APPENDIX 7

Additional Technical & Remediation Design Documents

- Curraong Beach Erosion Design Study (SMEC, 2011)
- Callala Bay Coastal Management Scheme (SMEC, 2008) + Landscape drawing incorporating remediation design (Arthouse, 2008)
- Ulladulla Harbour Coastal Erosion Remediation - detailed design (SMEC, 2011)
- Beach Survey methodology document (SMEC, 2009)
Project Name: Curramong Beach Erosion Design Study

Project Number: 3001859

Report for: Shoalhaven City Council

PREPARATION, REVIEW AND AUTHORISATION

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<td>1 (Draft)</td>
<td>5/11/10</td>
<td>M. Glatz, C. Adamantidis and A. Xiao</td>
<td>C. Adamantidis</td>
<td>C. Adamantidis</td>
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<td>2 (Final Draft)</td>
<td>22/03/11</td>
<td>M. Glatz, C. Adamantidis and A. Xiao</td>
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<td>C. Adamantidis</td>
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<td>3 (Final)</td>
<td>13/04/11</td>
<td>M. Glatz, C. Adamantidis and A. Xiao</td>
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<td>4 (Final)</td>
<td>11/05/11</td>
<td>M. Glatz, C. Adamantidis and A. Xiao</td>
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SMEC COMPANY DETAILS

SMEC Australia

Level 6, 76 Berry Street

Tel: 02 9925 5555
Fax: 02 9925 5566
Email: Chris.adamantidis@sme.com

www.smec.com

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Currrarong Beach Erosion Remediation Study — Options Assessment Report

For: Shoalhaven City Council
EXECUTIVE SUMMARY – CURRARONG BEACH EROSION REMEDIATION STUDY

Introduction

Currarong Beach is an open-coast beach located north-east of Jervis Bay on the Shoalhaven coast. It is subject to a relatively low wave climate being sheltered from southerly waves by Beecroft Head. Council has undertaken a Coastal Hazard Assessment and a Coastal Zone Management Plan for the different beaches including Currarong Beach.

This beach is subject to severe erosion and long-term recession that would make the development along Warrain Crescent more vulnerable in case of a significant storm.

This report documents possible options for the beach erosion remediation including sand nourishment, construction of a groyne or breakwater, realignment of Currarong Creek entrance and combinations of different options.

A Triple bottom line options assessment is presented, with the goal of short listing viable options to be considered for concept design.

A workshop was held with Council’s Coasts and Estuaries Committee on 30 August 2010. The workshop presented the various options available describing the advantages and disadvantages of each. Following this workshop, options were shortlisted for further concept design development. This report describes the concept design of the shortlisted options and documents the coastal investigations carried out to undertake the concept design.

Coastline Management Options

Coastline management at Currarong is consistent with the principles of ecologically sustainable development (ESD) and the requirements of the Coastal Protection Act, Local Government Act, SEPP 71, and the NSW Coastal Policy 1997.

Management options can fall under three main classes:

- **Retreat**: The over-arching philosophy of this management strategy is that it assumes natural processes will occur without intervention and that dwelling structures will be successively relocated landward away from the influence of hazards over time. Development approvals and associated controls acknowledge this philosophy, reducing the potential scale of economic losses, while enabling property owners to use their land for as long as possible until the physical coastal processes have subsumed any safe development margin. Retreat options include:
  - planning controls;
  - land acquisitions (voluntary purchase, leaseback of properties or compulsory acquisition);
  - relocation of public infrastructure;
  - physical relocation of private properties.
  Each option is described and advantage/disadvantages are provided.

- **Protect**: Protect options require physical intervention to slow down or prevent coastal erosion, and provide some degree of protection to public and private property from coastal hazards. Such options may involve construction of engineering works, such as seawalls, groynes and revetments, which can modify coastal processes and allow existing and future property and infrastructure to
remain viable into the future by protecting them from damage caused by coastal erosion. Protection options include:

- Seawalls;
- Revetments;
- Groynes;
- Artificial Reefs;
- Training walls.

Each option is described and advantage/disadvantages are provided.

- **Adapt**: Adapt options recognise that the coastline is receding due to the impacts of coastal processes, and advocate an approach whereby existing and proposed developments adapt to the changing conditions. Such an approach may entail a mixture of different management approaches, recognising immediate, short term, medium term and long term goals that are consistent with the changing nature of the threats to the coastline and the changing importance of the major issues as perceived by Stakeholders (including members of the local community, local businesses and local and State Authorities). Adaptation options include:
  - Beach nourishment;
  - Combination of various approaches;
  - Land management options (dune management).

Each option is described and advantage/disadvantages are provided.

**Detailed Option Assessment**

A preliminary options assessment has been carried out with all options considered. The purpose of the options assessment was to provide a basis for the Coastline Management Committee to workshop the various options for short listing for concept design. Nineteen management options, including retreat, protection and adaptation options were considered in the analysis. All of the options listed below include dune management measures and maintenance, which are considered high priority ongoing actions.

The options assessment has been carried out using a *Triple Bottom Line (TBL)* approach. The main criteria used for assessing the options include the three “pillars of sustainability” – namely economic, social and environmental factors. The criteria chosen for the comparison involve:

- Total cost;
- Effectiveness of the protection;
- Visual Impact;
- Impact of the option on recreational amenity;
- Approval required;
- Disruption to coastal processes;
- Preservation of the natural character of the beach;
- Ecological impact.

Each criterion was given a weighting and a total score was determined for each option to obtain a good assessment and a ranking of the options that was discussed in a workshop held with Council’s Coasts and Estuaries Committee on 30 August 2010.

The three preferred options selected during this workshop include:

- Beach nourishment
Construction of a groyne

The concept design of the different options is based on an analysis of the coastal processes occurring at the site as well as the provision of detailed design parameters for all the aspects of the proposed options.

**Coastal Processes**

An important step in understanding the coastal processes at the site is to develop an understanding of the wave climate.

The site is sheltered from southerly ocean swell waves by Beecroft Head and the presence of extensive reefs along the beach.

Wave height and direction are the principal drivers of longshore sediment transport at the site. Long period swell waves, which have the potential to cause sediment transport, would undergo severe refraction and diffraction around Beecroft Head and would be expected to arrive at the beach from a limited set of directions. In addition, these waves would be limited in height by wave breaking on the reefs located along the beach.

To examine this understanding of the wave climate in sufficient detail for design of a successful beach stabilisation option, a SWAN wave transformation model was set up, with detailed bathymetry provided by a combination of survey data at the site and bathymetric soundings from Admiralty Charts.

Diffraction is a significant phenomenon occurring in the vicinity of Currarong Beach around Beecroft Head and the several reefs located along the shoreline. The main diffraction that occurs around Beecroft Head and the nearshore reefs was determined using the diffraction diagram provided in the Coastal Engineering Manual. As the diffraction is associated with a strong refraction around the same features, it cannot be considered entirely independent of refraction. This makes the problem of combining refraction and diffraction processes strongly dependent on nearshore bathymetry variations at small spatial scales, making the problem very complex and intractable without the use of numerical modelling. For this reason, the combined refraction/diffraction model REF/DIF1 was used to determine this combine effect on the wave climate at the beach.

An assessment of the wave climate due to waves generated locally along Currarong Beach was also made. The wind wave climate was derived using the ACES wave forecasting algorithms.

From the above analysis of the wave climate for the site, it was found that:

- Swell waves can only approach the site from a narrow range of directions, due to severe wave refraction and diffraction around Beecroft Head;
- The *significant* swell wave height under extreme conditions (50 year ARI storm event) can reach $H_s = 1.9m$ at the western end of the beach due to ENE swells and $H_s = 0.90m$ due to SE swells;
- The locally generated waves can reach up to $H_s = 0.45m$ in typical conditions and up to $H_s = 1.6-1.9m$ during a 50 year ARI storm event;
- The direction of approach of wave energy at the site would mostly favour westward longshore sediment transport for the swell waves while the wind waves generate an eastward sediment transport.

The conclusion from the results of the detailed diffraction analysis confirms understanding of the coastal processes developed using the SWAN model, with:
• Longshore sediment transport from east to west along the beach located west of the central reef, with the beach realigning in response to the prevailing swell climate;
• Lower longshore sediment transport from west to east along the section of the beach located between the central reef and Curraong Creek entrance, generated by the prevailing wind wave climate and local diffraction effects;
• Enhanced longshore sediment transport during storm events;
• Offshore sediment transport by storm waves during severe storm events; and
• Offshore sediment transport by tides at Curraong Creek entrance.

Design of Coastal Management Options

Groyne Option

Crucial to the design of a successful groyne scheme is an understanding of the rate of longshore drift at the site.

Using the understanding of the coastal processes and the SWAN numerical model from Section 3.1, sediment transport pathways have been estimated for the site using the CERC formula and the Kamphuis expression.

Four potential locations for a groyne of approximately 30-80 m length were considered:
• On the central reef of the beach;
• At the eastern end of the beach along Curraong Creek entrance;
• East of the central reef; and
• Between the central reef and Plutus Creek, about 250m west of the central reef.

Groynes can be constructed of various materials, including rock/rubble mound, concrete or steel sheet piles, timber or geotextile. The materials selected in this study are rock for a permanent groyne and geotextile to use for the construction of a trial groyne as a preliminary structure.

Groyne design characteristics (e.g. dimension and rock sizes) as well as the impact on the beach alignment were provided for the four locations. Sizing of the groyne was undertaken using the Hudson equation for the rock groyne and Pilarcyk equation for the geotextile groyne.

Beach nourishment option

The success of the management scheme relies on beach nourishment – without this, a groyne would cause erosion downdrift of the structure, and the groyne compartment would take a long time to fill naturally, with erosion continuing in the meantime. Beach nourishment involves placement of sand onto the beach to create a dune, which provides a buffer against erosion due to storms. Such nourishment depends on locating a suitable source of sand, such as a nearby creek entrance. It works best when the sand placed on the beach closely matches the grain size and characteristics of the native beach sand, or when the sand is sourced from within the same coastal sediment compartment as the beach.

As potential sources for beach nourishment should ideally be located within the same active littoral system, the most suitable source of sand for nourishment appears to be from the entrance to Plutus Creek and Curraong Creek. An estimate of the available sand at these locations is around 10,000 cubic metres in front of Plutus Creek and around 7,000 cubic metres within Curraong Creek. Some further sediment supply may be extracted from Abraham Bosom Beach and the beach west of Plutus Creek entrance. An overfill
ratio of 1.10 would be required to stabilise the beach nourishment using sand from Curraong Creek, while no overfill would be needed should the sand be sourced from the area in front of Plutus Creek or from Abraham Bosom Beach.

**Geotextile Protection of Accessways**

Accessways can be rehabilitated using geotextile revetment protections as an emergency measure. Such protections have been designed for a 2 year ARI storm event. Design parameters for these protections were calculated using the Pilarczyk formula.

**Accessway Over Groyne**

Should the groyne be built along the beach an accessway allowing pedestrians to conveniently cross from one side of the groyne to the other would be required. If the groyne comprised geobags, settlement would generate some issues if an accessway is placed at the top of the groyne and geotextile may be slippery and cause user safety issues. Therefore, an accessway that would go around the groyne directly landward of it is recommended. This accessway would consist of a board and chain accessway or timber steps on each side of the groyne leading to a walkway along the dune.

**Transition from Geotextile to Rock Groyne**

If a geotextile groyne option is selected and proves to be an efficient protection along the beach, geotextile can be replaced by rock. Another possibility would be to use the existing geobags as core material for the rock groyne and capping the existing groyne with rock armour.

**Cost Estimate**

**Groynes**

From the dimension of the groynes and cost estimates for the hourly rate of labour, equipment hire, material used and administration from the Rawlinson book edition 2010, the concept costs were estimated as follows:

- If built using rocks:
  - the western groyne would cost around A$300,000;
  - the central groyne would cost around A$322,000;
  - the groyne east of the central reef would cost around A$224,000; and
  - the eastern groyne would cost around A$437,000.
- If built using geobags:
  - the western groyne would cost around A$162,000;
  - the central groyne would cost around A$143,000;
  - the groyne east of the central reef would cost around A$108,000; and
  - the eastern groyne would cost around A$246,000.

**Beach Nourishment**

A cost of a minimum of $26,000 was updated for the current situation to include including deployment of a dredge and equipment for pumping sand. Based on a pumping rate of $6.50/m$^3$ (updated from Coastal Engineering Solutions, 2003), the estimated cost of pumping 25,000 m$^3$ of sand would be approximately $100,000. Additional costs for labour (i.e. spreading the sand) and project management would be required. Given the limited
sand supply (estimated to be 17,000m$^3$), some sand may need to be imported and such sand would cost around $10-$20/m$^3$.

**Conclusion and Recommendations**

This report has examined the design of a beach management scheme for the area of Currarong Beach east of Plutus Creek and west of Currarong Creek. This area has been undergoing severe erosion where the front of the dune escarpment is very steep as a result of storm bite and a sediment budget deficit.

