Coastal Management Advice: 68 - 86 River Road, Shoalhaven Heads

WRL TR 2021/24, February 2022

By M J Blacka

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1 Introduction

1.1 Overview

In June 2016, the northern estuary foreshore adjacent to River Road at Shoalhaven Heads (Figure 1.1) was impacted by coastal erosion during a large storm event. The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Sydney was engaged by Shoalhaven City Council (hereafter "Council") to assess the immediate erosion risk levels along the area between Jerry Bailey Road in the west and the boat ramp in the east, and to provide recommendations for managing the impacts from the storm. WRL's assessment and recommendations were synthesised in a Technical Report (Blacka & Coghlan, 2017), which should be consulted as background information to this report, along with a corresponding review completed by Manly Hydraulics Laboratory (MHL, 2018).

Within our previous assessment (Blacka & Coghlan, 2017), a prioritisation of the site was completed which identified a stretch of approximately 170 m where the resulting erosion scarp and embankment was considered to be high risk in that it could become geotechnically unstable if further erosion of the embankment toe occurred. This would in turn have resulted in significant impacts to adjacent infrastructure including power poles and River Road itself.

Recommendations for managing the site were proposed by WRL, which included concept design for a rock revetment to provide immediate protection to the toe of the embankment between Renown Avenue and 66 River Road. A number of other short to medium term recommendations were also made, which included improved beach access, nourishment of a larger stretch of beach, revegetation works, and improvements to the management of stormwater where it crosses the beach, so as to also maintain the amenity of the beach for recreational use. Council subsequently engaged MHL to provide a technical review of the recommendations, which largely agreed with WRL's findings, though a more conservative revetment design was suggested by MHL. Detailed design of the management works was completed by Magryn during the 2018/19 period, and installation of the rock revetment, beach access steps and sand nourishment was completed by contractors in the first half of 2021.

Further minor erosion of areas to the east of the protected zone has occurred in recent months, with a small area of exacerbated erosion immediately adjacent to the eastern end of the revetment, and Council now require recommendations to mitigate the impacts of this subsequent erosion.

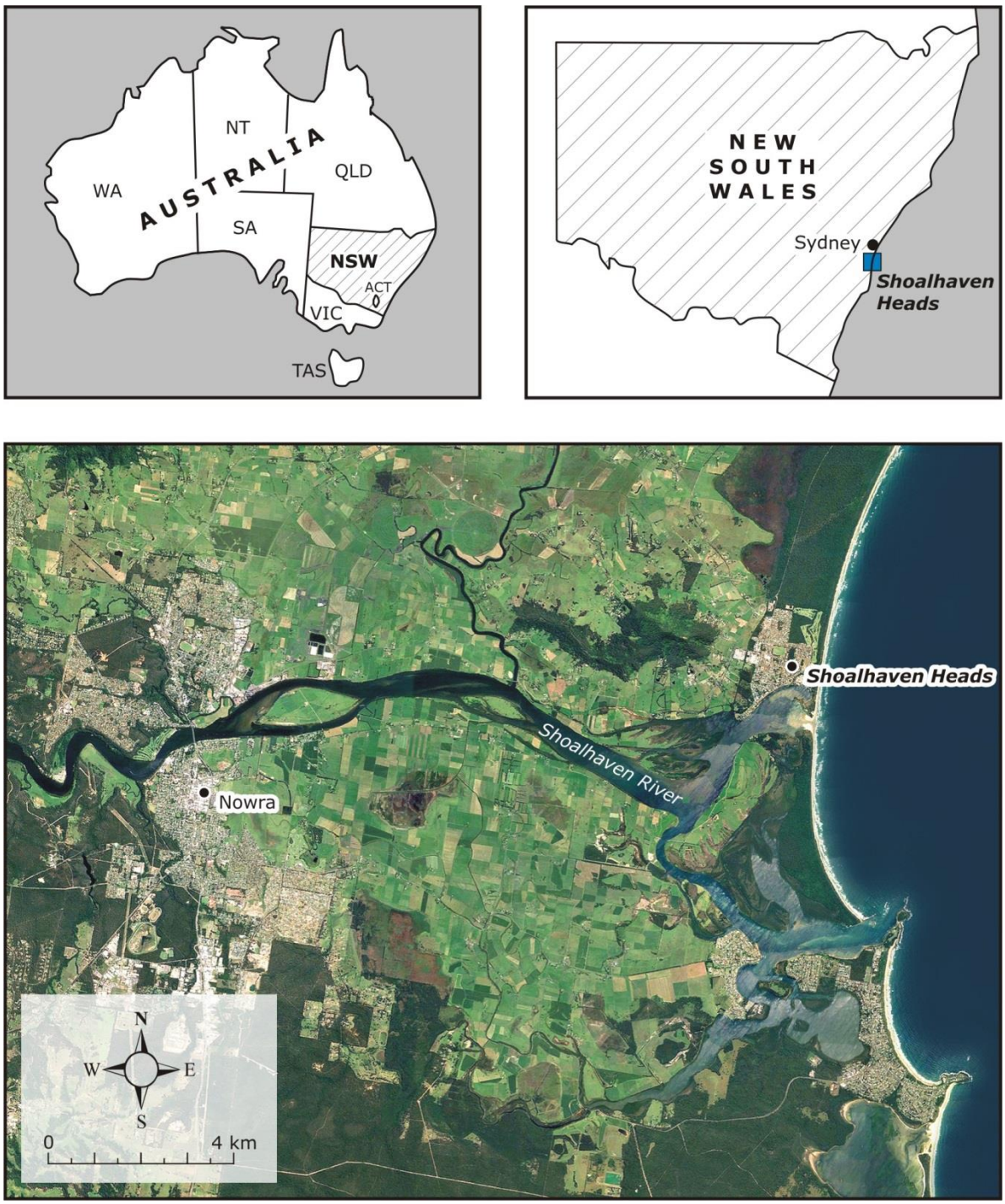


Figure 1.1 River Road foreshore location, Shoalhaven Heads

1.2 Scope and objectives

Council have requested coastal engineering advice specifically regarding:

- Improvements to the alignment of the eastern end of the new rock revetment so as to minimise revetment end-effects
- Implementation of erosion mitigation/control works for approximately 85 m of foreshore in front of properties at 68 to 74 River Road.

The locations of interest that are the focus of this report are shown in Figure 1.2. Based on discussions between Council and WRL, the agreed scope for this report (as outlined in WRL proposal P20210824) is presented in Table 1.1. Though the scope from Council (and focus of our investigation) was the foreshore in front of properties at 68 to 74 River Road, WRL's advice considers a broader section of the foreshore for context and to ensure issues have been considered more holistically.

Table 1.1 Scope of works

Task	Outcome
Site inspection – a coastal engineering inspection of the River Road foreshore area will be completed to view existing erosion control works, and to inspect the current condition of the foreshore between 68-86 River Road.	An initial site inspection will enable WRL staff to have a more informed position from which to make recommendations.
Desktop review – key environmental processes and events from the past 12 months will be reviewed to better understand the likely drivers of erosion at 68-86 River Road. Where data sets are available, this may include consideration of: • Estuary water levels • Entrance shoals and flood/tidal flows • Changes in beach profile/volume (for complete River Road compartment if available) • Alignment and end-effects of revetment (*other optional considerations were discussed during the proposal, but were considered beyond available budget at this stage*)	Information will be synthesised to develop a high-level contemporary understanding of: Current erosion drivers Slow and fast onset risks from erosion for 68-86 River Road Recommendations for future analysis to develop a more detailed understanding of the issues (such as hydrodynamic modelling)
Recommendations – Prioritised recommendations will be made for adjusting the alignment of the end of the existing revetment, as well as managing the 85 m stretch of shoreline impacted by present erosion issues (68-74 River Road).	A summary of recommendations, including advantages/disadvantages, will be made to reduce end-effects from the existing rock revetment, and to mitigate erosion. This will focus more on the response strategy and high level sketches, but not extend to concept design. The intention will be to provide Council with information to enable them to progress discussions with internal and external stakeholders.
Concept design – Concept design will be completed for one preferred option of both: • the revetment end treatment • bank stabilisation/erosion mitigation Desktop engineering analysis will be completed to establish the design of the preferred options. Analysis will be based on existing information and data only (i.e. no additional data/modelling will be completed to inform the designs).	Design drawings/plans to capture key details of the proposed works will be provided. Cost estimates for the works will be provided.
Reporting – Information and outcomes from each of the tasks will be synthesised into a report.	Depending on which tasks are selected by Council, a short letter report or detailed technical report will be provided.

Figure 1.2 Foreshore area of interest

2 Background and summary of previous WRL investigation

For the purposes of providing adequate background information, two pieces of information are synthesised here from WRL's previous 2016/17 investigation, these being:

1. An overview of the 2016 foreshore condition and coastal hazard risk assessment
2. An overview of the previous management recommendations that were made

WRL's previous investigation (Blacka & Coghlan, 2017) included an evaluation of coastal hazard risks around the complete stretch of foreshore between the public jetty opposite Jerry Bailey Road at the south-western limit, extending to the boat ramp at the north-eastern limit. A reference line was established along the foreshore as shown in Figure 2.1, to enable clear communication of both the condition and coastal hazard risks for the various areas of foreshore. The reference line starts at the south-western end of the foreshore with Chainage 0 m at the jetty, and proceeds to Chainage 1060 m at the north-eastern end of the foreshore adjacent to the boat ramp.

The foreshore was split into four zones with distinctly different morphological and/or erosion risk characteristics along the 1 km length. The location and description of these zones from our 2016 assessment are provided below and also indicated on Figure 2.2:

- Zone 1 (Chainage 0 to 140 m): South Western zone fronting the carpark and public toilet area opposite Jerry Bailey Road. Characterised by a relatively low flat area of fill that forms the car park, dropping down a steep (near vertical) bank of varying height (up to ~1 m), to the low gradient sandy beach.
- Zone 2 (Chainage 140 to 650 m): Southern central zone between the carpark/toilets and River Road intersection with Mathews Street. Characterised by a steep vegetated back-beach sand embankment (up to ~6 m height) between the low gradient sandy beach at the toe and a level grassed crest extending to the River Road pavement.
- Zone 3 (Chainage 650 to 970 m): Northern central zone between Mathews Street and the stormwater/creek outlet at the River Road Reserve. Characterised by elevated private properties with yards dropping to a level and grassed (in some areas) back-beach apron, fronted by a low gradient sandy beach.
- Zone 4 (Chainage 970 to 1060 m): North Eastern zone between the stormwater outlet at the River Road Reserve and the boat ramp. Characterised by a low-lying back beach area with car parking and footpaths, fronted by a low gradient sandy beach.

A qualitative assessment of management prioritisation was completed on the basis of:

- Potential for exposure to coastal processes causing hazard:
  - Erosion
  - Recession
  - Stormwater
- Assessed Risk Levels for geotechnical hazards:
  - Regression of existing land-slip scarps
  - Additional instability from ongoing erosion
  - Ongoing creep of embankment slope surface
- Site condition and characteristics:
  - Embankment toe setback distance from water
  - Asset setback distance from embankment crest
  - Steepness of embankment slope

The resulting priority for implementation of management works as reported in our 2016 assessment is summarised in Table 2.1.

Table 2.1 Summary of 2016 management prioritisation (Blacka & Coghlan, 2017)

Foreshore Zone	Description	Management Priority
1	South Western zone fronting the carpark and public toilet area opposite Jerry Bailey Road	Medium-High
2A	Southern central zone between the carpark and Renown Avenue	Medium
2B	Southern central zone between Renown Avenue and Mathews Street	Very High
3A	Northern central zone seaward of properties at 62-66 River Road	High
3B	Northern central zone seaward of properties at 68-86 River Road	Medium
4	North Eastern zone between the stormwater outlet at the River Road Reserve and boat ramp	Low

Figure 2.1 Reference line for study area

Figure 2.2 Study area and management priority (as determined in 2016)

A number of different management approaches were identified for the foreshore, with varying levels of impact/benefit to the environment and amenity of the site, costs, and implementation timeframes. Based on the potential of each of the management options to address the identified hazard types and risk level, the suitability of the various management options for each different foreshore zone were presented. The recommended management options for each foreshore zone from our 2016 assessment are presented in Table 2.2 (noting that the timeframe of "Now" in this table refers to 2016/17).

It should be emphasised that the suggested management approach was selected with a focus on addressing the immediate coastal hazards in the short term (as per the scope of WRL's 2016 project), while also not compromising the ability to implement a longer term management plan for this section of the estuary at a later date. It was recognised that alternative management approaches may provide longer term improvements in amenity of the foreshore (such as significant dredging of the estuary sand shoals and mass scale nourishment of the beach), however, these would require a range of additional investigations and funding beyond that available at the time, and were therefore not well suited to addressing the immediate engineering risks.

