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City of Wanneroo

Quinns Beach Erosion & Coastal Protection

M P ROGERS & ASSOCIATES

Coastal & Port Engineers

Job J248/7 Report R110 Rev 1

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1. Executive Summary

There has been a long history of coastal erosion at Quinns Rock. In the 1970s, erosion of the southern flank was stopped by the construction of a rock seawall near the toilet block near the end of Quinns Road and a small rock headland built near the Quinns Cusp in 1977. The later work moved the erosion from the Southern Beach to the Northern Beach. Between 1977 and 1997 the Northern Beach retreated about 20 metres due to the coastal erosion.

The data suggests that the recession of the Northern Beach was caused largely by the construction of the headland in 1977. The recession does not seem to have been affected by the construction of the breakwaters as part of the Mindarie Keys project. The rate of recession of the Northern Beach was similar for the period before and after the construction of Mindarie Keys.

Coastal erosion in the late 1990s led to coastal and port engineers M P Rogers & Associates being engaged to study the situation. The data suggested that the historical rate of erosion of the Northern Beach was about 8,500 m^3/year and the Southern Beach had been accreting at about 4,000 m^3/year. Based on the data, it was estimated that the future rate of erosion of the Northern Beach would be about 7,000 m^3/year. The small net movement of sand to the north was thought to be the result of the difference in much larger seasonal movements of sand along the beach. It was estimated that the seasonal movements along the Northern Beach could be in the order of 100,000 m^3 to the north in summer and autumn and a similar but slightly smaller flux to the south in winter and spring. The comparison of options was completed using these estimates.

The Department for Planning & Infrastructure surveyed the beaches in January 2000 and the survey data coupled with beach nourishment records indicated that the rate of erosion between December 1997 and January 2000 was about 6,000 m^3/year (insitu volume). This loss of sand was offset by the nourishment works completed by the City of Wanneroo and the coast remained reasonably stable. The performance of the sand nourishment work was not ideal in that some recession was still experienced at Frederick Stubbs Reserve. This suggested that some increase to the quantity of sand and adjustment to the location of future nourishment exercises would be warranted.

In late 2001 significant erosion of the Northern Beach was observed and the Department for Planning & Infrastructure completed a survey in February 2002. The results of this survey indicated that about 78,000 m^3 of sand had been lost over the 2 years between the 2000 and 2002 surveys. Other metropolitan beaches were also suffering from erosion at this time. It was thought that perhaps the fact that the winter of 2001 was particularly mild with fewer than usual storms could be a contribution. The winter storms are important at Quinns in that they can move sand from the beaches further to the north back to the beaches at Quinns.

The occurrence of such unusual weather conditions was not identified or considered in the assessment of options in Rogers & Associates (1999). The occurrence of such unusual weather may occur again, and the effectiveness of the Renourishment and Seawall option and the Groyne option need to be investigated under these conditions.

This study was commissioned by the City of Wanneroo with the agreement of the Department for Planning and Infrastructure to investigate:

- the reasons for the rapid erosion between January 2000 and February 2002 and revise the assessment of coastal processes accordingly,
- reassess the effectiveness and costs of the Renourishment and Seawall option for the revised assessment of coastal processes,
- reassess the effectiveness and costs of the Groyne option for the revised assessment of coastal processes, and
- reassess the effectiveness and costs of using headlands instead of groynes for the revised assessment of coastal processes.

This work included the set-up and calibration of a computer model of the movement of sand along the coast under the influence of waves. The model was run for the usual wave conditions and calibrated to match the observed long-term changes. Then the wave conditions experienced in 2001 were used as input to the model.

In 2001 there were only about half the usual number of winter storms. The model indicated that the lower number of winter storms had a large effect in that much less a quantity of sand was moved from the north into the beaches at Quinns than usual during winter. The quantity of erosion calculated using the calibrated computer model was similar to that measured in the DPI surveys. The computer modelling indicated that the rapid erosion in 2001 was largely due to the lack of winter storms.

The computer model was then used to assess the performance of the three options above. The modelling indicated that all three options could be used to deal with the erosion at Quinns. The use of groynes or headlands to alter the longshore transport regime could be effective but would not totally isolate the beaches from the impacts of very mild winters such as experienced in 2001. There would need to be some additional beach nourishment following such events. The extent of the beach nourishment would be less for the options using the groynes or headlands compared to the seawall and ongoing sand nourishment.

The Net Present Value of costs for the three options evaluated in this report are presented in Table 1.1 below. This table also lists the Capital Cost of the three options.

Table 1.1 NPV & Capital Costs for Options 1, 2 and 3

Option	NPV @ 4%	NPV @ 6%	Capital Cost
Option 1 – Groynes & Initial Nourishment	$3,738,000	$3,455,000	$2,711,000
Option 2 – Headlands & Initial Nourishment	$3,880,000	$3,585,000	$2,807,000
Option 3 – Seawall & Ongoing Nourishment	$3,937,000	$3,315,000	$1,366,000

Note: 1. Refer to Appendix A for details of discounted cash flow analysis.

This comparison indicates that all three options have quite similar Net Present Value of costs over a 35 year period using a 4% or 6% discount rate. Certainly, the differences are less than the likely error bands in the various cost estimates.

Option 1 has the lowest NPV when using a 4% discount rate. In addition, this option involves significant capital expenditure that can be shared between the City of Wanneroo and the State Government and does not rely so much on recurrent expenditure funding.

Option 3, by comparison has the lowest NPV when using a 6% discount rate. It involves about half the amount of capital expenditure and is much more reliant on recurrent expenditure.

The significant ongoing sand nourishment works in Option 3 may not be acceptable to the local residents after a number of years. Many communities have the belief that ongoing beach nourishment is wasting money despite the known benefits. Consequently, because of possible changes to community attitudes, management and government policy, the long term funding of significant ongoing recurrent expenditure such as in Option 3 may not be secure. If the recurrent funding were not available in future years, then the performance of the scheme would be compromised.

Option 1 uses groynes to adjust the longshore transport regime and move the erosion problem further along the coast. The use of groynes provides the opportunity to make minor adjustments to the scheme should there be differences between the computer model predictions and the scheme as built. This is important because the real coastal processes are very complex and the interaction of a number of factors. The modelling work is a simplification of the actual system.

Option 1 is recommended to be adopted for the long term solution to the erosion at Quinns because it has one of the lowest NPV of costs and provides a practical scheme that can be staged over a 3 to 4 year period. It also provides some scope for fine-tuning, should it be required.

It is recommended that the City of Wanneroo and the State Government review this report, discuss the options and jointly adopt a preferred option. Then the recent erosion, this report and the preferred option should be presented to a public meeting. At this public meeting, the acceptability of the use of groynes can be discussed, and hopefully the preferred option put forward by the City of Wanneroo and the State Government will be supported.

Following the public meeting, the detailed design and documentation of the preferred option will need to be completed. The work should then be put to public tender and constructed at the end of the coming spring to take advantage of the movement of sand to the south in winter and spring.

2. Introduction & Background

2.1 Background

There have been coastal erosion problems at Quinns for many decades. In 1970 the Shire of Wanneroo constructed a seawall to protect the parking lot and toilet block located at the end of Quinns Road (refer to Figure 2.1). Additional protection works were completed in 1977 when a rubble headland was built near the Quinns Cusp to encourage accretion along the Southern Beach. Following severe storms in 1996, sand nourishment was placed on the Southern Beach to protect Ocean Drive and on the Northern Beach to protect the Northern Car Park.

In 1997, Tremarfon Pty Ltd investigated the erosion and concluded that the erosion on both the Southern and Northern Beaches may be a result of the stormy winter in 1996. It was hoped that the situation would recover and sand nourishment was suggested for a 5 year period. The City of Wanneroo has been completing sand nourishment each year since receipt of the Tremarfon report.

In 1998 the City of Wanneroo engaged M P Rogers & Associates Pty Ltd to investigate the erosion and develop the best long term solution. Rogers & Associates (1998) indicated that the construction of the headland in 1977 helped halt the erosion of the Southern Beach but has caused the Northern Beach to erode. Between 1977 and 1997 the coastal vegetation line near the Northern Car Park and Toilet Block has retreated about 20 metres. The available information suggested that the recession was reasonably progressive although there were periods of more rapid recession. This finding was quite different to that in Tremarfon (1997). Differences in the assessment of coastal processes can occur because of the complexity of the natural systems and the very limited data available for the analysis.

The information suggested that the recession of the Northern Beach was caused by the construction of the headland in 1977. The recession does not seem to have been affected by the construction of the breakwaters at Mindarie Keys. The rate of recession was similar for the period before and after the construction of Mindarie Keys.

2.2 Beach Erosion 1997 to 2002

In Rogers & Associates (1999) the historical rate of erosion from the Northern Beach had been estimated to be about 8,500 m^3/year (insitu volume). The Southern Beach was accreting at an average rate of 4,000 m^3/year between 1977 and 1997. These estimates were based on the limited survey data augmented by shoreline movement plans and review of historical aerial photographs. Because the Southern Beach appeared to be stabilised, the future rate of erosion of the Northern Beach had been estimated to be about 7,000 m^3/year (insitu volume). The small net movement of sand to the north was thought to be the result of much larger seasonal movements. It was estimated that the seasonal movements along the Northern Beach could be in the order of 100,000 m^3 to the north in summer and autumn and a similar but slightly smaller flux to the south in winter and spring. The comparison of options was completed using these estimates.

The Department for Planning & Infrastructure surveyed the beaches in January 2000 and the survey data coupled with beach nourishment records indicated that the rate of erosion between December 1997 and January 2000 was about 6,000 m^3/year (insitu volume). This loss of sand was offset by the nourishment works completed by the City of Wanneroo and the coast remained reasonably stable. The performance of the sand nourishment work was not ideal in that some recession was still experienced at Frederick Stubbs Reserve. This suggested that some increase to the quantity of sand and adjustment to the location of future nourishment exercises would be warranted.

In late 2001 significant erosion of the Northern Beach was observed and the Department for Planning & Infrastructure completed a survey in February 2002. The results of this survey indicated that about 78,000 m^3 of sand had been lost over the 2 years between the 2000 and 2002 surveys. Other metropolitan beaches were also suffering from erosion at this time. It was thought that perhaps the fact that the winter of 2001 was particularly mild with fewer than usual storms could be a contribution. The winter storms are important at Quinns in that they can move sand from the beaches further to the north back to the beaches at Quinns.

