SHOALHAVEN COASTAL EROSION REMEDIATION: THE HOLY GRAIL

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Introduction

Coastal erosion threatens significant public and private assets at Mollymook, Collingwood and Callala Beaches on the NSW South Coast, which are listed as “authorised locations” for emergency protective works under the *Coastal Protection Act 1979*.

Shoalhaven City Council has recently prepared its draft Coastal Zone Management Plan (CZMP) and draft Emergency Action Plan (EAP) for the Local Government Area (LGA). Strategies and actions identified in the draft CZMP for the “authorised locations” beaches mainly focus on relocation of public assets, building dune resilience, and beach scraping. For some existing development exposed to coastal hazard risks, Council and the local communities now face the challenge of deciding how to mitigate the risks in the short-term, and manage the coastal impacts as they occur across a city where 35 beach compartments are managed by Council. This is reflected in a range of “make-safe/make-good” provisions in the draft EAP that can be introduced in the event of storms.

In the last two years, Haskoning Australia (a company of Royal HaskoningDHV), has developed for Council prefeasibility schemes and conceptual designs for “end-state” protection of public and private assets at the three “authorised locations” beaches to determine the extent of mitigation costs (Royal HaskoningDHV, 2012, 2013a and 2013b). Measures considered included revetments, beach nourishment and nearshore breakwaters of suitable scale to deliver comprehensive protection to threatened assets. These schemes were costed in the tens of millions of dollars for each beach, and would face a number of other constraints to implement.

Clearly, if asset protection is to be achieved, a more practical approach is required. This must offer affordable and feasible coastal protection that adequately mitigates some or all of the erosion risk.

In light of this, Council is currently preparing an Adaptive Works Strategy for all of its exposed beaches, but which focusses on a number of high risk beaches in making the transition from “make-safe/make-good” to “end-state” (Royal HaskoningDHV, 2014). Options being considered for the “authorised locations” beaches include construction of a buried toe as an initial stage for possible future revetment construction, and sand backpassing from local creek entrances.

Assets at Risk

The *Shoalhaven Public Asset Coastal Risk Management Review* (BMT WBM, 2012) was undertaken to prioritise public assets and infrastructure at threat from coastal hazards in the Shoalhaven LGA for the 2050 or 2100 planning periods. Several public assets at Mollymook Beach were identified as having 'Extreme' or 'High' risk ratings, most notably Mollymook Surf Club, sewage pump stations and the Golf Club. At Collingwood Beach, 'Extreme' or 'High' risk ratings were applied to a sewage pump station, wastewater infrastructure along Elizabeth Drive, the Illfracombe Avenue roadway and adjacent water infrastructure, and the public cycleway. At Callala Beach, 'High' risk ratings were identified for the Tennis Club (Callala Beach Community Centre), the Greenway Road roadway and adjacent water infrastructure.

Of all beaches in the Shoalhaven LGA, Mollymook Beach has the highest value of assets at risk (Table 1), heavily weighted by the Golf Club ($10 million) and Surf Club ($3 million). Wastewater assets are also significant, with sewage pump stations valued at $1 million each. Furthermore, it is noted that damage or destruction of these assets would disrupt essential community services and create health risks.

Table 1: Values of public assets at risk at subject beaches (BMT WBM, 2012)

Beach	Planning Period	Wastewater	Water	Buildings / Infrastructure	Roads	TOTAL
Mollymook	2050	$2.7 million	$80,000	$13 million	$300,000	**$16 million**
	2100	$3.1 million	$170,000	$13.6 million	$485,000	**$17.5 million**
Collingwood	2050	$1.8 million	$40,000	--	$340,000	**$2.2 million**
	2100	$1.8 million	$100,000	--	$390,000	**$2.3 million**
Callala	2050	--	--	$170,000	$60,000	**$230,000**
	2100	--	$170,000	$665,000	$245,000	**$1.1 million**

Coastline hazard lines for the Shoalhaven LGA were defined for the immediate, 2025, 2050 and 2100 planning periods. The location of these lines was at the landward edge of the Zone of Reduced Foundation Capacity (ZRFC), which takes account of the reduced bearing capacity of the sand adjacent to the storm erosion escarpment.

Hazard mapping illustrating the immediate, 2025, 2050 and 2100 landward limits of the ZRFC is shown in Figure 1 (Mollymook Beach), Figure 2 (Collingwood Beach) and Figure 3 (Callala Beach). Private assets at risk can be summarised as follows:

- At Mollymook Beach, 15 residential properties are located in the immediate coastal erosion risk area, while 46 residences are projected to be at risk in 2050, with 55 residences at risk by 2100. In addition, some 30 properties (highlighted in yellow) are at risk due to coastal inundation.
- At Collingwood Beach, 17 residential properties are located in the immediate coastal erosion risk area, while more than 100 properties are projected to be at risk in 2050.
- At Callala Beach, 12 residential properties are located in the immediate coastal erosion risk area, while more than 80 residences are projected to be at risk in 2050.

Figure 1: Coastal hazard zones for Mollymook Beach (Umwelt, 2012)

