City of Wanneroo
March 2000

Quinns Beach Coastal Protection Works

Stage 3 Report

Design & Specifications

M P ROGERS & ASSOCIATES PTY LTD
Coastal and Port Engineers
Report R078 Rev 0

City of Wanneroo
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Job J248
Report R078 Rev 0

Prepared by: ____________________ Date: _________

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Executive Summary

The City of Wanneroo (Wanneroo) has been involved in combating coastal erosion at Quinns Rocks since 1970. Presently, coastal erosion is threatening to undermine the car park located to the north of Quinns Cusp, and there are also concerns regarding the ongoing stability of the beach to the south and adjacent Ocean Drive. The aim of this study is to provide a comprehensive evaluation of suitable coastal protection options for Quinns. The study is defined by the following three stages:

- **Stage 1**
  The review of existing data and technical reports, the calculation of appropriate design criteria for coastal protection options, and the preliminary review of coastal protection options.
- **Stage 2**
  A comprehensive review of suitable coastal protection options.
- **Stage 3**
  The final design and cost estimate of the coastal management option nominated by Wanneroo.

This report documents Stage 3 of the Study and contains the design review, cost estimates and contract specification for the construction of a seawall and the placement of sand renourishment.

The purpose of the seawall is to provide increased protection to the Quinns northern beach car park and Fredrick Stubbs Grove during storm events. However, it should be noted that the construction of the seawall is not expected to significantly reduce the net losses of sediment from the area, and an average annual renourishment requirement of 7,000 m3/year (9,000 m3/year in the truck) is expected. Without sand renourishment the beach will be lost and excessive wave action will damage and undermine the seawall.

Contents

1. Introduction

1.1 General

The City of Wanneroo has been involved in combating coastal erosion at Quinns Rocks since 1970 when a seawall was constructed to protect the parking lot and toilet block located at the end of Quinns Road. Additional protection works were completed in 1977, with a rubble headland built to the immediate south of Quinns Cusp to encourage accretion along the Southern Beach. Presently, coastal erosion is threatening to undermine the car park located to the north of the cusp, and there are also concerns regarding the ongoing stability of the Southern Beach and adjacent Ocean Drive (refer to Figure 1.1).

In 1997, a study of the coastal processes at Quinns was prepared by Tremarfon (1997) which recommended a combination of sand renourishment and retreat in the short term, with the construction of seawalls at defined locations in the longer term if renourishment proved ineffective and the foreshore continued to recede. The option of seawalls was reviewed by the Department of Transport (Transport*)* and concerns were raised regarding the potentially adverse effects and likely costs.

The present study was commissioned by the Shire of Wanneroo (Wanneroo) to provide a comprehensive evaluation of the coastal protection options available. These options include renourishment, seawall construction, groynes / headlands and breakwaters. The study is defined by the following three stages:

- **Stage 1**
  The review of existing data and technical reports, the calculation of appropriate design criteria for coastal protection options, and the preliminary review of coastal protection options.
- **Stage 2**
  A comprehensive review of suitable coastal protection options.
- **Stage 3**
  The final design and cost estimate of the coastal management option nominated by Wanneroo.

The results of the Stage 1 and Stage 2 investigations were presented in Rogers & Associates (1999a & 1999b), and the results of Stage 3 are presented in this report.

1.2 Study Area

Quinns Beach is located approximately 35 km north of Perth, Western

Australia. Thousands of years ago sand accreted in the sheltered coastal region north-east of Quinns Rocks, forming what is referred to as Quinns Cusp (Smith, 1985). However, in more recent times, sections of this cusp have eroded, with the recession of the foreshore threatening to undermine public assets and reduce the recreational amenity of the beaches.

The focus of this study is the protection of amenities which are located along the section of coastline between Caldera Close in the south and Tapping Way in the north. For the purpose of the study Quinns Cusp will be referred to as the *Cusp*, the foreshore located to the south of the Cusp will be referred to as the *Southern Beach*, and the foreshore located to the north of the Cusp will be referred to as the *Northern Beach* (refer to Figure 1.1).

1.3 Results of Stage 1

Coastal Processes

Existing data and technical reports were reviewed. This information was supplemented through further investigation and analysis described in the Stage 1 Report (Rogers & Associates, 1999). The results of the study indicated that the artificial headland constructed to the south of the Cusp in 1977 greatly influenced the stability of the Quinns coast. Since its construction, the Southern Beach has remained relatively stable while the Northern Beach has progressively eroded. This finding was the principal difference between the Stage 1 Study and Tremarfon (1997). The latter indicated that the erosion of the Northern Beach may be the result of severe storms experienced between 1994 and 1996 rather than a progressive trend.

Sediment budgets based on shoreline movements and a comparison of surveys recorded between 1977 and 1997 indicated that the volume of sand along the Quinns beaches varied significantly with both seasonal and annual fluctuations. However, on average, about 4,000 m^3/year accreted on the Southern Beach and about 8,500 m^3/year was lost from the Northern Beach.

Design Criteria

Design still water levels were determined from the results of Steedman (1988) and analysis completed as part of the present study (refer to Table 1.1).

The computer model 2GWave was used to analyse the wave climate at Quinns and determine appropriate nearshore significant wave heights for a range of storm events (refer also to Table 1.1). However, in most cases the height of incident waves will be depth limited with energy losses occurring as the waves approach the foreshore entering shallower water.

Table 1.1 - Nearshore Design Criteria

ARI Event	Design Still Water Level	Significant Wave Height (at -4 m CD)
10 year	+1.75 m CD (≈ 1.0 m AHD)	2.6 m
20 to 30 year	+1.8 m CD (≈ 1.1 m AHD)	2.7 m
50 to 100 year	+1.9 m CD (≈ 1.2 m AHD)	2.9 m

1.4 Results of Stage 2

Southern Beach

Since the construction of the artificial headland in 1977, the Southern Beach has remained relatively stable. Survey results indicate that the region accreted by about 80,000 m^3 during the twenty years between December 1977 and December 1997. However, a localised loss of about 12,000 m^3 has occurred from the primary dune seawards of Ocean Drive. This amount is relatively small in the overall system. However, it does suggest that without appropriate coastal management, a succession of severe storm events may reduce the buffer protecting Ocean Drive and threaten to undermine it.

Suitable management options have been reviewed and the recommended option is to increase the present buffer (ie width of dune) protecting Ocean Drive and undertake sand renourishment following severe storm events which cause significant erosion of the primary dune. In total, about 20,000 m^3 (truck volume) would be used to increase the dune buffer. An alternative option is to construct a seawall; however, this option is likely to be more costly and may increase the amount of erosion which occurs to the north of the cusp.

Allowing the dune to continue to erode is not recommended as storm erosion may produce a recession of the primary dune which may threaten to undermine a section of Ocean Drive. The value of the assets which may be lost through erosion is considered to be significantly greater than the cost of protecting them.

Northern Beach

Since the construction of the artificial headland in 1977, the Northern Beach has progressively eroded, receding at a rate of about 1 m/year. The total net loss of sediment from the Northern Beach was about 170,000 m^3 during the twenty year period between December 1977 and December 1997 (ie about 8,500 m^3/year). The future rate of erosion has been estimated to be about 7,000 m^3/year.

The present buffer protecting the Northern Car Park and Fredrick Stubbs Grove is minimal, and without the appropriate coastal management these amenities are likely to be undermined. If the present trend of erosion continues in the longer term, a section of Ocean Drive may also be threatened.

Suitable management options have been reviewed and seawall construction combined with renourishment was found to be the most appropriate management option. This option was found to be more cost effective than straight renourishment because the construction of the seawall was less costly than an appropriate increase of the dune buffer using sand from an external source. However, it should be noted that the construction of the seawall is not expected to significantly reduce the losses of sediment from the area, and an average annual renourishment requirement of 7,000 m^3/year is expected (this is about 9,000 m^3/year using truck volume).

The construction of groynes or headlands is not recommended because they are not the most cost effective option as they will be visually and physically obstructive to the users of the beach. In addition, they are likely to have an adverse effect on the surrounding coastline, and may be less effective in the longer term. In essence this solution would transfer the erosion problem to the coast to the north.

Seawall construction without renourishment is not recommended. Although the seawall would preserve the Car Park, it is likely that the beach would be lost through continued erosion seawards and longshore of the seawall.

Allowing the erosion to continue (ie do nothing) is also not recommended. Although the upper foreshore would continue to supply sand to the eroding beach, access and other amenities would be lost, and in the longer term, a section of Ocean Drive may be threatened.

2. Seawall Design

2.1 Coastal Processes

Since the construction of the artificial headland in 1977, the Northern Beach has progressively eroded, receding at a rate of about 1 m/year. The total net loss of sediment from the Northern Beach was about 170,000 m^3 during the twenty year period between December 1977 and December 1997 (ie about 8,500 m^3/year).

Survey analysis, and wave modelling and analysis indicates that this loss of sediment is the result of small net differences in much larger seasonal fluctuations of longshore sediment transport. On average, there is a net movement of sand northwards along the coast. This sand is not replaced with sufficient quantities of sand entering the system from the south, and hence there is a net loss of sand from the Northern Beach.

Waves produced by summer sea-breezes are believed to be the principal cause of the northwards longshore transport of sediment. Although storms can produce offshore movements of sediment and recession of the primary dune, they are not believed to be the cause of the progressive erosion at the Northern Beach. In fact, storms from the north-west can produce significant southwards transport and reduce the net losses from the area.

Suitable management options were reviewed in Stage 2 and seawall construction combined with renourishment was found to be the most appropriate management option**.** This option was found to be more cost effective than straight renourishment because the construction of the seawall was less costly than an appropriate increase of the dune buffer using sand from an external source. However, it should be noted that the construction of the seawall is not expected to significantly reduce the losses of sediment from the area, and an average annual renourishment requirement of 7,000 m^3/year is expected (about 9,000 m^3/year truck volume).

2.2 Seawall Design Criteria

In Stage 2, SBEACH was used to model the effect of 20 to 30 year ARI and 50 to 100 year ARI storm events on the Northern Beach, with the inclusion of a seawall at Chainage 30 metres. The results of the modelling are described in Table 2.1.

Table 2.1 - Seawall Design Criteria (with renourishment)

Event	20 to 30 year ARI	50 to 100 year ARI
Significant wave height	0.8 metre	1.0 metre
Eroded depth at toe	-0.3 metre AHD	-1.0 metre AHD
Estimated eroded depth at toe with adequate toe protection	-0.1 metres AHD	-0.3 metre AHD

This modelling was checked in Stage 3 and additional runs were completed to evaluate other possible events such as 15 metres of beach erosion followed by 50 to 100 year ARI storm event. The results of this simulation indicated a maximum wave height of 1.5 metres and scour at the toe of the seawall of RL-1.3 metres AHD. This shows quite clearly the importance of maintaining the beach seawards of the seawall.

The seawall will remain accessible for maintenance should the need arise, and the degree of protection required for public assets such as car parks is generally viewed as less critical than the protection required for private residences and essential roadways. Therefore, a design event of 20 to 30 years ARI is generally considered appropriate. However, the stability of seawall is dependent on the protection provided by the beach which is to be maintained through renourishment. This introduces a process which requires regular monitoring and management activities which may be delayed due to unforeseen circumstances. Also, the prediction of coastal processes such as wave heights and scour depths is not an exact science and allowances should be made for possible errors. Therefore, a more conservative approach was adopted and a water level of RL +1.2 metres AHD, a design wave of H_s=1.2 metres and scour depth of RL –1 metre AHD were used.

2.3 Seawall Design Review

The preliminary seawall design prepared in Stage 2 was reviewed. The improvements made were as follows:

- It was found that cost savings could be achieved through changing the slope of the seawall from 1:2 to 1:1.5.

- It was also found that a filter layer of 0.4 metres may be insufficient. This was increase to 0.5 metres and the installation of filter cloth was also included.

- To improve the protection at the toe of the seawall the filter layer was extended 3 metres along the bed at RL –1 metre AHD.

- To prevent scouring below the car park pavement, the filter layer was extended to the level of the car park where the distance between the seawall and the car park was less than 3 metres.

- At the direction of the City of Wanneroo the seawall was extended southwards to protect Fredrick Stubbs Grove.

Detailed drawings of the seawall are contained within the specification attached in Appendix A.

2.4 Boat Ramp

Wanneroo requested that consideration be given to the re-establishment of the boat ramp after the construction of the seawall. This was achieved by bring the seawall closer to the car park at the location of the ramp, thus minimising the distance that the ramp must protrude seawards. This will minimise maintenance if a temporary ramp is constructed.

The construction of a permanent (higher quality) ramp is not recommended as the location is unsuitable for the launching of larger crafts. The Australian Standard's Guidelines for the Design of Marinas (AS3962-1991) recommends a yearly maximum wave height of 0.3 metres for boat ramps. Boat ramps in more exposed locations may make the launching and retrieval of vessels difficult and dangerous.

Safe boat launching facilities are currently provided for by the Mindarie Keys Marina immediately to the south. Therefore, encouraging boat launching at the exposed location of Quinns Beach is not recommended. If Wanneroo chooses to construct a ramp at this location, the use of the ramp should be limited to smaller craft which are less difficult to control. However, Wanneroo must be aware that facilitating the launching and retrieval of any vessels at this location may make the City liable for damage and injuries incurred by the users.

