The City of Wanneroo
Boas Avenue
Joondalup 6027

M P ROGERS & ASSOCIATES
Coastal & Port Engineers
3 / 135 Main Street
Osborne Park W.A. 6017
Tel: +61 8 9444 4045
Fax: +61 8 9444 4341

QUINNS

COASTAL PROCESSES STUDY

May 1997

Tremarfon Pty Ltd
2 Curtis Road
Melville 6156

SUMMARY

The Quinns Coastal Processes Study has been initiated by the City of Wanneroo to review and assess shoreline and nearshore coastal processes at Quinns and to determine options for coastal management of the area.

The Specific Study Area is that section of the City of Wanneroo coastline between Gateshead Avenue in the South and Tapping Way in the North. This area includes the sand cusp known as Quinns Beach. An Extended Study Area also includes that part of the coastline to the North and South of the Specific Study area in which activities may impact upon the Specific Study Area.

The Study is divided into two Stages. The primary objective of Stage 1 is to identify the coastal processes of the area and the impact of existing infrastructure on those processes. The primary objective of Stage 2 of the Study is to identify coastal protection strategies for the area, including, where appropriate, options for engineering solutions to short and long term cycles of erosion and accretion.

A Literature Review, presented in Section 3, has provided the basis for defining the coastal processes of the Specific Study Area. In particular, investigations conducted for the development of Mindarie Keys identified the lack of a sediment pathway from the South to the Specific Study Area and the seasonal variations in sediment transport on the North and South flanks of the Quinns cusp.

Data held by the Department of Transport, including foreshore movement plots and foreshore surveys, have been reviewed and found to corroborate the results of studies undertaken for the development of Mindarie Keys.

Analysis of the Foreshore Movement Plots in the Extended Study Area show that to the South the sandy foreshore has remained relatively stable since being eroded between 1941 and 1955. To the North the 1995 location of the vegetation line was approximately the same as its 1941 location after the area had experienced a period of accretion and erosion between 1955 and 1995.

The Foreshore Movement Plots also show that the North flank of Quinns cusp was relatively stable from 1955 to between 1985 and 1995. During this period the South flank retreated by up to 35m after having experienced significant retreat in the period from 1941 to 1955. Erosion of the North flank of the Quinns cusp, recorded on the 1995 plot of the vegetation line is likely to have occurred during the Winter of 1994. Over that time much of the Perth Metropolitan coastline suffered erosion from Winter storms.

The Nearshore and Foreshore Surveys, and their Difference Plots confirm aspects of the model for sediment transport postulated in investigations for Mindarie Keys including Northwards sediment movement from the South of the Southern flank of the Quinns cusp in Summer and minimal changes in sediment volumes further offshore than 50m to 100m from the shoreline. The three Nearshore and Foreshore Surveys provide sufficient density of coverage to enable a sediment budget to be established for the Spring and Winter period. The budget indicates a net loss of sediment from the area suggesting that gains to the area are in the Winter months and from the North.

Section 8 of the Report provides an description of the options available for foreshore management while Section 9 applies these options to the Specific Study Area. The recommendations of this Report relating to options for foreshore management may be summarised as -

a. defensive structures such as groynes or offshore breakwaters, or any device which may interrupt either the Northwards and Southwards transport of sand, should not be constructed in or to the immediate North of the Specific Study Area.

b. in the next 1 to 5 years the foreshore management option for the South Flank of the Cusp South of Quinns Road should be retreat. In the medium to long term the foreshore management option for this area will be decided by the foreshore management option adopted for the area to its immediate North.

c. in the next 1 to 5 years the foreshore management option for the South Flank of the Cusp from Quinns Road Northwards to the artificial headland should be annual renourishment. The cost of annual renourishment is estimated at $40,000 to $50,000 per annum (1997). In the medium to long term the foreshore management option for this area is the construction of a seawall. The cost of a concrete mattress seawall is estimated as $300,000

d. in the next 1 to 5 years the foreshore management option for the North Flank of the Cusp from the artificial headland Northwards to the carpark should be reactive renourishment. In the medium to long term the foreshore management option for this area will be decided by the foreshore management options adopted for the areas to its immediate North and South.

e in the next 1 to 5 years the foreshore management option for the North Flank of the Cusp from the South end of the carpark Northwards is retreat, particularly if the 1997 Winter is severe. If, for the short term, retreat and loss of the existing infrastructure in this area is unacceptable, then the reactive management option of renourishment at specific sites of erosion should be adopted. In the long term the foreshore management option for this area is the construction of a seawall at the level of the carpark. The cost of a concrete mattress seawall is estimated as $120,000

The Report also recommends that -

f. the City of Wanneroo, in consultation with the Department of Transport, commence investigations to identify a source of sand for recurrent renourishment total volume for five years of up to 50,000m^3 of suitable sand.

g. the City of Wanneroo, in consultation with the Department of Transport, commence detailed planning and design of a foreshore seawall which may be constructed to protect Ocean Drive between the immediate South of Quinns Road and the immediate North of Pearce Street,

h. the Department of Transport undertake further regular nearshore and foreshore surveys in October and March of each year to define the sediment budget of the area. Such surveys should cover as much as possible of the area within 200m seawards of Ocean Drive by land based surveying techniques.

i. that City of Wanneroo consider a public awareness campaign in anticipation of public enquiries during foreshore renourishment programs.

CONTENTS

CONTENTS UNDER SEPARATE COVER

Department of Transport Drawings used in this Study are provided under separate cover and include -

Shoreline Movement Plots

Oct 41, Dec 55, Oct 65, Nov 78, Jan 85 Drawing No. 351-1-1 6 493 900mN to 6 496 300mN	
Dec 54, Oct 65, Nov 88, Jan 85 6 495 500mN to 6 499 500mN	DoT Drawing No. 351-1-2A
Oct 41, Oct 65, Nov 78, Feb 87 6 495 500mN to 6 499 500mN	DoT Drawing No. 351-1-2
Oct 41, Dec 55, Oct 65, Nov 78, Jan 85, Jan 95 6 492 500mN to 6 495 000mN	DoT Drawing No. 351-5-1
Oct 41, Dec 55, Oct 65, Nov 78, Jan 85, Jan 95 6 490 000mN to 6 492 500mN	DoT Drawing No. 351-5-2
Nov 88, Jan 95 6 495 000mN to 6 497 500mN	DoT Drawing No. 351-5-3

Levels and Soundings

November 1974	DoT Drawing No. 50669-1-1
November - December 1977	DoT Drawing No. 50669-1-2
October 1979	DoT Drawing No. 50669-1-3 ?
May 1980	DoT Drawing Nos. 871-4-1 & -2
May 1981	DoT Drawing Nos. 871-2-1 & -2
May 1982	DoT Drawing Nos. 871-3-1 & -2
October 1996	DoT Drawing Nos. 871-1-1 & -2
December 1996	DoT Drawing Nos. 871-5-1 & -2
March 1997	DoT Drawing Nos. 871-13-1 & -2

Difference Plots

December 1977 minus November 1974	DoT Drawing Nos. 871-06-1 & -2
October 1979 minus December 1977	DoT Drawing Nos. 871-07-1 & -2
May 1980 minus October 1979	DoT Drawing Nos. 871-08-1 & -2
May 1981 minus May 1980	DoT Drawing Nos. 871-09-1 & -2
May 1982 minus May 1981	DoT Drawing Nos. 871-10-1 & -2
October 1996 minus May 1982	DoT Drawing Nos. 871-11-1 & -2
December 1996 minus October 1996	DoT Drawing Nos. 871-12-1 & -2
March 1997 minus December 1996	DoT Drawing Nos. 871-14-1 & -2
March 1997 minus October 1996	DoT Drawing Nos. 871-15-1 & -2

1 INTRODUCTION

The Quinns Coastal Processes Study has been initiated by the City of Wanneroo to review and assess shoreline and nearshore coastal processes at Quinns and to determine options for coastal management of the area.

The primary objective of Stage 1 of the Study was to identify the coastal processes of the area and the impact of existing infrastructure on those processes. Stage 1 of the Study specifically encompasses the requirements to -

- collate, review and analyse all existing coastal data for the area held by the Department of Transport and the City of Wanneroo,
- consult with representative from the Department of Transport and the City of Wanneroo, and other interested parties as necessary, to obtain a clear understanding of observed coastal processes and associated issues,
- identify impacts of existing infrastructure development on coastal processes in the Study Area, and,
- using all of the information derived from the previous three activities, define the coastal processes of the Study Area foreshore.

The primary objective of Stage 2 of the Study was to identify coastal protection strategies for the area, including, where appropriate, options for engineering solutions to short and long term cycles of erosion and accretion. Stage 2 of the Study specifically encompasses the requirements to -

- refine the understanding of the coastal processes of the Specific Study Area particularly with reference to data collected in pre and post Summer 1996-1997 surveys of the Specific Study Area,
- identify future impacts on the Specific Study Area of possible changes to short and long term erosion and accretion cycles,
- identify coastal protection strategies and a clearly defined range of solutions for coastal management for the Specific Study Area, and,
- recommend possible coastal engineering solutions to be included in coastal protection strategies, including indicative costs.

This Report responds to the requirements, as listed above, of the Quinns Coastal Processes Study.

2 THE STUDY AREA

The Specific Study Area is that section of the City of Wanneroo coastline between Gateshead Avenue in the South and Tapping Way in the North. This area includes the sand cusp known as Quinns Beach. An Extended Study Area also includes that part of the coastline to the North and South of the Specific Study area in which activities may impact upon the Specific Study Area. This Extended Study Area was initially defined as being 4km to both the North and South of the Specific Study Area. Work undertaken for this Interim Report has refined the Extended Study area as extending 3.5km South and 2km North of the Specific Study Area. This delineation of the Extended Study Area is based on the availability of coastline data and the occurrence of natural features which define coastal processes.

The Specific Study Area is shown in Figure 2.1.

3. LITERATURE REVIEW

"Report on Wanneroo Coastline"
Silvester, R.
University of Western Australia
April 1976

Silvester's Report to the (then) Shire of Wanneroo is a qualitative appraisal of all of the coastline of the Shire from south of Marmion Beach in the South to north of Two Rocks in the North. Silvester describes the coastal processes in the region generally from 2km offshore to 1km inshore. The Report includes a general discussion of typical shoreline processes and an extensive descriptive review of the coastal features of the Wanneroo shoreline.

With respect to Quinns, Silvester notes that the Southern end of the Southern flank of the Quinns cusp accretes in Winter and erodes in Summer. The report recommends the use of offshore structures at cuspate forelands (eg. Quinns) to maintain a tombolo for coastal protection.

"Report on Stabilization of Wanneroo Beach"
Silvester, R.
University of Western Australia
December 1976

Complementary to Silvester's April 1976 Report, this Report specifically addresses the coastal processes at Wanneroo or Quinns Beach and recommends an option for stabilisation of the Quinns cusp.

Silvester describes the movement of sediment in the area as being from South to North with transport past the limestone cliffs to the South being enhanced by waves reflected from the cliffs. It is postulated that when sediment being transported North past the limestone cliffs reaches the less reflective beaches of the Quinns cusp the sediment spreads to form banks of sand. The Report notes that the offshore shoal Quinns Rocks are to the South West of the apex of the Quinns cusp and that the cusp has been formed by the action of persistent South West swells which transport sediment on both flanks of the cusp towards its apex. Silvester notes that Winter storms impinge on the South flank of the cusp at a high angle and transport material southwards on the South flank to the limestone headland at the South of Quinns Beach. The angle of attack of Winter storm waves on the North flank is more perpendicular to the shoreline and accordingly the potential for sediment transport is smaller. Silvester suggests that in Summer, under the action of persistent South West swells, sediment is removed from the southern end of the South flank of the cusp if there is not an adequate supply of sediment (from the South) to replenish the area.

Silvester describes the action of an offshore structure, or headland, in dissipating wave energy and creating a shoal in its lee through the interception of longshore drift. The shoal area builds out from the shoreline. With the correct dimensions and placement of the headland the lee shoal can join, as a tombolo, with the headland. At this stage sediment transport along the shore bypasses the headland.

The construction of headland to the immediate South of the apex of the Quinns cusp is recommended in Silvester's Report as a means by which the Southern flank of the Quinns cusp might be accreted seawards by some 30m. The headland was constructed and sand placed during construction produced a tombolo.

Comment

Silvester's work appears to be based on the premise that there is a sufficient supply of sediment to the cusp from the South to protect the southern flank of the cusp and to bypass the headland to the northern flank. Work undertaken after Silvester's December 1976 Report, as described in the following sections, indicates that this premise was not correct.

"Environmental Review and Management Program
for Mindarie Keys Project"
Volume 1 - Report
Volume 2 - Technical Appendices
Smith Corporation Pty Ltd
March 1985

The Proponent for the development of Mindarie Keys, Smith Corporation Pty Ltd, prepared for submission to the (then) Department of Conservation and Environment and the Environmental Protection Authority, an Environmental Review and Management Program for the project.

Of specific interest to this Report is the work undertaken by the Environmental Consultants *LeProvost, Semeniuk and Chalmer (LSC)* for the ERMP regarding the existing environment and in particular the coastal dynamics at and adjacent to the Mindarie development. Of prime concern to the developer was -

- whether the breakwaters protruding offshore from the natural coastline would influence Quinns Beach, and,
- whether sediment transport South from Quinns Beach could have a detrimental impact on the proposed marina.

As little specific information was available pertaining to the sediment dynamics of the development site and North to Quinns, the Proponent commissioned *LSC* to undertake a series of desk studies and field investigations -

- to define the sediment transport pathways and sediment transport mechanisms of the area, and,
- to reliably assess the impact of the Mindarie development on Quinns Beach.

Following an appraisal of oceanographic factors influencing Quinns Beach, *LSC* proposed a model for sediment transport at and near Quinns Beach. *LSC* reasonably suggested that sediment transport was primarily driven by the prevailing Summer swells from the South West and by Winter storms from North of West. In particular, the impact of these wave conditions on the shoreline is influenced by Quinns Rocks in altering the inshore direction of waves as they are refracted and diffracted around the shoal areas of Quinns Rocks. LSC suggested the following conditions -

Summer

Prevailing South West Swell - refer Figure 3.1

The prevailing South West Summer swell, being of long wavelength, is refracted about Quinns Rocks. As a result, sediment transport on both flanks of the Quinns cusp is towards the apex of the cusp.

Sediment is moved from the South end of the South flank towards the apex and, with only minimal replenishment from the pocket beaches to the South, the South end of the South flank retreats. Sediment from the immediately adjacent pocket beaches to the South may be transported Northwards during periods of heavy swell.

Sediment transport North of the cusp, outside the influence of the offshore shoal areas is to the North.

The more gentle swells also transport sediment back to the foreshore from nearshore bars which were formed during Winter storms. *LSC* considered it unlikely that the gentle swells could transport sediments around the apex of the cusp from South to North.

Afternoon Sea Breeze - refer Figure 3.2

The shorter period waves locally generated by the Summer Afternoon Sea Breeze are less influenced by the offshore shoals than the longer period swells. As a result they maintain their general offshore direction and impinge upon both flanks of the cusp, and the shoreline to the North of the cusp, at angles which transport sediment to the North. As the angle at which these waves impinge on the Northern flank of the cusp is greater than on the Southern flank, Northwards transport on the North flank will be greater than on the South flank.

LSC consider that these shorter period waves could not transport sediment from nearshore bars back to the shoreline but could be capable of bypassing sediment northwards around the apex of the cusp.

