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“This report is a preliminary cost benefit analysis (CBA) for options identified in the Gosford Beaches Coastal Zone Management Plan, which has been certified and gazetted by the Minister. The CBA considers the economic merits of different protection and management scenarios compared to the ‘business as usual’ or ‘base case’. The CBA has investigated different management options from a broad economic standpoint. This work is an initial step to inform the consideration of future cost sharing arrangements and associated funding models to implement protection works. None of these options were progressed to either a fully developed concept or detailed design stage.”



FINAL REPORT

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Wamberal Beach Management Options: Cost Benefit and Distributional Analysis

Report prepared for NSW Office and Environment
and Heritage

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Executive summary

Wamberal is a coastal community located near Gosford on the central coast of NSW. Wamberal beach has a history of impacts from coastal processes, with consequential impacts on properties, beach visitation and public infrastructure.

Probabilistic modelling of the coastal processes affecting Wamberal beach has been carried out by the Office of Environment and Heritage (OEH) for this report and shows the impacts of coastal processes such as erosion, deposition, beach recession and sea level rise are complex and interact with Terrigal beach and Terrigal lagoon.

A range of structural engineering approaches have been considered to protect beachfront properties and other infrastructure at Wamberal beach and the surrounding lagoon properties from the effects of coastal processes. However, these options in isolation are unlikely to provide complete protection from these effects, and in the longer-term, sea level rise may have a more serious impact on properties at Wamberal beach, and especially around Terrigal lagoon.

This report uses a standard Cost-benefit Analysis (CBA) framework to estimate the direct and indirect costs and benefits of these options that may accrue to a range of key stakeholders.

The CBA reports the benefit-cost ratio and the net present value of each option compared to a base case of 'business as usual'¹. The analysis is based on the Office of Environment and Heritage (OEH) CBA Coastal Guidelines and has been undertaken to inform local government decision-making on seawall options. The material, methodology, assumptions and findings used in this report are taken from a cost benefit analysis of coastal recession management options commissioned from Marsden Jacobs and Associates, and managed by OEH on behalf of the Local Council.

The CBA concludes that none of the engineering options considered (Options 2-7) are expected to provide a net public benefit for the local community and for visitors to the area, under base assumptions. Only a Planned Retreat option (Option 8) provides greater benefits than a continuation of the current approach of no specific managed intervention (Option 1, maintaining current, status quo approaches).

The analysis concludes that the net costs imposed on residents, visitors and other parties from the loss of the beach and construction of a seawall, exceed the net benefits stakeholders would receive from the effects of a seawall. The key beneficiaries from construction of a seawall are the approximately sixty owners of beachfront properties at Wamberal.

It is estimated that there will be a marginal reduction in the number of beach visits to Wamberal due to the consequent loss of the beach for recreation and other enjoyment under the seawall options (Options 2-8), compared to the base case. Although beach nourishment has been considered as a means of restoring beach areas lost because of a seawall, sand replenishment is not an economically feasible strategy for restoring this beach.

The cost of sand replenishment is very high and outweighs the benefits of retaining a beach in front of a seawall. This means that seawall only options (Options 2, 4 and 6) result in a lower net public cost than seawall plus sand replenishment options (Options 3, 5 and 7). This CBA considered a number of sand replenishment options currently available for implementation. However, alternative sources of sand may become feasible in the future and replenishment costs may change as a result. The speed

¹ In this case, representing a situation with no specific intervention to mitigate the impacts of coastal processes

with which the beach will be lost will vary depending on the type and physical location of the seawall involved. A rubble mound revetment (Option 2 and 3) is likely to result in near immediate loss of most of the beach in winter based on the extensive assumed plan footprint and alignment of the wall. Vertical seawall designs (Option 6 and 7) have a much smaller plan footprint (possibly up to only 2 – 3 metres), but the characteristics of the wall results in increased reflection of wave energy and general lowering of the beach for longer periods following storms compared to rubble mound structures.

It is not certain which alternative form of protection (and alignment) considered would result in the fastest loss of the useable beach in the absence of sand nourishment, however under these circumstances, it is expected that the value of the beach for recreation will be near non-existent by 2064. Options with a seawall plus beach replenishment are likely to prolong beach use compared to seawall-only options. However, rising sea levels means that by 2064 the value of the beach for recreation will be similar to seawall-only options.

The loss of the beach will impact negatively on beach users (visitors and the local community), local businesses and property values.

As well as Wamberal businesses, Terrigal businesses may also be impacted, as Wamberal beach acts as an overflow area for visitors to Terrigal beach (the Central Coast's most popular beach) during the peak season.

As noted above, the trade-off from protecting some sixty beachfront properties with a seawall would be the potential loss of visits due to the loss of the beach. This loss of visitors may create some concern in the wider Central Coast Local Government Area, especially as 32% of the beach-front properties that would potentially be protected by a seawall (at the expense of the beach) are only occupied occasionally (i.e. they are owned by people who use them from time to time as holiday homes, rather than for permanent occupation).

The trade-off from protecting beachfront properties with a seawall plus beach replenishment would be to delay when loss of beach visitation will commence however this is offset by the additional cost of beach replenishment.

In the very long term, it is expected that Wamberal property values will be negatively impacted by increased flooding from sea level rise, which will result in the inundation of many, if not most properties surrounding Terrigal lagoon, the loss of Wamberal beach, and impacts on council assets such as water, electricity, sewerage and roads.

The geotechnical data available to inform this economic analysis concludes that a seawall along Wamberal beach will not mitigate the risk of this inundation around the lagoon, but will only mitigate the risk of damage to properties sitting on the Wamberal beach dune. However, the extent of damage risk to built assets faced by beachfront properties is largely mitigated where building stock is commensurate with piled foundations to bedrock. Thus, sand can be eroded from underneath these properties during storm events, and will only involve utility reconnection costs.

In summary, the seven engineering (seawall) options considered in this report (Options 2-7) all impose a net economic cost on the community, compared to continuing with the current status quo approach of no specific attempt to prevent the effects of coastal erosion (Option 1). The benefits of the engineering options (Options 2-7), which accrue mainly to beach-front property owners, will be outweighed by their net costs to the wider community. Each of the engineering options has a cost

benefit ratio (BCR) of less than 1 and a negative Net Present Value (NPV).² The only option with a BCR greater than 1 and a positive NPV is Option 8: Planned Retreat (see Table 1).

The limitations of any analysis should be clearly understood. Various assumptions have been detailed in this report that underpin the desktop assessment of the various engineering options.

There is significant uncertainty around how coastal processes will impact into the future and how engineering options may mitigate risks associated with those coastal processes. In particular, sand nourishment is a highly uncertain component (i.e., when it would be done, what quantities, how often and from what source site) with numerous variables affecting availability and cost.

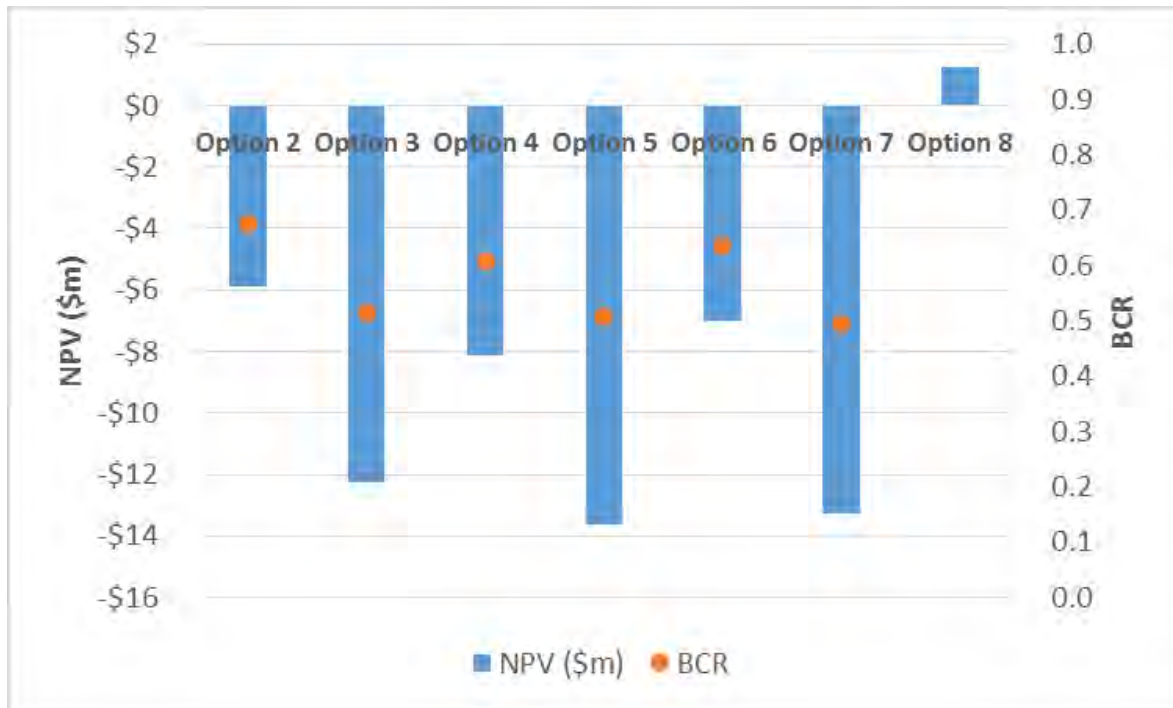
This work was undertaken as an initial step to inform consideration of potential future cost sharing arrangements and associated funding models for implementation of protection works. It is envisaged that the work contained herein provides an authoritative framework for considering more authoritative and definitive detailed designs when they are sufficiently advanced.

Table 1: Results of Cost-benefit Analysis relative to base case

Option	BCR	NPV
Option 1: “Business-as-usual” conditions at Wamberal beach if none of the proposed management options are implemented.	Base case	Base case
Option 2: A rubble mound revetment	0.70	-\$5.378 m
Option 3: A rubble mound revetment combined with beach nourishment	0.54	-\$11.688 m
Option 4: A Seabee revetment	0.55	-\$9.217 m
Option 5: A Seabee revetment combined with beach nourishment	0.49	-\$14.23 m
Option 6: A vertical seawall	0.49	-\$9.79 m
Option 7: A vertical seawall combined with beach nourishment	0.47	-\$13.975 m
Option 8: Planned retreat by managing the duration, type and intensity of future development within the coastal hazard area	5.03	\$1.178 m

The relative NPVs and BCRs of the options are shown in Table 2, and clearly indicate the difference between Option 8, with an NPV of \$1.17m and a BCR of 5, and the other options.

² See Glossary for an explanation of BCR and NPV

Figure 1: Visual Comparison of Results of Cost-Benefit Analysis

A seawall will provide benefits to beachfront properties by reducing the impacts of coastal processes. However, in the longer term, more properties in this area are likely to experience greater damage and loss of property values from the increased flooding of Terrigal lagoon associated with sea level rise. Higher sea levels will result in the increasingly frequent inundation of hundreds of properties surrounding the Terrigal lagoon, the loss of the beach, and impacts on council assets such as water, electricity, sewerage and roads.

The report contains eight main sections.

1. Introduction: the issue
2. Forecast physical impacts
3. Proposed management responses
4. Physical impacts of management options
5. Economic analysis of costs and benefits of management options
6. Results of the CBA
7. Distributional analysis
8. Conclusion

These sections follow below.

1. Introduction: the issue

Wamberal beach has a history of coastal processes causing damage to properties, beach visitation and public infrastructure. The area considered in this study is the foreshore area shown in Figure 2. The extent of foreshore considered is from the entrance to Wamberal lagoon (northern limit) to the entrance to Terrigal Lagoon (southern limit).

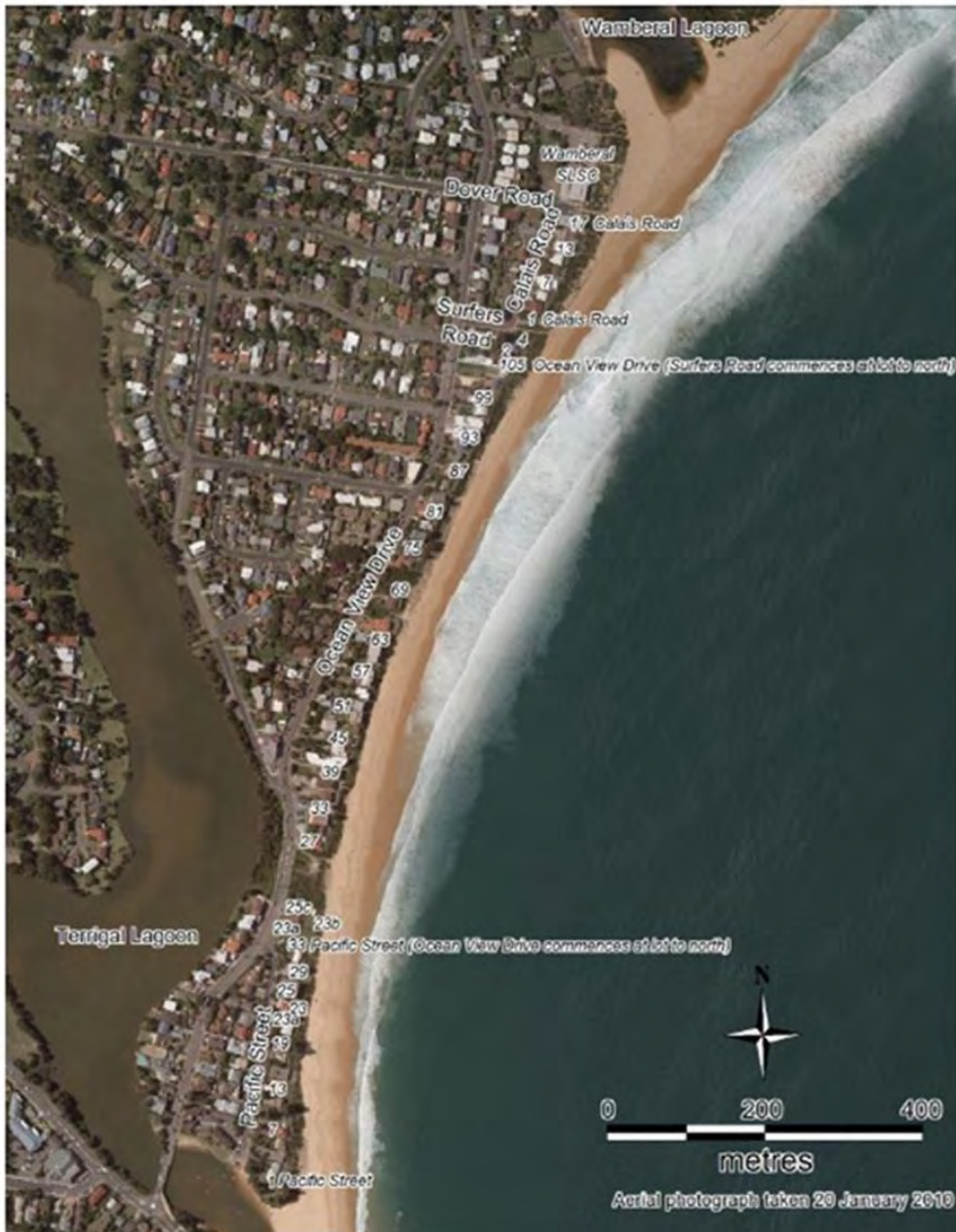
Figure 2: The study area



Most of the study foreshore is composed of a dune with a varying height and width. Much of the dune at Wamberal beach contains a modified substrate along its seaward face, due to past works attempting to stabilise the dune after storms. These works comprise dumped rock, ad hoc timber walls and remnants of wind fences, all of which have negligible dune stabilising capacity. Most of these works occurred after the 1974 storm and although common practice at the time, it is assumed that this type of work will not be repeated. The deleterious impacts of the ad hoc 1974 works on adjoining properties, including creation of ‘the ruins’, ultimately led to a 1989 Supreme Court action.

Detailed probabilistic modelling was carried out for this study to assess the likelihood of coastal processes affecting property owners and other stakeholders in the study area (see Figure 3).

Figure 3: Wamberal beach, with streets and house numbers



Source: Worley Parsons, 2015

This modelling was carried out by the Office of Environment and Heritage (OEH) to better understand the potential impacts of coastal processes on beachfront properties in the study area, and help estimate the economic costs and benefits of different options for addressing these impacts.

The modelling shows that the impacts of coastal processes such as erosion, deposition, beach recession and sea level rise are complex and interact with Terrigal beach and Terrigal lagoon (see Appendices A1-2). The modelling defined a potential impact zone for coastal properties at Wamberal based on a range of factors, including severe storm events, sand compartments along the beach, sea level rise and the dune system.

The modelling indicates that 82 properties in the study area are likely to be affected by coastal processes over a 20-year timeframe, and 92 properties over a 50-year timeframe, with some properties affected more than others, depending on their location along the beachfront.

Several properties in the study area have piled foundations (20 properties) required as a condition of their development consent. It is assumed that these structures are less likely to be undermined by coastal processes than the unpiled properties along the beachfront. Piled properties may be affected by sand washing away from under the property and by damage to access and services, well into the analysis timeframe.

The likelihood of physical impacts on activities and stakeholders in the potential impact zone was used to estimate expected changes in property values over the 20 and 50 year timeframes used in the modelling (see Appendices A2-4). A very significant proportion of the market value of properties on Wamberal beach relates to their proximity to the beach, i.e. a 'coastal premium value'. This coastal premium value would be affected in the event of shoreline erosion, since there are constraints on availability of coastal land within the LGA, i.e. there is no coastal greenfield land on which development could take place in the future. Costs associated with loss of coastal premium land value were derived from:

- estimates of the numbers of properties impacted in each year for each of the coastal erosion percentile bands;
- the probability that each property will be impacted in that year; and
- the coastal premium values of the affected properties.

Appendices 2-4 provide further details of the approach used to estimate expected changes in property values.

The next section of the report provides background information on demography, income and employment, housing and property ownership, and other features of the study area. This information is relevant to an analysis of the relative impact of the costs and benefits of the different options considered in the study on different stakeholder groups.

1.1. The study area: Socio-economic characteristics

In 2011, the total population of the Wamberal community was 390 people, living in 158 dwellings (Census data, Wamberal Statistical Area Level 1).³ Of these, 92 properties are at risk from coastal recession, with 82 of these properties currently occupied, and 10 vacant.

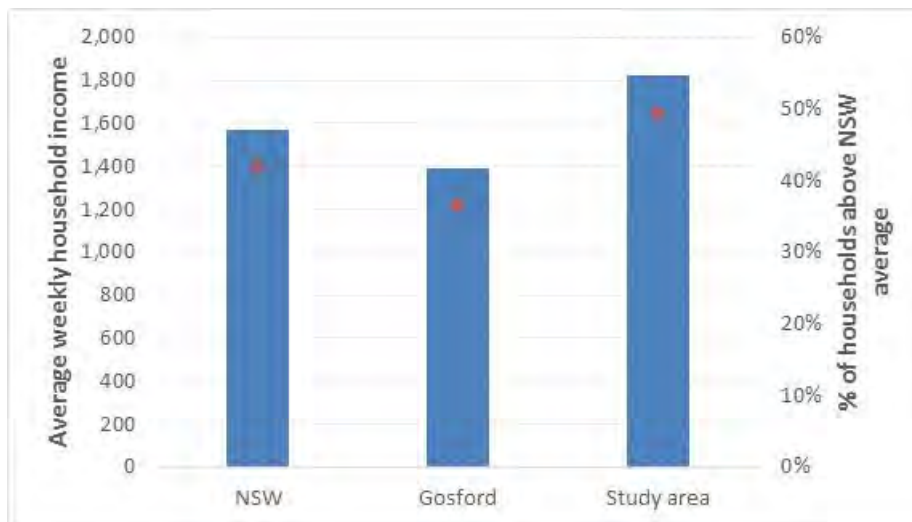
The average age of Wamberal residents in 2011 was 38 years, the same as the NSW average but lower than the average for the former Gosford LGA (41 years). The proportion of residents who were children (15 years and younger) was 19%, slightly lower than in Gosford and NSW (both 20%). On the other hand, the proportion of residents 65 years and over was only 11%, substantially lower than in Gosford (19%) and lower than in NSW (14%).

