BREAKWATERS AND TRAINING WALLS
THE GOOD, THE BAD AND THE UGLY

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Introduction

At several locations on the Australian eastern seaboard, breakwaters and training walls have instigated fundamental perturbations to coastal and estuary processes, inducing long term changes to foreshore alignments, tidal currents, tidal planes and marine ecologies with significant consequences, some having been realised only recently.

On coastlines with high rates of littoral drift transport, breakwaters have trapped sand on the up-drift side, thereby inducing beach erosion down-drift. Another less-appreciated impact of breakwaters on coastal alignments is the changes they can induce in near-shore wave patterns that, in turn, will re-align ocean foreshores significantly. Essentially, a long breakwater can act as a headland inducing a crenulated shaped bay onto what may have been a relatively straight beach, generating areas of erosion and accretion.

Further, field data and hydraulic theory confirm that breakwaters have increased the tidal conveyance of estuary entrance channels by removing sand bars, extraneous littoral currents and associated sand movements that, previously, impeded ebb tide discharges (Nielsen & Gordon 1980; 2007; 2008; 2011; 2015). Comprehensive water level monitoring in several NSW coastal lakes, where entrance breakwaters have been constructed, has shown that tidal ranges have been increasing steadily for decades with high tide planes rising, low tide planes falling, tidal velocities increasing, channels scouring and tidal deltas growing.

This paper presents examples of the potential long-term impacts of entrance breakwaters and training walls on coastal and estuary processes as gained from experience on the NSW coast.

Experience on the NSW coast

Coastal processes

Safe passage into the Tweed River has long been hindered by the periodic formation of sand shoals at the river entrance. River training works and dredging have been undertaken since the late 19th century in attempts to improve navigability. These works culminated in the extension of the training walls at the river entrance to form breakwaters during 1962-65. Although this improved navigation for a period, the entrance bar reformed and again created difficulties for navigation. The Tweed breakwaters have trapped sand, taking it out of the littoral system through the accretion of Letitia Spit, causing coastal erosion on the Gold Coast (Figure 1), requiring the construction of expensive sand-bypassing systems (Figure 2) and revetments (Figure 3) to offset their impacts.