Summer Summary - refer Figure 3.3

The resultant impact of wave conditions experienced during Summer is suggested by *LSC* to be a net northwards and onshore transport. The Northwards transport from the Southern end of the South flank of the cusp manifests itself as a significant retreat of the shoreline in that area and as an advance of the shoreline to the immediate South of the apex.

Winter

West to West South West Swell - refer Figure 3.4

The West to West South West Winter swell, although of slightly shorter wavelength than Summer swells, is refracted about Quinns Rocks. As a result, sediment transport on both flanks of the Quinns Beach cusp is towards the apex of the cusp. Sediment transport is to the North in the area North of the area influenced by Quinns Rocks. *LSC* also suggest that these swells would not readily rebuild the foreshore from offshore bars but could mobilise sediments in the pocket beaches to the South of Quinns.

Locally Generated Seas from the West South West - refer Figure 3.5

The short period waves generated by local storm winds are less influenced by the offshore shoals than longer period swells. In a similar manner to the Summer ASB they maintain their general offshore direction to the shoreline. These Winter waves approach from further north than the Summer ASB and result in a Southwards transport on the South flank of the cusp and a Northwards transport on the North flank of the cusp and further to the North. These waves are capable of drawing sediment off the foreshore into nearshore bars. The Southwards transport on the South flank of the cusp moves sediment to the Southern extremity of the cusp where it is captured and retained by the limestone headland.

North of West Storms - refer Figure 3.6

Waves produced by North West winter storms are the most energetic of wave conditions experienced. As they approach from the North West they are not influenced by the Quinns Rock shoal areas before impinging upon the shoreline. Over all of the cusp, and the area to the North, these waves initiate Southwards sediment transport. The orientation of the Northern flank of the cusp means that North West storm waves approach this area more perpendicularly than the Southern flank. As a result, Southwards transport on the Northern flank is less than on the Southern flank. These waves impinge on the Southern flank at a high angle and cause significant Southwards transport. As for the locally generated WSW seas this Southwards transport on the South flank of the cusp moves sediment to the Southern extremity of the cusp where it is captured by the limestone headland.

LSC consider that these wave conditions are capable of transporting sediment past the apex of the cusp from North to South. These waves also draw sediment from the foreshore into nearshore bars.

Winter Summary - refer Figure 3.7

The resultant impact of wave conditions experienced during Winter is suggested by *LSC* to be a net Southwards and offshore transport. The Southwards transport from the apex of the cusp caused by North of West storms manifests itself as a retreat of the shoreline in that area and as an advancement of the shoreline at the South end of the Southern flank.

LSC provided initial confirmation of their proposed model of sediment transport from stratigraphic studies and a review of aerial photographs.

From the stratigraphic investigations it was determined that the age of the present shoreline at Quinns is circa 3,500 years Before Present. This age suggests that the cusp either stopped accreting 3,500 years ago or did accrete to a more recent time but has since eroded back to its 3,500 years BP alignment. Whichever interpretation of the age of the shoreline is correct, the cusp is not, in a geological time frame, accreting.

The review of aerial photographs encompassed the period 1954 to 1984 and indicated that the Southern flank of the cusp had experienced a net erosion of 0.5 to 1.0 meters per year and that the Northern flank had remained relatively stable over the 30 years.

Sediment Transport Studies for the Mindarie Keys Project
Interim Report 1985 - 1987
LeProvost, Semeniuk and Chalmer, Environmental Consultants
November 1987

Following the work reported in the Mindarie Keys ERMP, the Proponent undertook to implement a monitoring programme aimed at confirming the predictions made by *LSC* relating to sediment transport pathways and the sediment transport mechanisms of the area. Three investigations were initiated, being -

- a provenance study, aimed at confirming the regional sediment dynamics,
- monthly beach profiling, to assess the migration and volumes of sediments, and,
- a sediment tracking study aimed at confirming nearshore sediment transport pathways,

Provenance Study

LSC's Provenance Study involved the sampling and analysis of sediments between Ocean Reef and Eglington Rocks. Sediment samples were taken over a 500m to 600m grid offshore at Quinns and from the shoreline.

The Provenance Study found that the sediment of the Quinns cusp is primarily quartz sand from Holocene whereas the sediments in pocket beaches on limestone cliffed shores are primarily limestone and skeletal. However, the first two pocket beaches to the immediate South of the Quinns cusp do contain sediments with the same quartz content as the cusp.

The study also found that the concentrations of sediment components offshore from Quinns were localised. As these components had not been spread or been mixed the results indicate a lack of net sediment transport. Further, *LSC* found no observable correlation between offshore and onshore distributions of sediment components. The change between onshore and offshore sediment components occurred within 50m of cusp beaches suggesting that -

a. shoreline sediment transport at Quinns is restricted to within 50m of the shoreline, and,
b. there is only minimal exchange of sediments between the offshore and the shoreline.

Beach Profiling

LSC surveyed beach profiles each month from September 1984 to December 1986. In the Quinns area the length of coast surveyed was from 7km North of the Quinns cusp to 3km South. The surveys confirmed that the South end of South flank of the Quinns cusp accreted in Winter and eroded in Summer whereas the North end of the South flank and the North flank eroded in Winter and accreted in Summer.

The beach profiling surveys also indicated that -

a. sediment volume fluctuations in the pocket beaches to the South of Quinns were not seasonally driven or correlated between pocket beaches,
b. sediment volume fluctuations in the pocket beach to the immediate South of the Quinns cusp were not correlated to the seasonal fluctuations of the South flank of the cusp, and,
c. sediment transport along the rocky shoreline to the South of Quinns is minimal.

Sediment Tracking and Trapping

This work was aimed at defining sediment transport pathways in the study area. The limited results of the investigations indicated that the sediment pathways, in order of magnitude are - in the swash zone of the sandy Quinns cusp, in the nearshore cusp and the swash zone of rocky shores and nearshore of rocky shores. It is noted that the transport pathways identified relate to the potential to transport sediment. As no sediment is available in the nearshore of rocky shores these investigations indicate that no major sediment pathways exist in front of the rocky shore coasts to the South of the Quinns cusp.

"Beach Erosion at Quinns Rocks
Eliot, I.
University of Western Australia
November 1988

Eliot's report to the (then) Department of Marine and Harbours is a response to the City of Wanneroo's concern with the "cyclic nature of erosion at Quinns Rocks and the need to reduce this erosion". Eliot notes that the survey information existing at the time of his report was inadequate to unequivocally establish characteristic patterns of shoreline movement. Up to the surveys conducted specifically for this Study no additional surveys were undertaken at Quinns after Eliot's report.

Eliot considers that the information available at the time was sufficient to indicate that -

a. long term shoreline recession of the Quinns promontory was not apparent and that recession did not occur in the period 1974 to 1984.
b. changes in the directions of storm onset will alter the locations of erosion and accretion on the northern and southern flanks of Quinns.

Eliot considered that there was insufficient information to identify cyclic or quasi-cyclic phenomena at any time scale and that the impact of individual storms could not be assessed due to the long time interval between surveys.

Eliot also reports on his observations from an inspection of the Specific Study Area. Importantly, Eliot notes that the height of the dunes in the vicinity of Kemp Street, which reduce seawards, indicates that the amount of sand available for dune reconstruction following a phase of erosion may be decreasing. The implication is that although the plan location of the foreshore may have been relatively constant the sandy beach may have been losing sediment.

Eliot concludes that the (Wanneroo) Council may need to accept occasional loss of beach amenities due to intermittent shoreline retreat. However, the cost of replacing the amenities should be balanced against the costs of constructing and maintaining engineered beaches.

4 FORESHORE MOVEMENT PLOTS

4.1 Method and Coverage.

Foreshore Movement Plots are derived photogrammetrically from controlled vertical aerial photography. The plots are at a scale of 1:500 and show the vegetation line and waterline at the time of photography. The location of the vegetation line is used as a measure of the erosion or accretion of the foreshore as the water line varies with the stage of the tide at the time of photography.

A series of Foreshore Movement Plots, produced by the Department of Transport, existed for the Extended and Specific Study Areas. In addition, the location of the January 1995 vegetation line was added to the existing plots specifically for this Study.

The coverage of the plots used in this Study extends from 4km South of Gateshead Avenue to 3.5km North of Tapping Way and includes photography taken in -

- October 1941,
- December 1955,
- October 1965,
- November 1978,
- January 1985, and,
- January 1995.

4.2 Presentation of Results

The locations of the vegetation lines for each of the years plotted, relative to the location of the 1941 vegetation line, were determined at generally 100m to 200m spacing along the Specific Study Area foreshore and at spacings up to 1km in the Extended Study Area. These absolute locations of the vegetation line are presented in Table 4.1. Table 4.2 shows the rate of change of the location of the vegetation line between each of the years plotted as a rate per year. This rate per year is a measure of accretion and erosion.

4.3 Interpretation of Foreshore Movement Plots

Interpretation of the foreshore movement plots is subdivided into consideration of the Extended Study Area to the North and South of the Specific Study area and into the North and South flanks of Quinns cusp in the Specific Study Area. These interpretations are presented in the following Sections. Figures 4.1 to 4.6 have been derived from the data presented in Tables 4.1 and 4.2

4.3.1 South of the Specific Study Area

As the coastline over the 1.5km immediately South of the Specific Study Area is rocky limestone, the plots of the location of the vegetation line are not appropriate in assessing erosion of accretion cycles.

From 1.5km to 3.3km South of the Specific Study Area, which is South of Mindarie Keys, the foreshore movement plots of the sandy foreshore show general stability over the period 1955 to 1995 following a period of erosion of 4m to 12m between 1941 and 1955. Compared with its 1955 location the vegetation line had retreated at a nominal rate of 0.1 to 0.3 metres per year to 1995.

4.3.2 North of the Specific Study Area

As shown in Table 4.1 the 2km North of the Specific Study Area is covered by four years of shoreline plots compared with six years in the remaining areas. The plots indicate that between 1941 and 1978 the North section of the Extended Study Area accreted at a rate averaging approximately 0.3 metres per year. Subsequent to 1978, the vegetation line retreated such that in January 1995 it was approximately at its 1941 location.

4.3.3 North Flank of the Quinns Cusp

Although the shoreline from Hall Road to the South end of the foreshore carpark is physically North of the apex of the Quinns cusp the foreshore behaviour in this area reflects more the behaviour of the South flank of the cusp. Accordingly the following comments pertain to the North flank of the Quinns cusp North of the South end of the foreshore carpark.

As shown in Figure 4.1 the foreshore of the North flank retreated by 7m to 12m between 1941 and 1955. Given the similar erosion experienced to the South in the Extended Study area, and the erosion of the South flank (see Section 4.3.4 following) during this period, it would appear that the 1941 to 1955 period was generally erosive and not specific to Quinns.

Between 1955 and 1965 the North flank recovered, as shown in Figure 4.2, and accreted to seawards of its 1941 location. As shown in Figures 4.3 to 4.5, this vegetation line location remained relatively stable, particularly North of Roberts Road, up to 1985 to 1995.

Figure 4.6 shows the location of the vegetation line in 1965, 1978, 1985, and 1995 with the vegetation line location in 1955 as the zero base. For the North flank of the cusp it is apparent from Figure 4.6 that little variation occurred in the location of the vegetation line from 1965 to 1985. This period includes the passage of ex-Tropical Cyclone Alby past the Perth Metropolitan beaches in April 1978. The November 1978 vegetation line is effectively coincident with the 1965 vegetation line on the North flank of the cusp. This suggests that the North flank was little influenced by, or quickly recovered from, the passage of Alby.

From Figure 4.6, the 1995 location of the vegetation line on the North flank of Quinns cusp shows a relatively uniform retreat of 10m compared with its 1985 location. As described in Section 3, the North flank of the cusp behaves in the classical manner of eroding in Winter and accreting in Summer. It is likely that this general 10m of erosion occurred during the 1994 Winter which was characterised by an early and severe storm event on May 24. It is also noted that both the 1995 and 1996 Winters have produced severe storm events. In particular the storms of July 1995 caused erosion of many of the Perth Metropolitan beaches, It is therefore likely that the location of the January 1995 vegetation line is a conservative measure of erosion experienced since 1985 on the North flank of the Quinns cusp.

4.3.4 South Flank of the Quinns Cusp

As shown in Figure 4.1 the South flank of the Quinns cusp, to the immediate South of the apex of the cusp, retreated by 55m between 1941 and 1955. During this period the minimum retreat of the South flank was 5m at Quinns Road. The South flank subsequently accreted to 1965 by up to 20m but was only seawards of its 1941 location to the South of Quinns Road where sediment would have been driven during the Winter preceding the October 1965 aerial photography.

From 1965 to 1978, as shown in Figure 4.3, the South flank again retreated, by 30m to 40m, and at Pearce Street reached its maximum retreat, of 60m, from its 1941 location. By January 1985 the North end of the South flank was seawards of its November 1978 location by up to 20m. Part of this advance could be attributable to the timing of the photography, with the 1985 photographs being taken at the time when the North end of the South flank typically accretes. However, by January 1995 the South flank between its apex and Quinns Road had again retreated to a maximum of 50m landwards of its 1941 location.

Table 4.2 shows that the South flank of the Quinns cusp experienced both erosion and accretion rates in excess of 3m per year during the period 1941 to 1995. Further, during the period 1955 to 1985, when the North flank of the cusp was relatively stable, the retreat of the vegetation line of the South flank totalled approximately 35m.

4.4 Summary of Foreshore Movement Plots

The foreshore movement plots indicate that -

a. the sandy foreshore in the Southern part of the Extended Study Area has remained relatively stable since being eroded between 1941 and 1955,

b. The sandy foreshore in the Northern part of the Extended Study Area has, since 1941, experienced a period of accretion to 1978 and erosion to 1995. The 1995 location of the vegetation line was approximately the same as its 1941 location.

c. the North flank of Quinns cusp was relatively stable from 1955 to between 1985 and 1995. It is likely that the erosion experienced on the North flank of the Quinns cusp, and recorded on the 1995 plot of the vegetation line, occurred during the Winter of 1994, during which time much of the Perth Metropolitan coastline suffered erosion from Winter storms.

d. the South flank of Quinns cusp experienced both erosion and accretion rates in excess of 3m per year during the period 1941 to 1995. While the North flank of Quinns cusp was relatively stable from 1955 to between 1985 and 1995, the South flank retreated by up to 35m.

5 NEARSHORE AND FORESHORE SURVEYS

5.1 Survey Area and Methods

Nearshore and Foreshore Surveys have been systematically undertaken at Quinns since 1974 by the Public Works Department, the Department of Marine and Harbours and, recently, by the Department of Transport.

Surveys prior to the surveys undertaken specifically for this Study were shore based. These shore based surveys were run on lines perpendicular to the shoreline with varying longshore spacing.

The October and December 1996 and March 1997 surveys undertaken specifically for this Study were a combination of land based surveys of the beach area and foreshore to 1.5m water depth, and echo sounding surveys from offshore depths of 8 to 9m extending inshore to overlap with the land based survey. The surveys, which were run on lines at 50m spacing perpendicular to the shoreline, extend from Gateshead Avenue in the South to Tapping Way in the North.

5.2 Presentation of Results

The results of the Nearshore and Foreshore Surveys are presented under separate cover. Two presentations are provided, being -

- Levels and Soundings, as a record of the surveys, to scales of 1:2500 and 1:2000, for -
  - November 1974,
  - November - December 1977,
  - October 1979,
  - May 1980,
  - May 1981,
  - May 1982,
  - October 1996,
  - December 1996, and,
  - March 1997.