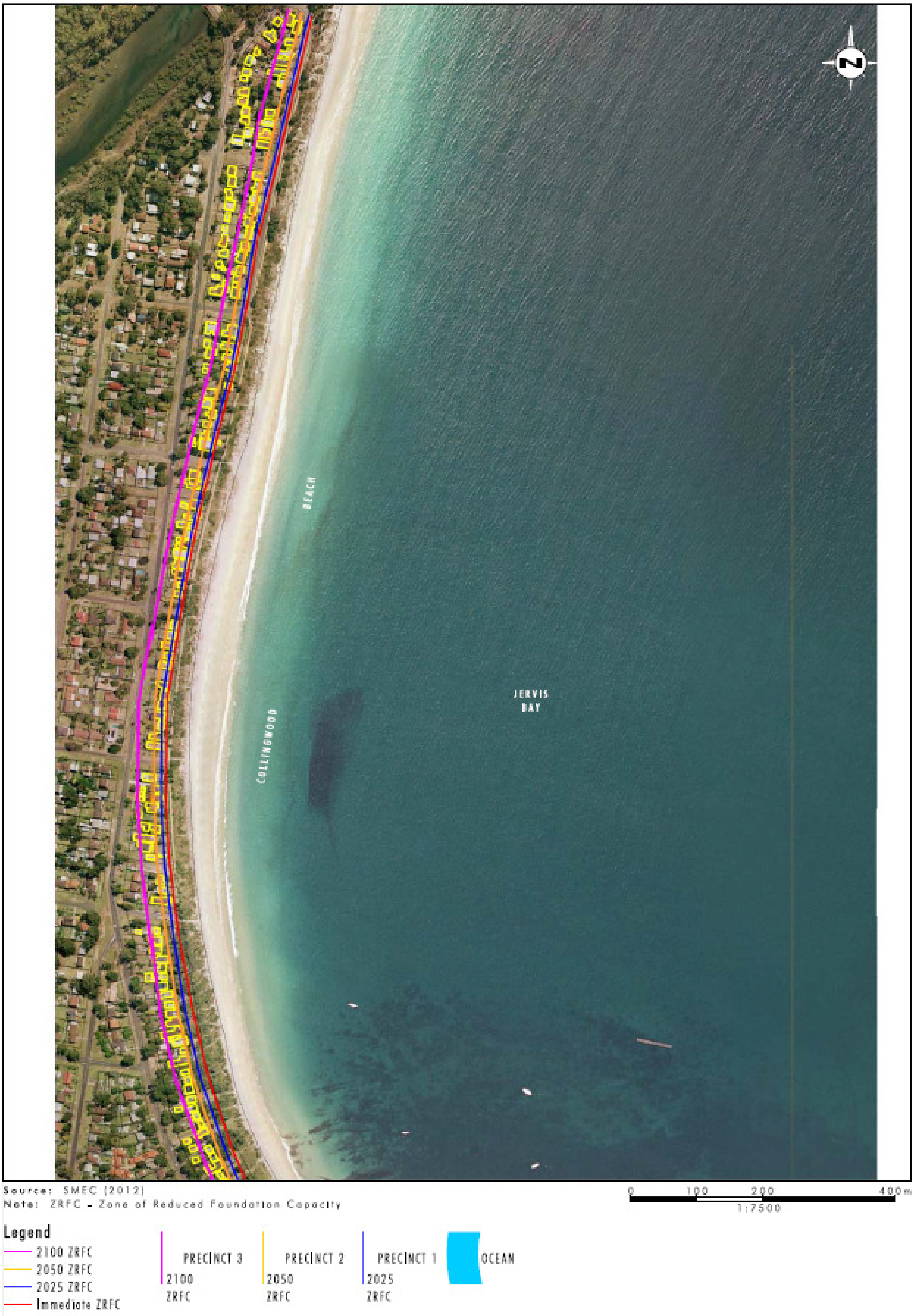

Figure 2: Coastal hazard zones for Collingwood Beach (Umwelt, 2012)

Figure 3: Coastal hazard zones for Callala Beach (Source: SMEC reported in Umwelt, 2012)

Existing Management Provisions

Draft CZMP

The management strategies and actions identified for the subject beaches in the draft CZMP include (Umwelt, 2012):

- building dune resilience by maintaining minimum dune crest levels of 5.5 m AHD (Mollymook Beach), 5.0 m AHD (Collingwood Beach), and 6.0 m AHD (Callala Beach) and vegetation management;
- beach scraping, particularly after storms;
- dune planting and rationalisation of private (and mostly illegal) beach access tracks at Mollymook Beach;
- reducing the number of pedestrian tracks on the frontal dune at Callala Beach to reduce pressures on the vegetation and encourage a resilient landform;
- auditing site constraints and structure foundation capacities (e.g. Mollymook Surf Club and sewage pump stations);
- review the design of the revetment that provides protection to Mollymook Golf Club;
- medium-term relocation of sewage infrastructure along the beachfront reserve between Argyle Street and Berry Street (Collingwood Beach);
- coastal condition and morphological monitoring; and,
- delivery of information to the community.

The actions and strategies in the draft CZMP could not be expected to fully mitigate the threat to public and private assets at the subject beaches, in particular that from design storm erosion.

Emergency Action Plan

Council has in place a number of emergency "make-safe/make-good" provisions, which are mainly enunciated in the draft EAP (Umwelt, 2011). In accordance with these Plans, Council will take the following generic actions during and after a coastal emergency event:

- temporarily close public accessways damaged by storm waves;
- monitor seawalls;
- implement beach scraping if necessary.

Preparatory nourishment to raise dune crest levels is also a proposed emergency action for Collingwood and Callala Beaches. Installation of sand-filled geotextile bags is also recommended at the toe of constructed accessways at Callala Beach, and to form a "tripper wall" at Blackwater Creek (Mollymook Beach). However, it must be recognised that it may not be feasible to implement these actions quickly before a storm hits.

“End-State” Solutions for Coastal Protection

Mollymook Beach

For the Mollymook Beach investigation (Royal HaskoningDHV, 2012), the beach was divided into five precincts (A, B, C, D and E) to identify protective works options, see Figure 4.

Seawall Protection

The existing 160 m seawall fronting the Golf Club and adjacent sewage pump station comprises a gabion revetment but is of insufficient capacity to provide 50 year protection due to a low and unacceptable Factor of Safety (FOS) against downslope failure, and because the fabric of the mattress could not be guaranteed for a further 50 years (Maunsell, 2008). The structure could be enhanced to meet the 50 year criterion by using it as an underlayer for a more robust cover protection. A total modified revetment cost in the order of $2.3 million ($14,500/m) is estimated.

Little is known about the design and construction of the three other seawalls in Precinct A, which extend approximately 175 m in length. Disregarding these existing structures and allowing for the construction of new upgraded walls throughout could be expected to cost an additional $2.6 million ($14,900/m) in Precinct A. This includes a 50 m stepped seawall section in the vicinity of the Surf Club to improve beach access and amenity in this high usage area.

The seawall upgrade works in Precinct A must be attended to immediately if the immediate threat to the infrastructure in the area is to be addressed.

The revetment concept design for Precinct B, shown in Figure 5, comprises a conventional basalt rock revetment with a minimum of two layers of armour rock over two layers of underlayer rock. The structure toe would be set at -2 m AHD, and a crest level of 6.2 m AHD has been adopted. A total cost in the order of $8.0 million ($23,000/m) is estimated to provide seawall protection along the entire 350 m length of Precinct B.