Please note that if the recess of the seawall included for the construction of a boat ramp is not used for this purpose, it will still be beneficial as it will facilitate pedestrian access to the beach.

3. Renourishment Design

3.1 Southern Beach

17,000 m^3 of sand (in situ, i.e. about 20,000 m^3 uncompacted in the truck) is required to increase the dune buffer between the active shore and Ocean Drive. This should be sufficient to increase the buffer to about 30 metres from Ocean Drive.

The renourishment should not be placed at a level above the present height of the dune as this may cause a wind blown sand problem. Also adjacent residents may object to a reduction of ocean views.

The seaward face of the renourishment should be stabilised to a slope of 1 vertical to 1.5 horizontal.

Brush should be placed along the top and on the seaward face of the renourishment to encourage natural vegetation growth.

Detailed drawings of the Southern Beach sand renourishment are contained within the specification attached in Appendix A.

3.2 Northern Beach

The construction of the seawall will introduce about 11,000 m^3 of material into the foreshore. However, about 9,000 m^3 of sand may be lost to the inshore area during its construction and about 3,000 m^3 of sand will fill the voids of the seawall armour.

Therefore, to establish the dune seawards of the seawall, which will feed sand into the system and prevent the loss of the beach, it will be necessary to import suitable sand. The amount of sand imported should be about twice the average yearly loss (i.e. 14,000 m^3 in situ) to allow for fluctuations in the mean erosion rates. It is proposed that this renourishment be conducted in the following components:

- 7,000 m^3 (i.e. about 9,000 m^3 uncompacted in the truck) seawards of the seawall to be conducted immediately after the construction of the seawall;
- 3,500 m^3 (i.e. about 4,500 m^3 uncompacted in the truck) south of the seawall to be conducted at the time of the construction of the seawall; and
- 3,500 m^3 (i.e. about 4,500 m^3 uncompacted in the truck) about six months later.

The first two components have been included in the main contract, while the final component will from part of the annual renourishment program.

Detailed drawings of the Northern Beach sand renourishment are contained within the specification attached in Appendix A.

3.3 Quality of Sand for Renourishment

It is preferable that the renourishment sand be very similar to the beach sand presently at Quinns Beach. Sand of a similar cream colour is desirable to minimise the visual impacts of the Works. However, the other coloured sands may be worth considering.

The particle size distribution of the sand is also important. If sand used for renourishment does not have the same particle size distribution as the native sand, the borrow sand responds differently to the coastal processes which influence the stability of the beach. Therefore, the evaluation of suitable sand should include the calculation and comparison of Overfill Factors as described in Sections 4 and 5 (Pages 4-12 to 4-16 & 5-10 to 5-12), of the Shore Protection Manual (1984) prepared by the US Army Corps of Engineers (refer to Appendix B). Using Overfill Factors is one method for quantifying how much extra borrow sand is required to replace native sand. For example, an Overfill Factor of 1.75 indicates that 1.75 m^3 of the borrow sand is required to replace 1 m^3 of native sand.

The Overfill Factor is calculated as follows:

R_A= Overfill Factor.

ϕ_x = Particle size in phi units, where x is the cumulative percentile of **coarser** material within the sediment sample.

Phi units (ϕ) = -log$_2$(diameter in mm)= $\frac{-\log_{10}(\text{diameter in mm})}{\log_{10} 2}$

$$\phi_x = \frac{-\log_{10}(\text{diameter in mm of (100\% - x \%) Passing})}{\log_{10} 2}$$

ϕ_{84} = 84th percentile in phi units.

$$= -\log_2(\text{diameter in mm}) = \frac{-\log_{10}(\text{diameter in mm of 16\% Passing})}{\log_{10} 2}$$

ϕ_{16} = 16th percentile in phi units.

$$= -\log_2(\text{diameter in mm}) = \frac{-\log_{10}(\text{diameter in mm of 84\% Passing})}{\log_{10} 2}$$

σ_ϕ = Standard deviation of grain size.

$$\sigma_\phi = \frac{(\phi_{84} - \phi_{16})}{2}$$

M_ϕ = Phi mean diameter of the grain-size distribution

$$M_\phi = \frac{(\phi_{84} + \phi_{16})}{2}$$

$\#_b$ = Subscript b refers to borrow material.

$\#_n$ = Subscript n refers to natural material.

The standard deviation and mean diameter are calculated for the borrow material and natural material, and the Overfill Factor is then obtained from Figure 5-3 of Appendix B.

A number of sand samples from Quinns Beach were analysed prior to the commencement of the renourishment programme. Appendix C contains a copy of the test certificate for a sample obtained from the base of the dune opposite Fredrick Stubbs Grove. This sample is considered indicative of the natural sand being eroded from Quinns Beach, and the test results of this sample can be used to assess the particle size distribution of borrow materials.

The following values were obtained from linear interpolation of the test results:

$$\phi_{84n} = -\log_2(0.228 \text{ mm}) = 2.13$$

$$\phi_{16n} = -\log_2(0.466 \text{ mm}) = 1.10$$

Therefore,

$$\sigma_{\phi n} = \frac{(2.13 - 1.10)}{2} = 0.515$$

$$M_{\phi n} = \frac{(2.13 + 1.10)}{2} = 1.62$$

As an example, if the borrow material has a particle size distribution with

ϕ_{84b} = -log$_2$(0.210 mm), and ϕ_{16b} = -log$_2$(0.650 mm), then following calculations would apply:

ϕ_{84b} = 2.25

ϕ_{16b} = 0.62

$\sigma_{\phi b} = \frac{(2.25 - 0.62)}{2}$ = 0.815

$M_{\phi b} = \frac{(2.25 + 0.62)}{2}$ = 1.44

$\frac{\sigma_{\phi b}}{\sigma_{\phi n}}$ = 1.58

$\frac{M_{\phi b} - M_{\phi n}}{\sigma_{\phi n}}$ = -0.35

Therefore, from Figure 5-3 Appendix B, R_A = 1.13 (i.e. 1.13 m^3 of the offered borrow material will be required to replace 1 m^3 of natural sand).

4. Cost Estimates for Designed Works

Table 4.1 provides a cost breakdown of the estimated costs associated with the designed works.

The estimated total cost is about $190,700 greater than the preliminary estimate made in Stage 2 (i.e. $835,000). This is primarily due to the additional 100 metres of seawall required to extend the seawall to protect Fredrick Stubbs Grove (estimated cost of about $100,000), and the cost of improvements to the seawall.

The design concept recommended in Stage 2 involved using of annual sand renourishment to prevent the progressive erosion of Fredrick Stubbs Grove, but accepting the possibility of some losses during severe storm events. Wanneroo has indicated that such losses would be unacceptable; therefore, the seawall has been extended to provide protection to Fredrick Stubbs Grove during storm events.

The cost of improvements to the rubble seawall make it similar in cost to the use of a seawall constructed from geofabric tubes filled with sand. However, the rubble seawall remains preferable as the losses that may occur if the seawall is damaged during a severe storm event are likely to be less than the losses that may occur if the geofabric tubes are punctured or torn.

The additional costs make the “Seawall and Renourishment Option” very similar in cost to the “Renourishment Option”. However, recommended option remains preferable as it provides greater certainty of protection during and after severe storm events.

The “Headland Option” has not become more cost effective as it will increase in cost due to the desire to provide increased protection to Fredrick Stubbs Grove.

Table 4.1 Cost Estimate of Designed Works

Item	Description	Unit	Quantity	Rate	Amount
1	**Mobilisation & Preliminaries**	Item	1	$20,000	$20,000
2	**Seawall Construction**				
2.1	Excavation & Reprofiling	m^3	22,000	$1.50	$33,000
2.2	Fill	m^3	1,100	$5.00	$5,500
2.3	Filter Cloth	m^2	5,900	$5.00	$29,500
2.4	Bedding Layer	m^3	2,700	$27.00	$72,900
2.5	Armour	m^3	8,400	$27.00	$226,800
3	**Sand Renourishment**				
3.1	Northern Sand Renourishment	m^3	13,500	$12.00	$162,000
3.2	Southern Sand Renourishment	m^3	20,000	$12.00	$240,000
4	**Brush Work**				
4.1	Northern Brush Work	m^2	7,100	$2.50	$17,750
4.2	Southern Brush Work	m^2	7,000	$2.50	$17,500
5	**Demobilisation & Site Clean Up**	Item	1	$20,000	$20,000
6	**Sub Total**				**$844,950**
7	Management			5%	**$42,248**
8	Contingencies			10%	**$84,495**
9	Further Sand Renourishment	m^2	4,500	$12.00	**$54,000**
10	**Total**				**$1,025,693**

5. References

Coastal Engineering Research Centre, 1984. *Shore Protection Manual*. US Army Corps of Engineers.

Department of Transport (WA), 1997. *Unpublished Data: Plan Set DOT 871*. Department of Transport, Fremantle, Western Australia.

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

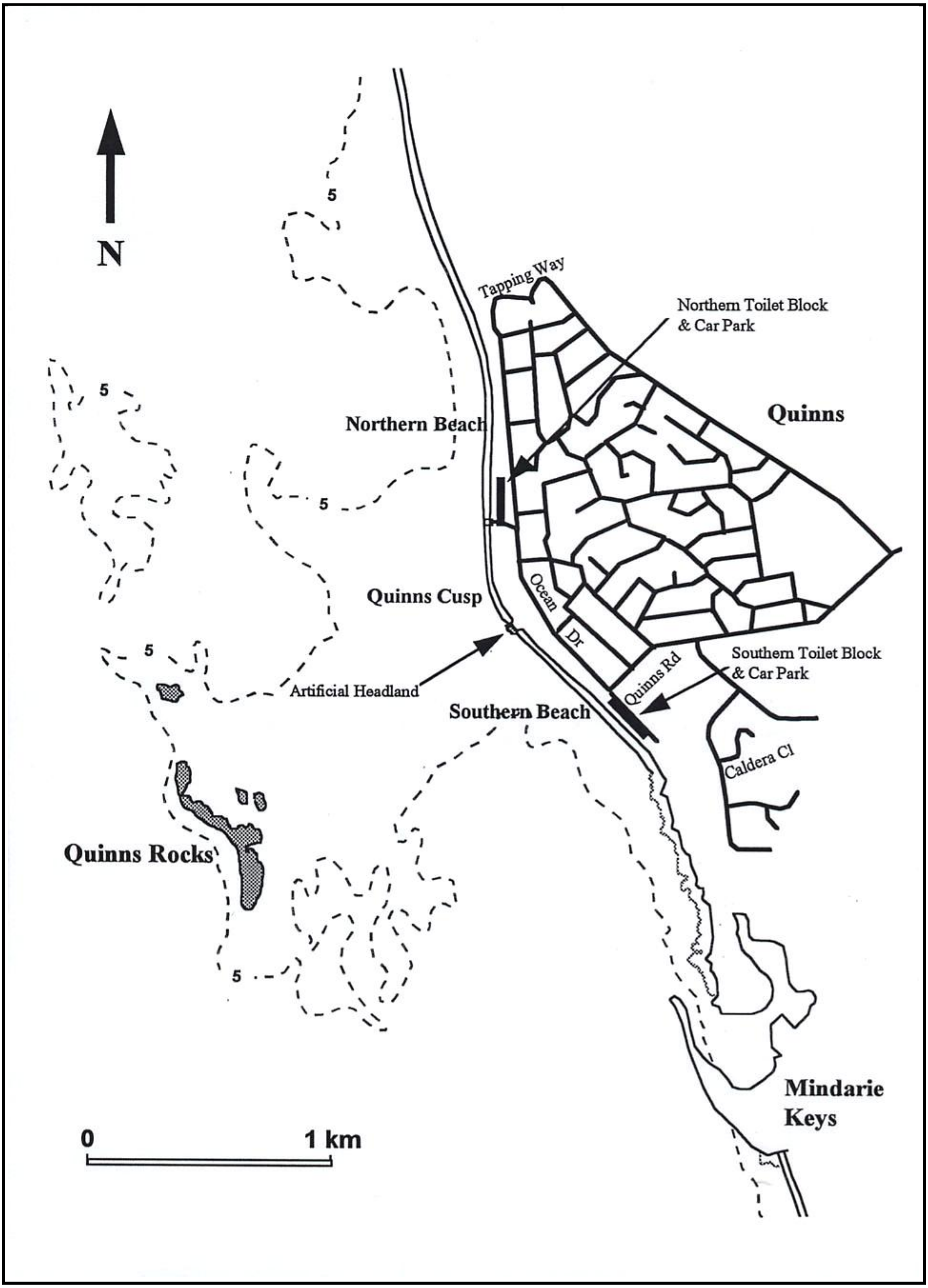
Rogers & Associates, 1999b. *Quinns Beach Coastal Protection Works Stage 2 Report.* Prepared for the Shire of Wanneroo by M P Rogers and Associates Pty Ltd, May 1999.

Tremarfon, 1997. *Quinns Coastal Processes Study.* Prepared for the City of Wanneroo by Tremarfon Pty Ltd, 1997.

Figures

Figure 1.1 Location Diagram

Figure 1.1 - Location Diagram



Appendix A - Specifications

S1 Description of Works

The works shall consist of the construction of a seawall adjacent to the Quinns Northern Beach car park and Fredrick Stubbs Grove located immediately to the south, and the placement and stabilisation of 33,500 m^3 of sand renourishment on the northern and southern flanks of Quinns Beach.