- Analysis of Survey Difference Plots, showing the difference in levels between each survey interpolated onto a 20m grid over the whole survey area, to 1:2000 scale, for -
  - December 1977 minus November 1974,
  - October 1979 minus December 1977,
  - May 1980 minus October 1979,
  - May 1981 minus May 1980,
  - May 1982 minus May 1981,
  - October 1996 minus May 1982,
  - December 1996 minus October 1996,
  - March 1997 minus December 1996, and,
  - March 1997minus October 1996.

The longshore line spacings of 300m to 400m of the 1981 and 1982 surveys are considered to be too large to be able to define representative difference plots for analysis and interpretation. For the 1974, 1977, 1979 and 1980 surveys the longshore line spacing in the area of the apex of Quinns cusp, between Pearce Street and Robert Road is considered sufficient for difference plots. However, the line spacings outside this area are considered to be too large for difference plots. All of the area surveyed in October and December 1996 surveys is appropriate to being used in difference plots.

As the result of the large line spacings on some surveys the difference plots considered for this Study were restricted to -

- in the area of the apex of Quinns cusp, between Pearce Street and Robert Road,
  - May 1980 minus October 1979,
  - October 1979 minus December 1977,
  - December 1977 minus November 1974, and,
- over all of the surveyed area,
  - December 1996 minus October 1996,
  - March 1997 minus December 1996, and,
  - March 1997minus October 1996.

5.3 Interpretation of Surveys

5.3.1 May 1980 minus October 1979 - Pearce Street to Robert Road

The differences between these two surveys would be expected to show the build up of sediment over Summer to the immediate South of the apex of the Quinns cusp and on the North flank of the cusp.

The difference plot between the apex of the cusp and Pearce Street shows shoreline accretions of up to 1.0m depth with backshore accretions, probably of wind blown sands, of over 2.5m depth. To the immediate North of the artificial headland the shoreline shows minor losses of sediment to 0.3m depth. Further North to Robert Road, the shoreline shows both losses and gains of sediment of 0.2m to 0.4m. In the immediate nearshore apparent sediment losses up to 1.2m depth are indicated. These apparent losses are likely to be the result of the Winter nearshore bar moving onshore.

Differences between surveys further offshore than approximately 75m are limited to both accretion and erosion up to 0.3m.

5.3.2 October 1979 minus December 1977 - Pearce Street to Robert Road

The differences between these two surveys would be expected to show the foreshore building processes of late Winter to early Summer on the North flank of the Quinns cusp and the movement of sediment from the South of the South flank towards the apex of the cusp.

The difference plot in the vicinity of the apex of the cusp indicates that at the time of the December 1977 survey sediment from the South of the South flank had not reached or bypassed the apex of the cusp. Sediment gains of up to 0.6m depth are apparent at Pearce Street but by the apex of the cusp and North to Hall Road these shoreline gains had become 0.2m to 0.9m losses. Minor shoreline accretion is apparent from Hall Road Northwards to the Robert Road. Sediment losses are also apparent in the nearshore but within 50m of the apex and the shoreline North to Robert Road. These losses are typically of 0.7m to 1.2m depth of sediment.

5.3.3 December 1977 minus November 1974 - Pearce Street to Robert Road

The difference plots for these two surveys indicate significant loss of sediments from the foreshore to the South of the apex of the cusp. Over the 150m South of the artificial headland, which was constructed during the period between the two surveys, sediment was lost from the foreshore to depths of up to 2.0m. This erosion is confirmed in the Shoreline Movement Plot for November 1978. As shown Figure 4.4, the November 1978 vegetation line at Pearce Street was 60m landwards of its 1941 location and up to 30m landwards of its October 1965 location.

Sediment depth increases of up to 1.0m are indicated at the artificial headland and to its immediate North. This accretion is likely to be due in part to the fill material which was placed for construction of the headland. However, as the accretion continues on the shoreline North to Robert Road at depths up to 1.0m it would appear that the accretion on the North flank of the cusp has also resulted from sediment transported from the South flank of the cusp.

Offshore from the apex of the cusp there are minor depth increases and decreases averaging 0.1m to 0.3m

The erosion of the South flank evidenced by this difference plot may have been the result of mild Winters in the period between the surveys not transporting sediment to the South of the South flank. Consequently, the South flank of the cusp would have been eroded in the following Summers.

5.3.4 December 1996 minus October 1996 - all of the Specific Study Area

As for the October 1979 minus December 1977 Difference Plot, the differences between these two surveys would be expected to show the foreshore building processes of late Winter to early Summer on the North flank of the Quinns cusp and the movement of sediment from the South of the South flank towards the apex of the cusp.

On the South flank of the cusp the difference plot shows sediment losses of up to 1.6m depth at Gateshead Avenue reducing to accretion on the foreshore approximately 350m North. Sediment gains of up to 0.5m depth are apparent between Quinns Road and Pearce Street but further North to the apex of the cusp, and Northwards, minor sediment losses are apparent close to shore. This suggests that the supply of sediment from the South of the South flank had not, by the time of the December survey, reached or bypassed the apex of the cusp. These differences reflect the movement sediment from the South to North under the action of prevailing South West swells and the Afternoon Sea Breeze. There are no definite trends to accretion or erosion indicated further than 50m offshore from the South flank of the cusp.

The North flank of the cusp, which had been renourished with approximately 6000 m^3 of sand in the vicinity of Hall Road in mid 1996, shows localised areas of accretion of up to 2.3m to the South of Hall Road. This is likely to be redistribution of the renourishment material. The trend between surveys within 50 to 100m offshore is to apparent erosion of up to 0.6m. These apparent losses are likely to be the Winter offshore bar moving onshore and Northwards under the action of the Afternoon Sea Breeze or Southwards under the action of prevailing South West swells. However, the lack of consistent accretion on or near the foreshore of the North flank does not indicate this onshore movement is uniform over the length of the North flank. There are no definite trends to accretion or erosion indicated further than 100m offshore from the North flank of the cusp.

5.3.5 March 1997 minus December 1996 - all of the Specific Study Area

The difference plots for these two surveys confirm the trends exhibited in the period from October to December 1996. Sediment losses from the South of the south flank extend as far north as Pearce Street and are confined to a relatively narrow strip approximately 40m to 80m wide. There are relatively minor gains on the foreshore to the immediate South of the artificial headland of up to 0.5m depth.

To the North of the artificial headland, and extending to Hall Road, there are depth gains on the foreshore of up to 1.1m suggesting that sand has been transported from the South to the North past the artificial headland. Further to the North, however, the foreshore gains are limited 0.4m and less. Sediment losses in the immediate nearshore range from 0.5m to the South of the carpark to 1.1m to the North of the carpark.

5.3.6 March 1997 minus October 1996 - all of the Specific Study Area

Typically this period is the time in which foreshores build and accrete after Winter erosion. The difference plots for the South flank of the cusp show increases in sediment depth on the foreshore in excess of 0.3m starting from 220m South of Pearce Street and extending North to the artificial headland. Maximum gains are up to 0.7m. The major feature on the South flank of the cusp is, however, the movement of sediment away from the South end of the cusp. Depth of sediment losses of up to 3m occurred opposite Gateshead Avenue and reduced to 0.5m Northwards to approximately 100m South of Pearce Street. In the area between Quinns Road and Pearce Street the sediment losses were offshore from the sediment gains.

On the North flank of the cusp accretion of up to 0.8m on the foreshore extends from the artificial headland to Hall Street. Although this was an area of renourishment during 1996, the distribution of sediment gains suggests that sand has been transported from the South to the North past the artificial headland. North of Hall Street gains on the foreshore are generally less than 0.3m except between Terry and Robert Roads at the carpark, where gains are from 0.4m to 0.6m. As for the South flank of the cusp, the major feature on the North flank of the cusp is loss of sediment in a nearshore 60m wide strip. Losses in this area, which extends from Hall Road to the North past Robinson Road are from 0.9m to 1.5m. These losses are the movement of the Winter nearshore bar which, under the more benign conditions of Summer swell, moves onshore and Northwards. However, gains on the foreshore of the North flank of the cusp are not of the same magnitude of the losses in the immediate nearshore.

5.4 Summary of Nearshore and Foreshore Surveys

All of the difference plots reviewed confirm aspects of the model for sediment transport postulated by *LeProvost, Semeniuk and Chalmer*, Section 3, including Northwards sediment movement from the South of the Southern flank of the Quinns cusp in Summer and minimal changes in sediment volumes further offshore than 50m to 100m from the shoreline. Southwards movement of sediment during Summer on the North flank of the cusp towards its apex is not clearly confirmed by the difference plots.

5.4.1 Sediment Budget - October 1996 to March 1997

The surveys of October and December 1996 and March 1997, which were undertaken specifically for this study, have sufficient density of coverage to allow an estimate of the sediment budget to be made.

Typically this period is the time in which foreshores build and accrete after Winter erosion. Over all of the survey area, of 2.3km longshore and 400m across shore, there was a net loss of sediment from October 1996 to March 1997 of 150,000m^3 . This volume translates to an average of 15cm over all of the survey area. Although the survey methods offshore, being from a boat, are less accurate than the land based onshore surveys, it is unlikely that any offshore survey errors would alter a 150,000m^3 loss of sediment into a net gain of sediment. It is considered reasonable to assume that there was a net loss of sediment from the survey area during the October to March period, although the value of 150,000m^3 may be an upper limit.

Over the area within 170m seawards of Ocean Drive, from the backshore to water depths of 3m to 4m depth, and considering only elevation changes in excess of 0.2m, there was a net loss of sediment from October 1996 to March 1997 of 91,000m^3. Table 5.1 shows the net loss comprised a gain of 24,000m^3 and a loss of 115,000m^3, with the greatest loss of 55,000m^3 being from the South flank in the period from December to March. The gain on the North flank of the cusp only occurred in the December to March period suggesting that it was due to a supply of sediment from the South flank. Gains on the South flank occurred during both the October to December and December to March periods, suggesting that they resulted from the movement of sediments from the South of the South flank.

Losses from the North flank in the October to December and December to March periods were 22,000m^3 and 21,000m^3 , respectively. Gains in the October to March period for the North and South flanks were 11,000m^3 and 13,000m^3, respectively.

Of the area within 170m seawards of Ocean Drive, approximately half was surveyed from land and half by boat. It can, therefore, be expected that the gains, which were primarily onshore and in the area of the land based surveys, are accurately represented. The losses, in the area surveyed by boat, are less accurate. Notwithstanding the relatively lower degree of accuracy associated with the volumes determined from surveys from a boat, it is considered reasonable to conclude that the whole of the survey area, and in particular the nearshore area, experienced a net loss of sediment in the October 1996 to March 1997 period.

6 SYNOPSIS OF DATA INTERPRETATIONS

The *Literature Review*, particularly with respect to the extensive field studies undertaken by LeProvost, Semeniuk and Chalmer for the Mindarie Keys project, has provided the basis for defining the coastal processes of the Study Area. In particular the work reported in the Literature Review identified the lack of supply of sediment to the Specific Study Area from the South and the seasonal variations in sediment transport on the North and South flanks of the Quinns cusp.

Analysis of the *Foreshore Movement Plots* in the Extended Study Area show that to the South the sandy foreshore has remained relatively stable since being eroded between 1941 and 1955. To the North the 1995 location of the vegetation line was approximately the same as its 1941 location after the area had experienced a period of accretion and erosion between 1995 and 1995.

The Foreshore Movement Plots also show that the North flank of Quinns cusp was relatively stable from 1955 to between 1985 and 1995. During this period the South flank retreated by up to 35m after having experienced significant retreat in the period from 1941 to 1955. Erosion of the North flank of the Quinns cusp, recorded on the 1995 plot of the vegetation line is likely to have occurred during the Winter of 1994. Over that time much of the Perth Metropolitan coastline suffered erosion from Winter storms.

The *Nearshore and Foreshore Surveys*, and their *Difference Plots* confirm aspects of the model for sediment transport postulated by LeProvost, Semeniuk and Chalmer, including Northwards sediment movement from the South of the Southern flank of the Quinns cusp in Summer and minimal changes in sediment volumes further offshore than 50m to 100m from the shoreline.

The *Sediment Budget* determined for the period October 1996 to March 1997 indicates a net loss of sediment from the survey area and in particular from the nearshore areas. As the loss of sediment was during the time of year when sandy foreshores are typically accreting, the implication is that the Specific Study Area must gain sediment during the Winter months. Such gains, given the lack of supply of sediment from offshore and from the South, must be from the North.

Coastal processes on the North flank of Quinns cusp are driven by more regular and persistent wave conditions from the West and South West in both Summer and Winter. As Winter storms from the North West approach the North flank more perpendicularly than they approach the South flank, erosive cycles have been less severe on the North flank. The North flank may, therefore, be classified as being less sensitive to wave conditions than the South flank.

The coastal processes on the South flank are dependent upon the action of Winter storms in creating a reserve of sediment in the South which is transported North in the Summer. Hence the South flank is dependent not only upon the direction of North of West Winter storms but also on their occurrence and severity. The South flank may, therefore, be classified as being sensitive to wave conditions and, as shown by the large excursions of the vegetation line, vulnerable to extensive erosion.

7 IMPACTS OF EXISTING INFRASTRUCTURE

7.1 Infrastructure within the Specific Study Area

Infrastructure development within the Specific Study Area includes -

- the carpark on the North face of the Quinns cusp,
- a Summer boat launching ramp at the South of the carpark,
- a Summer access ramp to the beach at the North of the carpark,
- various pedestrian access ways from Ocean Drive to the foreshore, and,
- an artificial headland to the South of the apex of the Quinns cusp.

Apart from storm water drainage from the carpark, it is not considered that any of these infrastructure developments have any significant detrimental impact on the coastal processes of the Specific Study Area. There is no evidence from the Foreshore Movement Plots or from the Nearshore and Shoreline Surveys that these features altered the erosion and accretion cycles in the Specific Study Area. Very localised erosion about the Summer boat launching ramp and Summer access ramp was noted during field inspections.

These comments do not imply that the existing infrastructure within the Specific Study Area does not require continued management, particularly with respect to pedestrian access ways from Ocean Drive to the foreshore and to storm water drainage.

Storm water drainage from the carpark may, during Winter storms, contribute to fluidising the beach adjacent to the carpark. If the beach is fluidised then it is more prone to erosion by waves which may otherwise not cause erosion. It is also noted that the City is considering upgrading Ocean Drive which presently is not kerbed. Should the upgraded Ocean Drive have kerbing then consideration should be given to not concentrating the storm water run off from the road to specific locations on the foreshore.

7.2 Infrastructure within the Extended Study Area

The only infrastructure within the Extended Study Area is Mindarie Keys 1.5km to 2.0km South of Quinns. The extensive investigations undertaken for the Mindarie Keys development concluded that the construction of the groyne and breakwater at Mindarie would not impact upon the stability of Quinns, nor would sediment transport from Quinns impact upon the Mindarie structures.

Although erosion has occurred on the North flank of Quinns cusp since the construction of the Mindarie groyne and breakwater, erosion has been experienced in the last three years on the majority of the Perth Metropolitan beaches. As the South flank of the Quinns cusp did not, prior to or since the construction of Mindarie, exhibit any consistent trend in shoreline behaviour it would be difficult, if not impossible, to assess the impact of any infrastructure on this section of foreshore.