³ At the time of the 2011 Census, Wamberal was in the Gosford Shire Local Government Area. Gosford council has now been amalgamated with Wyong council to form the new Central Coast Local Government Area.

1.2. Income and employment

In 2011 the average weekly household income of Wamberal residents was \$1,823; significantly higher than average incomes in Gosford (\$1,392) and NSW (\$1,572) (see Figure 4). Furthermore, 49% of households in Wamberal had incomes above the average NSW household income, compared to 36% in Gosford and 42% in NSW.

Figure 4: Average weekly household incomes, 2011 - NSW, Gosford and Wamberal community



Source: ABS 2011

The high incomes of Wamberal households relative to Gosford and NSW in part reflect the employment status of householders, with 52% of householders in the study area being in full-time or part-time employment, compared to 41% of householders in Gosford and 43% in NSW. Also, of those employed in Wamberal 59% are either managers, professionals, technicians or in trades. This compares with 48% in Gosford and 47% in NSW.

1.3. Attributes of properties in the study area

A comprehensive database of properties exposed to shoreline erosion at Wamberal beach has been compiled for this study. The database covers 98 properties, and builds on cadastre data provided by Central Coast Council. The database includes information for each property on:

- location
- unimproved value
- capital improved value
- coastal land premium value⁴
- annual rates
- land area
- zoning (residential, commercial, other/council reserve)

⁴ This is the estimated premium value that is attached to a property due to its location immediately adjacent or close to Wamberal beach (see Appendix A4).

- building type
- building setback distance⁵.

Summary information on some of these attributes, including property values, is provided in Table 3. A noteworthy aspect of this information is the average improved property value of \$2.8 million. This compares to a median price of houses in the Central Coast LGA approximately \$X million and in Sydney of approximately \$1.0 million. Three factors would appear to explain this situation. Firstly, the average residential allotment size in the study area (820m²) is significantly greater than the average in Gosford and Sydney (estimated to be about 500m²). Secondly, the average size of houses in the study area appears to be greater than average size of houses in Gosford and in Sydney. Finally, but most importantly, location of properties on or near the coast adds a premium to their value, estimated at approximately \$1.1 million per property. In effect, this represents the value that residents living adjacent to Wamberal beach place on the availability of the beach for their recreation and other non-consumptive uses.⁶

Table 2: Summary of the attributes of properties in the study area

Attribute	Value
Number of properties zoned 'residential' (R2, low density)	84
Number of properties zoned 'commercial' (B1, neighbourhood centre)	9
Number of properties zoned 'other' (RE1, council reserve)	5
Average unimproved value (\$m)	2.0
Average capital improved value (\$m)	2.8
Average coastal land premium value (\$m)	1.1
Average annual rates (\$)	9,340
Average land area (m ²)	820
Average setback distance of back of house from seaward property boundary (metres)	13

Source: Worley Parsons Economics, 2015

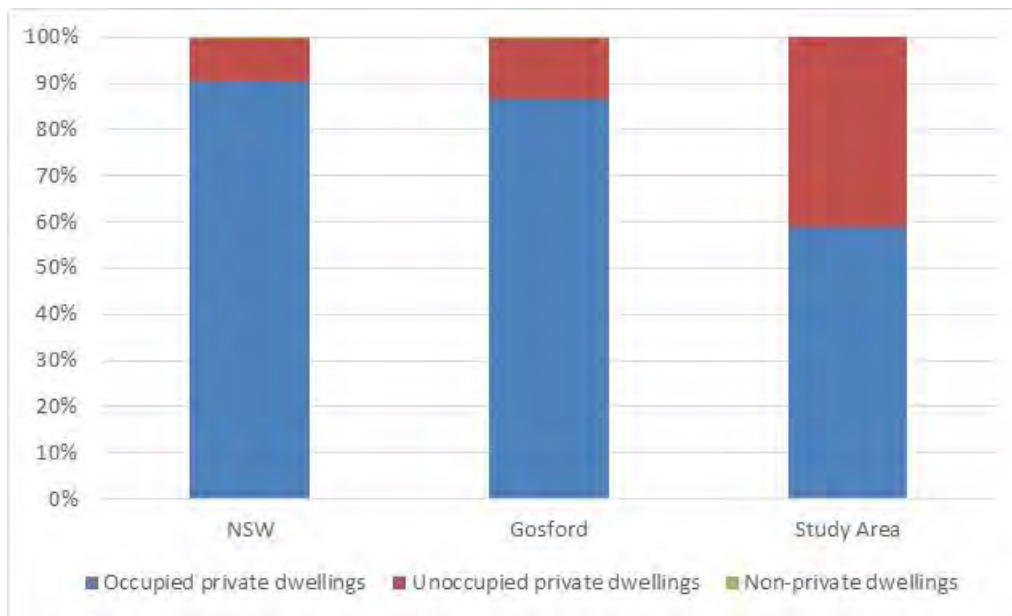
⁵ Measured as the average distance of the back edge of the building from the seaward property boundary.

⁶ See Appendices A3-4.

1.4. Occupation status of residential properties

In 2011, 41% of all dwellings were not occupied all year, a substantially greater proportion of unoccupied dwellings than in either Gosford (13%) or NSW (9%). It is reasonable to assume that a large proportion of the unoccupied dwellings in the study area are used as holiday homes and/or holiday rentals (see Figure 5). Data is not available on which individual properties are owner occupied, or holiday homes. The implications of the above assumption about permanent versus temporary occupation of properties are discussed further in Section 7.1.

Figure 5: Housing status - NSW, Gosford and Study area, 2011



Source: ABS 2011

1.5. Visitation and recreation

The beaches of the Central Coast LGA of NSW are highly valued by residents, and are an important asset in attracting visitors to the area. In 2015, the Central Coast received five million visitors who stayed almost nine million days, spending an estimated \$917 million in the LGA. Approximately 52% of days spent in the LGA and more than over 60% of expenditure came from domestic overnight visitors (see Table 4).

Table 3: Central Coast visitor data, 2015

Central Coast							
Visitor type	Number of visitors	Average length of stay (days)	Number of days	Total Expenditure (\$)	Percentage of days primarily beach driven	Beach visits	Beach-related expenditure (\$)
Domestic overnight	1,371,000	3.4	4,608,604	\$567,000,000	31%	1,430,971	\$176,053,500
Domestic day	3,569,000	1	3,569,000	\$298,000,000	14%	510,367	\$42,614,000
Overseas	45,000	16.1	725,192	\$52,000,000	19%	137,061	\$9,828,000
Total	4,985,000		8,902,796	\$917,000,000		2,078,400	\$228,495,500

Source: Destination NSW, 2016; Marsden Jacob analysis

Data from surveys of visitors compiled by Destination NSW (2016) indicates that for approximately 23% of visitors, the region's beaches were the primary factor behind a visit to the region. This equates to more than two million visits to the region's beaches.

The Surf Life Saving Clubs (SLSC) at Terrigal and Wamberal beaches have compiled visitation data for Terrigal and Wamberal beaches over the course of the 2014-15 season (September to April). Data has also been compiled by SLSCs for other beaches in Gosford. As shown in Table 4, there were an estimated 126,000 visitors to Wamberal beach in the 2014-15 season, at an average of over 500 per day. This represents about one quarter of the visitors to the adjoining Terrigal beach (Gosford's most popular beach), and 6% of all visits to Gosford's beaches.⁷ There will have been additional beach visits during the off-season (May to August), but based on visitation numbers in April, these are likely to be relatively small.

Unconfirmed reports suggest that a significant proportion of visitors to Wamberal beach are surfers, but that Wamberal beach also gets spillover visitation from Terrigal beach on crowded days (e.g.

⁷ The total number visitations to Gosford's beaches of 2.2 million is broadly consistent with beach visitor numbers shown in

, noting that the visitor numbers do not include visits by residents, or account for multiple visits by visitors, but include visits to other Central Coast beaches (e.g. Wyong).

weekends and public holidays). If so, this could explain the very significant jump in visits to Wamberal beach (in percentage terms) in January relative to other beaches.

Table 4: Visits to Terrigal, Wamberal and Gosford beaches, 2014-2015

	Terrigal	Wamberal	All Gosford beaches	Wamberal/ Gosford (%)
September	36,350	10,575	171,185	6.2%
October	59,980	13,269	201,840	6.6%
November	64,430	14,073	209,587	6.7%
December	105,260	18,450	396,733	4.7%
January	142,780	32,955	587,002	5.6%
February	45,860	13,280	208,357	6.4%
March	45,100	18,840	296,366	6.4%
April	20,650	4,190	83,294	5.0%
Total season	520,410	125,632	2,154,364	5.8%
Total off season	66,126	15,964	273,747	5.8%
Total annual	586,536	141,596	2,428,111	5.8%

Marsden Jacob analysis

Expenditure data from Table 4 and Wamberal beach visitation data from Table 4 can be used to estimate the proportion and expenditure of visitors to Wamberal beach from outside of Central Coast LGA as approximately \$9 million in 2014-15. This estimate is important for understanding the value that visitors place on the existence of Wamberal beach.

Expenditure by residents in Central Coast that can be specifically attributed to visiting Wamberal beach is assumed to be minimal. In any case, if residents chose to visit another Central Coast beach in preference to Wamberal beach any related expenditure would continue to occur within the LGA.

Note: this report assumes no increase in visitation over time. This impacts on how nourishment options are assessed. Costs of nourishment outweigh benefits. If visitation increases, then nourishment options improve relative to non-nourishment options.

1.6. Visitation-related businesses

Several local businesses in Wamberal provide goods and services to visitors and local residents as part of their experience of using the beach. Changes which affect levels of visitation to the beach will influence the revenue these businesses receive.

1.7. Beach maintenance

Management of beach recession is currently carried out by the Central Coast Council through land use planning, development control and protection of public assets. The council has several measures in place to respond to recession including the following.

Development controls

Council has implemented new planning controls to mitigate the impacts of coastal processes, as set out in the Gosford Development Control Plan (DCP) 2013. Key controls include the following.

- All new development must be constructed landward of the coastal building line (DCP Section 6.2.7).
- Subdivisions and intensification of development of properties seaward of the Coastal Hazard Line are not permitted (DCP Section 6.2.8.1).
- New buildings and structures are not permitted on, over or below land seaward of the coastal building line (DCP Section 6.2.8.2a).
- Redevelopment of existing buildings within the coastal hazard area is only permitted if the foundation design is demonstrated to have been constructed to withstand coastal processes (i.e. buildings are constructed as 'piled' buildings).

In 2016 there were 20 piled houses in the study area. The number of piled houses is assumed to increase by an average of one each year in the future (~2% of the housing stock) in line with the requirements for redevelopment outlined above.

Ongoing maintenance

It is understood that the two maintenance activities undertaken by Council are:

- Opening of the entrances to Terrigal lagoon when the water level reaches pre-determined levels set to minimise flooding along the developed foreshores of the lagoon (an average of twelve openings per year are assumed in the OEH modelling).
- Erection of wind fencing to assist with dune rebuilding after storms, predominantly along the northern Wamberal beach area. There are likely to be some ongoing costs associated with maintaining this fencing.

In addition, the Central Coast Council issues evacuation notices for unsafe properties, and implements actions needed to ensure site safety. Demolition of unsafe properties is carried out within specified time periods depending on the ability and/ or willingness of home owners to pay for demolition. Lengthy delays may occur. If properties are left in a 'dangerous' condition for several years, Council may be forced to close off sections of the beach for long periods, during which the benefits of beach access/ visitation will be foregone.

As noted above, modelling was commissioned for this project to predict the physical impacts of coastal processes on Wamberal beach over the next fifty years, assuming no preventative measures

are taken to mitigate their effects.⁸ Expected physical impacts under modelled conditions are discussed in Section 2.

⁸ These conditions reflect the views of MJA and Water Technology using information from OEH, Council and other sources. The coastal processes are highly uncertain and the best information has been used to inform the predicted impacts.

2. Physical impacts predicted by modelling

This section of the report discusses the physical impacts of coastal processes on features of Wamberal beach over the next fifty years, based on the above OEH modelling, which assumes that no specific interventions are made to prevent the effects of coastal processes.

2.1. Beach and dune response

A considerable amount of work has been undertaken to define the existing coastal processes and the beach response to storm events, with the most recent relevant studies being:

- Worley Parsons (2014): Open Coast and Broken Bay Beaches Coastal Processes and Hazard Definition Study; and
- NSW Office of Environment & Heritage (OEH)(2016): Forecast of Potential Shoreline Change - Wamberal beach (Gosford City Council).⁹

Information from these reports has been used in the following discussion of the impacts of coastal processes affecting Wamberal beach.

2.2. Shoreline recession

The statistical Monte Carlo modelling used to forecast shoreline recession change uses an 'alongshore averaged beach-dune profile for Wamberal beach'. Based on the averaged beach-dune profile, the potential for shoreline change has been defined in Appendix A1 (taken from Figure 3 and Figure 4 of OEH, 2016) for the 2034 and the 2064 sea level change estimates. These shoreline change estimates have been used to predict the extent of recession in 2034 and 2064 for each of the coastal recession percentile bands (i.e. 10, 20, 30, 40 ... 99.9), assuming that any underlying historical rock and timber structures will have no measurable impact on limiting recession.

The above information has in turn been used to estimate the numbers of properties impacted in 2034 and 2064 for each of the percentile bands. This has been done by overlaying the percentile bands on the Wamberal beach cadastre (see Appendix A2).

It is assumed in the modelling that no beach nourishment will take place, in the short-term. This assumption is based on available documentation and studies that define the beach as a relatively closed system with no net sediment losses. That is, sand that enters the lagoons is flushed out again when the lagoons open, and sand that is eroded and moved offshore during storms, returns to the beach during ambient conditions and aeolian (wind-driven) sand movement returns the sand to re-build dunes.

It is assumed that the active system will move landward over time at a rate of 0.2m/year (based on a Worley Parsons recommendation that has already been built into the OEH Monte Carlo modelling of shoreline change, described in Appendices 1-2). As well, in the longer-term under sea level rise, there

⁹ Based on statistical modelling of the eroded beach-dune sand volume using the Monte Carlo sampling technique.

will be a further recession based on the Bruun Rule.¹⁰ This has also been built into the OEH Monte Carlo modelling.

2.3. Dune breakthrough and overtopping

Potential for dune breakthrough has been assessed, but is considered highly unlikely over the timescale of the present study (to 2064).¹¹

Based on available information, it is highly unlikely that a dune breakthrough (itself an unlikely event), will result in a new channel into Terrigal Lagoon. The breakthrough will be a result of run-up washing over the dune and cutting through it, but the base level of any cut is unlikely to extend down to the level of the Ocean View Drive. The breakthrough is more likely to result in a sand washover and deposition on the road and on the lagoon side of the road. Should all the sand be washed over the road, the road would still be a barrier to breakthrough. That is, although a single storm (even the 100 year ARI event in 2064) may erode the dune back to the road, it is unlikely to have the duration at high water levels to breach the road. Hence a new channel would not be created.

Therefore, any impacts will primarily relate to the impact of the breakthrough on the dune itself. In any case, it is likely that any breach in the dune will be rectified after it occurs to re-establish the present-day configuration.

Some services may also be affected by a breakthrough. (However, although the potential for breakthrough is most likely between [REDACTED], there is no sewer connection at this location which could be ruptured). Another possible impact of dune breakthrough would be temporary road blockage due to sand deposition.

2.4. Beach condition

Wamberal beach is an active beach system which is assumed to move landward at a rate of 0.2 m/year. Further beach/ dune recession in the long- term is expected from sea level rise¹², which by 2034 is projected to be about 8 metres and by 2064 about 20 metres¹³.

In addition to the beach response described above, it is important to consider the likely form/condition of the beach in terms of the 2034 and 2064 sea level rise estimates used in the modelling. It needs to be appreciated that the beach can have a range of visual and use attributes under any sea level rise estimate, depending on the season and when the last storm event occurred. The historical severe storm events of 1974, 1978, 1986 and 2016 occurred in winter (June to August). The implication here is that in general the beach will be narrower, at high tide, over winter than over summer. During the project site visit of April 2016, the beach was very wide, reflecting that at the end of summer the

¹⁰ See Glossary

¹¹ Dune breakthrough is a highly complex and rare physical process. Even with the extent of modelling undertaken by OEH, the impacts of breakthrough are expected to be highly uncertain and unlikely. Modelling suggests that the likelihood of this event is only $\leq 1\%$ at 2034 and $\leq 5\%$ at 2064 (see Appendices A1-2). Given this, the effects of dune breakthrough are only considered as a coarse parameter in the economic analysis.

¹² Sea level rise is estimated at 0.2 metres in 2034 and 0.45 metres in 2064 relative to 1990.

¹³ Under the Bruun Rule about 200m³ of sand will be eroded per metre length of beach by 2064.

beach will, under normal conditions, be in a 'full' state. This is due to the predominance of mild wave conditions over the summer months. During mild wave conditions, there is a tendency for sand to move onshore, and warm onshore winds tend to dry the sand and move it to the upper beach and dune by aeolian action. During storms, which predominantly occur over the winter months, sand moves offshore and the beach will tend to be much narrower than in summer.

Projected long-term beach recession due to sea level rise will exacerbate this seasonal change (i.e. a 2034, sea level rise of 0.2m by 2034). Over summer it is expected that a beach berm would build up in front of the eroded dune providing a reasonable area for beach use, however during winter this could be substantially reduced by severe storm events.

2.5. Lagoon processes

Current lagoon processes are expected to continue under the modelled conditions. This means that properties affected by the flooding of the lagoon will continue to be inundated as water tends to rise in the lagoon. Coastal recession will have no impact on these processes.

Because of development at low levels around Terrigal lagoon, Council periodically opens the lagoon entrance to maintain lagoon water at a level that avoids unacceptable flooding.¹⁴ The trigger level for opening is 1.23m AHD.

As sea level rises, it is expected that there will be more onshore movement of sand towards the lagoon entrance, resulting in a more rapid closure of the entrance due to sand build up. The difference in water level between the lagoon and the ocean will lessen as sea level rise results in a lower volume of water being discharged from the lagoon each time it is opened. Assuming rainfall stays approximately constant with time, the lagoon will reach its trigger level more rapidly; hence the need for an increase in the number of openings. Therefore, under the modelled conditions, there are expected to be more times that the entrance will need to be opened.

2.6. Dune system

Although the dune system at Wamberal beach has largely been developed, there are some small sections of native vegetation in areas of public land that do not contain houses or major infrastructure. Although Council and a local Bushcare group aim to maintain and revegetate these areas through fencing and other maintenance works, it is assumed in the modelling that these areas will eventually be lost from the action of coastal processes.

2.7. Impacts on properties under the modelled forecasts

As noted above, detailed probabilistic modelling was carried out for this study to assess the likelihood of coastal processes affecting property owners and other stakeholders in the study area (see Figure 9). The modelling has defined a potential impact zone for coastal recession at Wamberal based on a range of factors, including severe storm events, sand compartments along the beach, sea level rise and the dune system (see Appendix A1).

¹⁴ Some flooding still occurs however when storm events correspond with high tides.

The likelihood of physical impacts on activities and stakeholders in this zone is then used to estimate the expected changes in property values over the timeframes used in the analysis, i.e. 20 and 50 years (see Appendices A2-3).

It is estimated that 82 beachfront properties in the study area may be affected by coastal processes over a 20-year timeframe, and 92 beachfront properties over a 50-year timeframe, with some properties affected more than others depending on the location of the properties along the beachfront.

- Shoreline recession extending to private properties will impact on the coastal premium land value of those properties, proportional to the extent of land lost to recession.¹⁵
- When shoreline recession reaches the seaward edge of unpiled buildings they will be lost. Piled buildings will remain, but from time to time their owners will incur costs for reconnecting services and accessing the property. Also, once impacted by recession, the value of piled buildings will decline over time in proportion to the area of land lost to recession.
- In the short to medium term (e.g. 2034), loss of land and dwellings from recession will primarily be driven by severe storms.
- In the longer term (e.g. 2064) land and buildings will be impacted (due to sea level rise) even without severe storm activity.