The Contract includes all operations, labour, plant, materials, supervision, survey, overheads, profit and everything else required for the construction and completion of the whole of the Works as described in this Specification, as shown on the Drawings together with any additional work or variations ordered by the Superintendent.

S2 Site & Access

S2.1 Site

The extent of the northern and southern site areas are detailed in the relevant Setout and Renourishment plans.

S2.2 Northern Beach

The site of the seawall and associated sand renourishment shall be accessed via the adjacent car park. This car park shall be closed to the public for the duration of the works and shall be available for the placement of site sheds and the storage of plant. Plant movements between the car park and the foreshore shall be limited to the ramps at seaward side of the northern and southern ends of the car park. Plant and works shall not encroach on the vegetated areas landwards of Set Out Line A.

S2.3 Southern Beach

The site of the southern beach sand renourishment shall be accessed via a track located adjacent to the junction of Pearce Street and Ocean Drive. Plant and works shall not encroach on the vegetated areas landwards of the renourishment area.

S3 Site Preparation

S3.1 Set Out

The Contractor shall clearly mark out Set Out Line A shown on the Seawall Set Out Plan. The Contractor shall obtain approval of this line from the Superintendent prior to the commencement of any excavation or construction works. Set Out Line A will remain marked out until the completion of the works.

S3.2 Protection of Pavements

The works shall be conducted in a controlled manner that minimises damage to all road and car park pavements. At the completion of the works the pavements shall be returned to their original state at the cost of the Contractor and to the satisfaction of the Superintendent.

S3.3 Clearing Vegetation

Vegetation seawards of Set Out Line A shall be removed by the Contractor. If appropriate, this vegetation may stockpiled at locations approved by the Superintendent and later be used for brush work on the top portion of the beach renourishment. Otherwise, the Contractor shall dispose of the vegetation at an appropriate offsite location.

S3.4 Removal of Excess Pavement

Any car park pavement seaward of Set Out Line C shall be removed and disposed of by the Contractor at an appropriate offsite location.

S3.5 Excavation

The Contractor shall excavate material as necessary to construct of the seawall. If necessary the Contractor will conduct dewatering.

The Quinns site is a sandy beach and it is not expected that reef or bedrock will be encountered during the excavation works. However, if during the excavation works loose rock is removed which is suitable for the construction of the seawall, than it may be incorporated into the Works to the satisfaction of the Superintendent.

Where other loose rock or foreign objects are removed during the excavation works, they shall be stockpiled at onsite locations approved by the Superintendent. The removal of this material from the stockpiles to appropriate offsite locations shall be the responsibility of the Principal.

Excavated sand may be used to form a bund seaward of the excavated area; however, it is desirable to minimise the amount of sand lost to the ocean. After each section of the seawall is completed, the sand bund shall be moved landward to form a beach slope of about 1 vertical to 15 horizontal from the swash zone to the seawall. The total amount of sand lost to the ocean through this process shall be less than half of the quantity of sand excavated.

S3.6 Filling

Where it is necessary to achieve an adequate operational area seaward of Set Out Line A, the Contractor shall place compacted fill. Sand from the excavation works can be used for this purpose.

The Fill Material shall be in accordance with Section 5.3

The Fill Material shall be placed in accordance with Section 6.1.

S4 Filter Cloth

Geofabrics Australia Bidim HN30 Filter Cloth or an equivalent approved by the Superintendent shall be placed as shown on the Drawings. The minimum overlap between sheets shall be 1.0 metre for the full length of the lap, after placement of the rock on top of the Filter Cloth.

The Contractor shall plan and execute the placement of the Filter Cloth to ensure that there is no damage to the Filter Cloth and that it forms a continuous barrier to the leaching of sand from beneath the seawall.

All damaged areas of Filter Cloth shall be repaired by overlaying the area with new Filter Cloth with a minimum overlap of 1.0 metre from the damaged area.

S5 Quarry Materials

The quarry materials to be supplied, delivered and placed in the construction of the seawall shall include the following.

S5.1 Armour Type I

Armour Type I shall consist of individual, hard, dense and angular quarry rocks broken out by explosives, free from weak cleavages and other faults, and of such strength that it will not break in handling, transporting and placing. Not more than 10% of the armour stones shall have the greatest dimension more that 2.5 times the smallest dimension. The Armour Type I stones shall vary in mass from 0.5 t to 2 t. At least 50% of the Armour Type I stones shall have a mass greater than 1 t.

S5.2 Bedding Layer Material

The Bedding Layer Material shall consist of well graded freshly quarried limestone up to a maximum size of 300 mm diameter with 50% of the stones being greater than 150 mm diameter. The proportion of stones less than 10 mm shall not exceed 10%.

S5.3 Fill Material

The compacted fill shall be clean, free draining sand, totally free from organic material and other foreign matter. Not more than 4% shall pass a 75 µm sieve.

S5.4 Renourishment Sand

It is preferred that the renourishment sand be very similar to the beach sand presently at Quinns Beach. Sand of a similar cream colour is desirable to minimise the visual impacts of the Works However, the other coloured sands may considered. To assist with the evaluation of tenders, each submission must include a sample of the sand offered. The samples should be about 500 mL, securely sealed in a container or bag, and clearly marked with its origin.

The particle size distribution of the offered sand is also important. In general, similar or coarser grade sands are preferable. The review of tender submissions will include the calculation and comparison of Overfill Factors as described in Attachment A. To assist with the evaluation of tenders, each submission must include the analysis of calcium carbonate content (%), average soil particle density (g/cm3), and sieve analysis of a minimum of three (3) samples from the source of the offered sand. The Superintendent will calculate the Mean Overfill Ratio of the offered sand (RO) by averaging the Overfill Ratios of each of the samples, and this ratio will be used in the comparison of tender submissions and the assessment of supplied sand (refer to Section 9.2).

Tenderers may offer a number of sand sources and types for the Superintendent to choose from. However, a sample and the analysis above must be submitted for each type of sand offered. Where the choice of sand type influences the cost of the project, the submission must include a completed Table of Rates and Contract Lump Sum for each type of sand offered, with the type of sand offered clearly identified.

S5.5 Sources of Supply of Quarried Materials

The Contractor shall make his own arrangements for opening up and operating all quarries required for the completion of the Works whether they are on Crown Land or privately owned land. These arrangements shall include payment of royalties, if required, and any other charges incidental to opening up, excavating, operating and winning from the quarries including the construction, upgrading and maintenance of any access roads required between the quarries and public roads. All such costs shall be deemed to be included in the prices submitted in the tender.

S5.6 Type of Rock, Strength and Minimum Density

All Armour Stone shall be limestone with a minimum Saturated Surface Dry Density of 1.9 t/m3. The Bedding Layer Material shall be limestone with a minimum Saturated Surface Dry Density of 1.7 t/m3. The Contractor shall arrange and pay for laboratory testing of samples from each quarry used for the Works to determine the Saturated Surface Dry Density of the rock from that quarry. The laboratory shall be NATA registered and the density tests shall be completed in accordance with AS 1141. The Superintendent shall select the samples for the Contractor to arrange the measurement of the density of the quarry rock at the rate of one sample per 3,000 m3 of armour or part thereof from each quarry used by the Contractor.

All Armour Stone and Bedding Layer Material shall be of sufficient strength that is does not break in quarry, transport and placement operations. All Armour Stones that break during transport or placement operations shall be removed from the armour layers at the Contractors expense.

S5.7 Truck Routes and Traffic

The Contractor shall endeavour to minimise the disruption to the area caused by truck traffic and other work activities, and is liable for any damage caused to roads and buildings by truck traffic. The Contractor shall liaise with the Superintendent and the City of Wanneroo to minimise the disruption to the surrounding areas.

The Contractor shall obtain approval for the proposed truck routes from the Superintendent and the City of Wanneroo.

S5.8 Samples of Armour Stones

At the commencement of the Works, the Contractor shall supply samples of the Armour stones to be used in the Works. Armour stones with masses of approximately 0.5 t, 1.0 t, and 2.0 t shall be provided as samples at the Quinns site as well as the quarry site or sites.

After weighing, the Armour stone samples shall be marked with their masses and retained on site and at the quarry for visual reference purposes for the duration of the Works. At the completion of the Works the sample stones shall be removed from the Quinns site or incorporated into the Works to the satisfaction of the Superintendent.

S6 Placing Quarried Materials

S6.1 Placing of Fill Material

The Contractor shall place and compact the fill in a planned and controlled manner to achieve the lines and levels shown on the Drawings. The Fill Material shall be placed and compacted in layers not more than 500 mm thick when compacted. All layers shall extend the full width of the fill area. The fill shall be compacted to achieve 6 blows with a Perth Sand Penetrometer between 150 and 400 mm below the surface level in accordance with AS1289 F3.3 - 1984.

S6.2 Placing Bedding Layer Material

The Bedding Layer Material shall be delivered and placed to the dimensions, lines, levels and slopes shown on the Drawings. The Bedding Layer shall be constructed to the levels shown on the Drawings plus or minus 0.1 metre and to the widths shown on the Drawings plus 0.1 metre or minus 0.0 metre.

Any Bedding Layer Material placed beyond the specified limits shall be removed by the Contractor at his own cost.

The Bedding Material shall not be dropped onto the Filter Cloth from a height greater than 1 metre.

S6.3 Placing Armour Stone

The Armour Stone shall be delivered and placed to the layers, dimensions, lines, levels and slopes shown on the Drawings. The Armour Stone shall be constructed to the levels shown on the Drawings plus 0.3 metre or minus 0.0 metre and to the top widths shown on the Drawings plus 0.3 metre or minus 0.0 metre.

Armour Stone shall be placed by crane or hydraulic excavator or other machine approved by the Superintendent in a manner that Armour Stone is lifted and them placed firmly on to the previously placed layer. The Armour Stones shall be in close contact with at least three other stones of the same layer.

The Contractor is required to remove all Armour Stones which have rolled to the beach/seabed and are not part of the structure.

S6.4 Rate of Placing

The Armour Stones shall be placed progressively on the side of the Bedding Layer to full height as soon as is practical. At the end of each working day, the placement of Armour Stones shall not be more than 5 metres from the end of the underlayers.

S6.5 Placing of Sand Renourishment

The Contractor shall place the sand renourishment in a planned and controlled manner to achieve the lines, grades, cross-sections and dimensions shown on the Drawings. The finished levels shall be +/-0.2 metres of that shown on the Drawings.

The Contractor shall place 9,000 m3 of sand renourishment along the length of the seawall. The width of the sand dune formed seaward of Set Out Line B shall be relatively uniform. A further 4,500 m3 of sand will be placed along the foreshore immediately south of the seawall

The Contractor shall place 20,000 m3 of sand on the southern beach between Pearce Street and Quinns Road. The width of the sand dune formed seawards of Ocean Drive shall be relatively uniform.

The quantity of sand specified in the contract and supplied by the Contractor will be identified and measured in uncompacted cubic metres on the truck. Prior to the commencement of delivery, the tray dimensions of each delivery truck will be measured to the satisfaction of the Superintendent. Each truck will then be filled with a normal load of sand and transported to site.

At site the sand will be levelled, the height of the sand will be measured, and the volume of the load calculated for each truck. Where delivery trucks are of similar capacity, a single set of measurements may be use to assign an appropriate load volume, provided it is acceptable to both the Superintendent and the Contractor.

Throughout the Works, the Superintendent may choose to measure the volume of sand delivered by any truck at any time. If the supplied volume is found to be less than the agreed volume, the percentage difference shall be applied in the calculation of the total volume of material supplied between the time of the volume check and the time of the previous measurement.

The Contractor shall prepare a delivery docket for each load delivered to site. Each docket shall clearly identify the following;

- the date and time of delivery;
- the location of delivery;
- the registration of the delivery vehicle; and
- the estimated volume of sand delivered.

At the point of receipt, the load must be approved and the associated docket signed by the Superintendent or Superintendent's Representative prior to unloading. All completed delivery dockets shall be submitted to the Superintendent with the progress claim. **The Contractor shall only be paid for deliveries which are appropriately documented and signed for by the Superintendent or Superintendent's Representative.**

S7 Brush Work

To minimise wind blown sand and encourage natural revegetation, the Contractor shall lay appropriate brush in the areas shown on the Drawings. The works must be conducted under the direct supervision of personnel experienced in dune stabilisation. The works must be conducted using proven techniques including placement patterns and types of brush. The density of the brush should be sufficient to minimise sand loss, while being sparse enough for vegetation growth and the minimisation of fire hazard.

The following shall be included in the Tender Submission:

- the name of the site supervisor (or Subcontractor if applicable) of the brush works;
- the relevant experience of the site supervisor (or Subcontractor if applicable);
- a brief description of the materials and methods for the works; and
- any other relevant information that will enable the Superintendent to better assess the quality of the proposed works.

For the information of the Tenderers that may have limited experience in this area, Ian Lovegrove of Coastal Revegetation (08 9921 6739) has recently completed similar works at Quinns to the satisfaction of the City of Wanneroo, and may be available to conduct the works as a Subcontractor. Alternatively, Steve Czaba (08 9335 0545) of CALM may be able to assist.

S8 Damage by Storms

The Contractor shall plan and execute the Works to minimise any damage by storms or other natural events. Any damage to the partially completed works shall be immediately rectified by the Contractor at his own cost.