Given the extensive field work undertaken by the Proponents of the Mindarie Keys development to confirm the model of sediment transport in the Quinns area and the findings that there is not a sediment pathway from the South to Quinns, it is considered -

a. highly unlikely that the development of Mindarie Keys has impacted on the coastal processes of the Quinns area, and,

b. impossible to show, from the available data, any impact on the coastal processes at Quinns which could not be attributed to oceanographic conditions which have impinged upon all of the Perth Metropolitan coastline in recent Winters.

8 GENERAL OPTIONS FOR FORESHORE MANAGEMENT

A sequence of foreshore management options may be considered which preserve a beach area and/or protect the adjacent infrastructure from risk by erosion. As shown in Figure 8.1 the primary consideration in selecting a foreshore management option is whether or not the foreshore is persistently eroding. In this context persistent erosion refers to a long term trend to erosion established over many years with erosion not recovered by accretion. Persistent erosion does not refer to foreshore erosion during one season which is recovered in the following season.

If the foreshore is consistently eroding and any threatened infrastructure can be either sacrificed or relocated, then allowing the foreshore to erode is a management option, sometimes called the 'retreat' option.

However, if the foreshore is persistently eroding and there is significant adjacent infrastructure which cannot be relocated, then the available options are may be categorised as 'defend' options. The 'defend' options include recurrent renourishment or construction of foreshore protection structures. For the construction options the type of protection must be cost effective, compatible with the coastal processes of the area and satisfy the needs of the community. Foreshore protection structures include -

- timber or rubble mound groynes,
- seawalls, and,
- offshore breakwaters.

If the foreshore does not have an established history of persistent erosion then, as shown in Figure 8.1, the foreshore management options are -

- do nothing, and,
- reactive management.

It is important to note that these foreshore management options are based on the current location and use of infrastructure. No assumptions have been made regarding any future changes in the location, intensity or use of existing infrastructure as these considerations were outside the scope of the report. The options for foreshore management are described below.

The 'Do Nothing' Option

The 'do nothing' option is appropriate where the foreshore is not persistently eroding or there is not a threat to adjacent infrastructure from storm events. Under this option the normal seasonal cycles of erosion and accretion of the foreshore occur in an appropriately wide buffer area.

The Retreat Option

The 'retreat' option is appropriate where the foreshore is persistently eroding but there is not an immediate threat to adjacent infrastructure from storm events or where the adjacent infrastructure can be relocated or sacrificed. Under this option the normal seasonal cycles of erosion and accretion of the foreshore occur in a buffer area which is widened by the relocation of existing infrastructure. As this option relates to a persistently eroding foreshore it may be seen as buying time until the buffer area can no longer be widened and retreat is no longer an option.

Reactive Management

Reactive management can be appropriate where the foreshore is not persistently eroding but is occasionally attacked by severe storms. When severe storms do occur which threaten the adjacent infrastructure the foreshore managers react by protecting eroded sections of the foreshore by sand renourishment. Under this management option there need not be a specific annual budget as long as funds can be allocated for emergency purposes.

Reactive management may be seen by the community as a 'do nothing' option and thereby be open to criticism. There is a accordingly a necessity under this management option for the foreshore managers to be aware of the medium to long term behaviour of the foreshore and to recognise when reactive management is no longer appropriate.

Recurrent Renourishment

Recurrent renourishment involves the planned and regular seasonal placement of sand onto persistently eroding beaches to make up the sand lost to erosion. The volume of recurrent renourishment is determined from the long term erosional trend of the foreshore. Renourishment does not alter the natural appearance or character of the beach and, unlike the options described below, can be modified to meet varying erosion and accretion cycles. Recurrent renourishment requires an annual budget allocation.

Recurrent renourishment may be perceived by the community as 'throwing money into the sea'. No tangible assets are immediately produced for the expenditure and there is often not an immediately obvious requirement for renourishment. Public awareness programs can be initiated to assist in overcoming this perception.

Timber or Rubble Mound Groynes

Groynes are structures which run perpendicular to the coast and intercept the longshore sediment being transported in the surf zone. Timber groynes are not appropriate at Quinns as the Winter wave climate is too severe. As the purpose of a groyne is to realign an eroding foreshore such that longshore transport is reduced, groynes are usually constructed as part of groyne field.

As a groyne is constructed to intercept longshore drift the foreshore downdrift of the groyne, will be eroded unless the groyne is artificially filled at the time of construction. A groyne will not inhibit cross shore transport as, for example, a nearshore bar forms in the Winter months, but should enable a larger buffer of sand to be available to erosion.

As will shown in the following Section, the construction of groynes at Quinns is not recommended.

Seawalls

Seawalls provide a landwards limit to erosion and are placed high on the foreshore where only the waves from extreme events can reach them. Seawalls are reflective and will initiate a higher rate of sand loss when waves from severe storm events reach them. As a result, recovery of the foreshore will be inhibited. Unless the foreshore is stable or accreting in the longer term then there is likely to be a net loss of sand in front of a seawall which will mean that it is more prone to attack in subsequent severe events. A seawall should, therefore, be seen as protecting the area behind the wall from erosion and not as increasing the area of the beach.

Offshore Breakwaters

This option involves the construction of a rubble mound groyne generally parallel with, and offshore from, the foreshore area to be protected. The offshore breakwater modifies the wave pattern such that a cusp is formed on the beach in the lee of the breakwater. The length of foreshore influenced by the breakwater depends, inter alia, on the wave climate, sediment characteristics, the length of the breakwater and its distance offshore. To ensure that the cusp formed on the foreshore does not reach the offshore breakwater and totally stop longshore transport, the breakwater should be constructed at a distance offshore which is greater than its length. Sufficient sand would need to be placed on the foreshore during construction to ensure that the initial capture of longshore transport did not impact on sediment transport to downdrift of the breakwater.

As will shown in the following Section, the construction of offshore breakwaters at Quinns is not recommended.

9 QUINNS FORESHORE MANAGEMENT

As shown in Figure 8.1 the primary decision to be made by the foreshore manager in selecting foreshore management options is whether or not the foreshore is persistently eroding. The work of *LeProvost, Semenuik and Chalmer*, as reviewed in Section 3, established that, in a geological time frame, the Quinns cusp either stopped accreting 3,500 years Before Present, or accreted to a more recent time but has since eroded back to its present alignment. Accordingly, the cusp is not, in a geological time frame, accreting.

The interpretation of foreshore movement plots, as presented in Section 4, shows that all of the Study Area foreshore experienced erosion between 1941 and 1955 and that the South flank of the cusp has experienced significant erosion and accretion cycles since 1955. If the 54 years from 1941 to 1995 is considered then the results presented in Table 4.1 show that all of the foreshore between the rocky limestone cliffs in the South to 150m North of the Surf Life Saving Club in the North eroded at a rate up to 1.0m per year and typically in excess of 0.5m per year. Accordingly, in an engineering design life time, the cusp may be considered to be eroding.

By contrast, the foreshore movement plots show that the North flank of the cusp accreted after 1955 and remained stable between 1965 and at least 1985 and probably 1993. This area of the cusp may therefore be considered as being stable over these 20 to 28 years.

In recent times, and as the result of severe Winter storms after 1993, the North flank of the cusp and the Northern part of the South flank have eroded by at least 10m. For this short time frame this part of the cusp has eroded. However this is not necessarily persistent erosion.

A sediment budget derived from nearshore and foreshore surveys undertaken for this Study for the period from October 1996 to March 1997 suggests a net loss of sand from the Specific Study Area. Without a sediment budget for the period March to October 1997 it is not possible to determine if these net losses are balanced in the Winter months by gains from the transport of sand from the North.

Given the lack of clearly defined sediment supply to the area, the history of erosion, albeit tempered on the North flank by a prolonged period of stability, and the urgency created by the recent Winter storms, it would be prudent to consider that the foreshore of the Specific Study Area exhibits a tendency to erosion.

In selecting foreshore management options, the different erosion and accretion potentials of different areas must be recognised together with the location and significance of existing infrastructure. In this respect the foreshore of the Specific Study Area has been divided into four sub-areas, being -

1. the South flank of the cusp, South of Quinns Road.
2. the South flank of the cusp from Quinns Road North to the artificial headland,
3. the North flank of the cusp from the artificial headland North to the carpark, and,
4. the North flank of the cusp from the South end of the carpark Northwards.

Further, short term and long term management options must be identified. The short term options, to be applied over 1 to 5 years, must not preclude the long term options which may be applied over an engineering design life time of up to 50 years.

For all four sub-areas the construction of defensive structures such as groynes or offshore breakwaters, or any device which may interrupt either the Northwards and Southwards transport of sand, is not considered appropriate. The work of *LeProvost, Semenuik and Chalmer,* and the sediment budget presented in Section 5, indicate that, although Northwards transport out of the Specific Study Area in the Summer months could be retained by groynes or offshore breakwaters, such structures would stop the replenishment of the area by sands transported from the North during the Winter months.

South Flank of the Cusp - Quinns Road North to the Artificial Headland

This is the most critical area for consideration as the existing infrastructure, Ocean Drive, cannot be sacrificed. Further, the natural sand buffer has been attacked by recent Winter storms and is less than 20m wide to the South of Pearce Street. The foreshore movement plots presented in Figure 4.6 indicate that this area did recover naturally, between 1978 and 1985, from a worse period of erosion which occurred between 1965 and 1978.

In the short term, from 1 to 5 years hence, recurrent renourishment of this area is recommended. At the end of Summer this area is at its most accreted state as sand has moved from the South to the North of the South flank of the cusp. Early renourishment before this sand has again moved South with the onset of Winter storms would not be appropriate. Annual renourishment should therefore be timed to occur from mid Winter as the area becomes depleted in sand. The precise timing of renourishment will require the area to be regularly inspected during the early to mid Winter period.

The area of renourishment should be from the immediate North of Pearce Street Southwards for 200m. As the berm was up to 7m high in October 1996, a total volume of $40m^3$ per metre of foreshore will add approximately 6m of buffer to the area. Accordingly a total volume of at least $8,000m^3$ should be placed in this area annually with the placement starting from the Northern end. The estimated cost for this renourishment is $40,000 to $50,000 per annum.

For recurrent renourishment to be viable a reserve of up to $50,000m^3$ of suitable sand will need to be identified. Sand from the maintenance dredging of Ocean Reef Marina, which was used for renourishment on the North flank of the cusp in 1996, should not be relied upon as its cost may be prohibitive and the timing of its availability inappropriate.

In the long term , if the Specific Study Area is experiencing persistent long term erosion, then an engineering solution is required for this area. As the ultimate aim in this area will be to protect Ocean Drive, it is recommended that the long term option be the construction of a seawall from Pearce Street to the immediate South of Quinns Road. A concrete mattress seawall is appropriate, with rubble toe protection. The concrete mattress would be laid at a 1:1 slope between -1m and +7m CD. The cost, including earthworks, laying and design overheads is estimated as $600 to $700 per metre run of wall. To protect the 400m of Ocean Drive from Pearce Street to the immediate South of Quinns Road would therefore cost up to $300,000.

Should a viable a reserve of sand for recurrent renourishment not be identified then the option for this area in the short term becomes retreat, with the possibility of the existing narrow buffer further eroding. It is therefore recommended that the City, in consultation with the Department of Transport, initiate detailed planning and design of a seawall from Pearce Street to the immediate South of Quinns Road.

It should be recognised that if a seawall is to be constructed in the long term then its purpose is to protect the area behind the wall from erosion and not to preserve an area of the beach. The construction of a seawall should only be necessary if significant erosion is experienced over all of the Specific Study Area in the short to medium term.

South Flank of the Cusp - South of Quinns Road

The foreshore management option for this area will depend on the success of the foreshore management option selected for the area to its immediate North. The recurrent renourishment recommended for the North section of the South flank of the cusp in the short term will generally add sand to the South flank of the cusp which, during the latter part of Winter, will be transported South of Quinns Road. As determined by *LeProvost, Semeniuk and Chalmer,* and described in Section 3, there is minimal exchange of sand between the Quinns shoreline and offshore. Therefore, the addition of sand to the South cusp, which is transported to the South in Winter may be sufficient to maintain this area.

In the short term, from 1 to 5 years hence, the foreshore management option recommended for this area is retreat. Cycles of erosion and accretion should be accommodated in a buffer area which may include the existing carpark.

In the medium to long term the foreshore management option for this area will be decided by the foreshore management option adopted for the area to its immediate North. If erosion becomes sufficiently advanced to necessitate the construction of a seawall to the North of this area then further loss of infrastructure may need to be accepted until the area is captured as a pocket beach. However, it is considered that recurrent renourishment of the area to the immediate North will also benefit the area South of Quinns Road.

North Flank of the Cusp - Artificial Headland North to the Carpark

In the short term, from 1 to 5 years hence, the foreshore management option for the North Flank of the Cusp from the artificial headland Northwards to the carpark should be reactive renourishment. As this is the apex of the cusp erosion and accretion cycles are not only linked to the severity of storms but also to the direction of the storm attack. Accordingly while one face of the apex may erode in response to a storm, the opposite face may accrete. Reactive renourishment allows the area of renourishment to be varied to cater for these changes.

In the medium to long term the foreshore management option for this area will be decided by the foreshore management options adopted for the areas to its immediate North and South. In particular, it is considered that recurrent renourishment of the area to the immediate South will also benefit this area as additional sand is transported Northwards past the artificial headland in Summer.

North Flank of the Cusp - Northwards from the South end of the Carpark

The foreshore movement plots presented in Section 4 show that this area accreted after 1955 and remained stable between 1965 and at least 1985 and probably 1993. As the result of severe Winter storms after 1993, the North flank of the cusp has eroded by at least 10m. Because of the orientation of the North flank of the cusp it is less susceptible to attack by Winter storms than the South flank. In selecting a foreshore management option for this area it is considered appropriate not to accept the recent storm erosion as persistent long term erosion. The infrastructure in this area includes the carpark, reserve, toilet block, SLSC facility and seasonal boat ramps

In the short term, from 1 to 5 years hence, the foreshore management option recommended for this area is retreat, particularly if the 1997 Winter is severe. Under this option, erosion of the foreshore into the carpark and reserve to its South is accepted. In the short term erosion should be allowed to occur, if it occurs, over the width of approximately the Western third of the carpark. If erosion persists such that more than this additional buffer area is required for cycles of erosion and accretion then the longer term option described below will need to be adopted.

If, for the short term, retreat and loss of the existing infrastructure in this area is unacceptable, then the reactive management option of renourishment at specific sites of erosion should be adopted.

In the long term , if the Specific Study Area is experiencing persistent long term erosion, then an engineering solution is required for this area. The management aim in this area will be to halt erosion before it reaches the high escarpment to Ocean Drive. It is recommended that the long term option be the construction of a seawall over the length of the existing carpark and at the level of the carpark, leaving sufficient area for one row of angled parking. A concrete mattress seawall is appropriate, with rubble toe protection. The concrete mattress would be laid at a 1:1 slope between -1m and +6m CD. The cost, including earthworks, laying and design overheads is estimated as $500 to $600 per metre run of wall. To protect the 300m of carpark would therefore cost up to $180,000.

It should be recognised that if a seawall is to be constructed in the long term then its purpose is to protect the area behind the wall from erosion and not to preserve an area of the beach. The construction of a seawall should only be necessary if significant erosion is experienced over all of the Specific Study Area.

Compared with the long term option of construction of a seawall from Pearce Street to the immediate South of Quinns Road it is considered that erosion which would necessitate the construction of a seawall on the North flank would be experienced over all of the Metropolitan coastline and be very significant.

10 DISCUSSION AND RECOMMENDATIONS

It is considered that this Report meets the requirements of both Stages of the Quinns Coastal Processes Study.