Several properties in the study area have piled foundations (20 properties) required as condition of their development approval (see Section 1.2.5.). It is assumed that these structures are less likely to be undermined by shoreline recession than the unpiled properties along the beachfront. Piled properties may be affected by sand washing away from under the properties, and damage to access and services well into the analysis timeframe.

2.8. Impacts on beach use under the modelling

The appearance and use of the beach will depend on the season and when the last storm event occurred. In general, the beach will be narrower at high tide, over winter than over summer. During mild wave conditions, sand is likely to move onshore, and warm winds would tend to dry the sand and move it to the upper beach and dune. During storms, which predominantly occur in winter, sand moves offshore, and the beach will tend to be much narrower than in summer.

The modelling assumes that no beach nourishment occurs, but sand that is eroded and moved offshore during storms, will return to the beach during ambient conditions and wind action will return the sand to rebuild dunes.

However, under the forecasted conditions, the beach will continue to move landward at a rate of 0.2 m/year. Additional recession is expected to occur in the long term from sea level rise. By 2034 the beach may lose significant quantities of sand during the winter storm season, but over summer will recover sufficiently to provide reasonable to good beach availability for recreation.

¹⁵ Costs associated with loss of coastal premium land value were derived from: estimates of the numbers of properties impacted in each year for each of the coastal erosion percentile bands; the probability that each property will be impacted in that year; and the coastal premium values of the affected properties. Appendix A4 provides further details of the approach used to estimating the expected values.

Thus, over the forecast period, and assuming no major programs are undertaken to remediate the impact of coastal processes on beachfront properties, beach users will still be able to access the beach over summer, but not in winter. Over time there will be less beach available even in summer due to beach recession and sea level rise.

3. Proposed management responses to physical impacts

Several options have been proposed by the Council and OEH to protect beachfront properties from the effects of coastal processes, although there will still be some processes that cannot be addressed by these options, particularly sea-level rise. An alternative option has also been considered, which aims to allow natural coastal processes to take place without building engineering structures to counteract those processes. This planned retreat would allow the temporary use and occupation of coastal lands until coastline hazards threaten life and property; then once the erosion escarpment encroaches within a certain distance of a development, the development is required to be relocated further back from the escarpment or removed where relocation is not possible.

For the purposes of this study, and based on discussion between the Central Coast Council and OEH, the following options have been considered as ways to respond to the impacts of coastal processes.

- Option 1: No specific preventative measures
- Option 2: A rubble mound revetment
- Option 3: A rubble mound revetment combined with beach nourishment
- Option 4: A Seabee revetment
- Option 5: A Seabee revetment combined with beach nourishment
- Option 6: A vertical seawall
- Option 7: A vertical seawall combined with beach nourishment
- Option 8: Planned Retreat by managing the duration, type and intensity of future development in the coastal hazard area.

Each management option proposes a way of addressing the physical impacts of coastal processes predicted under the modelling. However, each option will have its own combination of physical impacts on the beach and surrounds, and economic impacts on stakeholders.

As noted above, it is difficult to accurately predict the behaviour of the coastal processes affecting coastline recession, and thus their physical impacts on stakeholders under the different options. Key assumptions about the impacts of the above management options have been subject to sensitivity testing (see Section 6).

3.1. Overview Option 1

Option 1 involves a continuation of current management approaches to coastal processes, with no specific planned program of interventions to prevent the impacts of coastal processes on beachfront properties. The impacts of implementing Option 1 are the impacts predicted in the modelling forecasts as described in Section 2.

3.2. Overview Options 2-7

Options 2-7 involve different types of revetment, with and without beach nourishment, i.e. a rubble mound (rock) seawall, a Seabee (concrete unit) seawall; and a vertical seawall.

A 1998 final design report by the Water Research Laboratory (WRL) (Design Study for Wamberal beach Terminal Protective Structure in October 1998) included an assessment and capital cost estimates for rubble mound, Seabee and Contiguous piled (Vertical) seawall options.

The designs proposed by WRL appear to be technically reasonable, and provide an appropriate starting point for the CBA. The designs are suitable for the purposes of comparing seawall options in a CBA, but more up-to-date documentation would be required for detailed engineering purposes.

Two design factors have changed since the 1998 report: the allowance for sea level rise by 2064, and the adopted toe design for Seabee seawall. At the time of the study, the nominated allowance for sea level rise for a 50-year horizon was 155mm. In contrast, the nominated value for sea level rise to 2064 (the 50-year planning used in this study) is 350mm. The current nominated value for 2034 is 125mm.

In general, the unit costs applied by WRL (1998) have been adopted with a nominal 70% construction cost index (CCI) increase to 2016. Details of costs and updates to the above estimate made for this study are given in Section 5.

The design cross-section proposed and costed by WRL (1998) has been used for the revetment types i.e. the rubble mound and the vertical wall (Options 2-3 and 6-7). For the Seabee seawall (Options 4-5), the Gabion and Reno mattress toe has been replaced with a piled toe. The variations from WRL (1998) relate to seawall height. In the WRL (1998) a constant seawall height of 8m (AHD) was assumed, whereas the design height of the seawall varied from 6 to 8 metres (AHD), with most the wall at 8m.¹⁶

It is assumed that the engineering works for Options 2-7 would be carried out as a single continuous process, with component activities occurring at the same time, and not carried out as individual stages over time. Staging construction activities would cause different physical and economic impacts on stakeholders during the different phases of construction and complicate attempts to estimate the direct and indirect costs and benefits of the different options.

3.3. Options 2 and 3: Rubble Mound Revetment: description

Options 2 and 3 involve a standard rubble mound seawall slope form of two layers of four tonne armour rock underlain by two layers of secondary rock with a geotextile membrane separating the rock from the underlying trimmed sand slope. The geotextile prevents sand leaching out through the rock. Option 2 is a rubble mound revetment without sand nourishment; Option 3 is a rubble mound revetment with sand nourishment.

The toe of the seawall (under-layer) is set at 2m AHD to accommodate beach and dune recession so that the integrity of the seawall remains even after a 50 year ARI storm at elevated sea levels. Under an extreme event there may be some undermining of the toe of the structure, but the combination of the geotextile, under-layer rock and armour rock toe structure would be expected to slump without any significant settlement of the rubble mound wall itself.

¹⁶ The construction and maintenance costs in Section 5 take account of the variable seawall height.

Height

The crest of the rubble mound is set at about 6.75m AHD. A recurved concrete wall with its top at 8m AHD is cast onto the top of the rubble mound wall to minimise wave overtopping.

Footprint

The footprint (width) of this structure is 17 ½ metres when it is fully exposed. When it is constructed, (presumably not in winter because of potential limited access and wave inundation of works), only about 50% of this total width would be exposed. The balance would be buried using sand excavated for construction purposes.

Under summer conditions, with present day sea level, much of the seawall will be buried under the upper beach and dune. As sea level rises, combined with the natural recession of the shoreline nominally estimated at 0.2m/year, (Worley Parsons, 2014), it is expected that the amount of the seawall exposed will increase as the beach width diminishes.

Preparatory earthworks, which entail the removal of sand and other materials to trim the dune face in preparation for the placing of rubble mound seawall materials, will require some 175,000 m³ to be rehandled. All sand excavated will be placed back on the beach.

The total amount of rock involved is almost 91,000 tonnes. All the rock will need to be transported via road to Wamberal beach. It is likely that storage and rehandling will need to be undertaken at both the Terrigal and Wamberal Lagoon ends of the beach. Materials will then need to be transported to the works area by off-road equipment.

The wave reflecting recurved wall requires some 1,900 tonnes of concrete, which equates to about 100 to 150 concrete trucks accessing the beach road.

The construction time is likely to be over 1 year (391 days of supervision and survey). It therefore may be necessary to stage the works over two years, to allow for work to stop over the busiest summer months and to allow for weather delays over winter.

3.4. Options 4 and 5: Seabee Revetment: description

A Seabee revetment is a sloped seawall constructed of concrete blocks with hexagonal or rectangular holes on the slope to discharge wave energy and assist with sand collection. For this analysis, the design proposed and costed by WRL (1998) has been adopted with the following exception – the Gabion and Reno mattress toe has been replaced with a piled toe. This increases its costs but will greatly improve its reliability.

If constructed, the Seabee revetment would comprise a standard Seabee seawall slope form of one layer of 800mm high Seabee units underlain by 2 layers of 250mm rock with a geotextile membrane separating the rock from the underlying trimmed sand slope. The geotextile prevents sand leaching out through the rock and the Seabees.

Option 3 is Seabee revetment without sand nourishment, Option 4 is a Seabee revetment with sand nourishment.

Height

The crest of the Seabee wall would be set at about 6.75m AHD. A recurved concrete wall with its top at 8m AHD would be cast onto the top of the Seabee wall to minimise wave overtopping.

Footprint

The footprint (width) of the structure would be 13 metres when fully exposed. When it is constructed only about 50% of this total width would be exposed. The balance would be buried using sand excavated for construction purposes.

In summer, with present day sea levels, much of the seawall would be buried under the upper beach and dune. As sea level rises it can be expected that the amount of the Seabee exposed will increase as the beach width diminishes.

Options 6 and 7: Vertical Revetment: description

The vertical seawall proposed under Options 6 and 7 is in effect a series of side-by-side reinforced concrete piles anchored back into the dune. For this analysis, the design proposed and costed by WRL (1998) has been used with the following exception. A constant seawall height of 8m (AHD) was used in the WRL (1998), but this study assumes a variable seawall height of 6 to 8 metres (AHD), although with much of the wall at 8m. There would effectively be no wall footprint, on the beach, implying that approximately an extra 15 metres width of dune and beach remains seaward of the wall.

Option 6 involves a vertical seawall without sand nourishment; Option 7 is a vertical seawall with sand nourishment

The seawall proposed under this option would be constructed by building up the dune area where the wall is constructed with compacted sand, and then drilling through the sand to create the concrete reinforced piles. Some excavation would also be required behind the piles to install the anchors. A recurved wave wall would be installed on top of the piling to limit wave overtopping. The piling depth and ground anchoring would be designed to allow for erosion at the toe of the wall down to -1m AHD.

In the summer, with present day sea level, most of the seawall would be covered by the upper beach and dune. As sea level rises it can be expected that the amount of the seawall exposed will increase as the beach width diminishes.

Negative features of the seawall compared to a sloped dissipative structure (the revetments) are likely to include:

- appearance: when the beach is eroded, the wall will be visually high and unattractive;
- access: access to the beach will require sets of steps from the top of the wall down to a beach level;
- Erosion: the rate of sand erosion will be greater for the vertical wall than other types of seawall because it does not include a dissipative structure, however the rate of erosion will be balanced by the extra distance of the wall from wave action resulting in erosion taking longer to occur.

Beach nourishment

Options 3, 5 and 7 involve construction of the above types of seawall accompanied by beach nourishment.

Beach nourishment is a highly uncertain component (i.e., when it would be done, what quantities, how often and from what source site) with numerous variables affecting availability and cost.

This work was undertaken as an initial step to inform consideration of potential future cost sharing arrangements and associated funding models for implementation of protection works. It is envisaged

that the work contained herein provides an authoritative framework for considering more authoritative and definitive detailed designs when they are sufficiently advanced.

A potential terrestrial sand source for nourishment for Wamberal beach was not identified in available documentation.¹⁷ The ‘Beach Sand Nourishment Scoping Study’ for Sydney beaches by AECOM (2010) recommends that the initial sand nourishment required for Sydney beaches is equivalent to the beach lost due to a sea level rise of 0.3 metres. The 0.3 metres is composed of 0.2m attributable to sea level rise to 2010, and 0.1m to handle sea level rise over the next 10 years. The overall premise behind these numbers is that sea level rise over a planning period of 50 years is about 0.1m per 10 years and the beach loss attributable to sea level rise can be estimated by the Bruun Rule.¹⁸ The sand volume required for initial beach nourishment at Wamberal is 300m³/m length of beach, which equates to 408,000 for the full length of the beach. A detailed discussion of beach nourishment issues is given in Appendix A5.

3.5. Overview Option 8: Planned retreat

Planned Retreat is an approach that aims to allow natural coastal processes to take place without building engineering structures to prevent the impact of these processes. It is generally implemented through planning policies and related instruments. The physical processes would be assumed to be the same as in Option 1.

On an eroding coastline, such as Wamberal beach, Planned Retreat would allow the temporary use and occupation of coastal lands until coastline hazards threaten life and property. Once the erosion escarpment encroaches within a certain distance of a development, the development is required to be relocated further back from the escarpment or removed where relocation is not possible.

There are several possible models of Planned Retreat including:

- managing the duration, type and intensity of future development within the identified coastal hazard area;
- compulsory or voluntary property acquisition within the identified coastal hazard area, combined with tight restrictions on new developments; or
- property acquisition within the identified coastal hazard area, combined with lease back of properties for continued use while it is safe to do so, and tight restrictions on new development.

Taking these factors into account, we have assumed no construction cost differential between demountable houses and an equivalent fixed house under the base case.

Option 8: Planned retreat: description

The proposed Planned Retreat model comprises a series of actions aimed at controlling development to maintain a rolling development-free buffer along the Wamberal beach foreshore. The buffer is designed to accommodate natural coastal processes and reduce the level of risk associated with coastal erosion and inundation to persons, development and infrastructure. The Planned Retreat model assessed in this study includes the following features:

¹⁷ Nevertheless, beach nourishment from non-terrestrial (i.e. offshore) sources is included in the analysis of these options.

¹⁸ See Glossary

- Control of development on land within designated hazard areas for approvals under the provisions of the Environmental Planning and Assessment Act, 1979 via planning controls under Central Coast LEP, DCPs, and the Coastal Zone Management Plan. Controls would include:
- exclusion of development within the buffer zone of a property; nominally all land within the property boundary that is seaward of the assessed developable area (e.g. land seaward of the 2045 erosion line as detailed in the Gosford DCP, Section 6.2);
- all the structures receiving development consent are required to be built/rebuilt as demountable or relocatable structures;
- development consent is subject to a condition that once the erosion line moves within the developable area of the property, the consent lapses and the structure must either be moved back, relocated or demolished; and
- when a development consent lapses, a new consent is required, supported by a revised assessment of the property's developable area and buffer zone.
- Provision of advice to purchasers of property within coastal planning precincts on the hazard risk restrictions associated with that land via issue of Section 149 planning certificates at time of purchase.
- A structure built under earlier approvals processes, prior to introduction of the planned retreat policy, is treated the same as it would be under the base case (i.e. it can continue to be used for its intended purpose while it is safe to do so and can be serviced).
- Removal of unapproved structures.
- Development of supporting planning instruments and policies.

In effect, the proposed model modifies existing development controls, with controls requiring new developments in the hazard area to be piled being replaced by a requirement for new developments to be demountable/moveable.

Available information suggests that demountable houses are unlikely to be costlier to construct than equivalent sized fixed houses. Indeed, because demountable houses are by their nature 'kit homes' they could be cheaper (e.g. \$1200-1800/ sq. metre compared to \$1500 - \$2200 / sq. metre for an on-site built house with equivalent fittings). This is particularly so, since, under Option 1 construction of a fixed house will require piling, which entails significant additional costs. On the other hand, because demountable houses are kit homes they are likely to lose out in comparison to an architect or purpose designed house where a home owner's preference is for a house with bespoke elements.

4. Physical impacts of management options

4.1. Physical impacts on coastal features

The potential physical impacts of Option 1 (which are the same as the impacts predicted by the probabilistic modelling commissioned for this study) have already been described in Section 2. The next part of this section discusses the potential physical impacts of Options 2-8 on the coastal processes affecting Wamberal beach.

Beach condition Options 2-8

Wamberal beach can have a range of visual and recreational use characteristics at any sea level depending on the season and when the last storm event occurred. The historical severe storm events of 1974, 1978, 1986 and 2016 occurred in winter (June to August). The implication is that in general the beach will be narrower, at high tide, over winter than over summer.

During the mild wave condition expected in summer months there is a tendency for sand to move onshore and for warm onshore winds tend to dry the sand and move it to the upper beach and dune by Aeolian action. During storms, which predominantly occur over the winter months, sand moves offshore and the beach will tend to be much narrower than in summer.

Infrastructure Options 2, 4 and 6 are likely to increase the deterioration of the beach. In the short-term, the structures themselves (rubble mound, Seabee revetment or seawall) will be intrusive, resulting in some loss of beach area (more so with rubble mound and Seabee revetments). In the longer term, in the absence of beach nourishment, the infrastructure options are likely to accelerate loss of sand, with the toe of the seawall being exposed most winters to the extent that a full beach recovery of the beach will not occur in most summers.

Infrastructure options involving beach nourishment (Options 3, 5 and 7) are likely to significantly reduce the long term adverse impacts on the beach associated with Options 2, 4 and 6, and improve beach condition relative to Option 1. However, the cost of beach nourishment is high and could also involve negative environmental impacts associated with off-shore dredging (consideration of these impacts is beyond the scope of the present report).

Option 8 (Planned Retreat) is likely to have a slightly positive impact on the beach area.

Lagoon processes under Options 2-8

The lagoon processes are expected to continue as assumed in the modelling (and in Option 1) for all the options. Thus, properties affected by the flooding of the lagoon will continue to be inundated as water tends to rise in the lagoon.

Because of development at low levels around Terrigal lagoon, Council periodically opens the lagoon entrance to maintain lagoon water at a level that avoids unacceptable flooding¹⁹. The trigger level for opening is 1.23m AHD.

As sea level rises over time, it is expected that there will be more onshore movement of sand towards the lagoon entrance, resulting in a more rapid closure of the entrance after it has been opened. The

¹⁹ However, some flooding still occurs when storm events correspond to high tides.

difference in water level between the lagoon and the ocean will reduce as sea level rises, resulting in a lesser volume of water being discharged from the lagoon each time it is opened. Assuming rainfall is approximately constant over time, the lagoon will reach its trigger level more rapidly; requiring the lagoon to be opened more frequently, with associated costs.

Dune system under Options 2-8

Under Options 1-7, it is expected that by 2034 there will be a reduced dune/ upper berm width, with the likelihood that in most years, sand will be removed over winter, exposing the top of the seawall toe. It is expected that sand would be restored to the beach to cover the toe of the seawall, and still provide a reasonable area for beach use during summer.

By 2064, the toe of the seawall is likely to be fully exposed in most winters under Options 2, 4 and 6. It is also likely that a full beach recovery will not occur in most years; and the beach area available for recreation will be negligible over winter and limited over summer.

Options 3, 5, and 7, involve beach nourishment, and thus will provide beach areas for recreation; however, following initial beach nourishment, further nourishment will be required after ten years.

It is anticipated that without beach nourishment, wave run-up and overtopping would become unacceptable after 2064, and Council will need to be consider raising the seawall crest to offset continuing sea level rise. This work is likely to require removing the recurved wall, raising the rubble mound to crest level, and rebuilding the recurved wall. If the recurved wall was still fully intact and functional at that time, it may be possible to cast a new wall and tie it to the old wall. These costs have not been included in the CBA.

The above issues will not apply under Option 8 as changes to the beach area will not be affected by the presence of a sea wall.

As noted in Section 2, there are some small sections of native vegetation in the dune area. Council and a local Bushcare group aim to maintain and revegetate these areas through fencing and other maintenance works. It is assumed that the infrastructure Options (2-7) would protect these remaining areas, but that they would be lost under Option 8 and Option 1.

4.2. Physical impacts on properties and beach use (Options 2-8)

The impacts of Option 1 on properties and beach use are discussed in Section 2, as they are the same as the modelled impacts (see Appendices A1-2).

Physical Impacts on properties (Options 2-7)

The impacts of Options 2-7 will be basically the same type for each option.

- Options 2-7 should significantly reduce the damage to beachfront properties from coastal processes in the short- to medium-term. However, seawall structures will have no effect on the longer-term impacts of sea level rise.
- As seawalls will limit the impacts of coastal processes on beachfront properties in general, properties with pilings will not have the structural advantage over unpiled properties that they have under Option 1 and Option 8.
- In the short to medium term (i.e. to 2034) beach loss will primarily be driven by severe storms.

