



<http://researchspace.auckland.ac.nz>

ResearchSpace@Auckland

Copyright Statement

The digital copy of this thesis is protected by the Copyright Act 1994 (New Zealand).

This thesis may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- Any use you make of these documents or images must be for research or private study purposes only, and you may not make them available to any other person.
- Authors control the copyright of their thesis. You will recognise the author's right to be identified as the author of this thesis, and due acknowledgement will be made to the author where appropriate.
- You will obtain the author's permission before publishing any material from their thesis.

To request permissions please use the Feedback form on our webpage.

<http://researchspace.auckland.ac.nz/feedback>

General copyright and disclaimer

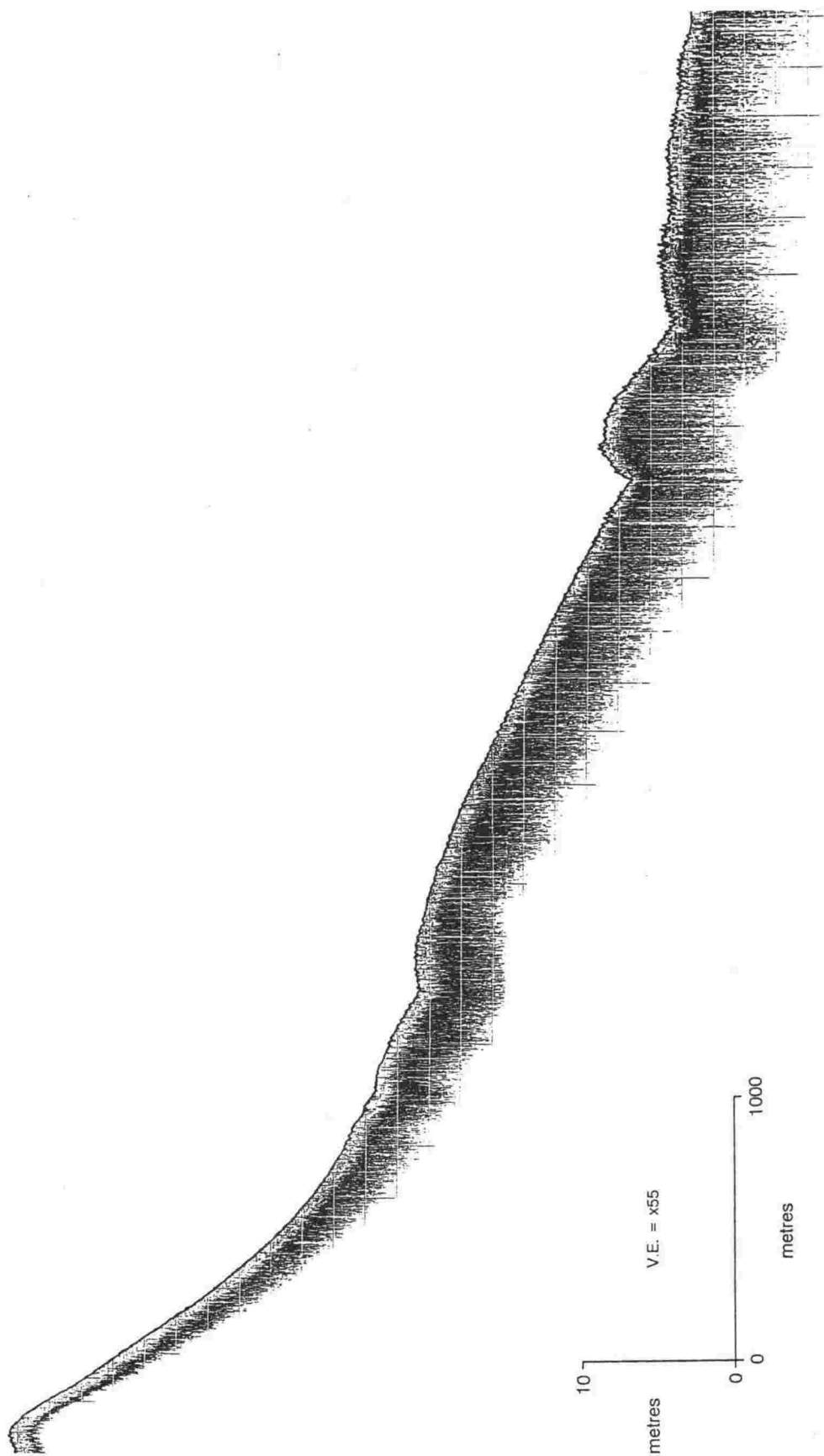
In addition to the above conditions, authors give their consent for the digital copy of their work to be used subject to the conditions specified on the Library Thesis Consent Form.