An examination of the coastal processes in this area was undertaken, based on the results of wave refraction modeling (SWAN), combined wave refraction and diffraction model (REF/DIF), nearshore wave transformation model (SBEACH), wave forecasting algorithms (ACES) and updated bathymetric/subaerial survey data provided by Shoalhaven City Council. It was found that this area is subject to potential for longshore drift, with sand moving from east to west on the western side of the beach and from west to east on the eastern side of the beach, due to the oblique angle of the ambient wave climate, windborne waves and severe storm events.

A potential management scheme which would be appropriate for this situation involves the construction of a groyne, coupled with beach nourishment. The design parameters for the groyne were developed based on an understanding of the coastal processes, including the length of the groyne, groyne profile, and optimum location of the groyne.

Sand available for beach nourishment would be best sourced from the entrance to Plutus Creek and Currarong Creek which are within the same active littoral system. Some sand may also be available at nearby Abrahams Bosom Beach.

A central groyne would not have much impact on the beach alignment and therefore on the protection of the properties along Warrain Crescent. A groyne at the eastern end of the beach may act as a training wall for Currarong Creek and would avoid sand to be moved from the beach back to the creek entrance. However, sand would accumulate between the central reef and the groyne that would not provide any protection to the dwellings located along Warrain Crescent, unless it is constructed to a length of 180m and associated with extensive beach nourishment work as presented by CES (2003). This would have a consequent impact on the environment and cost. A groyne just east of the central reef coupled with beach nourishment would prevent loss of nourishment material back into the creek but may result in an increased risk of breakout of Currarong Creek entrance through the narrow sand spit. Positioning the groyne at the narrowest part of the spit would potentially minimise this risk, while preventing loss of nourishment sand into Currarong Creek and still providing some storm erosion buffer for the eastern half of Warrain Crescent. Detailed design of the tie-in between the groyne and the shoreline would be required to prevent undermining of the landward end of the groyne should Currarong Creek break through the spit in the vicinity of the groyne.

Geotextile protection to the beach accessways, especially for the Peel Street accessway, would reduce the impact of the creek breakout on erosion at the western end of the beach.

It is recommended that beach nourishment be carried out to provide some protection to the eroded beach embankment against storm bite. A geotextile groyne could be constructed east of the central reef to prevent beach nourishment sand from being washed back into the creek. It is recommended that some beach nourishment sand also be placed downdrift of the groyne, to minimise downdrift erosion. A groyne constructed at the narrowest part of the spit east of the central reef was seen as the most appropriate location, as this would reduce the risk of break-out of Currarong Creek through the spit, prevent loss of sand into Currarong Creek and provide some storm erosion buffer to the
eastern end of Warrain Crescent. The preferred management scheme for Currarong is provided in Figure A.

Further, it is recommended that the completed beach management scheme be monitored for its effectiveness, with the beach response monitored over time. A geotextile groyne would have a design life of around 5 years, during which the scheme would be operating on a pilot basis, to confirm the longshore sediment transport pathways and confirm the understanding of the coastal processes as presented in this report. Following this period, if the groyne is successful, the geotextile groyne could be replaced by a more durable rock structure.

The nourished dune should be vegetated and fenced, in accordance with the NSW Department of Land and Water Conservation (2001) Coastal Dune Management Manual.
Core (quarry run)
2 layers armour
W\text{50} = 587 kg
D\text{50} = 700 mm

Underlayer
W\text{50} = 59 kg
D\text{50} = 330 mm

Minimum crest width 1.8m
Crest level = 2m AHD

Geotextile

SECTION VIEW

-1 m AHD

Layer thickness: 0.70m

Core (quarry run)

1V
2H

Expected Profile Without Beach Nourishment

Beach Nourishment
(60 cubic meter/metre)
to withstand storm
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1 INTRODUCTION

Currarong Beach is an open-coast beach located north-east of Jervis Bay on the Shoalhaven coast. It is subject to a relatively low wave climate being sheltered from southerly waves by Beecroft Head. Council has undertaken a Coastal Hazard Assessment and a Coastal Zone Management Plan for the different beaches including Currarong Beach.

Currarong Beach is approximately 950 metres long and is flanked by the entrance to Currarong Creek at the eastern end and a bedrock outcrop at the western end, with a prominent rock outcrop along the beach around 300 metres west of the creek entrance. The presence of the rock outcrop near the centre of the beach has resulted in the formation of a small salient and has influenced the planform of the beach. Urban development on Warrain Crescent is located behind a vegetated dune, the front face of which is very steep due to severe erosion.

Existing studies have highlighted a long-term recession rate of 0.17m/yr along the western half of the beach and of 0.25m/yr along the eastern half (SMEC, 2007). Such a long-term recession would result in a landward movement of approximately 8.5 to 12.5m within 50 years and would make the development along Warrain Crescent more vulnerable in case of a significant storm. Council has therefore decided to undertake a study to determine appropriate options for beach erosion remediation.

This report documents possible options for the beach erosion remediation including sand nourishment, construction of a groyne or breakwater, realignment of Currarong Creek entrance and combinations of different options.

A Triple bottom line options assessment is presented, with the goal of short listing viable options to be considered for concept design.

A workshop was held with Council’s Coasts and Estuaries Committee on 30 August 2010. The workshop presented the various options available describing the advantages and disadvantages of each. Following this workshop, options were shortlisted for further concept design development. This report describes the concept design of the shortlisted options and documents the coastal investigations carried out to undertake the concept design.
2 COASTLINE MANAGEMENT OPTIONS

2.1 Coastline Management Goals And Objectives

Coastline management at Currarong must be consistent with the principles of ecologically sustainable development (ESD), as described in Table 2.1. This is a requirement under the Coastal Protection Act, Local Government Act, SEPP 71, and the NSW Coastal Policy 1997. Within this framework, the coastline issues identified in SMEC’s report *Currarong Beach Coastal Hazard Study* (2007) and CES’s report *Currarong Beach Foreshore Erosion and Management Options Study* (2003) are to be addressed and specific management actions identified.

Management options applied at Currarong must be consistent with the following objectives (from the NSW Coastal Policy 1997):

- Protecting, rehabilitating and improving the natural environment of the coastal zone.
- Recognising and accommodating the natural processes of the coastal zone.
- Protecting and enhancing the aesthetic qualities of the coastal zone.
- Protecting and conserving the cultural heritage of the coastal zone.
- Providing for ESD and use of resources.
- Providing for ecologically sustainable human settlement in the coastal zone.
- Providing for appropriate public access and use.
- Providing information to enable effective management of the coastal zone.
- Providing for integrated planning and management of the coastal zone.

These objectives must be individually addressed by the management responses adopted in the coastal zone.

<table>
<thead>
<tr>
<th>ESD Principle</th>
<th>Relevant to management option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation of biological diversity and ecological integrity.</td>
<td>Options must provide for conservation of the variety of all life forms and species and ensure that the productivity, stability and resilience of ecosystems are maintained.</td>
</tr>
<tr>
<td>Inter-generational equity.</td>
<td>Options must ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations. Social equity considerations must also be taken into account in terms of equal access opportunities to resources.</td>
</tr>
<tr>
<td>Improved valuation, pricing and incentive mechanisms.</td>
<td>Environmental factors, such as the value of ecosystems, must be incorporated into the valuation of assets and services.</td>
</tr>
<tr>
<td>The precautionary principle.</td>
<td>Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty is not to be used as a reason for postponing measures to prevent environmental degradation.</td>
</tr>
</tbody>
</table>

As discussed above, the overriding guiding principles for management decisions on the coastline are the principles of ESD. Within these overriding principles, there are three
The main classes of management options that reflect various approaches regarding management of the coastline. The options can fall under three main classes:

- Retreat
- Protect
- Adapt

Each of these three approaches is discussed in greater detail in the following sections. The focus is on the assessment of management issues, planning consideration and processes, advantages and disadvantages and cost issues (including valuation of existing property).

### 2.2 Retreat Options

The over-arching philosophy of this management strategy is that it assumes natural processes will occur without intervention and that dwelling structures will be successively relocated landward away from the influence of hazards over time. Development approvals and associated controls acknowledge this philosophy, reducing the potential scale of economic losses, while enabling property owners to use their land for as long as possible until the physical coastal processes have subsumed any safe development margin.

A Retreat approach recognises that coastal processes and coastline hazards are impacting on the coastline, and that the nature of this impact is likely to worsen in the future. Such an approach also recognises that it is not ecologically sustainable to modify natural processes to eliminate or reduce the coastline hazards.

As the impact of coastline hazards worsens, the ability of the community to maintain infrastructure and keep existing properties in their current locations begins to decline. Infrastructure such as water supply, electricity and sewer becomes increasingly exposed to coastal erosion, and eventually it will be more difficult to maintain services for some of the more exposed seaside properties.

With coastal erosion continuing at the current rate, seaside properties such as those along Warrain Crescent will eventually lose their access, as portions of the roadway are lost due to future coastal erosion. Eventually, loss of structural integrity of the dwellings themselves may result and the existing housing may become unsuitable for habitation.

A retreat option provides a strategy for gradual movement of infrastructure inland to avoid potential threats. It may in the first instance involve providing temporary access for properties that have lost their road access due to coastal erosion, gradual voluntary buyback of properties that are under threat (at a fair value) and the return of the land to public ownership, and restrictions on future development, recognising that the threat to property will increase in the future.

Such options must take into account social equity principles and adequately compensate property owners for the loss of their property, while at the same time being consistent with the principles of ESD. Such options may also allow property owners to enjoy the attributes of beachside living for the present, as long as they are informed of the long term risk.

A retreat type strategy may be staged as the coastline hazard risk increases with time. The stages involved may include:

1. Informing beachside owners of the coastline hazard risk to their property; (short term)
2. Adoption of planning controls on the type and scale of future beachfront development; (short term)
3. Reducing the width of the beachside access road to accommodate the receding coastline; (short-medium term)

4. Movement of services and infrastructure landward to accommodate the future coastline hazard; (medium term)

5. Providing rear access to properties as coastline recession continues; (medium term)

6. Voluntary purchase of affected properties at market value and return of the land to public ownership (or uses compatible with coastline hazards); (medium-long term)

7. Compulsory acquisition of properties that are no longer serviceable. (long term)

Strategies for planned retreat are discussed below as are the advantages and disadvantages of each strategy.

### 2.2.1 Planning Controls

Implementation of planning controls for new development within the coastal hazard risk zones identified by the Coastal Hazard Study would be a way to reduce the quantum of the coastal risk. The potential planning controls are discussed in the draft Shoalhaven Coastline Management Plan and the draft Shoalhaven DCP118.

The planning controls could be implemented in conjunction with other options discussed in this report.

There are many methods of development controls that can adequately facilitate planned retreat. Another strategy may involve the requirement of all development landward of the immediate stable foundation zone to be relocatable and conform to limited height, scale and modularity principles, without the need for piled foundations. This would allow development to move landward as the erosion escarpment moves landward. The land could also be potentially rezoned in the future to commercial, which would allow the land to be redeveloped in a manner compatible with the coastal hazard risk (eg. Caravan Park). This would allow the landowners to maintain the equity in their properties.

The implementation of planning controls would reduce the existing costs and time involved with assessing DAs for coastal property development, and provide consistency for development assessment within the affected areas. They would provide a consistent framework for assessment of DAs and provide guidance to Council officers in assessing applications fairly and equitably.

### 2.2.2 Land Acquisitions

#### 2.2.2.1 Voluntary Purchase

A Voluntary Purchase program for housing under threat from coastal processes could be implemented, with Council and Government purchasing properties either as they come onto the market, or through offers to existing landholders. Such a strategy would necessitate property being purchased at market value.

The land purchased by Council would then be returned to public ownership, and its use changed to be more compatible with the nature of the coastline hazard. For example, purchased land can be converted into public reserve, can be rehabilitated as coastal dune environment, or be converted to community use such as for passive recreation, or to provide additional car parking for day visitors to the beach. The transfer of lands to public ownership is authorised under the Local Government Act (LG Act).

As there is no legal requirement for the NSW Government to purchase properties under threat, advice from the Government has indicated that financial assistance for a voluntary
Such a voluntary purchase scheme would require capital outlay to buy each property, as well as demolition works, removal of services and rehabilitation of the area as public open space. Such a scheme would realistically only apply to those dwellings at greatest risk—i.e. the dwellings at Warrain Crescent east of Canbewarra Road (i.e. 10 dwellings). The present day market value of those dwellings could range from $850,000 to $1.2 million according to www.allhomes.com.au. A voluntary purchase scheme would be more of a long term prospect, with dwellings becoming under direct threat from coastal erosion sometime between 2025 and 2050.

2.2.2.2 Leaseback Of Properties

Properties purchased under a voluntary purchase scheme may be able to be “leased back” from Council by their occupants.

Such an option could involve possible voluntary buyback of property at market value, with the occupant leasing it back on a rolling 10 or 20 year lease arrangement, allowing homeowners to stay in their properties in the medium term (as well as realise existing market value of the property) until the coastline hazards become too severe (i.e. in the next 15-30 years).