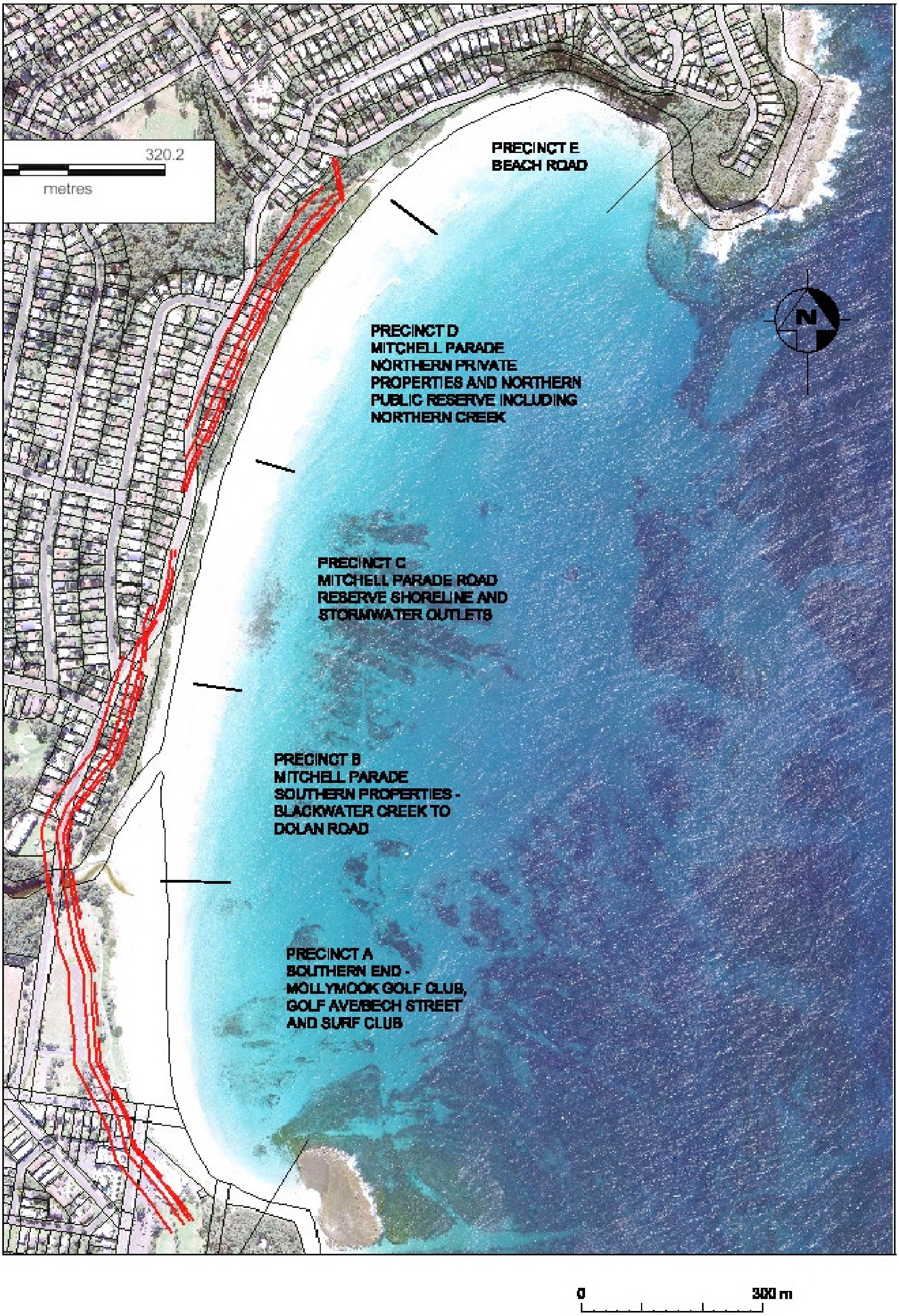

Figure 4: Mollymook Beach precincts (Royal HaskoningDHV, 2012)

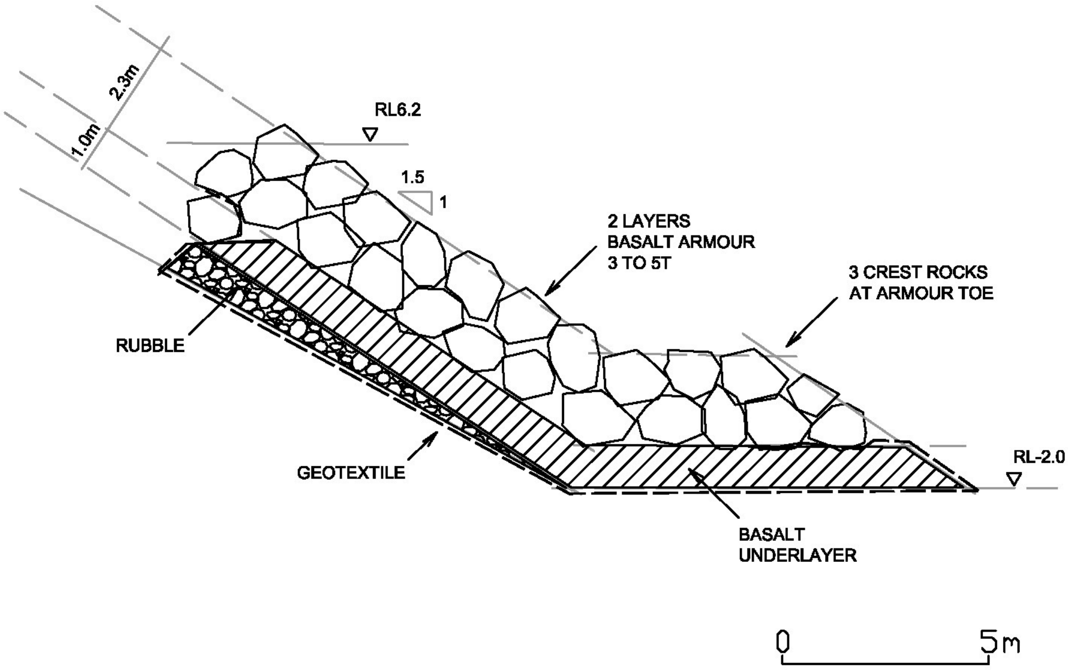

Figure 5: Concept section for proposed revetment section for Precinct B, Mollymook Beach (Royal HaskoningDHV, 2012)

At the present time, the five southern-most properties in Precinct B are at immediate risk from coastal hazards. Creek training and dune enhancement works proposed in Royal HaskoningDHV (2012) would effectively translate the coastline hazard lines in the southern portion of the precinct such that the degree of risk to all 14 of the private properties in Precinct B is equalised. Assuming that these works are undertaken immediately, construction of the Precinct B revetment could be delayed until a time when the slumped erosion escarpment from a future storm encroaches to within say 20 m of the seaward wall of any dwelling within the precinct. Based on predicted recession rates (SMEC, 2009), it is expected that this situation is unlikely to occur before 2025.

Precinct C includes two stormwater outlets, a road and concrete footpath, and a sewer pump station, all designated to be at immediate risk from coastal hazards (Umwelt, 2012). A terminal revetment constructed along the entire 370 m length of Precinct C would be required immediately to protect these assets. The Precinct B revetment concept design (Figure 5), including wall end returns to minimise the impact of flanking erosion, could be implemented in Precinct C at a total estimated cost of $8.4 million ($22,800/m).

The private properties in Precinct D could be protected by a revetment extending along the 330 m length of shoreline fronting the properties, plus wall end returns to minimise the impact of flanking erosion. Construction of the Precinct D revetment could be delayed until a time when the slumped erosion escarpment from a future storm encroaches to within say 20 m of the seaward wall of any dwelling within the precinct. Based on predicted recession rates (SMEC, 2009), it is expected that this situation is unlikely to occur before 2025. The Precinct B revetment concept design (Figure 5), modified to include a slightly higher crest level ranging between approximately 7.0 m AHD and 7.5 m AHD (south to north), could be implemented in Precinct D at a total estimated cost of $8.9 million ($26,900/m).