S9 Quality Control and Acceptance Testing

S9.1 General

The Contractor shall continuously monitor the quality, density, size, grading and placement of all quarry materials used in the Works. The Contractor shall undertake a program of inspection, testing and supervision that will ensure that all materials incorporated into the Works conform to the full requirements of these Specifications. Such quality control and acceptance testing shall be to the satisfaction of the Superintendent.

S9.2 Quality Control of Sand Renourishment

The Contractor is responsible for ensuring that the quality of the supplied sand meets the requirements specified. The extent of the sand quality monitoring undertaken by the Contractor is up to the Contractor's discretion, with all associated costs to be incorporated within the tendered rate.

In addition to monitoring undertaken by the Contractor, the Superintendent will implement the following monitoring programme.

Prior to the supply of renourishment sand, Superintendent or Superintendent's Representative will inspect the borrow site and collect a minimum of three (3) sand samples which will be analysed for calcium carbonate content (%), average soil particle density (g/cm3), and particle size distribution. If the test results indicate that the quality of the sand is significantly less than the quality of the sand offer at the time of the tender submission, the Superintendent may chose not to accept the sand or may renegotiate with the Contractor an appropriate supply and delivery price.

During the course of the supply of renourishment sand, the Superintendent or Superintendent's Representative will take a minimum of one sample of each 1,000 m3 of sand delivered to Quinns Beach. Each sample will be analysed for calcium carbonate content (%), average soil particle density (g/cm3), and particle size distribution. The Mean Overfill Ratio of the supplied sand will be determined by averaging the Overfill Ratios of each of the samples taken by the Superintendent or the Superintendent's Representative during the renourishment session (note: the properties of the native sand to be used in these calculations are ϕ_{84n} =2.13, ϕ_{16n} = 1.10)).

If the Mean Overfill Ratio of the supplied sand (RS) is greater than 125% of the Mean Overfill Ratio of the sand offered during tender submission (RO), the payment will be reduced proportionally as follows:

$$\text{Total Payment (\$)} = \frac{(\text{Volume } (m^3)) * (\text{Agreed Rate } (\$ / m^3)) * (R_O)}{R_S}$$

All sand samples taken by the Superintendent and Superintendent's Representative will be analysed by a NATA approved laboratory, with the results available to the Contractor on request.

The Principal will meet all costs associated with the monitoring undertaken by the Superintendent.

S9.3 "As Constructed" Contract Drawings

The Contractor shall keep one set of full size prints of the Contract Drawings for "As-Constructed" purposes. This set of prints shall be maintained in a clean condition on site and shall be marked up by the Contractor to show the "As-Constructed" Works. "As-Constructed" measurements shall be made by a qualified surveyor. Deviations to the Plans shall be marked on the prints in red ink with unchanged dimensions and levels underlined in red ink. Each drawing shall be certified "As-Constructed" dated and signed by the Contractor and the Superintendent's Representative as soon as practicable after completion of the work shown on that drawing. In due course the full set of "As Constructed" Drawings shall be delivered to the Superintendent who will acknowledge receipt in writing.

The Certificate of Practical Completion of the Works will not be issued until after the Superintendent has received the full set of approved "As-Constructed" Drawings.

LUMP SUM BILL OF QUANTITIES

for

QUINNS BEACH – COASTAL PROTECTION WORKS

All items in this Bill shall be priced and extended by the Tenderer and the prices as extended shall, on addition, equal the Lump Sum accepted by the Principal for the execution of the work to which this Bill relates.

The rates and prices entered shall include fully for all the obligations of the Tenderer under the Contract.

This Bill of Quantities forms part of the Contract for the purpose of assessing the value of progress payments and variations and for no other purpose.

Item No.	Description	Quantity	Unit (In Place)	Rate $	Amount $	Total $
1	**Mobilisation**	SUM	Ea			
2	**Seawall Works**					
2.1	Excavation & Beach Reprofiling	22,000	m^3			
2.2	Supply and Place Fill	1,100	m^3			
2.3	Supply and Install Filter Cloth	5,900	m^2			
2.4	Supply and Place Bedding Layer	2,700	m^3			
2.5	Supply and Place Armour	8,400	m^3			
3	**Sand Renourishment Works**					
3.1	Supply and Place Northern Renourishment	13,500	m^3			
3.2	Supply and Place Southern Renourishment	20,000	m^3			
4	**Brush Works**					
4.1	Supply and Place Northern Brush Work	7,100	m^2			
4.2	Supply and Place Southern Brush Work	7,000	m^2			
5	**Demobilisation & Site Clean Up**	SUM	Ea			

TOTAL LUMP SUM TENDER PRICE: $...

* Note: The quantities included in the above table are estimates for information only. The Contractor should verify these quantities and they shall not form part of the Contract.

Name of Tenderer: ______________________________

Signature: ______________________________

Attachment A – Overfill Calculation

The particle size distribution of the offered sand is also important. If sand used for renourishment does not have the same particle size distribution as the native sand, the borrow sand responds differently to the coastal processes which influence the stability of the beach. The review of tender submissions will include an evaluation of the properties of the sand being offered, including the calculation and comparison of Overfill Factors as described in Sections 4 and 5 (Pages 4-12 to 4-16 & 5-10 to 5-12), of the Shore Protection Manual (1984) prepared by the US Army Corps of Engineers (refer to Attachment B). Using Overfill Factors is one method for quantifying how much extra borrow sand is required to replace native sand. For example, an Overfill Factor of 1.75 indicates that 1.75 m^3 of the borrow sand is required to replace 1 m^3 of native sand.

The Overfill Factor is calculated as follows:

R_A= Overfill Factor.

ϕ_x = Particle size in phi units, where x is the cumulative percentile of **coarser** material within the sediment sample.

Phi units (ϕ) = $-\log_2$(diameter in mm)= $\dfrac{-\log_{10}(\text{diameter in mm})}{\log_{10}2}$

$$\phi_x = \frac{-\log_{10}(\text{diameter in mm of (100\% - x \%) Passing})}{\log_{10}2}$$

ϕ_{84} = 84th percentile in phi units.

$$= -\log_2(\text{diameter in mm}) = \frac{-\log_{10}(\text{diameter in mm of 16\% Passing})}{\log_{10}2}$$

ϕ_{16} = 16th percentile in phi units.

$$= -\log_2(\text{diameter in mm}) = \frac{-\log_{10}(\text{diameter in mm of 84\% Passing})}{\log_{10}2}$$

σ_ϕ = Standard deviation of grain size.

$$\sigma_\phi = \frac{(\phi_{84} - \phi_{16})}{2}$$

M ϕ = Phi mean diameter of the grain-size distribution

$$M_\phi = \frac{(\phi_{84} + \phi_{16})}{2}$$

$\#_b$ = Subscript b refers to borrow material.

$\#_n$ = Subscript n refers to natural material.

The standard deviation and mean diameter are calculated for the borrow material and natural material, and the Overfill Factor is then obtained from Figure 5-3 of Attachment A.

A number of sand samples from Quinns Beach were analysed prior to the commencement of the renourishment programme. Attachment B is a copy of the test certificate for a sample obtained from the base of the dune opposite Fredrick Stubbs Grove. This sample is considered indicative of the natural sand being eroded from Quinns Beach, and the test results of this sample will be used to assess the particle size distribution of borrow material offered by the tenderers.

The following values were obtained from linear interpolation of the test results:

$$\phi_{84n} = -\log_2(0.228 \text{ mm}) = 2.13$$

$$\phi_{16n} = -\log_2(0.466 \text{ mm}) = 1.10$$

Therefore,

$$\sigma_{\phi n} = \frac{(2.13 - 1.10)}{2} = 0.515$$

$$M\phi_n = \frac{(2.13 + 1.10)}{2} = 1.62$$

As an example, if the offered borrow material had a particle size distribution with $\phi_{84b} = -\log_2(0.210 \text{ mm})$, and $\phi_{16b} = -\log_2(0.650 \text{ mm})$, then following calculations would apply:

$$\phi_{84b} = 2.25$$

$$\phi_{16b} = 0.62$$

$$\sigma_{\phi b} = \frac{(2.25 - 0.62)}{2} = 0.815$$

$$M\phi_b = \frac{(2.25 + 0.62)}{2} = 1.44$$

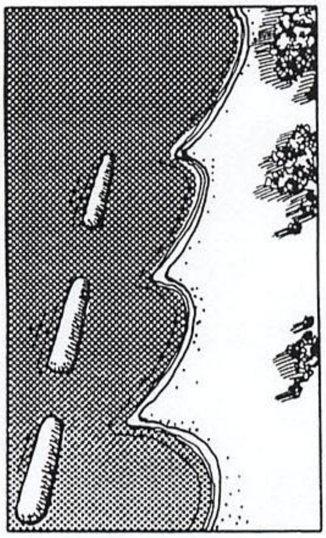
$$\frac{\sigma_{\phi b}}{\sigma_{\phi n}} = 1.58$$

$$\frac{M_{\phi b} - M_{\phi n}}{\sigma_{\phi n}} = -0.35$$

Therefore, from Figure 5-3 Attachment B, R_A = 1.13 (i.e. 1.13 m^3 of the offered borrow material will be required to replace 1 m^3 of natural sand).

Attachment B - Extracts from Shore Protection Manual (1984)

US Army Corps of Engineers



SHORE PROTECTION MANUAL

VOLUME I

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road
Vicksburg, Mississippi 39180-6199

1984
Second Printing

Prepared for

DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314

Net longshore transport rates along ocean beaches range from near zero to 765,000 cubic meters (1 million cubic yards) per year, but are typically 76,500 to 382,00 cubic meters (100,000 to 500,000 cubic yards) per year. Such quantities, if removed from a 16- to 32-kilometer (10- to 20-mile) stretch of beach year after year, would result in severe erosion problems. The fact that many beaches have high rates of longshore transport without unusually severe erosion suggests that an equilibrium condition exists on these beaches, in which the material removed is balanced by the material supplied.

II. LITTORAL MATERIALS

Littoral materials are the solid materials (mainly sedimentary) in the littoral zone on which the waves, wind, and currents act.

1. Classification.

The characteristics of the littoral materials are usually primary input to any coastal engineering design. Median grain size is the most frequently used descriptive characteristic.

a. Size and Size Parameters. Littoral materials are classified by grain size into clay, silt, sand, gravel, cobble, and boulder. Several size classifications exist, of which two, the Unified Soil Classification (based on the Casagrande Classification) and the Wentworth classification, are most commonly used in coastal engineering (see Fig. 4-7). The Unified Soil Classification is the principal classification used by engineers. The Wentworth classification is the basis of a classification widely used by geologists, but is becoming more widely used by engineers designing beach fills.

For most shore protection design problems, typical littoral materials are sands with sizes between 0.1 and 1.0 millimeters. According to the Wentworth classification, sand size is in the range between 0.0625 and 2.0 millimeters; according to the Unified Soil Classification, it is between 0.074 and 4.76 millimeters. Within these sand size ranges, engineers commonly distinguish size classes by median grain size measured in millimeters.

Samples of typical beach sediment usually have a few relatively large particles covering a wide range of diameters and many small particles within a small range of diameters. Thus, to distinguish one sample from another, it is necessary to consider the small differences (in absolute magnitude) among the finer sizes more than the same differences among the larger sizes. For this reason, all sediment size classifications exaggerate absolute differences in the finer sizes compared to absolute differences in the coarser sizes.

As shown in Figure 4-7, limits of the size classes differ. The Unified Soil Classification boundaries correspond to U.S. Standard Sieve sizes. The Wentworth classification varies as powers of 2 millimeters; i.e., the size classes have limits, in millimeters, determined by the relation 2^n, where n is any positive or negative whole number, including zero. For example, the limits on sand size in the Wentworth scale are 0.0625 and 2 millimeters, which correspond to 2^{-4} and 2^{+1} millimeters.