**PROCESSES OF SEDIMENTATION ON THE
SHOREFACE AND CONTINENTAL SHELF
AND THE DEVELOPMENT OF FACIES
PAKIRI, NEW ZEALAND**

Thesis submitted by
Michael John Hilton MA (Hons) (Auck)
in January 1990

for the degree of Doctor of Philosophy in
the Department of Geography at the
University of Auckland

Frontispiece A typical shore-normal echosound record across the shoreface and continental shelf, Walkway transect (08.05.89), Pakiri Bay, New Zealand.



ABSTRACT

This dissertation presents the results of research of physical and biological processes of sedimentation on the shoreface and continental shelf in Pakiri Bay, on the east coast of the Northland Peninsula, New Zealand. These environments comprise the subtidal portion of the Pakiri sand body.

Sand bodies that are contiguous with unconsolidated sediments of coastal barriers are characteristic of the embayed east coasts of the Auckland and Northland Regions, yet little is known of their geomorphology. Existing models of shoreface and shelf sedimentation afford limited assistance because they were developed in different environments. Factors that distinguish the study area from other coasts include tectonic stability, lack of modern (non-biogenic) sediment inputs, the predominance of currents related to shoaling surface waves, and a sea level stillstand for the last 6,500 years.

The model of sedimentation developed is derived from intensive field investigation of the morphology, sedimentology and ecology of the Pakiri Bay shoreface and continental shelf. Investigations of sediment transport entail interpretations of the sediments and sedimentary structures of the seabed, application of existing sediment transport models and the analysis of morphodynamic data.

The geomorphology of the Pakiri sediment body is characterized by a regular pattern of morphologic components and associated sediment types. Alongshore variation in these characteristics is generally minor compared with shore normal variation. The shoreface comprises a curvilinear concave surface, that extends offshore from the alongshore bar approximately 1500 m, to water depths of about 22 m. The inner continental shelf comprises an equally curvilinear, mostly convex, surface that slopes seaward to the relatively flat middle continental shelf. Secondary morphological variations result from the presence of large-scale bedforms on the middle continental shelf

and landward margin of the inner shelf.

The sediments of the shoreface are fine, very well sorted quartz-feldspathic sands of 2 ϕ mean grain size. The inner shelf sediments grade offshore from a medium sand to very coarse sands and fine gravels (mean grain size 0.0 to 0.5 ϕ). In contrast the sediments of the mid shelf are very fine sands (mean grain size 2.0 to 2.5 ϕ), with a mud content of 5 to 10 percent.

Carbonate skeletal debris, derived mostly from molluscs, comprises a significant proportion of inner and mid shelf sediments. The concentration of carbonates in the sediments increases offshore from 0 to 5 percent on the shoreface to 30 percent at the base of the inner shelf. The carbonate fraction of the sediments is size graded on the inner shelf and mid shelf in accordance with the grain size characteristics of the non-carbonate fraction.

A model of the distribution and abundance of living macrobenthos (mostly of the phyla mollusca) is derived from benthos surveys in Pakiri Bay. Species that are diagnostic of high and low energy environments are characteristic of the shoreface and middle continental shelf respectively. The pattern of carbonate concentration in the sediments of the subtidal sediment body does not correlate with the pattern of modern biogenic production. Highest levels of modern shell production occur across the shoreface, whereas carbonate concentrations are greatest at the base of the inner shelf. Hypotheses are advanced to explain this dichotomy.

The geomorphology of the shoreface and inner continental shelf is seen as a response to modern processes of sedimentation. Sediment transport occurs primarily in response to currents related to shoaling waves. Two process regimes are recognized. During typically calm (swell wave) conditions the fine sands of the shoreface may be transported landward as a result of an onshore mass transport current. During severe storm events this process may transport bed sediments landward across the inner shelf and middle

continental shelf, forming the characteristic sediment and morphologic patterns observed. However, during such events this onshore flow is probably counteracted by return flows that are able to transport eroded foreshore and inshore sediments seaward.