This option may allow homeowners to stay on their properties, but with future redevelopment of their land restricted to buildings which are able to be physically relocated landward as the coastline hazards worsen.

The advantages of this approach include:

- It allows property owners concerned about future property prices to obtain a fair market price for their property;
- It allows property owners to occupy their houses under a rolling 10 or 20 year lease, which allows the owners to still enjoy the benefits of their seaside location;
- It allows Council to recover some of the cost of purchase of the property;
- It allows the leases to be re-negotiated following updated information about coastal hazards.

Such a scheme would ensure that property owners are fully compensated for the eventual resumption of their property, while at the same time allowing them to live and enjoy full benefits of their current location in the medium term. If at the end of the term of the lease the coastal hazard risk to the property makes the property unviable, the land can be brought back into public use and rehabilitated. A disadvantage of such a scheme is that the occupier would need to be evicted once the coastal hazard risk becomes too great for the property to remain viable.

The total cost of such a scheme would be somewhat reduced over time compared to a more conventional voluntary purchase scheme, as the rehabilitation of the land would be delayed. It may also be more acceptable to existing property owners as it allows them to enjoy the benefits of their seaside location for longer.

Such an arrangement would need to be entered into with the consent of the current landowners, and could be undertaken under standard contractual processes.

2.2.2.3 Compulsory Acquisition

Compulsory acquisition of properties at very high risk from coastal hazards may be required in the future (between 2025 and 2050). Such properties may include those that are no longer able to be serviced or accessed due to accelerated coastal erosion, or that...
are no longer safe for habitation due to the risk of catastrophic consequences such as loss of the building in a large storm event. Such an acquisition should be carried out at a fair value for the property.

Councils have the power to compulsory acquire land under the Local Government Act. However, the purposes for which land can be compulsory acquired are defined within the Act and relate primarily to infrastructure. The council would require consent of the Minister to allow for the compulsory acquisition of land outside the scope set in the Act.

2.2.3 Relocation Of Public Infrastructure

As the coastal hazard risks increase with time, public infrastructure will continue to come under threat from coastal hazards, and will need to be relocated inland. Such infrastructure includes water supply, electricity, sewer and other services. To continue to keep the properties along Warrain Crescent serviceable as coastal hazards increase, a staged retreat strategy for public infrastructure could be put into place. Such a process could involve:

- Relocation of essential services to the rear of the properties on Warrain Crescent;
- Provision of rear vehicle access to the Warrain Crescent properties and conversion of the Warrain Crescent roadway into public reserve in front of threatened lots. Warrain Crescent could be reconstructed through Crown land to the rear of the existing properties.
- A possible buy-back of parts of Caravan Park land can be undertaken to reconstruct threatened homes as Crown Land is available.
- There is also a potential for retreat within the existing lots.
- Lots can be rezoned as commercial so that residents do not lose the equity in their land and can relocate. Lots can then be used for purposes more compatible with the coastal engineering threat (e.g. Burrill caravan park).

The costs and problems associated with this would involve engineering works to relocate the essential services and would also involve coordination between all the relevant agencies, authorities and service providers responsible for provision of the various services. Disruption to the community caused by these works would be likely over an extended period of time, however the extent would be relatively localised.

2.2.4 Physical Relocation Of Private Property (Modular Homes)

The provision of development controls on land affected by coastal hazards would restrict the type of development that can take place. Where dwellings have reached the end of their design life, landowners could be allowed to redevelop their land by constructing relocatable buildings rather than fixed dwellings.

Modular homes are houses that can be assembled together from multiple modules or sections which have been manufactured at a remote facility before being transported to the desired location for complete assembly. These relocatable homes are typically built to local state or council codes and are governed by the regulatory requirements set out in the 2005 Local Government (Manufactured Home Estates, Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation. This would require the rezoning of land to accommodate moveable dwellings and related infrastructure.

Several advantages exist for modular homes.

- The ability to relocate an already built house to another location if necessary
- Versatility in building a house at a much wider range of locations, where traditional housing may not be possible
Typically a more cost and time effective alternative to the construction of a regularly built home

- The ability to enjoy the benefits of coastal living at a reduced risk associated with coastal hazards

Such homes can then be moved landward in response to the increasing coastal recession threat.

Disadvantages of this option include that it may be more practical to implement development controls, specifying no development allowed once land is being impacted by coastal hazards. There are also liability issues as this option would still allow people to reside close to the zone of hazard.

In addition, there may be a negative perception from residents about these types of homes and their urban design impact (i.e. built amenity).

### 2.2.5 Advantages Of Planned Retreat

A planned retreat strategy would be consistent with the principles of ESD and the requirements of the NSW Coastal Policy, in that land at risk due to coastal processes is eventually transferred into public ownership, improving public access to the beach and restoring the coastal environment on that land.

A planned retreat strategy conforms to the principles of inter-generational equity, in that the coastline hazard threat is not passed onto future generations, and provides an opportunity to improve the health, diversity and productivity of the environment within the resumed land areas.

Social equity considerations must also be taken into account in terms of equal access opportunities to resources. With land at threat from coastal erosion coming into public ownership, the recreational amenity of the area can be improved for the wider community by returning the land to the coastal dune system.

While the resumption of coastal land is expensive, the benefit of returning the land to public ownership and enhancing its ecological value is clear but difficult to quantify in terms of currency. Returning the land to public ownership could also improve public access to the foreshore, as this access would otherwise become restricted over time with ongoing coastline recession. Providing for appropriate public access and use is one of the objectives of the NSW Coastal Policy 1997.

Planned retreat reduces the coastline risk by progressively removing the risk, and is therefore consistent with the conduct of coastline planning using a risk-averse approach.

### 2.2.6 Disadvantages Of Planned Retreat

The main disadvantages of this option include the cost to ratepayers of buying back several beachfront properties, which collectively would present a high cost outlay to the wider community (in the order of tens of millions of dollars in the long term). Alternative access arrangements may be necessary for properties along Warrain Crescent in the longer term, due to the risk of erosion of Warrain Crescent. Relocation of infrastructure would cause disruption to the community while the relocation works are taking place.

### 2.3 Protection Options

Protect options require physical intervention to slow down or prevent coastal erosion, and provide some degree of protection to public and private property from coastal hazards.
Such options may involve construction of engineering works, such as seawalls, groynes and revetments, which can modify coastal processes and allow existing and future property and infrastructure to remain viable into the future by protecting them from damage caused by coastal erosion.

Some types of engineering works may be more effective than others at providing this protection, and all require maintenance. Some combinations of various engineering structures could be used to provide the dual goals of improvement in beach amenity as well as protection of infrastructure. Other structural interventions may improve protection at the expense of amenity, while still others can improve amenity but provide a lesser degree of protection. Future maintenance will become more costly, and this is a cost which will need to be borne by the community in future generations.

While such protection options would allow coastal property owners to realise the value of their assets at present and to enjoy the values of the coast, future climate change impacts mean that maintenance of structural coastline protection would not remain viable indefinitely.

While some of these options may serve the dual purpose of improving beach amenity and improving beach access, they will have varying degrees of effectiveness depending on the level of intervention applied. Some of these types of options would not provide sufficient protection to property on their own, and would need to be considered in conjunction with the same types of property development controls that are necessary under a planned retreat strategy.

These types of options may involve “hard” coastal engineering works such as seawalls, groynes, revetments or artificial reefs. Other types of options, termed “soft” options, may involve beach nourishment to improve beach amenity and provide a buffer of sand to lessen the impact of future storms on erosion of the embankment.

Adoption of these types of options would need to consider the Coastal Protection Act 1979 and Environmental Planning and Assessment Act 1979 in the first instance. The principles of ESD and the provisions of the NSW Coastal Policy must also be considered in the selection of such options. Environmental assessments would need to be carried out for these types of options.

A combination of hard engineering or softer management approaches may be adopted. All of these options have a finite design life and would require regular maintenance. These costs would need to be borne by the community.

These types of options may be part of a medium term strategy, and could be combined with planning controls and a longer term strategy of planned retreat from the coastline. There may be avenues for obtaining funding, such as seeking a Special Rate Charge from affected landowners to pay for engineering works that protect private property. Such a Special Rate Charge would require Local Government Ministerial approval.

A discussion of potential management options, their advantages and disadvantages, and relative costs is provided below.

Specifically for Currajong, the following protection type options are discussed:

- Seawalls
- Revetments
- Groynes
- Artificial Reefs
- Training walls
2.3.1 Seawalls

Seawalls are structures designed to prevent or alleviate overtopping or flooding of the land and the structures behind, due to storm surges and waves. They also work to reduce coastal erosion and hold the coastline in place. Seawalls are often used to protect promenades, roads, and houses located on or immediately landward of the frontal dune.

A seawall will cause removal of sand from the beach and terminal erosion at its ends. It will also cause localised erosion in front of the structure which may cause undermining and collapsing of the structure if it is not properly designed and constructed.

Many designs of such structures are available based on different material types, aesthetic requirements and to cater for different types and levels of protection. Typically, they are constructed of rock, concrete armour units, or a combination of these, which vary in height, length and shape. They are built parallel to the shoreline as a reinforcement and range from vertical face structures to sloping structures.

One possible design for a vertical front seawall is shown in Figure 2.1. For that design, the vertical wall is constructed by placing a concrete mass at the base of the coastline edge, with the void between the concrete block and the embankment crest backfilled with sand and then sealed with asphalt.

While they perform well in stopping or reducing the large scale landward erosion of the coastline, they can often enhance erosion of the seabed immediately in front of the structure, as a result of increased wave reflection caused by the seawall (Coastal Engineering Manual, 2003). This results in a steeper seabed profile, which subsequently promotes larger waves that impact on the seawall. Thus seawalls are in danger of instability caused by erosion of the seabed at the foot of the structure in conjunction with an increase in the magnitude and extent of wave action; this is illustrated in Figure 2.1.

The stability of the structure’s face (or slope for revetments) is very dependent on intact toe support, which means that loss of toe support will likely result in significant damage to the armour layer, if not complete failure of the armoured slope. Higher rates of beach erosion may also occur at the ends of the seawall due to edge effects. Due to their potential vulnerability to scour, seawalls are often complemented with another beach control system, such as groynes and beach nourishment (Coastal Engineering Manual, 2003). Due to their size, material and construction requirements, seawalls are among the most durable engineering solutions available to prevent coastal erosion, and often, also one of the most expensive. Throughout the life of the seawall, monitoring and maintenance will be required to preserve its aesthetic and structural integrity.

Advantages of seawalls include:

- They can be effective in protecting the landward infrastructure from erosion;
- If well designed they can improve the amenity of the beach – e.g. they can improve pedestrian access along the foreshore; and
- They would allow properties at Warrain Crescent to be redeveloped without the need for special development controls as they effectively reduce the coastline risk to those properties.

Disadvantages of seawalls include:

- They can be costly to construct;
- They can detract from the visual and recreational amenity of the beach;
- They can result in the loss of the beach berm in front of them due to increased erosion in front of the wall (refer Figure 2.2);
- They can result in higher rates of beach erosion at the ends of the seawall due to edge effects and therefore require more beach nourishment;
- They are only partly consistent with the objectives of the Coastal Policy and Coastal Protection Act (i.e. ESD principles); and
- They require on-going maintenance.

Figure 2.1 – (a) Typical vertical seawall; (b) Seawall instability caused by toe scour
Figure 2.2 – Beach loss eventually occurs in front of a seawall for a beach experiencing net long term retreat

For the section of beach most at risk at Warrain Crescent, a 200 m long vertical seawall could be constructed to a height of approximately 5 m above mean sea level, which would sit approximately 1 to 2 m below the current level of the road. This would prevent erosion of the embankment due to wave action. A preventative measure to reduce overtopping rates can be put in place in the form of a wave return structure at the top of the wall, which would redirect most of the oncoming wave energy back into the ocean rather than overtopping the seawall. Figure 2.1 provides an illustration of this concept. This preventative structure is however relatively expensive and would incur additional costs.

Generally, under SEPP (Infrastructure) and SEPP 71, Council can undertake maintenance including revetments and seawalls following due process as a self-determining authority. However, this is dependent on the level of impact of the proposed works. If there are indirect impacts including loss of beach access and amenity, a full environmental assessment under the EP&A Act is likely.

### 2.3.2 Revetments

Similar to seawalls, revetments are a more specific structure type with a similar purpose of protecting the shoreline from wave-induced erosion by placing an erosion resistant cover directly on an existing slope or embankment (Coastal Engineering Manual, 2003). Seawalls are often a vertical front wall, whereas revetments are often set at a slope and are designed to absorb rather than reflect wave energy.

Revetments share some common concepts and structural elements with seawalls, with the common purpose of protection against coastal erosion. Three major features of revetments are a stable armour layer, a filter cloth or underlayer, and toe protection (Coastal Engineering Manual, 2003). The filter and underlayer support the armour, yet allow for passage of water through the structure. Toe protection prevents undercutting and provides support for all the layer materials. A wide range of designs and materials is available for use in revetments. Typical revetment options are summarised in Figure 2.3.