- In the longer term (i.e. to 2064) land and buildings will be impacted, even without severe storm activity, principally from the effects of sea level rise.

Physical impacts on beach use (Options 2-7)

The appearance and recreational value of the beach under all options will vary with the season and when the last storm event occurred.

The impacts of Option 1 for properties and beach use are discussed in Section 2, as they are the same as the modelled impacts (see Appendix A1).

In general, under Options 2-7, physical structures will lead to the gradual loss of the beach from hydrophysical action, exacerbated in winter by storm action.

Although beach use can continue (at gradually reducing rates, and times), the speed at which the beach and its use shrinks will vary with the type of seawall involved. The council-proposed rubble mound revetment (Options 2 and 3) will result in immediate loss of most of the beach in winter. Vertical seawall designs (Options 6 and 7) only have a two to three metre footprint, but their design means that the rate of sand erosion is faster than with a rubble mound revetment once erosion has reached the seawall – though this is offset by the fact that it will take longer for erosion to reach a vertical seawall than rubble mound or Seabee seawalls.

Options with a seawall plus beach replenishment are likely to prolong beach use compared to seawall-only options. However, rising sea levels means that by 2064 the value of the beach for recreation will be similar to seawall-only options.

It is not clear which design will lead to full beach loss the fastest, but it is expected that the beach area will be all but lost by 2064. The loss of the beach will impact negatively on beach users (visitors and the local community), local businesses and property values.

Options 3, 5, and 7 propose seawalls accompanied by beach nourishment as a means of restoring the lost beach. However, a potential terrestrial sand source for nourishment for Wamberal beach was not identified in available documentation. An assessment of offshore sand sourcing concludes that sand replenishment is not a financially feasible strategy for restoring this beach. This CBA considered a number of sand replenishment options currently available for implementation. However, alternative sources of sand may be feasible in the future and replenishment costs may change as a result.

Physical impacts on properties (Option 8)

Option 8 consists of a range of actions for managing the duration, type and intensity of future property development in the coastal hazard area. It includes modifying current development controls requiring developments in the hazard area to be piled, with requirements for new developments to be demountable/ moveable. Option 8 places restrictions on the size, nature, location and risk exposure of new, and existing developments in the hazard zone.

Option 8 is expected to have the following impacts on properties:

- Restrictions on development in the buffer zone of properties in the hazard zone
- all structures in the hazard zone receiving development consent will need to be built/rebuilt as demountable or relocatable structures;
- development consent will lapse and structures must either be moved back, relocated or demolished; once the erosion line specified in planning instruments reaches the developable area of the property in question.

- when a development consent lapses, a new consent is required subject to a revised (risk) assessment of the property's developable area and buffer zone.
- Prospective buyers of properties in affected areas must be advised of the risks associated with that land.
- A legal structure built before the introduction of the planned retreat policy, can only be used for its intended purpose while it is safe to do so and can be serviced.
- Unapproved structures will be removed.

Physical impacts on beach use (Option 8)

Planned Retreat would allow the continued use of the beach over the period of analysis by visitors and the local community, albeit given beach reduction from recession and sea level rise at the rates predicted in the modelling as outlined in Section 2.

5. Economic analysis of costs and benefits of management options

5.1. Types of costs and benefits considered

This CBA considers the following types of costs and benefits associated with each option:

- Construction
- Maintenance
- Property values
- Beach users and visitor related businesses

As noted above, Option 1 represents a continuation of the existing approach of no specific interventions to prevent the impacts of coastal processes on beachfront properties (i.e. the status quo). The physical impacts of this approach on Wamberal beach are the same as the modelled forecasts, as they are both based on the assumption of a continuation of current conditions.

As Option 1 represents a situation of no intervention, for the purposes of the CBA, Option 1 represents the Base Case²⁰ against which the relative costs and benefits of Options 2-8 should be compared.

Engineering/construction costs (Options 2-7)

This section considers the construction and engineering costs associated with seawalls and revetments. As Option 8 does not involve structural engineering costs, Option 8 costs are not included in the following section, but considered separately below. (Option 1, being the base case of no intervention, also does not involve any construction and maintenance costs).

It is assumed that these costs will accrue to the community of the LGA.²¹

The major differences in the revetment design options considered in the CBA are the costs associated with the different designs of the proposed seawall, and the recreational use values of the beach. For example, although a rubble mound has a lower capital cost than the other types of revetment considered in this analysis, its design footprint means that it will take up a larger area of beach than the other structures, with a consequent cost from loss of recreation and other non-consumptive uses.

The most expensive options are the Seabee Options 3 and 4 with an expected capital cost of \$20.5 m, and the least expensive designs are the Rubble mound Options 2 and 3 with an expected \$16.6m capital cost.²² Table 6 summarises the costs of the various designs.

²⁰ i.e. 'The counterfactual' situation representing what would happen in the absence of options 2-8.

²¹ The subject of how Council on behalf of the community obtains funds for, and finances, these construction and maintenance works is not considered in this report.

²² Construction of a revetment will also generate costs to beach users with the loss of the beach for recreation and other uses, and associated loss of trade for local visitor-related businesses, as discussed in Section 5.1.4.

Table 5: Summary of Type of Revetment, Costs, Beach condition, and design features (base and height)

	Rubble mound Options 2,3	Seabee Option 3,4	Vertical Option 5,6
Capital Cost	\$16,106,909	\$20,543,688	\$19,007,975
Maintenance Cost	\$402,673	\$308,155	\$285,120
Transport impacts	\$0	\$96,000	\$96,000
Base	17.5 m	13 m	?
Height	6.75 m AHD	6.5m AHD	8.0m AHD

Rubble mound revetment (Options 2 and 3)

Table 6 7 provides summary costs of the main items used in estimating the costs of Options 2 and 3. The main items influencing costs are as follows.

A rate of \$32/tonne was applied for the supply of basalt in 1998. Boral Seaham Quarry near Newcastle quotes \$79/tonne plus GST for armour rock and Boral Peats Ridge Quarry near Gosford quote \$52.50/tonne for secondary armour. These rates have been used in the costing.

Preparatory earthworks, which entail the removal of sand and other materials to trim the dune face in preparation for the placing of rubble mound seawall materials, requires some 175,000 m³ to be rehandled. All sand excavated will be placed back on the beach.

The total amount of rock required is almost 91,000 tonnes. All the rock will need to be transported via road to Wamberal beach. It is likely that storage and rehandling will need to be undertaken at both the Terrigal and Wamberal Lagoon ends of the beach. Materials will then need to be transported to the works area by off-road equipment.

The wave reflecting recurved wall requires some 1,900 tonnes of concrete, which equates to about 100 to 150 concrete trucks accessing the beach road.

With Option 3, the sand volume required for an initial beach nourishment is for 300m³/m length of beach, which equates to 405,000 m³ for the full length of the beach.

The sand volume required for subsequent renourishment is for 300m³/m length of beach, which equates to 405,000 m³ for the full length of the beach. Overall costs of nourishment, including mobilisation and operating costs using a dredge to access sand from offshore are estimated at approximately \$23/m³. This estimate is based on the advice of an independent dredging consultant, [REDACTED] for undertaking the beach nourishment as a one-off project.

Table 6: Summary cost estimates for Options 2 and 3

Item	Notes	Cost
Option planning	Includes detailed design, community consultation, DA, tendering, project management. Costs are over four years.	\$420,000
Construction	Includes site works, materials, supervision, transport, contingency	\$16,106,909
Maintenance	Annual costs @ 2.5% of construction cost	\$402,673
Transport impacts	Impact of transport on local roads during construction	\$96,000
Beach nourishment	Initial nourishment, Option 3	\$9,315,000
Renourishment	Subsequent renourishments, every 10 years, Option 3	\$2,875,000

Seabee revetment (Options 4 and 5)

Table 7 provides summary costs of the main items used in estimating the costs of Options 4 and 5. The main items influencing costs are as follows.

Preparatory earthworks, which entails the removal of sand and other materials to trim the dune face in preparation for the placing of rubble mound seawall materials, requires some 122,225 m³ to be rehandled. All sand excavated will be placed back on the beach.

The wall is constructed from about 40,600 concrete blocks, each of which costs \$12.60.

The concrete required for the wave return is about 2,000 m³ at \$1,050/ m³.

The total amount of rock required for secondary armour is approximately 12,600 tonnes.

Under Option 5, the sand volumes required for an initial beach and subsequent beach nourishments are the same as for Option 3.

Table 7: Summary cost estimates for Options 4 and 5

Item	Notes	Cost
Option planning	Includes detailed design, community consultation, DA, tendering, project management. Cost are over four years.	\$420,000
Construction	Includes site works, materials, supervision, transport, contingency	\$20,543,688
Maintenance	Annual costs @ 1.5% of construction cost	\$308,155
Transport impacts	Impact of transport on local roads during construction	\$96,000

Beach nourishment	Initial nourishment, Option 5	\$9,315,000
Renourishment	Subsequent renourishments, every 10 years, Option 5	\$2,875,000

Vertical seawall (Options 6 and 7)

Table 8 provides summary costs of the main items used in estimating the costs of Options 6 and 7. The main items influencing costs are as follows:

- Preparatory earthworks require some 39,945 m³ to be rehandled.
- The wall is constructed from about 15,000 concrete piles, each of which costs \$560.
- The concrete required for the wave return is about 934 m³ at \$1,050/ m³.
- The construction time is likely to be over 1 year (391 days of supervision and survey). As with Options 2-5 it may be necessary to stage the works over two years.
- Under Option 7, the sand volumes required for an initial beach and subsequent beach nourishments are the same as for Option 3.

Table 8: Summary cost estimates for Options 6 and 7

Item	Notes	Cost
Option planning	Includes detailed design, community consultation, DA, tendering, project management. Cost are over four years.	\$420,000
Construction	Includes site works, materials, supervision, transport, contingency	\$19,007,975
Maintenance	Annual costs @ 1.5% of construction cost	\$285,120
Transport impacts	Impact of transport on local roads during construction	\$96,000
Beach nourishment	Initial nourishment. Option 7	\$9,315,000
Renourishment	Subsequent renourishments, every 10 years, Option 7	\$2,875,000

Maintenance and other infrastructure costs (Options 2-7)

As well as the construction costs incurred under Options 2-7, there will be potential costs associated with options which include beach sand nourishment. Under Options 3, 4 and 6, Council would renourish the beach at an initial cost of \$9,315,000, with renourishment expected to cost \$2,875,000 every 10 years.

Reconnection of services to homes impacted by coastal recession would not occur under Options 2-7 (revetment options).

The probability of coastal recession impacting Ocean View Drive (which runs behind the first row of houses at Wamberal) is highly unlikely under all options, and would only occur in the event of dune breakthrough which is modelled as having a very low probability of occurring (see Section 2).

Under all options, Council would continue to open the lagoon on a regular basis, and would continue under the same assumptions made in Option 1.

Planning & implementation, monitoring, and relocation costs (Option 8)

As noted above, Option 8 does not involve structural engineering costs. The main items influencing the costs of Option 8 (which do not occur under Options 2-7), relate to option planning and implementation, monitoring, relocation costs and construction of demountable buildings. These costs are discussed below.

- It is assumed that one additional unpiled beachfront property within the hazard zone will require a development application (DA) each year (approximately 2% of the housing stock). However, instead of the buildings on these properties being redeveloped as piled houses, they are redeveloped as demountable houses.
- Remaining properties will continue to be used for their currently approved use while it is safe to do so.
- Based on the above assumptions, it is anticipated that by the end of the 50-year period of this assessment, approximately 50 beachfront properties will have been redeveloped as demountable structures.

Table 9 provides summary costs of the main items used in estimating the costs of Option 8.

Table 9: Summary costs for Option 8

Item	Notes	Cost
Option planning & implementation	Includes design, community consultation, planning scheme amendments. Costs are over three years.	\$155,000
Monitoring	Annual costs	\$5,000
Relocation costs	Cost of relocating demountable houses, per house. Includes transport, restumping, finishing, permits and contents removal	\$46,200
Construction	Additional construction costs of a demountable house relative to a fixed house	-

Beach use and visitor-related business costs (Options 2-8)

As noted above, Options 2--7 will lead to a loss of the beach with associated impacts on beach use by residents and visitors, and reduced trade for visitor-related businesses. Option 8 will also lead to reduced beach use and trade, but at a gradual rate as the beach is affected by coastal erosion, recession, and sea level rise processes over time.

The economic value of visitation and visitor-related businesses at Wamberal Beach can be estimated by valuing consumer surplus for recreation use of the beach for visitors and producer surplus for the

value of visitor-related businesses. Consumer surplus is an economic measure of the difference between the total amount that consumers are willing and able to pay for a good or service (e.g. a visit to the beach), and the total amount that they actually pay (see Glossary).

Producer surplus is a measure of the difference between the amount a producer of a good or service (e.g. a tourism service provider) receives, and the minimum amount the producer would be willing to accept for the good. The surplus amount is the economic benefit received by the producer for selling the service.

Estimating the consumer surplus for beach visitation and the producer for visitor-related business involves three types of information:

Visitation and expenditure data

Data on numbers of visits to Wamberal beach by residents and non-residents and their estimated of expenditure is shown in Table 4.

It is important to note that because the geographic boundary of this analysis is the Central Coast Shire (rather than NSW), consumer surplus associated with non-residents is outside the scope of the analysis. However, the consumer surplus of residents visiting Wamberal beach is in scope, as is the producer surplus resulting from expenditure with local businesses by non-resident visitors to Wamberal beach.

Consumer surplus estimates

Consumer surplus associated with travel by residents to Wamberal beach was estimated as the cost and time associated with going to Wamberal beach compared to the additional cost and time associated with going to the nearest comparable alternative beaches. The alternative beaches are assumed to be a combination of North Avoca, Copacabana & Foresters beaches.

Consumer surplus is an economic measure of the difference between the total amount that consumers are willing and able to pay for a good or service (e.g. a visit to the beach), and the total amount that they actually pay (see Glossary). Consumer surplus relating to beach use was estimated by comparing the cost and time incurred by visitors outside the area travelling to Wamberal beach, with the cost and time associated with going to the nearest comparable alternative beaches (see Table 11). The alternative beaches are assumed to be a combination of North Avoca, Copacabana & Foresters beaches. Estimates of the cost and time involved in accessing Wamberal beach compared to the alternatives are provided in Table 11.

Table 10: Time and cost associated with visiting Wamberal beach compared to the nearest comparable alternatives

	Wamberal	Alternative beaches
Travel by walking (%)	50%	0%
Travel by car (%)	50%	100%
Average return travel distance walking (kms)	1.8	0
Average return travel time walking (mins)	27.0	0.0
Average return travel distance driving (kms)	5.0	15.0

Average return travel time driving (mins)	7.5	22.5
Opportunity cost of time walking (c/min)	13.8	13.8
Opportunity cost of time driving (c/min)	47.7	47.7
Vehicle running costs (c/km)	17.7	17.7
No. people per vehicle	2.5	2.5

Producer surplus estimates

Producer surplus resulting from expenditure with local businesses by non-resident visitors to Wamberal beach was calculated drawing on an estimate of total expenditure by the non-resident visitors. Producer surplus was calculated as the profit margin on that expenditure, with estimates on the breakdown of different types of expenditures and margins being sourced from ABS and Tourism Research Australia (TRA) data (see Table 11).

Producer surplus is a measure of the difference between the amount a producer of a good or service (e.g. a tourism service provider) receives, and the minimum amount the producer would be willing to accept for the good. The surplus amount is the economic benefit received by the producer for selling the service. Producer surplus will be relevant to the economic impacts on visitor-related businesses from reduced beach use.

Producer surplus relating to local visitor-related businesses is expressed as the profit margin on total expenditure by non-resident visitors to Wamberal beach.

Table 11: Profit by industry (%) and associated margins (%) associated with expenditure by non-resident visitors to Wamberal beach

Industry	Proportion of expenditure (%)	Average margin (%)
Fuel retailing	6%	2.4%
Other retail	17%	5.4%
Food, drink and accommodation	77%	10.5%

Sources: ABS 2015, TRA 2015

Changes to consumer and producer surplus relating to beach use

Under Option 1 (the Base Case) and Options 2-8 Wamberal beach recreation and visitor-related business activity are expected to change over time due to coastal processes, compared to today.

Changes to consumer surplus and producer surplus were estimated by developing an ‘Amenity Factor’ for all the options, with One (1) representing the level of beach recreation and related values at present. Changes to visitation relating to relative loss/ change of beach access under the different

options are expressed as deviations from this value of One (1), with a score of Zero (0) representing a complete loss of beach use and related activities under Options 2, 4 and 6 (seawalls without sand nourishment).

These 'amenity factors' were then applied proportionately to producer and consumer surplus estimates to identify the likely loss of consumer surplus (for visitors) and producer surplus (for businesses) over time, between 2016 and 2034 and 2066 under Options 1-8 (see Table 13).

Visitation to Wamberal beach is expected to decline over time due to coastal processes. Under Option 1 Wamberal beach is expected to lose recreational use gradually over the long-term time. Loss of visitation is likely to worsen under Options 2, 4 and 6, and especially under Option 6 (vertical wall), compared to the Option 1 (the base case). However, if options include beach nourishment (as in Options 3, 5 or 7), the loss of visitation will be reduced, and in the very long term Options 3, 5 and 7 may even lead to more available beach area than under Option 8 or Option 1. Option 8 (planned retreat) is likely to result in marginally better beach amenity than Option 1 in the long term.

Visitor-related business is expected to respond to the above expected changes in availability of beach area for recreation under the different options, with relatively greater loss under Options 2, 4 and 6 (seawalls without nourishment) than under other options.

Table 12: Summary of impacts on beach use and other non-consumptive values

Option	Description of beach and dune condition	2034 amenity		2066 amenity	
		Description	Amenity factor	Description	Amenity factor
1. Base case	Beach may lose a significant quantity of sand during winter storm season, but over summer will recover providing reasonable to good beach amenity in the medium term (i.e. to 2034). Clean-up after storms may be required to maintain amenity. In the longer term shoreline recession due to SLR results in dunes migrating landwards. Beach remains at toe of dune, but may narrow with loss of access at high tide, especially after storms.	Minor loss of amenity	0.9	Moderate loss of amenity	0.75
2. Rubble mound	The rubble mound structure will be intrusive resulting in a significant loss of beach amenity. In the medium term, the beach may lose significant quantity of sand during the winter storm season but over summer will recover, providing reasonable beach amenity. In the longer term, in the absence of beach nourishment, the toe of the seawall will be exposed most winters and it is likely that a full beach recovery will not occur most years, i.e. beach amenity will be negligible over winter and may be limited over summer.	Significant loss of amenity	0.5	Substantial loss of amenity	0.25
3. Rubble mound + nourishment	As per Option 2 but nourishment will limit loss of amenity. Note, nourishment will need to be ongoing in order to maintain the same amenity factor in 2066 as in 2034.	Moderate loss of amenity	0.75	Moderate loss of amenity	0.75
4. Seabee	Initially less intrusive than Option 2. This combined with a loss of sand over time, similar to Option 2, means that winter and summer amenity will remain somewhat better than under Option 2.	Moderate loss of amenity	0.75	Significant loss of amenity	0.5
5. Seabee + nourishment	As per Option 4 but nourishment will limit loss of amenity. Note, nourishment will need to be ongoing in order to maintain the same amenity factor in 2066 as in 2034.	Minor loss of amenity	0.9	Minor loss of amenity	0.9
6. Vertical wall	Initially less intrusive than Option 2, as the seawall will be set back. Over time however, loss of sand during winter could be greater and recovery over summer slower than Option 2, resulting in similar loss of winter and summer amenity in the longer term.	Moderate loss of amenity	0.75	Substantial loss of amenity	0.25

7. Vertical wall + nourishment	As per Option 6 but nourishment will limit loss of amenity. Note, nourishment will need to be ongoing in order to maintain the same amenity factor in 2066 as in 2034.	Moderate loss of amenity	0.75	Moderate loss of amenity	0.75
8. Planned retreat	Similar to Option 1 except that there will be greater scope for maintaining access and amenity in the longer term.	Minor loss of amenity	0.9	Minor loss of amenity	0.9

Amenity factors: 1=full amenity (relative to present); 0.9 = minor loss of amenity; 0.75 = moderate loss of amenity; 0.5 = significant loss of amenity; 0.25 = substantial loss of amenity; 0 = complete loss of amenity

5.2. Benefits

The relative benefits of Options 1-8 relate to the impacts of the options on beach front and other properties in the area and their market values.