Beach Nourishment

If stand-alone beach nourishment was adopted as the sole erosion remediation strategy for Mollymook Beach, a total sand volume of around 750,000 m^3 would be required initially at an estimated cost of around $22 million. In order to meet this significant volume requirement, dredging from offshore sand deposits would be required. However, at the present time, offshore mineral extraction along the NSW coastline is prohibited under the *Offshore Minerals Act 1999*.

Ongoing beach nourishment would also be required to account for any future sand losses associated with beach recession due to sea level rise. Based on predicted recession rates (SMEC, 2009), ongoing nourishment requirements at Mollymook Beach are estimated at 22,000 m^3/year, at an estimated cost of $33 million over 50 years. It may be possible to source these volumes through regular dredging campaigns at the major entrances in the Shoalhaven LGA, in particular Lake Conjola. However, this would limit opportunities to beneficially re-use dredged material at other locations in the LGA.

Nearshore Breakwater

It may be possible to provide a nearshore breakwater to protect the shoreline at Precinct C. A single 200 m long nearshore breakwater constructed from homogeneous basalt rocks say 6 m wide at a crest of 2 m AHD with slopes of 1:1.5 would not be expected to exceed a placement of 10,000 tonnes. Assuming the breakwater was built via a temporary causeway from the shore, it should be feasible to construct the breakwater to protect Precinct C for approximately $1.5 million. However, there remains excessive uncertainty surrounding the functional and structural feasibility of this option. Geotechnical investigations would be required to confirm the extent of bedrock and settlement behaviour, and design development to prove up armour size and materials, and construction method.

Collingwood Beach

For the Collingwood Beach investigation (Royal HaskoningDHV, 2013b), the beach was divided into five precincts (A, B, C, D and E) to identify protective works options, see Figure 6.

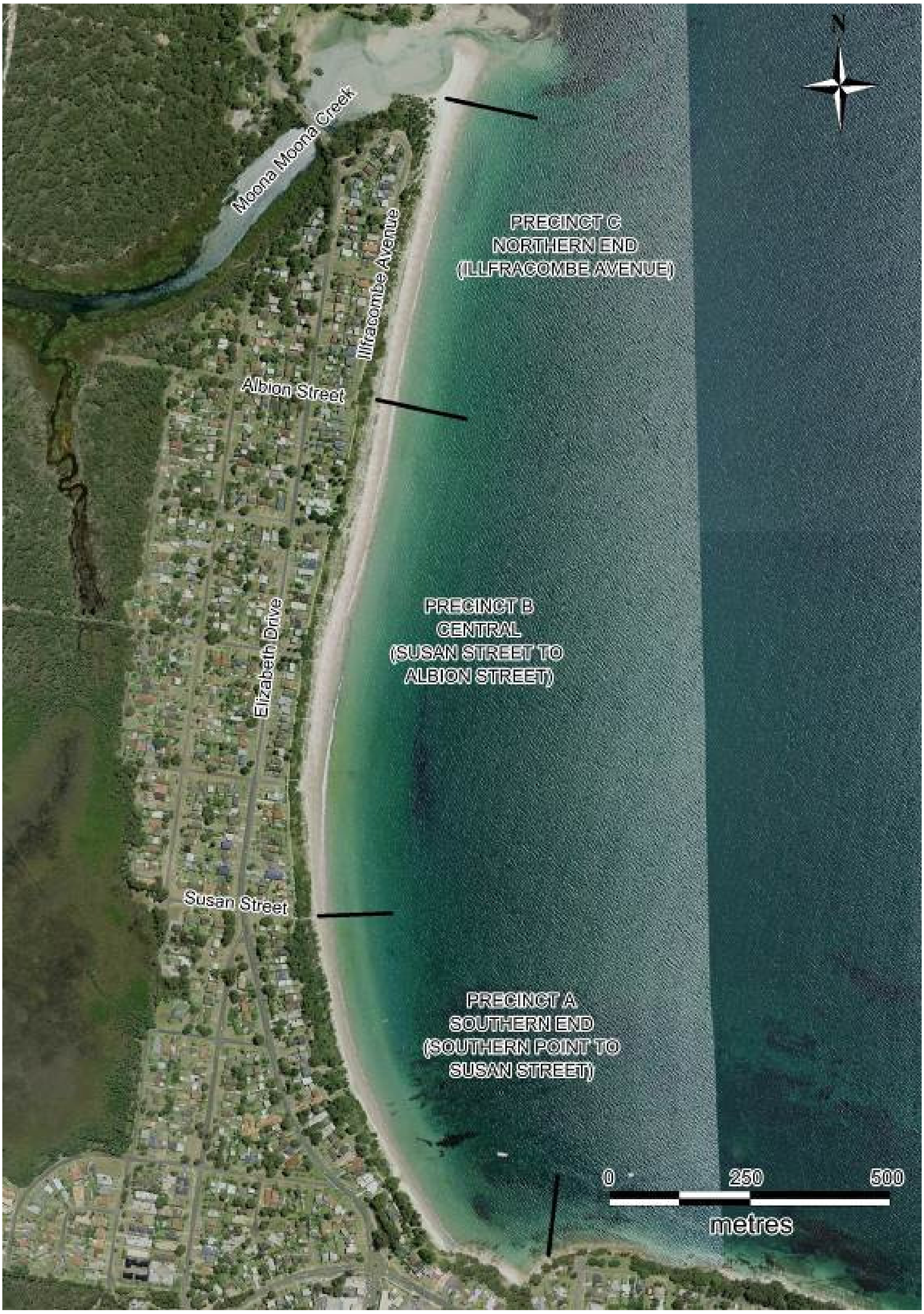

Figure 6: Collingwood Beach precincts (Royal HaskoningDHV, 2013b)

Seawall Protection

The public cycleway and sewage infrastructure in Precinct A are at immediate risk from coastal hazards (Umwelt, 2012). While immediate protection could be afforded to the sewage infrastructure through construction of a seawall along Precinct A, a more cost effective approach would be to relocate this infrastructure, estimated to cost around $1 million. Options to relocate the public cycleway are limited, and the cost-benefit of protecting this asset with a revetment is not favourable. As such, it has been assumed that this asset would not be protected and may therefore be lost or significantly damaged during a design storm event.

Based on predicted recession rates (SMEC, 2009), it is expected that private properties in Precinct A would become threatened by coastal hazards in around 2050. A terminal revetment constructed along the entire 800 m length of Precinct A would protect these properties from such a time. The concept design comprises a conventional basalt rock revetment with a minimum of two layers of armour rock over two layers of underlayer rock. The structure toe would be set at -1.5 m AHD, and a crest level of 4.5 m AHD was adopted. A total cost in the order of $8.2 million ($10,200/m, or $145,000 per beachfront property) is estimated to provide seawall protection in Precinct A.