Revetment armour can be either flexible or rigid, although rigid concrete or asphalt slabs are generally unable to accommodate any settling. While performing the same purpose, large artificial concrete armour units have been developed and designed over the last 50 years to provide an alternative to using large rocks, where such resources cannot be sourced. Generally, the casting and constructing process requires significant financial input and may also detract from visual amenity of the environment in some cases. In the
case of rock revetments, they may be buried in native sand to restore beach amenity and revegetated to form a dune. Following a storm event the sand will erode and the revetment will act to prevent further erosion. Rock revetments generally tend to have a slope ranging between 1V:1.5H and 1V:5H.

Specific to Curraong, available options include constructing a rock armour or concrete unit revetment covered with sand along the eastern half of the beach (Figure 2.4) or a geotextile bag revetment. Another potential option is a gabion revetment, similar to the existing revetment at Mollymook Golf Club. However, gabion baskets may be subject to breakage in energetic coastal environments and damage due to salt attack on the gabion wire frames.

A revetment would require some surface regrading work on the existing embankment to provide a minimum 1V:1.5H slope. This work will involve placing extra fill on the current slope to decrease its gradient to allow for stable rock placement.

Revetment structures are an effective hard engineering solution that protects a coastline from the general landward recession caused by wave-induced erosion. If they are coupled with beach nourishment and covered in a vegetated dune, natural aesthetics can be improved. The loss of sand in front of a revetment structure would be lower when compared with a vertical face seawall because there is much less wave reflection in front of the structure.

Figure 2.3 – Typical Revetment Options (after Coastal Engineering Manual, 2003)
The dune can also be reinforced with geotextile. This option consists of geotextile bags filled with sand placed along the dune and covered with sand. This method would reinforce the dune and allow a steeper slope. Examples of such works are illustrated in Figure 2.5. This option can be applied in two different ways. The first possibility consists of the superposition of different geotextile layers in what is known as wrap-around technique (see Figure 2.5 (A)). A final layer of sand is then deposited on top of the geotextile layers before revegetation. The second possibility consists of using large sandbags of tubular shape that can reach up to 100m long and a maximum nominal diameter of 4.9m (Figure 2.5 (B)). This nominal diameter will reduce by 40% once the sand settles. These tubes would be placed at the bottom of the dune to protect its toe. Once the different layers of tubes are installed, they can be covered with sand to shape the dune profile and protect it against environmental influences. Such a geotextile revetment would provide a lesser degree of protection and have a shorter design life than a rock revetment or concrete seawall.

\[ \text{Figure 2.5 – Example of dune reinforced with geotextile (Antunes do Carmo et al., 2009)} \]

Advantages of revetments include:
- They can be effective in protecting the landward infrastructure from erosion;
- They can be covered with beach nourishment sand and planted over with native vegetation to reduce their visual impact and in this way, may only become visible after a major storm;
- They absorb wave energy and result in less erosion on the seaward side of the structure when compared with a vertical seawall. However, they can still cause erosion on the seaward side of the structure depending on the structure slope; and
- They would allow properties on the eastern half of Warrain Beach to be redeveloped without the need for special development controls as they effectively reduce the coastline risk to those properties.

Disadvantages of revetments include:

- They can be costly to construct;
- They can detract from the visual and recreational amenity of the beach if they are not combined with beach nourishment;
- They have a large footprint area and would disturb a large width of embankment during their construction;
- They can result in higher rates of beach erosion at the ends of the revetment due to edge effects and therefore require more beach nourishment;
- They are only partly consistent with the objectives of the NSW Coastal Policy 1997 and Coastal Protection Act 1979 (i.e. ESD principles); and
- They require on-going maintenance.

As is the case with seawalls, under SEPP (Infrastructure) and SEPP 71, Council can undertake maintenance including revetments and seawalls following due process as a self-determining authority. However, this is dependent on the level of impact of the proposed works. As there are indirect impacts including loss of beach access and amenity, a full environmental assessment under the EP&A Act is likely to be required.

### 2.3.3 Groynes

Groynes are structures constructed perpendicular to the shoreline to act as a physical barrier to trap sand and hold it within a beach segment in the direction of longshore transport through the system.

Groynes can be constructed from wood, concrete, or rock armour, although temporary structures may also be constructed from geotubes filled with sand as a trial to observe the effect of a groyne on the system without the full cost or process impacts of a permanent structure.

The design of the groyne for different environments is important in ensuring that the amount of sediment trapped is limited and excess sediment transport is free to continue through the system. It is necessary that the coastal processes at a site where groynes are being considered be well understood and quantifiable to ensure that sand is available to fill the groyne compartment and that the resultant downdrift erosion is acceptable. Groynes that are too long may trap all the sediments and cause significant reduction in beaches on the down-drift side as no sediments can pass the groyne. Conversely, groynes that are too short, low or permeable may become ineffective in trapping sand and little sand accretion is witnessed. Usually, groynes are not suitable where a large tidal range permits too much bypassing at low tide and overpassing at high tide or where there is little alongshore sediment transport.

The construction of groynes would be accompanied by sand nourishment to reduce beach recession further from the groyne compensating for the accretion along the groyne.
Another option could be a change in the configuration of Curarrong Creek entrance making the inlet of the creek straight instead of bending eastward when reaching the back of the beach dune as described by CES (2003) and illustrated in Figure 2.6. A training wall was suggested to be built on both sides of the newly created entrance while the old entrance is expected to be closed. Sand will be trapped on the eastern side of the entrance and the western breakwater will also generate some accretion on its western side. It involves two training walls which will be very expensive. It will also reduce the tidal prism, as the old channel entrance will be silted up.

Groynes can also be used as training walls for Curarrong Creek entrance. This option consists of beach nourishment along Curarrong Beach with an additional breakwater/groyne constructed at the eastern end of the beach to retain the sand – on the western side of Curarrong Creek. The option is expected to be effective to control the erosion of the beach on its western side. Its influence along the beach will depend on its length. The breakwater would stabilise the sand and a smaller volume of sand will be necessary for the replenishment. This option has been suggested by CES (2003) and is illustrated in Figure 2.7.

A last option consists of placing a groyne at the level of the reef at the centre of the beach as illustrated in Figure 2.8. Such a groyne could involve simply raising the level of the existing natural reef using large boulders to achieve a natural looking structure. This would improve the effectiveness of the reef by inducing wave breaking as future sea levels rise. This option would generate a realignment of the beach and an accretion of the dune directly on both sides of the groyne. However, this option might generate some issues at the Curarrong Creek entrance where a breakthrough can impact the dwellings currently protected by the sand bar between the ocean and the creek.

Figure 2.6 – Relocation of Curarrong Creek entrance option (CES, 2003)
Figure 2.7 – Beach nourishment option with sand retention groyne (CES, 2003)
Figure 2.8 – Construction of a groyne along the reef at the centre of the beach
Groynes have the following advantages:

- They are effective in creating a usable beach on the updrift side if there is a strong rate of longshore drift
- They can increase the width of the beach berm and therefore provide an area of beach that can be used by the public
- They allow the beach to accrete on the updrift side, providing a buffer of sand to protect infrastructure against storm erosion, and
- They can be installed as temporary geotube structures to study their effectiveness and optimise their location (refer Figure 2.9).

Disadvantages of groynes include:

- They can be costly to construct
- The structure itself can detract from the visual and recreational amenity of the beach
- They can cause erosion on the downdrift side of the structure
- They can create a hazard to swimmers at their seaward end
- They require careful design and detailed understanding of the coastal processes
- They can cause loss of sand from the beach system if they are too long
- They require on-going maintenance
- A groyne at the creek entrance may lead to unstable scouring of the entrance area and while acting as a training wall, can create a permanent change to the tidal prism and ecology of the estuary.
- They are not a certifiable coastal protection measure and do not guarantee full or continual protection of the coastline from landward recession. Development Controls would still be needed.
- In severe storm events, any accreted sand will be transported away from the beach profile and wave action from an extended storm event will continue to erode the coastline.
- They can generate rip currents causing sand to be jetted seaward
- They are only partly consistent with the objectives of the NSW Coastal Policy 1997 and Coastal Protection Act 1979 (i.e. ESD principles).
A groyne will require DA approval and a full environmental assessment. Although it could be classed under SEPP (Infrastructure) as a major project, there are environmental and amenity concerns that will have to be considered prior to the commencement of construction. Acts that apply include the EP&A Act, Coastal Protection Act, Local Government Act, SEPP 71 and SEPP (Infrastructure).

### 2.3.4 Artificial Reefs

Artificial Reefs are coast-parallel, long or short submerged structures built with the objective of reducing the wave action on the beach by inducing wave breaking over the reef (Coastal Engineering Manual, 2003).

These are built offshore and may consist of rubble-mound structures constructed of rock or concrete armour units. They can be designed to be stable or allowed to reshape under wave action. Artificial reefs may be narrow crested like detached breakwaters in shallow water or, in deeper water, they may be wide crested with lower crest elevation like most natural reefs that cover a fairly wide rim parallel to the coastline. They may be fully submerged or have a crest level above water.

Artificial reefs modify the nearshore wave climate by inducing wave breaking and subsequent energy dissipation, and they can also be used to regulate wave action by refraction and diffraction. They can also be designed to improve surfing conditions while at the same time protecting the beach from erosion. A major disadvantage of artificial reefs is that they often present a non-visible hazard to swimmers and boats.

Such structures have been constructed elsewhere, such as by Gold Coast City Council at Narrowneck (Figures 2.10 and 2.11), and a smaller scale reef has been constructed at Semaphore Park in South Australia.

The Narrowneck Artificial Reef was intended as an off-shore defence mechanism against beach erosion, but also aimed to improve surfing conditions at Narrowneck Beach. The reef construction involved using sand filled geotextile bags dropped onto the seabed. The reef has been in place for around 10 years and monitoring has shown that it has been successful in maintaining a wider nourished beach (Jackson et al 2007). The reef is part of an ongoing beach protection strategy which includes regular beach nourishment.
The Northern Gold Coast Beach Protection Strategy was implemented at a cost of $9 million and involved the dredging of more than 1.1 million cubic meters of sand from the Broadwater and deposited as beach nourishment on Surfers Paradise beaches.

An artificial reef of the scale of the Narrowneck Reef is likely to be too large and not practical for Currrarong. A smaller scale structure such as one used for Semaphore Park in South Australia, could be designed for Currrarong (Townsend, 2005).

Advantages of offshore breakwaters and artificial reefs include:

- They can lead to build up of sand on the beach in the lee of the structure
- They can enhance surfing conditions if properly designed, and
- If they are located underwater they are visually unobtrusive.

Disadvantages of offshore breakwaters and artificial reefs include:

- They can be costly to construct
- They can have a significant environmental impact as they can smother benthic ecosystems
- They can pose a navigation hazard or hazard to swimmers
- They can cause erosion of the beach on either side of the structure
- They do not work very well when the dominant sediment transport mechanism is longshore transport.
- They require maintenance.
- They are not a certifiable coastal protection measure and do not guarantee full or continual protection of the coastline from landward recession. Development Controls will be needed, and
- They are only partly consistent with the objectives of the Coastal Policy and Coastal Protection Act (i.e. ESD principles).

A suggested location of the artificial reef is illustrated in Figure 2.12.

Artificial Reef is not a practical option for Currrarong – because of its cost and the difficulty in predicting its effectiveness.
Figure 2.10 – Artificial Reef - Narrowneck Reef, Gold Coast

Figure 2.11 – Artificial Reef – Aerial View of Narrowneck Reef, Gold Coast (GCC, 2007)
Figure 2.12 – Suggested Location for Curarrong Artificial Reef and typical reaction of the beach to such structure (red line is indicative only)
2.4 Adaptation Options

Adapt options recognise that the coastline is receding due to the impacts of coastal processes, and advocate an approach whereby existing and proposed developments adapt to the changing conditions.

Such an approach may entail a mixture of different management approaches, recognising immediate, short term, medium term and long term goals that are consistent with the changing nature of the threats to the coastline and the changing importance of the major issues as perceived by Stakeholders (including members of the local community, local businesses and local and State Authorities).

An adaptation approach requires the key issues to be addressed, in order of importance and with a long term strategy in mind. The most urgent issues would be given the highest priority for immediate action, and short, medium and long term strategies would be defined for particular issues at the appropriate timescale. For example, a short term action may be to close off dangerous beach accessways; medium term actions may involve planning controls on development or engineering works to improve beach amenity and provide some coastal protection for infrastructure. Long term actions may involve infrastructure and land moving into public ownership or moving landward, as these become unable to be sustained with the future increased coastal hazard risk. Ongoing actions would involve community education, review of the coastal hazard risk, and ongoing maintenance and restoration of the coastal dune environment.

Such an approach represents a combination of strategies that takes into account the timescales of the coastal processes and the relative importance of each of the issues, working with the natural processes rather than against them, but still allowing future development and use of the coastal area within the framework of ESD.