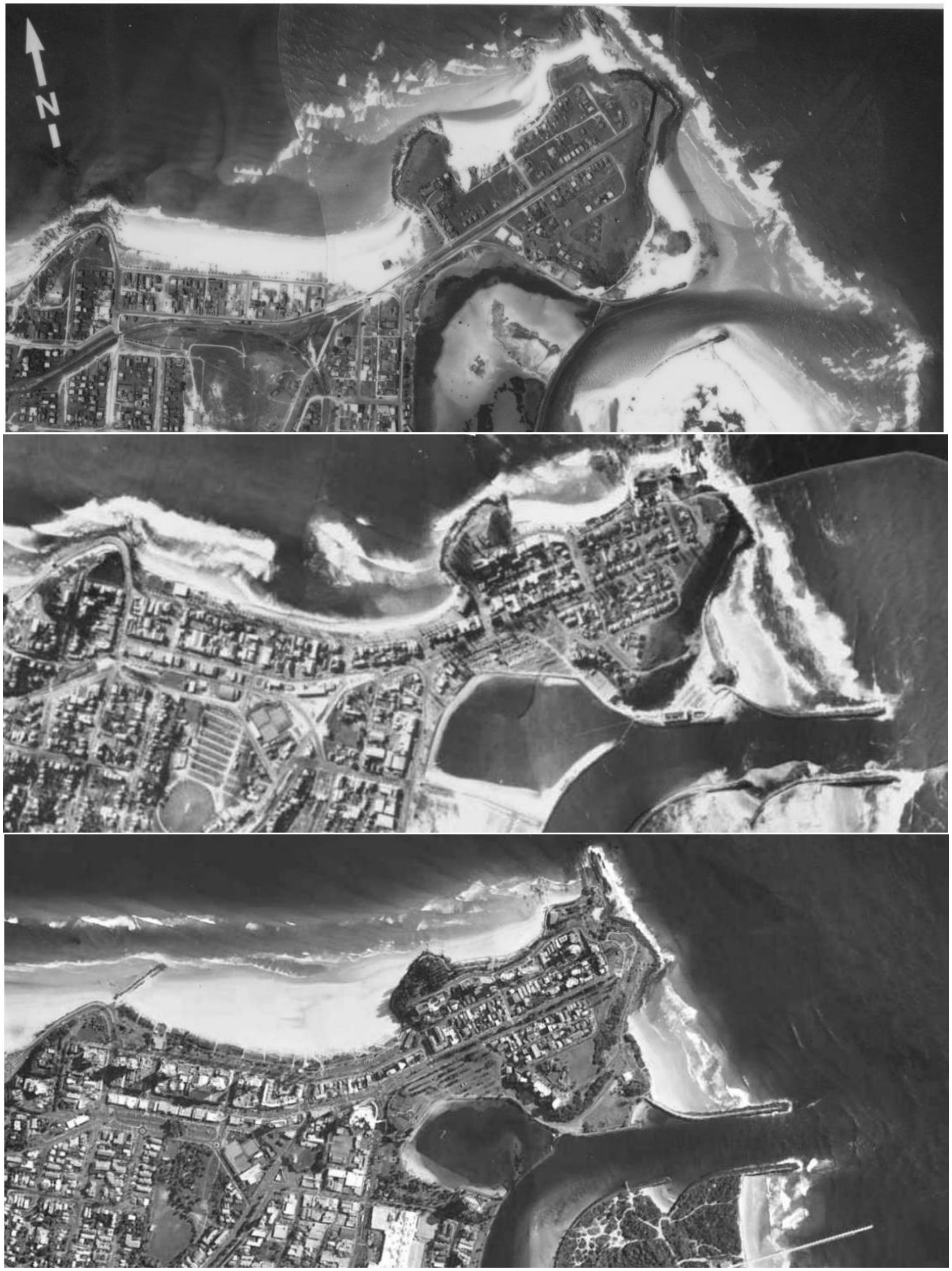


Figure 1. Top: Tweed River entrance in 1935 prior to breakwater extension. Centre: Tweed River entrance in 1967 following breakwater extension. Note improvements to channel navigation and the depletion of Coolangatta Beach. Bottom: Tweed River entrance in 2004 following installation of sand bypassing system. Note accretion of Coolangatta Beach. (from Ackworth & Lawson, 2011)

Figure 2. Tweed River entrance and sand-bypassing system comprising trestle, sand pumps and pipelines (©Tweed River Entrance Sand Bypassing Project (TRESBP))

Figure 3. Revetment under construction, Palm Beach, Gold Coast

Mobile bed scale modelling has demonstrated conclusively that breakwaters can change beach alignments by creating artificial headlands forming crenulated bays on what previously were linear shorelines (Figure 4, Miller and Nielsen 1995; Gordon 2011). Where the scale of the breakwater is larger than the local wavelength, which would be in the order of 100 m, the perturbation will alter local wave transformation patterns thereby inducing a re-alignment of sandy foreshores.

