand from May-June 1974 storm erosion event. "B" – area immediately north of creek entrance, beach berm volume fluctuations 200 – 300 $m^3/m$, indicative of estuary entrance instability hazard.**

Following the placement of the additional sand sourced from the dredging of Lake Conjola for the dune enhancement works and assuming that this sand is compatible with the native beach sand at Mollymook, the dune enhancement introduces an additional 13 $m^3/m$ of dune sand available to feed the storm erosion demand. This additional 13 $m^3/m$ has been taken into account in the hazard mapping for the section

of the beach which includes the new dune. To estimate the limit of the Zone of Slope Adjustment hazard line for a 1% AEP equivalent coastal storm event for this section of Mollymook Beach, the storm erosion demand was applied to a beach profile taken from LIDAR data provided by Council, at a time when the creek entrance was tracking toward the south. This is considered to be representative of the conditions on the northern side of the entrance area following implementation of the entrance works, which have been shown to be effective against a coastal storm event with a 1% Annual Exceedance Probability.

This eliminates the creek entrance instability hazard for the area immediately north of the creek entrance. Including the effect of the new works, re-analysis of the maximum storm erosion demand found the following:

- A storm erosion demand immediately south of the entrance to Blackwater Creek of 230 $m^3/m$, which takes into account estuary entrance fluctuations;
- A storm erosion demand of 130 $m^3/m$ for 300 m north of the entrance to Blackwater Creek, taking into account the presence of the entrance tripping structure and beach nourishment works.

A revised coastal hazard assessment has been carried out using the waterRIDE™ Coastal Toolkit described in Adamantidis *et al.* (2014) and adopting the revised storm erosion demand values and base profiles described above. A comparison of the immediate coastal hazard under a 1% AEP coastal storm event prior to and following the implementation of the works is provided in Figure 10. This shows that the coastal hazard for the lots in the area north of the creek entrance has been completely eliminated as a result of the works.

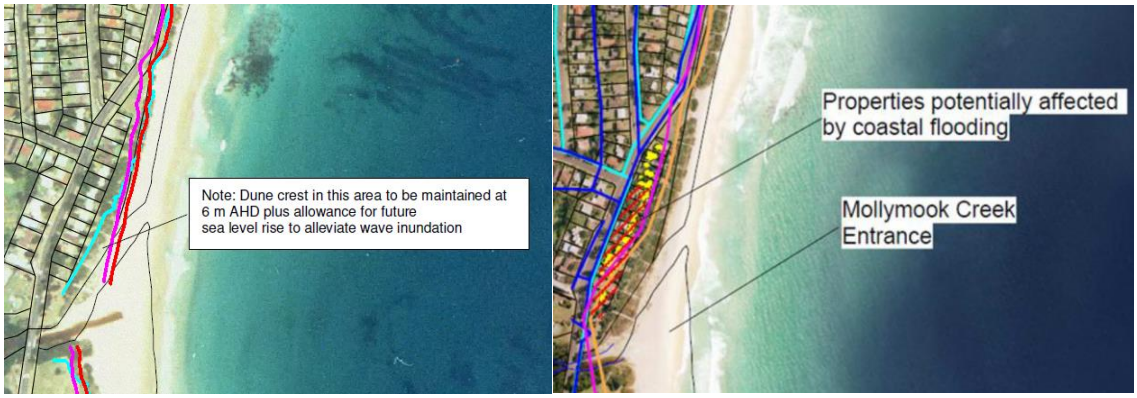


**Figure 10 – Left – 2016 Coastal Hazard Assessment, immediate timeframe (Advisian 2016). Right – 2011 SMEC Coastal Hazard Assessment, immediate timeframe.**

In addition to the reduction in coastal hazards, the works have provided enhanced protection to patches of coastal saltmarsh and Swamp Oak Floodplain Forest present along the northern foreshore of the creek (Haskoning Australia 2015), which are recognised as endangered ecological communities and which may have faced risk of damage in the event of a creek breakout toward the north.

## Summary

The implementation of the estuary entrance and dune enhancement works has led to the following outcomes:

- Elimination of the estuary entrance instability hazard by preventing creek breakout and dune undermining in front of an area where significant public and private assets are located
- Combining the elimination of the estuary entrance instability with dune crest level enhancement has “broken the cycle” that has led to low dune crest levels and has enhanced local area protection against wave overtopping. It has also enhanced the ability for natural dune growth to occur.
- Sand for dune enhancement can be sourced from other projects as long as the sand is compatible with the native beach sand
- Establishment of healthy vegetation on the dune enables enhancement of the erosion and wave inundation protection provided by the dune and promotes natural dune growth by modifying the local onshore wind field.

The techniques presented in this paper to enhance the dunes and eliminate the estuary entrance instability hazard could be applicable at a number of estuary entrances throughout NSW, where estuary entrance instability poses a threat to infrastructure.

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