Key words: Sedimentation, shoreface, continental shelf, wave dominated, carbonate sedimentation, sediment body, facies.

CONTENTS

	Page
ABSTRACT	ii
CONTENTS	v
LIST OF TABLES	xi
LIST OF FIGURES	xii
ACKNOWLEDGEMENTS	xx
1 SHALLOW MARINE SEDIMENTATION	1
1.0 Introduction and rationale	1
1.1 Research objectives and thesis organization	4
1.2 Characteristics of the Pakiri coast	6
1.2.1 Geology	8
1.2.2 Sedimentology	12
1.2.3 Fluvial sediment inputs	13
1.2.4 The marine environment	14
1.2.5 Summary	21
1.3 Variations in shelf sedimentation, New Zealand	21
1.4 Research methodology	24
2 INTERPRETATIONS OF SHALLOW MARINE SEDIMENTATION	27
2.0 Concepts of shoreface and shelf sedimentation	27
2.1 The origin of facies in marine environments	28
2.2 Classification of shoreface and shelf profiles and sediments	31
2.3 Concepts of onshore-offshore sediment transport	33
2.4 Onshore-offshore sediment transport by storm waves	34
2.5 Onshore-offshore sediment transport by shoaling waves	37
2.6 Investigations and interpretations of sediment texture on the shoreface and continental shelf	40

3	SEDIMENT PATTERNS OF THE PAKIRI SHOREFACE AND CONTINENTAL SHELF	45
3.0	Introduction	45
3.1	Sampling strategy	45
3.1.1	Sample analysis and interpretation	47
3.2	Grain size characteristics of beach, shoreface and continental shelf sediments	49
3.2.1	Variation in mean grain size, sorting and fines	49
3.2.2	Intrastation variations - Williams transect	56
3.2.3	Sediment types and morphological associations	58
3.2.4	Interpretation of raw grain size data	63
3.2.5	Alongshore variation in grain size characteristics	66
3.3	Variations in sediment composition	73
3.3.1	Distribution of carbonate material	73
3.3.2	Variations in mineralogy	81
3.4	Implications for sediment transport	82
3.5	Conclusions	85
4	CARBONATE SEDIMENTATION IN PAKIRI BAY	89
4.0	Introduction	89
4.1	General concepts of carbonate sedimentation	90
4.2	Carbonate sedimentation on the east coast of Northland	91
4.3	Investigations of living Pakiri Bay macrobenthos	93
4.3.1	Sampling design	93
4.3.2	Sampling technique and treatment of samples	94
4.3.3	Cape Rodney to Okakari Point (rocky coast) benthos	96
4.3.4	Comparison of Pakiri Bay and rocky coast phyla	97
4.3.5	Species composition, abundance and distribution	98

4.4	Modern shell production	105
4.5	Comparison of the patterns of modern shell production and carbonate concentration in the sediments of Pakiri Bay	108
4.6	Environmental interpretation of Pakiri Bay macro-benthos	113
4.7	Summary and conclusions	115
5	MORPHOLOGY AND MORPHODYNAMICS OF THE PAKIRI SHOREFACE AND CONTINENTAL SHELF	119
5.0	Introduction	119
5.1	Survey techniques	120
5.1.1	Onshore and echosound survey techniques	120
5.1.2	Side-scan sonar technique	123
5.1.3	Sub-bottom sonar technique	125
5.2	Morphologic components of the study area	126
5.2.1	Shoreface	126
5.2.2	Inner continental shelf	128
5.2.3	Hummocks	130
5.2.4	Middle continental shelf	138
5.3	Alongshore variations in subtidal and coastal geomorphology	140
5.4	Coastal, shoreface and inner shelf stability	141
5.4.1	Coastal dunes	142
5.4.2	Beach and inshore morphodynamics	143
5.4.3	Historical fluctuations in shoreline position	144
5.4.4	Evidence of shoreface and inner shelf morphodynamics	148
5.5	Investigation of sub-strata	152
5.6	Conclusions	160
6	THE NATURE AND HYDRAULIC SIGNIFICANCE OF BEDFORMS ON THE SHOREFACE AND CONTINENTAL SHELF, PAKIRI BAY	164
6.0	Introduction	164