Table 2.2 2016 Recommended management approaches (Blacka & Coghlan, 2017)

Foreshore Management Zone	Suggested Management Approach
Zone 1	Now: Re-profile erosion scarp, stabilise erosion surface, revegetate, consider improved public access. Short Term Future: Nourish beach.
Zone 2A	Now: Remove/cover tree stumps, revegetate, monitor tree safety. Short Term Future: Nourish beach, monitor beach width/volume, monitor embankment (if impacted by erosion).
Zone 2B	Now: Remove debris, improve stormwater outlets, protect embankment toe with rock or geotextile bag revetment, train stormwater across beach, monitor embankment and crest area. Short Term Future: Nourish beach, monitor beach width/volume.
Zone 3A	Now: Remove debris, improve stormwater outlets, upgrade existing protection to embankment toe with rock or geotextile bag revetment, train stormwater across beach, monitor embankment. Short Term Future: Nourish beach, monitor beach width/volume.
Zone 3B	Now: Re-profile erosion scarp, stabilise erosion surface, revegetate, consider improved access. Short Term Future: Nourish beach.
Zone 4	Short Term Future: stabilise erosion scarps, revegetate, nourish opportunistically.

The revetment concept design that was recommended by WRL for zones 2B and 3A is shown in Figure 2.3, and consisted of:

- A revetment slope of 1V:1.5H extending from -1 m AHD to +4 m AHD
- Two layers of armour stone with median stone mass (M_{50}) of 150 kg, overlaying a double layer secondary armour
- Geotextile underlayer.

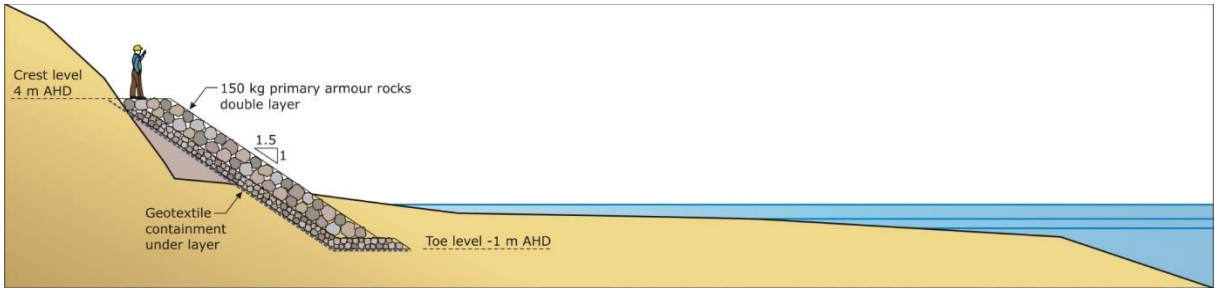


Figure 2.3 Concept revetment design recommended by WRL (Blacka & Coghlan, 2017)

3 Synthesis of erosion management works completed to-date, and current foreshore condition

Magryn were engaged to complete the detailed design of the foreshore management works. A typical cross section for their detailed revetment design is shown in Figure 3.1, with the design consisting of:

- A revetment slope of 1V:1.5H extending from -1 m AHD to +4 m AHD
- Two layers of armour stone with median stone mass (M_{50}) of 750 kg, overlaying a double layer of secondary armour with median stone mass (M_{50}) of 75 kg
- Geotextile underlayer.

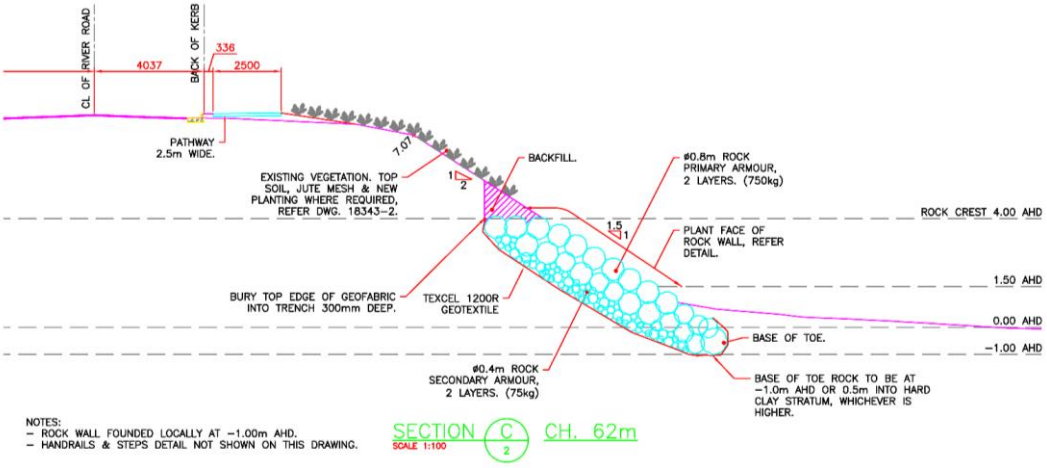


Figure 3.1 Typical cross section of revetment detailed design (extracted from Magryn drawing 18343 Rev0)

Construction of the rock revetment was completed between January and June 2021, along with placement of nourishment sand along the beach at the toe of the revetment. A coastal engineering inspection of the foreshore was completed by WRL on 13/09/2021. The purpose of the inspection was primarily to:

- view the completed management works
- inspect the current condition of the foreshore immediately to the east of the works
- develop an understanding of the influence of the works on erosion of the adjacent unprotected foreshore areas.

Figure 3.2 to Figure 3.5 provide an overview of the main section of the installed rock revetment, and include photos from 2016 for comparison purposes. Further photos of the eastern end of the revetment as well as the current condition of the natural foreshore extending further east to the boat ramp are shown in Figure 3.6 to Figure 3.9. The chainages referred to on these figures are based on the WRL reference line shown in Figure 2.1.

Figure 3.2 Western end of rock revetment, at Ch 550 m looking west

Figure 3.3 Central section of rock revetment, at Ch 550 m looking east

Figure 3.4 Eastern section of rock revetment, at Ch 600 m looking east

Figure 3.5 Eastern end section of rock revetment, at Ch 700 m looking west

Figure 3.6 Eastern end section of rock revetment (Ch 680 - 720 m)

Figure 3.7 Natural foreshore Ch 715 to 740 m (top) and Ch 750 to 800 m (bottom)

Figure 3.8 Natural foreshore Ch 800 to 870 m (top) and Ch 840 to 930 m (bottom)

Figure 3.9 Natural foreshore Ch 920 to 970 m (top) and Ch 980 to 1060 m (bottom)

With regards to the eastern end of the constructed revetment (east of the private concrete boat ramp at 64 River Road, ~Ch 690 m), a number of relevant observations were made during our inspection (see Figure 3.5 to Figure 3.7 for photos):

- The revetment end is formed by a single row of very large armour stones (in comparison to the grading of the primary armour rock within the rest of the revetment)
- The alignment of the revetment has not been keyed or tapered back into the natural bank, but instead follows a similar alignment to the rest of the revetment such that it appears forward of the natural bank alignment
- The revetment also appears to be quite flat in gradient, therefore occupying a significant footprint and adding to the seaward position of the toe relative to the natural bank position
- the termination of the rock wall is resulting in additional scour of the adjacent unprotected beach/bank. This is most significant in the localised 10 to 15 m of beach immediately east of the end of the revetment
- When compared with the western and central stretches of the revetment, the beach is lower toward the eastern end of the revetment such that the toe of the rock wall is submerged and interacting with swash at higher stages of the tide. This is exacerbating the localised scouring effect around the armour stones that form the termination of the revetment.

Figure 3.10 shows a drawing of the detailed revetment design alignment completed by Magryn (extracted from drawing 18343-2 Rev 0), overlaid on a pre-construction aerial image. Figure 3.11 shows the same design drawing overlaid on a post-construction aerial image. In both figures the position of the aerial imagery relative to the Magryn design seawall alignment is for illustrative purposes only, due to the tolerances of the horizontal positioning of the imagery. Figure 3.12 shows the eastern end of the revetment design drawing, along with the "*as constructed*" survey of armour stone levels/positions, geotextile underlayer levels/positions and the levels of the nourishment beach ("*as constructed*" survey from MGN Civil drawing PR149216-4a). Figure 3.13 shows the detailed design cross section drawing from Magryn (extracted from drawing 18343-4 Rev 0) for this stretch of revetment. It is apparent from the design revetment alignment and cross section drawing that the intention of the design was for the final 5 to 15 m of the revetment at the eastern end to deviate slightly landward (north) in alignment, with the structure to become progressively tapered into the natural bank slope. Only the upper section of the revetment armour above approximately 2 m AHD was to be exposed above the natural bank in this area. In comparison, Figure 3.11 and Figure 3.12 show that the alignment of the as-constructed revetment has not deviated landward, with the revetment sitting approximately 5 m seaward of the design alignment and natural bank alignment. This design deviation is consistent with observations from our site inspection.

Council have also completed a survey of cross shore transects of the foreshore in October 2021. These are discussed in more detail in later sections of this report. For reference, Figure 3.14 shows the surveyed transect at approximately Chainage 660 m, in front of 62 River Road. At this transect, the revetment slope has been measured at 1V:2.2H, which is a significantly lower gradient than the design profile proposed by Magryn. Similar gradients were measured for the revetment further to the west, which are consistent with our observations from the site inspection.

Figure 3.15 shows the beach elevation levels collected during a post construction survey by MGN Civil (drawing PR149216-4a), with the levels provided as "*As Constructed Sand Nourishment*". The measured beach nourishment levels are noted to not cover the full extent of the revetment. As noted in our observations, the beach in front of the eastern end of the revetment was notably lower than areas in front of the central and western sections of the revetment. This was a result of nourishment sand not being placed at the eastern end, due to a lack of available sand for the contractor (SCC, personal communication).

Figure 3.10 Magryn design revetment alignment, pre-construction background image

(Image: Nearmap 4/11/2020)

Figure 3.11 Magryn design revetment alignment, post-construction background image

(Image: Nearmap 30/07/2021)

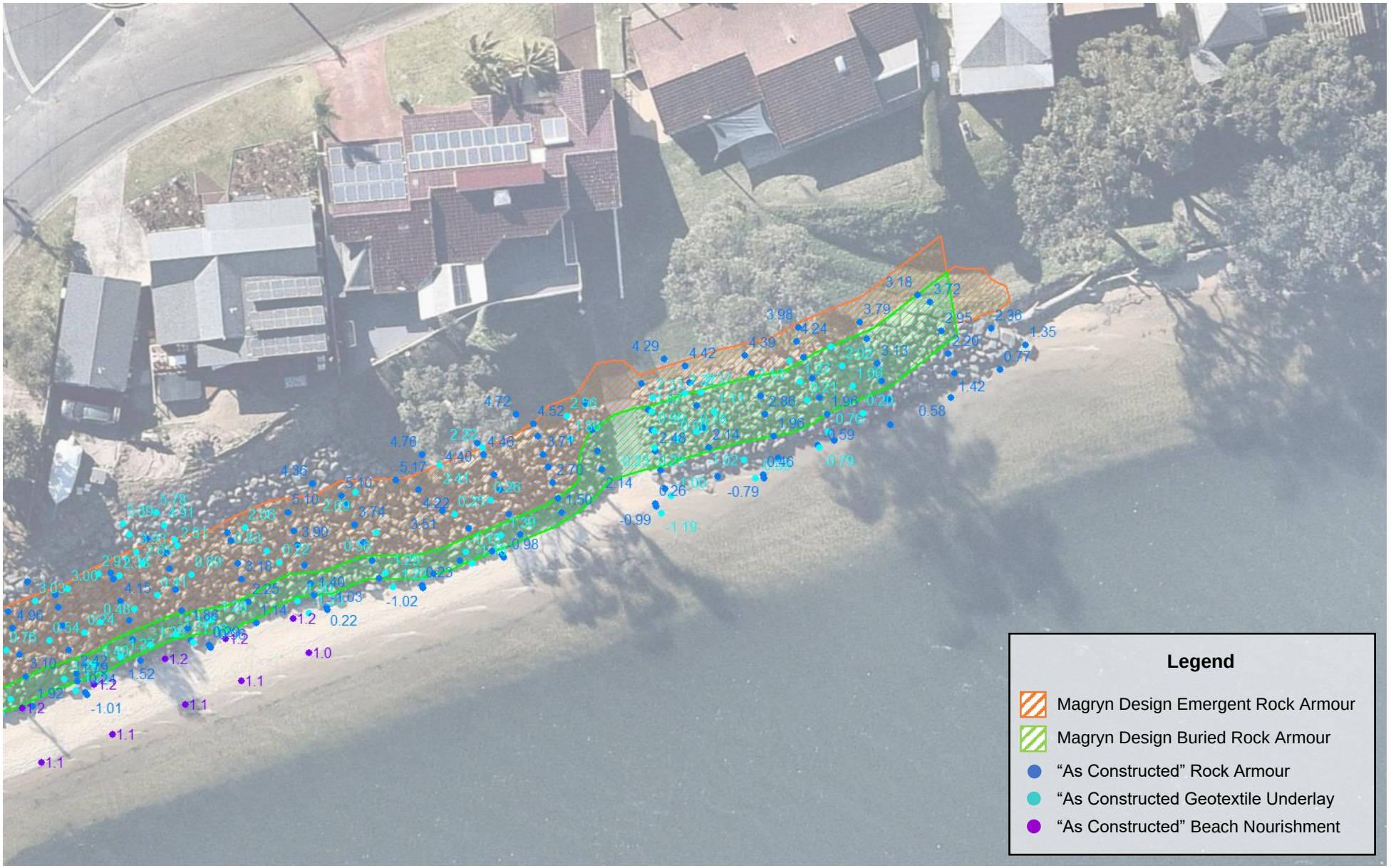


Figure 3.12 Magryn design revetment alignment and as construced armour stone levels, post-construction background image