The occurrence of such unusual weather conditions was not identified or considered in the assessment of options in Rogers & Associates (1999). The occurrence of such unusual weather may occur again, and the effectiveness of the Renourishment and Seawall option and the Groyne option need to be investigated under these conditions.

The City of Wanneroo has surveyed the position of the toe of the erosion bank along the Northern Beach. The surveys have been completed on 26 April, 9 May and 13 May 2002. These surveys show that the recession has continued. Between 22 February and 13 May 2002, the erosion scarp near the Northern Car Park has moved landward about 10 to 15 metres. This is significant and needs to be included in the analysis of options.

2.3 Funding Environment

Rogers & Associates (1999) examined a range of options for the long term stabilisation of the Northern Beach. The analysis considered both capital and recurrent costs over a 35 year period. The Net Present Value of costs for the Renourishment and Seawall option and the Groyne option were quite similar. The Renourishment and Seawall option was assessed to have less impact on the aesthetics and beach use than the Groyne option. On this basis and because there was some opposition to groynes by some people in the local community, the Renourishment and Seawall option was put forward as the preferred long term solution.

In the last few years, it has become apparent that there could be future changes in management, government and community attitudes which may make funding large recurrent expenditure for coastal stabilisation works less secure in future years. This makes the implementation of options involving ongoing recurrent expenditure less secure than those involving expenditure primarily in the first few years. In other words, the ongoing funding of the Renourishment and Seawall option may not be secure, regardless of the present day attitude of the parties providing the funding.

2.4 Scope of Present Study

This study was commissioned by the City of Wanneroo with the agreement of the Department for Planning and Infrastructure to investigate:

- the reasons for the rapid erosion between January 2000 and February 2002 and revise the assessment of coastal processes accordingly,
- reassess the effectiveness and costs of the Renourishment and Seawall option for the revised assessment of coastal processes,
- reassess the effectiveness and costs of the Groyne option for the revised assessment of coastal processes, and
- reassess the effectiveness and costs of using headlands instead of groynes for the revised assessment of coastal processes.

3. Modelling the Coastal Processes

3.1 Calibration / Validation of GENESIS Model

The GENESIS model was developed by the US Army Corp of Engineers (1991). It is a generalised model for simulating shoreline change resulting from gradients in the movement of sand along the beach caused by waves. This model requires a number of parameters as input to the model. The following are the main input data.

- Sediment size,
- Shoreline alignment and location of structures such as headlands and groynes,
- Depth of active zone and level of beach berm, and
- Nearshore wave conditions.

Estimates of most of this data were available from the earlier coastal engineering studies. The nearshore wave conditions for the following key wave conditions were available from computer modelling completed in the earlier work.

- Swell,
- Sea breeze and land breeze cycle, and
- Winter storm activity.

DPI operates a non-directional Waverider Buoy in 50 meters of water southwest of Rottnest Island. Review of the DPI wave records and wind data from the Bureau of Meteorology was completed to determine the frequency of occurrence of the various wave events. This was done for the period 1995 to 1999, 2000 and 2001. The results are shown in Table 3.1 below.

Table 3.1 Annual Number of Days of Key Wave Events

Wave Event	Average 1995 to 1999	2000	2001
Large Swell (days)	70	86	88
Light Swell / Calm (days)	111	97	94
Land / Seabreeze (days)	150	148	171
Usual Winter Storms (days)	30	34	18
Severe Winter Storms (days)	4	0	0

Notes:
1. The number of days of each wave event was manually estimated by review of available wave and wind records.
2. This analysis is approximate only.
3. Swells greater than 2m are considered large.

This table highlights that the winter of 2001 was particularly mild with far less storm activity than usual. In addition, there was more seabreeze activity and large swell than usual. The lack of winter storm activity and increased seabreeze and swell could greatly affect the transport of sediment along the shore at Quinns. The net sediment transport along the beach to the north could be much larger than usual because the northwesterly and westerly seas in the winter storms usually moves a large volume of sand along the beaches from north to south.

The GENESIS model was setup for the undeveloped Northern Beach and run using the usual number of wave events as per 1995 to 1999 in Table 3.1. The run was calibrated to obtain the gross and net sediment fluxes derived from the analysis of surveys between 1977 and 1997. The model gave seasonal fluxes of about 80,000 m^3 and the net movement of about 7,000 m^3/year to the north. The model run indicated that the Southern Beach would accrete at about 3,000 m^3/year and the Northern Beach would erode at about 10,000 m^3/year. This is reasonable agreement with the survey results between 1977 and 1997 where Southern Beach was accreting at about 4,000 m^3/year and the Northern Beach was eroding at about 8,500 m^3/year. The GENESIS model was predicting a slightly higher rate of erosion of the Northern Beach but slightly lower seasonal fluxes and accretion on the Southern Beach.

This GENESIS run indicates that the model can reasonably predict the longshore movements and associated areas of accretion and erosion at Quinns. It was concluded that the GENESIS model provides an appropriate tool for the representation of the dominant longshore coastal processes at Quinns. The model would be suitable to examine the recent episode of erosion in 2000 and 2001 and examination of various schemes to stabilise the beaches at Quinns. Naturally the model is a simplification of the complex coastal processes at Quinns.

The anecdotal evidence of the erosion between the January 2000 and February 2002 surveys suggests that most of the erosion occurred towards the end of 2001. The GENESIS model was then run using the number of wave events estimated for 2001. This run gave a very different result compared to the typical wave conditions. The net transport was about 74,000 m^3 to the north for the year. About 42,000 m^3 was lost from the Southern Beach and 32,000 m^3 lost from the Northern Beach. This is consistent with the results of the analysis of the surveys from January 2000 and February 2002 where the calculated loss was some 78,000 m^3. The surveys also indicated that about 43,000 m^3 was lost from the Southern Beach and 35,000 m^3 was lost from the Northern Beach.

A summary of the survey and GENESIS results for various periods and locations are presented in Table 3.2 below.

Table 3.2 GENESIS Results Compared to Survey Data

Item	Surveys	GENESIS
Gain in Southern Beach for average year	4,000 m^3/yr	3,000 m^3/yr
Loss from Northern Beach for average year	8,500 m^3/yr	10,000 m^3/yr
Seasonal fluxes for average year	100,000 m^3/yr	80,000 m^3/yr
Loss in Southern Beach for 2001 conditions	43,000 m^3/yr	42,000 m^3/yr
Loss in Northern Beach for 2001 conditions	35,000 m^3/yr	32,000 m^3/yr

The model runs provide some confirmation and confidence that the cause of the large recent erosion was the mild winter of 2001 coupled with higher than average seabreeze and swell activity.

There is very limited data on the frequency of occurrence of conditions such as experienced in 2001. There are wave and wind records for the 7 years since 1995. On the face of it, the mild winter conditions could occur once every 7 years. Figure 3.1 shows the position of the coastal vegetation line at the Northern Beach Car Park between 1977 and 1998. It appears that there is another period when the vegetation line retreated more rapidly than the average. The period is between 1981 and 1984 and the vegetation line appears to have retreated some 15 metres. This may be another period of mild winters and / or more numerous seabreeze and swell activity. This may indicate two periods of rapid erosion in the period 1977 to 2001 inclusive (25 years).

In view of this, it is suggested that the schemes to stabilise the area be tested for two periods of rapid erosion (such as in 2001) every 25 years.

4. Option 1 – Groyne Field & Initial Beach Nourishment

4.1 Description & Performance of Option 1

In Rogers & Associates (1999) the Groyne Field & Initial Beach Nourishment option comprised of 3 groynes and large scale initial nourishment to "saturate" the groynes. The main focus of the protection was from Frederick Stubbs Reserve to the coast near Tapping Way to the north. This scheme in the earlier report would provide little protection for the area between Frederick Stubbs Reserve and the headland built at the cusp in 1977. At some times this section of beach could be quite narrow and recreational use would be difficult. It was thought that this should be avoided if possible.

With this in mind, a new layout of groynes was selected and is shown in Figure 4.1. There are 3 groynes equally spaced between the headland at the cusp and the beach near Tapping Way in the north. The groynes are about 460 metres apart. This is about half of the length of the Southern Beach from the headland at the cusp to the natural and rocky headland south of the Caravan Park.

This groyne field with large scale initial nourishment was examined using the calibrated GENESIS model. The first model run was using the following:

- the average wave conditions for 1995 to 1999,
- 3 groynes extending 20 metres beyond the initial waterline, and
- sand nourishment to form a new waterline that at the end of summer would be 10 meters seaward of the existing waterline at the southern ends of the compartments and 20 metres seaward of the existing waterline at the northern ends of the beach compartments.

The large scale initial nourishment would provide a seaward movement of the waterline of 15 metres on average. This would involve about 180,000 m^3 of sand for nourishment spread over 1.4 km of coast. The GENESIS model run indicated that there was a loss of about 4,000 m^3 of sand from the compartments in the year.

In view of this, the length of the groynes was increased to 25 metres from the existing waterline (plus approximately 15 metres across the beach giving about 40 metres in total length). The GENESIS model was run for the average wave conditions, the 3 longer groynes and the 180,000 m^3 of initial sand nourishment. This has been called Option 1.

The model results for this configuration and the sea conditions for a typical year indicated that there would still be a large seasonal flux of sand into and out of the area. There would be little, if any, loss of sand from the compartments between the groynes. The erosion area was moved to north of the most northerly groyne near Tapping Way. In other words the groyne field had halted erosion on the Northern Beach by moving the erosion further to the north.

It is expected that the beach to the north of the groyne field would erode initially at 1 to 3 metres per year and in the longer term the erosion rate would decrease and the average be about 1 to 2 metres per year. The set back to the new development in this area is more than 100 metres. On this basis, it is likely that the erosion of this beach could be tolerated for about one decade before additional beach stabilisation work would be needed. Such future beach stabilisation work will be included in the evaluation of the Net Present Value of Costs of Option 1 as an additional groyne and nourishment built about a decade after the first groyne.

Examination of the shoreline movement predicted in the GENESIS model run for Option 1 with average wave conditions indicated that the various beach compartments rotate in response to the seasonal changes in the wave conditions. In summer and autumn, the prevalence of the seabreeze activity moves sand from south to north and the beaches between the groynes rotate anti-clockwise. In winter and spring, the westerly and northwesterly storm waves cause movement from north to south and beaches rotate clockwise in response. The model suggests that for the average wave conditions the seasonal movements at the northern ends of the beach compartments would be about 10 metres. At the southern ends of the compartments the movements were predicted to be up to 15 metres. The initial nourishment would provide a buffer of about 10 metres at the northern ends of the compartments. At the southern ends, the buffer could be a few metres less than the initial 10 metres at some times. This is shown diagrammatically in Figure 4.2.