The primary objective of Stage 1 of the Study was to identify the coastal processes of the area and the impact of existing infrastructure on those processes. Data held by the Department of Transport, including foreshore movement plots and foreshore surveys, have been reviewed and found to corroborate the results of extensive studies undertaken for the development of Mindarie Keys.

As discussed in Section 6, the major coastal processes of the Specific Study area have been identified and the difference between the behaviour of the South and North flanks of the Quinns cusp defined.

The North flank of Quinns cusp behaves in a similar manner to the majority of the Perth Metropolitan coastline, eroding in Winter and accreting in Summer. It is considered that the recent erosion of the North flank, after 30 years of relative stability can be attributed to Winter storms over the past three years. These storms caused significant erosion on many Metropolitan and South West beaches.

The South flank of the cusp, by contrast, is sensitive not only to the foreshore building processes of Summer but also to the occurrence and severity of Winter storms. Paradoxically, mild Winters with less than average North West storms could result in Summer erosion of the South flank of Quinns cusp if insufficient sediment is driven Southwards on the South flank during Winter to meet the sediment transport demands of Summer wave conditions. While the North flank of the cusp exhibited relative stability over the 30 years from 1955 the South flank experienced erosion and accretion cycles in excess of 3m per year.

The objectives of Stage 2 of the Study were to refine the understanding of coastal processes of the area and to identify coastal protection strategies and a range of solutions for coastal management of the Specific Study Area.
As a result of a third nearshore and foreshore survey the understanding of the coastal processes of the area have been refined and a sediment budget quantified for the Spring and Summer periods. Future surveys should be conducted to define a sediment budget over Winter.

The general options for foreshore management have been presented and applied to the Specific Study Area. The recommendations of this Report relating to options for foreshore management may be summarised as -

a. defensive structures such as groynes or offshore breakwaters, or any device which may interrupt either the Northwards and Southwards transport of sand, should not be constructed in or to the immediate North of the Specific Study Area.

b. in the next 1 to 5 years the foreshore management option for the South Flank of the Cusp South of Quinns Road should be retreat. Cycles of erosion and accretion should be accommodated in a buffer area which may include the existing carpark.

In the medium to long term the foreshore management option for this area will be decided by the foreshore management option adopted for the area to its immediate North.

c. in the next 1 to 5 years the foreshore management option for the South Flank of the Cusp from Quinns Road Northwards to the artificial headland should be annual renourishment. Such annual renourishment of up to 8,000m^3 should be timed so that it is undertaken at the end of the natural movement of sand from the area to the South end of the cusp. The cost of annual renourishment is estimated at $40,000 to $50,000 per annum (1997).

   In the medium to long term the foreshore management option for this area is the construction of a seawall between the immediate South of Quinns Road and the immediate North of Pearce Street. This long term management option will be realised if recurrent renourishment is unsuccessful in abating erosion and Ocean Drive is threatened. The cost of a 400m long concrete mattress seawall is estimated as $300,000

d. in the next 1 to 5 years the foreshore management option for the North Flank of the Cusp from the artificial headland Northwards to the carpark should be reactive renourishment. In the medium to long term the foreshore management option for this area will be decided by the foreshore management options adopted for the areas to its immediate North and South.

e. in the next 1 to 5 years the foreshore management option recommended for the North flank of the cusp Northwards from the South end of the carpark is retreat, particularly if the 1997 Winter is severe. If, for the short term, retreat and loss of the existing infrastructure in this area is unacceptable, then the reactive management option of renourishment at specific sites of erosion should be adopted.

   In the long term the foreshore management option for this area is the construction of a seawall at the level of the carpark. This long term management option will only be realised if significant erosion occurs over all of the Metropolitan coastline. The cost of a 300m long concrete mattress seawall is estimated as $180,000

It is further recommended that -

f. the City of Wanneroo, in consultation with the Department of Transport, commence investigations to identify a source of sand for recurrent renourishment total volume for five years of up to 50,000m^3 of suitable sand.

g. the City of Wanneroo, in consultation with the Department of Transport, commence detailed planning and design of a foreshore seawall which may be constructed to protect Ocean Drive between the immediate South of Quinns Road and the immediate North of Pearce Street,

h. the Department of Transport undertake further regular nearshore and foreshore surveys in October and March of each year to define the sediment budget of the area.

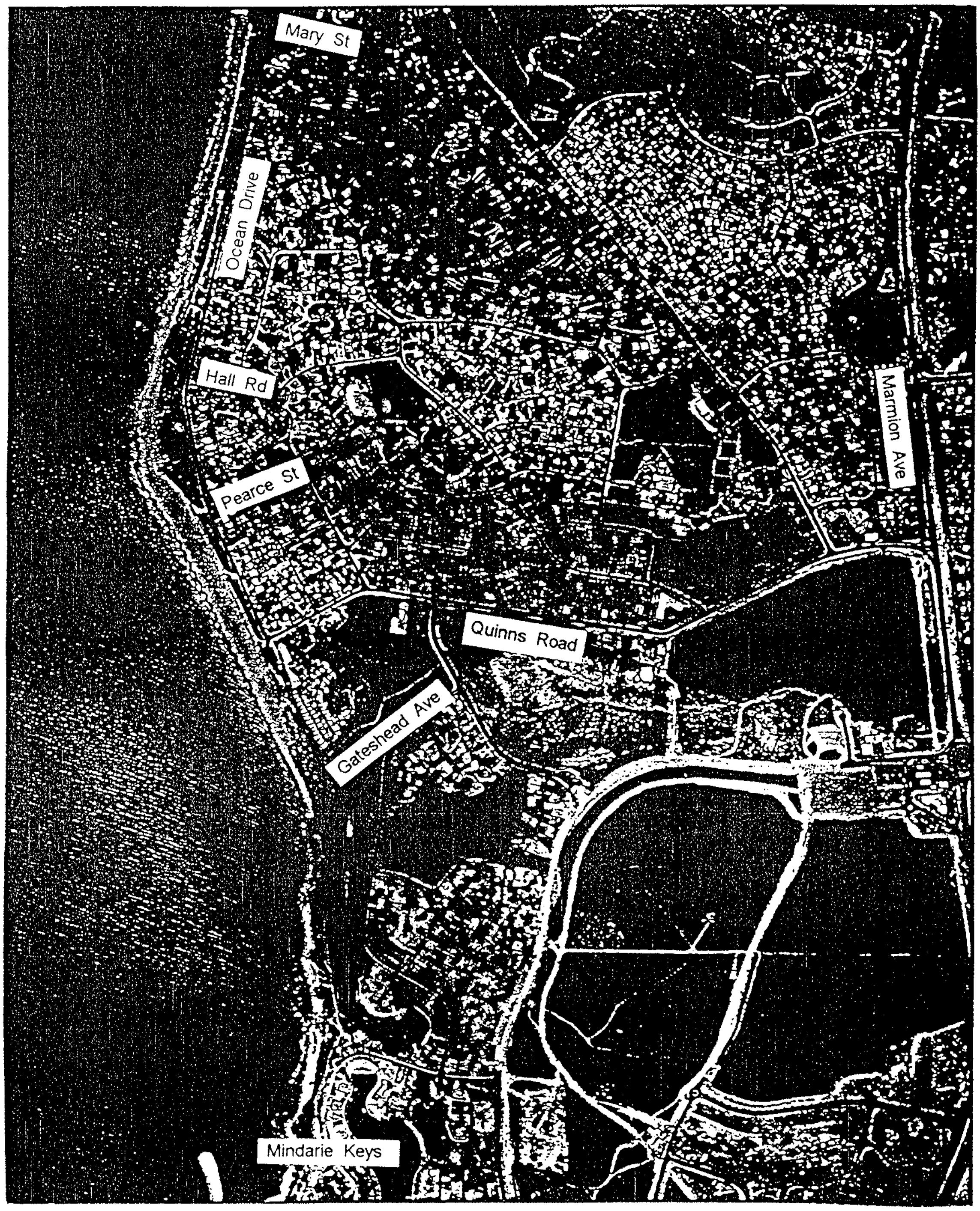
Such surveys should cover as much as possible of the area within 200m seawards of Ocean Drive by land based surveying techniques.

i. that City of Wanneroo consider a public awareness campaign in anticipation of public enquiries during foreshore renourishment programs.