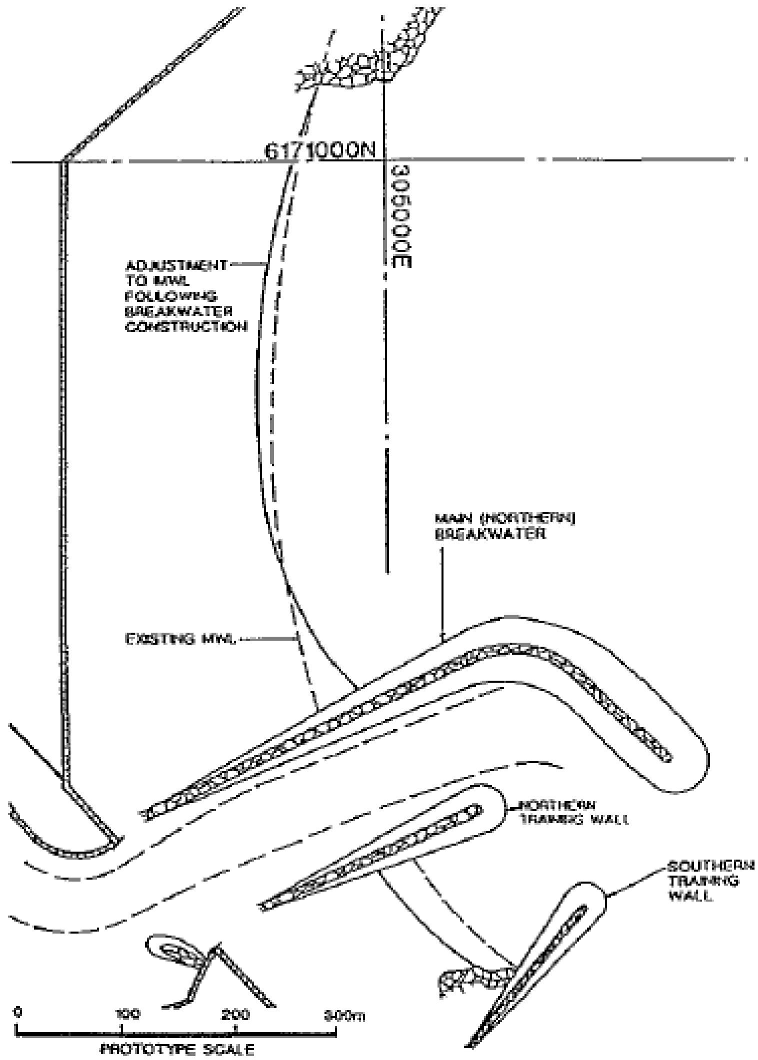


Figure 4. Mobile bed model study of the impact of breakwaters on beach alignment (Miller & Nielsen, 1995)

Between 1960 and 1962 twin breakwaters were constructed at the entrance to the Brunswick River. Up until that time a small rock outcrop on the northern side of the river created a slight deflection of the long beach between Byron Bay and Hastings Point. However, the breakwaters effectively created a new headland resulting in significant accretion and re-alignment of the beach to the south and erosion and formation of a crenulated shoreline to the north. Initially, the impact of the sand trapping to the south was sufficient that, within 10 years, the small village of Sheltering Palms, on the northern side, was devastated completely with cyclone waves breaking through the village into the North Arm of the Brunswick River. After natural by-passing was established and with the assistance of beach scraping, dunes and a beach were re-established to the north. However, the new alignment of the overall embayment reflects the imposition of the artificial “headland” of the Brunswick breakwaters.

Figure 5. The destruction of Sheltering Palms village to the north of the entrance breakwaters on the Brunswick River

In between 1818 and 1856 a breakwater was constructed on the south side of the Hunter river entrance to connect the rock outcrop at Nobbys to the mainland. Between 1875 and 1915 this was extended offshore from Nobbys to provide further protection to the harbour entrance. Effectively, this extended the "headland" at the entrance. But it was the northern breakwater constructed between 1898 and 1912 that had the most significant impact on the shoreline at Stockton. This breakwater cut off the flood tide channel that had run along the beach and into the entrance. The result was the effective removal of the entrance bar and a significant accretion of sand on the northern side of the north breakwater. This accretion moved the shoreline approximately 300 metres seaward at the breakwater and resulted in a build up estimated to be of the order of two million cubic metres of beach sand at Stockton. However, it also induced erosion to the north as the shoreline responded to the changed tidal flow and wave conditions. A software package called *Model for Equilibrium Planform of Bay Beaches* (MEPBAY; Klein *et al.* 2003) was used to calculate the shoreline planform of Stockton Beach prior to breakwater construction (Figure 6 right). This modelled shoreline was verified by reference to historical surveys (Figure 6 left) and indicated both the accretion that has occurred on the northern side of the breakwater and the severe erosion that has occurred on Stockton Beach following breakwater construction as a result of the formation of a crenulated embayment. The erosion has continued as a result of both the realignment of the beach and the net loss of sand into the dunes of Newcastle Bight (Gordon and Roy, 1977). This has resulted in the requirement to construct a rock revetment to protect Mitchell Street and the village.