Option 1 was then examined for the mild conditions in 2001. This GENESIS run indicated that the beaches in the groyne field would suffer minor erosion, but the Southern Beach would lose about 46,000 m^3. In addition, the beach to the north of the groyne field would lose about 15,000 m^3. The average wave conditions were then used with the GENESIS model to examine the recovery of the Option 1 configuration. In one year the Southern Beach gained about 17,000 m^3 and the beach compartments in the groyne field lost a similar volume. From these results, it would appear that Option 1 would need to be augmented with some additional nourishment after conditions such as 2001. It has been judged that about 40,000 m^3 of additional nourishment may be needed.

Option 1 would halt the erosion trend and provide an additional 5 to 10 metre buffer to the Northern Car Park. This buffer should be sufficient to accommodate possible errors in the modelling and provide a buffer for some storm erosion. The buffer is not sufficient to accommodate possible changes caused by Climate Change over the coming century. Option 1 would transfer the erosion problem to the beaches to the north and there may be the need for more stabilisation works in a decade or so. Such works have been included in the financial analysis in Appendix A.

4.2 Staging Option 1 Works

The City of Wanneroo requested that this investigation include staging the capital works over a 3 year period to match the likely available funding. The following staged development was examined.

- Year 1 – Construct 2 groynes and complete 60,000 m^3 of beach nourishment between the groynes.

- Year 2 – Construct the 3rd groyne and complete 60,000 m^3 of beach nourishment.

- Year 3 – Complete 72,000 m^3 of beach nourishment.

The GENESIS modelling of this staged development indicated that an additional 12,000 m^3 of beach nourishment would be needed on top of the 180,000 m^3 in Option 1. This is because of the losses from the groyne field area during the staged development. It was concluded that staging the development over a 3 year period would be practical. The staged approach would have the benefit of spreading the truck traffic for the groyne construction and beach nourishment over a number of years.

This assessment has been based on the results of the GENESIS model runs. The model is a simplification of the complex coastal processes at Quinns. It can be expected that the model may not be perfectly accurate in all respects. It would be wise to include a contingency sum in Year 4 to enable adjustments to the works should they become necessary to fine tune the performance of the option.

4.3 Estimated Costs and NPV of Option 1

The preliminary design of the groynes that extend 25 metres seaward of the present day waterline was completed using the design data in Rogers &

Associates (1999). The armour rock for the head of the groynes would be about 5 tonnes and the crest level would need to be about 4 mAHD.

In order to minimise the impact of the groyne on the beach users, the level of the groyne trunk could be reduced to about 2 mAHD. This would mean that the groyne trunk would often be buried or partially buried. A long-section along the groyne is shown in Figure 4.3. Two representative cross sections of the groyne trunk and groyne head are shown in Figure 4.4

The capital cost of constructing one rock groyne that extends 25 metres past the existing waterline has been estimated in Table 4.1 below. The total groyne length is about 40 metres and the landward 15 metres would be built at a level of about 2 mAHD.

Table 4.1 Capital Cost Estimate for Groyne

Item	Quantity	Rate	Cost
Mobilisation & survey	1	$7,000	$7,000
Access track or pavement repair	1	$4,000	$4,000
Armour stone	1,750 m^3	$30/$m^3$	$52,500
Core stone	1,250 m^3	$20/$m^3$	$25,000
Site clean-up & demobilisation	1	$7,000	$7,000
Engineering design & mgmt		10%	$9,500
Contingencies		5%	$5,500
TOTAL CAPITAL COST			**$110,500**
SAY			**$110,000**

The cost of 60,000 m^3 of sand nourishment has been estimated in Table 4.2 below.

Table 4.2 Capital Cost Estimate for 60,000 m^3 of Nourishment

Item	Quantity	Rate	Cost
Mobilisation & survey	1	$2,000	$2,000
Supply sand from local sources	4,000 m^3	$6.8/$m^3$	$27,200
Supply sand nourishment	56,000 m^3	$9.4/$m^3$	$526,400
Spread sand on site	60,000 m^3	$1.5/$m^3$	$90,000
Brush work to stop wind erosion	3,500 m^2	$4/$m^2$	$14,000
Site clean-up & demobilisation	1	$5,000	$5,000
Engineering design & mgmt		2%	$13,300
Contingencies		5%	$33,900
TOTAL CAPITAL COST			**$711,800**
SAY			**$712,000**

Notes:
1. Sand volumes are insitu not loose.
2. Sand supply cost is $4/tonne for first 4,000 m^3 then $5.5/tonne.
3. Average cost of nourishment is $11.9/$m^3$ insitu and includes brush work.

Table A.1 lists the capital and recurrent costs that are envisaged to be required for Option 1. The capital cost has been staged over the first 3 years and a contingency sum in Year 4 in the following amounts.

- Year 1 - $932,000,
- Year 2 - $822,000,
- Year 3 - $857,000, and
- Year 4 - $100,000 (contingency sum).

The total capital cost is estimated to be some $2,711,000 in 2002 terms.

Following the construction, there will be the need for the following items throughout the life of the option.

- Groyne maintenance about every decade,

- Episodic beach nourishment of about 40,000 m^3 in years 12 and 24 to rectify deficiencies caused by abnormally mild winters such as in 2001, and

- Beach stabilisation works at year 10 to address the erosion north of the groyne field.

Table A.1 in Appendix A lists the Net Present Value of costs for Option 1 for various discount rates. The analysis has been made over a 35 year period and the Net Present Value of Costs is estimated to be $3,455,000 for a 6% discount rate.

5. Option 2 – Headlands & Initial Nourishment

5.1 Description & Performance of Option 2

The City of Wanneroo requested that as an alternative to the groynes in Option 1, rock headlands be examined. The headlands would be somewhat similar to the existing headland built at the cusp in 1977. The position of the headlands along the coast could be the same spacing as for the groynes. The headlands could be located such that the seaward side is some 25 metres seaward of the present day waterline. This would put the headlands in the same location as the head of the groynes in Option 1.

The layout for Option 2 with 3 headlands is shown on Figure 5.1 and a cross section is shown in Figure 5.2. The initial large scale beach nourishment would be 180,000 m^3 as for Option 1.

Option 2 was modelled using the GENESIS model. The model results for this option indicated that there would be little if any loss of sand from the compartments between the headlands. The erosion area was moved to north of the most northerly headland near Tapping Way. In other words the headlands had halted erosion on the Northern Beach by moving the erosion further to the north.

Overall, the performance of the headlands in Option 2 was assessed to be the same as for the groyne field in Option 1. The predicted beach rotations are shown in Figure 5.3. The headlands would be expected to provide less of a barrier to those using the beach as there would not be a trunk as with the groynes. One significant disadvantage of the headlands compared to groynes is the lack of ability to make minor adjustments to the position of the seaward portion of the structure. With the groynes in Option 1, they could be made slightly longer or shorter should the monitoring data indicate that a modification was appropriate. This is a major advantage for the options using groynes in that they are less reliant on the coastal processes modelling being exactly correct.

It is expected that the beach to the north of the headland field would erode initially at 1 to 3 metres per year and in the longer term the erosion rate would reduce and the average be about 1 to 2 metres per year. The set back to the new development in this area is more than 100 metres. On this basis, it is likely that the erosion of this beach could be tolerated for about a decade before additional beach stabilisation work would be needed. Such future beach stabilisation work needs to be included in the evaluation of the Net Present Value of Costs of Option 2.

Option 2 would halt the erosion trend and provide an additional 5 to 10 metre buffer to the Northern Car Park. This buffer should be sufficient to accommodate possible errors in the modelling and provide a buffer for some storm erosion. The buffer is not sufficient to accommodate possible changes caused by Climate Change over the coming century. Option 2 would transfer the erosion problem to the beaches to the north and there may be the need for more stabilisation works in a decade or so. Such works have been included in the financial analysis in Appendix A.

5.2 Staging Option 2 Works

The City of Wanneroo requested that this investigation include staging the capital works over a 3 year period to match the likely available funding. The following staged development was examined.

- Year 1 – Construct 2 headlands and complete 60,000 m^3 of beach nourishment between the headlands.
- Year 2 – Construct the 3rd headland and complete 60,000 m^3 of beach nourishment.
- Year 3 – Complete 72,000 m^3 of beach nourishment.

The GENESIS modelling of this staged development indicated that an additional 12,000 m^3 of beach nourishment would be needed on top of the 180,000 m^3 needed if built all in Year 1. This is because of the losses from the headland field area during the staged development. It was concluded that staging the development over a 3 year period would be practical. The staged approach would have the benefit of spreading the truck traffic for the headland construction and beach nourishment over a number of years.

This assessment has been based on the results of the GENESIS model runs. The model is a simplification of the complex coastal processes at Quinns. It can be expected that the model may not be perfectly accurate in all respects. It would be wise to include a contingency sum in Year 4 to enable adjustments to the works should they become necessary to fine tune the performance of the option.

5.3 Estimated Costs and NPV of Option 2

The preliminary design of the headlands located with their seaward face about 25 metres seaward of the present day waterline was completed using the design data in Rogers & Associates (1999). The armour rock for the seaward face of the headlands would be about 5 tonnes and the crest level would need to be about 4 mAHD.

The capital cost of constructing one rock headland has been estimated in Table 5.1 below. The total length of the headland is about 30 metres between the heads.

Table 5.1 Capital Cost Estimate for Headland

Item	Quantity	Rate	Cost
Mobilisation & survey	1	$7,000	$7,000
Access road	1	$4,000	$4,000
Access bund across beach	1	$3,000	$3,000
Armour stone	2,400 m^3	$\$30/m^3$	$72,000
Core stone	1,500 m^3	$\$20/m^3$	$30,000
Site clean-up & demobilisation	1	$7,000	$7,000
Engineering design & mgmt		10%	$12,300
Contingencies		5%	$7,000
TOTAL CAPITAL COST			**$142,300**
SAY			**$142,000**

The cost of 60,000 m^3 of sand nourishment has been estimated in Table 4.2 to be $712,000 or $\$11.90/m^3$.

Table A.2 lists the capital and recurrent costs that are envisaged to be required for Option 2. The capital cost has been staged over the first 3 years in the following amounts.

- Year 1 - $996,000,
- Year 2 - $854,000,
- Year 3 - $857,000, and
- Year 4 - $100,000 (contingency sum).