FIGURES

Figure 2.1

Specific Study Area



Aerial Photograph Copyright DOLA

Figure 3.1

Sediment Transport

Prevailing Summer South West Swell

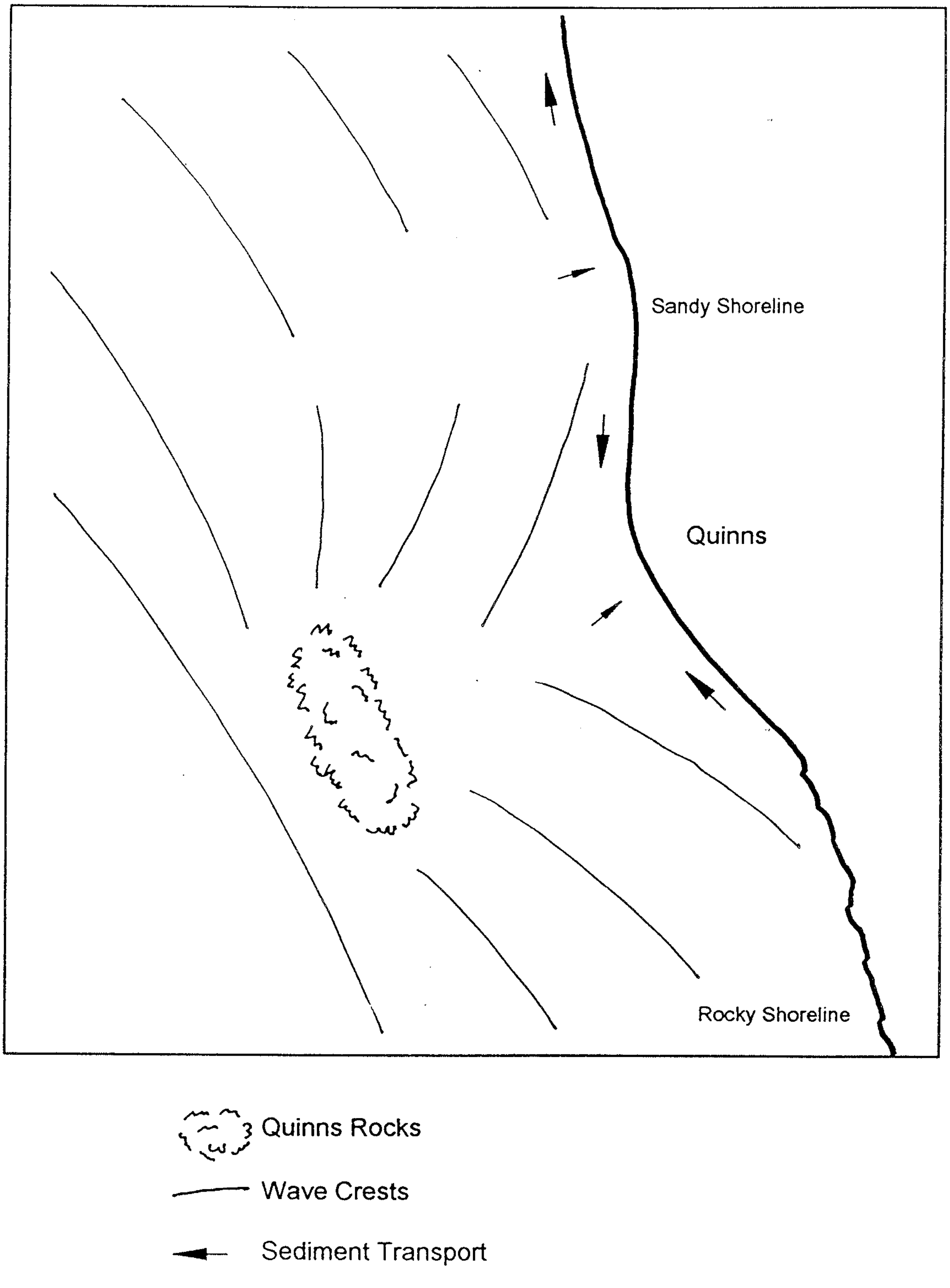


Figure 3.2

Sediment Transport

Summer Afternoon Sea Breeze

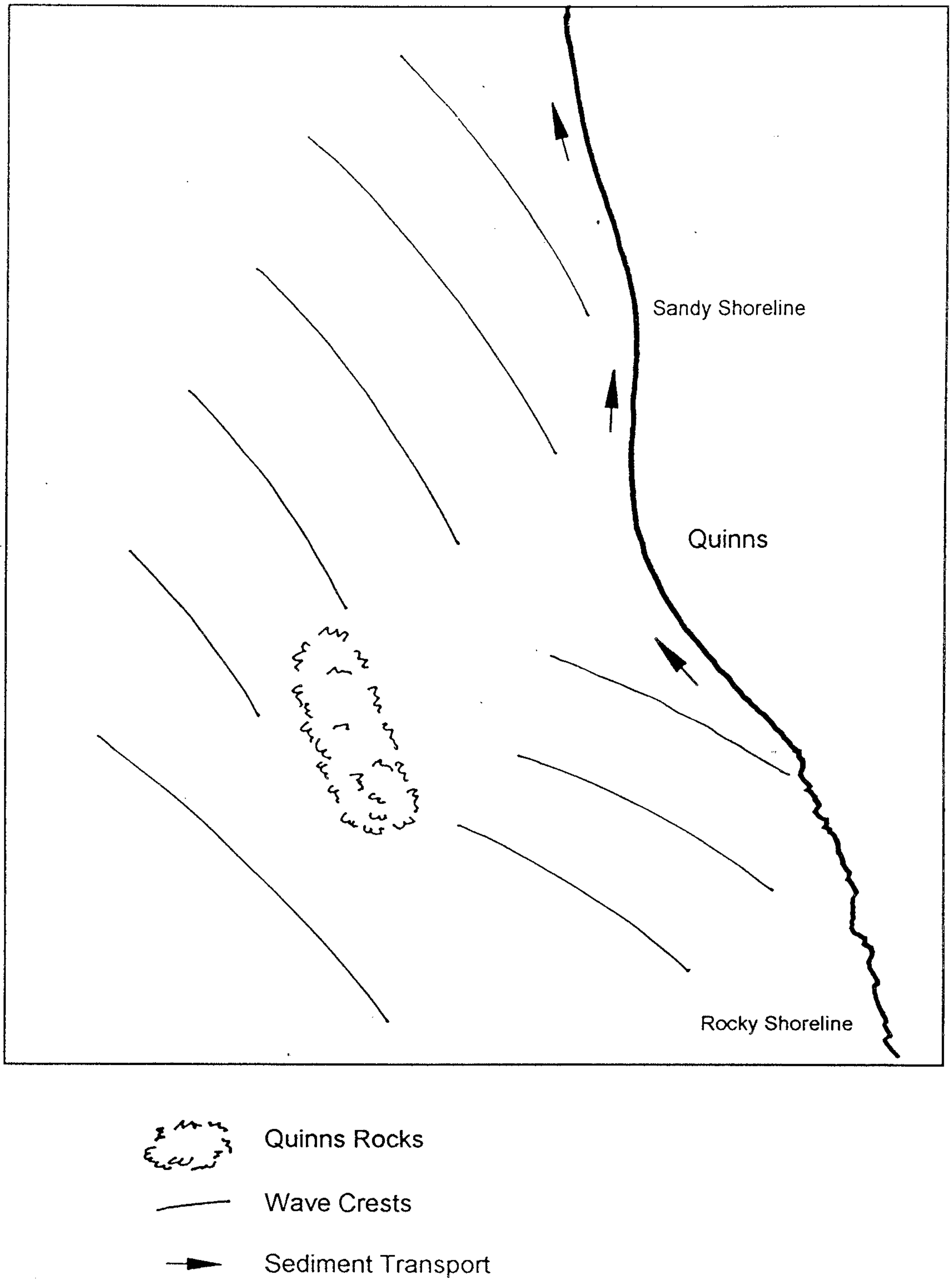


Figure 3.3

Sediment Transport

Summer

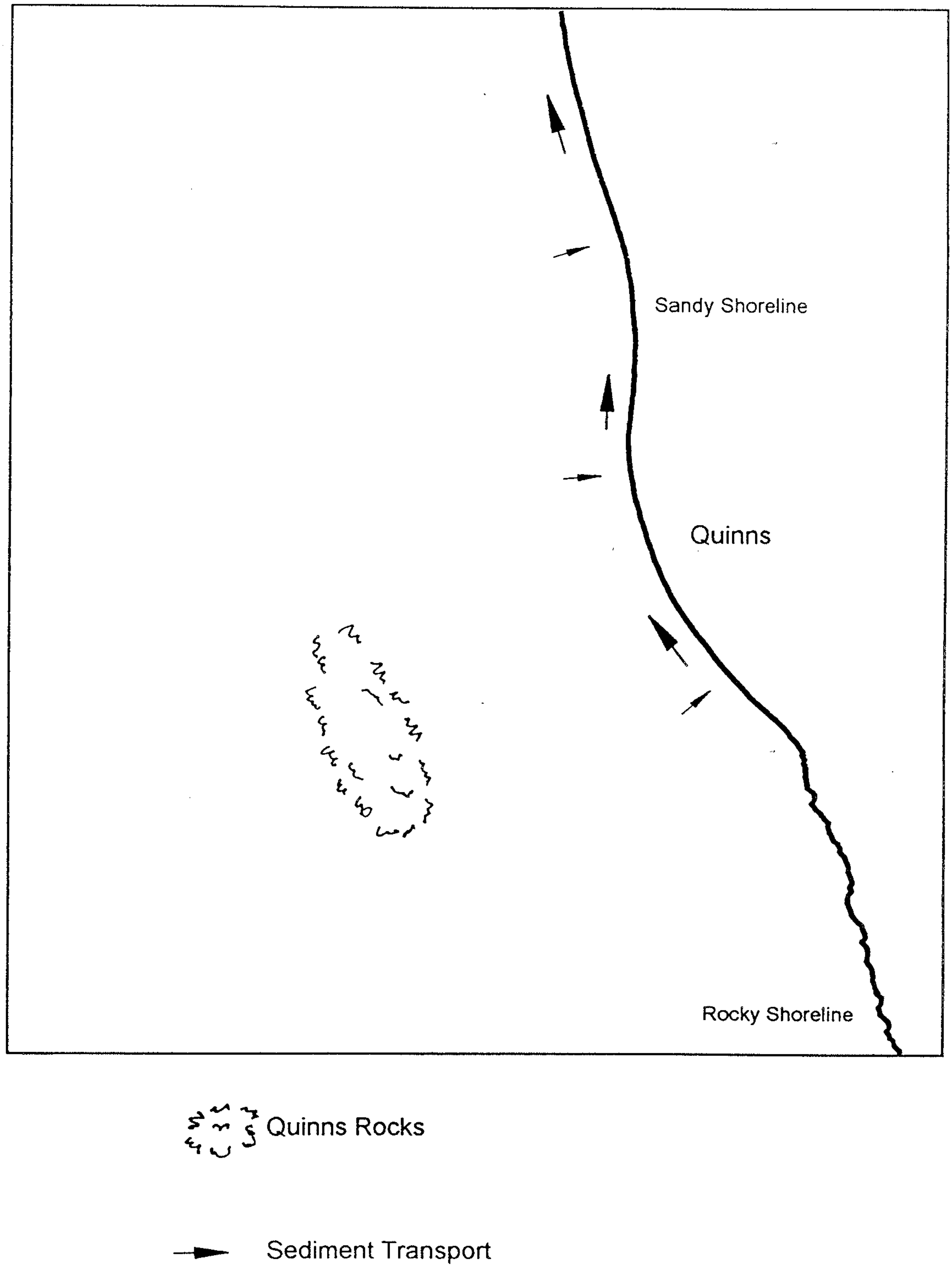


Figure 3.4

Sediment Transport

West to South West Winter Swell

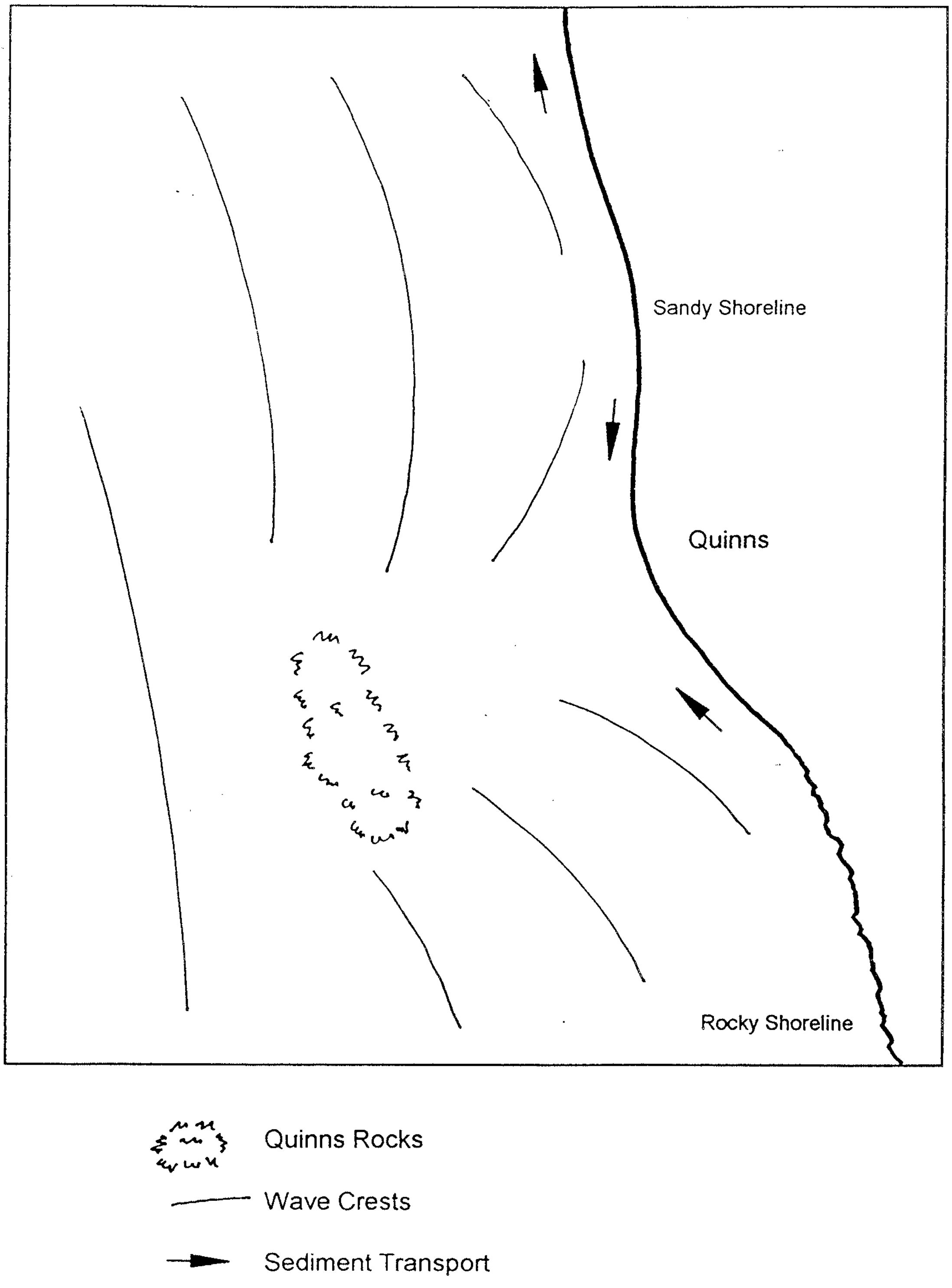


Figure 3.5

Sediment Transport

West to South West Winter Seas

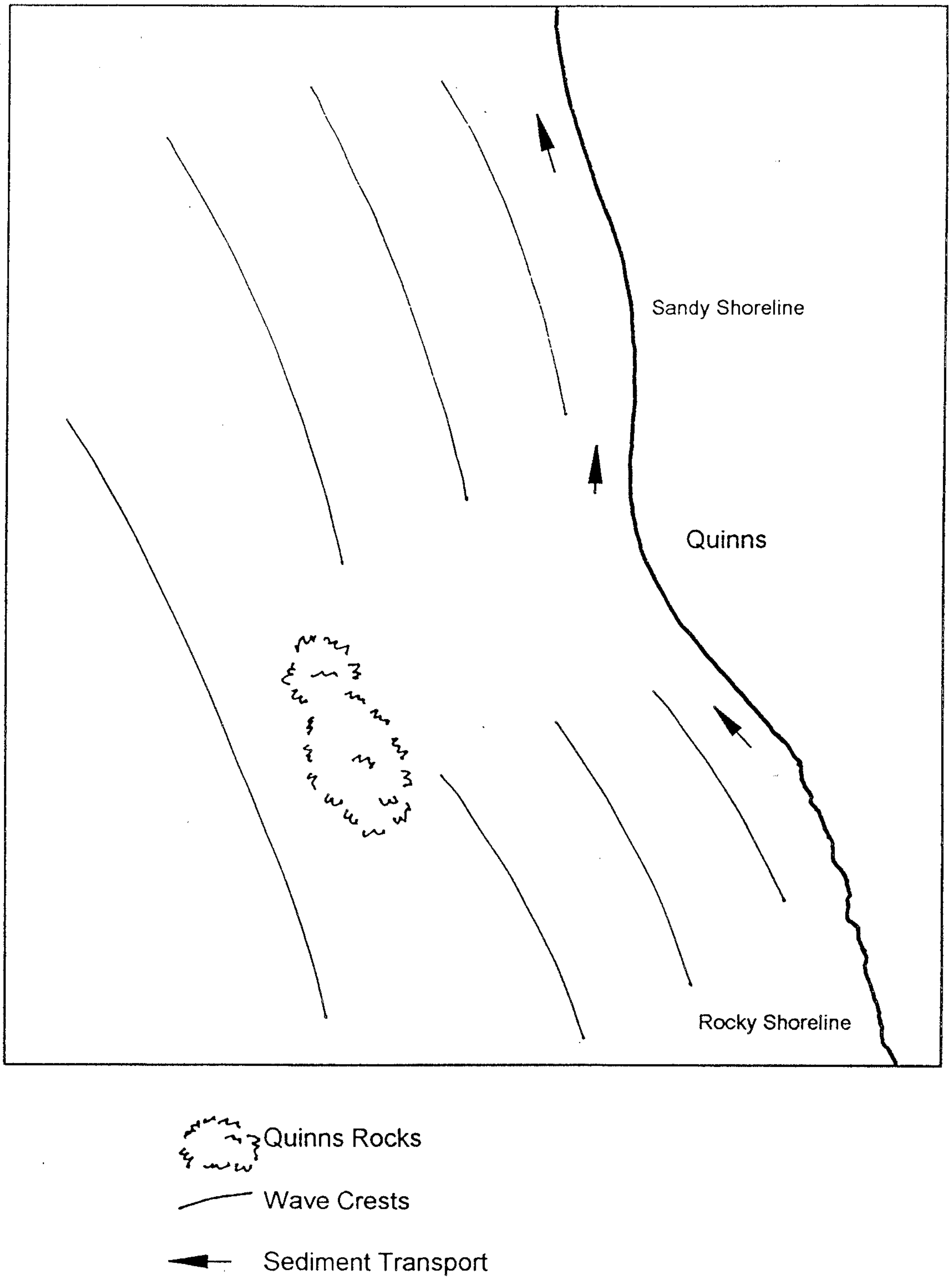


Figure 3.6

Sediment Transport

North of West Winter Storms

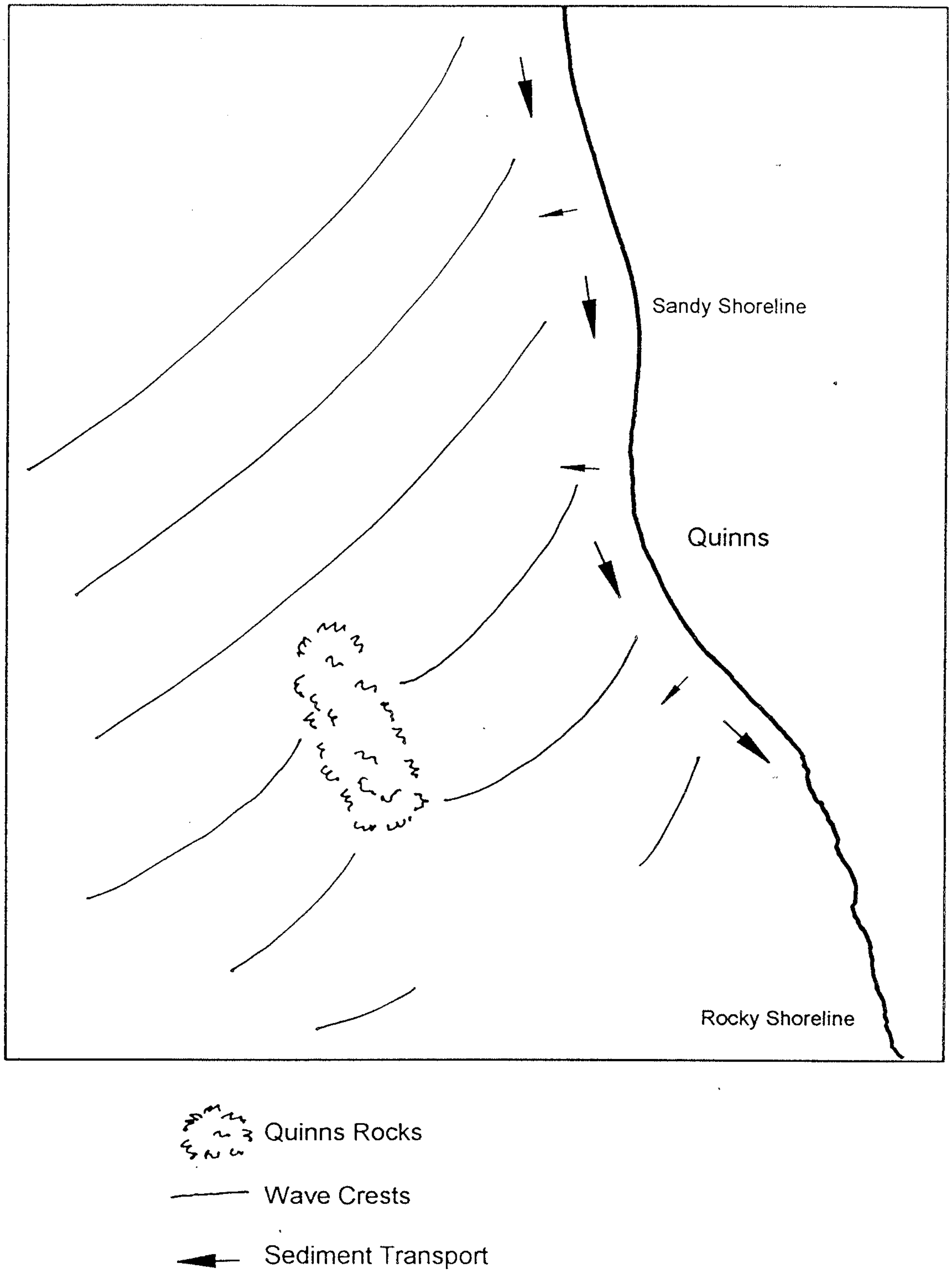


Figure 3.7

Sediment Transport

Winter

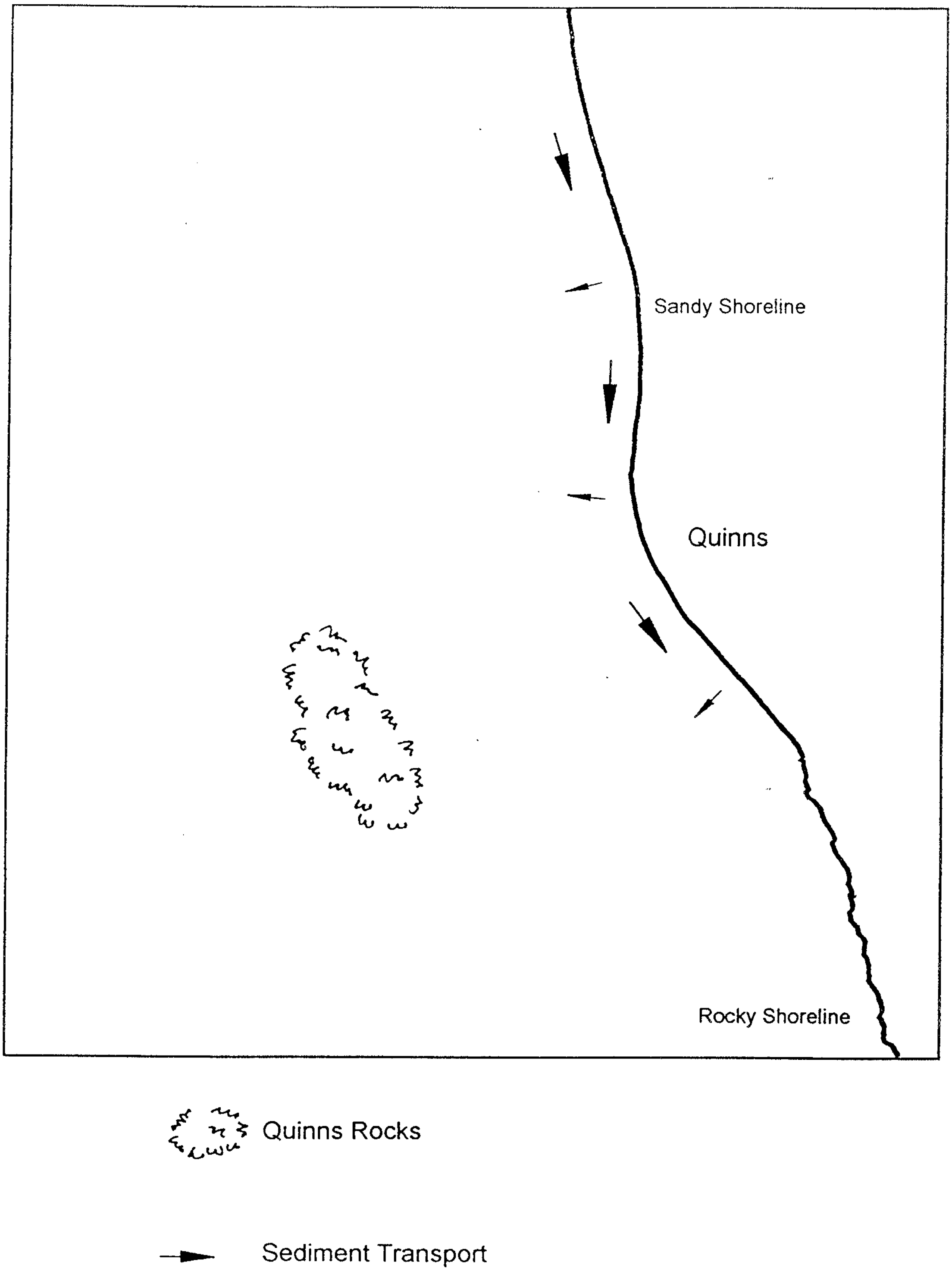


Figure 4.1 **1941 to 1955**

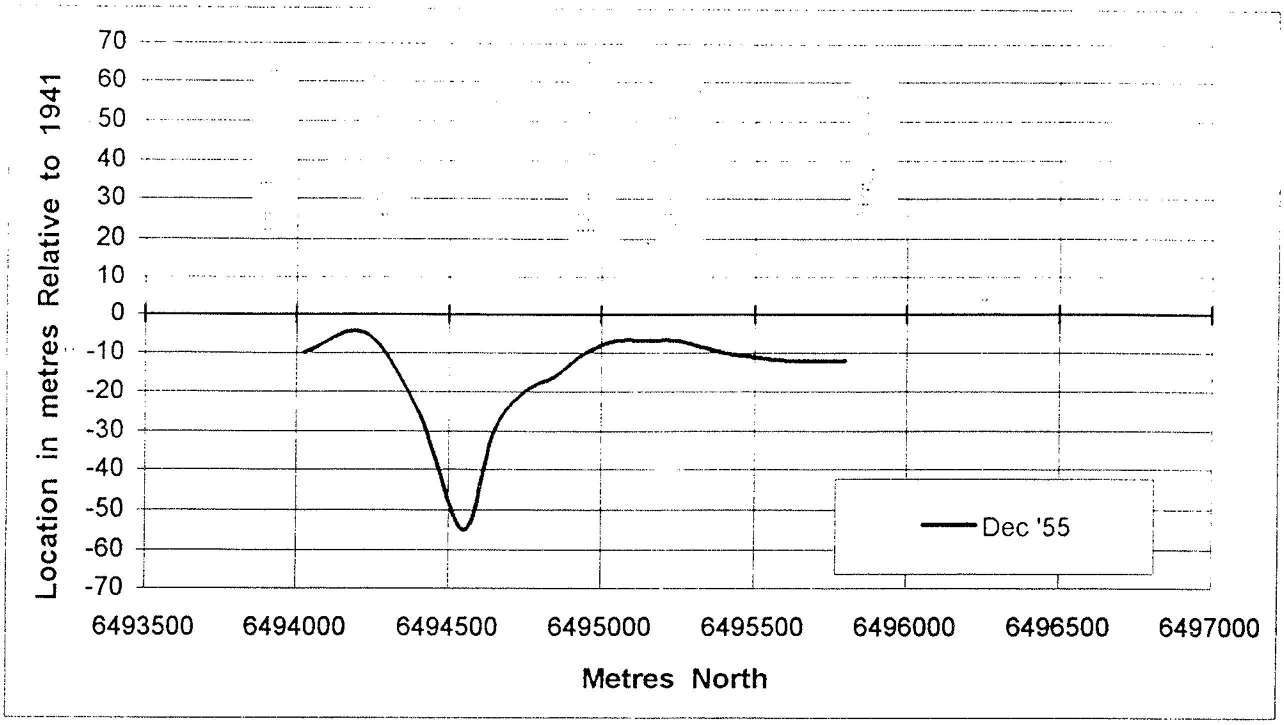


Figure 4.2 **1955 to 1965**

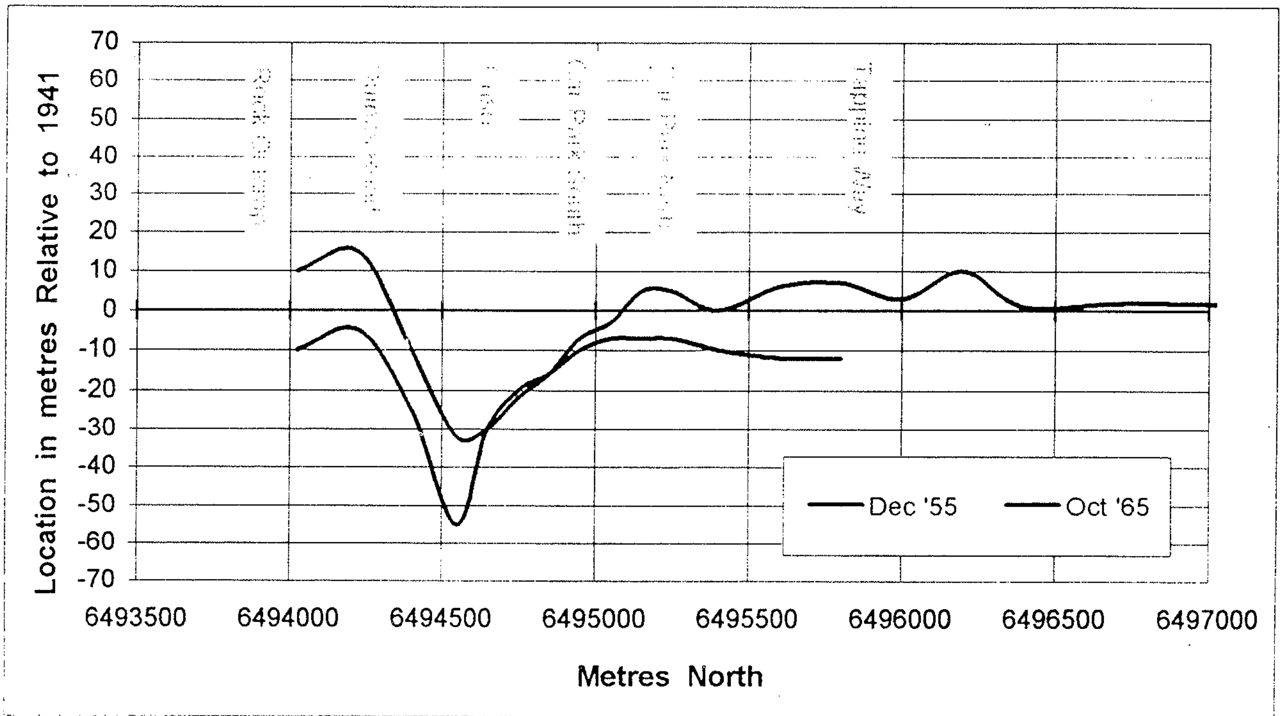


Figure 4.3 **1965 to 1978**

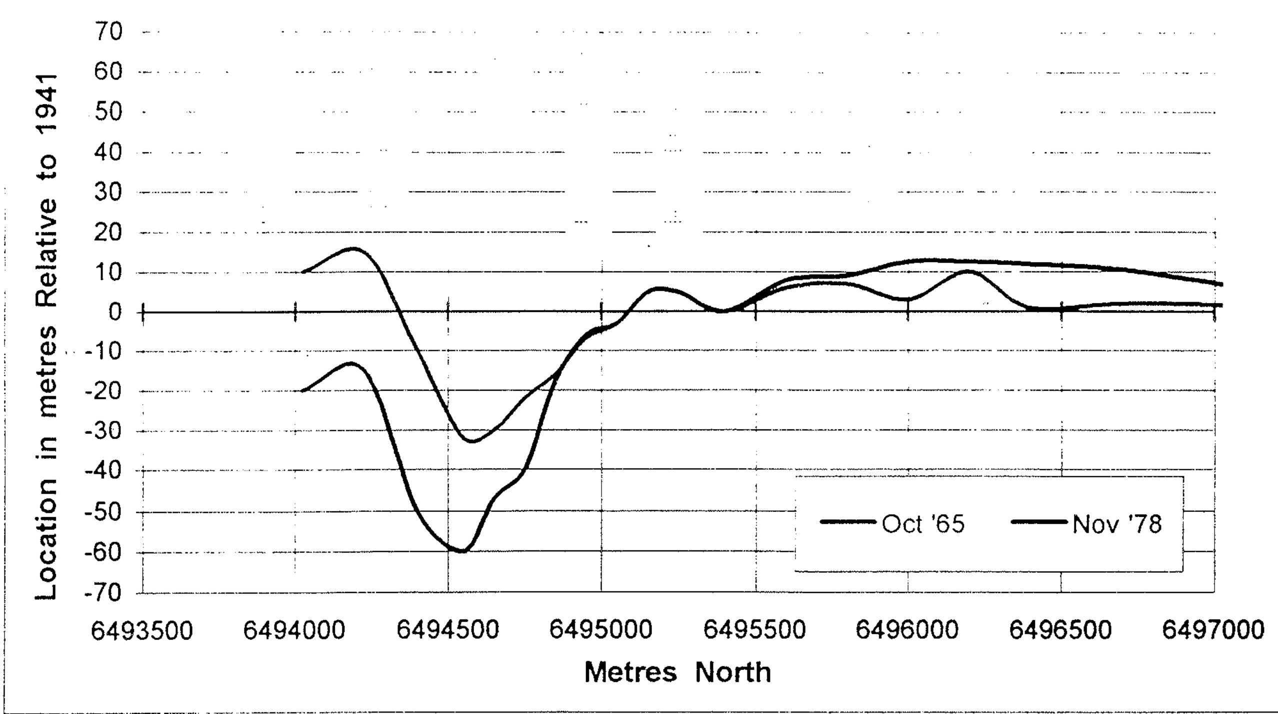


Figure 4.4 **1978 to 1985**

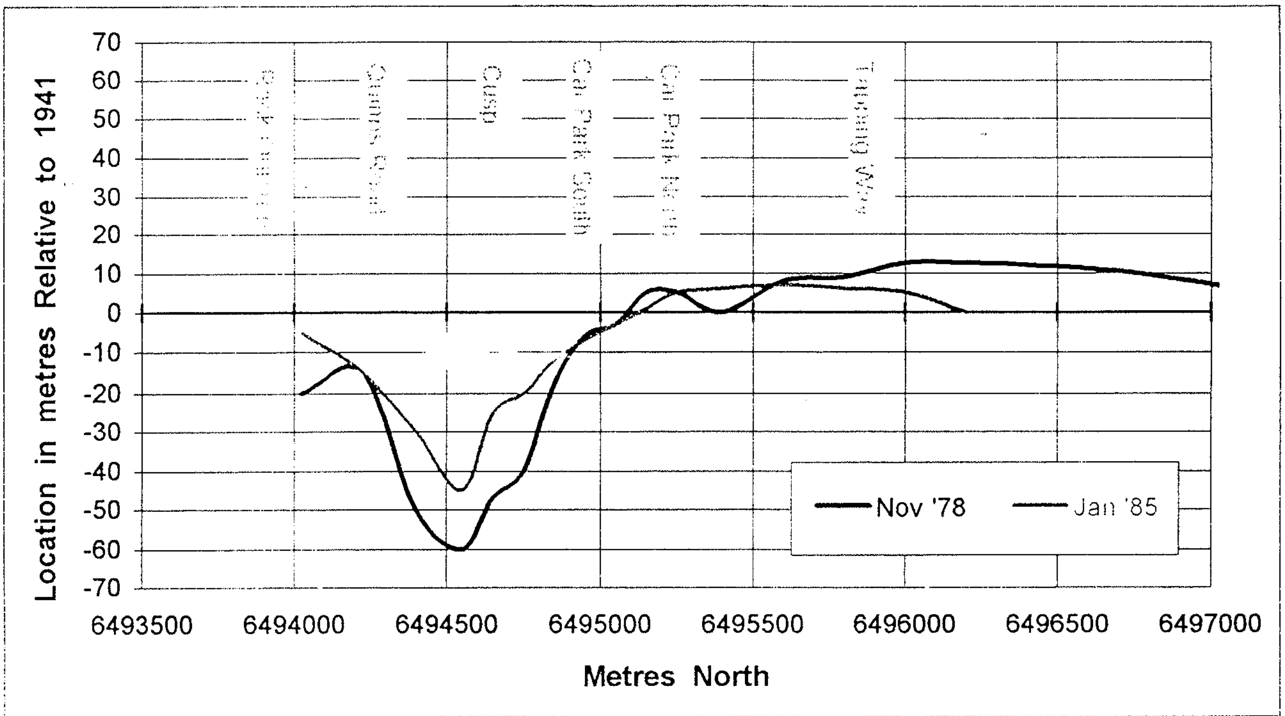


Figure 4.5 **1985 to 1995**

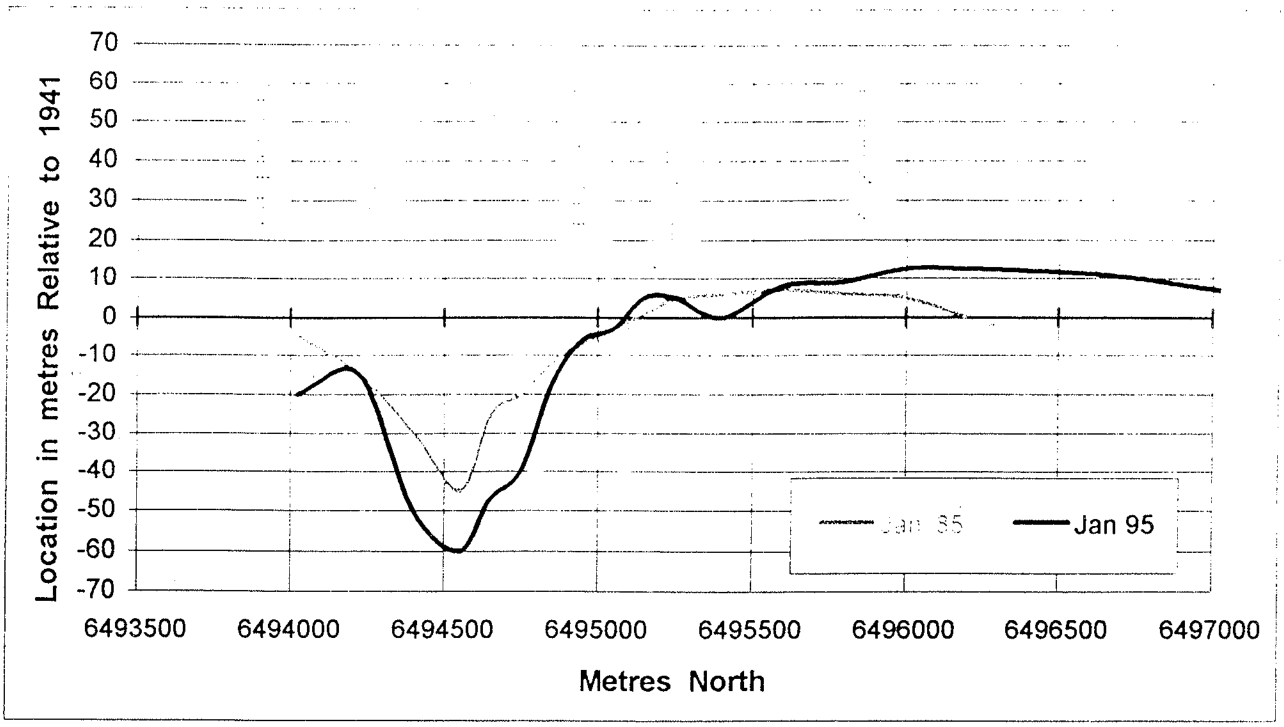
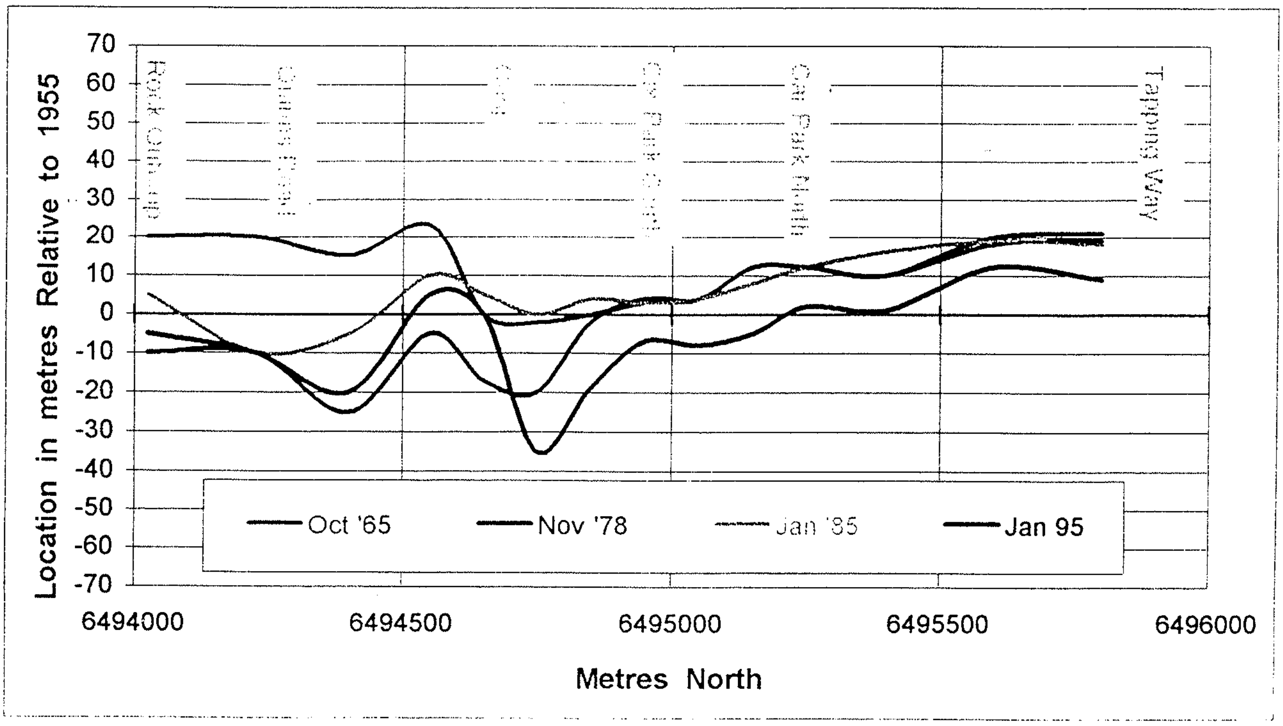
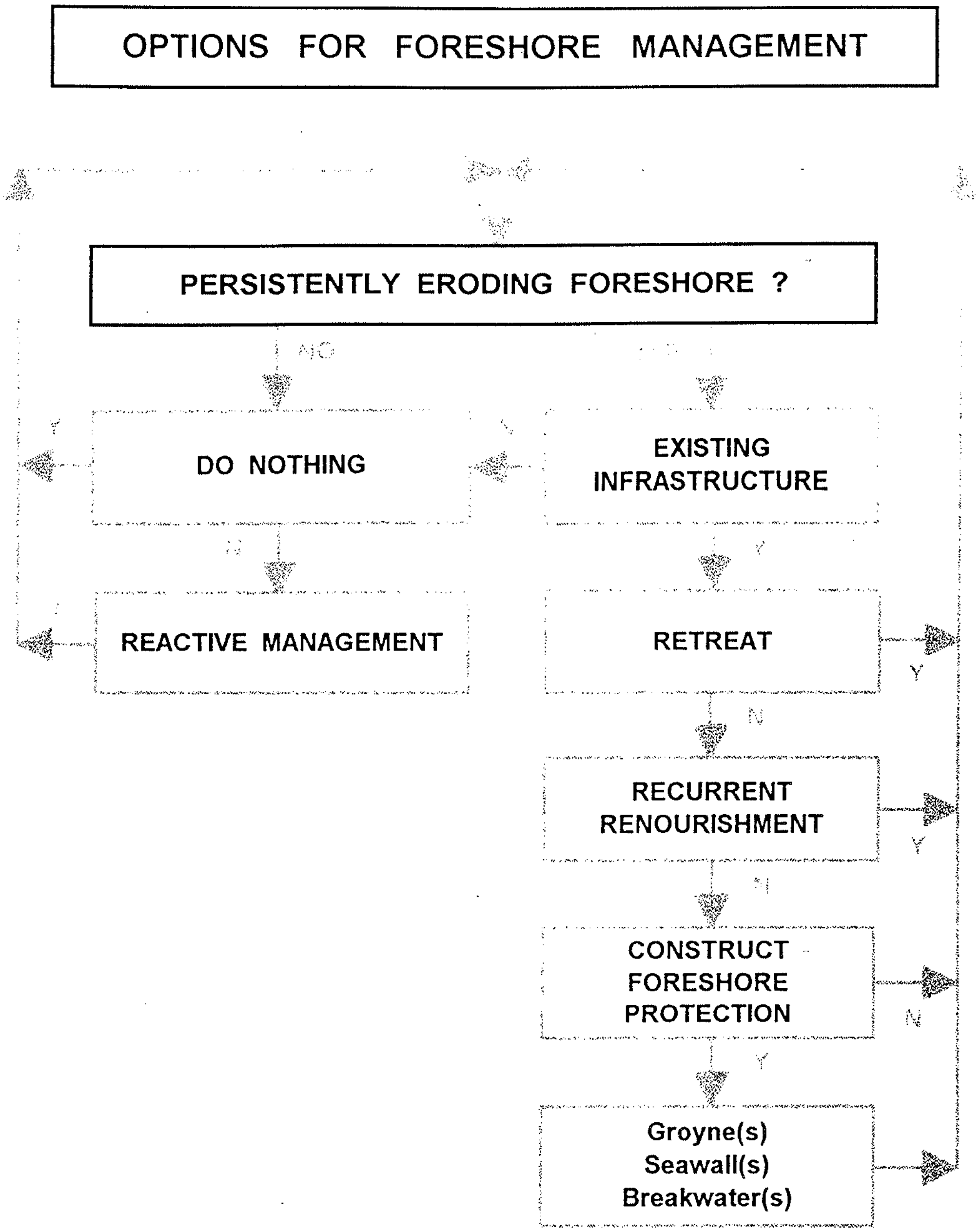


Figure 4.6 **1955 to 1995**




OPTIONS FOR FORESHORE MANAGEMENT
PERSISTENTLY ERODING FORESHORE ?
NO
DO NOTHING
EXISTING INFRASTRUCTURE
REACTIVE MANAGEMENT
RETREAT
RECURRENT RENOURISHMENT