(Image: Nearmap 30/07/2021)

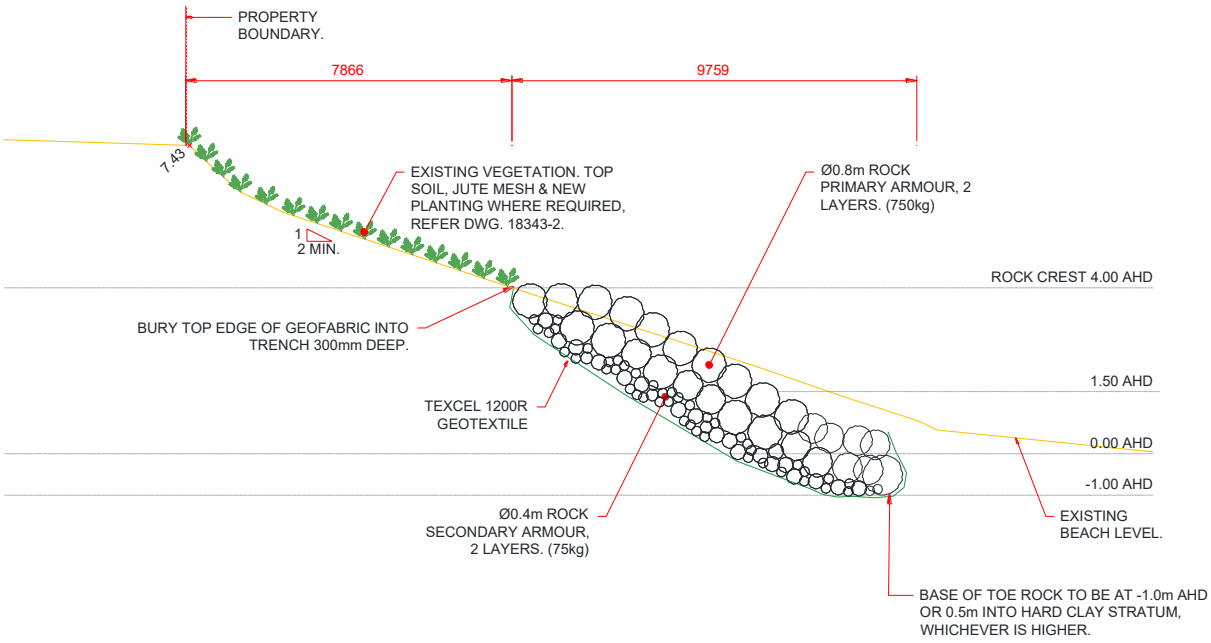


Figure 3.13 Detailed design revetment cross section by Magryn
(Note indicative natural profile alignment relative to revetment armour alignment)

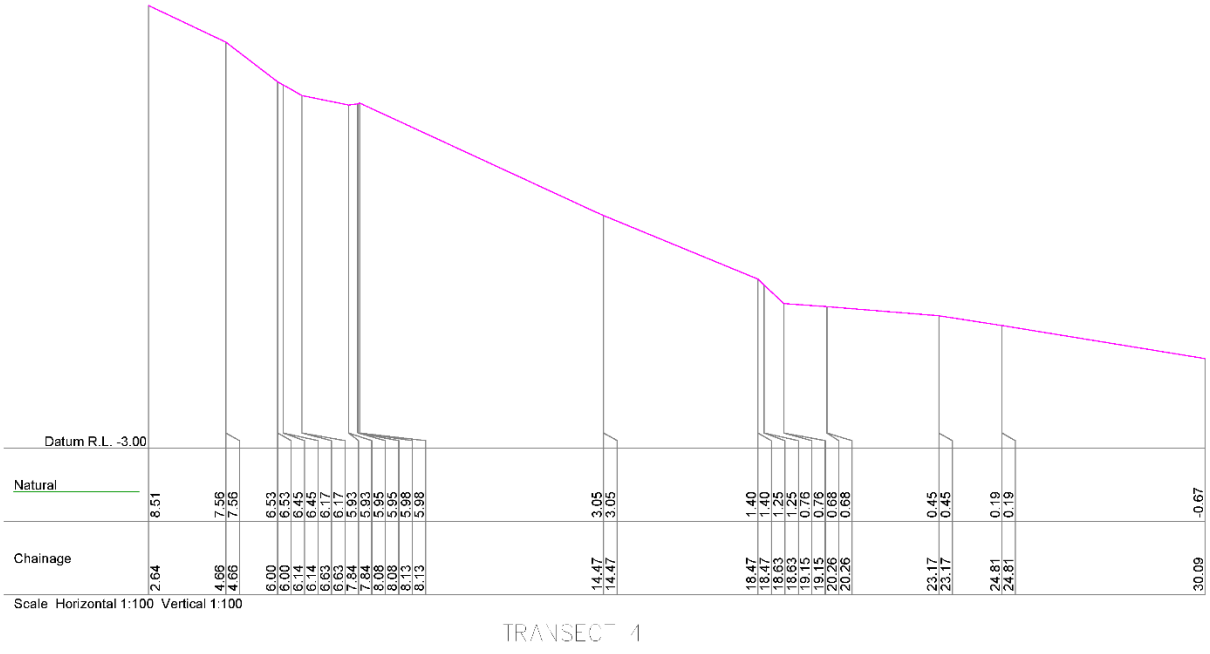


Figure 3.14 Survey across revetment cross section completed by Council
(Survey Transect 4, Ch 660 m)

Figure 3.15 Measured beach nourishment levels (m AHD) from "As Constructed Survey"
(Levels extracted from from MGN Civil drawing PR149216-4a.dwg; Image: Nearmap 30/07/2021)

4 Desktop review of coastal erosion processes and risks

4.1 Overview of evaluation

An updated assessment of coastal erosion processes and the current risks has been completed by WRL, with the assessment focussed on the foreshore in front of properties at 68 to 74 River Road. Consideration has also been given to the broader area within Zone 3B as indicated on Figure 2.2, to provide context of any baseline changes at the site further removed from the 2021 coastal management works. To maintain clarity and continuity with the previous investigations, we have documented our updated assessment with continued use of the same reference line for description of the current foreshore condition.

The updated assessment of erosion risk has been completed on the basis of:

- Our coastal engineering inspection of the site
- Analysis of changes to the foreshore that have occurred since 2016, on the basis of:
    - comparison of photos from both 2016 and 2021
    - mapping of the position of the erosion scarp/vegetation line
    - beach profile surveys from Council
- The current estuary state/processes.

4.2 Analysis of foreshore changes: 2016 to 2021

It was apparent from the site inspection that the foreshore immediately adjacent to the eastern end of the rock revetment has experienced some recent erosion. There were also signs of minor erosion at various locations between the end of the revetment and the boat ramp, with features such as minor scarping/undercutting of the toe of the bank at the back of the beach, and exposure of tree roots. To form an understanding of the rate of erosion and give consideration to the risk of future erosion, it is prudent to establish an understanding of how this stretch of unprotected foreshore has changed in recent years. This analysis has been completed firstly by comparing imagery of the foreshore taken by WRL during a September 2016 inspection, with co-located imagery collected in our September 2021 inspection. Secondly, high-resolution aerial imagery has been used to map the position of the toe and crest of the bank at the back of the beach as best as possible for the period between 2011 and 2021. Finally, beach profile data from Council surveys has been compared to further understand and quantify the cross shore changes.

Figure 4.1 to Figure 4.7 show images of the beach and foreshore through the area of interest, extending from the eastern end of the rock revetment (Chainage 720 m) through to the beach in front of 80 River Road (Chainage 850 m). Each of these figures show a specific location along the foreshore in 2016 and again in 2021. Noting that the 2016 inspection images were collected shortly following a series of erosion events, there was an obvious erosion scarp at the time. Where relevant, the 2016 scarp has also been marked onto the 2021 images for reference.

In considering this visual comparison of inspection photos it is apparent that:

- the area immediately east of the revetment end (Ch 720 to 750 m) appears to have experienced some localised erosion (though this is difficult to quantify from the imagery)
- north of Ch 750 m, the bank defining the back of the beach has not visibly retreated since 2016, with the 2016 erosion scarp still visible at most locations
- between Ch 750 m and Ch 810 m, the level of the beach immediately at the toe of the bank appears to have lowered/eroded slightly (of the order of 100 to 200 mm), evident as slight undercutting of the bank at some localised sections.

Figure 4.1 Foreshore taken at Ch 730 m, looking at Ch 670 to 730 m

Figure 4.2 Foreshore taken at Ch 770 m, looking at Ch 750 to 770 m

Figure 4.3 Foreshore taken at Ch 780 m, looking at Ch 750 to 780 m

Figure 4.4 Foreshore taken at Ch 790 m, looking at Ch 740 to 790 m

Figure 4.5 Foreshore taken at Ch 760 m, looking at Ch 760 to 800 m

Figure 4.6 Foreshore taken at Ch 775 m, looking at Ch 775 to 790 m

Figure 4.7 Foreshore taken at Ch 790 m, looking at Ch 790 to 850 m

Georeferenced, high-resolution aerial imagery was obtained from Nearmap for the area of interest, covering the 10 year period 2011 to 2021 (almost annually). The imagery was initially overlaid in GIS and close comparison showed that there were slight discrepancies (of the order of 0.2 to 0.8 m) in image positioning due to the verticality and georeferencing of the images. Further corrections in image alignment were made by WRL using a set of common ground control points to improve the alignment of the imagery relative to the 2021 image, with the end result being a time series of images that were aligned with a relative horizontal accuracy in the order of 0.25 m or better.

This time series of imagery was subsequently used to map the alignment of the bank along the back of the beach through the area of interest during the period 2011 to 2021. The mapping was completed for two features:

- The toe of the bank (2011 – 2021)
- The top of the bank following the 2016 erosion events (2017 – 2021).

Figure 4.8 shows the mapping for the toe of the bank between 2011 and 2021. For clarity, these time periods are further broken down into sub-sets of time in Figure 4.9, Figure 4.10 and Figure 4.11. A number of important pieces of information can be ascertained from the bank toe mapping:

- The position of the bank toe has been least stable towards the western end and more stable towards the eastern end of the mapped zone
- The position of the bank toe has eroded between 2011 and 2021, with the envelope of erosion decreasing from west to east
- The erosion in the 2016 period is apparent (compare 2016 and 2017 lines in Figure 4.9) with the toe of the bank retreating approximately 2 m at the western end (Ch 720 to 750 m) and 0.5 m at the eastern end (Ch 750 to 950 m) during this period
- The toe of the bank accreted (or shifted towards the channel through bank slope adjustment) between 2016 and 2019 as shown in Figure 4.10
- The toe of the bank eroded in 2020 and 2021 (Figure 4.11), such that the toe alignment is now
    - Slightly further eroded than following the 2016 storms for the area Ch 720 to 750 m
    - Similar to the position following the 2016 storms for the area Ch 750 to 950 m
- There has been minimal change to the bank toe since November 2020 (Figure 4.11).