Specifically for Curraorong, the following types of options are discussed:

- Beach nourishment
- Combination of various approaches
- Land management options (dune management)

2.4.1 Beach Nourishment

Beach nourishment involves placement of sand onto the beach to create a dune, which provides a buffer against erosion due to storms. Such nourishment depends on locating a suitable source of sand, such as a nearby estuary. It works best when the sand placed on the beach closely matches the grain size and characteristics of the native beach sand, or when the sand is sourced from within the same coastal sediment compartment as the beach.

An example of beach nourishment work is shown in Figure 2.13. This work is typically followed by vegetation planting on the dune to stabilise the sand and preventing sand from being blown away by wind. Fencing off the dune and limitation of the number of accessways would avoid dune destabilisation caused by informal access.

Umwelt (2009) suggested minimising the number of accessways across the steep eroding dune face and spacing the others at 100m intervals.

For Curraorong, a suitable source of sand for renourishing the beach should be available from the foreshore to the north of Plutus Creek or from within the entrance of Curraorong Creek. Sand could be moved by off-road vehicles along the beach to the Warrain Crescent precinct where it would be placed and spread to nourish the beach.
A wooden dune fence can be constructed at the top of the dune face to help stabilise the dune. Once the wooden barrier is constructed, vegetation can be planted to further stabilise the dune and capture the sand. This option would require time to allow the vegetation to establish. An example of such a dune configuration is illustrated in Figure 2.14.

Advantages of beach nourishment include:

- It can work with rather than disrupt the natural coastal processes to replace the sand on the beach
- It provides a buffer of sand to help protect infrastructure from dune erosion due to storms
• It can improve the visual and recreational amenity of the beach by providing an area of sand that can be used by the public
• It can allow revegetation and rehabilitation of dune vegetation
• It is consistent with Council’s Entrance Management and Dredging Strategies.

Disadvantages of beach nourishment include:

• Beach nourishment conducted in isolation would be rapidly transported by longshore drift back out of the beach system
• It can be costly to implement
• Beach nourishment sand can be lost in subsequent storms and would need periodic replenishment and maintenance
• If the source of sand is unsuitable it could lead to large losses of sand from the beach during storms
• In some cases, it can cause temporary water quality impacts due to dredging and smothering of seagrasses due to fine material being released into the water column, and
• They are not a certifiable coastal protection measure and do not guarantee full or continual protection of the coastline from landward recession. Development Controls will still be needed.

Sand nourishment would require revegetation and fencing works to be carried out at the dune, which would provide a measure of protection to the dune against erosion.

While beach nourishment works best when the borrow sand has the same characteristics as the native sand from the nourishment area, sand from outside the littoral compartment can be used to provide a supply to augment the natural sand reserves of the beach. Detailed studies of sediment budgets could be required to determine the most appropriate source region for the sand, and a detailed environmental approvals process (often an REF or EIS) would need to be carried out, as extraction of sand from the estuary could be seen as an “extractive industry” under the Environmental Planning and Assessment Act.

Rather than undertaking one large beach renourishment exercise, smaller quantities of sand could be placed on Currrarong Beach at regular intervals - or possibly after severe storms. According to CES (2003), over a 50 year period the overall volume of sand required for such intermittent renourishment would still be 100,000 cubic metres. The advantages of staged nourishment are that shoreline changes would be less dramatic, and initial losses would be reduced. A disadvantage would be the periodic disruption to recreational beach activities caused by carting sand along the beach. Costs would also be higher because of the need to mobilise for a number of nourishment campaigns. The performance of the beach nourishment and build-up of sand in the estuary entrance would require monitoring over time, and the exercise repeated when required. It has been suggested that a shore perpendicular structure near the creek entrance be constructed to reduce the movement of sand into the creek entrance.

2.4.2 Combination Of Various Approaches

A combination of the above management options could be implemented successfully at Currrarong to protect the vulnerable areas from erosion and improve the amenity of the beach at the same time. Such combinations could include:

• Provision of a groyne along the western side of Currrarong Creek entrance or enhancement of the natural rock reef combined with beach nourishment in front of Warrain Crescent. This option would improve the amenity of the beach, as well as reduce the downdrift impact of the groyne. The groyne could consist of a temporary
or trial structure such as a sand-filled geotube, which could be removed over time if ineffective, or replaced with a more durable permanent structure if it proves to be effective. The beach nourishment sand could be shaped into a dune, replanted and fenced to provide formalised beach accessways for the public.

- Combination of a revetment and beach nourishment. This option would involve the burial of a revetment constructed along Warrain Crescent (eastern half) with beach nourishment sand, so that the revetment would normally not be visible. The revetment would only be exposed following erosion due to storm events and would provide additional protection to the infrastructure fronting Warrain Crescent.

- Combination of a revetment along Warrain Crescent buried with beach nourishment sand, with a groyne at either the eastern end of the beach (i.e. western side of Currarong Creek entrance) or enhancement of the natural rock reef. Such an option would provide maximum protection to the Warrain Crescent area as well as allow the best prospect of developing a long-term sandy beach that can be used by the public.

Any of the above approaches could be implemented at Currarong but would be subject to careful detailed design and environmental assessment. Currently all the land seaward of Warrain Crescent is under public ownership. The above options also present an opportunity to improve the amenity of the beach at Currarong.

The major disadvantage of these types of options is the cost. There are also social equity issues associated with a large expenditure of funds that can be argued would benefit relatively few people within the LGA and the broader community. Funding for other essential services elsewhere within the Council area may suffer.

### 2.4.3 Dune Management Options

Continuation of Shoalhaven City Council’s dune management policy by vegetation with native species and control of weeds would reduce the erosion of the dune, as native species have more extensive root systems and can hold the dune together more effectively. Tall vegetation can alter the wind field at the beach, also assisting dune growth.

Management of the dune could also include the following measures:

- Maintenance of formalised beach accessways to provide residents with beach access and prevent informal beach access through sensitive vegetation areas
- Residents want the dune at Currarong protected and retained as well as accessways maintained as Currarong has more accessways along the beach than at other places in Shoalhaven.
- Fencing off areas of dune rehabilitation
- Revegetation of the dune with native species - shorter, scrubby wattles possibly more appropriate than tall banksias that impact on views.
- Signage for community education about dune processes and public safety.

An example of effective dune management is presented in Figure 2.15.

These land management options represent the minimum maintenance required for the area. They would improve the amenity of the area in the short term but do not address the medium-long term problem of coastal erosion and risk to property and infrastructure. Dune management, while having a number of environmental advantages, would not be very effective in controlling the existing erosion and recession problem at Currarong. It would need to be implemented in conjunction with any of the options presented above.
2.5 Detailed Options Assessment

A preliminary options assessment has been carried out with all options considered. The purpose of the options assessment was to provide a basis for the Coastline Management Committee to workshop the various options for short listing for concept design. Several management options, including retreat, protection and adaptation options were considered in the analysis. All of the options listed below include dune management measures and maintenance, which are considered high priority ongoing actions.

The 19 options considered include:

1. **Vertical Seawall (300 m)**: Provision of a 300 m long vertical front concrete seawall to protect the eastern end of Warrain Crescent from coastal erosion;

2. **Revetment (300 m)**: Provision of a 300 m long sloping rock or gabion revetment to protect the eastern end of Warrain Crescent from coastal erosion;

3. **Vertical Seawall (entire beach)**: Provision of a vertical front seawall extending from the entrance of Plutus Creek to the entrance of Curraong Creek to protect Warrain Crescent (950 m long)

4. **Revetment (entire beach)**: Provision of a sloping revetment extending from the entrance to Plutus Creek to Curraong Creek (950 m long)

5. **Artificial Reef**: Provision of an artificial reef offshore to improve the wave climate of the beach and encourage accretion along Warrain Crescent

6. **Groyne (rock) at the centre of Curraong Beach**: Provision of a permanent rock groyne which would involve using boulders to raise the level of the existing rock reef at the centre of the beach to encourage accretion of sand updrift and improve recreational amenity of the beach on both sides of the groyne. This option includes beach nourishment of the beach;

7. **Groyne (geotubes) at the centre of Curraong Beach**: Provision of a more temporary geotube groyne at the existing rock reef at the centre of the beach to encourage accretion of sand updrift and improve recreational amenity of the beach.
beach on both sides of the groyne. Such a groyne would be subject to evaluation of its effectiveness over time. This option includes beach nourishment of the beach;

8. **Groyne (rock) at eastern end of Currarong Beach:** Provision of a permanent rock groyne on the western side of Currarong Creek acting as a training wall to encourage accretion of sand updrift and improve recreational amenity of the beach west of the groyne. This option includes beach nourishment of the beach;

9. **Groyne (geotubes) at eastern end of Currarong Beach:** Provision of a more temporary geotube groyne acting as a training wall on the western side of Currarong Creek to encourage accretion of sand updrift and improve recreational amenity of the beach west of the groyne. Such a groyne would be subject to evaluation of its effectiveness over time. This option includes beach nourishment of the beach;

10. **Relocation of Currarong Creek entrance with training wall:** Creation of training walls to straighten Currarong Creek entrance to encourage accretion on both sides of the new entrance;

11. **Beach nourishment only:** Beach nourishment of the western half of Currarong Beach using sand obtained from Plutus Creek to form a dune and beach berm;

12. **Beach nourishment plus groyne and revetment (300 m):** Beach nourishment of the area seaward of Warrain Crescent using sand obtained from Plutus Creek and Currarong Creek to form a dune and beach berm, combined with construction of a rock or geotube groyne to prevent loss of the nourished beach profile due to longshore drift at the centre of the beach and construction of a 300 m long revetment to reduce the coastline hazard risk to the eastern half of Warrain Crescent;

13. **Beach nourishment plus vertical wooden dune fence:** Regular beach nourishment of the area seaward of Warrain Crescent using sand obtained from Plutus Creek and Currarong Creek, combined with the construction of a timber dune fence to stabilise the newly created dune and berm;

14. **Beach nourishment plus dune reinforcement with geotextile:** Regular beach nourishment of the area seaward of Warrain Crescent using sand obtained from Plutus Creek and Currarong Creek to form a dune and beach berm, combined with an underlayer composed of geotextile wrap or sand tube;

15. **Planned Retreat with voluntary purchase:** Planned retreat from the coastline, involving voluntary purchase of homes at risk on Warrain Crescent east of Cambewarra Rd at market value and rehabilitation of the land on which they were on, with its return to public use;

16. **Road relocation:** Removal of Warrain Crescent east of Cambewarra Rd where at threat and creation of a new access road landward of the houses;

17. **Planning controls:** Planning controls which prevent further development to the houses when in the coastal hazard zone through the DCP and LEP;

18. **Dune Management Only:** Dune management including accessway management;

19. **Do nothing:** This option assumes a “Status Quo” of Council’s activities.

The above options have legislative aspects and environmental approvals that would need to be obtained for their implementation. The list is not exhaustive and various combinations of options could be implemented progressively.

All the options require development of management plans directed at mitigating impacts. Most of the structural options may require environmental approval under the EP&A Act.
The options assessment has been carried out using a *Triple Bottom Line* approach, discussed below.

### 2.5.1 Triple Bottom Line Assessment

A Triple Bottom Line (TBL) approach is presented to compare the options outlined above, which allows various options to be compared with a common index.

The main criteria used for assessing the options include the three “pillars of sustainability” – namely economic, social and environmental factors.

Rather than comparing options purely based on financial benefits, the TBL approach provides a more comprehensive assessment that encompasses additional factors such as environment and social factors. In doing so, weightings can be applied to the financial, social and environmental factors based on community concerns and preferences so that the balance between these three areas is representative of community preference. This project focuses on the erosion remediation and therefore the efficiency of the option was considered as the most significant factor. The result of this approach can be subjective as there are many intangible factors to consider. However, it provides the stakeholders with a method by which they can examine the options and discuss the weightings where necessary.

Each of the three main factors has been given further subcategories to provide more detail and increase the robustness of the assessment. Scores from 0 – 10 are then given to all the categories and subcategories in terms of benefits (higher scoring) and costs (lower scoring) for each of the proposed options.

To subjectively rank the available options from most favourable to least favourable, the abovementioned scoring system was applied to each of the options and scores given to each option depending on how well they are able to meet the criteria from all the categories. In doing so, the option with the highest score represents the most favourable option and the option with the lowest score is least favourable.

It should be noted that the analysis should not be seen to provide a definitive result but to provide some guidance on the most favourable options for workshopping with the Coastline Management Committee.

### 2.5.2 Criteria

Several criteria were chosen against which to rank the various options. These criteria reflected the three categories of Economic, Social and Environmental. Each of the chosen criteria encapsulates the major issues associated with each option, with several issues spanning all three categories of economic, social and environmental criteria. Such issues encapsulated within the chosen criteria include the effectiveness of each option in removing the coastal hazard risk, the compatibility of the option with the principles of ESD, and the likely community acceptance of each option based on community consultation carried out to date.

The subcategories included in the TBL and their reasons for inclusion are outlined below.