CONSTRUCT FORESHORE PROTECTION
Groyne(s)
Seawall(s)
Breakwater(s)

TABLES

Shoreline Movement Plots

Location of Vegetation Line Relative to Location of 1941 Vegetation Line

Northing	Oct 1941	Dec 1955	Oct 1965	Nov 1978	Jan 1985	Jan 1995	Location
	Month and Year						
6490700	0	-12	-13	-14	-15	-16	
6491125	0	-12	-13	-14	-15	-16	
6491375	0	-4	-3	-4	-5	-6	
6491625	0	-4	0	-4	-5	-6	
6491875	0	6	-4	-6	-7	-8	
6492000							
6492500							Mindarie Keys
6493000							Mindarie Keys
6493500							
6494000							Rock Outcrop
6494025	0	-10	10	-20	-5	-15	
6494225	0	-5	15	-15	-15	-15	Quinns Road
6494400	0	-25	-10	-50	-30	-45	
6494550	0	-55	-32	-60	-45	-50	Pearce Street
6494650	0	-30	-30	-47	-25	-30	*Apex of*
6494750	0	-20	-22	-40	-20	-55	*Quinns cusp*
6494850	0	-16	-16	-18	-12	-35	Hall Road
6494950	0	-10	-7	-6	-7	-17	Car Park South
6495050	0	-7	-3	-3	-3	-15	Robert Road
6495150	0	-7	5	5	1	-12	
6495250	0	-7	5	5	5	-5	SLSC
6495400	0	-10	0	0	6	-9	
6495600	0	-12	6	8	7	0	
6495800	0	-12	7	9	6	-3	Robinson Ave.
6496000	0		3	13	5	0	Tapping Way
6496200	0		10	13	0	-1	
6496400	0		1	12		2	
6496750	0		2	10		0	
6497500	0		1	1		3	
6498000							Rock Outcrop

Shoreline Movement Plots

Rate of Change of Location of Vegetation Line Between Survey Dates
metres per year

Month and Year

Northing	Oct 1941 – Dec 1955	Dec 1955 – Oct 1965	Oct 1965 – Nov 1978	Nov 1978 – Jan 1985	Jan 1985 – Jan 1995	Location