Figure 4.12 shows the mapping for the top of the bank between 2016 and 2021. From this mapping it can be concluded that:

- Between Ch 720 m and Ch 860 m, there has been no discernible change in position of the top of the bank at the back of the beach since the erosion events of 2016 (within the accuracy of the mapping method)
- East of Ch 860 m, it would appear from the mapping that the top of the bank has pro-graded, though this may be an artifact of changes in vegetation at the top of the bank that have occurred between aerial images.

These conclusions from the mapping of the bank position confirm the visual observations previously reported from site inspection photos.

Figure 4.8 Mapping of the position of the bank toe at the back of the beach (2011 to 2021)

(Background Image, Nearmap 30/07/2021)

Figure 4.9 Mapping of the position of the bank toe before and after 2016 storms

(Background Image, Nearmap 30/07/2021)

Figure 4.10 Mapping of the position of the bank toe between 2017 and 2019

(Background Image, Nearmap 30/07/2021)

Figure 4.11 Mapping of the recent position of the bank toe between 2019 and 2021

(Background Image, Nearmap 30/07/2021)

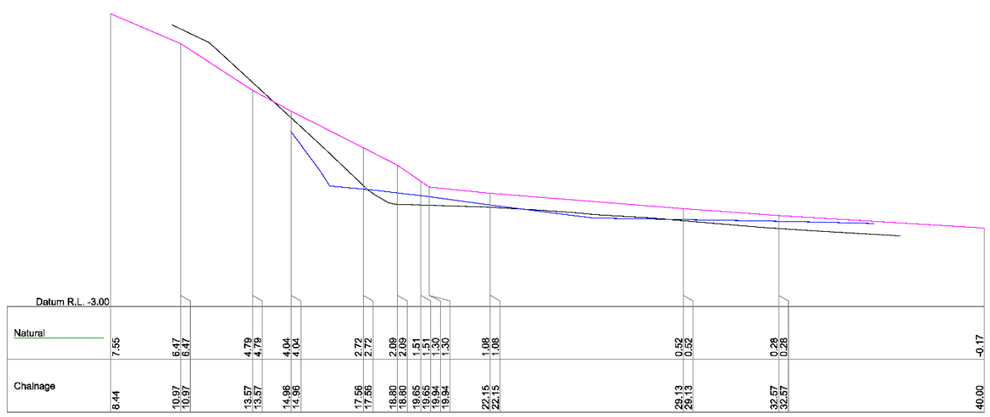
Figure 4.12 Mapping of the position of the bank top at the back of the beach (2017 to 2021)

(Background Image, Nearmap 30/07/2021)

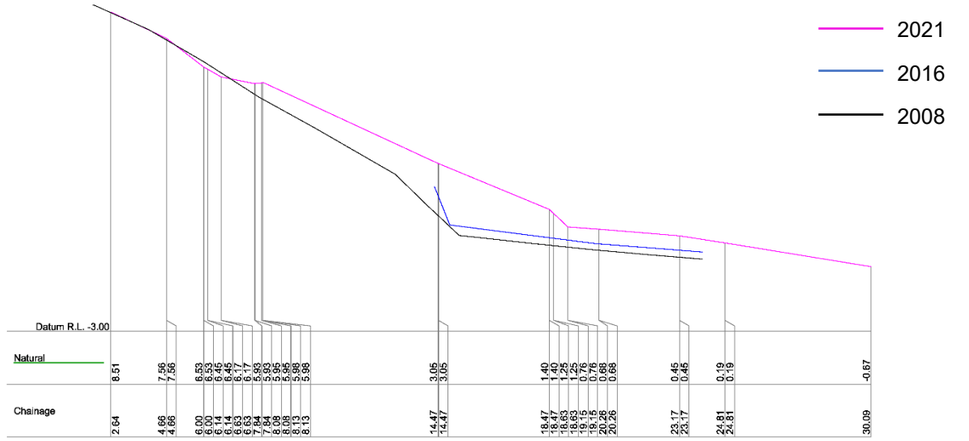
Council collected cross shore profile surveys for specific transects of the River Road foreshore in August 2008, June 2016 and October 2021. The locations of the six survey transects are presented in Figure 4.13, while the survey profiles themselves are presented in Figure 4.14. Transect 4 passes through the rock revetment towards its eastern end, and clearly shows the position of the revetment surface (2021 survey line) sitting approximately 4 m towards the estuary channel relative to the natural pre-construction profile (2016), as noted in previous sections of this report. The 2021 survey also confirms that the beach level at the toe of the revetment at its eastern end (Transect 4), is approximately 0.7 m AHD, which is 0.4 m lower than the beach at the toe of the revetment sections further west (Transects 2 and 3).

In considering the un-protected section of foreshore captured in Transects 5 and 6/6A, the survey data indicates that there has been negligible change in the position of the beach or bank at the rear of the beach between the 2008, 2016 and 2021 surveys. This data further supports our field observations and measurements from aerial imagery.

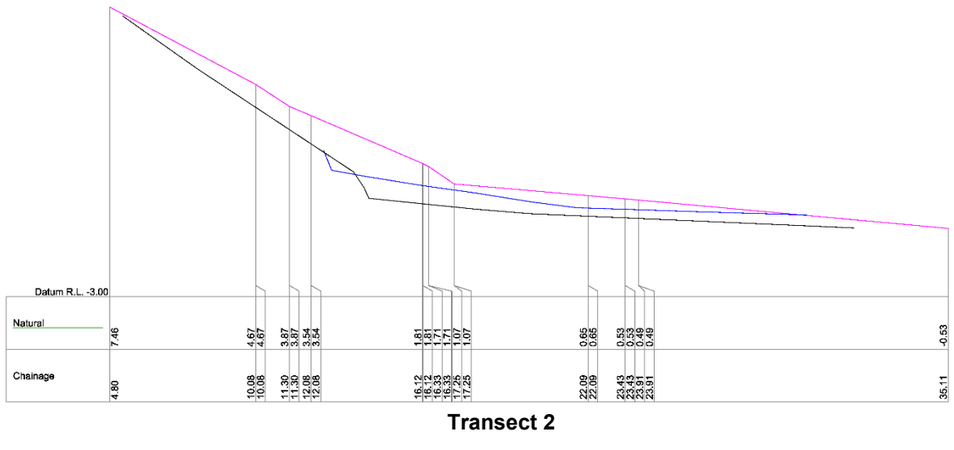
Figure 4.13 Location of foreshore survey transects



Transect 1



Transect 4



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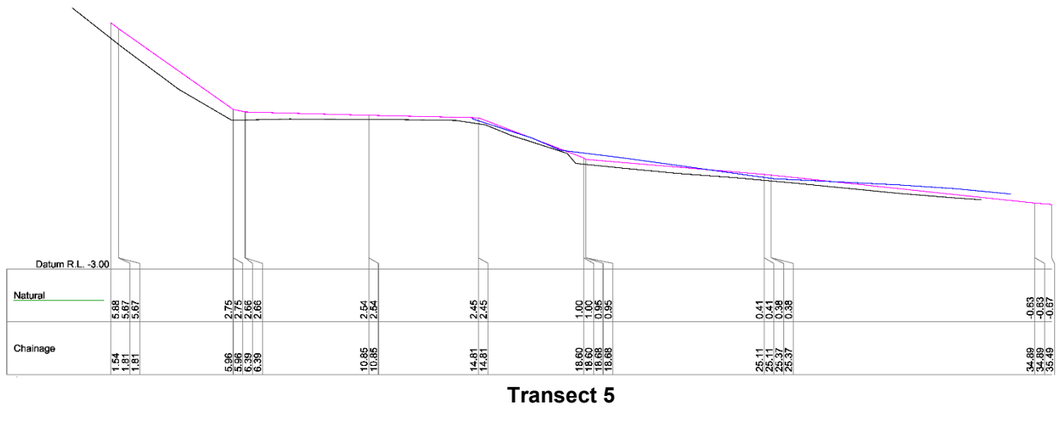

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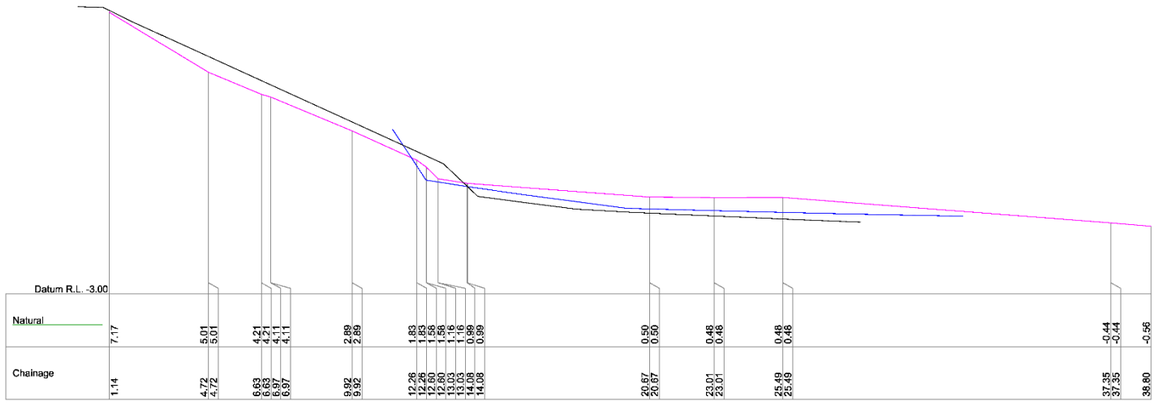

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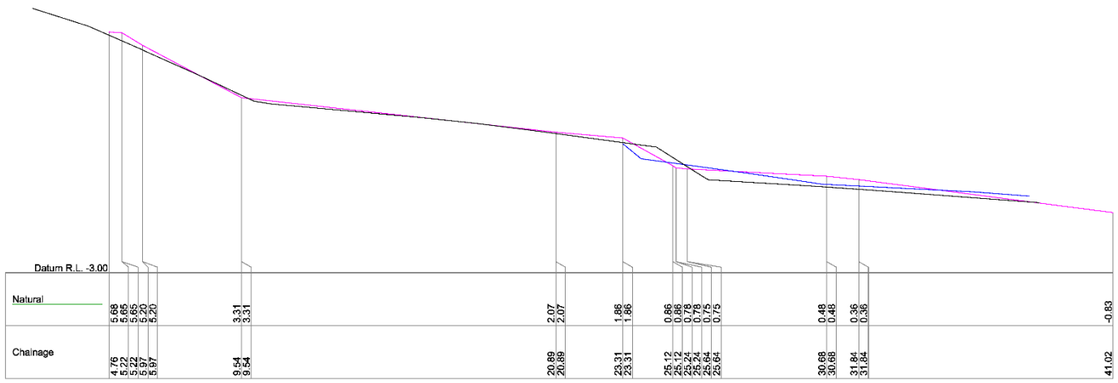

Transect 6 (2008 & 2016) and Transect 6A (2021)

Figure 4.14 Foreshore survey profile comparison for August 2008, June 2016 and October 2021

4.3 Current estuary state and erosion processes

The localised erosion that is evident in the area immediately adjacent to the end of the rock revetment (Ch 720 to 750 m) is occurring only during periods of high tide estuarine water level. At mid to low tide, or even high neap tides, the back of the beach and toe of the embankment is above swash processes. At high tide water levels, swash that is generated by wind waves, boat wakes or a small amount of swell wave energy (if the Shoalhaven estuary entrance is open), is interacting with the end of rock revetment to generate the localised scour which is removing sand from the beach and the toe of the back-beach bank. During flood periods with further elevated estuarine water levels, it is expected that the erosion would be exacerbated with wave energy impacting directly on the erosion scarp/bank (though this was not observed during the conditions of our field inspection).

Water level data was obtained from the Manly Hydraulics Laboratory Shoalhaven Heads tide gauge for the period 2015 until present. This gauge provides a good indication of estuarine water levels at the River Road foreshore area. Data was also obtained for the Crookhaven tide gauge for comparison purposes, as it provides a reasonable indication of oceanic tide conditions on the Shoalhaven coastline. The Shoalhaven heads data (Figure 4.15 top) shows that there have been a notably high number of events with elevated estuarine water level (above say 1 m AHD) in the past 12 months, compared with the full 5.5 year analysis period. In particular, there have been a larger than usual number of occurrences since March 2021. These cumulative high water level events are likely to have exacerbated or accelerated the erosive impacts adjacent to the revetment end, compared to the conditions previously experienced between late 2016 and early 2020 for example.