The total capital cost is estimated to be some $2,807,000 in 2002 terms.

Following the construction, there will be the need for the following items throughout the life of the option.

- Headland maintenance about every decade,
- Episodic beach nourishment of about 40,000 m^3 in years 10 and 24 to rectify deficiencies caused by abnormally mild winters such as in 2001, and
- Beach stabilisation works at year 10 to address the erosion north of the groyne field.

Table A.2 in Appendix A lists the Net Present Value of costs for Option 2 for various discount rates. The analysis has been made over a 35 year period and the Net Present Value of Costs is estimated to be $3,585,000 for a 6% discount rate.

6. Option 3 – Seawall & Ongoing Nourishment

In order to make an informed decision concerning the financial effectiveness of the Groyne and Headland options, the City of Wanneroo requested that the option to build a rock seawall and complete ongoing sand nourishment be examined. The latest data on coastal processes was used in the assessment of this option.

Option 3 – Seawall & Ongoing Sand Nourishment includes the following items:

- construction of a 400 metre long rock seawall to protect the Northern Car Park and parts of Frederick Stubbs Reserve,
- initial sand nourishment of about 80,000 m^3 (insitu volume) to compensate for the large losses experienced in 2001,
- ongoing sand nourishment of about 8,500 m^3 (insitu volume) to compensate for the typical losses due to the gradient in longshore drift,
- maintenance of the seawall from time to time, and
- episodic sand nourishment of 80,000 m^3 placed over two years (40,000 m^3/yr) to compensate for periods of abnormal weather conditions such as in 2001.

The cost of the rock seawall was estimated using the design data from Rogers & Associates (1999) and the bathymetry from the February 2002 survey. Table 6.1 below provides the details of the capital cost for the seawall.

Table 6.1 Capital Cost Estimate for Seawall

Item	Quantity	Rate	Cost
Mobilisation & survey	1	\$7,000	\$7,000
Excavation	6,000 m^3	\$3/m^3	\$18,000
Armour stone	6,100 m^3	\$30/m^3	\$183,000
Bedding layer	2,800 m^3	\$35/m^3	\$98,000
Geotextile	5,600 m^2	\$8/m^2	\$44,800
Site clean-up & demobilisation	1	\$7,000	\$7,000
Engineering design & mgmt		10%	\$35,800
Contingencies		5%	\$19,700
TOTAL CAPITAL COST			**\$413,300**
SAY			**\$414,000**

The cost of sand nourishment has been estimated to be \$11.90/m^3 (insitu volume) in Table 4.2 above.

Table A.3 lists the capital and recurrent costs that are envisaged to be required for Option 3. The capital cost spent in Year 1 is as follows.

- Year 1 - \$890,000, and
- Year 2 - \$ 476,000.

The total capital cost is estimated to be some \$1,366,000 in 2002 terms.

Following the construction, there will be the need for the following items throughout the life of the option.

- Annual sand nourishment of about 8,500 m^3 insitu volume,
- Seawall maintenance about every decade, and
- Episodic beach nourishment of about 40,000 m^3 in years 10, 11, 24 and 25 to rectify deficiencies caused by abnormally mild winters such as in 2001.

Table A.3 in Appendix A lists the Net Present Value of costs for Option 3 for various discount rates. The analysis has been made over a 35 year period and the Net Present Value of Costs is estimated to be $3,315,000 for a 6% discount rate.

7. Comparison of Options

The Net Present Value of costs for the three options evaluated in this report are presented in Table 7.1 below. This table also lists the Capital Cost of the three options.

Table 7.1 NPV & Capital Costs for Options 1, 2 and 3

Option	NPV @ 4%	NPV @ 6%	Capital Cost
Option 1 – Groynes & Initial Nourishment	$3,738,000	$3,455,000	$2,711,000
Option 2 – Headlands & Initial Nourishment	$3,880,000	$3,585,000	$2,807,000
Option 3 – Seawall & Ongoing Nourishment	$3,937,000	$3,315,000	$1,366,000

Note: 1. Refer to Appendix A for details of discounted cash flow analysis.

This comparison indicates that all three options have quite similar Net Present Value of costs over a 35 year period using a 4% or 6% discount rate. Certainly, the differences are less than the likely error bands in the various cost estimates.

Option 1 has the lowest NPV when using a 4% discount rate. In addition, this option involves significant capital expenditure that can be shared between the City of Wanneroo and the State Government and does not rely so much on recurrent expenditure funding.

Option 3, by comparison has the lowest NPV when using a 6% discount rate. It involves about half the amount of capital expenditure and is much more reliant on recurrent expenditure.

The significant ongoing sand nourishment works in Option 3 may not be acceptable to the local residents after a number of years. Many communities have the belief that ongoing beach nourishment is wasting money despite the known benefits. Consequently, the long term funding of Option 3 may not be secure. If the recurrent funding were not available in future years, then the performance of the scheme would be compromised.

Option 1 uses groynes to adjust the longshore transport regime and move the erosion problem further along the coast. The use of groynes provides the opportunity to make minor adjustments to the scheme should there be differences between the GENESIS model predictions and the scheme as built. This is important because the real coastal processes are very complex and the interaction of a number of factors. The modelling work is a simplification of the actual system.

Option 1 is recommended to be adopted for the long term solution to the erosion at Quinns because it has one of the lowest NPV of costs and provides a practical scheme that can be staged over a 3 to 4 year period. It also provides some scope for fine-tuning, should it be required.

It is recommended that the City of Wanneroo and the State Government review this report, discuss the options and jointly adopt a preferred option. Then the recent erosion, this report and the preferred option should be presented to a public meeting. At this public meeting, the acceptability of the use of groynes can be discussed, and hopefully the preferred option put forward by the City of Wanneroo and the State Government will be supported.

Following the public meeting, the detailed design and documentation of the preferred option will need to be completed. The work should then be put to public tender and constructed at the end of the coming spring to take advantage of the movement of sand to the south in winter and spring.

8. References

Department for Planning & Infrastructure (2002) *Quinns Rocks Plan Set 871.*

Rogers & Associates, 1999. *Quinns Beach Coastal Protection Works Stage 1 Report.* Prepared for the Shire of Wanneroo by M P Rogers and Associates Pty Ltd, January 1999.

Rogers & Associates, 1999. *Quinns Beach Coastal Protection Works Stage 2 Report.* Prepared for the Shire of Wanneroo by M P Rogers and Associates Pty Ltd, October 1999.

Tremarfon Pty Ltd, 1997. *Quinns Coastal Processes Study.* Tremarfon Pty Ltd, Perth, Western Australia, May 1997.

US Army Corp of Engineers, 1991. *GENESIS: Generalized Model for Simulating Shoreline Change.* Technical Report CERC-89-19. Prepared for Department of the Army by US Army Corp of Engineers, December 1989.