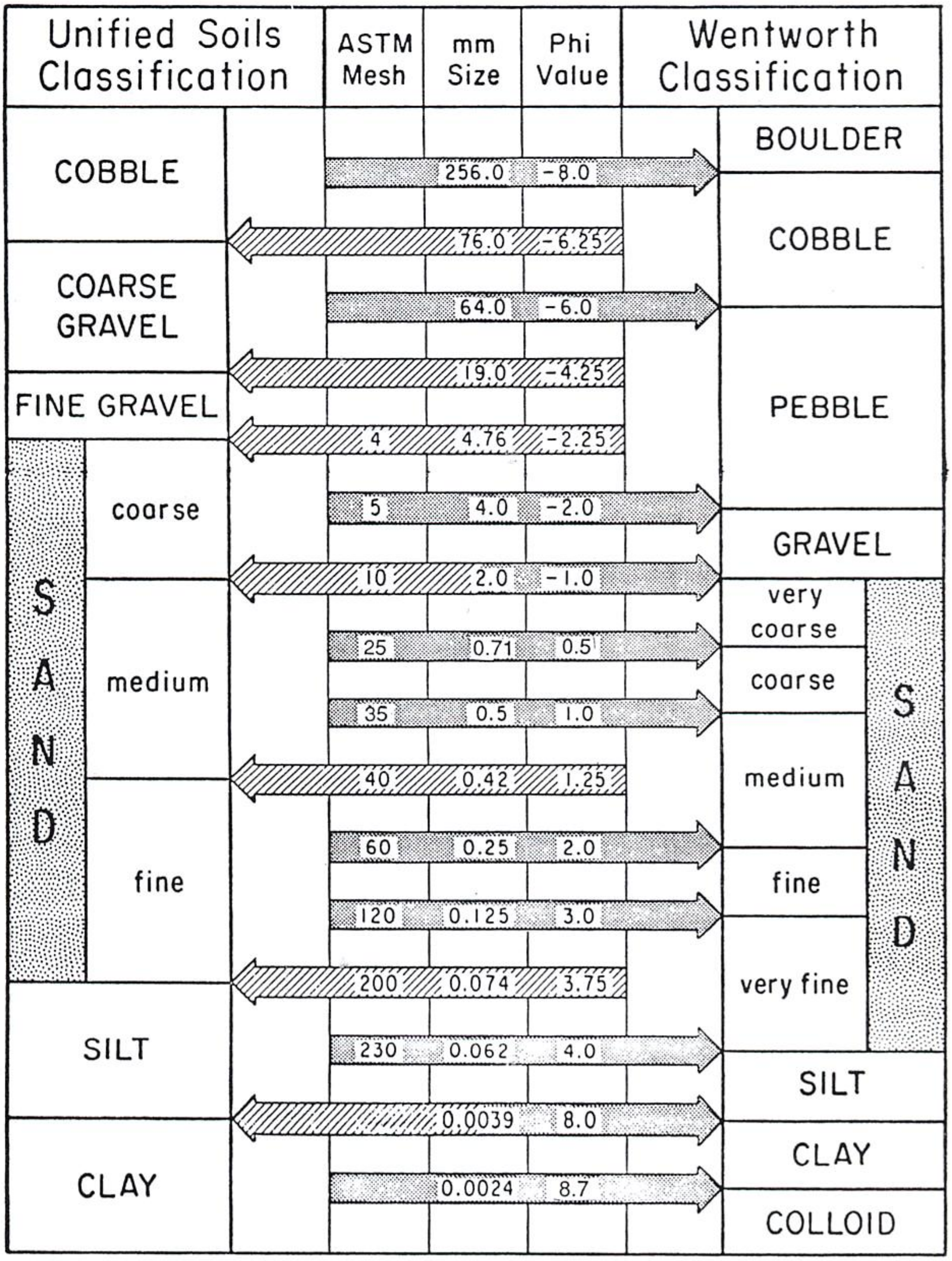


Figure 4-7. Grain-size scales (soil classification).

This property of having class limits defined in terms of whole number powers of 2 millimeters led Krumbein (1936) to propose a phi unit scale based on the definition:

$$\text{Phi units } (\phi) = -\log_2 (\text{diameter in mm}) \qquad (4\text{-}1)$$

Phi unit scale is indicated by writing ϕ or phi after the numerical value. The phi unit scale is shown in Figure 4-7. Advantages of phi units are

(1) Limits of Wentworth size classes are whole numbers in phi units. These phi limits are the negative value of the exponent, n, in the relation 2^n. For example, the sand size class ranges from +4 to -1 in phi units.

(2) Sand size distributions typically are near lognormal, so that a unit based on the logarithm of the size better emphasizes the small significant differences between the finer particles in the distribution.

(3) The normal distribution is described by its mean and standard deviation. Since the distribution of sand size is approximately lognormal, individual sand size distributions can be more easily described by units based on the logarithm of the diameter rather than the absolute diameter. Comparison with the theoretical lognormal distribution is also a convenient way of characterizing and comparing the size distribution of different samples.

Of these three advantages, only (1) is unique to the phi units. The other two, (2) and (3), would be valid for any unit based on the logarithm of size.

Disadvantages of phi units are

(1) Phi units increase as absolute size in millimeters decreases.

(2) Physical appreciation of the size involved is easier when the units are millimeters rather than phi units.

(3) The median diameter can be easily obtained without phi units.

(4) Phi units are dimensionless and are not usable in physically related quantities where grain size must have units of length such as grain size, Reynolds number, or relative roughness.

Size distributions of samples of littoral materials vary widely. Qualitatively, the size distribution of a sample may be characterized (1) by a diameter that is in some way typical of the sample and (2) by the way that the sizes coarser and finer than the typical size are distributed. (Note that size distributions are generally based on weight, rather than number of particles.)

A size distribution is described qualitatively as *well sorted* if all particles have sizes that are close to the typical size. If the particle sizes are distributed evenly over a wide range of sizes, then the sample is said to be *well graded*. A well-graded sample is poorly sorted; a well-sorted sample is poorly graded.

The *median diameter* (M_d) and the *mean diameter* (M) define typical sizes of a sample of littoral materials. The median size M_d, in millimeters, is the most common measure of sand size in engineering reports. It may be defined as

$$M_d = d_{50} \tag{4-2}$$

where d_{50} is the size in millimeters that divides the sample so that half the sample, by weight, has particles coarser than the d_{50} size. An equivalent definition holds for the median of the phi-size distribution, using the symbol $M_d\phi$ instead of M_d.

Several formulas have been proposed to compute an approximate mean (M) from the cumulative size distribution of the sample (Otto, 1939; Inman, 1952; Folk and Ward, 1957; McCammon, 1962). These formulas are averages of 2, 3, 5, or more symmetrically selected percentiles of the phi frequency distribution, such as the formula of Folk and Ward.

$$M_\phi = \frac{\phi_{16} + \phi_{50} + \phi_{84}}{3} \tag{4-3}$$

where ϕ is the particle size in phi units from the distribution curve at the percentiles equivalent to the subscripts 16, 50, and 84 (Fig. 4-8); ϕ_x is the size in phi units that is exceeded by x percent (by dry weight) of the total sample. These definitions of percentile (after Griffiths, 1967, p. 105) are known as graphic measures. A more complex method--the method of moments--can yield more precise results when properly used.

To a good approximation, the median M_d is interchangeable with the mean (M) for most beach sediment. Since the median is easier to determine, it is widely used in engineering studies. For example, in one CERC study of 465 sand samples from three New Jersey beaches, the mean computed by the method of moments averaged only 0.01 millimeter smaller than the median for sands whose average median was 0.30 millimeter (1.74 phi) (Ramsey and Galvin, 1971).

Since the actual size distributions are such that the log of the size is approximately normally distributed, the approximate distribution can be described (in phi units) by the two parameters that describe a normal distribution--the mean and the standard deviation. In addition to these two parameters, skewness and kurtosis describe how far the actual size distribution of the sample departs from this theoretical lognormal distribution.

Standard deviation is a measure of the degree to which the sample spreads out around the mean (i.e., its sorting) and can be approximated using Inman's (1952) definition by

$$\sigma_\phi = \frac{\phi_{84} - \phi_{16}}{2} \tag{4-4}$$

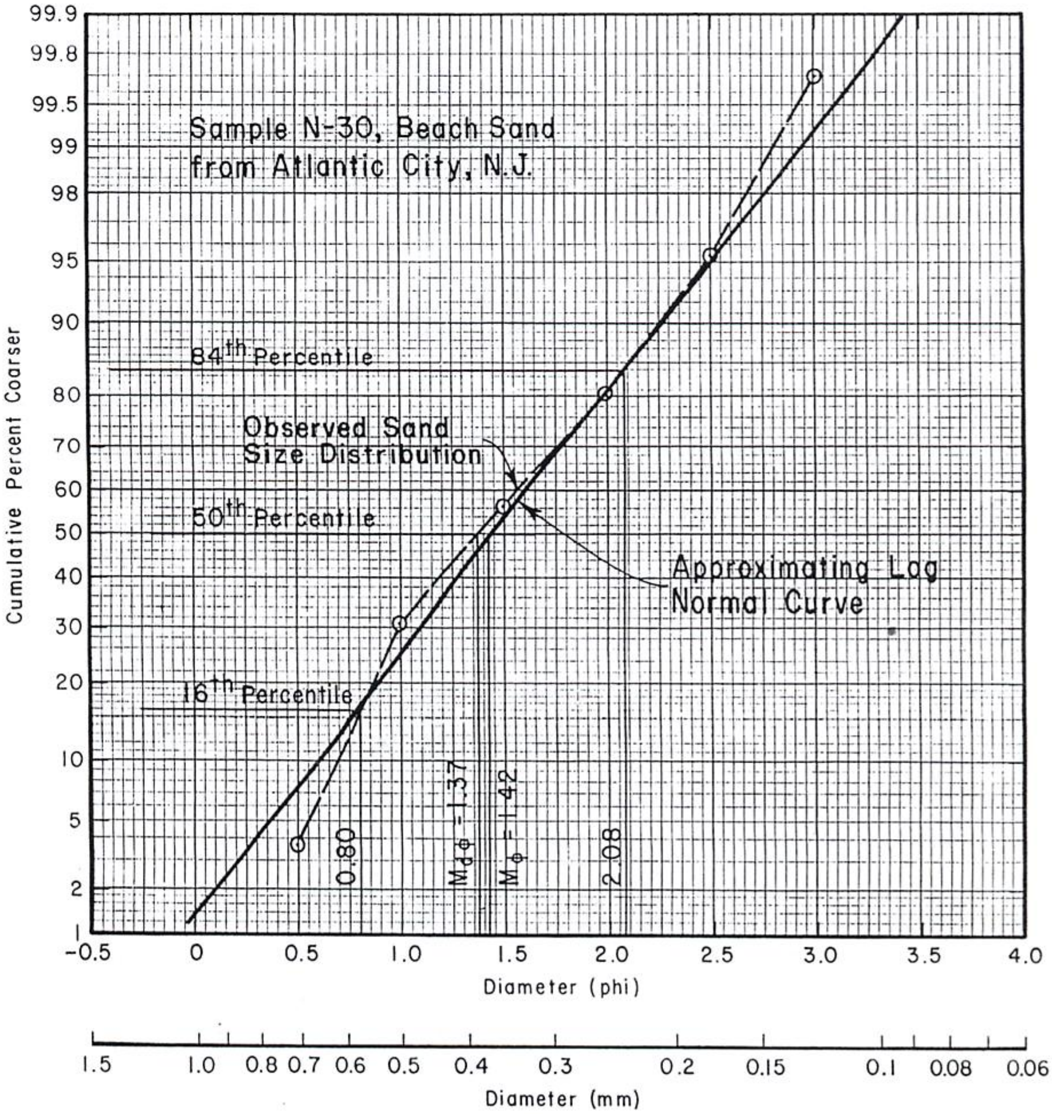


Figure 4-8. Example size distribution.

The distribution of grain sizes naturally present on a stable beach represents a state of dynamic equilibrium between the supply and the loss of material of each size. Coarser particles generally have a lower supply rate and a lower loss rate; fine particles are usually more abundant but are rapidly moved alongshore and offshore. Where fill is to be placed on a natural beach that has been relatively stable (i.e., exhibiting a steady rate of change or dynamic stability, or only slowly receding) the size characteristics of the native material can be used to evaluate the suitability of potential borrow material. Borrow material with the same grain-size distribution as the native material is most suitable for fill; material slightly coarser is usually suitable. If such borrow material is available, the volume required for fill may be determined directly from the project dimensions, assuming that only insignificant amounts will be lost through sorting and selective transport and that the sorting is not significantly different from the native material. In cases where these conditions do not apply, an additional volume of fill may be required as determined by an overfill factor.

(1) Overfill Factor. Unfortunately it is often difficult to find economical sources of borrow material with the desired grain-size distribution. When the potential borrow material is finer than the native material, large losses of the beach-fill material often take place immediately following placement. Currently, there is no proven method for computing the amount of overfill required to satisfy project dimensions. Krumbein's (1957) study provides a quantitative basis for comparison on the material characteristics considered to have the greatest effect on this relationship. Subsequent work by Krumbein and James (1965), James (1974), Dean (1974), and James (1975) developed criteria to indicate probable behavior of the borrow material on the beach. The use of the overfill criteria developed by James (1975) will give the best results in the majority of cases. It should be stressed, however, that these techniques have not been fully tested in the field and should be used only as a general indication of possible beach-fill behavior.

The procedures require that enough core samples be taken from the borrow area to adequately describe the composite textural properties throughout the entire volume of the borrow pit (see Hobson, 1977). Textural analyses of both borrow and native beach samples can be obtained using either settling or sieving grain-size analysis techniques. The composite grain-size distributions are then used to evaluate borrow sediment suitability.