The water level analysis was extended to consider the differences in high tide water level at Shoalhaven Heads compared with the open ocean, as well as the influence of the Shoalhaven estuary entrance state on high tide water levels at Shoalhaven Heads. Firstly, the daily high tide peak water level was determined for the Shoalhaven Heads gauge through the analysis period (Figure 4.15 bottom; note that the Shoalhaven Heads entrance condition is shown as red (closed) or green (open)). This showed spring high tide levels at Shoalhaven Heads to be typically in the range of 0.8 – 1.0 m AHD, while neap high tides are typically 0.4 to 0.5 m AHD. When compared with the Crookhaven tide data as an indicator of ocean tides, it can be seen that during spring tides the high tide level at Shoalhaven Heads is typically 0.1 m lower than the open ocean, while during neap tides the difference in high tide level is slightly reduced (almost negligeable difference). Immediately following flood events that open the Shoalhaven entrance and during periods when the entrance is well-scoured, there is also negligible difference between high tide levels in the ocean (Crookhaven data as a proxy) and high tide levels at Shoalhaven Heads. This indicates that the state of the Shoalhaven estuary entrance has a minor, but measurable impact on high tide levels at Shoalhaven Heads, such that higher spring tide levels are experienced at Shoalhaven Heads if the Shoalhaven entrance is open compared to if it were closed. This small difference in spring high tide water level is unlikely to influence the erosion risk profile along the River Road foreshore to any significant degree.

Events that are more likely to exacerbate erosion and scour adjacent to the revetment primarily include catchment floods with elevated estuary water levels, waves created by strong south-westerly winds, or coastal storms with a positive tidal anomaly that generate high estuarine water levels, penetration of swell to the site, or a combination of all three. At present, the Shoalhaven estuary entrance is closed and therefore it is not possible for ocean swell penetration to reach the site (though it is acknowledged that this could change at any point in time). Even with an open estuary entrance, the area of River Road foreshore east of the revetment (Ch 720 to 950 m, Zone 3b) has a much lower exposure to swell wave energy compared with the zones now protected by the revetment (Blacka & Coghlan, 2017).

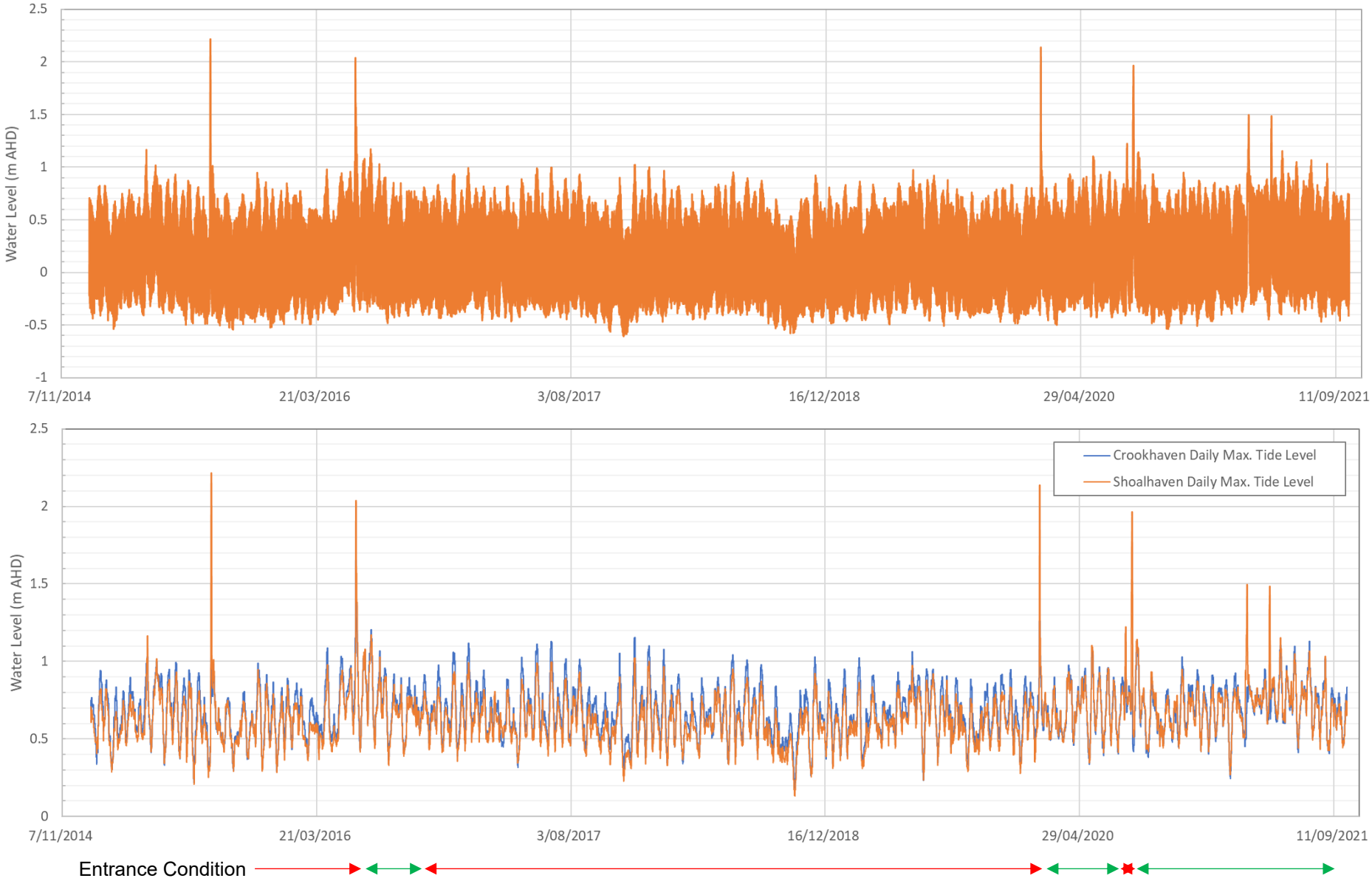

Figure 4.15 Analysis of tidal data for Shoalhaven Heads
(Top) and daily maximum tide level (bottom) – Note Shoalhaven Heads entrance condition is shown as red (closed) and green (open)

4.4 Updated management prioritisation ratings

As shown in Figure 3.6, Figure 3.7 and discussed in Section 4.2, the area of beach immediately adjacent to the eastern end of the rock revetment (Ch 720 to 750 m) has experienced recent scouring, which is primarily the result of swash interacting with the revetment end in this area. The beach is also noted to be lower in this area and to have a lower sand volume compared with areas further west or east. Mapping (Figure 4.12) has shown that the top of the erosion scarp/bank in this area has not receded significantly since construction of the revetment, though it is difficult to tell from comparisons of photographs due to the extent of change with the revetment construction.

Given the interaction of swash with the toe and end of the revetment at higher stages of the tide, the beach changes (erosion) immediately east of the revetment are likely to be part of the beach re-adjusting alignment to form a new equilibrium due to the disturbance (construction) of the revetment. This is reported in coastal engineering literature as a revetment end effect. Once that equilibrium is reached (a scoured or receded alignment of the beach immediately east of the revetment end), ongoing changes would reduce and the foreshore would likely stabilise in the new alignment. While there is a buffer of land within the reserve that separates the private properties from the beach, it is difficult to quantify the ultimate extent of realignment and final position of the erosion scarp. This process may also continue to degrade the beach condition in this area, and the erosion may cause out-flanking issues for the revetment end. On this basis, we have escalated the management priority rating for this stretch (Ch 720 to 750 m; 66 to 70 River Road) from a medium up to a "*high*" rating.

While the erosion scarp/bank in the area between Ch 750 m and Ch 800 m has not receded beyond the 2016 erosion extent, from our inspection and comparison of photos, the intertidal section of the beach has lost a small amount of sand volume and lowered slightly in this area. It is unclear if this is the result of the consecutive high water level events in 2021 (i.e. natural background fluctuations in the beach), the influence of the revetment construction (i.e. a permanent impact on the beach), or a combination of both. While it is considered unlikely that this area will experience rapid or unpredictable erosion and there is a reserve acting as a buffer to separate the erosion scarp from private property boundaries, it is prudent that this area receive some degree of management action in the near future (noting that the management works recommended in our 2016 report for this area have not yet been implemented). On this basis, we have escalated the management priority rating for this stretch (Ch 750 to 850 m; 72 to 74 River Road) from medium up to "*medium-high*" rating.

In considering the information presented in Section 4.2, it is clear that since 2016 erosion of the beach to the east of Ch 800 m (76 River Road) has been relatively mild in nature, and is considered within natural fluctuations for an active estuarine beach. Indeed, the beach and the bank at the rear of the beach are considered to be quite stable in this zone. It is very unlikely that this area will experience rapid erosion and it is acknowledged that there is a strip of reserve acting as an additional buffer separating the beach from private properties. On this basis, we consider this area to be of relatively low risk, and management response is only required to build resilience of the foreshore, more so than reduce erosion risks. We consider that the qualitative management priority is the same now as in our 2016 assessment, which was a "*medium*" rating.

Table 4.1 and Figure 4.16 provide an updated prioritisation of management response for the study area covered within this report.

Table 4.1 Updated summary of qualitative management prioritisation

Foreshore zone	Description	Management priority
Ch 720 - 750 m	Immediately east of the revetment end, and seaward of properties 66 to 70 River Road	High
Ch 750 - 800 m	Seaward of properties 72 to 74 River Road	Medium-High
Ch 800 - 950 m	East from 76 River Road	Medium

Figure 4.16 Study area and updated 2021 management priority

5 Foreshore management options

5.1 Overview of management options

A number of different management approaches remain possible and applicable for the stretch of River Road foreshore covered in this report. The management options have varying levels of impact/benefit to the environment and amenity of the site, costs and implementation timeframes. These options include (but are not limited to):

- Do nothing
- Monitoring with no active management works
- Monitoring in combination with management works
- Relocating sand that is already within the River Road foreshore compartment (beach scraping and dredging)
- Stabilisation of erosion scarps and revegetation
- Modification to the end section of the rock revetment (Ch 680 to 720 m)
- Extending the rock revetment toward the east
- Nourishment of the beach (small or large scale) with sand dredged from within the estuary shoals, or imported from an alternative site (such as excavated from the entrance area).

Table 5.1 provides an overview of advantages and disadvantages of each of these potential management responses, with consideration given to the magnitude of costs, reduction in current erosion issues, resilience to future erosion issues, and improvement in amenity that would be achieved.

Each of the potential management responses summarised in Table 5.1 have both advantages and disadvantages. To maintain or enhance the recreational amenity and environmental value of the beach will ultimately require the addition of a further significant volume of nourishment sand, beyond that which can realistically be achieved by on-site sand re-distribution alone (e.g. beach scraping). This larger scale nourishment is considered to be a necessary approach, regardless of other management interventions that may be implemented. Nevertheless it is difficult to predict the longevity of beach nourishment in these situations (which depends on environmental and climate variables for example), and long-term maintenance nourishment should be expected.

While there are some benefits to an extension of the rock revetment (for example an extension to cover the area in front of 68-74 River Road, or further east), there are also a number of disadvantages:

- Construction would require either further removal of mature trees/shrubs or a revetment alignment that would encroach further onto the useable beach width
- This may exacerbate erosion in front of the revetment, further degrading beach amenity and environmental value
- There is a risk of shifting the current “end-effect” erosion to a new location further east, impacting a stretch of shoreline that is currently stable
- There would be a requirement for further environmental assessments (such as an REF) and approvals/permits from several agencies, making it less suitable for short term implementation.

As there is no clear coastal engineering requirement for a significant extension to the revetment, and the broader community drivers for the beach are centred around recreational and environmental values, beach amenity and functionality, such an extension at this point in time is considered to be at odds with

objectives for coastal management of the area. Nevertheless, it may require further consideration as part of a long term management strategy within the Shoalhaven Estuary CMP, as opposed to a short term management response.

Table 5.1 Advantages and disadvantages of various management responses

Management intervention	Applicability Ch. 680-720 m	Ch. 720-800 m	Ch. 800-950 m	Advantages	Disadvantages
Do nothing	X	X	✓	No current financial cost.	Does not resolve current issues; Does not improve environmental or amenity value; Does not build resilience or reduce risk of ongoing erosion.
Monitoring of erosion	✓	✓	✓	Enables understanding of ongoing changes; Enables triggered response; Improves engagement with community; Informs long-term management solutions; Minimal financial cost.	Does not resolve current issues, build resilience or reduce risk of ongoing erosion if implemented in isolation.
Redistribution of sand (within foreshore area)	✓	✓	✓	Low financial cost; Immediate improvement in buffer of sand volume for impacted areas; Improves beach width for recreational amenity.	Limited volume of sand that can be utilised; Requires heavy equipment working within intertidal zone; Short-term resilience unless combined with re-vegetation.
Re-profiling of erosion scarps and revegetation	✓	✓	✓	Nature-based approach to build resilience of bank/scarp; Low financial cost; Revegetation provides long-term resilience; Improves visual amenity.	Does not increase volume of sand for erosion buffer; Does not improve beach width for recreational amenity; Has initial establishment time to become effective.
Modification to the eastern end section of the rock revetment	✓	X	X	May reduce ongoing erosion end-effect; Small gain in beach width for recreational amenity.	Does not build resilience for areas east of revetment end; Requires heavy equipment working within intertidal zone; Moderate financial cost.
Extension of eastern end of rock revetment	✓	X	X	Forms a permanent erosion limit in protected area.	High financial cost; Requires heavy equipment working within intertidal zone; May require further tree removal; Reduces available beach width for recreational amenity; May shift erosion end-effect further to the east.