9. Figures

Figure 2.1 – Location Diagram

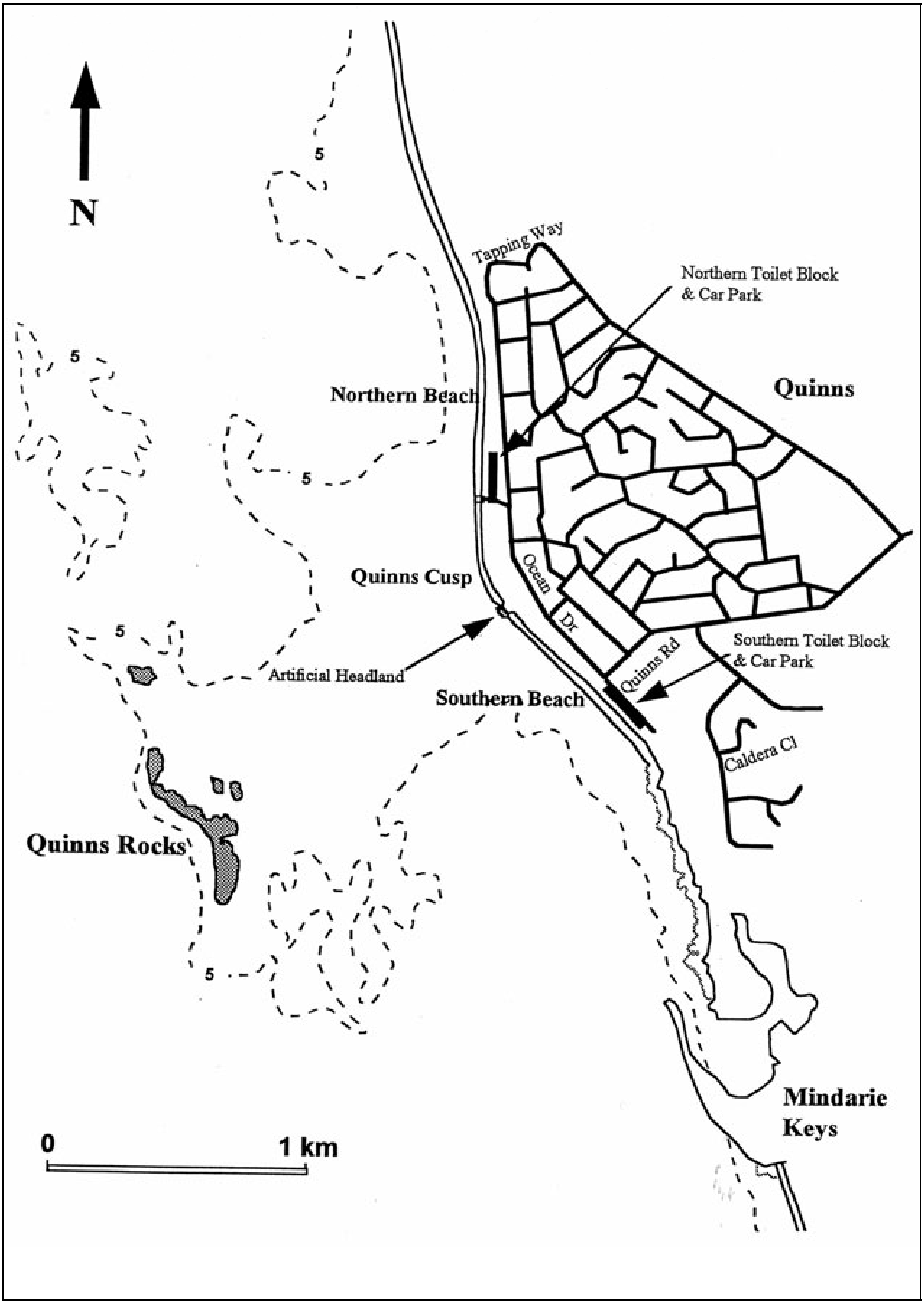


Figure 3.1 – Vegetation Line Plot for Foreshore Seawards of Northern Car Park

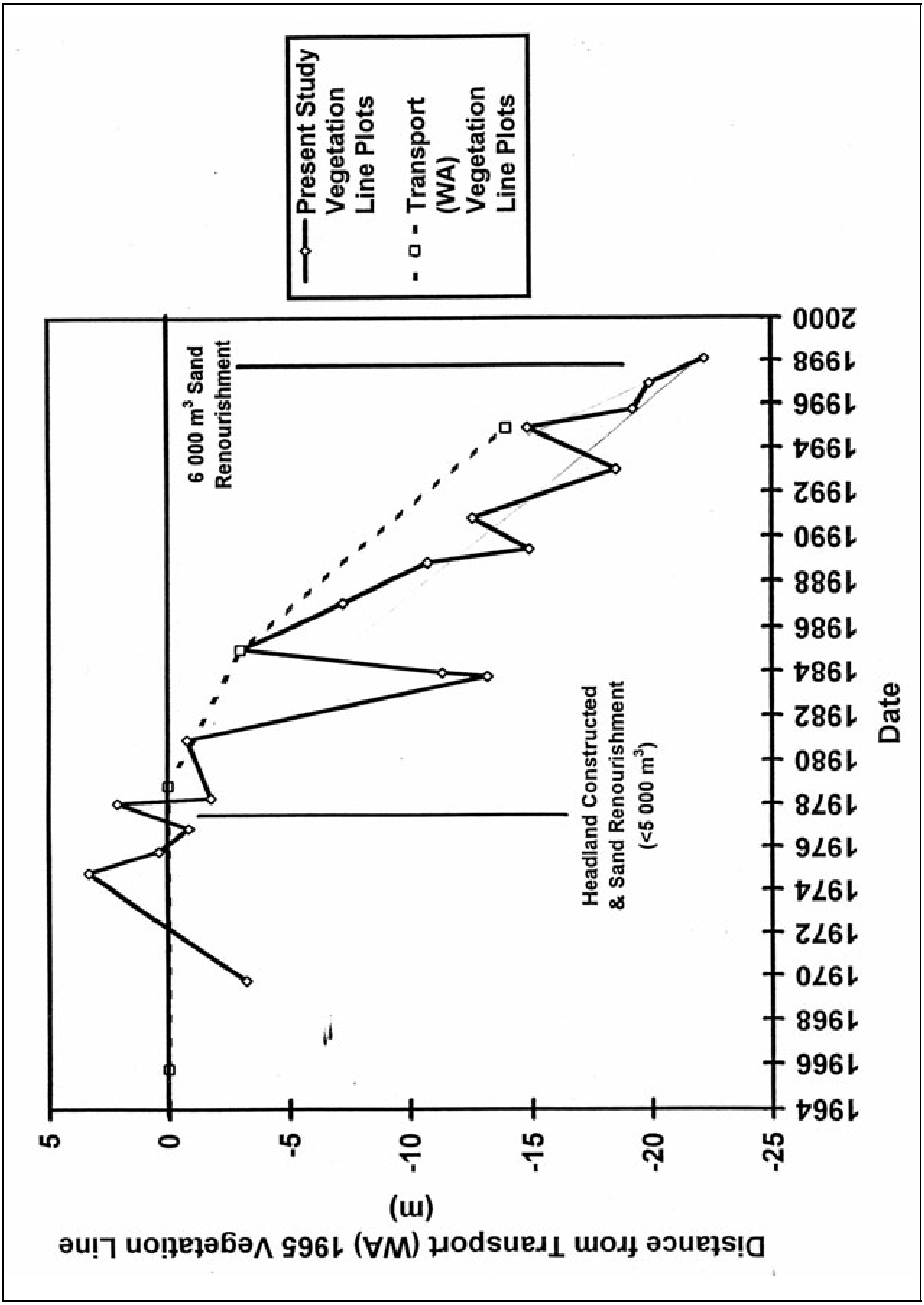


Figure 4.1 – Option 1: Layout of Groynes