Property effects (Options 2-8)

Benefits as avoided damage costs (Options 2-8)

Each of the infrastructure options (Options 2 to 7) is expected to prevent coastal processes damaging beachfront properties and other built assets at Wamberal beach for the whole period of the analysis (i.e. to 2065). All costs associated with these impacts (including loss of unpiled buildings, loss of premium value of land, maintenance costs of piled buildings and loss of dune values) will be avoided under Options 2 to 7. (i.e. in this case an avoided cost represents a benefit).²³

Under Options 2-7 benefits will accrue to beach front property owners because they will not need to incur costs related to the loss of parts of their property to coastal processes. Avoided costs (i.e. benefits) will accrue to owners of both unpiled and piled buildings.

Unlike Options 2-7, Option 8 will not reduce the impacts of coastal processes on beach front properties on their land values relative to Option 1 (the base case of no management intervention). Option 8 will however, provide some benefits in the form of avoided costs, such as reduced costs of maintaining dunes under piled houses, and avoided costs for reconnecting services to piled houses, compared to the Option 1. Avoided dune maintenance and service restoration costs in the future will apply to those properties that are redeveloped with demountable structures rather than piled structures. Avoided costs will vary from year to year depending how many properties are exposed to coastal processes, from approximately \$80,000 to 500,000/ year. (As noted above these maintenance and reconnection costs under Option1 do not occur under options 2-7).

Benefits as avoided short term loss of property values (Options 2-7)

Under Options 2-7 beach front property owners will not experience the reduced value of their built asset that would occur under Option 1 and Option 8.²⁴ (Under Option 8, loss of land and associated costs will still occur, but part of the costs associated with loss of their built asset will be avoided compared to Option 1, as loss of property to coastal processes will be part of a managed process under planned retreat (Option 8) rather than unplanned, as under Option 1).

A significant proportion of the market value of properties on Wamberal beach relates to their proximity to the beach, i.e. a 'coastal premium value'. This coastal premium value would be impacted by coastal processes, since there are constraints on the availability of coastal land within the LGA, i.e. there is no coastal greenfield land on which development could take place in the future. It is possible that hinterland properties near Wamberal beach, and other coastal properties, could attract a higher premium in the longer term due to the loss of coastal properties at Wamberal beach, this is unlikely within the timeframe of the CBA.

²³ NB the study has not estimated the impact of options on the value of crown land (i.e. land between high tide mark and seaward the boundaries of private property).

²⁴ Beach front property owners may experience declining asset values for the other reasons.

By protecting properties from coastal processes in the short-term, Options 2-7 will provide a benefit to property owners by reducing the loss of property value that would occur under Options 1 and 8, which do not provide such levels of protection.

Appendices 2-4 provide detailed and comprehensive explanations of the relationship between the modelled impacts of coastal processes and changes to property values under different rates of coastal process. This information was used to model the relative impacts of different options on properties and property values, and to estimate the economic impacts (benefits and costs) of the different options on properties.

The CBA suggests that the major benefits of the proposed seawall options for Wamberal Beach (Options 2-7) will accrue to Wamberal beach property owners. Some benefits will occur under Option 8 from avoided dune maintenance and service restoration costs, compared to Option 1.

6. Results of the cost-benefit analysis

Table 14 and Figure 6 present results of the CBA. Option 8 (planned retreat) has an estimated NPV of \$1.1 million over the period of the analysis (2017-2066) and a BCR of 5.0, and is therefore expected to deliver a net benefit to society relative to Option 1 (the base case). These findings are based on a range of assumptions which are discussed and tested in Section 6.1.

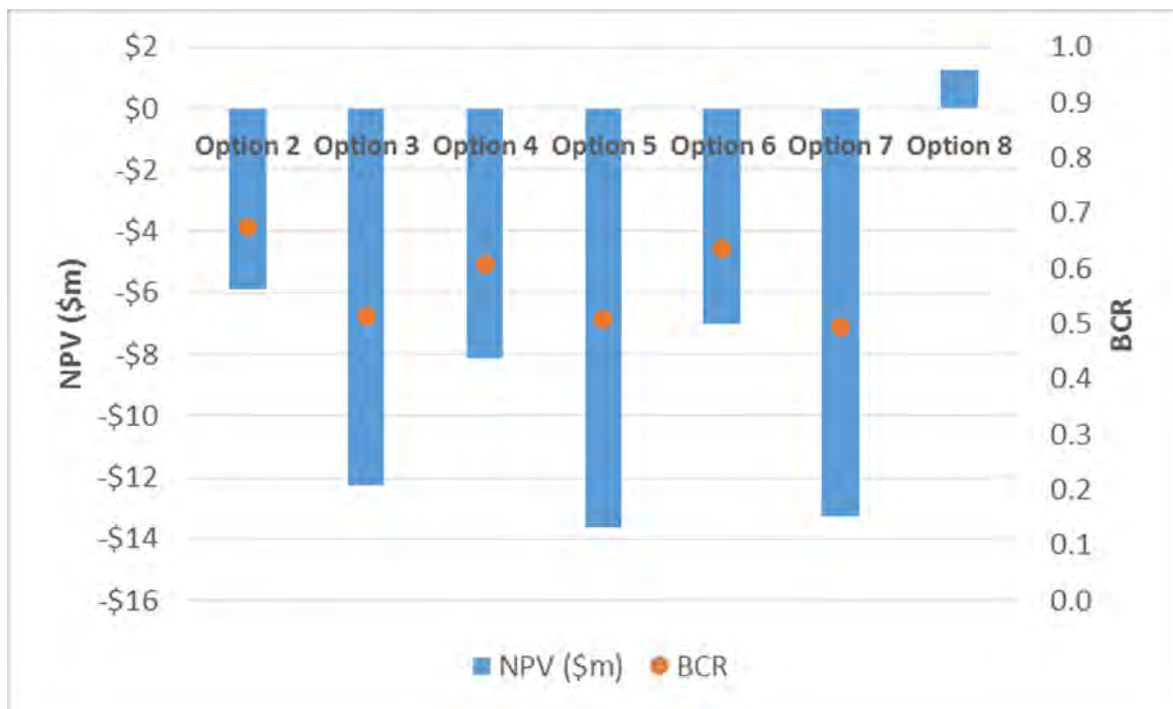
Options 2 to 7 (infrastructure options) have negative NPVs and BCRs of less than 1 suggesting that none of those options are likely to deliver net benefit relative to the status quo to society based on central assumptions adopted in the study. All the options with beach nourishment (Options 3, 5 and 7) have worse outcomes than the options without nourishment because of the very high cost associated with beach nourishment.

Table 13: Summary of results of the Cost-benefit Analysis

Option	BCR	NPV
Option 1 (base case): “Business-as-usual” conditions at Wamberal beach if none of the proposed management options are implemented.	Base case	Base case
Option 2: A rubble mound revetment	0.70	-\$5.378 m
Option 3: A rubble mound revetment combined with beach nourishment	0.54	-\$11.688 m
Option 4. A Seabee revetment	0.55	-\$9.217 m
Option 5: A Seabee revetment combined with beach nourishment	0.49	-\$14.23 m
Option 6: A vertical seawall	0.49	-\$9.79 m
Option 7: A vertical seawall combined with beach nourishment	0.47	-\$13.975 m
Option 8: Planned retreat by managing the duration, type and intensity of future development within the coastal hazard area	5.03	\$1.178 m

The relative NPVs and BCRs of the options are shown below, clearly showing the difference between Option 8 with an NPV of \$1.17m, and BCR of 5, and the other options.

Figure 6: Visual representation of the results of the cost benefit analysis



Detailed information on CBA findings is given in Appendix A6.

As discussed in Section 4, infrastructure Options 2, 4 and 6 are likely to accelerate deterioration of the condition of the beach that will also occur under Option 1. This will have negative impacts on recreational and other non-consumptive uses of the beach (which are included in the results). Infrastructure options involving beach nourishment (Options 3, 5 and 7) are likely to significantly mitigate the adverse impacts of the infrastructure on the beach, but could also entail environmental impacts associated with off-shore dredging. Option 8 (planned retreat) is likely to have a small positive impact on beach values relative to Option 1.

7. Sensitivity testing

7.1. Sensitivity testing

Sensitivity analysis has been used to test assumptions which may have the potential to significantly affect the findings of an analysis. This has been done for the present CBA by developing ‘high’ and ‘low’ cases which modify the ‘central case’ assumptions used in the CBA (see Table 15).

Table 14: Sensitivity Analysis high and low cases

Variable	% change relative to ‘most likely’ (central) case	
	High case	Low case
Land value (coastal premium)	+50%	- 50%
Built asset value	+20%	-20%
Capital and operating costs of protection infrastructure (Options 2-7)	-25%	+25%
Beach nourishment costs (Options 3,5,7)	-25%	+25%

The new assumptions made under the high and low cases are significantly different from those of the central case. If the central case is sensitive to changing assumptions, it is expected that the new estimates being made under the high and low cases would also show significant differences from those under the central case.

Re-estimated NPVs and BCRs for the options under the high and low cases compared to the central case are shown in Table 16.

The results show that even with large changes to the original BCA assumptions about land and built asset values and construction and operating costs under the high and low cases, there is little effective change to the overall findings of the CBA.

Option 8 is the only option with both a BCR greater than one and a positive NPV, under all three cases (i.e. the high, low and central case). All other options have either a BCR no greater than one, and/ or a negative NPV, in at least two cases.

Apart from Option 8, the only option to achieve a NPV more than close to zero and a BCR greater than 1, is Option 2 under the high case. However, for Option 2 to provide a positive NPV and BCR, it would be necessary for land value to increase by 50%, built asset value to increase by 20%, and seawall capital and operating costs to decrease by 25%, and beach nourishment costs to decrease by 25%.

It is understood that it would be highly unlikely for these events to occur in combination. Thus, it can reasonably be concluded that the assumptions used in the CBA, and the estimated NPVs and BCRs based on these assumptions, are sufficiently robust and defensible. Option 8 remains the only option to provide a net economic benefit to the community.

Table 15: Results of ‘high’, ‘low’ sensitivity analysis - a) Central case, b) High case and c) Low case

a) Central case			b) High case			c) Low case		
	NPV (\$m)	BCR		NPV (\$m)	BCR		NPV (\$m)	BCR
Option 2	-\$5.4	0.70	Option 2	\$3.4	1.25	Option 2	-\$14.4	0.36
Option 3	-\$11.7	0.54	Option 3	-\$1.5	0.92	Option 3	-\$22.0	0.29
Option 4	-\$9.2	0.55	Option 4	\$0.2	1.01	Option 4	-\$18.9	0.27
Option 5	-\$14.2	0.49	Option 5	-\$3.5	0.84	Option 5	-\$25.3	0.26
Option 6	-\$9.8	0.49	Option 6	-\$0.8	0.95	Option 6	-\$19.1	0.20
Option 7	-\$14.0	0.47	Option 7	-\$3.6	0.82	Option 7	-\$24.6	0.24
Option 8	\$1.2	5.03	Option 8	\$1.2	5.32	Option 8	\$1.1	4.78

Proportion of properties owned outside of the LGA

Another factor which can influence the CBA is the number of properties in the study area which are assumed to be owned by people living outside of the LGA. Under the central case, 32% of properties are assumed to be owned by non-residents. The benefits of implementing options that might otherwise be expected to be realised by these property owners therefore fall outside of the geographic boundaries of the analysis (i.e. Central Coast LGA). However, if it assumed that 100% of properties in the study area are owned by residents living within the Central Coast LGA, then the NPVs and BCRs will be significantly higher for all options though only Option 2 achieves a positive NPV. As shown in Table 17, this assumption influences the findings of the analysis. (This result shows the extent to which the benefits of the options 2-8 accrue to property owners living outside the LGA.) However, it is important to note that the ranking of options does not change under an assumption of 100% local ownership compared to 32% ownership, with Option 8 still clearly having the highest NPV and BCR, and Option 2 having the same NPV, but a BCR of only just above 1.

Table 16: Results of sensitivity analysis with change to number of properties owned outside of LGA

a) 32% of properties owned outside of LGA			b) All properties are owned by LGA residents		
	NPV (\$m)	BCR		NPV (\$m)	BCR
Option 2	-\$5.4	0.70	Option 2	\$2.5	1.14
Option 3	-\$11.7	0.54	Option 3	-\$3.8	0.85
Option 4	-\$9.2	0.55	Option 4	-\$1.3	0.94
Option 5	-\$14.2	0.49	Option 5	-\$6.4	0.77
Option 6	-\$9.8	0.49	Option 6	-\$1.9	0.90
Option 7	-\$14.0	0.47	Option 7	-\$6.1	0.77
Option 8	\$1.2	5.03	Option 8	\$5.7	21.0

Changes to the discount rate

The discount rate used in a CBA can also affect the results of the analysis. A lower discount rate will give greater weight to costs or benefits occurring in the distant future than to those occurring in the near future, while a higher discount rate will give greater weight to costs and benefits occurring in the near future than in the more distant future. Varying the discount rate used in a CBA can lead to a different ranking of options if the options differ in their temporal distribution of costs and benefits.

The BCA has used a reference discount rate of 7% applying a lower discount rate of 4% significantly increases the BCRs of all options, although Options 2 to 7 still have BCRs of less than 1, and the ranking of the options does not change. Conversely, a higher discount rate of 10% decreases the NPV of the options, although Option 8 is still the only option with a positive NPV and a BCR >1 under the different discount rates (see Appendix A6).

8. Distributional Analysis

The economic analysis described in Section 6 has identified costs and benefits of different options for managing coastal processes affecting Wamberal beach. This section considers the distribution of these costs and benefits among different stakeholders in local community. Cost and benefits of options relate to the differential impacts of construction and maintenance, beach access, property values, and visitor-related business.

The Stakeholders and the main type of impact they will experience are as follows.

Beach users

Beach users including surfers, walkers, swimmers, and dog walkers will be affected by the loss of beach associated with a seawall under Options 2, 4 and 6, although beach nourishment under Options 3,5, and 7 will mitigate these impacts. Potential loss of the beach will impact those residents in the LGA who do not own properties on the beach front but who use the beach. These impacts will not occur under Option 8.

Visitors to the LGA

Similar impacts to beach users are expected.

Business Owners

The construction of the seawall without nourishment will lead to a temporary loss of producer surplus to business owners in the area. However, as noted in the OEH CBA guidance. The timeframe of the analysis will mean that other businesses may open to replace the beach related businesses and still service the community with non-beach related services and goods. This impact is not expected to occur under Option 8.

Local community

Impacts on the local community predominantly relate to the costs of construction and maintenance, and the effectiveness of the options in preventing the impacts of coastal processes. The local community will also incur costs associated with the loss of the beach under Options 2-7. Costs will be incurred by beach users in particular. For the purposes of the CBA, beach users are treated as a separate category of the local community.

Local Council

Local council impacts are limited to damage to council assets such as Ocean View Drive. Modelling suggests that the presence or absence of a seawall under options 2-8 will have no effect on damage to Ocean View Drive. Damage to Ocean View Drive is more likely to come from flooding in Terrigal Lagoon.

The presence of a seawall under Options 2-7 will reduce the costs to council for reconnection of services to properties that would occur in the absence of the seawall protection under Option 8.

Property Owners on the beachfront

The main impacts on property owners along the beachfront will be the benefits of protection from coastal processes should a seawall be constructed under Options 2-8.

State government

There are approximately five allotments along the beachfront plus the land in front of the surf club that may be protected should a seawall be constructed. The expected value to the State government from protection of these properties by a seawall will be minor compared to the benefits to individual property owners as the state-owned land is undevelopable, and has not been considered further.

8.1. Summary of distributional analysis

The distributional analysis carried out for this study compares the net benefits of Options 2-8 with the base case (Option 1) for different stakeholders. The analysis shows that beach users will be significantly disadvantaged by the increased loss of the beach in front of the seawall under Options 2, 4 and 6. Planned retreat (Option 8) will not have this effect. Visitors and LGA residents to Wamberal enjoy substantial recreational and associated benefits from using the beach, and this benefit will be reduced by the impacts of a seawall which will lead to the loss of suitable beach areas for recreation. Options 3, 5 and 7 will delay the loss of beach through sand replenishment. Beach users will be able to enjoy recreational and associated benefits for a longer period of time compared to seawall-only options. However, the trade-off for this additional benefit is offset by the high costs of sand replenishment.

Property owners may lose direct access to the beach and some non-consumptive uses associated with living by the beach, because of a seawall. However, the presence of a seawall would reduce the potential impacts of coastal processes on their properties. Many of these property owners are likely to live outside the area, and only use their beach front properties as holiday homes and/or holiday rentals (see Figure 7). The 2011 census suggests that 41% of all beachfront properties were not occupied all year at Wamberal beach.

Property owners adjacent to the beach are the largest beneficiaries of the seawall options (Options 2-7). The impacts on the community include changes in recreational use of the beach, and the costs of protection, maintenance and nourishment for those options where they are required. Seawall options with nourishment (Options 3, 5 and 7) will have larger impacts on the community than options without (Options 2, 4 and 6) as nourishment will add extra costs to the overall costs of the option in question.

Relative to Option 1 (the base case of no management intervention), Option 8 provides net benefits to property owners, local businesses, the local community in general and beach users as a specific category of the local community. Property owners are the greatest beneficiaries under Option 8, as their properties will be lost at a slower rate under planned retreat than they would be under Option 1, properties will still retain market value until the time that they can no longer be habitable. There will be little difference in the area of the beach available for recreation and non-consumptive uses between Options 1 and 8 (as shown in the relatively low net benefits for beach users under Option 8 at the 20 and 50 year points, as shown in Tables 18 and 19).

Tables 18 and 19 provide details of the distributional impacts of the options at 20 years and 50 years, using a 7% discount rate to convert figures to today's dollars. Figure 7 and 8 show these impacts graphically, showing the percentage distribution between stakeholders.