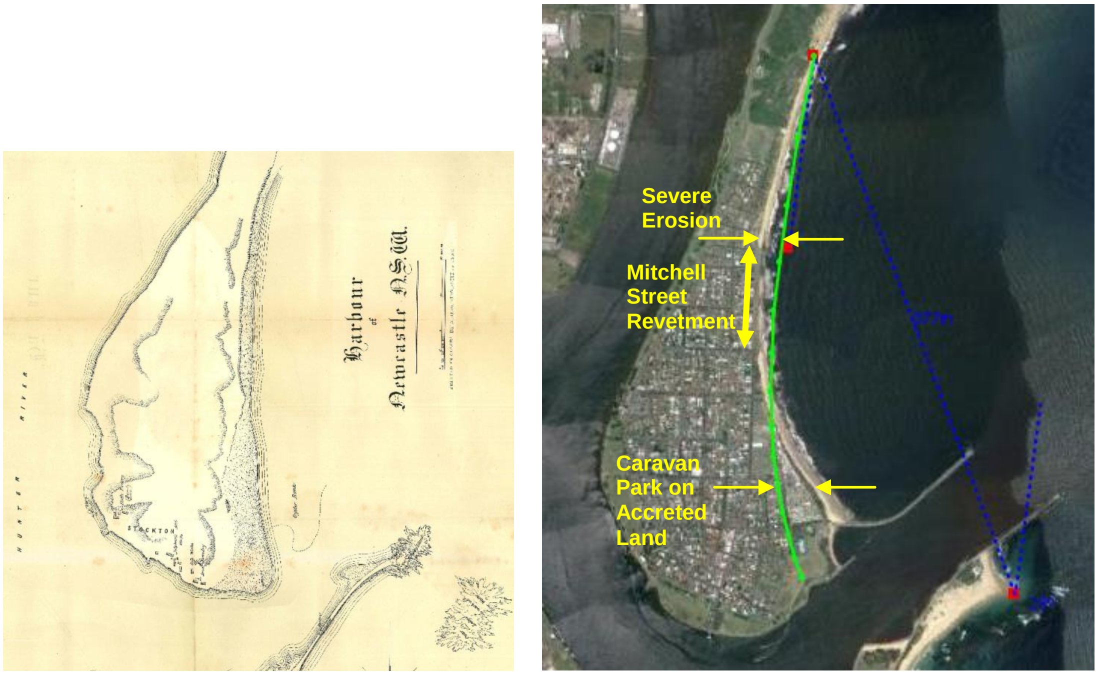
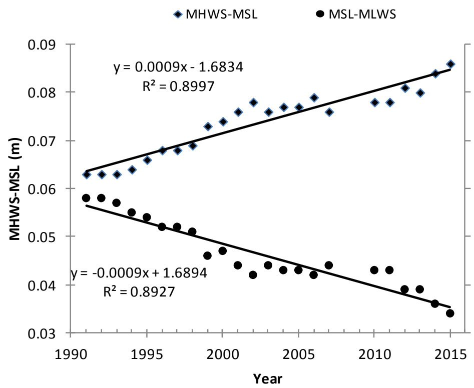


Figure 6. Left: Entrance to Newcastle Harbour (*circa* 1850). Right: Present-day entrance with MEPBAY 1850 predicted shoreline superimposed indicating foreshore re-alignment and severe erosion and accretion.

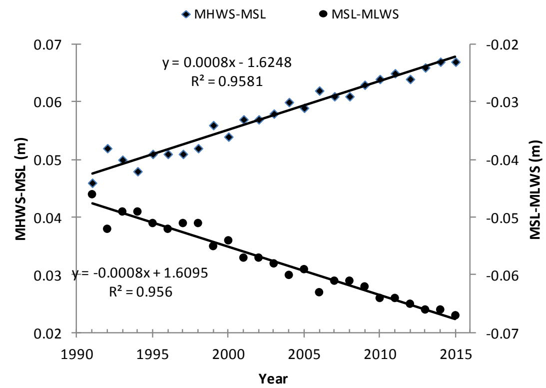
At Coffs Harbour a causeway was constructed between 1915 and 1927 to connect South Coffs Island to the mainland thereby providing protection for shipping visiting Coffs wharf. The causeway effectively cut the northerly drift of sand through the gap and onto the northern beaches thus creating the new headland feature of South Coffs Island. Subsequently, northern and eastern breakwaters were constructed to provide further protection. Sand volume changes (Lord & van Kerkvoort 1981; Gordon 2011) indicated that prior to the causeway construction the annual rate of littoral drift transport through the gap averaged 75,000 m^3/a. After breakwater construction, Boambee Beach, to the south of the harbour, responded by building out at a rate of between 3 and 5 m/a. Over the past 100 years between 5 and 6 million cubic meters of littoral drift were trapped south of the harbour with a further 1 million trapped inside the harbour. The harbour entrance has reduced in depth from 13 m to 6.5 m over the same period with significant shoaling throughout the harbour. Boambee Beach has realigned as a result of the accretion and the beaches to the north have experienced long term recession.