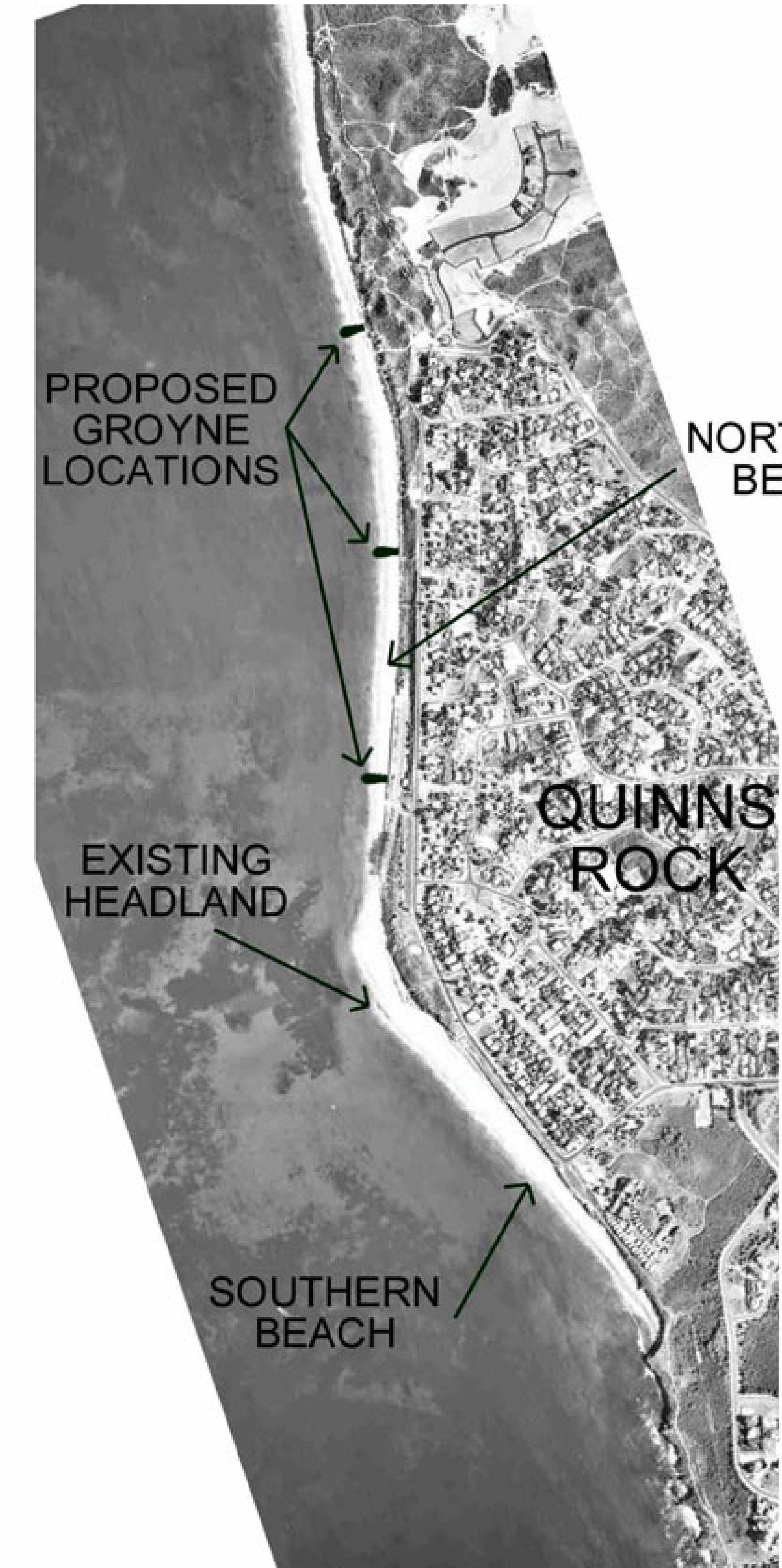


Figure 4.2 – Option 1: Beach Rotations

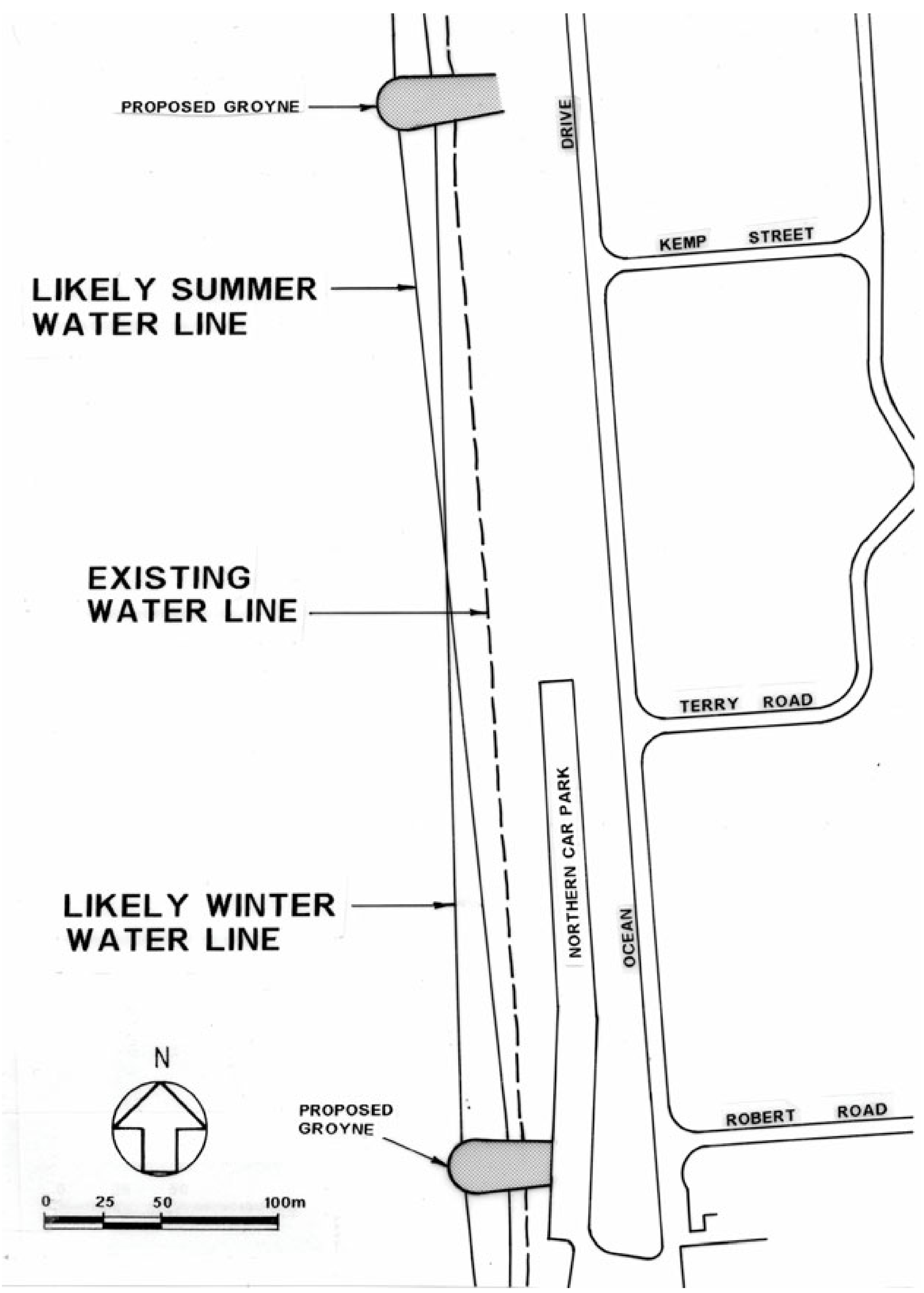


Figure 4.3 – Long Section of Groyne

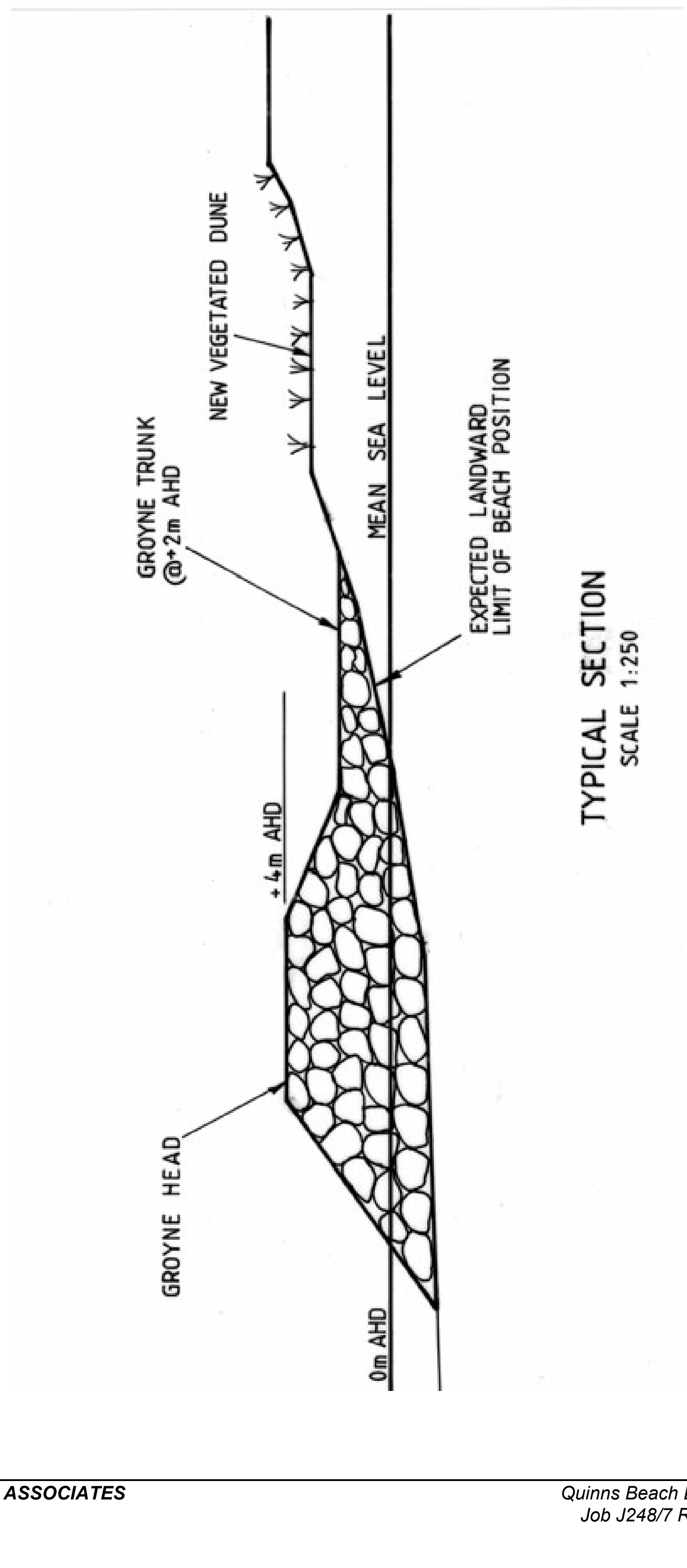


Figure 4.4 – Cross Sections of Groyne