Almost any offshore borrow source near the shore will include some suitable size material. Since the source will control cost to a major degree, an evaluation of the proportional volume of borrow material with the desired characteristics is important in economic design. The overfill criteria developed by James (1975), presented graphically in Figure 5-3, give a solution for the overfill factor, R_A , where

R_A = the estimated number of cubic meters of fill material required to produce 1 cubic meter of beach material when the beach is in a condition compatible with the native material,

σ_ϕ = the standard deviation and is a measure of sorting (see Ch. 4, Sec. II) where

$$\sigma_\phi = \frac{\left(\phi_{84} - \phi_{16}\right)}{2} \tag{5-1}$$

M_ϕ = the phi mean diameter of grain-size distribution (see Ch. 4, Sec. II) where

$$M_\phi = \frac{\left(\phi_{84} + \phi_{16}\right)}{2} \tag{5-2}$$

$\_{b}$ = subscript b refers to borrow material

$\_{n}$ = subscript n refers to natural sand on beach

ϕ_{84} = 84th percentile in phi units

ϕ_{16} = 16th percentile in phi units

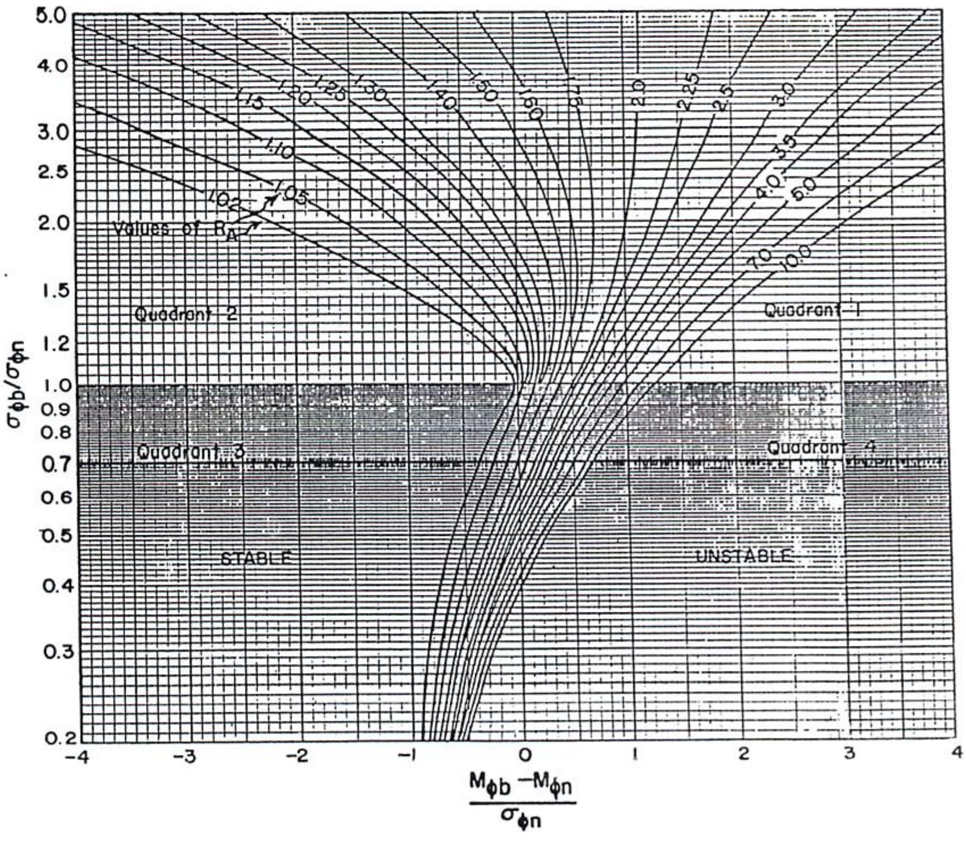


Figure 5-3. Isolines of the adjusted overfill factor, R_A, for values of phi mean difference and phi sorting ratio (from James, 1975).

This technique assumes that both composite native and borrow material distributions are nearly lognormal. This assumption is correct for the composite grain-size distribution of most natural beaches and many borrow materials. Pronounced bimodality or skewness might be encountered in potential borrow sources that contain multiple layers of coarse and fine material, such as clay-sand depositional sequences, or in borrow zones that crosscut flood plain deposits associated with ancient river channels.

The four possible combinations that result from a comparison of the composite grain-size distribution of native material and borrow material are listed in Table 5-1 and indicated as quadrants in Figure 5-3.

The engineering application of the techniques discussed above requires that basic sediment-size data be collected in both the potential borrow area and the native beach area. An estimation of the composite grain-size characteristics of native material should follow the guidelines in Hobson (1977). The determination of the composite distribution of the borrow zone material depends on the variation of materials and their individual properties. If the textural properties of the potential borrow material exhibit considerable variation in both area and depth, extensive coring may be required to obtain reliable estimates of the composite distribution of properties. Since detailed guidelines have not been established for evaluating borrow deposits, it is recommended that core sampling be carried out as a two-phase program--the first phase inventories the general borrow region and the second phase samples in detail those areas with the greatest potential.

(2) Renourishment Factor. James (1975) provides a second approach to the planning and design of nourishment projects. This approach, which relates to the long-term maintenance of a project, asks the basic question of how often renourishment will be required if a particular borrow source is selected that is texturally different from the native beach sand. With this approach, different sediment sizes will have different residence times within the dynamic beach system. Coarse particles will generally pass more slowly through the system than finer sizes. This approach also requires accurate composites of native and borrow sediment textures.

To determine periodic renourishment requirements, James (1975) defines a renourishment factor, R_J , which is the ratio of the rate at which borrow material will erode to the rate at which natural beach material is eroding. The renourishment factor is given as

$$R_J = e^{\left[\Delta\left(\frac{M_{\phi b} - M_{\phi n}}{\sigma_{\phi n}}\right) - \frac{\Delta^2}{2}\left(\frac{\sigma^2_{\phi b}}{\sigma^2_{\phi n}} - 1\right)\right]} \qquad (5\text{-}3)$$

where Δ is a winnowing function. The Δ parameter is dimensionless and represents the scaled difference between the phi means of noneroding and actively eroding native beach sediments. James (1975) estimates values of Δ ranging between 0.5 and 1.5 for a few cases where appropriate textural data were available and recommends $\Delta = 1$ for the common situation where the textural properties of noneroding native sediments are unknown. Equation (5-3) is plotted in Figure 5-4 for $\Delta = 1$. Figure 5-3 should be used for

Appendix B – Design Drawings

CITY OF WANNEROO
QUINNS BEACH PROTECTION

DRAWING INDEX

Works North of Pearce Street

D248 – 1 –1	SEAWALL – SET OUT PLAN
1 –2	SEAWALL – TYPICAL SECTION
1 –3	SEAWALL – SECTION AT RAMPS
D248 – 2 –1	NORTHERN BEACH RENOURISHMENT PLAN
2 –2	BEACH RENOURISHMENT AT SEAWALL – TYPICAL SECTION
2 –3	BEACH RENOURISHMENT SOUTH OF SEAWALL – TYPICAL SECTION

Works South of Pearce Street

D248 – 3 –1	SOUTHERN BEACH RENOURISHMENT PLAN
3 –2	SOUTHERN BEACH RENOURISHMENT – TYPICAL SECTION

REV	DATE	APP'D	DESCRIPTION

CLIENT: CITY OF WANNEROO

DESIGNED: B Moloney | CHECKED: MPR | APPROVED:

DRAWN: VAR | CHECKED: MPR

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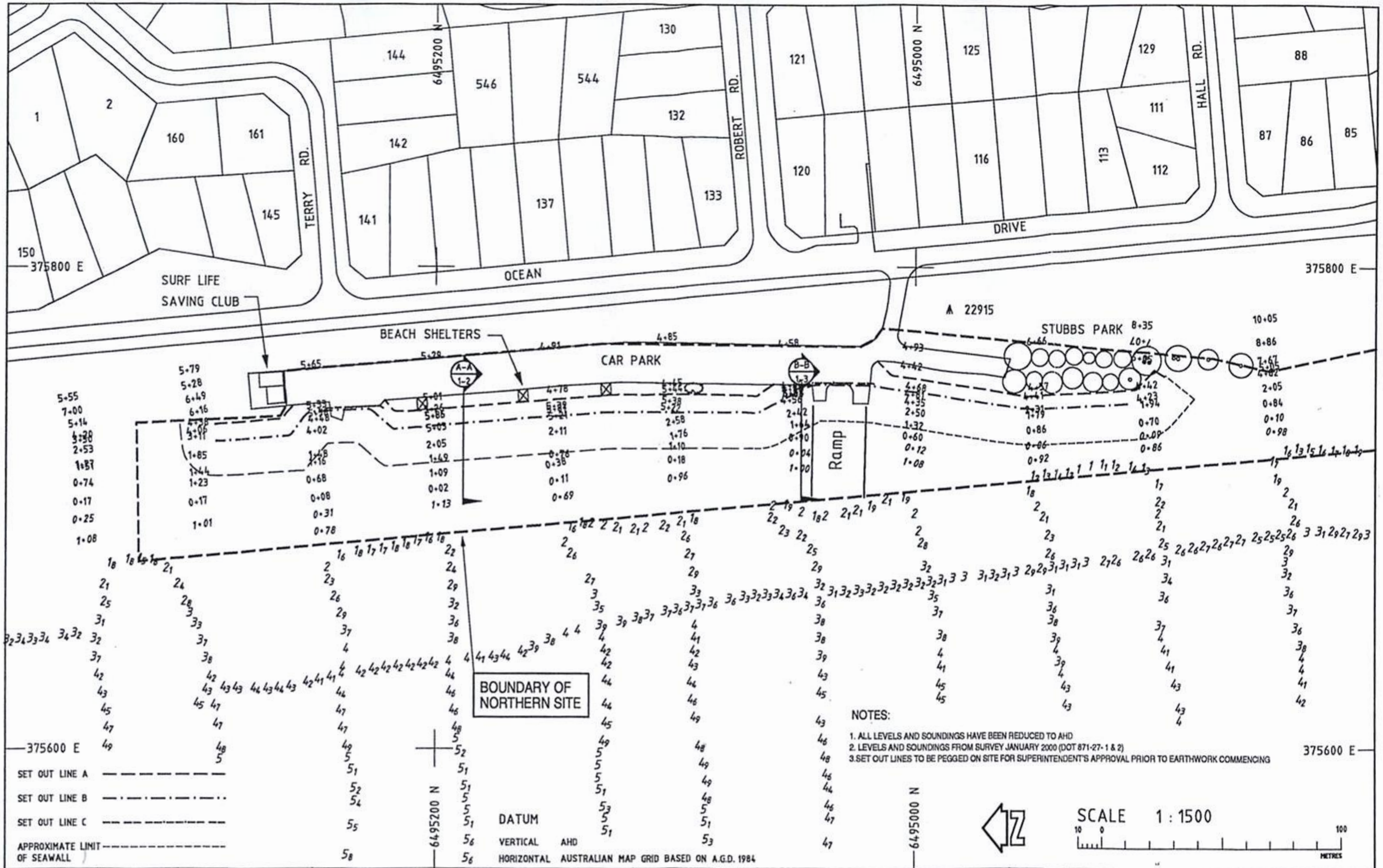
PROJECT: QUINNS BEACH PROTECTION

TITLE: DRAWING INDEX

SCALE AT A3 | DRAWING NUMBER: D 248 - 0 - 1 | REV



REV	DATE	APP'D	DESCRIPTION
A	3/00	MPR	ISSUED FOR APPROVALS

CLIENT: CITY OF WANNEROO

DESIGNED: B MOLONEY — CHECKED: M P ROGERS — APPROVED:

DRAWN: BEBBINGTON CARTOGRAPHICS — CHECKED: M P ROGERS

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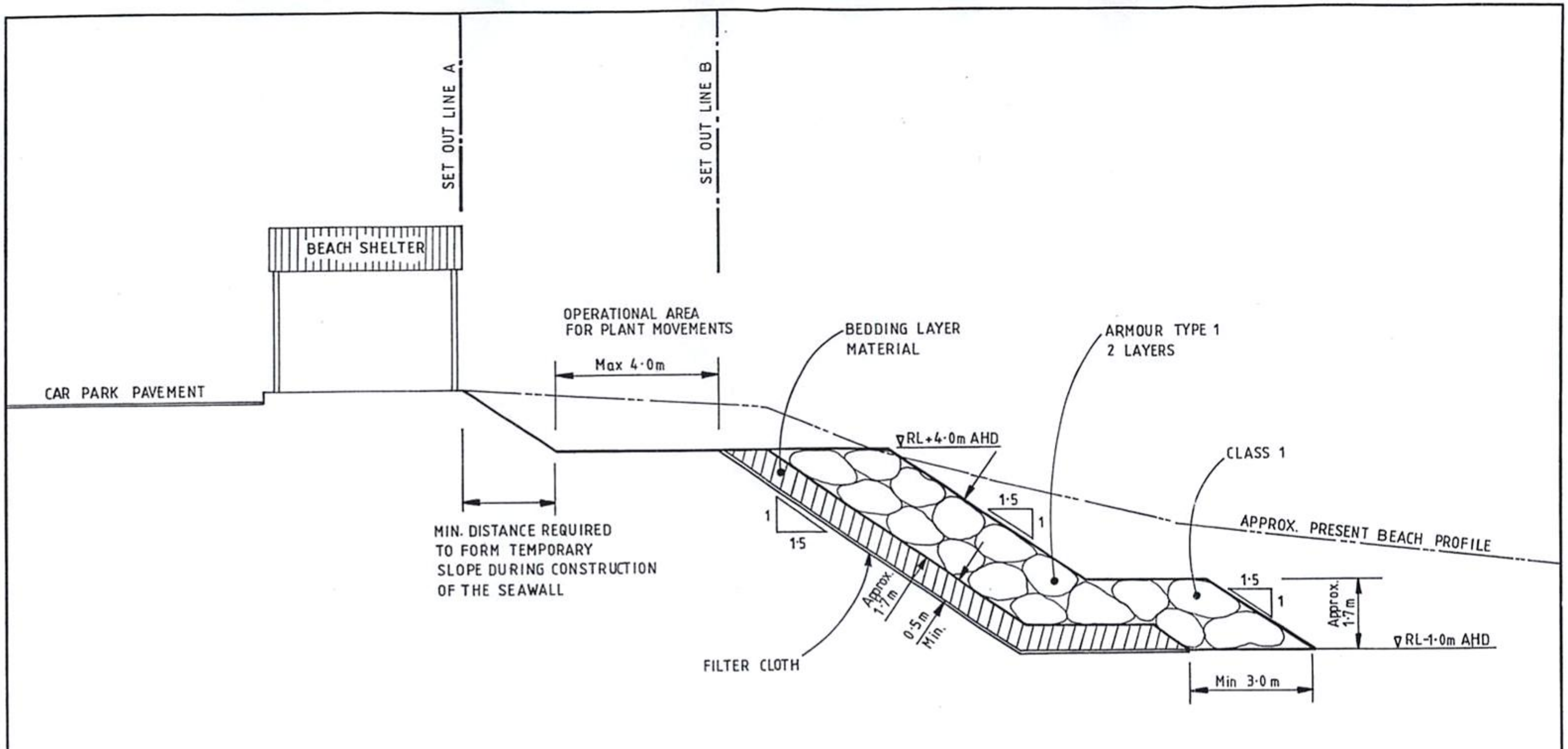
PROJECT: QUINNS BEACH PROTECTION

TITLE: SEAWALL SETOUT PLAN

SCALE AT A3: 1:1500 — DRAWING NUMBER: D248-01-01 — REV: A



ARMOUR TYPE 1 = ARMOUR STONE 0·5t TO 2t (50% > 1t)

BEDDING LAYER MATERIAL = BEDDING MATERIAL NOT MORE THAN 300mm DIAMETER.
50% > 150mm DIAMETER.
NOT MORE THAN 10% < 10mm DIAMETER.