Table 5.1 Advantages and disadvantages of various management responses (Cont.)

Management intervention	Applicability Ch. 680-720 m	Ch. 720-800 m	Ch. 800-950 m	Advantages	Disadvantages
Moderate-scale nourishment of beach (imported sand)	✓	✓	✓	Low-impact/nature-based approach; Moderate to large gain in beach width for recreational amenity; Provides immediate reduction in current erosion risks, and builds resilience to future erosion; Reduces revetment end-effect erosion; Preserves as many foreshore trees as possible.	Uncertain duration of risk reduction (months to years); High financial cost; Requires heavy equipment working within intertidal zone.

Based on the potential of each of the management options to address the identified issues and current risk (Figure 4.16), as well as the advantages/disadvantages described in Table 5.1, the recommended management options for each foreshore zone are described in Table 5.2 and shown in Figure 5.1.

Table 5.2 Recommended management approaches

Foreshore management zone	Recommended management approach[1]
Ch 680 - 720 m	Now: Modify this section of rock revetment including: • Temporarily remove rock armour (primary and secondary) and geotextile underlayer • Re-align and profile lower section of earth bank to a slope of 1V:1.5H • Replace geotextile, secondary armour and a single layer of primary armour only, to a maximum crest height of 4 m AHD (adjacent to private boat ramp) and reducing to level of natural ground at the eastern end • Place excess/excavated soil onto current erosion scarp at eastern end of rock revetment, burying end of revetment within bank alignment if possible Nourish the intertidal area of beach to elevate it to a consistent longshore level (at least 1.1 m AHD) against revetment toe, per current level of beach areas further to the west.
Ch 720 - 800 m	Now: Nourish the intertidal section of beach in this localised area to achieve a more suitable beach volume, including re-building of the back-beach erosion scarp to a more stable slope. Stabilise the re-profiled bank surface and crest through revegetation and ground cover. Consider improved pedestrian access controls. Mid-Term Future: Nourish beach more extensively if needed, or if recommended short-term nourishment volumes cannot be achieved.
Ch 800 - 950 m	Now: Re-profile erosion scarp, stabilise surface, revegetate, consider improved access. Mid-Term Future: Nourish beach more extensively if needed.
All sections	Monitor the beach through regular beach profile surveys or UAV surveys and collect photographs: • Quarterly (minimum 6-monthly) • After erosion events

Notes:

1. It should be emphasised that the suggested management approach has been selected with a focus on addressing the immediate issues in the short term (as per the scope of WRL's project), while also not compromising the ability to implement a longer term management plan for this section of the estuary at a later date, such as within a Coastal Management Program (CMP). It is recognised that alternative management approaches may provide longer term improvements in amenity of the foreshore (such as significant dredging of the estuary sand shoals and mass scale nourishment of the beach), however, these would require a range of additional investigations, community engagement and funding, and are therefore more suited to analysis as part of a CMP.

Figure 5.1 Overview of recommended management works

5.2 Concept design of revetment modifications (Ch 680 to Ch 720 m)

The foreshore between Ch 680 m and Ch 720 m has a reduced exposure to swell waves when the Shoalhaven estuary entrance is open to the sea, compared to the revetment section further west that was considered by WRL's previous concept design. On the basis of the wave height analysis completed in Blacka and Coghlan (2017), design significant wave heights at Ch 680 to 720 m have been estimated to be:

- Wind waves when entrance is closed: H_s = 0.7 m
- Swell waves with small entrance opening, H_s = 0.4 m
- Swell waves with large entrance opening, H_s = 1.1 m.

For the purposes of verifying minimum armour size requirements for this stretch of the revetment, we have considered the same relatively conservative design risk level as recommended in MHL (2018), which allowed for a large estuary entrance opening, and therefore a design significant wave height, H_s of 1.1 m. These wave conditions were evaluated using the method of Nurmohamed et al. (2007), and found that for a well-placed single layer of rock armouring, a conservative design median armour mass of approximately 300 kg would be sufficient. A note has been included at the end of Section 5.2 which further discusses the requirements/expectations for "well-placed" armour compared with randomly placed armour, and should be considered in conjunction with the concept design information.

While it is acknowledged that single layer rock armouring is typically not recommended in coastal engineering guidelines, in this case the median mass of the armour stone currently utilised in this area and which would be re-used, was specified as 750 kg, and therefore has a factor of safety of at least two. Noting also that the importance level of the structure in this specific 40 m stretch is relatively low (i.e. the structure is not providing immediate protection to high value assets), and the benefits of reducing the structure footprint as much as possible are great, on balance the reduction of the revetment to a single armour layer in this area is considered a reasonable solution.

Figure 5.2 shows a schematic to illustrate the comparative difference between the current revetment construction in this area (as measured by Council's profile survey in October 2021), with the modified single layer design proposed by WRL. The modified structure will occupy approximately 4 to 5 m less beach width, and therefore have an alignment much closer to that recommended in Magryn's original design, as well as the alignment of the natural bank east of the revetment. This improved alignment will help to reduce scouring and end effects of the revetment on the adjacent stretch of beach, in particular with additional sand nourishment to raise the level of the beach against the revetment toe.

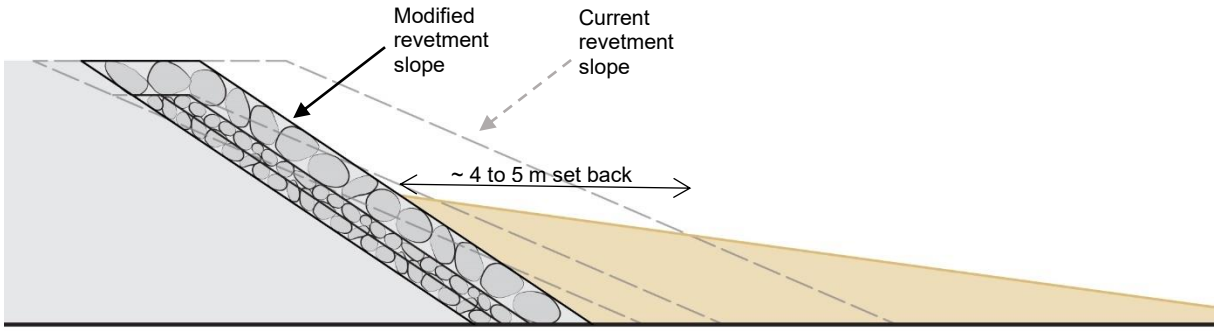

Figure 5.2 Comparison of current revetment and modified design for Ch 680 to Ch 720 m

Figure 5.3 shows the indicative existing revetment cross section design at Ch 690 m. The modified cross section design at Ch 690 m is shown in Figure 5.4, while the modified cross section further east at Ch 720 m is shown in Figure 5.5, noting the reduced revetment crest level to blend with the natural ground level at this location. The modified cross section design incorporates a single layer primary armour of tightly placed 750 kg armour stones, and a slope that is steepened from the current 1V:2.3H to 1V:1.5H.

To implement the proposed design would require removal of primary and secondary armour, removal of geotextile underlayer, and reshaping of the embankment behind the revetment to form the correct slope and alignment, followed by replacing of the geotextile and armouring. It is envisaged that this modification would happen sequentially (i.e. stripping and rebuilding ~10 m sections of the structure at a time). During this process it may be possible to retain and re-use the existing geotextile if it is not damaged, as the modified design has a reduced geotextile coverage area.

It may be possible to retain the existing revetment immediately east of the private boat ramp (Ch 680 to Ch 690 m), and transition to the modified design over a 10 to 15 m distance (Ch 690 to Ch 700 m), with the eastern 20 m of the revetment constructed to the modified design (Ch 700 to Ch 720 m). This approach would see existing armouring retained for Ch 680 to Ch 690 m as per Figure 5.3, while Ch 700 to 720 m would be constructed to the modified design as per Figure 5.4 and Figure 5.5. There would be a transition between existing and modified armouring between Ch 690 and Ch 700 m. However, it is recommended that Council discuss this option with the construction contractor, as it introduces complexity to the modification process and may not save any significant construction costs. Implementation of a transitioning design would require close technical monitoring throughout construction to ensure that the finished segment of revetment achieves the design intent (improved slope and alignment, reduced footprint and impact on beach processes, meets wave stability requirements).

The revetment modification works should be completed in partnership with the beach nourishment, so as to form an integrated solution. Modification of the revetment without nourishing the beach will likely result in similar issues to those currently being experienced, whereby sand is scoured from the toe and end of the revetment, and there is little trafficable dry beach in front of the revetment at high tide.

Consideration by the contractor will need to be given to the location of temporary stockpile areas for the primary armour and secondary armour during the modification process, so as to minimise impacts on surrounding areas of beach and foreshore, while also minimising additional materials handling. Other construction and site management factors will also require consideration, likely through an Environmental Management Plan, such as (but not limited to):

- Site accessibility for construction plant along the beach and during various stages of the tide
- Pedestrian control
- Noise and dust impacts
- Other safety and environmental considerations.

Council will also need to investigate whether the additional coastal management works fit within current approvals, permits and licences for the overall project, or if modifications to the approvals will be required.