Estuary processes

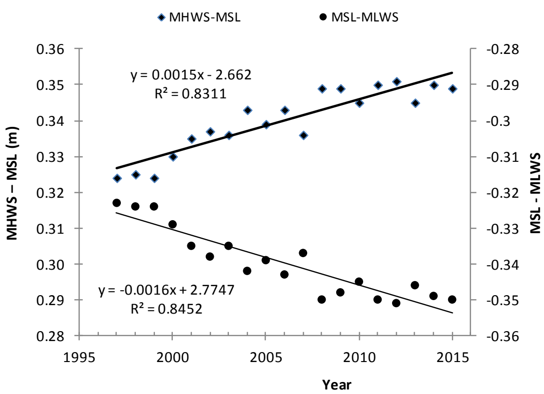
The construction of entrance breakwaters on Wallis Lake, Lake Macquarie, Lake Illawarra and Lake Wagonga has triggered unstable scouring modes at these estuary entrance channels. As shown in Figure 7, from 1990 to 2015 the spring tidal ranges in both Wallis Lake and Lake Macquarie have been increasing at a rate of 1.8 mm/a over lake areas of some 100 km^2. That represents annual increases of some 400,000 m^3 in the volume of water flowing into and out of the lakes each day on spring tides. At Lake Wagonga (Narooma) the spring tidal range has been increasing at a rate of 3 mm/a over an area of 7 km^2, representing an annual increase of some 40,000 m^3 in the volume of water flowing into and out of the lake each day on spring tides. At Lake Illawarra the rate of increase is some 8 mm/a. Ever-increasing channel velocities are causing channel scour and sand deposition in the lakes and the coastal littoral drift systems.



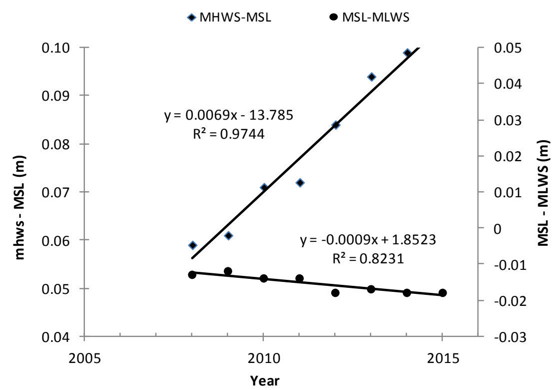
(a) Wallis Lake



(b) Lake Macquarie



(c) Lake Wagonga



(d) Lake Illawarra

Figure 7. History of changes in spring tidal planes in (a) Wallis Lake, (b) Lake Macquarie, (c) Lake Wagonga, (d) Lake Illawarra. High water levels are increasing while low water levels are decreasing (Note various scales)

Training walls in tidal channels increase hydraulic conveyance and channel velocities (Nielsen 2002; Nielsen & Gordon 2016 in press). In 1987 a rock training wall was constructed on the northern bank of the Coffs Creek entrance. As indicated in Figure 8, this changed an ICOLL to a permanently open estuary. The deepened channel discharged spring ebb tides at speeds over 1 m/s and the creek bed portrayed current-related bedforms over 0.5 m high (Nielsen 2002). These fast-flowing, undulating conditions are attractive to swimmers who like to use the creek as a water slide. On 23rd January 1999, one such enthusiast was sporting in the creek when his head hit a bedform as he dived into the fast-flowing turbid waters of unknown and variable depth, rendering him quadriplegic. After the trial the Council erected four signs at access points: three on the northern bank of the creek and one on the southern side. Under a heading "GENERAL WARNINGS", there appeared under pictorial devices the words "SUBMERGED OBJECTS", "DANGEROUS CURRENT", "SLIPPERY ROCKS" and "NO LIFEGUARD OR LIFESAVING SERVICE HERE TODAY" (Gummow 2005).