FILTER CLOTH = BIDIM HN30

TYPICAL SECTION THROUGH SEAWALL
SECTION AA

REV	DATE	APP'D	DESCRIPTION
A	3/00		ISSUED FOR APPROVALS

CLIENT: CITY OF WANNEROO

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DRAWN: VAR | CHECKED: MPR

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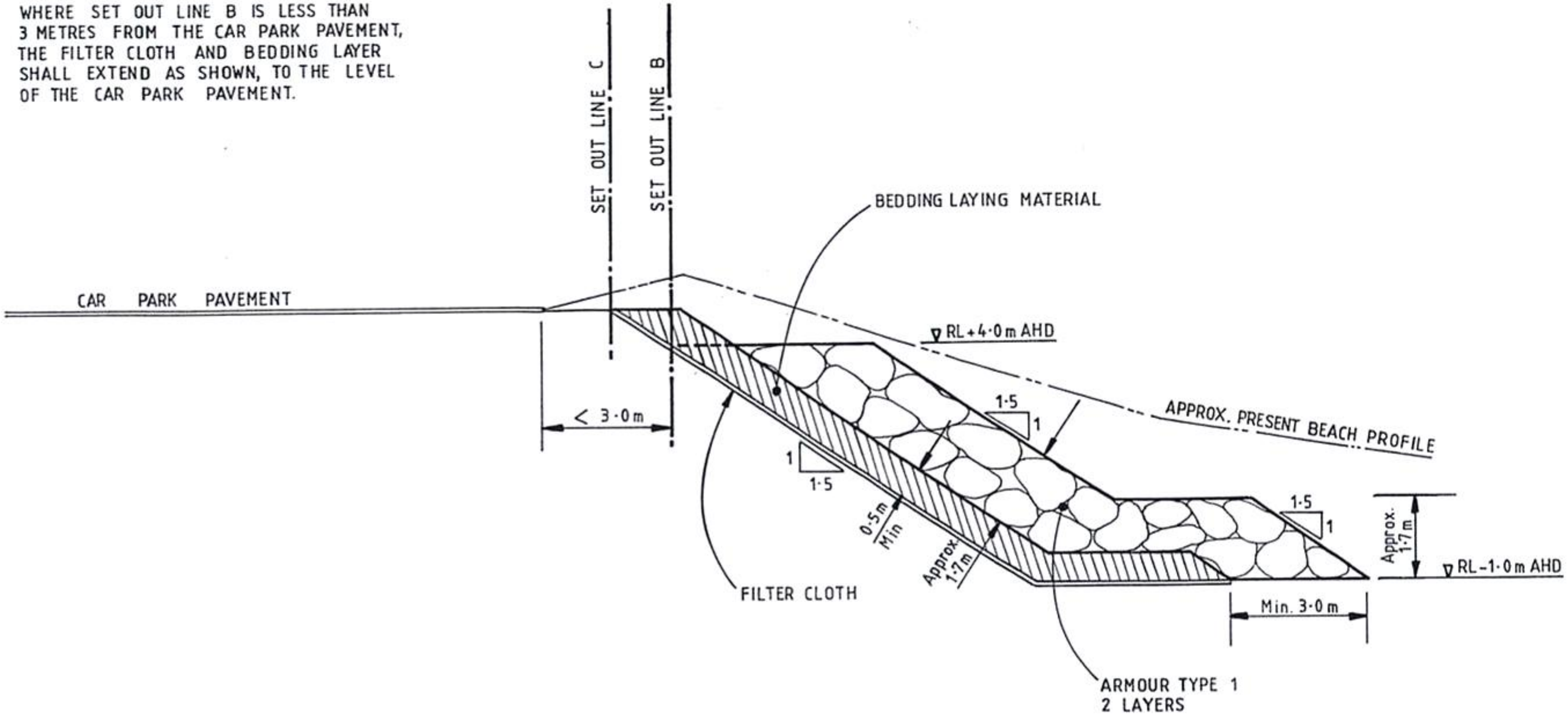
PROJECT: QUINNS BEACH PROTECTION

TITLE: SEAWALL TYPICAL SECTION

SCALE AT A3: 1:100 | DRAWING NUMBER: D248 -1 -2 | REV: A

NOTE WHERE SET OUT LINE B IS LESS THAN 3 METRES FROM THE CAR PARK PAVEMENT, THE FILTER CLOTH AND BEDDING LAYER SHALL EXTEND AS SHOWN, TO THE LEVEL OF THE CAR PARK PAVEMENT.



SECTION BB

ARMOUR TYPE 1 = ARMOUR STONE 0·5 t TO 2 t (50% > 1 t)

BEDDING LAYER = BEDDING MATERIAL NOT MORE THAN 300 mm DIAMETER
50% > 150 mm DIAMETER
NOT MORE THAN 10% < 10 mm DIAMETER

FILTER CLOTH = BIDIM HN 30

REV	DATE	APP'D	DESCRIPTION
A	3/00		ISSUED FOR APPROVALS

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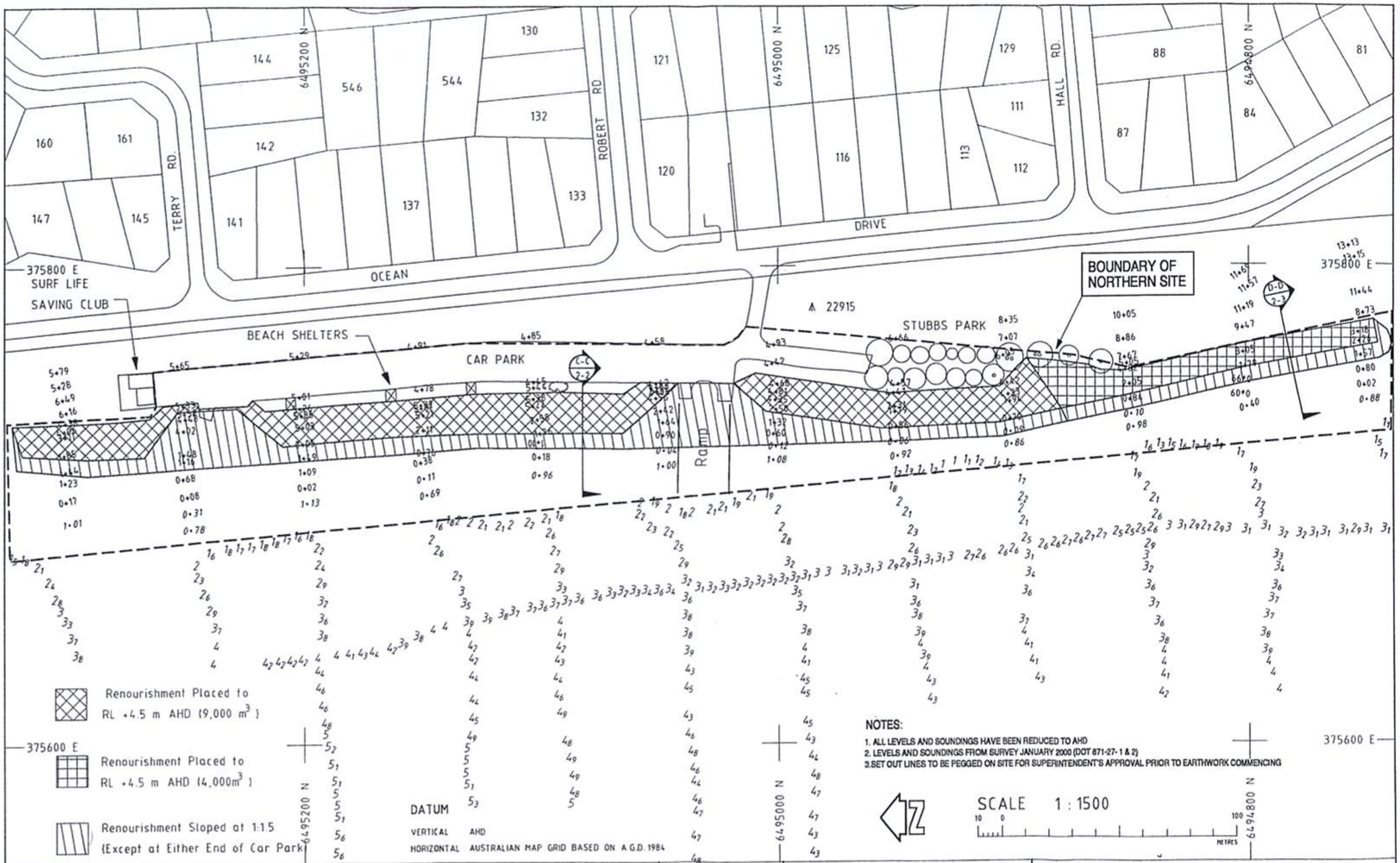
PROJECT: QUINNS BEACH PROTECTION

TITLE: SEAWALL SECTION AT RAMPS

SCALE AT A3: 1:100 | DRAWING NUMBER: D248-1-3 | REV: A



REV	DATE	APP'D	DESCRIPTION
A	03/00	MPR	ISSUED FOR APPROVALS

CLIENT: CITY OF WANNEROO

DESIGNED: B MOLONEY — CHECKED: M P ROGERS — APPROVED:

DRAWN: BEBBINGTON CARTOGRAPHICS — CHECKED: M P ROGERS

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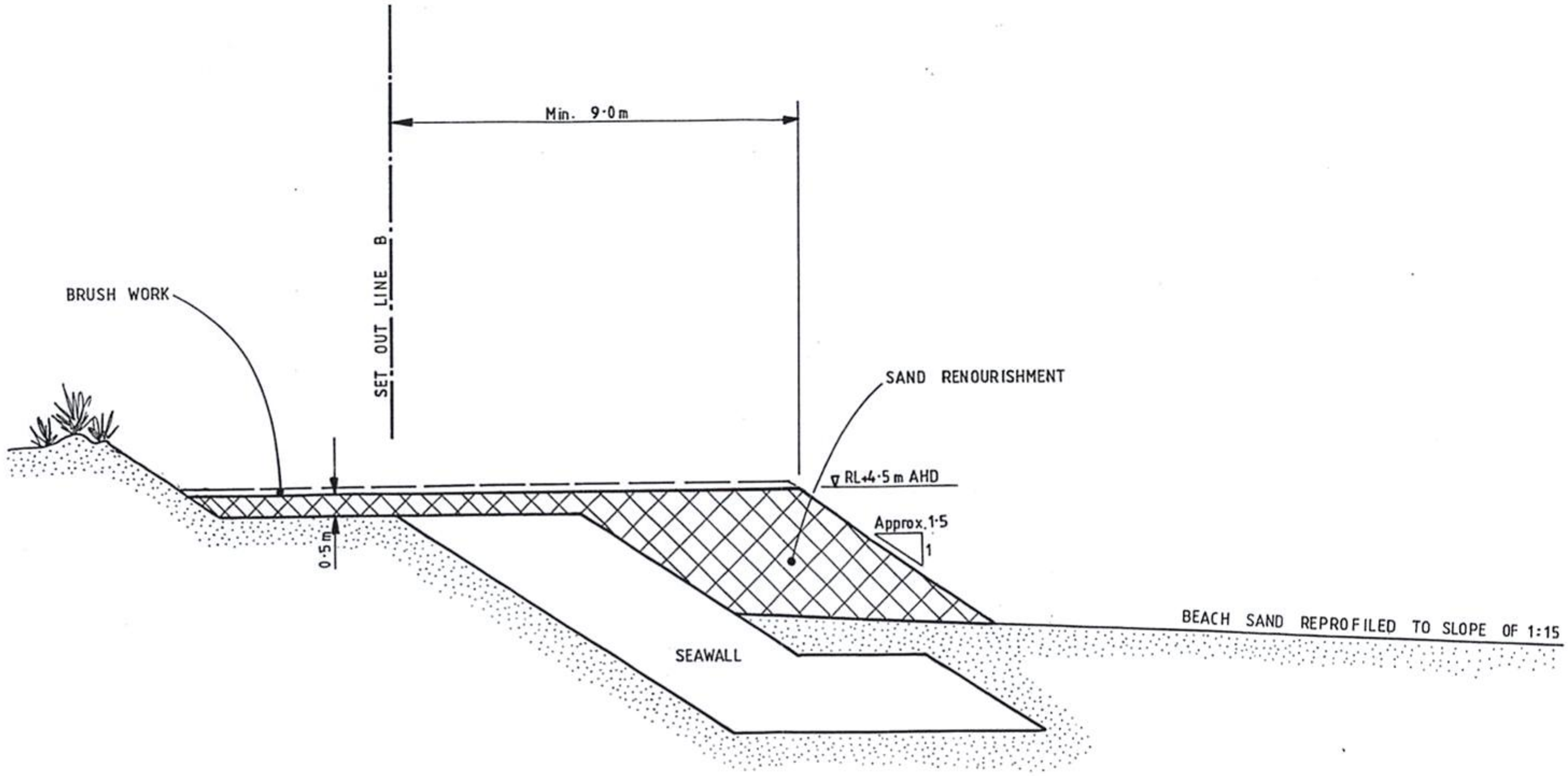
PROJECT: QUINNS BEACH PROTECTION