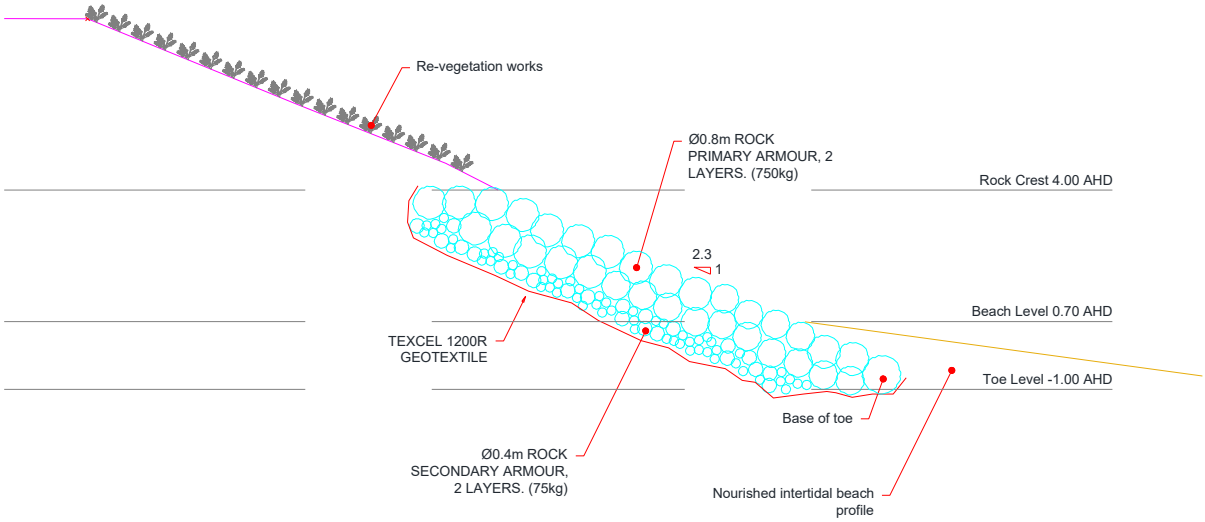

Figure 5.3 Indicative existing revetment section at Ch 690 m

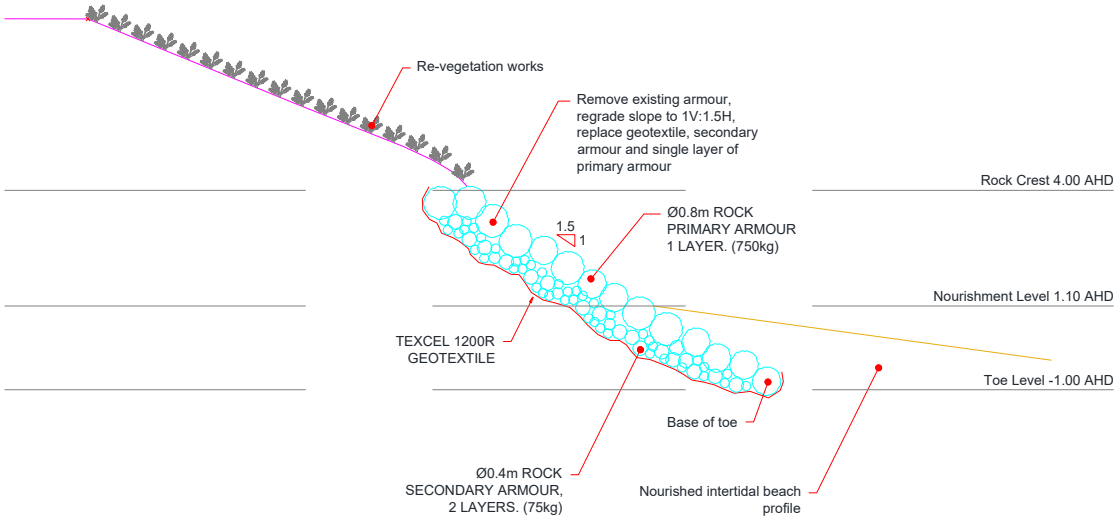

Figure 5.4 Concept design for modified revetment section at Ch 690 m

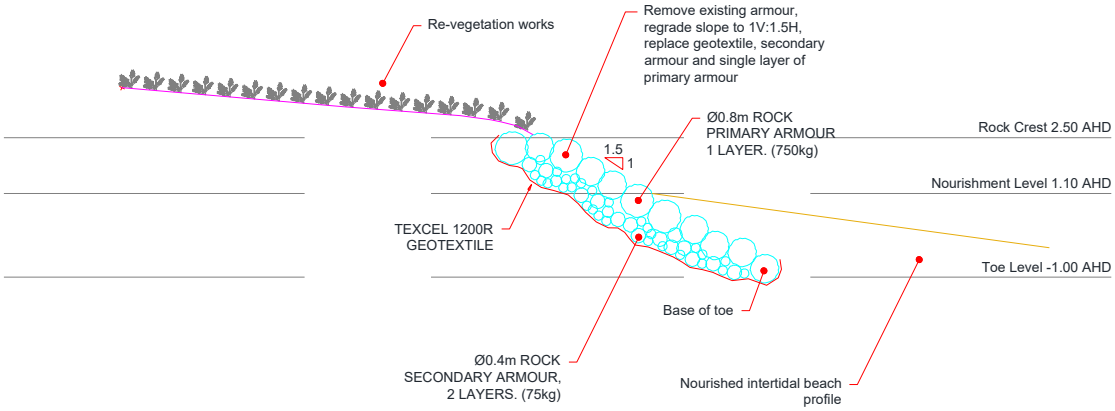

Figure 5.5 Concept design for modified revetment section at Ch 720 m

Note regarding re-use of excess armour

Excess armour stone will be generated by the modifications to the revetment which will need to be transported off site. Council may consider re-using a portion of the excess armour stone to further improve the alignment of the eastern end of the revetment in the localised area of the current "end-effect" erosion scarp. Re-use of some of the excess armour stone in this way should aim to:

- Taper the end flank of the revetment landward of the natural bank alignment, such that the end of the revetment is buried within the bank (there is no abrupt or exposed termination of the rock armouring)
- End at a crest level no higher than the natural existing grassed bench immediately behind the bank/scarp
- Terminate sufficiently west of the existing trees in front of Number 70 River Road, to avoid exacerbating scour of the bank around the root balls of the trees.

This revetment end treatment would be constructed with a similar cross section to Figure 5.5, with an indicative alignment as illustrated in Figure 5.6 and Figure 5.7.

Figure 5.6 Indicative modified revetment concept alignment

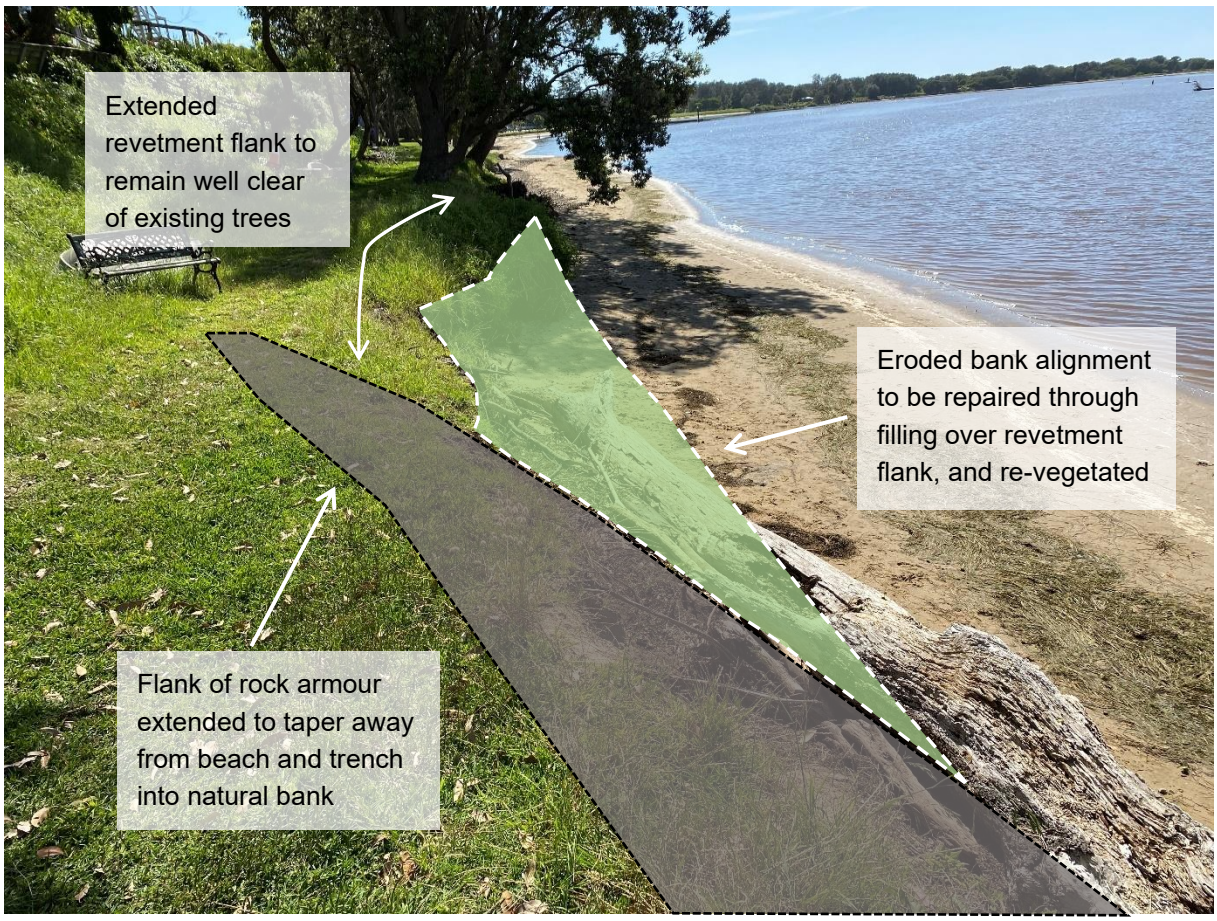

Figure 5.7 Indicative modified revetment flank concept alignment

Note regarding single layer armour placement:
The single layer rock armouring suggested for the concept design has been specified as "well-placed". The original publication used in this assessment to verify the hydraulic stability of the armour (Nurmohamed et al., 2007) used the terms "orderly placed" or "pitched" to describe the rock armour placement. For the purpose of this assessment we consider the terms "well-placed", "orderly-placed" or "pitched" to be interchangeable. Nurmohamed et al. (2007) provides several qualitative descriptions with regards to placement technique as summarised below. Further visual representation of "well-placed" rock armour compared with randomly dumped armour are shown in Figure 5.8.

"*Orderly placed means that attention has been paid to a way of constructing the slope in a more stable manor than only by random dumping.*"

"*…rocks were pitched one by one and put together in such a way that they form a single tightly packed, but porous layer.*"

"*All rocks have contact with each other and "loose" rocks do hardly or not exist.*"

Figure 5.8 (L) Pitched rock slope with randomly dumped rock in front. (R) Pitched rock slope (Nurmohamed et al., 2007)

WRL's expectation is that the single layer rock armour will be placed by an experienced contractor with a higher degree of care than a more traditional "random" bulk placement method, including:

- The use of a hydraulic grab or bucket to place and manoeuvre individual stones in the armour layer
- Aligning stones to maximise contact/interlocking between adjacent armour stones, and achieving three-point contact/support wherever possible
- Repositioning of stones that are noted to be able to rock even after placement of adjacent stones
- Ensuring a well-trimmed finish surface that is free of projecting stones.

5.3 Concept design of beach nourishment (Ch 600 to Ch 800 m)

The concept design for beach nourishment works has adopted a target beach profile similar to the current beach toward the western end of the revetment, as measured by Council in October 2021 (Council Transect 2, at approximately Chainage 540 m, Figure 4.14). The beach profile at this western transect is considered to have a more functional width for recreational and coastal protection purposes, and therefore the objective of future short-term nourishment should be to achieve a similar beach condition along the complete length of the revetment and areas further to the east.

Using the available beach profiles measured by Council in October 2021 as well as observations from the site, current beach profiles were estimated for the area between Chainages 600 and 800 m, and the target nourished beach profile was overlaid. Nourishment volumes required to achieve the target beach profile were estimated by comparing the target and existing beach profiles. The nourishment plan has considered three separate zones, as shown in Figure 5.9:

- Nourishment Zone A, Ch 600 to 680 m (Figure 5.10)
    - Central-eastern section of revetment
    - Though immediate nourishment of this area is not necessary for recreational purposes, it would provide a sand buffer for future storm events
- Nourishment Zone B, Ch 680 to 720 m (Figure 5.11)
    - Eastern section of revetment in front of numbers 64-66 River Road

    - The beach in this area is currently lower than desirable, with swash impacting the toe of the revetment during periods of high tide. This reduces the recreational value of the beach (e.g. forces beach walkers to traverse the rock revetment at high tide), and exacerbates the impact of the revetment on beach erosion processes
- Nourishment Zone C, Ch 720 to 800 m (Figure 5.12)
    - Un-protected stretch of beach east of the revetement end, in front of numbers 68-74 River Road
    - The beach in this area is currently lower than desirable, with swash impacting the toe of the erosion scarp during periods of high tide. The erosion is worst at the immediate end of the revetment, and reduces further to the east. Nourishment here is required to offset the un-recovered beach volume losses experienced in the 2016 storms and since the construction of the revetment, including protection of remaining mature trees.

While the nourishment of Zone A would further improve the beach condition, it is not essential as the design beach profile (up to ~1 m AHD at the revetment toe) was already achieved in this area during previous beach nourishment works. Nourishment of Zones B and C is required in the short term to build the resilience of these areas against the impacts of future storms. The target nourishment zones extend across the complete intertidal profile from the toe of the revetment or natural bank, out to the low tide level on the edge of the channel (approximately -0.5 m AHD).

Most sections of the beach require 0.3 to 0.6 m of nourishment thickness to achieve the target minimum profile. Table 5.3 provides a summary of the estimated minimum nourishment volumes within each zone.

Table 5.3 Estimated minimum nourishment volumes

Nourishment zone	Description	Nourishment rate (m^3 per m of beach length)	Total nourishment volume (m^3)
Zone A: Ch 600 - 680 m	Central-eastern section of revetment	5.2	413
Zone B: Ch 680 - 720 m	Eastern section of revetment in front of numbers 64-66 River Rd	3.6	144
Zone C: Ch 720 - 800 m	Un-protected stretch of beach in front of numbers 68-74 River Rd	9.7	772

The nourishment concept design has considered placement of sand only within the intertidal zone (approximately -0.5 m AHD to +1.1 m AHD). While a broader swath of nourishment would be beneficial for sand stability purposes, restricting placement of sand to this area will help to reduce potential impacts on the adjacent estuary channel, such as shallowing from infill and smothering of sea grasses or other benthic ecology.

Given the site is of estuarine environment and comprises a mixture of both naturally occurring and imported sediment, it is difficult to determine the optimum sand grain size for nourishment purposes. Nevertheless, the nourishment sand should be clean marine sand and preferably sourced from local coastal areas. Potential source options that could be considered during the detailed planning for the project would be either (or a combination of):

- Sand extracted from maintenance of the Shoalhaven estuary entrance dry notch
- Quarried sand from Cleary Bros' Gerroa Sand Resource (though it is understood that this may not currently be available for commercial sale)
- Local sand from the shoals within the lower Shoalhaven estuary (which may be constrained by seagrass beds and/or shorebird habitat and foraging areas)
- Sand scraped from the intertidal areas of the River Road foreshore compartment.