For detailed assessment, a 50 year planning period is suggested to estimate total maintenance and construction costs in considering the different spans of design life and frequency of maintenance for the various options. The 50 year planning period is a typical design life span for a residential dwelling used by the Australia Taxation Office for depreciation purposes.
2.5.2.1 Economic Criteria
The economic criteria chosen for the options assessment involved the total cost of the option. The total cost includes both the construction and the maintenance costs. The cost of each option is ranked, with the most expensive option receiving the lowest score of 1 out of 10, and the cheapest option receiving the highest score of 10.

2.5.2.2 Social Criteria
The social criteria chosen for the options assessment involved:

- **Effectiveness of the protection** – options with a high benefit to property owners affected by coastal hazards are given a high score for this criterion, with a low score assigned for options which do not provide much benefit for property owners affected by coastal hazards. This criterion was considered as the most significant criteria and was therefore given the largest weight.

- **Visual Impact** – options that have a positive visual impact are given a high score while options having a negative impact on the visual aspect are given a low score.

- **Impact of the option on recreational amenity** – options which improve beach amenity and beach access are given a higher score than those which detracted from or provided only a marginal benefit to recreational amenity.

- **Approval Required** – Options that need the least approval and are therefore the easiest to implement are given a high score while options that need several approvals and are therefore more difficult to implement are given a low score.

2.5.2.3 Environmental Criteria
The Environmental Criteria chosen for the TBL assessment included:

- **Disruption to Coastal Processes** – this is a measure of to what degree the option would disrupt the natural coastal processes – options that disrupt the natural coastal processes in a detrimental way receive a lower score than those that work with or do not disrupt the natural coastal processes.

- **Preservation of the natural character of the beach** – this is a measure of the degree to which the natural character of the beach is maintained by implementing the particular option. Options that detract from the natural character of the beach receive a low score, whereas options that improve the natural character of the beach receive a high score for this criterion.

- **Ecological impacts** – this is a measure of the impact of the proposed option on the local ecology of the area. Options that have a detrimental impact on the local ecology of the area receive a low score for this criterion, whereas options with a positive impact receive a high score.

2.5.2.4 Weightings
Weighting factors can be assigned to various criteria to reflect their importance relative to legislation requirements (i.e. Coastal Protection Act, ESD principles, Coastal Policy etc).

Following comments from some members of the Coastal Management Committee, weighting factors were assigned due to the relative importance of the various components as follows:

- **Economic** - total cost weighting = 2.5
- **Social** - visual impact weighting = 0.5
- **Social** - Effectiveness of option weighting = 4
- **Social** - Beach/Recreational amenity = 1
- **Social** - Approvals required = 0.5
- **Environmental** - Preservation of natural character of the beach = 1
- **Environmental** - Impact on ecology, flora and fauna = 1
- **Environmental** - Disruption to natural coastal processes = 1

The assessments for each of the options considered are provided below.
2.5.3 Option 1 – Vertical Seawall (200m)

Table 2.2 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.2 – Vertical Seawall (200m) – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>3.3</td>
<td>This option has a high capital cost, including material and construction requirements, ongoing dune management and seawall maintenance. This option is ranked 7th most expensive out of 19 options for total cost.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>1</td>
<td>The beach will not look natural any more in the presence of a vertical seawall along coast. The beach berm in front of the seawall may suffer from increased erosion which could result in a loss of the beach area.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>8</td>
<td>This option would provide effective coastal protection to the landward infrastructure (i.e. urban development) from erosion over a long life period.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>3</td>
<td>A vertical seawall may increase public use of the area and improve coastal views by providing a promenade for the public to walk along the seashore. The resultant loss of beach in front of the seawall represents a net reduction in beach recreational amenity.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>4</td>
<td>A seawall along the beach is likely to require a full environmental assessment.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>1</td>
<td>Construction of a vertical seawall would replace the vegetation from the embankment with concrete and permanently change the visual character of the beach.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>1</td>
<td>Destruction of the dune vegetation would result in a net detrimental impact on coastal ecology of the area. There are also ecological impacts associated with construction and use of resources.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>2</td>
<td>Wave reflections from a vertical front seawall would result in a reduction in beach width. A seawall would artificially hold the beach in place and does not allow for natural replenishment of the beach with material from the dune.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>49.8</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.4 Option 2 – Vertical Seawall (entire beach)

Table 2.3 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.3 – Vertical Seawall (entire beach) – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>0.6</td>
<td>This option is estimated to have a higher capital cost compared to the construction of a 200m seawall since it covers the entire beach. This option is ranked 2nd most expensive out of 19 options for total cost.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>0</td>
<td>The entire beach will not look natural with the construction of a seawall along the coast. The beach berm in front of the seawall may suffer from increased erosion which would result in loss of beach area.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option 10</td>
<td>10</td>
<td>This option would perform effectively in stopping or reducing large scale landward erosion over a long life period. Compared to short distance seawall protection, long distance seawall protection will improve the stability of the structure and enlarge the protected area. It would also reduce the impact of edge effects at the ends of the seawall.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity 2</td>
<td>2</td>
<td>A long distance vertical seawall would increase public use of the area and improve coastal views by providing a promenade for the public to walk along the seashore. The loss of beach in front of the seawall represents a net reduction in beach recreational amenity.</td>
</tr>
<tr>
<td>Social – Approval Required 2</td>
<td>2</td>
<td>Seawall construction along the entire beach will require higher capital cost and greatly change the natural character which would increase the time required for approval.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach 0</td>
<td>0</td>
<td>Construction of a vertical seawall would replace the dune vegetation with concrete and permanently change the visual character of the beach.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna 0</td>
<td>0</td>
<td>Destruction of the dune vegetation would result in a net detrimental impact on coastal ecology of the area. There are also ecological impacts associated with construction and use of resources.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes 1</td>
<td>1</td>
<td>Wave reflections from a vertical front seawall would result in a reduction in beach width. A seawall would artificially hold the beach in place and does not allow for natural replenishment of the beach with material from the dune.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>45.5</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.5 Option 3 – Revetment (200m)

Table 2.4 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.4 – Revetment (200m) – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>3.9</td>
<td>Revetment structure is estimated to have a similar financial cost as a seawall. Beach nourishment would increase the capital cost. This option is ranked 8th most expensive out of 19 options for total cost.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>5</td>
<td>Revetment structures coupled with beach nourishment will improve the natural aesthetics; however, the artificial layers may be exposed in the long term and after a significant storm.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>8</td>
<td>Revetment structures are an effective hard engineering solution that protect all the layer materials and provide toe protection. A revetment would result in less impact on the beach than a vertical seawall as the structure absorbs wave energy. However, the replenished sand covering the surface of the structure will suffer from sand loss after several years of erosion.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>5</td>
<td>The loss of sand in front of a revetment structure would be lower compared to a vertical seawall. The structure in isolation would not significantly impact on the existing recreational amenity of the area.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>4</td>
<td>A revetment along the beach is likely to require a full environmental assessment.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>4</td>
<td>Construction of a revetment would result in removal of dune vegetation and change the visual character of the beach. Once covered with sand, the beach would recover its natural character. However, the revetment would be exposed in case of a significant storm and in the long term.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>2</td>
<td>Destruction of the dune vegetation for revetment construction would result in a net detrimental impact on coastal ecology of the area. There are also ecological impacts associated with construction and use of resources.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>3</td>
<td>A revetment would not be subject to the same wave reflection as a vertical front seawall and consequently there would be less impact on the beach width. A revetment, however, would artificially hold the beach in place and does not allow natural replenishment of the beach with material from the dune.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>60.3</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.6 Option 4 – Revetment (entire beach)

Table 2.5 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.5 – Revetment (entire beach) – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>1.1</td>
<td>This option is estimated to have a higher capital cost compared to the 200m revetment option since it covers the entire beach. This option is ranked 3rd most expensive out of 19 options for total cost.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>4</td>
<td>Revetment structures coupled with beach nourishment would improve the natural aesthetics; however, the artificial layers may be exposed in the long term.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>10</td>
<td>Revetment structures are effective hard engineering solutions that protect all the layer materials and provide toe protection. A revetment would result in less impact on the beach than a vertical seawall as the structure absorbs wave energy. However, the replenished sand covering the surface of the structure will suffer from sand loss after several years of erosion.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>4</td>
<td>The loss of sand in front of a revetment structure would be lower compared to a vertical seawall. The structure in isolation would not significantly impact existing recreational amenity of the area.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>2</td>
<td>A revetment along the beach is likely to require a full environmental assessment.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>3</td>
<td>Construction of a revetment would result in removal of dune vegetation and permanently change the visual character of the beach.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>1</td>
<td>Destruction of the dune vegetation would result in a net detrimental impact on coastal ecology of the area. There are also ecological impacts associated with construction and use of resources.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>2</td>
<td>A revetment would not be subject to the same wave reflection as a vertical seawall and consequently there would be less impact on beach width. A revetment, however, would artificially hold the beach in place and does not allow for natural replenishment of the beach with material from the dune.</td>
</tr>
</tbody>
</table>

TOTAL**  55.8

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.7 Option 5 – Artificial Reef

Table 2.6 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.6 – Artificial Reef – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>2.8</td>
<td>Artificial reef can be costly to construct as it is a submerged structure built with rock or geotubes. This option is ranked 6th most expensive out of 19 options for total cost.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>8</td>
<td>If they are located underwater, there would be no visual impacts. This option may improve the net accretion of sand which would widen the beach area.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>6</td>
<td>While this option may reduce the existing coastal risk for the suggested protection area, it would not guarantee full or continual protection on either side of the structure and development controls would still be required on the land.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>5</td>
<td>Surfing conditions can be improved. However swimming conditions may be made more dangerous by the presence of the structure. The net accretion of sand can increase public use of the beach area.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>1</td>
<td>This option would likely require an EIS.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>8</td>
<td>An artificial reef would not disrupt the existing character of the beach as it does not involve any shoreline works. However, wave climate and beach plan-form would be altered.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>7</td>
<td>It was considered that an artificial reef would provide habitat for marine life, encouraging fish and colonisation by seagrasses.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>1</td>
<td>An artificial reef would disrupt the natural coastal processes by changing wave climate and sediment transport processes generating uncertainties.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>56.5</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.8  Option 6 – Rock Groyne at the Centre of the Beach

Table 2.7 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.7 – Rock Groyne at the Centre of the Beach – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic – Total Cost</strong></td>
<td>5.6</td>
<td>This option is ranked 11\textsuperscript{th} most expensive out of 19 options for total cost as the groyne will be constructed from rock at the centre of the beach where there is already a natural reef.</td>
</tr>
<tr>
<td><strong>Social – Visual Impact</strong></td>
<td>4</td>
<td>This option may increase the width of the beach berm. However, a breakthrough may be generated at the western side of Curraong Creek. The sand dredged from the creek and used for beach nourishment may have different visual characteristics to the native sand and may make the beach look less natural.</td>
</tr>
<tr>
<td><strong>Social – Effectiveness of Option</strong></td>
<td>6.5</td>
<td>A rock groyne is a permanent structure that generates a realignment of the beach and an accretion of the dune on both sides of the groyne. The beach erosion would be slowed down by the presence of the groyne and beach nourishment. However, it can not guarantee full or continual protection of the coastline from landward recession.</td>
</tr>
<tr>
<td><strong>Social – Beach/Recreational Amenity</strong></td>
<td>6</td>
<td>A groyne could result in accretion of sand updrift of the structure which would improve the existing recreational amenity of the area. However, loss of access along the beach and erosion downdrift of the structure may occur.</td>
</tr>
<tr>
<td><strong>Social – Approval Required</strong></td>
<td>5</td>
<td>A groyne would require DA approval and a full environmental assessment.</td>
</tr>
<tr>
<td><strong>Environmental – Preservation of natural character of beach</strong></td>
<td>4</td>
<td>A groyne at the centre of the beach would enlarge the existing reef to provide a buffer of sand against beach erosion and may be detrimental to the preservation of the natural character of the beach.</td>
</tr>
<tr>
<td><strong>Environmental – Impact on ecology, flora and fauna</strong></td>
<td>4</td>
<td>Some seagrass may be damaged due to sand accumulation and the natural assemblages of marine life would change as a result of the presence of the structure. There are also ecological impacts associated with the construction and use of resources.</td>
</tr>
<tr>
<td><strong>Environmental – Disruption to natural coastal processes</strong></td>
<td>4</td>
<td>A groyne would disrupt the natural littoral drift along the beach and erosion of downdrift areas could result from its construction.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>62.5</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by \((\text{Cost Rank})/(\text{no. options})/10\) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.9 Option 7 – Geotube Groyne at the Centre of the Beach