Table 17: 20-year distributional analysis at 7 per cent discount rate

Stakeholder	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Property owner	\$10,306,155	\$10,306,155	\$10,306,155	\$10,306,155	\$10,306,155	\$10,306,155	\$300,665
Local businesses	-\$705,020	-\$263,282	-\$266,053	-\$263,282	-\$268,825	-\$263,282	\$98
Council	-\$81,759	-\$81,759	-\$81,759	-\$81,759	-\$81,759	-\$81,759	-\$184,224
LGA Community	-\$16,357,216	-\$22,629,239	-\$19,225,674	-\$25,497,697	-\$17,788,487	-\$24,060,511	\$0
Beach users	-\$174,175	-\$325,128	-\$328,826	\$26,341	-\$332,525	-\$325,128	\$131
Total	-\$7,012,014	-\$12,993,252	-\$9,596,157	-\$15,510,242	-\$8,165,441	-\$14,424,524	\$116,671

Table 18: 50-year distributional analysis at 7 per cent discount rate

Stakeholder	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Property owner	\$13,283,556	\$13,283,556	\$13,283,556	\$13,283,556	\$13,283,556	\$13,283,556	\$1,117,965
Local businesses	-\$1,395,837	-\$401,244	-\$565,475	-\$401,244	-\$729,706	-\$401,244	\$96,974
Council	\$78,385	\$78,385	\$78,385	\$78,385	\$78,385	\$78,385	-\$200,258
LGA Community	-\$17,648,479	-\$24,684,465	-\$20,213,845	-\$27,249,831	-\$18,702,789	-\$25,738,775	\$0
Beach users	-\$225,069	-\$506,926	-\$726,085	\$157,923	-\$945,244	-\$506,926	\$129,407
Total	-\$5,907,445	-\$12,230,693	-\$8,143,464	-\$14,131,211	-\$7,015,798	-\$13,285,003	\$1,144,089

Figure 7: Distributional percentage impacts (negatives represent net costs and positives represent net benefits)

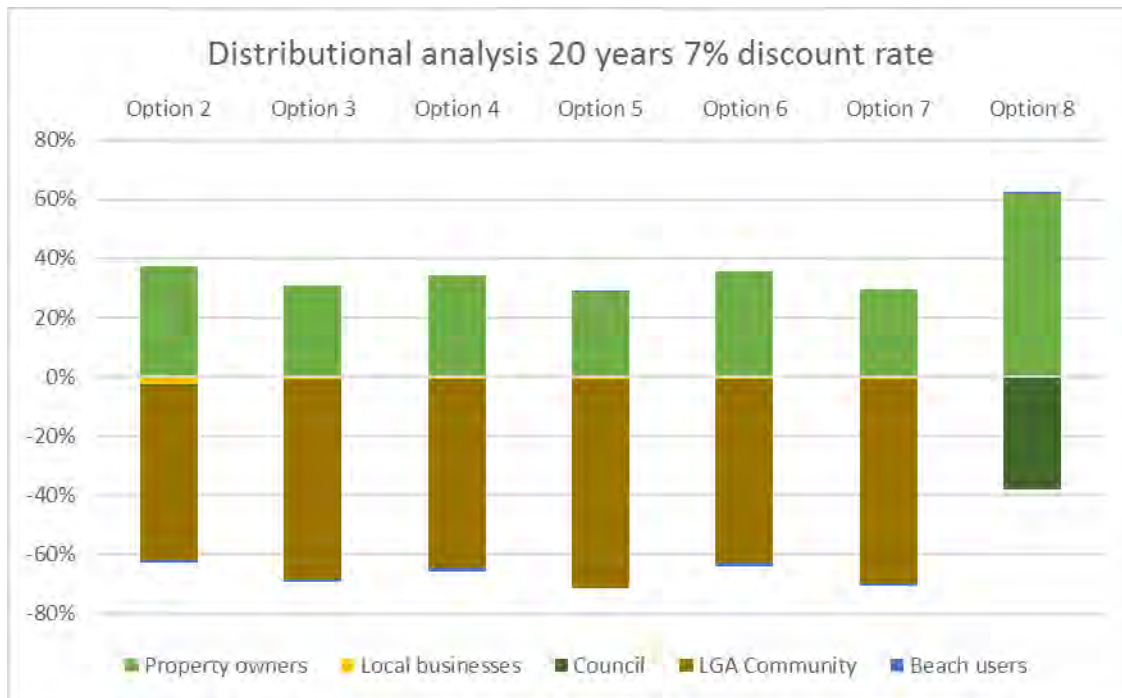
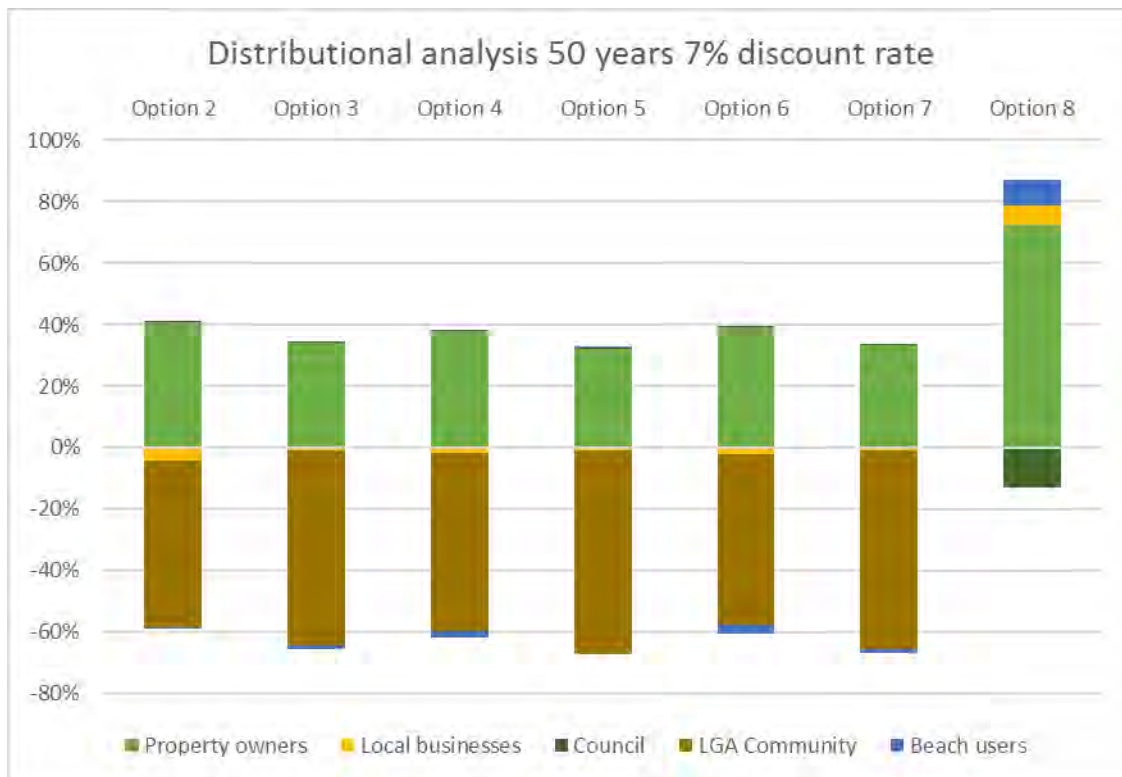


Figure 8: Distributional percentage impacts (negatives represent net costs and positives represent net benefits)



9. Conclusion

Wamberal beach has a history of impacts from coastal processes, with consequential impacts on properties, beach visitation and public infrastructure. Probabilistic modelling of the coastal processes affecting Wamberal beach shows that the impacts of coastal processes such as erosion, deposition, beach recession and sea level rise are complex and interact with Terrigal beach and Terrigal lagoon.

A range of structural engineering approaches have been considered to protect beachfront properties and other infrastructure at Wamberal beach. While surrounding lagoon properties will also be impacted by coastal processes the management options are specific to protecting beachfront properties and provide no benefits to lagoon properties.

This report uses a standard Cost-benefit Analysis (CBA) framework to estimate the direct and indirect costs and benefits of these options which may accrue to a range of key stakeholders. The CBA reports the benefit-cost ratio and the net present value of each option compared to a base case of 'business as usual'²⁵.

The analysis indicates that construction of a seawall will provide benefits to beachfront property owners by reducing the impacts of coastal processes. However, this will come at the expense of adverse impacts on the beach.

The speed with which the beach will be lost will vary with the type of seawall involved. The council-proposed rubble mound revetment (Options 2 and 3) will result in immediate loss of most of the beach in winter. Vertical seawall designs (Options 6 and 7) only have a two to three metre footprint, but their design means that the rate of sand erosion is faster than with a rubble mound revetment. This is offset by the fact that it will take longer for erosion to reach a vertical wall than rubble mound and Seabee walls.

It is not certain which design will lead to full beach loss the fastest, but it is expected that the value of the beach for recreation will be all but lost by 2064 due to sea level rise, regardless of design. The loss of the beach will impact negatively on beach users (visitors and the local community), local businesses and property values.

Options with a seawall plus beach replenishment are likely to prolong beach use compared to seawall-only options. Beach users will be able to enjoy recreational and associated benefits for a longer period of time compared to seawall-only options. This additional benefit is offset by the high costs of sand replenishment. In any case, rising sea levels means that by 2064 the value of the beach for recreation will be similar to seawall-only options.

It is estimated that the loss of the beach for recreation and other enjoyment will lead to fewer beach visits to Wamberal under the seawall options (Options 2-7) compared to the base case (Option 1). Although beach nourishment has been considered as a means of restoring beach areas lost because of a seawall, sand replenishment is not a financially feasible strategy for restoring this beach. This CBA considered a number of sand replenishment options currently available for implementation. However, alternative sources of sand may become feasible in the future and replenishment costs may change as a result.

As well as Wamberal businesses, Terrigal businesses are also likely to suffer, as Wamberal beach acts as an overflow area for visitors to Terrigal beach (the Central Coast's most popular beach) during the

²⁵ In this case, representing a situation with no specific intervention to mitigate the impacts of coastal processes
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peak season. Loss of Wamberal beach will reduce the numbers of visitors to Terrigal, and potentially to the Central Coast.

Although Options 2-7 will provide some protection from coastal processes, they cannot provide protection from all effects. Longer term sea level rise will result in eventual loss of a useable beach, and more frequent flooding from Terrigal lagoon. This flooding will impact on an increasing number of properties surrounding Terrigal lagoon, and negatively affect council assets (such as water, electricity and sewerage) and road access to Terrigal lagoon and beach front properties.

The geotechnical assessment carried out to inform this CBA concluded that a seawall along Wamberal beach will not mitigate the risk of this flooding, but will only mitigate the risk of damage to properties sitting on the Wamberal beach dune. In the case of twenty beachfront properties the extent of damage risk faced is already mitigated due to a building requirement to put down piles to bedrock. Thus, sand can be eroded from underneath these properties during storm events, and will only involve utility reconnection costs.

The CBA suggests that the key beneficiaries from construction of a seawall are the approximately sixty owners of beachfront properties at Wamberal Beach. The trade-off from protecting these beachfront properties with a seawall would be the loss of annual visits due to the loss of the beach. This loss of visitors may create some concern in the wider Central Coast LGA, especially as 41% of the beach-front properties that would potentially be protected by a seawall (at the expense of the beach) are not permanently occupied and 32% are owned by people residing outside the Central Coast LGA.

The CBA shows that of all the options considered, Option 8 is the only option that will provide a net gain in economic welfare for the residents of the Central Coast LGA when compared to a base case of no specific management of beach recession (Option 1). Option 8 has the highest Net Present Value of \$141,213 for twenty years and 1,178,077 for fifty years, and a Benefit: Cost Ratio of 1.61 or 20 years, and 5.03 for 50 years. This result is mainly due to the high value of the recreational and related benefits to the local community which are available under Option 8, but not under Options 2-7.

In summary, the seven engineering (seawall) options considered in this report (Options 2-7) all impose a net economic cost on the community, compared to continuing with the current status quo approach of no specific attempt to prevent the effects of coastal erosion (Option 1). The benefits of the engineering options (Options 2-7) will accrue to beach-front property owners, but are outweighed by their net costs to the wider community. Each of the engineering options has a benefit: cost ratio (BCR) of less than 1 and a negative Net Present Value (NPV).²⁶ The only option with a BCR greater than 1 and a positive NPV is Option 8: Planned Retreat. Therefore, from an economic perspective, the recommended option for management of coastal processes affecting Wamberal beach is the Planned Retreat option, as described in Section 4.3.

As noted above, all options involve a mix of costs and benefits for different stakeholders, and whatever option is chosen for implementation there will be winners and losers. Options 2-7 provide a level of benefits to owners of beach properties, but impose a greater level of costs on beach users, businesses and other sections of the local community. Ideally, benefiting stakeholders are able to compensate those stakeholders that face net costs associated with any option, such that overall no stakeholder is worse off. With respect to the situation at Wamberal, the only option where such re-distribution of benefits could be feasible is Option 8, where a relatively small number of property

²⁶ See Glossary for an explanation of BCR and NPV
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owners affected makes re-distribution practically feasible, as opposed to other options where very large numbers of the community and beach users would need to be compensated.

Glossary

Amenity – In this report, a general term to cover recreational and other non-consumptive uses of the beach, including aesthetic values attached to the existence of the beach.

Beach – The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach, unless otherwise specified, is the mean low water line. A beach includes foreshore and backshore.

Beach erosion – The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind. May occur during storms or with elevated water levels.

Beach profile – A cross-section taken perpendicular to a given beach contour; the profile may include the face of a dune or seawall, extend over the backshore, across the foreshore, and seaward underwater into the nearshore zone.

Benefit cost ratios (BCR) – assess benefits and costs in terms of their relativity to one another. A $BCR < 1$ indicates that the costs outweigh the benefits. A $BCR > 1$, indicates that the benefits of a project outweigh the costs and it is therefore viable, assuming that it also has a positive NPV.

Bruun Rule – a commonly used method for estimating the response of a sandy shoreline to rising sea levels.

Coastal engineering – A branch of civil engineering that applies engineering principles specifically to projects within the coastal zone (nearshore, estuary, marine, and shoreline).

Coastal management terms – Recognise, foster, protect, maintain, restore, enhance, support, acknowledge. These terms provide an indication of the outcome to be achieved, relative to the current state of the environment, access, recreational use and other coastal values.

Consumer surplus is defined as the difference between the total amount that consumers are willing and able to pay for a good or service (indicated by the demand curve) and the total amount that they do pay (i.e. the market price).

Cost–benefit analysis (CBA) is a form of economic appraisal that can be used to estimate changes to the economic wellbeing of local and wider communities. A CBA is used to estimate and compare the costs and benefits of implementing a proposed project or management activity with the costs and benefits of a ‘base case’, which represents a continuation of current conditions under which the proposed project/ policy is not implemented.

Discount rates – are rates used to discount a future stream of welfare/ wellbeing changes, whether they are costs or benefits.

Expected value – the value of a cost or benefit multiplied by the probability of it occurring.

Extreme storm event – Storm for which characteristics (wave height, period, water level etc.) were derived by statistical ‘extreme value’ analysis. Typically, these are storms with average recurrence intervals (ARI) ranging from one to 100 years.

Gabion – Steel wire–mesh basket to hold stones or crushed rock to protect a bank or bottom from erosion; or structures composed of masses of rocks, rubble or masonry held tightly together usually by wire mesh to form blocks or walls. Sometimes used on heavy erosion areas to retard wave action or as a foundation for breakwaters or jetties.

Geomorphology – A branch of physical geography which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.; or the investigation of the history of geologic changes through the interpretation of topographic forms.

Intermittently Closed and Open Coastal Lake or Lagoon (ICOLL) – Coastal lakes and lagoons where the entrance may be closed to the sea from time to time and for varying periods, by accretion of a berm. ICOLLs have sensitive water quality because they accumulate loads of sediment and nutrients from the catchment and may have poor water circulation and flushing. The fifteen highly sensitive waterways listed in the Coastal Management SEPP, and whose catchments are included in the Coastal Environment Area, are all ICOLLs.

Lagoon – A shallow body of open water, partly or completely separated from the sea by a coastal barrier or reef. Sometimes connected to the sea via an inlet.

Net present value – Is the value of welfare changes over time in a cost-benefit analysis, it is discounted to reflect the social opportunity cost of time and alternative social investments.

Outflanking or end effects – Erosion behind or around the land-based end of a groyne, jetty or breakwater or the terminus of a revetment or seawall, usually causing failure of the structure or its function.

Planned retreat is a coastal hazards management approach that acknowledges coastal processes and hazards as ongoing natural phenomena. The long-term recession of parts of the Byron Shire coastline is a dominant factor in planning for the use of coastal areas.

Probabilistic model – Mathematical model in which the behaviour of one or more of the variables is either completely or partially subject to probability laws.

Producer surplus is an economic measure of the difference between the amount a producer of a good receives and the minimum amount the producer is willing to accept for the good. The difference, or surplus amount, is the benefit the producer receives for selling the good in the market.

Revetment or sea wall – A type of coastal protection work which protects assets from coastal erosion by armouring the shore with erosion-resistant material. Large rocks/boulders, concrete or other hard materials are used, depending on the specific design requirements.

Sea level rise – An increase in the mean level of the oceans. Relative sea level occurs where there is a local increase in the level of the ocean relative to the land, which might be caused by ocean rising, the land subsiding, or both. In areas with rapid land level uplift (e.g. seismically active areas), relative sea level can fall.

Welfare economics – the basic concepts underpinning CBA are drawn come from a branch of economics known as ‘welfare economics’. Welfare economics is concerned with the effect of making choices about how scarce resources such as time, labour, money, can be allocated to increase the economic wellbeing of individuals and groups. These parties in aggregate can be defined as ‘the community’.

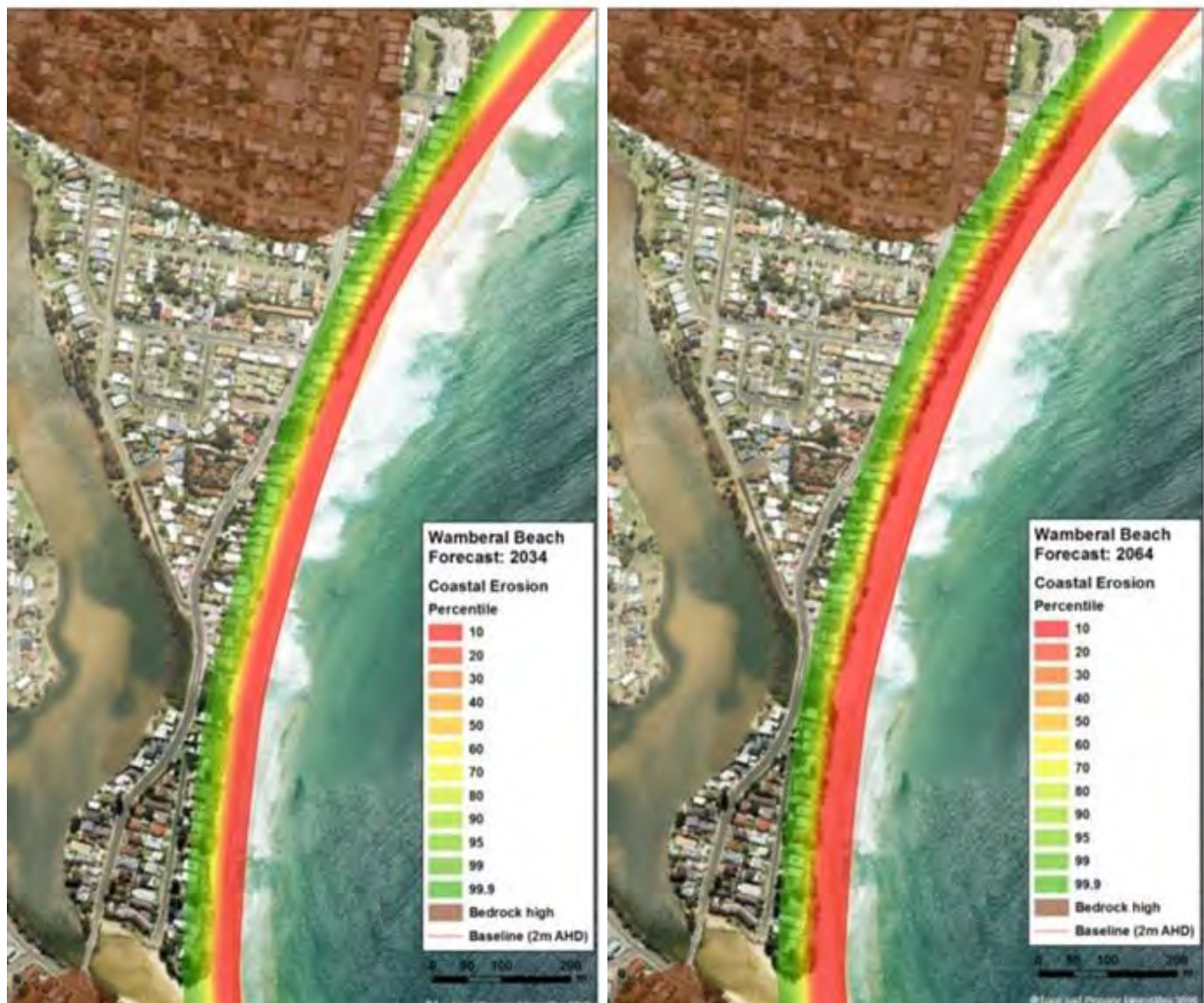
Appendices

A1. Recession profile: Modelling of potential shoreline change at Wamberal beach

In 2016, the Coastal & Marine Science unit of the NSW Office of Environment & Heritage (OEH) completed a *Forecast of Potential Shoreline Change* study of Wamberal beach (OEH 2016). The shoreline change study builds on the *Open Coast and Broken Bay Beaches Hazard Definition Study* completed for Gosford City Council in 2013, which includes Wamberal beach.