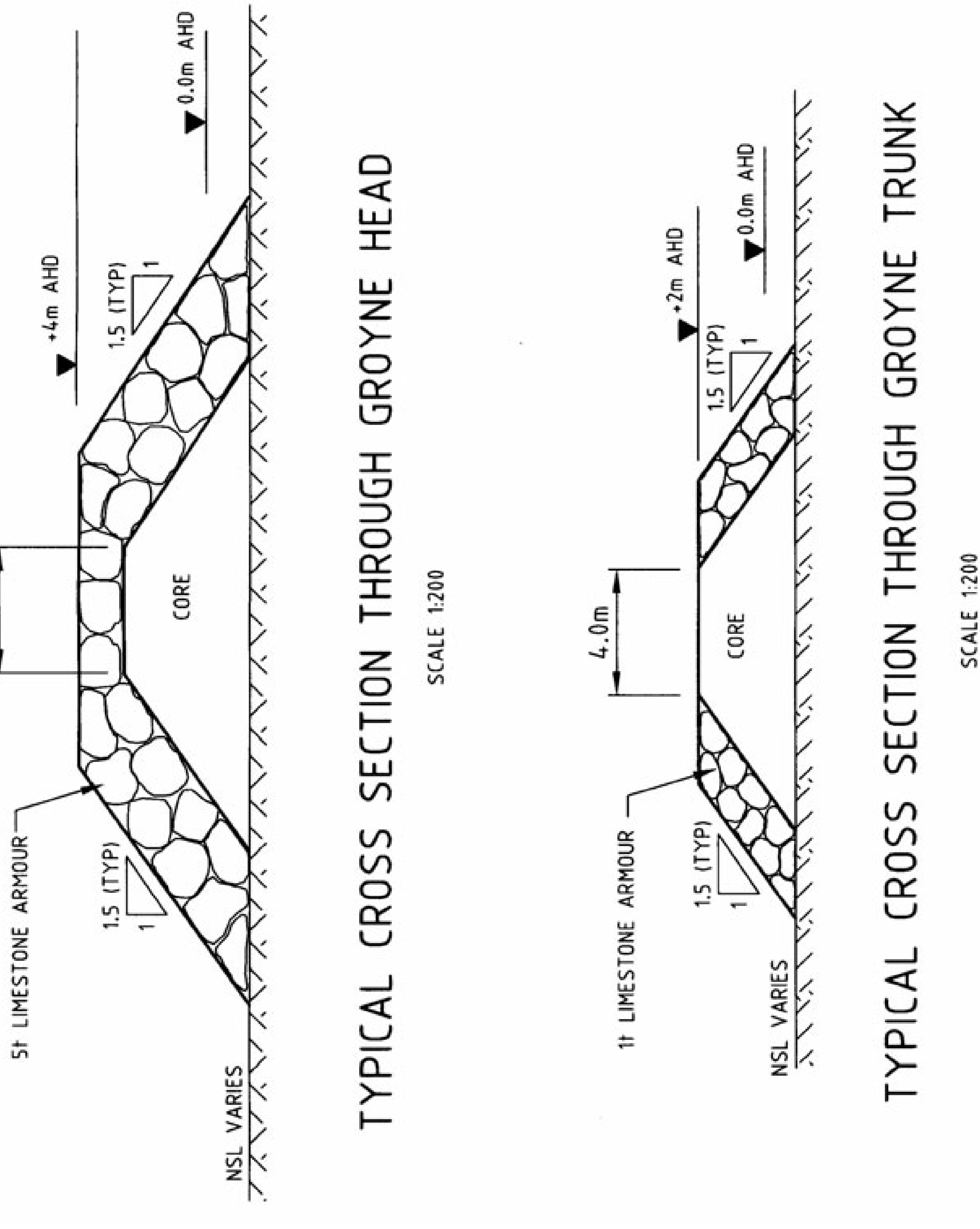


Figure 5.1 – Option 2: Layout of Headlands

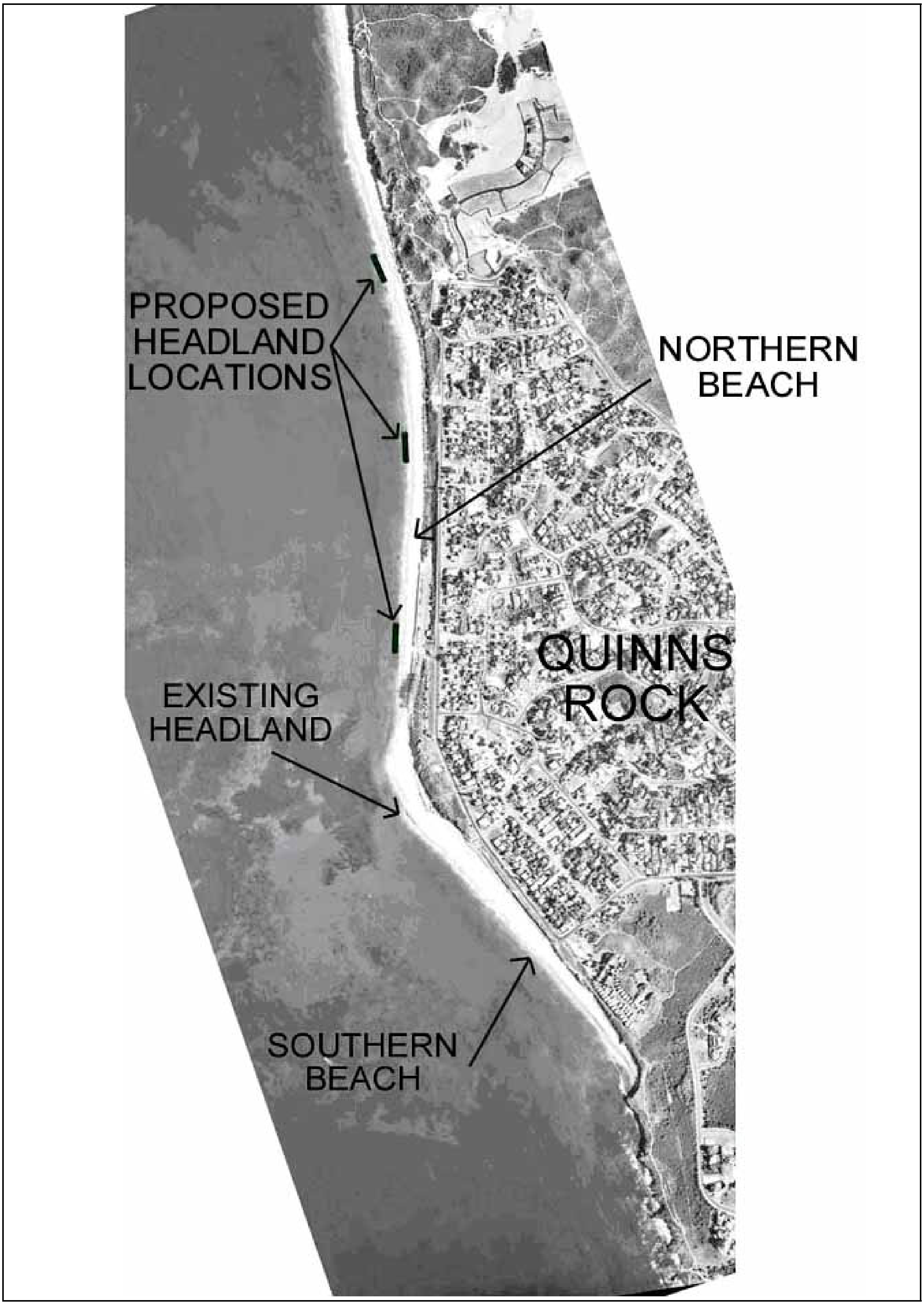


Figure 5.2 – Cross Section of Headland

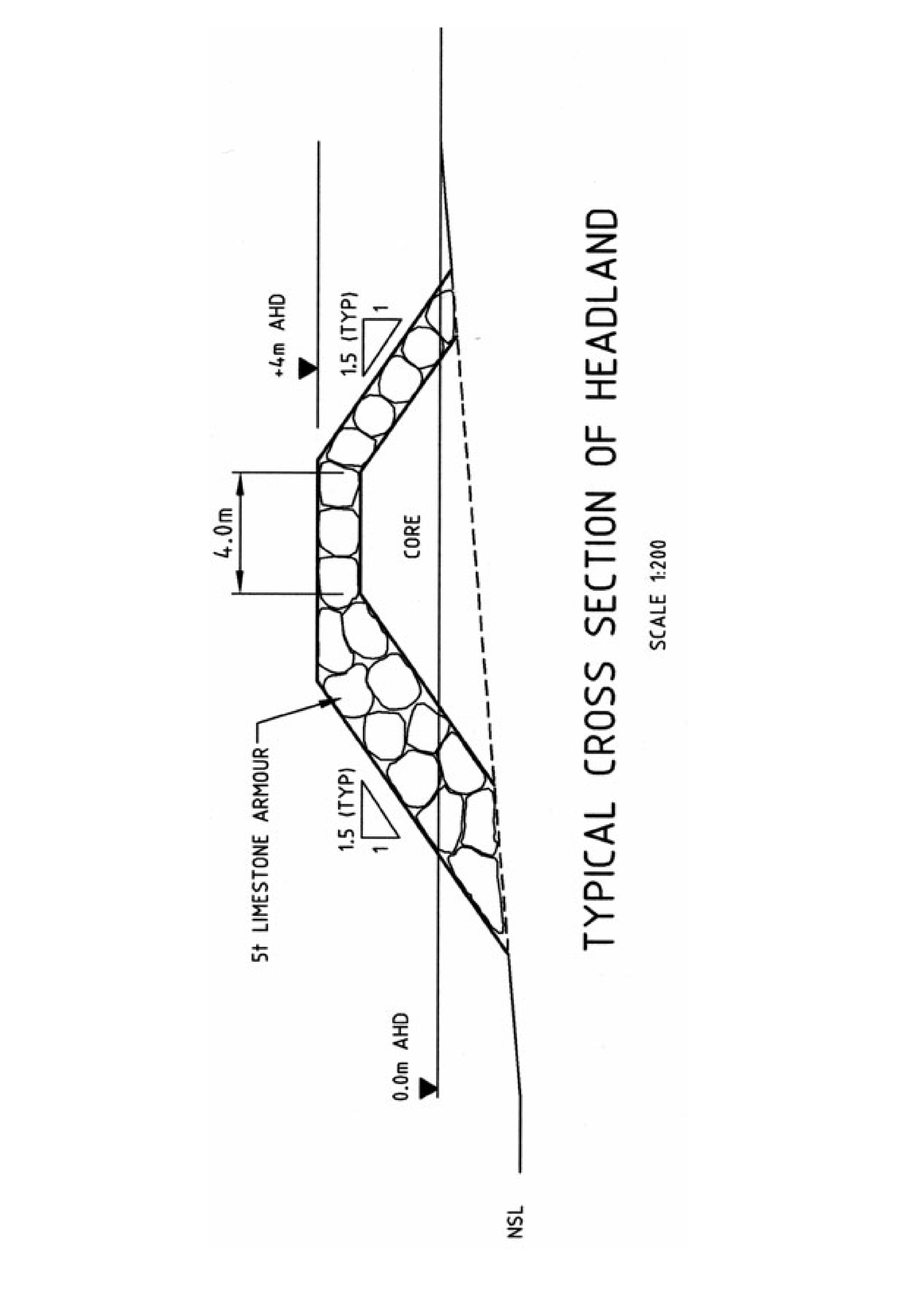
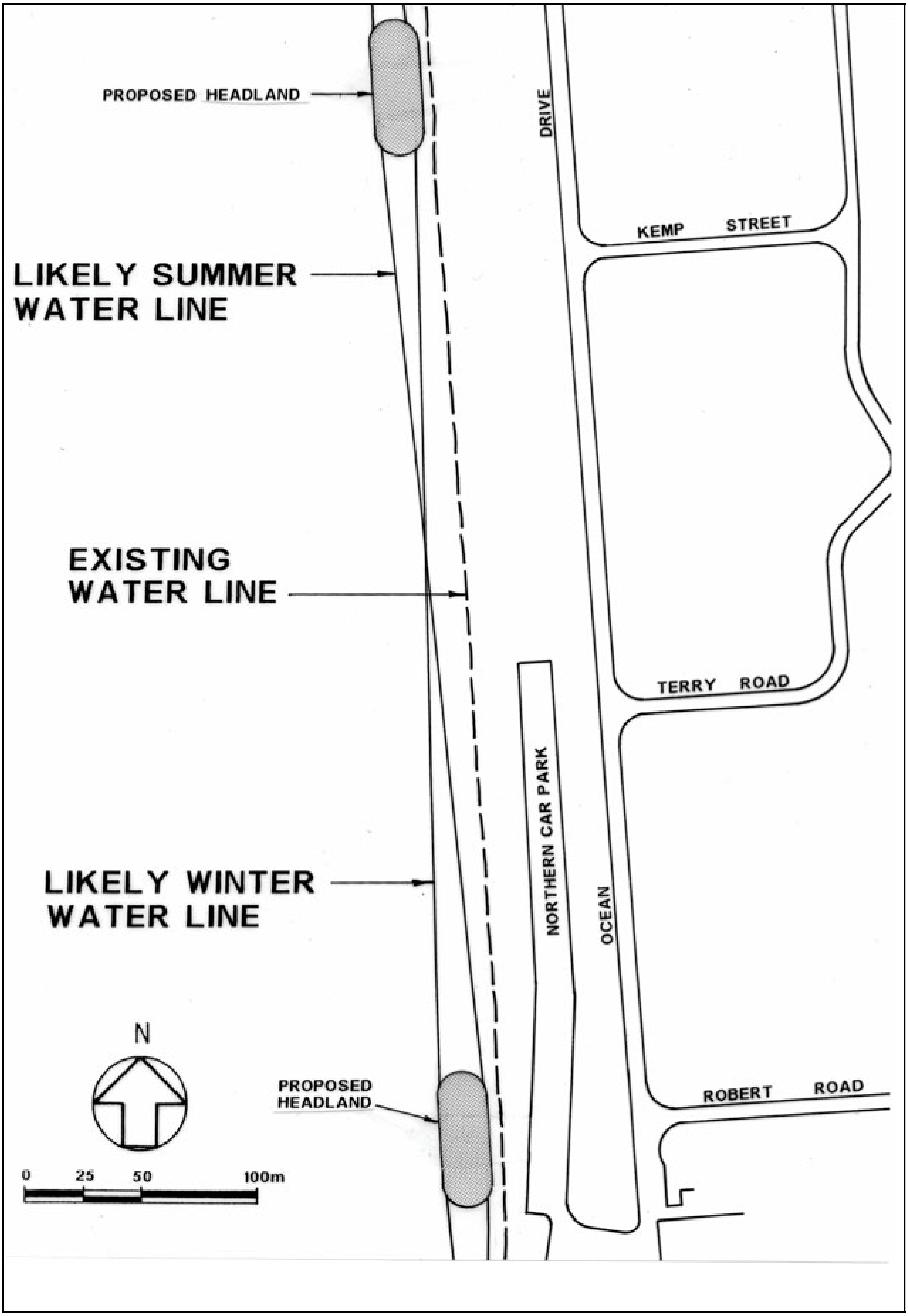