Table 2.8 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

**Table 2.8 – Geotube Groyne at the Centre of the Beach – TBL assessment**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>6.1</td>
<td>This option is ranked 12th most expensive out of 19 options for total cost as the groyne will be constructed from geotubes which are not as expensive as rock.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>2</td>
<td>This option may increase the width of the beach berm. However, a breakthrough may be generated at the western side of Currajong Creek. The sand dredged from the creeks and used for beach nourishment may have different visual characteristics to the native sand and may make the beach look less natural. Geotube groyne would be an obvious human-built feature of the beach compared to the rock groyne.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>6</td>
<td>A geotube groyne is a temporary structure that generates a realignment of the beach and an accretion of the dune on both sides of the groyne. The beach erosion would be slowed down by the presence of the groyne and beach nourishment. However, it cannot guarantee full or continual protection of the coastline from landward recession and the protection will be lost when the groyne is removed.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>5</td>
<td>A groyne could result in accretion of sand updrift of the structure which would improve the recreational amenity of the area at present. However, loss of access along the beach and erosion downdrift could also result.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>6</td>
<td>A groyne would require DA approval and a full environmental assessment. The less permanent feature may make the approval easier than for a permanent groyne.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>2</td>
<td>A geotube groyne would be an obvious human-built feature of the beach and would be detrimental to the preservation of the natural character of the beach. However, it is a less permanent feature than a rock groyne and could be removed.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>3</td>
<td>A geotube groyne will provide fewer habitats for flora and fauna than a rock groyne as it would be removed before marine organisms can properly settle along it.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>5</td>
<td>A groyne would disrupt the natural littoral drift along the beach and erosion of downdrift areas could result. However, the geotube groyne can be monitored and easily removed if it does not prove beneficial.</td>
</tr>
</tbody>
</table>

**TOTAL** | 58.3  | **Note** – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10. **Note** – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion. |
2.5.10 Option 8 – Rock Groyne at the Eastern End of the Beach

Table 2.9 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

*Table 2.9 – Rock Groyne at the Eastern End of the Beach – TBL assessment*

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>4.4</td>
<td>This option is ranked 9th most expensive out of 19 options for total cost as the rock groyne at the eastern end of the beach would require more material than the one at the centre of the beach as it would be longer.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>4</td>
<td>This option may increase the width of the beach berm at the site of the groyne. The sand dredged from the creeks and used for beach nourishment may have different visual characteristics to the native sand and may make the beach look less natural.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>6</td>
<td>Rock groyne at the eastern end of the beach will protect the eastern end of Currarong Beach and the entrance of Currarong Creek. Development controls would still be required.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>6</td>
<td>A groyne may create a hazard for swimmers. The accretion of sand updrift of the structure would improve the recreational amenity. It would also block pedestrian access across the entrance of Currarong Creek but may improve navigation for boats.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>4</td>
<td>A rock groyne at the eastern end would cause a permanent change to the estuary hydraulics which may increase the requirements for approval.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>4</td>
<td>A groyne would be an obvious human-built feature of the beach and would be detrimental to the preservation of the natural character of the beach.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>4</td>
<td>Some seagrass could be destroyed due to sand accumulation and the natural assemblages of marine life would change as a result of the presence of the structure. There are also ecological impacts associated with construction and use of resources.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>4</td>
<td>The groyne located at the eastern end is a new structure, compared with the groyne at the centre which enlarges the existing natural reef. This will increase the disruption to natural coastal processes.</td>
</tr>
</tbody>
</table>

**TOTAL**                                    | 56.0  |

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.  
**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.*
2.5.11 Option 9 – Geotube Groyne at the Eastern End of the Beach

Table 2.10 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.10 – Geotube Groyne at the Eastern End of the Beach – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic – Total Cost</strong></td>
<td>5</td>
<td>This option is ranked 10th most expensive out of 19 options for total cost as a geotube groyne at the eastern end would require more material than the one at the centre of the beach as it would be longer.</td>
</tr>
<tr>
<td><strong>Social – Visual Impact</strong></td>
<td>2</td>
<td>A geotube groyne would not look as natural as a rock groyne and there is no natural reef at the eastern end of the beach which will make a significant visual difference.</td>
</tr>
<tr>
<td><strong>Social – Effectiveness of Option</strong></td>
<td>5.5</td>
<td>Geotube groyne is a temporary structure which can not guarantee full or continual protection of the coastline from landward recession. A geotube groyne would have less resistance to erosion and undermining near the creek entrance than a rock structure at the same location.</td>
</tr>
<tr>
<td><strong>Social – Beach/Recreational Amenity</strong></td>
<td>5</td>
<td>A groyne could result in accretion of sand updrift of the structure which would improve the recreational amenity of the area at present. However, loss of access along the beach and erosion downdrift could also occur.</td>
</tr>
<tr>
<td><strong>Social – Approval Required</strong></td>
<td>5</td>
<td>A groyne at the eastern end needs detailed understanding of its influence on coastal processes since it is a new structure without natural reef basis. The less permanent feature may make approval easier than for a permanent groyne.</td>
</tr>
<tr>
<td><strong>Environmental – Preservation of natural character of beach</strong></td>
<td>2</td>
<td>A geotube groyne at the eastern end would be an obvious human-built feature of the beach. However, it is a less permanent feature than a rock groyne and could be removed.</td>
</tr>
<tr>
<td><strong>Environmental – Impact on ecology, flora and fauna</strong></td>
<td>3</td>
<td>Geotube groynes will provide fewer habitats for flora and fauna than a rock groyne as it would be removed before marine organisms can properly settle along it.</td>
</tr>
<tr>
<td><strong>Environmental – Disruption to natural coastal processes</strong></td>
<td>4</td>
<td>The groyne located at the eastern end is a new structure, compared to the groyne at the centre. This will increase the disruption to natural coastal process. However, the geotube groyne can be monitored and easily removed if it does not prove beneficial.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>52.0</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.12 Option 10 – Beach nourishment only

Table 2.11 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>7.8</td>
<td>This option is ranked 15th most expensive out of 19 options for the total cost as beach nourishment is cheaper than the construction of any concrete, rock or geotextile structure.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>9</td>
<td>Beach nourishment has a positive visual impact as the beach appears very natural.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>4</td>
<td>This option would slightly slow down the beach erosion. However, it would not stop erosion in case of a significant storm.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>8</td>
<td>This option would widen the beach improving the recreational amenity.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>7</td>
<td>Beach nourishment would most likely require an REF.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>10</td>
<td>Beach nourishment gives a very natural aspect and totally preserves the natural character of the beach.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>5</td>
<td>This option will have a positive impact on the beach as it would increase the dune habitat but it could also have some adverse impact in the dredging area (i.e. Currarong and Plutus Creek).</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>8</td>
<td>This option has no significant impact on the oceanic processes and it would enhance the build up of the dune.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>74.5</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.13 Option 11 – Beach nourishment stabilised by dune fencing

Table 2.12 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.12 – Beach nourishment with vertical wooden dune fence – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>7.2</td>
<td>This option is slightly more expensive than the “beach nourishment only” option but remains cheaper than the construction of any rock, concrete or geotextile structure. It is ranked 14th more expensive option out of 19 options for the total cost.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>8</td>
<td>Beach nourishment has a very natural aspect and the visual impact will be good. The wooden dune fence has a better visual impact than concrete or rock and will be covered with vegetation over time.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>5</td>
<td>This option would slightly slow down the beach erosion and stabilise the dune. However, it would not stop erosion in case of a significant storm.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>8</td>
<td>This option will widen the beach improving the recreational amenity.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>7</td>
<td>Beach nourishment would most likely require an REF.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>8</td>
<td>Beach nourishment gives a very natural aspect and totally preserves the natural character of the beach. The wooden dune-fence would change the natural character slightly but will be covered with vegetation over time.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>7</td>
<td>This option will have a positive impact on the beach as it would increase the dune habitat and the dune-fence will help the dune vegetation to grow. However, it could also have some adverse impact in the dredging area (i.e. Currarong and Plutus Creek).</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>8</td>
<td>This option has no significant impact on the oceanic processes and it would enhance the build up of the dune.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>76.5</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.14 Option 12 – Beach nourishment with reinforcement with geotextile

Table 2.13 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.13 – Beach nourishment and reinforcement with geotextile – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>6.7</td>
<td>The cost of such an option will be higher than the “beach nourishment with wooden dune fence” option. It is ranked 13th most expensive out of 19 options.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>8</td>
<td>Beach nourishment has a very natural aspect and the visual impact will be good. The geotextile should not be visible except in case of significant storm.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>6</td>
<td>This option would slow down the beach erosion and stabilise the dune. However, it would probably not stop erosion in case of a significant storm.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>8</td>
<td>This option will widen the beach improving the recreational amenity.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>7</td>
<td>Beach nourishment would most likely require an REF.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>7</td>
<td>Beach nourishment gives a very natural aspect and totally preserves the natural character of the beach. The geotextile reinforcement should not be exposed except in case of a significant storm.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>5</td>
<td>This option will have a positive impact on the beach as it would increase the dune habitat. However, it will also have some adverse impact in the dredging area (i.e. Currarong and Plutus Creek).</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>8</td>
<td>This option has no significant impact on the oceanic processes and it would enhance the build up of the dune.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>76.3</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
### 2.5.15 Option 13 – Revetment (200m) with groyne and beach nourishment

Table 2.14 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

**Table 2.14 – Revetment (200m) with groyne and beach nourishment – TBL assessment**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic – Total Cost</strong>*</td>
<td>2.2</td>
<td>This option is ranked 5th most expensive out of 19 options as it needs the construction of a groyne in addition to a revetment.</td>
</tr>
<tr>
<td><strong>Social – Visual Impact</strong></td>
<td>3</td>
<td>Although the revetment would be covered with sand at the beginning, it would be exposed in the long term due to erosion and would also be exposed in case of a significant storm. Moreover, the groyne constructed at the centre of the beach may degrade the natural aspect of the rock reef. This option would therefore have an adverse visual impact.</td>
</tr>
<tr>
<td><strong>Social – Effectiveness of Option</strong></td>
<td>9</td>
<td>The properties located behind the revetment would be totally protected as the revetment would stop the erosion and the beach erosion would be slowed down by the presence of the groyne and beach nourishment.</td>
</tr>
<tr>
<td><strong>Social – Beach/Recreational Amenity</strong></td>
<td>4</td>
<td>Although the revetment would be covered with sand at the beginning, it would be exposed in the long term due to erosion and would also be exposed in case of a significant storm. Therefore, the beach amenity would be reduced.</td>
</tr>
<tr>
<td><strong>Social – Approval Required</strong></td>
<td>3</td>
<td>This option would need approval processes for the beach nourishment, for the groyne construction and for the revetment construction.</td>
</tr>
<tr>
<td><strong>Environmental – Preservation of natural character of beach</strong></td>
<td>3</td>
<td>The natural character of the beach would be relatively preserved except for the groyne that will change the natural aspect of the rock reef. However, during/after a storm and in the long term, the revetment would be exposed which would change the natural character of the beach.</td>
</tr>
<tr>
<td><strong>Environmental – Impact on ecology, flora and fauna</strong></td>
<td>2</td>
<td>The construction of the revetment would generate damage to the dune habitat and to the vegetation covering the dune. Once covered with sand, the habitat would be restored but would need a long time to recover and in the long term, the revetment may be exposed by erosion which would reduce the habitat again. Furthermore, the beach nourishment may impact the ecology where the sand will be dredged (i.e. Plutus and Currarong Creeks).</td>
</tr>
<tr>
<td><strong>Environmental – Disruption to natural coastal processes</strong></td>
<td>3</td>
<td>The presence of the revetment will impact the natural dune building processes while the groyne will change the oceanic processes. The natural impact would therefore be significantly altered.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>56.5</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.16 Option 14 – Planned retreat (purchase) with dune management

Table 2.15 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.15 – Planned retreat (purchase) with dune management – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic – Total Cost</strong></td>
<td>0</td>
<td>This option is ranked first most expensive out of 19 options as it required to buy around 10 seafront houses which would be more expensive than any construction.</td>
</tr>
<tr>
<td><strong>Social – Visual Impact</strong></td>
<td>8</td>
<td>The visual impact would be improved if the dwellings are removed and the area rehabilitated.</td>
</tr>
<tr>
<td><strong>Social – Effectiveness of Option</strong></td>
<td>8</td>
<td>This option will be very effective as it will solve the issue by removing the houses at risk.</td>
</tr>
<tr>
<td><strong>Social – Beach/Recreational Amenity</strong></td>
<td>6</td>
<td>The purchase and removal of the seafront properties would provide more room for eventual recreational amenities at the back of the beach.</td>
</tr>
<tr>
<td><strong>Social – Approval Required</strong></td>
<td>7</td>
<td>The only approval required would be the one from the owners of the different houses to be purchased.</td>
</tr>
<tr>
<td><strong>Environmental – Preservation of natural character of beach</strong></td>
<td>10</td>
<td>Once the properties are purchased and removed, the back of the dune could be rehabilitated and the natural character of the beach would therefore be improved.</td>
</tr>
<tr>
<td><strong>Environmental – Impact on ecology, flora and fauna</strong></td>
<td>8</td>
<td>The removal of the houses would increase wildlife habitat at the back of the dune.</td>
</tr>
<tr>
<td><strong>Environmental – Disruption to natural coastal processes</strong></td>
<td>10</td>
<td>Removal of the houses would significantly improve the dune building process.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>73.5</td>
<td><strong>Note</strong> – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion</td>
</tr>
</tbody>
</table>
2.5.17 Option 15 – Relocation of Warrain Crescent east of Cambewarra Rd and dune management