The shoreline change study applies a statistical Monte Carlo modelling method to generate forecasts of potential future shoreline change at Wamberal beach in 2034 and 2064 for coastal erosion percentile bands (see Figure 9). These percentile band changes provide the basis for estimating the potential impacts of coastal processes on properties discussed in the study.

Figure 9: Forecast coastal erosion percentile bands, 2034 and 2064



Source: OEH, 2016

A2. Shoreline change and impacts on property

As noted above, modelling of potential shoreline change at Wamberal beach was undertaken by the Office of Environment & Heritage (OEH 2016). The shoreline change study applies Monte Carlo modelling to generate forecasts of potential future shoreline change at Wamberal beach in 2034 and 2064 for coastal erosion percentile bands (i.e. 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99 and 99.9). These percentile band changes provide the basis for estimating the potential impacts of erosion under the base case including:

- loss of coastal premium land values;
- destruction of unpiled houses and commercial buildings;
- loss of building values and costs of maintaining and servicing unpiled houses.
- Costs associated with each of these variables were derived from estimates of:
 - the numbers of properties or buildings impacted in each year;
 - the probability of each property or building being impacted in that year; and
 - the values of the impacted properties (premium land value) or buildings (built asset value) or the cost of maintaining and servicing a piled house.

This is shown by the equation:

$$EV(C) = \sum C_i p_i = C_1 p_1 + C_2 p_2 + C_3 p_3 \dots$$

Where:

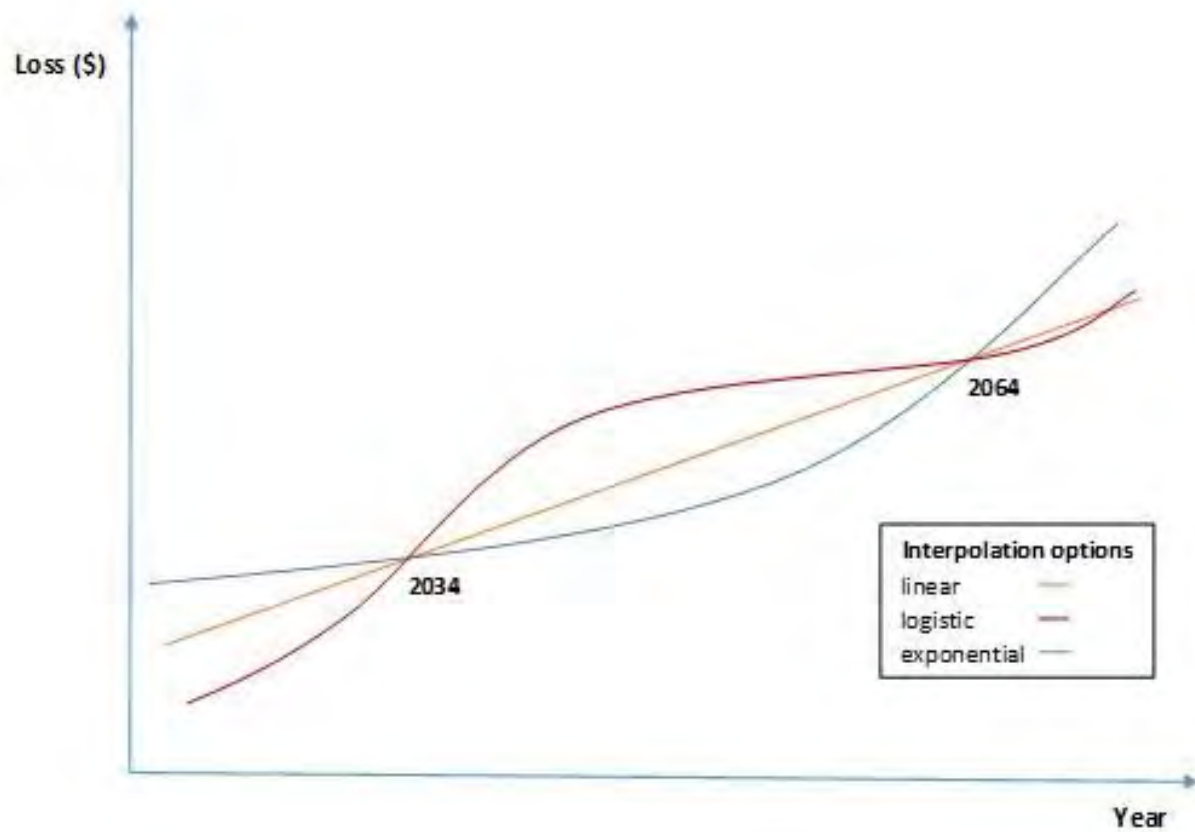
- **C** is the coastal premium land value, value of the built asset (unpiled houses) or maximum maintenance (piled houses);
- **p** is probability of the property or built asset being impacted by shoreline erosion in any one year; and
- **n** is the number of affected properties.

The coastal erosion percentile bands were used to assess the probability of each property or building being impacted, with a probability weighting of 0.1 attached to each tenth percentile band from 10 to 90, 0.05 for the 95th percentile band, 0.04 for the 99th percentile band and 0.009 for the 99.9th percentile band (see snapshot of the probabilities and expected values for 2016).

It is important to note that because coastal erosion percentile bands have been forecast for only two time periods (2034 and 2064), interpolation was applied to estimating the probability of each property being impacted in the intervening years of the analysis (i.e. 2017-2033 and 2035-2063). Consideration was given to applying either an exponential or a logistic ('s') function to derive the interpolated values, reflecting either sea level rise projections (exponential) or the potential impact of shoreline change on properties over the long term. In the end, linear interpolation was selected as the most straightforward approach. By using linear interpolation however, it is possible that the impacts of coastal erosion on properties and buildings under the base case are overstated in the early years of the analysis but understated in the middle years of the analysis.

It is also important to note that, because the impacts of shoreline erosion are essentially one-off impacts, rather than recurring impacts, to avoid double counting, estimates of the costs of impacts on properties in each year are not calculated as the absolute cost of the impacts in that year but as the cost in that year incremental to the previous year.

Figure 11: Possible approaches to interpolating the probability of land being impacted by recession (and associated losses) for years 2016-2033 and 2035-2063



A4. Impacts on coastal premium land values

Much of the market value of residential or commercial land on Wamberal beach stems from the fact that the land is zoned residential or commercial. If that land is lost due to coastal processes, its 'zoning value' is unlikely to be foregone in economic terms because, provided there is not an absolute constraint on land availability within the LGA (and hence property owners are not forced to move away from the LGA), the loss of zoning value to the affected property owners can be expected to be offset by an increase in land values elsewhere within the LGA once additional land is rezoned. This represents a transfer of value of the land from the affected property owners to land developers.

On the other hand, a very significant proportion of the market value of properties on Wamberal beach is bound up in their proximity to the beach, i.e. a 'coastal premium value'. This coastal premium value would be impacted in the event of shoreline erosion, since there are constraints on availability of coastal land within the LGA, i.e. there is no coastal greenfield land on which development could take place in the future. While it is possible that hinterland properties within the vicinity of Wamberal beach and other coastal properties could attract a higher premium in the longer term due to the loss of coastal properties at Wamberal beach, this is unlikely within the timeframe of the analysis.

The coastal premium land value of each property in the study area has been calculated as a proportion of the total unimproved value land value of each property. Hedonic pricing is the method used to calculate the premium. Hedonic pricing is a statistical method that assesses the extent to which specific attributes of a good or service (such as proximity of a property to a beach or a park) adds to its market price²⁷. A separate hedonic pricing analysis of the study area was beyond the scope of this study; thus, a literature review was completed of hedonic pricing studies undertaken in other locations to obtain a suitable hedonic transfer.

Of several Australian and international hedonic pricing studies considered, a study by Anning (2012) of the price premiums of beachfront properties in the Collaroy-Narrabeen area of Sydney is considered the most suitable. Anning's hedonic price analysis, which was applied as part of a broader range of methods to assessing beach values in Sydney, found that risk-free beachfront properties were subject to price premiums of around 264% relative to average properties in the sample area but that properties located in higher risk areas, subject to erosion, had lower but still high premiums of about 130%. Properties within the coastal zone, but not located on the beachfront, attracted a premium of about 75%.

Anning noted that these price premiums are substantially higher than those in the published literature but concluded that this "...can be explained in terms of the exclusivity of beachfront property in the Sydney region" (Anning, 2012, p.294), as well as differences in the samples and methods applied in other studies (e.g. the other studies generally included non-beachfront as well as beachfront properties in their samples). We concur with this conclusion and note also that the 'exclusivity' that applies to Sydney region beachfront properties likely also applies to properties on the Wamberal beachfront. On that basis, but also noting the erosion risk that applies to Wamberal beachfront properties, we have applied a coastal premium value of 130% to beachfront properties in the central (most likely) case. A

²⁷ The basic premise of the hedonic pricing is that the price of a marketed good or service is related to a range of characteristics. In the case of property prices, the hedonic pricing method applies multiple regression analysis to statistically estimate a function that relates property values in a location or region to property characteristics such as, for example, house size, distance to the beach, distance to shopping centres etc.

coastal premium value of 75% has been applied to properties in the study area that are located one street back from the beach (referred to in this study as the ‘beach precinct’).

These percentages were applied to the unimproved land values respectively for beachfront and beach precinct properties to estimate that portion of their total value that can be attributed to their location on or near to Wamberal beach. Estimated in this way, the properties in the study area are estimated to have an average coastal premium value of \$1.1 million per property out of their average total unimproved value of \$2.0 million.

The coastal premium estimates were validated by cross checking the market prices of a sample of properties in the study area with the market prices of comparable, non-beachfront properties in the Gosford region. Nevertheless, a range of alternative premiums have been applied for sensitivity testing (see Table 19).

Table 19: Central, Low and High coastal premium values used in the analysis²⁸

Case	Beachfront properties	Beach precinct properties
Central (most likely)	130%	75%
Low	65%	38%
High	195%	112%

²⁸ Note percentages represent the increase in unimproved value of a property relative to its unimproved value due to its location on, or close to, the beach. For example, if a local property that is located away from the beach has an unimproved value of \$500,000, a property located on the beach but in all other respects having similar attributes (e.g. size, proximity to shops etc.) would have an unimproved value of \$1,150,000 assuming a coastal premium of 130%.

A5. Beach nourishment

The options considered in the analysis include permutations for each nourishment for each of the seawall types considered i.e.:

- Rubble mound (rock) seawall;
- Seabee (concrete unit) seawall; and
- Vertical seawall.

A potential sand source for nourishment for Wamberal beach was not identified in available documentation. Background documents on coastal processes identify that the “storm bite” for a severe 100 year ARI event is 250m³/m length of beach. For Wamberal, this equates to some 340,000m³. The “Beach Sand Nourishment Scoping Study” for Sydney beaches by AECOM (2010) recommends that the initial sand nourishment required for Sydney beaches is that which is equivalent to the beach loss due to a sea level rise of 0.3 metres. The 0.3 metres is composed of 0.2m attributable to sea level rise to 2010 and 0.1m to handle sea level rise over the next 10 years. The overall premise behind these numbers is that sea level rise over a planning period of 50 years is about 0.1m per 10 years and the beach loss attributable to sea level rise can be estimated by the Bruun Rule. The sand volume required for an initial beach nourishment at Wamberal is 300m³/m length of beach which equates to 408,000 for the full length of the beach.

The AECOM (2010) study identifies a cost of \$25/m³ for sand nourishment if a volume of 12 million cubic metres of sand was utilised. Sand sources for Wamberal are expected to be available at similar offshore water depths as that defined for Sydney beaches and a similar costing structure can be expected. However, a sand volume of 408,000 cubic metres would have a significant additional mobilisation loading because very large dredges that can work in water depths more than 25 metres need to be utilised. The effective cost would be \$50 to \$60 /cubic metre. However, it is unlikely that a dredging company would mobilise their large dredges for such a relatively small quantity of sand. So, to undertake beach nourishment from offshore sources it will be necessary to co-ordinate several beach nourishment projects in the Sydney – North Coast area. If such a co-ordination can be achieved, then the cubic metre rate should be able to be reduced.

We have sought the advice of an independent dredging consultant, [REDACTED] to identify the real cost of undertaking beach nourishment at Wamberal beach as a one-off project. His interim advice is that a suitable dredge should be able to be mobilised from the Singapore area at a cost of \$5 million. He is referring to a smaller dredge, say with 3,500m³ hopper capacity but still able to dredge to a depth of up to 35 metres. Such a dredge can be expected to have a draft of up to 7 metres and could readily “rainbow” (spray) the sand from a location in a water depth of 8 metres to the 6m contour. The cost is estimated at \$10/m³. Costs overall therefore, including mobilisation and operating costs, could be approximately \$22-23/ m³ to undertake beach nourishment at Wamberal for a volume of about 400,000 cubic metres of sand.

Options where beach nourishment has been considered have a BCR less than 1 and have negative net present values for the community. This is partly due to the costs of beach nourishment outweighing the recreational use benefits of the beach if the beach is maintained in front of a seawall.

A6. Results of the CBA

Table A6.1 shows the results of the CBA. Option 8 (Planned Retreat) has an estimated NPV of \$1.1 million over the period of the analysis (2017-2066) and a BCR of 5.0 and is therefore expected to deliver a net benefit to society relative to the Option 1 (the base case, or status quo, based on central assumptions about costs and benefits used in the study (see Section 6)).

Options 2 to 7 (infrastructure options) have negative NPVs and BCRs of less than 1, suggesting that none of those options are likely to deliver a net benefit relative to society compared to the status quo, based on the central assumptions used in the study. All the options entailing beach nourishment (Options 3, 5 and 7) will have worse outcomes than the options without nourishment because of the very high cost associated with beach nourishment.

Table 20: Results of the CBA, Options 2 to 8 (Present Value, 2017-2066)

Option 2	NPV (\$2016)
Costs of option	\$18,102,416
Capital cost	\$13,148,036
Maintenance	\$4,500,444
Beach nourishment	\$0
Transport & planning	\$453,937
Benefits/avoided costs of option	\$12,724,382
Avoided impacts on buildings and land	\$13,921,352
Amenity impacts ²⁹	-1,164,601
NPV	-\$5,378,034
BCR	0.70
Option 3	NPV (\$2016)
Costs of option	\$25,138,402
Capital cost	\$13,148,036
Maintenance	\$4,500,444
Beach nourishment	\$7,035,985
Transport & planning	\$453,937
Benefits/avoided costs of option	\$13,469,743
Avoided impacts on buildings and land	\$13,921,352
Amenity impacts	-\$419,240
NPV	-\$11,668,658
BCR	0.54
Option 4	NPV (\$2016)
Costs of option	\$20,667,782
Capital cost	\$16,769,769
Maintenance	\$3,444,076
Beach nourishment	\$0
Transport & planning	\$453,937
Benefits/avoided costs of option	\$11,450,464
Avoided impacts on buildings and land	\$13,921,352
Amenity impacts	-\$2,438,520
NPV	-\$9,217,318
BCR	0.55
Option 5	NPV (\$2016)
Costs of option	\$27,703,768

²⁹ ‘Amenity’ is used here as a blanket term to cover recreational and other non-consumptive uses of the beach, including aesthetic values attached to the existence of the beach.

Capital cost	\$16,769,769
Maintenance	\$3,444,076
Beach nourishment	\$7,035,985
Transport & planning	\$453,937
Benefits/avoided costs of option	\$13,469,743
Avoided impacts on buildings and land	\$13,921,352
Amenity impacts	-\$419,240
NPV	-\$14,234,024
BCR	0.49

Option 6	NPV (\$2016)
Costs of option	\$19,156,726
Capital cost	\$15,516,170
Maintenance	\$3,186,620
Beach nourishment	\$0
Transport & planning	\$453,937
Benefits/avoided costs of option	\$9,362,967
Avoided impacts on buildings and land	\$13,921,352
Amenity impacts	-\$4,526,017
NPV	-\$9,793,759
BCR	0.49

Option 7	NPV (\$2016)
Costs of option	\$26,192,711
Capital cost	\$15,516,170
Maintenance	\$3,186,620
Beach nourishment	\$7,035,985
Transport & planning	\$453,937
Benefits/avoided costs of option	\$12,217,245
Avoided impacts on buildings and land	\$13,921,352
Amenity impacts	-\$1,671,739
NPV	-\$13,975,466
BCR	0.47

Option 8	NPV (\$2016)
Costs of option	\$292,150
Demountable costs	\$91,892
Planning costs	\$200,258
Benefits/avoided costs of option	\$1,470,227
Avoided impacts on buildings and land	\$1,207,824
Avoided amenity impacts	\$262,402
NPV	\$1,178,077
BCR	5.03

As discussed above, infrastructure Options 3, 4 and 6 are likely to accelerate deterioration of the condition of the beach that will also occur under Option 1 (the base case). This will have negative impacts on recreational and other non-consumptive values of the beach (which are included in the results). Infrastructure options involving beach nourishment (Options 3, 5 and 7) are likely to significantly mitigate the adverse impacts of the infrastructure on these values, but could also entail environmental impacts associated with off-shore dredging. Option 8 (planned retreat) is likely to have a small positive impact on beach values compared to Option 1.

A7. Impacts of options for different stakeholders

This appendix is an expanded version of the material in Section 7 on the distribution of the costs and benefits of the different options on a range of stakeholders.

Implications of protection without nourishment Options 2,4,6

Beach users – Local Community

The seawall options without nourishment will have the largest direct impact on non-beachfront property owner residents of the LGA with the potential loss of the beach by 2064. The boundary of the analysis is the LGA and the potential loss of the beach will impact those residents in the LGA who do not own properties on the beach front. This will include surfers, walkers, swimmers, and even dog walkers.

Visitors to the LGA

Visitors to the LGA who visit the beach at Wamberal will also be impacted by the seawall option as they must visit alternative beaches if the wall is constructed without nourishment over the period of the analysis.

Business Owners

The construction of the seawall without nourishment will lead to a temporary loss of producer surplus to business owners in the area. However, as noted in the CBA guidance the timeframe of the analysis will mean that other businesses may open to replace the beach related businesses and still service the community with non-beach related services and goods.

Local Council

Ocean View drive will not be impacted by coastline recession if the wall is not constructed. Flooding of Ocean View drive will not occur under the status quo base case scenario because of coastline recession in the timeframe of the analysis. The flooding is more likely to result from Terrigal Lagoon.

The reconnection of services to properties because of coastline recession will not occur under the protection of properties and is treated as a benefit to council under the revetment options.

Property Owners on the beachfront

The main impacts in terms of benefits of the protection options will flow to property owners along the beachfront. These are direct benefits that flow to the property owners. The value of these benefits is determined by the expected value of the protection their properties will receive should a seawall be constructed. This is the largest group of beneficiaries of the building a seawall. The funding and financing principles developed by the council based on the distributional analysis will need to identify the property owners as the largest group; in the community that benefits.

State government

There are approximately five allotments along the beachfront plus the land in front of the surf club that may be protected should a seawall be constructed. The expected value of these benefits of protection will flow to the state government. These are minor in comparison to the private benefits that individual property owners will obtain from the protection of their properties. This is due to the fact the land value is relatively low as the allotments are currently undevelopable.

Economic implications of protection with nourishment Options 3,5,7

Beach users – Local community

The seawall options with nourishment will not directly impact on non-beachfront property owner residents of the LGA as the beach will be maintained however at relatively high cost to the Council. The boundary of the analysis at the time of the analysis was the Gosford LGA and the potential loss of the beach will not impact those residents in the LGA who do not own properties on the beach front. This will include surfers, walkers, swimmers, and even dog walkers. According to the Marsden Jacob Associates analysis, the amenity value placed on the beach by these recreational beach goers may not outweigh the costs of nourishment. This is due the lack of terrestrial sand sources and costs of off-shore dredging. Access may also be limited given the protection options being considered.

The costs of nourishment may be borne by the entire LGA community but that will be dependent on how the council will fund and finance the nourishment strategy which is assessed in this analysis.