TITLE: NORTHERN BEACH RENOURISHMENT PLAN

SCALE AT A3: 1:1500 — DRAWING NUMBER: D248-02-01 — REV: A



SECTION CC

REV	DATE	APP'D	DESCRIPTION
A	3/00		ISSUED FOR APPROVALS

CLIENT: CITY OF WANNEROO

DESIGNED: B. Moloney | CHECKED: MPR | APPROVED:
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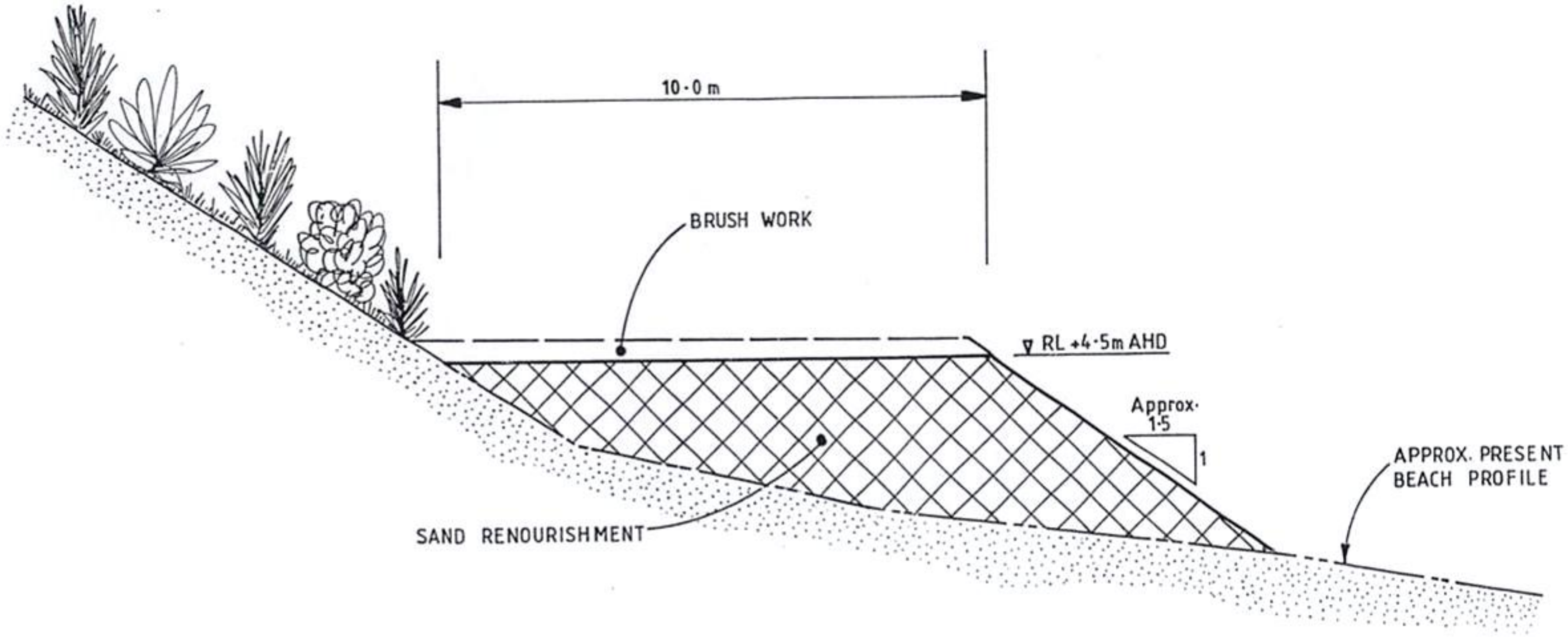
PROJECT: QUINNS BEACH PROTECTION

TITLE: SEAWALL
BEACH RENOURISHMENT
TYPICAL SECTION

SCALE AT A3: 1 : 100 | DRAWING NUMBER: D248 - 2 - 2 | REV: A



SECTION DD

REV	DATE	APP'D	DESCRIPTION
A	3/00		ISSUED FOR APPROVALS

CLIENT: CITY OF WANNEROO

DESIGNED: B. Moloney | CHECKED: MPR | APPROVED:

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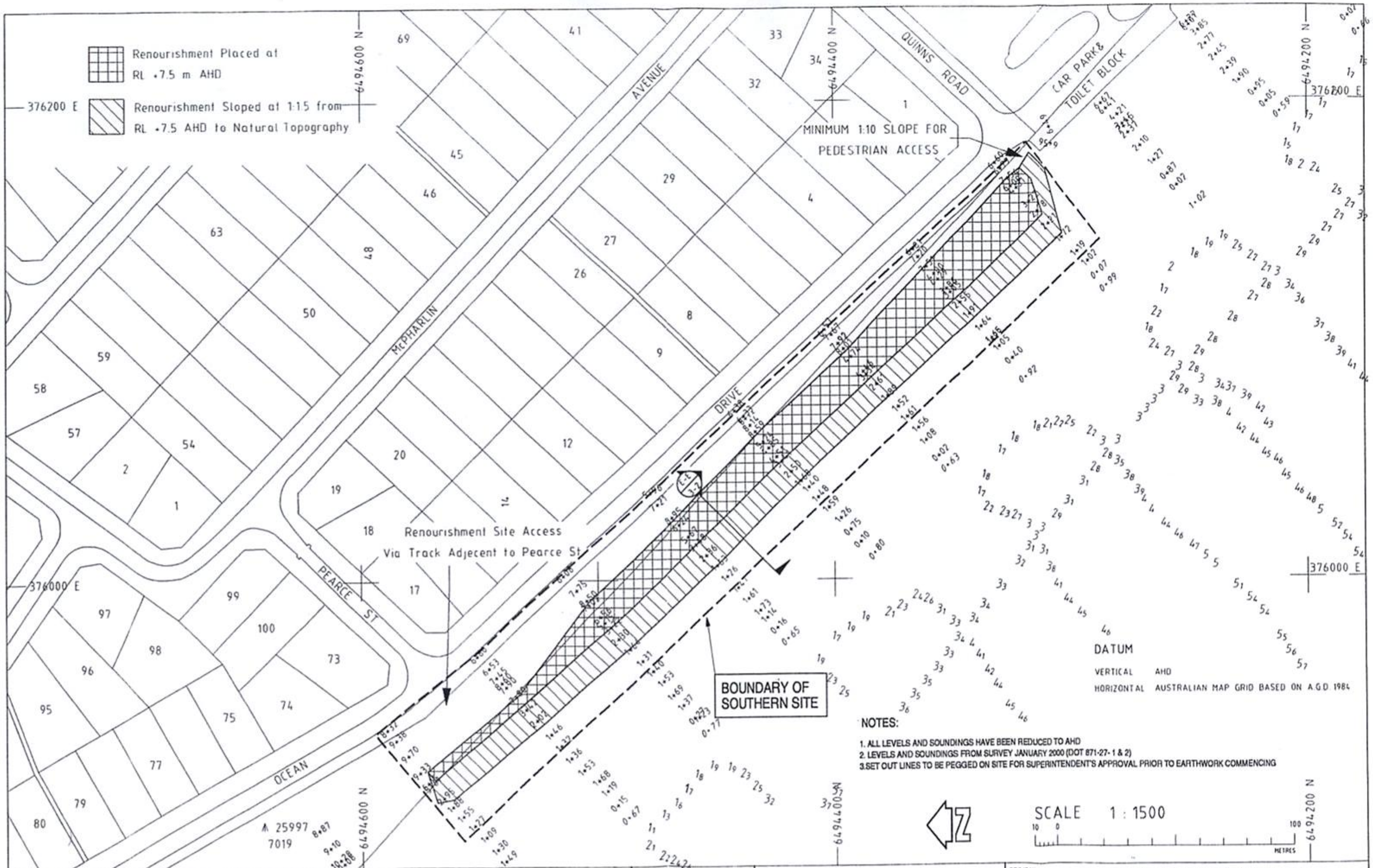
PROJECT: QUINNS BEACH PROTECTION

TITLE: BEACH RENOURISHMENT SOUTH OF SEAWALL TYPICAL SECTION

SCALE AT A3: 1:100 | DRAWING NUMBER: D248 - 2 - 3 | REV: A



A	03/00	MPR	ISSUED FOR APPROVALS
REV	DATE	APP'D	DESCRIPTION

CLIENT: CITY OF WANNEROO

DESIGNED: B MOLONEY | CHECKED: M P ROGERS | APPROVED:

DRAWN: BEBBINGTON CARTOGRAPHICS | CHECKED: M P ROGERS

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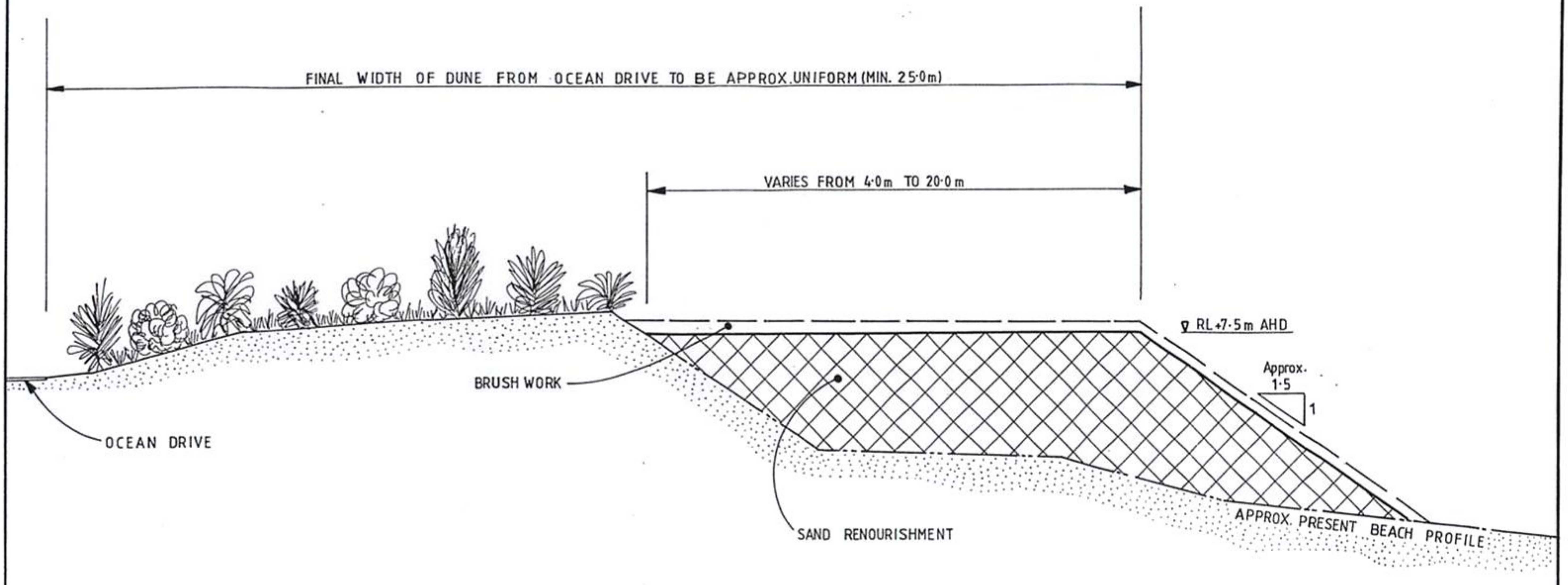
PROJECT: QUINNS BEACH PROTECTION

TITLE: SOUTHERN BEACH RENOURISHMENT PLAN

SCALE AT A3: 1:1500 | DRAWING NUMBER: D248-03-01 | REV: A



SECTION EE

REV	DATE	APP'D	DESCRIPTION
A	3/00		ISSUED FOR APPROVALS

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DESIGNED: B. Moloney | CHECKED: MPR | APPROVED:

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PROJECT: QUINNS BEACH PROTECTION

TITLE: SOUTHERN BEACH RENOURISHMENT TYPICAL SECTION

SCALE AT A3: 1:100 | DRAWING NUMBER: D248 - 3 - 2 | REV: A