Table 2.16 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.16 – Road relocation with dune management – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic – Total Cost</strong></td>
<td>8.3</td>
<td>This option is ranked 16th most expensive out of 19 options. This option would be cheaper than any concrete, rock or geotextile structures as well as beach nourishment.</td>
</tr>
<tr>
<td><strong>Social – Visual Impact</strong></td>
<td>8</td>
<td>The removal of the road at the back of the beach would allow the dune and vegetation to expand landward while the dune management would improve the dune aspect.</td>
</tr>
<tr>
<td><strong>Social – Effectiveness of Option</strong></td>
<td>5</td>
<td>This option would only remove some asset that could be reached by erosion but would neither slow down nor stop the erosion process.</td>
</tr>
<tr>
<td><strong>Social – Beach/Recreational Amenity</strong></td>
<td>4</td>
<td>Access to the beach would be more difficult where the road has been removed.</td>
</tr>
<tr>
<td><strong>Social – Approval Required</strong></td>
<td>7</td>
<td>Approval would be required to use Crown Road to build a new street behind the homes or Warrain Crescent.</td>
</tr>
<tr>
<td><strong>Environmental – Preservation of natural character of beach</strong></td>
<td>10</td>
<td>The removal of the road at the back of the beach would allow the dune and vegetation to expand landward which would increase the natural character of the beach.</td>
</tr>
<tr>
<td><strong>Environmental – Impact on ecology, flora and fauna</strong></td>
<td>5</td>
<td>This option would allow the vegetation to grow where the road was previously located but it would not stop or slow down erosion.</td>
</tr>
<tr>
<td><strong>Environmental – Disruption to natural coastal processes</strong></td>
<td>10</td>
<td>This option would improve the dune building process.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>77.3</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.*
2.5.18 Option 16 – Planning controls and dune management

Table 2.17 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.17 – Planning controls with dune management – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>9.4</td>
<td>This option is ranked 18th most expensive out of 19 options as it would only need administrative expenses.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>8</td>
<td>There would not be any adverse visual impact and the dune management would improve the dune aspect by control of the accessways.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>2</td>
<td>This option would not provide any protection against erosion.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>5</td>
<td>The beach and recreational amenities would be unchanged.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>9</td>
<td>There is no significant approval needed for the planning controls.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>8</td>
<td>The natural aspect of the beach would be preserved as unchanged. However, in the long term the natural aspect might be reduced if erosion reaches the road as the natural dune vegetation would be eroded away.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>5</td>
<td>This option would have no impact either beneficial or adverse on the beach.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>10</td>
<td>This option would not generate any disruption to the natural coastal processes.</td>
</tr>
<tr>
<td>TOTAL**</td>
<td>68.0</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion.
2.5.19 Option 17 – Dune management only

Table 2.18 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

Table 2.18 – Dune management only – TBL assessment

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic – Total Cost</strong></td>
<td>8.9</td>
<td>Dune management is ranked 17th most expensive out of 19 options as it only requires low cost for the dune maintenance.</td>
</tr>
<tr>
<td><strong>Social – Visual Impact</strong></td>
<td>9</td>
<td>The improvement of the beach access would be associated with a better visual aspect.</td>
</tr>
<tr>
<td><strong>Social – Effectiveness of Option</strong></td>
<td>1</td>
<td>This option would not protect the properties from erosion.</td>
</tr>
<tr>
<td><strong>Social – Beach/Recreational Amenity</strong></td>
<td>6</td>
<td>This option will improve the access to the beach.</td>
</tr>
<tr>
<td><strong>Social – Approval Required</strong></td>
<td>10</td>
<td>The accessways already exist and would just be maintained which does not require any approval.</td>
</tr>
<tr>
<td><strong>Environmental – Preservation of natural character of beach</strong></td>
<td>9</td>
<td>The accessway management would give a better natural character as it would remove the unnecessary accesses.</td>
</tr>
<tr>
<td><strong>Environmental – Impact on ecology, flora and fauna</strong></td>
<td>8</td>
<td>The management of the dune would improve the vegetation stabilisation.</td>
</tr>
<tr>
<td><strong>Environmental – Disruption to natural coastal processes</strong></td>
<td>10</td>
<td>The control of the accessways would improve the dune building process by reducing uncontrolled access to the beach and removing unnecessary accessways.</td>
</tr>
</tbody>
</table>
| **TOTAL** **

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion**
### 2.5.20 Option 18 – Currarong Creek entrance relocation with training walls

Table 2.19 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

**Table 2.19 – Currarong Creek entrance relocation with training walls – TBL assessment**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economic – Total Cost</strong></td>
<td>1.7</td>
<td>This option is ranked 4th most expensive out of 19 options as it requires the construction of training walls around the suggested new creek entrance.</td>
</tr>
<tr>
<td><strong>Social – Visual Impact</strong></td>
<td>2</td>
<td>The presence of the training walls would have an adverse visual impact along the beach.</td>
</tr>
<tr>
<td><strong>Social – Effectiveness of Option</strong></td>
<td>6</td>
<td>This option would slow down erosion and avoid unpredicted breakthrough of the creek. However, some properties would still be at risk in the long term and in case of significant storms.</td>
</tr>
<tr>
<td><strong>Social – Beach/Recreational Amenity</strong></td>
<td>4</td>
<td>This option would generate a new fishing spot along the training walls and improve the boat access from the creek. However a part of the beach has to be removed to allow the construction of the new entrance and the part of the beach east of the entrance would not be easily accessible for the residents living west of the creek entrance.</td>
</tr>
<tr>
<td><strong>Social – Approval Required</strong></td>
<td>2</td>
<td>This option would require approval for the construction of the training walls as well as an EIS (Environmental Impact Statement) for the new creek entrance.</td>
</tr>
<tr>
<td><strong>Environmental – Preservation of natural character of beach</strong></td>
<td>1</td>
<td>The presence of the training walls would highly degrade the natural character of the beach.</td>
</tr>
<tr>
<td><strong>Environmental – Impact on ecology, flora and fauna</strong></td>
<td>1</td>
<td>A part of the vegetated beach would be removed and the impact on Currarong Creek will be significant as it will be more directly exposed which may impact the ecosystem of the creek.</td>
</tr>
<tr>
<td><strong>Environmental – Disruption to natural coastal processes</strong></td>
<td>2</td>
<td>The training walls would modify the oceanic and hydrodynamic processes while the newly created entrance would change the estuarine processes into the creek.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>38.3</td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion."
### 2.5.21 Option 19 – Do nothing (Status quo)

Table 2.20 provides the scores for each of the criteria for this particular option, and reasoning for choosing each particular score.

**Table 2.20 – Do nothing – TBL assessment**

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Score</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic – Total Cost*</td>
<td>10</td>
<td>This option would not have any cost so it is ranked 19th most expensive out of 19 options.</td>
</tr>
<tr>
<td>Social – Visual Impact</td>
<td>8</td>
<td>The visual impact would be unchanged and the dune would remain natural. However, there could be an adverse visual impact in the long term if erosion reaches the road.</td>
</tr>
<tr>
<td>Social – Effectiveness of Option</td>
<td>0</td>
<td>This option would neither stop nor slow down erosion.</td>
</tr>
<tr>
<td>Social – Beach/Recreational Amenity</td>
<td>5</td>
<td>Beach amenity would not be impacted.</td>
</tr>
<tr>
<td>Social – Approval Required</td>
<td>10</td>
<td>No approval is required.</td>
</tr>
<tr>
<td>Environmental – Preservation of natural character of beach</td>
<td>8</td>
<td>The natural character of the beach would be preserved. However, there could be an adverse impact in the long term if erosion reaches the road.</td>
</tr>
<tr>
<td>Environmental – Impact on ecology, flora and fauna</td>
<td>5</td>
<td>This option would not have any impact on the ecology.</td>
</tr>
<tr>
<td>Environmental – Disruption to natural coastal processes</td>
<td>10</td>
<td>Natural coastal processes will be unaffected.</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>62.0</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Note – The Total Cost score out of 10 is calculated by (Cost Rank)/(no. options/10) to standardise the cost rank to a score out of 10.

**Note – The Total Score is calculated by adding the scores out of ten of each option multiplied by the selected weighting coefficient for each criterion

### 2.5.22 Summary and Conclusion

There are various management options that could be applied to the identified issues at Currajong. Some of these management options could provide opportunities to address several community concerns at the same time.

Potential options would need to specifically address the continuing erosion of the dune embankment and dune vegetation as well as improving beach amenity for the benefit of the community and the threatened properties. The options also need to be economical, satisfy social criteria and be ecologically sustainable under the NSW Coastal Policy.

Nineteen (19) Management options were considered that included:

- Construction of structural engineering works to reduce hazard threat to private property, which may include seawalls, revetments, groynes, artificial reefs, training walls for a new Currajong Creek entrance, etc.
- Beach nourishment works to provide a buffer against storm erosion
- Voluntary purchase of affected homes
- Planning Controls
- Do nothing
- Relocation of infrastructure and provision of alternative property access
- Dune management
- A combination of the above

These options were considered in terms of economic, social and environmental criteria using a Triple Bottom Line Assessment. A summary of the results of the TBL assessment are given in Figure 2.16 and Table 2.21, while more details are given in Appendix A.

Table 2.21 – Score and rank of each option from the Triple Bottom Line assessment (TBL)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Option</th>
<th>Total Score from TBL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Planned Retreat (Road Relocation) + Dune Management</td>
<td>77.3</td>
</tr>
<tr>
<td>2</td>
<td>Beach Nourishment + Vertical Wooden dune fence</td>
<td>76.5</td>
</tr>
<tr>
<td>3</td>
<td>Beach Nourishment + Reinforcement with Geotextile</td>
<td>76.3</td>
</tr>
<tr>
<td>4</td>
<td>Beach Nourishment</td>
<td>74.5</td>
</tr>
<tr>
<td>5</td>
<td>Planned Retreat (Purchase) + Dune Management</td>
<td>73.5</td>
</tr>
<tr>
<td>6</td>
<td>Dune Management (in isolation) ie Accessway</td>
<td>68.8</td>
</tr>
<tr>
<td>7</td>
<td>Planned Retreat (Planning Control) + Dune Management</td>
<td>68.0</td>
</tr>
<tr>
<td>8</td>
<td>Groyne Centre (rock)+Beach Nourishment</td>
<td>62.5</td>
</tr>
<tr>
<td>9</td>
<td>Do Nothing</td>
<td>62.0</td>
</tr>
<tr>
<td>10</td>
<td>Revetment (200m)+Beach nourishment</td>
<td>60.3</td>
</tr>
<tr>
<td>11</td>
<td>Groyne Centre (geotubes)+Beach Nourishment</td>
<td>58.3</td>
</tr>
<tr>
<td>12</td>
<td>Artificial Reef</td>
<td>56.5</td>
</tr>
<tr>
<td>13</td>
<td>Revetment + Groyne + Beach Nourishment (200m)</td>
<td>56.5</td>
</tr>
<tr>
<td>14</td>
<td>Groyne Eastern End (rock)+Beach Nourishment</td>
<td>56.0</td>
</tr>
<tr>
<td>15</td>
<td>Revetment (entire beach, rock) + Beach nourishment</td>
<td>55.8</td>
</tr>
<tr>
<td>16</td>
<td>Groyne Eastern End (geotubes)+Beach Nourishment</td>
<td>52.0</td>
</tr>
<tr>
<td>17</td>
<td>Vertical Seawall (200m)</td>
<td>49.8</td>
</tr>
<tr>
<td>18</td>
<td>Vertical Seawall (entire beach)</td>
<td>45.5</td>
</tr>
<tr>
<td>19</td>
<td>Currarong Creek Entrance Relocation with training walls</td>
<td>38.3</td>
</tr>
</tbody>
</table>
Figure 2.16 – Triple Bottom Line (TBL) assessment results
The five first options scored more favourably than the others by around 10 points. These options include dune management, retreat planning and beach nourishment options while the options involving the construction of structures (groyne, seawall, revetment, training wall and artificial reefs) have a lower score due to a more significant cost and a larger impact on the environment.

The initial assessment favoured the following options:

- Relocation of Warrain Crescent landward of the properties east of Cambewarra Road to maintain access;
- Dune management;
- Beach nourishment (in isolation or with stabilising dune fencing).

Viable structural options for further consideration may include a rock groyne structure to enhance the effect of the natural rock reef at the centre of the beach or an artificial reef.

A further assessment was undertaken during a workshop with Council and the Coasts and Estuaries Committee to shortlist options for further consideration and concept design. The options shortlisted for further design consideration included:

- Beach nourishment;
- Construction of a groyne (temporary or rock structure); and
- Geotextile protection for repair of localised erosion and accessways.

The preferred options are developed in Section 3.

Appendix C provides details of the presentation given to the Coasts and Estuaries Committee on 30 August 2010.