Several assets in Precinct B are at immediate risk due to coastal hazards, including the public cycleway, gravity and rising mains, road heads, and 17 private properties. The Precinct A revetment concept design, modified to comprise a slightly lower crest level of 4.0 m AHD, could be implemented along the full 900 m length of Precinct B at a total estimated cost of $8.4 million ($9,300/m, or $165,000 per beachfront property).

In Precinct C, the public cycleway and Illfracombe Avenue roadway are at immediate risk due to coastal hazards, while it is expected that private properties would become threatened by coastal hazards in around 2025. There is no opportunity to close the road here to curtail through traffic and remove the risk to infrastructure as it directly services the 23 private properties located immediately landward. As such, the revetment construction would be required immediately to mitigate the risk. The Precinct B revetment concept design could be implemented along the entire 500 m length of Precinct C at a total estimated cost of $4.8 million ($9,600/m).

Beach Nourishment

If stand-alone beach nourishment was adopted as the sole erosion remediation strategy for Collingwood Beach, a total sand volume of around 250,000 m^3 would be required initially at an estimated cost of around $7.5 million. In order to meet this significant volume requirement, dredging from offshore sand deposits would be required (which is currently prohibited under NSW legislation).

Based on predicted recession rates (SMEC, 2009), ongoing nourishment requirements at Collingwood Beach are estimated at 11,000 m^3/year, at an estimated cost of $16.5 million over 50 years. These volumes could be partially met through regular dredging campaigns at Currambene Creek, supplemented with additional material sourced from major entrances such as Lake Conjola.

Nearshore Breakwaters

For the 1.4 km length of beach that requires immediate protection (Precincts B and C), it is envisaged that five 200 m long breakwaters should be suitable. An additional two breakwaters would be required to protect the shoreline in Precinct A from 2050.

A 200 m long nearshore breakwater constructed 300 m from the shore (to encourage salient response) would be founded at a bed level of around -5.0 m AHD. Adopting a crest width of 4.6 m (three rock diameters) and a crest level of RL 0 (submerged structure at high tide) with side slopes of 1:1.5 would require a placement of some 32,000 tonnes of rock per breakwater. The total cost to construct five offshore breakwaters to protect Precincts B and C is estimated at $40 million, plus a further $16 million to protect Precinct A from 2050. Cost savings could apply if concrete armour units (e.g. Hanbars) were used in place of rock armour.

There is a reduced performance certainty for nearshore breakwaters, with preference typically given to the development of lower impact onshore structures such as seawalls. Given the Marine Park status of the site, an overarching requirement is to minimise environmental impact which may not be achieved with breakwaters.

Callala Beach

For the Callala Beach investigation (Royal HaskoningDHV, 2013a), the beach was divided into two precincts (A and B) to identify protective works options, see Figure 7.

Seawall Protection

A terminal revetment constructed along the entire 1.4 km length of Precinct A would protect development, including the 12 residential properties at immediate risk. The concept design comprises a conventional basalt rock revetment with a minimum of two layers of armour rock over two layers of underlayer rock. The structure toe would be set at -1.5 m AHD, and a crest level of 6.0 m AHD was adopted. A total cost in the order of $27.4 million ($19,500/m, or $350,000 per beachfront property) is estimated to provide seawall protection in Precinct A.

In Precinct B, the Greenway Road roadway is predicted to be at risk due to coastal hazards by 2025, and revetment construction could be delayed until this time. The Precinct A revetment concept design could be implemented along the entire 600 m length of Precinct B at a total estimated cost of $4.8 million ($20,800/m).

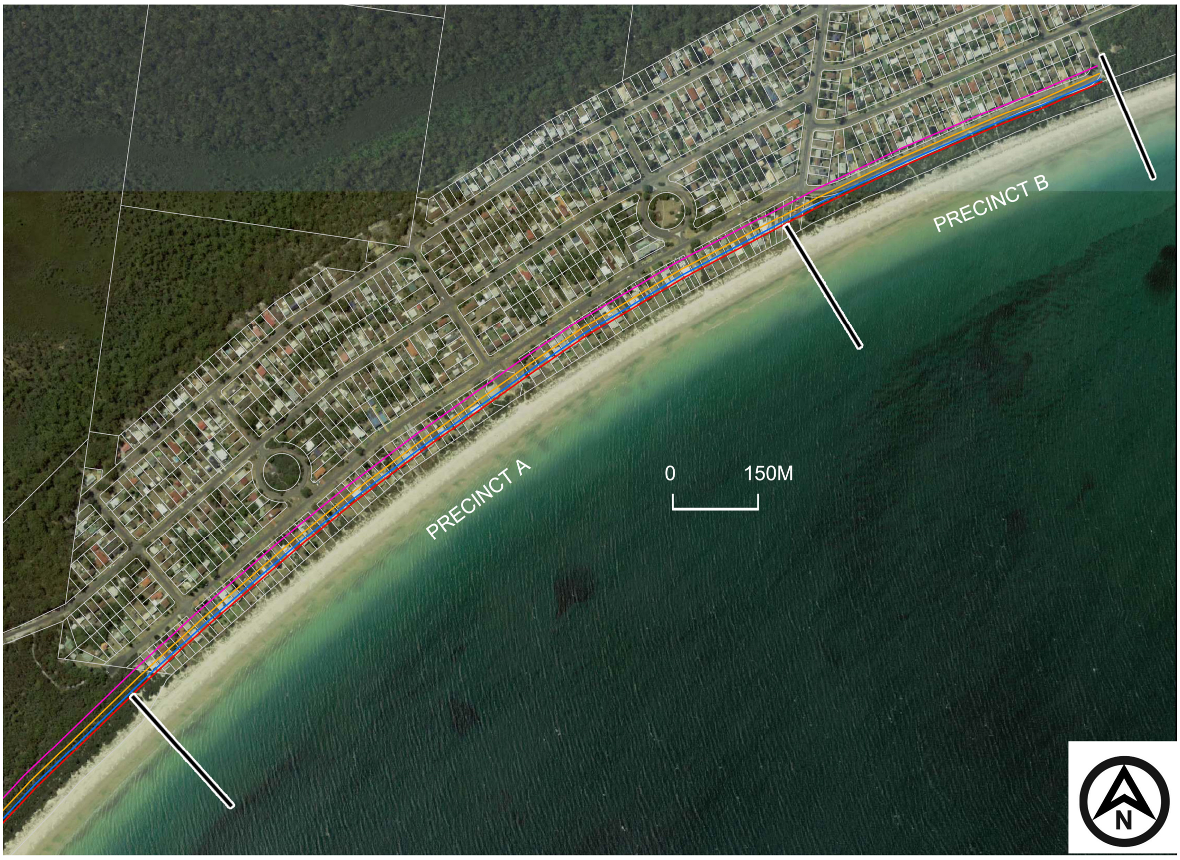

Figure 7: Callala Beach precincts (Royal HaskoningDHV, 2013a)

Beach Nourishment

If stand-alone beach nourishment was adopted as the sole erosion remediation strategy for Callala Beach, a total sand volume of around 720,000 m^3 would be required initially at an estimated cost of around $21.6 million. In order to meet this significant volume requirement, dredging from offshore sand deposits would be required (which is currently prohibited under NSW legislation).