Visitors to the LGA

The seawall options with nourishment will have no impact on visitors to the LGA as the beach will be maintained if the wall is constructed. However, the relatively high costs of nourishment will be borne by the local community. Access may be limited to a degree because of the proposed structure.

Business Owners

The seawall options with nourishment will have no impact on business owners in the area however the relatively high cost of nourishment may be incurred may the local community.

Local Council

The seawall option with nourishment will maintain amenity of the beach for the local community however the costs of nourishment maybe prohibitive.

Property Owners

Property owners under this option will have their properties protected and have the beach maintained in front of their properties. The amenity value of property owners will be capitalised in their property values.

State government

There are approximately 5 allotments along the beachfront plus the land in front of the surf club that may be protected should a seawall be constructed. The expected value of these benefits of protection will flow to the state government. These a minor in comparison to the private benefits that individual property owners will obtain from the protection of their properties. This is due to the fact the land value is relatively low as the allotments are currently undevelopable.

Option 8 Planned Retreat

Beach users – Local community

No impact on beach users from the local community for the period of the analysis relative to the base case. The beach will continue to move landward, however over the period of analysis the recreational use southern portion of the beach may be reduced. This is captured in the base case so there is no change from the status quo.

Visitors to the LGA

No impact on visitors outside the LGA for the period of the analysis relative to the base case. The beach will continue to move landward, however over the period of analysis the recreational use southern portion of the beach may be reduced. This is captured in the base case so there is no change from the status quo.

Business Owners

No impact on business owners relative to the base case.

Local Council

The proposed planned retreat model comprises a series of actions aimed at controlling development to maintain a rolling development-free buffer along the Wamberal beach foreshore. The buffer is designed to accommodate natural coastal processes and reduce the level of risk associated with coastal erosion and inundation to persons, development and infrastructure.

The planned retreat model assessed in this study includes the following features:

- Control of development on land within designated hazard areas for approvals under the provisions of the Environmental Planning and Assessment Act, 1979 via planning controls under Central Coast LEP, DCP's, and the Coastal Zone Management Plan. Controls would include:
- Exclusion of development within the buffer zone of a property - nominally all land within the property boundary that is seaward of the assessed developable area (e.g. land seaward of the 2045 erosion line as detailed in Section 6.2 of the Gosford DCP);
- All the structures receiving development consent are required to be built/rebuilt as demountable or relocatable structures;
- Development consent is subject to a condition that once the erosion line moves within the developable area of the property, the consent lapses and the structure must either be moved back, relocated or demolished; and
- When a development consent lapses, a new consent is required, supported by a revised assessment of the property's developable area and buffer zone.
- Provision of advice to purchasers of property within coastal planning precincts on the hazard risk restrictions associated with that land via issue of Section 149 planning certificates at time of purchase.
- A structure built under earlier approvals processes, prior to introduction of the planned retreat policy, is treated the same as it would be under the base case (i.e. it can continue to be used for its intended purpose while it is safe to do so and can be serviced).
- Removal of unapproved structures.
- Development of supporting planning instruments and policies.

In effect, the proposed model modifies existing development controls, with current controls requiring new developments within the hazard area to be piled, being replaced by a requirement for new developments to be demountable/moveable. Thus, the proposed model is gradualist in nature, which significantly reduces its potential costs but, to some extent, also limits its potential benefits.

Available information suggests that demountable houses are unlikely to be costlier to construct than equivalent sized fixed houses. Indeed, because demountable houses are by their nature 'kit homes' they could be cheaper (e.g. \$1200-1800/ sq. metre compared to \$1500 - \$2200 / sq. metre for an on-site built house with equivalent fittings). This is particularly so, since, under the base case construction of a fixed house will require piling, which entails significant additional costs. On the

other hand, because demountable houses are kit homes they are likely to lose out in comparison to an architect or purpose designed house where a home owner's preference is for a house with bespoke elements.

Property Owners

As with the base case one additional unpiled beachfront property within the hazard area is assumed to seek a development application (DA) each year (approximately 2% of the housing stock). However, instead of the buildings on these properties being redeveloped as piled houses they are redeveloped as demountable houses.

Remaining properties will continue to be used as per their currently approved use while it is safe to do so.

Based on the above listed assumptions, it is anticipated that at the end of the 50-year period of this assessment approximately 50 beachfront properties will have been redeveloped as demountable structures.

State government

There are approximately five allotments that may be impacted by the beach moving landward over the period of the analysis plus the land in front of the surf club. The expected value of these costs will flow to the state government. These are minor in comparison to the private costs that individual property owners will incur. This is due to the fact the land value is relatively low as the allotments are currently undevelopable.

A8. Engineering information: revetment options

This appendix provides detailed technical description of Options 2-7.

General Comments

For the revetment types – Rubble mound and Vertical wall – the study has adopted the design cross - section proposed and costed by WRL (1998). For the Seabee seawall, we replaced the Gabion and Reno mattress toe with a piled toe. The variations from WRL (1998) relate to:

- Seawall height. In the WRL (1998) costing a constant seawall height of 8m (AHD) was adopted, whereas the design height of the seawall varied from 6 to 8 metres (AHD), with most the wall at 8m. Our costing considers the variable seawall height.
- WRL (1998) considered both basalt and local limestone armour rock. We have not considered local sandstone because:
 - The unit size of sandstone armour increases to 7 tonnes whereas the unit size for basalt is 4 tonnes.
 - This effectively increases the volume (tonnes) of rock that must be transported to the beach by 75% and increases the volume of truck traffic by a similar percentage.
 - Sand stone has a density of 2,300kg/m³ whereas basalt is 2670kg/m³. The increased unit weight coupled with the lower density means that the rock layers are significantly thicker for a sandstone seawall than a basalt seawall which means the footprint of the seawall is significantly wider, estimated at 1.5 to 2 metres wider, with a corresponding loss of beach width.

- With the increased rock tonnage and the need to handle large armour rock it is likely that whilst the supply cost (per tonne) may be 30 to 40% lower than for basalt, the total constructed cost is likely to be higher.
- Costs have generally been updated by allowing for an approximate 70% CCI increase since 1998. The main exceptions to this are:
- Supply and placement of basalt rock as described in the “Background”??? above are higher than WRL (1998). The supply cost has been obtained from local quarries capable of producing the required product and the placement cost is based on our current industry experience.
- Geotextile supply cost reflects the use of a heavier duty geotextile as industry experience suggests that this is appropriate.
- Supervision and survey costs have been adopted from the more recent WRL (2013) costing for similar work at Byron Bay.

Option 2: Rubble Mound Revetment

Figure 12 is a reproduction of the rubble mound seawall sketch (Figure 18, WRL, 1998).

Figure 12: Basalt Rubble Mound Seawall – Generic 8m AHD Crest

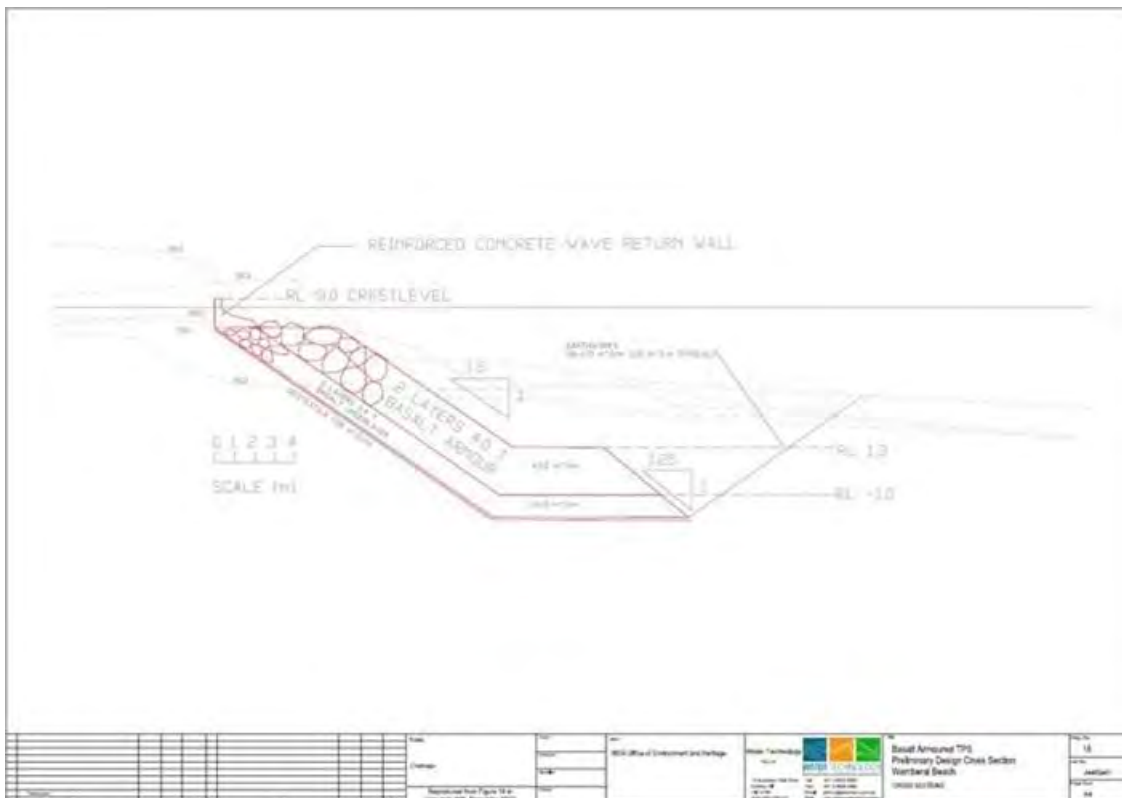


Figure 12 shows:

- A summer scenario with present day sea level and much of the seawall buried under the upper beach and dune.
- The toe of the seawall (underlayer) is set at -2m AHD to accommodate beach and dune erosion so that the integrity of the seawall remains even after a 50 year ARI storm at elevated sea

levels. Under an extreme event there may be some undermining of the toe of the structure but the combination of the geotextile, underlayer rock and armour rock toe structure would be expected to slump without any significant settlement of the rubble mound wall itself.

- The crest of the rubble mound is set at about 6.75m AHD. A recurved concrete wall with its top at 8m AHD is cast onto the top of the rubble mound wall to minimise wave overtopping.
- A standard rubble mound seawall slope form of two layers of 4 tonne armour rock underlain by 2 layers of secondary rock with a geotextile membrane separating the rock from the underlying trimmed sand slope. The geotextile prevents sand leaching out through the rock.
- The footprint (width) of this structure is 17 ½ metres when it is fully exposed. When it is constructed, presumably not in winter because of potential limited access and wave inundation of works, only about 50% of this total width would be exposed. The balance would be buried using sand excavated for construction purposes.

As sea level rises, combined with the natural recession of the shoreline, nominally 0.2m/year, Worley Parsons (2014), it is expected that the amount of the seawall exposed will increase as the beach width diminishes.

Like the Base Case, it is expected that by 2034 there will be a reduced dune/upper berm width and it may be expected that in most years, sand may be removed over winter exposing the top of the seawall toe. Over summer it can be expected that sand would be restored to the beach to cover the toe of the seawall and still provide for reasonable beach enjoyment.

For the 2064 scenario, it can be expected that the toe of the seawall will be fully exposed most winters. It is also likely that a full beach recovery will not occur most years. That is, the beach area will be negligible over winter, and may be limited over summer.

In the absence of beach nourishment, it is anticipated that wave run-up and overtopping may become unacceptable after 2064 and consideration will need to be made to raise the seawall crest if sea level rise is ongoing. This is likely to entail removing the recurved wall, raising the rubble mound crest level and rebuilding the recurved wall. If the recurved wall was still fully intact and functional, it may be possible to retain it and cast a new wall tied into the old wall.

Preparatory earthworks, which entails the removal of sand and other materials to trim the dune face in preparation for the placing of rubble mound seawall materials, require some 175,000 m³ to be rehandled. All sand excavated will be placed back on the beach.

The total amount of rock is almost 91,000 tonnes. All the rock will need to be transported via road to Wamberal beach. It is likely that storage and rehandling will need to be undertaken at both the Terrigal and Wamberal Lagoon ends of the beach. Materials will then need to be transported to the works area by off road equipment.

The wave reflecting recurved wall requires some 1,900 tonnes of concrete which equates to about 100 to 150 concrete trucks accessing the beach road.

The construction time is likely to be over 1 year (391 days of supervision and survey). It therefore may be necessary to stage the works over two years, to allow for work to stop over the busiest summer months and to allow for weather delays over winter.

trimmed sand slope. The geotextile prevents sand leaching out through the rock and Seabees to minimise overtopping.??

- The footprint (width) of this structure is 13 metres when it is fully exposed. When it is constructed, presumably not in winter because of potential limited access and wave inundation of works, only about 50% of this total width would be exposed. The balance would be buried using sand excavated for construction purposes.

The toe of the seawall is shown schematically as a contiguous piled wall from RL 0.0 AHD down to -5.0m AHD. This is a variation to the combined Seabee seawall – contiguous beam option shown in Figure 24 of WRL (1998). Here the focus is on providing a dissipative sloped wall down to the beach toe level, to minimise reflection and scouring by waves at the toe of the seawall. A steel sheet pile wall is another option. Two important aspects of the toe area: (1) that it should not fail because failure implies failure of the seawall above; and (2) sand cannot leach out from behind the wall if the toe is undermined. Therefore, a continuous wall is nominated rather than a toe beam supported by spaced piles. Since this is not an engineering design report we have opted to cost this arrangement by using appropriate pro-rata rates from the WRL (1998) rates for a combined Seabee – Contiguous piled wall.

The discussion in relation to sea level rise and the beach condition at the Seabee seawall is like that for a rubble mound wall, namely:

As sea level rises, combined with the natural recession of the shoreline, nominally 0.2m/year, Worley Parsons (2014), it is expected that the amount of the seawall exposed will increase as the beach width diminishes.

Like the Base Case, it is expected that by 2034 there will be a reduced dune/upper berm width and it may be expected that in many years, sand may be removed over winter exposing the top of the piled toe. Over summer it can be expected that sand would be restored to the beach to cover the toe of the seawall and still provide a reasonable beach area for enjoyment.

For the 2064 scenario, it can be expected that the toe of the Seabee seawall (piles) may be fully exposed most winters. It is also likely that a full beach recovery will not occur most years. That is, the available beach area will be negligible over winter, and may be limited over summer.

In the absence of beach nourishment, it is anticipated that wave run-up and overtopping may become unacceptable after 2064 and consideration will need to be made to raise the seawall crest if sea level rise is ongoing. This is likely to entail either re-configuring the recurved wall to a higher level or removing the recurved wall (which may have outlived its life anyway), raising the Seabee wall level and rebuilding the recurved wall.

[Option 5: Seabee Revetment with Beach Nourishment](#)

For the purposes of this analysis it is again assumed that beach nourishment will be delayed for several years which implies the full depth and height of the seawall, as per Figure 14, still needs to be allowed for and costed.

Under this option the purpose of the sand nourishment up to 2064 is to ensure adequate beach area for recreation, rather than providing protection to the properties and assets.

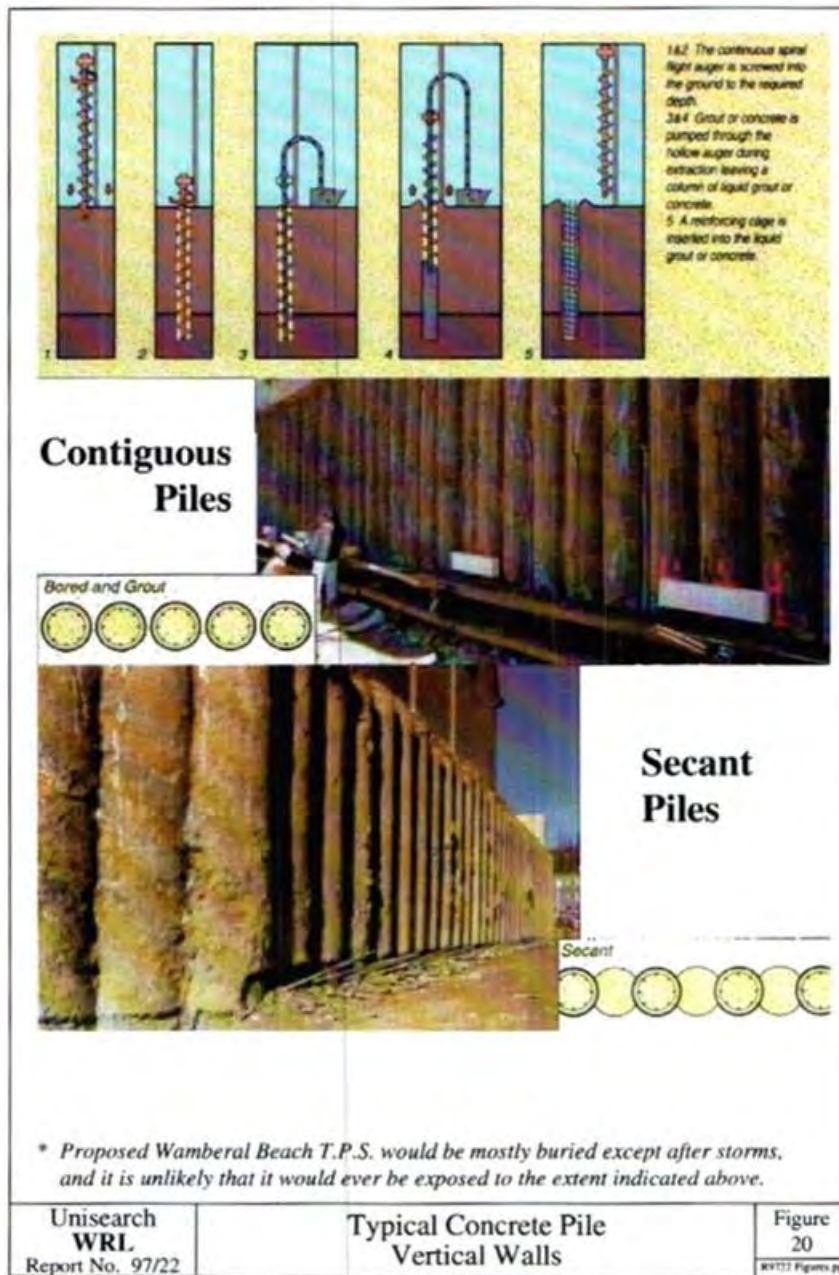
The sand nourishment approach adopted here is as per the AECOM Sydney beaches study, where 400,000 cubic metres is placed as soon as possible and top-up nourishments of 125,000 cubic metres

- When the beach is eroded, the wall is visually high and unattractive (from WRL (1998)).
- Access to the beach requires sets of steps from the top of the wall down to a beach level. Ideally they would extend down to the lowest likely beach level and founded on piles. They would be considerably more expensive and are likely to require more maintenance than steps formed into a Seabee or rubble mound wall.
- A vertical wall will tend to result in a greater amount of wave topping than a sloped dissipative wall. It is noted in the WRL (1998) work that the crest level of the contiguous wall is set at the same level as for sloped walls. However, the extent of wave overtopping can be expected to be significantly higher. This is because when the wave hits a vertical wall it tends to send a jet of water up in the air. During the peak of the storm it is likely there will be strong onshore winds that can then push this jet onshore, even with the included recurved wall.

Option 7: Contiguous Vertical Wall with Beach Nourishment

For the purposes of this analysis it is again assumed that beach nourishment will be delayed for several years which implies the full depth and height of the seawall, as per Figure 15, still needs to be allowed for and costed.

Figure 15: Contiguous Piled Seawall – image from WRL (1998)



Under this option the purpose of the sand nourishment up to 2064 relates to ensuring an adequate beach for recreation and related uses rather than providing protection to the properties and assets.

The sand nourishment approach used here is as per the AECOM Sydney beaches study, where 400,000 cubic metres is placed as soon as possible and top up nourishments of 125,000 cubic metres are applied every 10 years on the basis that sea level rise is occurring at a rate of 100mm each 10 year. However, the costing is based on the costs developed by [REDACTED].