6490700	-0.9	-0.1	-0.1	-0.1	-0.1	
6491125	-0.9	-0.1	-0.1	-0.1	-0.1	
6491375	-0.3	0.1	-0.1	-0.1	-0.1	
6491625	-0.3	0.4	-0.3	-0.1	-0.1	
6491875	0.4	-1.0	-0.2	-0.1	-0.1	
6492000						
6492500						Mindarie Keys
6493000						Mindarie Keys
6493500						
6494000						Rock Outcrop
6494025	-0.7	2.0	-2.3	2.1	-1.0	
6494225	-0.4	2.0	-2.3	0.0	0.0	Quinns Road
6494400	-1.8	1.5	-3.1	2.9	-1.5	
6494550	-3.9	2.3	-2.2	2.1	-0.5	Pearce Street
6494650	-2.1	0.0	-1.3	3.1	-0.5	*Apex of*
6494750	-1.4	-0.2	-1.4	2.9	-3.5	*Quinns cusp*
6494850	-1.1	0.0	-0.2	0.9	-2.3	Hall Road
6494950	-0.7	0.3	0.1	-0.1	-1.0	Car Park South
6495050	-0.5	0.4	0.0	0.0	-1.2	Robert Road
6495150	-0.5	1.2	0.0	-0.6	-1.3	
6495250	-0.5	1.2	0.0	0.0	-1.0	SLSC
6495400	-0.7	1.0	0.0	0.9	-1.5	
6495600	-0.9	1.8	0.2	-0.1	-0.7	
6495800	-0.9	1.9	0.2	-0.4	-0.9	Robinson Ave.
6496000			0.7	-1.1	-0.5	Tapping Way
6496200			0.2	-1.8	-0.1	
6496400			0.8	-1.7		
6496750			0.6	-1.4		
6497500			0.0	-0.1		
6498000						Rock Outcrop

Table 5.1

Sediment Budget - October 1996 to March 1997

	North Flank of Quinns Cusp		South Flank of Quinns Cusp
October to December			
Gain	nil	Gain	5,000 cu. m
Loss	22,000 cu. m	Loss	17,000 cu. m
December to March			
Gain	11,000 cu. m	Gain	8,000 cu. m
Loss	21,000 cu. m	Loss	55,000 cu. m
October to March			
Gain	11,000 cu. m	Gain	13,000 cu. m
Loss	43,000 cu. m	Loss	72,000 cu. m
Net	***32,000 cu. m LOSS***	***Net***	***59,000 cu. m LOSS***