Based on predicted recession rates (SMEC, 2009), ongoing nourishment requirements at Callala Beach are estimated at 14,000 m^3/year, at an estimated cost of $21 million over 50 years. As per Collingwood Beach, these volumes could be partially met through regular dredging campaigns at Currembene Creek, supplemented with additional material sourced from major entrances such as Lake Conjola.

Nearshore Breakwaters

Given that the length of beach that requires protection is approximately 2 km, it is envisaged that six 200 m long breakwaters, each separated by a distance of around 100 m, should be appropriate for Callala Beach. The nearshore breakwater concept design outlined previously for Collingwood Beach could be applied, although a slightly larger rock size would be required due to a higher design nearshore significant wave height at Callala Beach. The total cost to construct the six offshore breakwaters would be in the order of $50 to $60 million.

However, given the reduced performance certainty for nearshore breakwaters and Marine Park status of the site, it is highly unlikely that this scheme would be feasible.

Adaptive Works Strategy

Preamble

Based on the information presented above, it is evident that the investigated "end-state" solutions for coastal protection could not be feasibly implemented for the subject beaches. Each scheme would be very expensive, running into the tens of millions of dollars for each beach. Other technical limitations are attached to each option which would also make implementation difficult, including:

- coastal revetments can have adverse impacts on a beach, including localised erosion and reduced beach widths associated with increased wave reflections, and possible flanking erosion at the ends of the structures;
- beach nourishment on the scale described herein would require access to offshore sand sources which is currently prohibited by NSW legislation, and even if these sources were available, major dredging campaigns would be necessary to source the required volumes; and
- nearshore breakwater schemes require a known and sufficient supply of sand to develop the salients that provide the required level of protection, which is yet to be established at Mollymook, Collingwood and Callala Beaches.

Clearly, if asset protection is to be achieved, a more practical approach is required, which offers affordable and feasible coastal protection options that adequately mitigate some or all of the erosion risk.

In light of this, Council is currently preparing an Adaptive Works Strategy for all of its exposed beaches, including the three beaches considered herein, in making the transition from "make-safe/make-good" to "end-state" (Royal HaskoningDHV, 2014). Adaptive management is a structured, iterative process of robust decision making in the face of uncertainty. Because of the long timeframes over which any coastal management strategies are implemented, management objectives may change over time and new measures may be required to match changed conditions. New information may also become available over time, e.g. improved estimates of sea level rise and associated beach responses.

Adaptive management typically includes provisions for ongoing monitoring, and outlines triggers for the commencement of detailed feasibility and design studies, e.g. when the erosion escarpment moves to within a certain distance of important infrastructure. Staging of works is another adaptive response, however staging may not necessarily be cost effective due to typically high mobilisation costs for infrastructure projects.

A number of possible strategies for transitional works between "make-safe/make-good" and "end-state" structures are discussed below for the subject beaches.

Transitional Arrangements for Protective Works

The recommended revetment sections developed for protection at Mollymook, Callala and Collingwood Beaches comprise a sloped rock structure with a rock toe. It may be feasible to construct a modified revetment section as a part-construction to an "end-state" solution such that it alleviates the erosion threat to assets, either as a complete project in its own right, or as the staged construction of the full revetment section. This scheme is depicted in Figure 8.

Using procedures for wave attenuation over submerged rock structures set out in the Coastal Engineering Manual (USACE, 2002), it is found that the transmission coefficient over the toe mound of an end-state revetment section for a design 100 year wave and water level condition is around 50%. Since wave energy is proportional to the square of the wave height, and assuming that storm erosion is directly proportional to wave energy, it follows that the design erosion demand in the lee of the transitional rock placement should reduce by approximately 75%. This could be investigated further through physical model testing.

Thus choosing to construct only the toe of a full rock revetment would not remove the erosion risk completely, but it should significantly mitigate that risk and permit a seaward relocation of the coastline hazard lines. In addition, if the toe mound alone was to be constructed, the structure would occupy a narrower footprint on the beach and could be sited further landward than a full height revetment, thereby reducing potential erosive impacts of the structure on the beach. In comparison to full height revetments, cost savings in the order of 30% are estimated.

However, with the rear wall missing in the partial construction, additional forces may develop at the back of the toe due to severe wave overtopping and this may require the inclusion of additional rocks which do not form part of the full design section. The long term shoreline response of a toe mound rock placement at the back of the beach should also be considered.