Figure 5.3 – Option 2: Beach Rotations



10. Appendices

Appendix A Cost Analysis

Appendix A Cost Analysis

Year	Item	Cost in 2002	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$4,605,800	$4,108,061	$3,737,943	$3,454,487	$3,231,560	$3,052,067
1	2 groynes	$220,000	$220,000	$220,000	$220,000	$220,000	$220,000
1	60,000 m3 nourishment	$712,000	$712,000	$712,000	$712,000	$712,000	$712,000
2	1 groyne	$110,000	$107,843	$105,769	$103,774	$101,852	$100,000
2	60,000 m3 nourishment	$712,000	$698,039	$684,615	$671,698	$659,259	$647,273
3	72,000 m3 nourishment	$856,800	$823,529	$792,160	$762,549	$734,568	$708,099
4	Contingency sum	$100,000	$94,232	$88,900	$83,962	$79,383	$75,131
5	Nil	$0	$0	$0	$0	$0	$0
6	Nil	$0	$0	$0	$0	$0	$0
7	Nil	$0	$0	$0	$0	$0	$0
8	Nil	$0	$0	$0	$0	$0	$0
9	Nil	$0	$0	$0	$0	$0	$0
10	Additional groyne to north	$110,000	$92,043	$77,285	$65,109	$55,027	$46,651
10	60,000 m3 nourishment	$712,000	$595,770	$500,242	$421,432	$356,177	$301,958
11	Groyne maintenance	$33,000	$27,071	$22,294	$18,427	$15,285	$12,723
12	Mild winter as per 2001 - 40,000 m3 nourishment	$476,000	$382,829	$309,201	$250,751	$204,148	$166,835
13	Nil	$0	$0	$0	$0	$0	$0
14	Nil	$0	$0	$0	$0	$0	$0
15	Nil	$0	$0	$0	$0	$0	$0
16	Nil	$0	$0	$0	$0	$0	$0
17	Nil	$0	$0	$0	$0	$0	$0
18	Nil	$0	$0	$0	$0	$0	$0
19	Nil	$0	$0	$0	$0	$0	$0
20	Nil	$0	$0	$0	$0	$0	$0
21	Nil	$0	$0	$0	$0	$0	$0
22	Groyne maintenance	$44,000	$29,030	$19,309	$12,943	$8,741	$5,946
23	Nil	$0	$0	$0	$0	$0	$0
24	Mild winter as per 2001 - 40,000 m3 nourishment	$476,000	$301,858	$193,126	$124,615	$81,070	$53,159
25	Nil	$0	$0	$0	$0	$0	$0
26	Nil	$0	$0	$0	$0	$0	$0
27	Nil	$0	$0	$0	$0	$0	$0
28	Nil	$0	$0	$0	$0	$0	$0
29	Nil	$0	$0	$0	$0	$0	$0
30	Nil	$0	$0	$0	$0	$0	$0
30	Nil	$0	$0	$0	$0	$0	$0
31	Nil	$0	$0	$0	$0	$0	$0
32	Groyne maintenance	$44,000	$23,815	$13,044	$7,227	$4,049	$2,292
33	Nil	$0	$0	$0	$0	$0	$0
34	Nil	$0	$0	$0	$0	$0	$0
35	Nil	$0	$0	$0	$0	$0	$0

Table A.1 - Option 1 Groynes & Nourishment

Year	Item	Cost in 2002	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$4,788,800	$4,266,535	$3,880,034	$3,585,160	$3,353,959	$3,168,256
1	2 headlands	$284,000	$284,000	$284,000	$284,000	$284,000	$284,000
1	60,000 m3 nourishment	$712,000	$712,000	$712,000	$712,000	$712,000	$712,000
2	1 headland	$142,000	$139,216	$136,538	$133,962	$131,481	$129,091
2	60,000 m3 nourishment	$712,000	$698,039	$684,615	$671,698	$659,259	$647,273
3	72,000 m3 nourishment	$856,800	$823,529	$792,160	$762,549	$734,568	$708,099
4	Contingency sum	$100,000	$94,232	$88,900	$83,962	$79,383	$75,131
5	Nil	$0	$0	$0	$0	$0	$0
6	Nil	$0	$0	$0	$0	$0	$0
7	Nil	$0	$0	$0	$0	$0	$0
8	Nil	$0	$0	$0	$0	$0	$0
9	Nil	$0	$0	$0	$0	$0	$0
10	Additional headland to north	$142,000	$118,819	$99,767	$84,050	$71,035	$60,222
10	60,000 m3 nourishment	$712,000	$595,770	$500,242	$421,432	$356,177	$301,958
11	Headland maintenance	$48,000	$39,377	$32,427	$26,803	$22,233	$18,506
12	Mild winter as per 2001 - 40,000 m3 nourishment	$476,000	$382,829	$309,201	$250,751	$204,148	$166,835
13	Nil	$0	$0	$0	$0	$0	$0
14	Nil	$0	$0	$0	$0	$0	$0
15	Nil	$0	$0	$0	$0	$0	$0
16	Nil	$0	$0	$0	$0	$0	$0
17	Nil	$0	$0	$0	$0	$0	$0
18	Nil	$0	$0	$0	$0	$0	$0
19	Nil	$0	$0	$0	$0	$0	$0
20	Nil	$0	$0	$0	$0	$0	$0
21	Nil	$0	$0	$0	$0	$0	$0
22	Headland maintenance	$64,000	$42,226	$28,085	$18,826	$12,714	$8,648
23	Nil	$0	$0	$0	$0	$0	$0
24	Mild winter as per 2001 - 40,000 m3 nourishment	$476,000	$301,858	$193,126	$124,615	$81,070	$53,159
25	Nil	$0	$0	$0	$0	$0	$0
26	Nil	$0	$0	$0	$0	$0	$0
27	Nil	$0	$0	$0	$0	$0	$0
28	Nil	$0	$0	$0	$0	$0	$0
29	Nil	$0	$0	$0	$0	$0	$0
30	Nil	$0	$0	$0	$0	$0	$0
30	Nil	$0	$0	$0	$0	$0	$0
31	Nil	$0	$0	$0	$0	$0	$0
32	Headland maintenance	$64,000	$34,640	$18,973	$10,512	$5,889	$3,334
33	Nil	$0	$0	$0	$0	$0	$0
34	Nil	$0	$0	$0	$0	$0	$0
35	Nil	$0	$0	$0	$0	$0	$0

Table A.2 - Option 2 Headlands & Nourishment

Year	Item	Cost in 2002	Net Present Value of Cost for a Range of Discount Rates				
			0.02	0.04	0.06	0.08	0.10
	Totals	$6,263,350	$4,856,192	$3,936,585	$3,315,351	$2,881,995	$2,570,333
1	400 m seawall	$414,000	$414,000	$414,000	$414,000	$414,000	$414,000
1	40,000 m3 nourishment	$476,000	$476,000	$476,000	$476,000	$476,000	$476,000
2	40,000 m3 nourishment	$476,000	$466,667	$457,692	$449,057	$440,741	$432,727
3	8,500 m3 nourishment	$101,150	$97,222	$93,519	$90,023	$86,720	$83,595
4	8,500 m3 nourishment	$101,150	$95,316	$89,922	$84,927	$80,296	$75,995
5	8,500 m3 nourishment	$101,150	$93,447	$86,463	$80,120	$74,348	$69,087
6	8,500 m3 nourishment	$101,150	$91,615	$83,138	$75,585	$68,841	$62,806
7	8,500 m3 nourishment	$101,150	$89,818	$79,940	$71,307	$63,742	$57,097
8	8,500 m3 nourishment	$101,150	$88,057	$76,866	$67,271	$59,020	$51,906
9	8,500 m3 nourishment	$101,150	$86,331	$73,909	$63,463	$54,648	$47,187
10	8,500 m3 nourishment	$101,150	$84,638	$71,067	$59,871	$50,600	$42,897
11	Mild winter as per 2001 - 40,000 m3 nourishment	$476,000	$390,486	$321,569	$265,796	$220,480	$183,519
11	Seawall maintenance	$20,000	$16,407	$13,511	$11,168	$9,264	$7,711
12	40,000 m3 nourishment after mild winter	$476,000	$382,829	$309,201	$250,751	$204,148	$166,835
13	8,500 m3 nourishment	$101,150	$79,756	$63,178	$50,268	$40,168	$32,230
14	8,500 m3 nourishment	$101,150	$78,192	$60,748	$47,423	$37,193	$29,300
15	8,500 m3 nourishment	$101,150	$76,659	$58,412	$44,739	$34,438	$26,636
16	8,500 m3 nourishment	$101,150	$75,156	$56,165	$42,206	$31,887	$24,215
17	8,500 m3 nourishment	$101,150	$73,682	$54,005	$39,817	$29,525	$22,013
18	8,500 m3 nourishment	$101,150	$72,238	$51,928	$37,564	$27,338	$20,012
19	8,500 m3 nourishment	$101,150	$70,821	$49,930	$35,437	$25,313	$18,193
20	8,500 m3 nourishment	$101,150	$69,432	$48,010	$33,431	$23,438	$16,539
21	8,500 m3 nourishment	$101,150	$68,071	$46,164	$31,539	$21,702	$15,035
21	Seawall maintenance	$20,000	$13,459	$9,128	$6,236	$4,291	$2,973
22	8,500 m3 nourishment	$101,150	$66,736	$44,388	$29,754	$20,094	$13,668
23	8,500 m3 nourishment	$101,150	$65,428	$42,681	$28,070	$18,606	$12,426
24	Mild winter as per 2001 - 40,000 m3 nourishment	$476,000	$301,858	$193,126	$124,615	$81,070	$53,159
25	40,000 m3 nourishment after mild winter	$476,000	$295,939	$185,698	$117,562	$75,065	$48,326
26	8,500 m3 nourishment	$101,150	$61,654	$37,943	$23,568	$14,770	$9,336
27	8,500 m3 nourishment	$101,150	$60,445	$36,484	$22,234	$13,676	$8,487
28	8,500 m3 nourishment	$101,150	$59,260	$35,080	$20,975	$12,663	$7,715
29	8,500 m3 nourishment	$101,150	$58,098	$33,731	$19,788	$11,725	$7,014
30	8,500 m3 nourishment	$101,150	$56,959	$32,434	$18,668	$10,856	$6,376
31	8,500 m3 nourishment	$101,150	$55,842	$31,186	$17,611	$10,052	$5,797
31	Seawall maintenance	$20,000	$11,041	$6,166	$3,482	$1,988	$1,146
32	8,500 m3 nourishment	$101,150	$54,747	$29,987	$16,614	$9,307	$5,270
33	8,500 m3 nourishment	$101,150	$53,674	$28,834	$15,674	$8,618	$4,791
34	8,500 m3 nourishment	$101,150	$52,621	$27,725	$14,787	$7,980	$4,355
35	8,500 m3 nourishment	$101,150	$51,589	$26,658	$13,950	$7,389	$3,959

Table A.3 - Option 3 Seawall & Ongoing Nourishment