Sand sourced from nourishment of the estuary entrance dry notch is preferable to the other potential sources for a number of reasons including approvals pathways, compatibility and cost. Council will need to further consider the combination of sand sources during the detailed planning of the works, along with the required permits and stakeholder consultation for the nourishment activity. The specific permits will depend on the source(s) of nourishment sand supply. If dry notch maintenance sand is used, then the requirements are expected to be similar to those for the recent nourishment works that were completed during construction of the rock revetment, and would include as a minimum, further consultation with:

- DPI Fisheries
- TfNSW Maritime
- Crown Lands
- DPIE
- Local residents and community groups.

Figure 5.9 Proposed beach nourishment zones

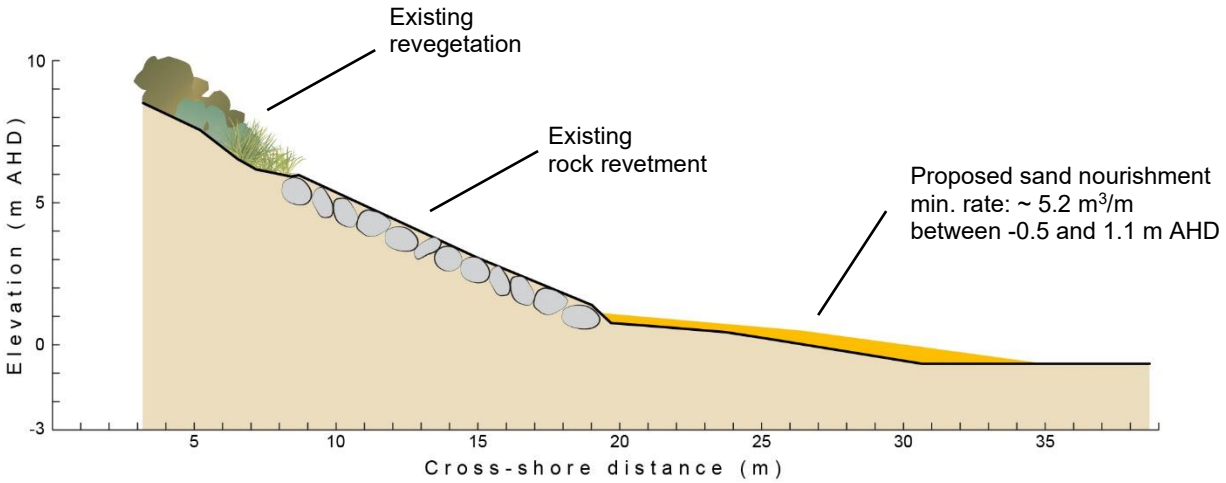

Figure 5.10 Nourishment design Zone A, Ch 600 to 680 m

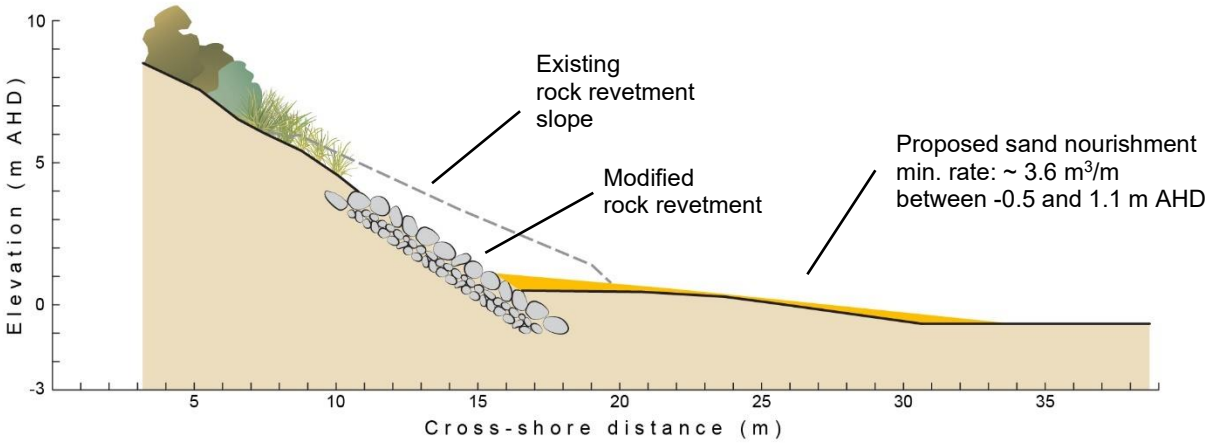

Figure 5.11 Nourishment design Zone B, Ch 680 to 720 m

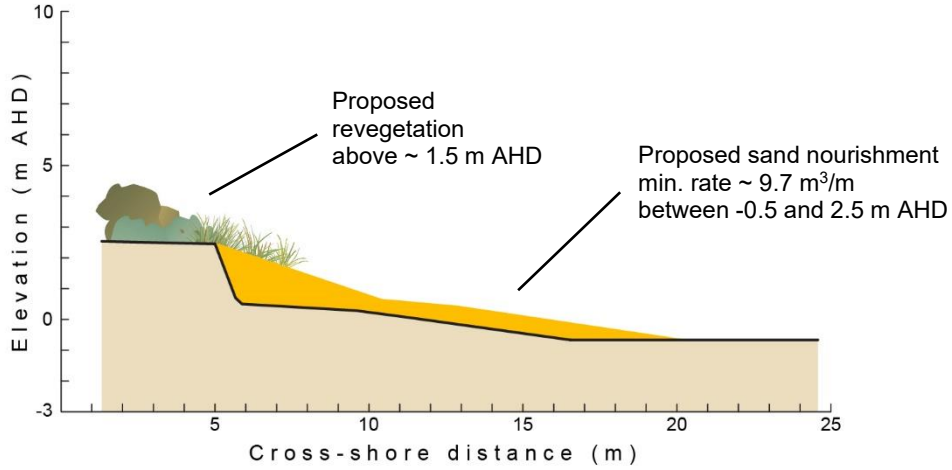

Figure 5.12 Nourishment design Zone C, Ch 720 to 800 m

5.4 Preliminary cost estimates for recommended works

Table 5.4 provides a preliminary cost estimate breakdown for different components of the recommended works.

Table 5.4 Preliminary cost estimates

Activity		Estimated costs (ex. GST)
Excavate toe sand, remove existing rock armouring, remove geotextile, reprofile bank alignment/slope and rebuild revetment for ~30 m of revetment length in front of 66-68 River Rd. Make good the surrounding area. Remove excess armour rock offsite[1]		$40,000 - $50,000[2]
Supply and place nourishment sand[3]	Dry Notch	Nearby Quarry
• Zone A (413 m^3)	$10,000-$13,000	$50,000-$65,000
• Zone B (144 m^3)	$4,000-$6,000	$15,000-$25,000
• Zone C (772 m^3)	$17,000-$25,000	$100,000-$120,000
Foreshore revegetation works (5 m wide swath along foreshore bank/crest)[4]		
• Ch 720 to 800 m (80 m of foreshore, ~400 m^2)		$10,000-$13,000
• Ch 800 to 950 m (150 m of foreshore, ~750 m^2)		$19,000-$24,000

Notes:

1. A nominal haulage value for removal of excess armour rock has been included in these cost estimates, however, the final removal cost will depend on the location of the final storage site relative to Shoalhaven Heads.
2. These costs have been determined on the basis of previous experience and standard construction estimation methods. It is recommended that Council verify the costs with an experienced contractor to accommodate local nuances and site specific constraints.
3. The cost of sand nourishment will depend greatly on the sand supply source, or combination of sources. The estimated costs provided here are indicative only on the basis of previous experience and standard construction estimation methods. It is recommended that Council verify the costs with local contractors and sand suppliers.
4. Cost estimates for revegetation works include an allowance for:

    - groundcover and small tube stock both planted at ~1/m^2 (i.e. 2 plants per m^2 total)
    - tree guards
    - jute matting and pins
    - mulch applied at ~0.1 m thickness.

    The cost estimates do not include an allowance for ongoing maintenance of revegetation works.

6 Conclusions

In June 2016, the estuary foreshore adjacent to River Road at Shoalhaven Heads was impacted by coastal erosion during a large storm event. Recommendations for managing the site were proposed by WRL, which included concept design for a rock revetment to provide immediate protection to the toe of the embankment between Renown Avenue and 66 River Road. A number of other short to medium term recommendations were also made which included improved beach access, nourishment of the beach, revegetation works, and improvements to the management of stormwater, so as to also maintain the amenity of the beach for recreational use. Detailed design of the management works was completed by Magryn, and installation of the rock revetment, beach access steps and sand nourishment was completed by contractors in the first half of 2021. Further minor erosion of areas to the east of the protected zone has occurred in recent months, with a small area of exacerbated erosion immediately adjacent to the eastern end of the revetment. Council engaged WRL to provide further recommendations to mitigate the impacts of this subsequent erosion, with the recommendations provided within this report.

A coastal engineering inspection of the foreshore was completed by WRL on 13/09/2021. The purpose of the inspection was primarily to:

- view the previously completed management works
- inspect the current condition of the foreshore immediately to the east of the works
- develop an understanding of the influence of the works on erosion of the adjacent unprotected foreshore areas.

It was apparent from the site inspection that the foreshore adjacent to the eastern end of the rock revetment has experienced some recent erosion. There were also signs of minor erosion at various locations between the end of the revetment and the boat ramp, with features such as minor scarping/undercutting of the toe of the bank at the back of the beach, and exposure of tree roots. To form an understanding of the rate of erosion and give consideration to the risk of future erosion, an analysis was completed to identify how this stretch of foreshore has changed in recent years. The analysis was completed firstly by comparing photos of the foreshore from 2016 with co-located photos from September 2021. Secondly, high-resolution aerial imagery was used to map the position of the toe and crest of the bank at the back of the beach for the period between 2011 and 2021. Finally, beach profile data from Council surveys was compared to further quantify beach changes. The results of this analysis concluded:

- the area immediately east of the revetment end (Ch 720 to 750 m) appears to have experienced some localised erosion
- north of Ch 750 m, the bank defining the back of the beach has not visibly retreated since 2016, with the 2016 erosion scarp still visible at most locations
- between Ch 750 m and Ch 810 m, the level of the beach immediately at the toe of the bank appears to have lowered/eroded slightly (of the order of 100 – 200 mm), evident as slight undercutting of the bank at some localised sections
- On the basis of detailed mapping, the position of the bank toe has eroded between 2011 and 2021, with the envelope of erosion decreasing from west to east
- Between Ch 720 m and Ch 860 m, there has been no discernible change in the position of the top of the bank at the back of the beach since the erosion events of 2016.

A number of different management approaches were considered by WRL, with varying levels of impact/benefit to the environment and amenity of the site, costs and implementation timeframes. After

consideration of the erosion rates and risks as well as the advantages and disadvantages of the various options, our recommendations can be summarised as:

- Ch 680 to 720 m: Modifications to the rock revetment to reduce its occupation space and minimise impacts on adjacent stretches of unprotected foreshore. These modifications include stripping of the armour and rebuilding the structure with a steeper slope and single layer of well-placed primary armour stones. Nourishment of the beach in front of the revetment to lift the beach level to at least 1.1 m AHD, so as to reduce the interaction of swash with the rocks and the resulting scouring effects currently being experienced.
- Ch 720 to 800 m: Nourishment of the intertidal section of beach to achieve a more suitable beach volume, including re-building of the back-beach erosion scarp to a more stable slope. Stabilisation and re-profiling of the bank surface and crest through revegetation and ground cover.
- Ch 800 to 950 m: Re-profiling of the erosion scarp, stabilisation and revegetation of the bank surface.
- The recommended modifications to the end section of rock revetment will produce an excess of armour stone. Council may consider re-using a portion of this armour stone to further improve the alignment of the revetment's eastern end and to repair the current "end-effect" erosion.

Concept designs and preliminary cost estimates for these recommendations have been provided.

It is strongly recommended that the revetment modifications, beach nourishment and revegetation works are conducted as an integrated management solution. The effectiveness of the management works to resolve current issues will likely be reduced if any aspect is completed in isolation (completing the revetment modifications only, for example).

7 References

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Nurmohamed, N, Steendam, GJ, & Van der Meer, JW (2007), Weight and stability assessment of single layers of orderly placed and of pitched natural rock, Coastal Engineering 2006, pp. 4815-4827.