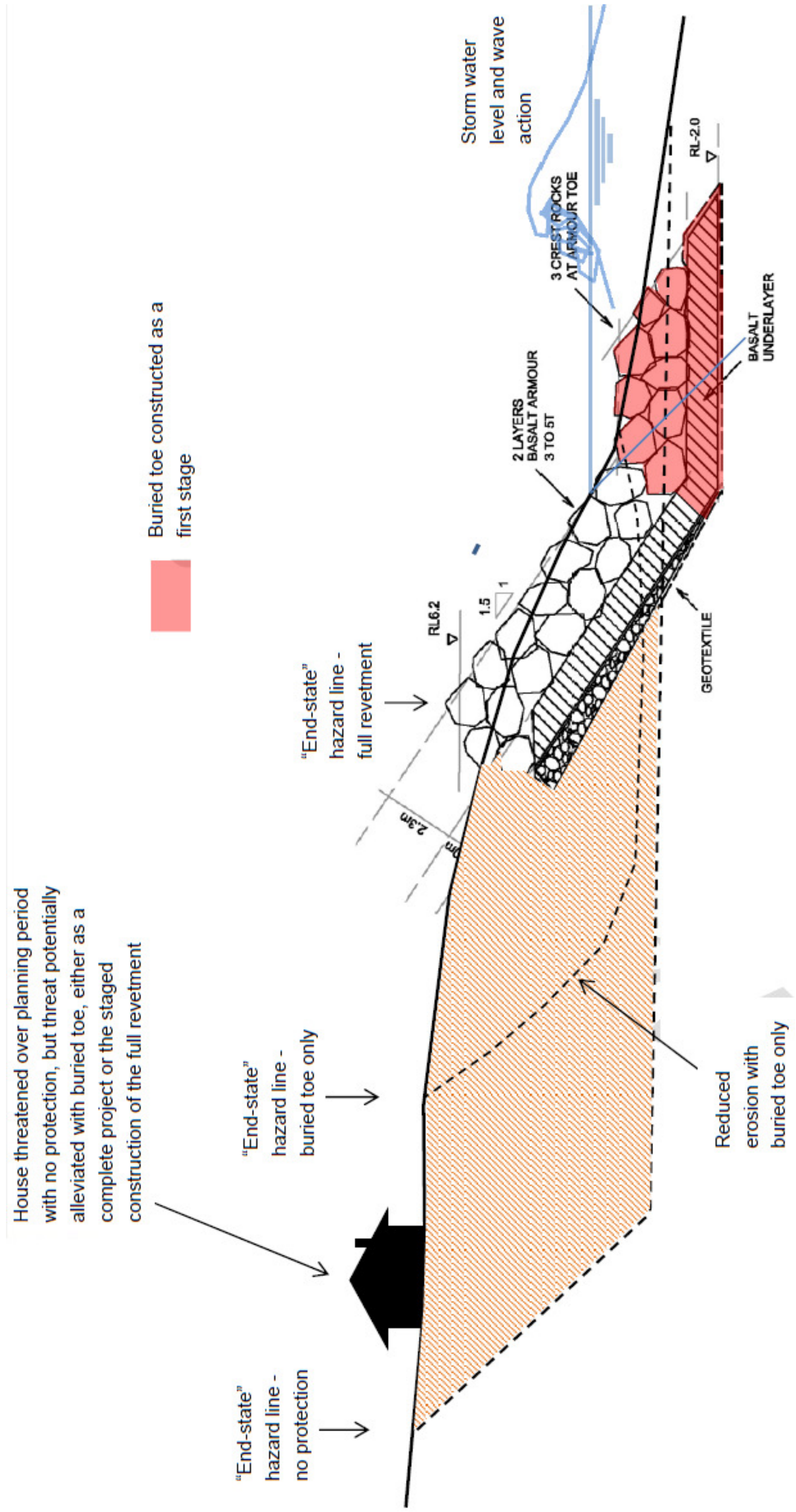

Figure 8: Partial or staged construction of rock revetment to potentially alleviate coastal risk. Revetment profile shown developed for Mollymook Beach in Royal HaskoningDHV (2012). Scheme subject to further investigation

Another staged revetment philosophy was implemented by Wyong Shire Council in 2012 at Cabbage Tree Bay on the NSW Central Coast. Designed by WorleyParsons, the single armour layer structure provides an interim solution to protect the bluff associated with a 15 year design life (Figure 9). The 15 year life was selected by Council to postpone a higher capital investment associated with the 50 year full life design. Ongoing monitoring could be undertaken in the interim to inform any future design upgrades, particularly with regard to sea level rise. The structure was installed for approximately $10,000/m (Lex Nielsen, WorleyParsons, presentation to NSW Coastal Ocean and Ports Engineering Panel, September 2012).

Figure 9: Completed Interim Structure at Cabbage Tree Bay, Norah Head, Wyong (Photo 2012 courtesy WorleyParsons)

Transitional Arrangements involving Sustainable Recycling of Beach Sand

Beach sand recycling involves the intermittent relocation of sand from a destination source to an eroding beach. Recycling of beach sand is carried out periodically in NSW at Collaroy-Narrabeen Beach in Sydney and at Jimmys Beach in Port Stephens. A permanent sand beach renourishment scheme also exists at Noosa Heads Beach in Queensland.

For this to be potentially feasible in the Shoalhaven, there is strong preference for the sand to be sourced from a downdrift subaerial beach or a downdrift entrance to a coastal creek. Attempting to dredge sand from the seabed (including that of Jervis Bay) would be fraught with technical and approvals difficulties and is not countenanced here as a possible recycling scheme.

Beach sand recycling in the Shoalhaven would therefore need to be considered as a transitional arrangement for erosion mitigation and not a full "end-state" arrangement in that the sand quantities that could be delivered would not meet the volumes required for comprehensive protection. However, it would account for a component of any ongoing sand loss from the beach, thereby permitting some seaward translation of the coastline hazard lines whilst the recycling scheme is operational. Like all erosion mitigation measures, backpass sand recycling could be implemented together with a partial revetment to provide a higher level of certainty by adding redundancy to the erosion protection system.

Moona Moona Creek at the northern end of Collingwood Beach exhibits an entrance area filled with a reasonable quantity of sand. It would be technically feasible to recycle a proportion of this material onto Collingwood Beach through a beach sand recycling scheme, which is depicted in Figure 10.

Further investigations would be required to assess the feasibility of beach sand recycling at Collingwood Beach. In baseline terms, this would depend on the assumed predominance of a south-to-north longshore sediment transport regime on the beach, and the quantity of sand that could be sustainably removed from the entrance to the creek. Although much of this sand may eventually return to the creek entrance, progressive backpass placements must effectively occur before a return cycle is completed in order to permit sustained sand residence on the beach and thus some material protection from erosion. The importance of Moona Moona Creek as a relatively undisturbed ecological asset in Jervis Bay must also be considered. Clearly, further coastal hydrodynamic, sedimentological and ecological investigations would be necessary to test the value and sustainability of any sand recycling scheme for Collingwood Beach.

The entrance shoals of Currambene Creek are a potential source of clean marine sand, with available volumes estimated in the order of 7,000 m^3 to 8,000 m^3 every 10 years (Peter Spurway and Associates, 2013). Regular dredging of this material would have the added benefit of improving navigation and boating safety in this area. While sand could feasibly be transported (probably by pumping) the 2.5 km distance from Currambene Creek to Collingwood Beach, it is not likely that Currambene Creek would be a sustainable source for Collingwood Beach with these two sites less likely to share a coastal littoral compartment within Jervis Bay compared to Currambene Creek and Callala Beach.

As an adjunct to a transitional revetment scheme, it would be possible to re-use dredged material from the entrance of Currambene Creek to build up the foredune at Callala Beach in accordance with the draft CZMP, to assist with protection against medium term coastal risk. The sustainability of any such sand placement would be influenced by the ultimate destination of the sand, after it has been eroded from Callala Beach in later years. There is no information at this time on the littoral interconnection between Currambene Creek and Callala Beach for which further investigation would be required. This could be expected to include sediment sampling and numerical modelling, preferably calibrated and verified against field data.

As noted previously, creek training and dune enhancement works proposed for Mollymook Beach would remove the immediate risk to the southern properties of Mitchell Parade (Precinct B). This scheme includes a sand placement of some 5,100 m^3, which could possibly be sourced from Council's lake entrance clearing activities (4,000 m^3 to 8,000 m^3 available over a two year period), or alternatively from a dedicated dredging of the entrance shoals in Lake Conjola. It is understood that dredging works at estuary entrances will be proceeding in the Shoalhaven in the next few years including at the entrance to Currambene Creek and Lake Conjola.