Figure 8. Coffs Creek entrance 1969 (left) and 1996 (right) © NSW Land Information Centre

Impacts of breakwater and training wall construction

The good:

- Enhanced hydraulic conveyance of entrance channels has increased discharge capacity which has eliminated nuisance flooding of low-lying areas and improved water quality (Tuncurry).
- Channel thalwegs have stabilised and depths have increased, which has improved navigation (Narooma).
- Marine sands have been added to the littoral system and nourished beaches where entrance scour has jetted sand out into the littoral system (Forster/Tuncurry, Lake Macquarie, Lake Wagonga).
- In some situations breakwaters have made entrance navigation safer (Newcastle and Coffs Harbour).
- Improved surfing opportunities due to "new breaks" created by breakwaters (Foster/Tuncurry).

The bad:

- Channel scour in the estuaries has resulted in the loss of seagrass (Wallis Lake, Lake Wagonga, Lake Macquarie).
- Sand transport into the lakes as flood tide delta growth has smothered seagrass (Wallis Lake, Lake Illawarra, Lake Wagonga).
- Wetland areas have been eroded (Lake Macquarie).
- Changing tidal planes have increased the rates of salt marsh loss and mangrove colonisation (Lake Wagonga).
- Channel scour has necessitated rock works along the banks (Lake Macquarie, Lake Wagonga).
- Channel scour has necessitated expensive bridge foundation works (Wallis Lake).

- Some dangerous entrances have been created where the entrance bars remain and are a hazard to navigation, particularly during periods of moderate to high waves (Lake Wagonga) or high spring tides (Wallis Lake).
- Coastal littoral drift has been interrupted (Coffs Harbour).
- Expensive capital works have been necessary to reinstate beaches that have eroded as a consequence of breakwater construction (Tweed River)

The ugly:

- Channel scour has resulted in the total collapse of some foreshore buildings and undermined bridge foundations as well as undermining river training works (e.g., Swansea Channel Lake Macquarie Figure 9).

- Breakwaters have re-aligned the foreshore causing beach erosion, loss of residential development and other infrastructure (e.g., Brunswick Heads Figure 5;).

- Breakwaters causing erosion have sometimes necessitated revetment construction to limit erosion thereby destroying beach amenity (e.g., Stockton Beach at Hunter River Newcastle Figure 10).

- Training walls in tidal channels can create dangerous conditions that may cause serious injury to swimmers (e.g., Coffs Creek).

- High ebb tide velocities on the ocean bars have presented challenges to recreational boating and have seen boating fatalities (e.g., Foster; Lake Wagonga Narooma Figure 11).

Figure 9. At Lake Macquarie, the collapse of a Swansea Channel foreshore building comprising restaurant, offices and residences on 8 February 2016 (Photo: Fire & Rescue NSW).

Figure 10. Left: Rock revetment to protect Mitchell Street. Right: Severe erosion north of the rock revetment

Figure 11. Charter boat smashed on the end of the Narooma Breakwater (Photo Batemans Bay Post). Since 1970 there have been more than 11 deaths and 100 rescued.

Conclusions

Breakwaters constructed at estuary entrances have the potential to alter fundamental coastal and estuary processes inducing changes that may take centuries to resolve. While many beneficial and adverse impacts of breakwater construction have been well-known for many years, such as the improvements to navigation and flood mitigation and the interruption to littoral drift transport causing down-drift erosion, some impacts have not been understood and have been indentified only recently, such as:

- Breakwaters can change local wave transformation patterns, inducing large scale changes to beach alignments
- Breakwaters and training walls can enhance tidal conveyance, tripping estuaries into an unstable scouring mode

Such changes invariably have benefits, the reasons for which they were designed. However, such benefits invariably are accompanied by adverse impacts, many of which have included:

- Coastal erosion and loss of development and infrastructure
- Channel scour leading to damage to infrastructure and development and loss of seagrass
- Dangerous boating conditions causing injury and death
- Changes to and loss of fringing marine habitat impacting fisheries
- Sediment deposition smothering seagrass

A broader understanding and consideration of the impacts of breakwater and training wall construction is warranted.

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