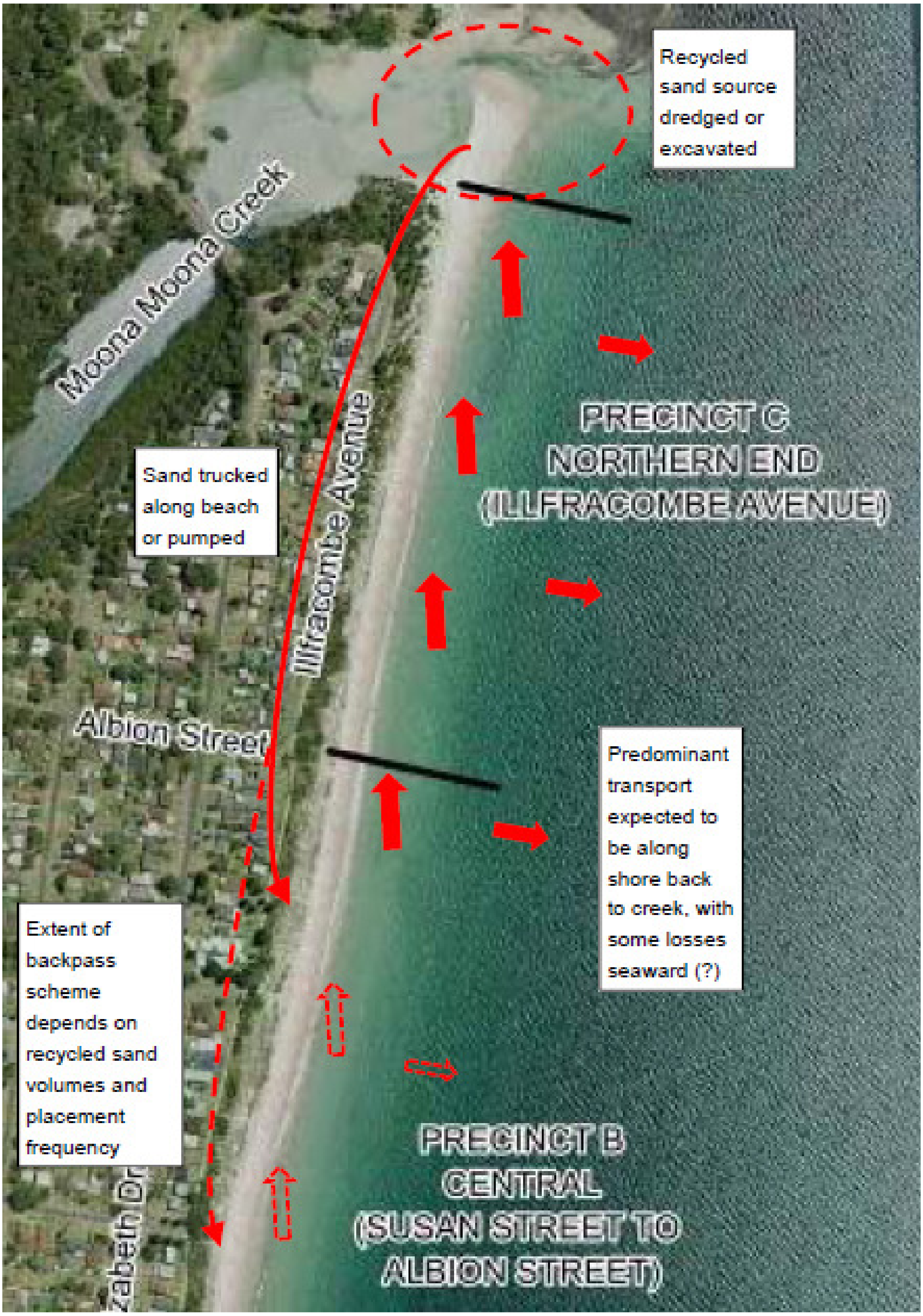

Figure 10: Schematic showing possible beach sand recycling scheme at Collingwood Beach (Royal HaskoningDHV, 2014)

Conclusions

Coastal erosion threatens significant public and private assets at Mollymook, Collingwood and Callala Beaches. Existing management provisions for these beaches are based on sound coastal management principles and should be implemented where feasible, however these projects could not be expected to fully mitigate the erosion hazard at these locations.

So-called "end-state" solutions, including revetments, stand-alone beach nourishment programs, and potentially nearshore breakwaters, would deliver comprehensive protection to threatened assets. However, these schemes are prohibitively expensive and would face a number of other constraints for implementation. It should also be noted that these schemes are typically designed for relatively long timeframes, e.g. 50 years, which may exceed the frequency at which new information on coastal processes becomes available.

It is evident that there is no single solution to provide the desired level of protection at the subject beaches. A more practical approach may involve adaptive management schemes which enable transition between the existing management provisions and end-state solutions. For example, the construction of toe mound structures rather than full scale revetments may not entirely remove the erosion hazard but may sufficiently mitigate risks, at least in the short to medium term. Beneficial re-use of sand obtained from local sources may also mitigate erosion risks. Given the substantial potential life cycle costs savings available, further detailed investigations are warranted to explore these adaptive works ideas including detailed desktop literature review, cost-benefit assessment and physical modelling.

References

BMT WBM (2012), *Shoalhaven Public Asset Coastal Risk Management Review*, July 2012, for Shoalhaven City Council

Maunsell (2008), *Mollymook Golf Club Coastal Hazard Assessment*, 11 February 2008, for Paynter Dixon

Peter Spurway and Associates (2014), *Shoalhaven Citywide Dredging Feasibility Study*, March 2014, for Shoalhaven City Council

Snowy Mountains Engineering Corporation [SMEC] (2009), *Shoalhaven Coastal Hazard Study – Summary Report*, July 2009, for Shoalhaven City Council

Royal HaskoningDHV (2012), *Shoalhaven 'Authorised Locations' Coastal Erosion Remediation Options - Mollymook Beach*, October 2012, for Shoalhaven City Council

Royal HaskoningDHV (2013a), *Shoalhaven 'Authorised Locations' Coastal Erosion Remediation Options - Callala Beach*, March 2013, for Shoalhaven City Council

Royal HaskoningDHV (2013b), *Shoalhaven 'Authorised Locations' Coastal Erosion Remediation Options - Collingwood Beach*, October 2013, for Shoalhaven City Council

Royal HaskoningDHV (2014), *Shoalhaven Coastal Erosion Remediation – Adaptive Works Strategy for Transitioning from “Make-Safe/Make-Good” to “End-State” Protection*, Draft, June 2014, for Shoalhaven City Council

Umwelt (2011), *Draft Coastal Emergency Action Subplans for Beaches in Shoalhaven City Council*, Report No 2239/RO4/V1, February 2011, for Shoalhaven City Council

Umwelt (2012), *Draft Coastal Zone Management Plan for the Shoalhaven Coastline*, Report No. 2239/R04/V1, May 2012, for Shoalhaven City Council

United States Army Corp of Engineers [USACE] (2002), *Coastal Engineering Manual*, EM 1110-2-1100 (Part VI), 2002 to 2006