6.1	Hydraulic interpretation of bedforms	168
6.1.1	Method	168
6.2	Problems associated with the interpretation of bedforms	173
6.3	Survey techniques	175
6.3.1	Remote controlled photographic system	177
6.4	Results	178
6.4.1	Results of photographic and side-scan bedform surveys	178
	a. Middle continental shelf	178
	b. Inner continental shelf	180
	c. Shoreface	186
6.5	Discussion	188
6.6	Application of existing hydraulic models	194
6.6.1	Results	194
6.7	Conclusions	199
7	HYDRAULIC CONDITIONS AND A MODEL OF SEDIMENTATION AND FACIES DEVELOPMENT IN PAKIRI BAY	202
7.0	Introduction	202
7.1	Tidal and long period (non storm) currents in Pakiri Bay	203
7.1.1	Aanderaa current meter deployment	203
7.1.2	Sediment transport in Pakiri Bay due to tidal and residual currents	210
7.2	Wave induced currents	211
7.2.1	Wave transformations in the Hauraki Gulf and study area	211
7.2.2	Bed disturbance by oscillatory currents	212
7.2.3	Sediment transport by wave-induced currents	215
7.2.4	Infragravity and internal waves	218
7.3	A model of shoreface and continental shelf sedimentation	219

7.4	Discussion	221
	a. Sediment characteristics	222
	b. Morphology	225
	c. Bedform configurations	226
7.5	Conclusions	226
8	SUMMARY AND CONCLUSIONS	229
8.0	Introduction	229
8.1	Morphological characteristics of the Pakiri sediment body	230
8.2	Non carbonate sediment patterns	231
8.3	Patterns of carbonate sedimentation	232
8.4	The hydraulic regime in Pakiri Bay	233
8.5	An interpretation of sedimentation in Pakiri Bay	234
8.6	Comparison with other models of shoreface and continental shelf sedimentation	236
8.7	Implications for the management of human activities	237
8.8	Future research	240
	REFERENCES	241
	APPENDICES	264
A	Sampling technique	265
B	Offshore navigation and station location	267
C	Laboratory techniques	270
D	Location and reduced levels of Pakiri-Mangawhai datums	277
E	Summary of sediment analyses	281
F	Method of benthos sampling	291
G	Systematics and relative abundance of living bivalves and gastropods dredged from Pakiri Bay	293
H	Species composition and abundance: Initial surveys, Rocky coast and Pakiri Bay	296
I	Offshore echosound survey technique and sources of error	301

J	Specifications of the Klein side-scan sonar system and ORE sub-bottom profiler as deployed at Pakiri	307
K	Historical shoreline fluctuations, Pakiri Bay	308
L	Operating parameters of the remote-controlled photographic system	314
M	Characteristics of ripples derived from photographic images and side scan sonar	315
N	Aanderaa current meter deployment, Pakiri Bay	322
O	Wave transformations in Pakiri Bay due to shoaling and refraction	326
P	Management of the New Zealand coastal sand mining industry: Some implications of a geomorphic study of the Pakiri coastal sand body.	341

LIST OF TABLES

	Page	
1.1	Sea state observations, Goat island, 16-23 July 1978	18
3.1	Association between morphologic components and sediment types	66
4.1	Species associations, densities and environmental circumstances	104
4.2	Species composition of (lower) inner shelf, carbonate rich sediments, Pakiri Bay	112
5.1	Pakiri offshore surveys	121
5.2	Pakiri beach surveys (1978 to 1988)	122
5.3	Location and dimensions of hummocks	133
6.1	Ripple characteristics and derived flow conditions for representative continental shelf ripples	173
6.2	Reported occurrences on the inner shelf of coarse bedded, shore normal orientated rippled depressions	192
6.3	Computation of wave heights (H) required to generate U_m (derived from inner shelf megaripples) at various combinations of depth (h) and wave period (T) using Airy wave theory	195
6.4	Computation of wave heights (H) required to generate U_m (derived from middle shelf megaripples) at various combinations of depth (h) and wave period (T) using Airy wave theory	196
7.1	Aanderaa current meter summary statistics of the edited raw data set	205
7.2	Critical threshold velocities under unidirectional currents	210
7.3	Calculation of mass transport velocities under calm, storm and severe storm waves	217

LIST OF FIGURES

	Page
1.1 Location of the study area in (a) the Outer Hauraki Gulf and (b) relative to the major morphologic components of the continental shelf	7
1.2 Characteristic morphologic components of the (a) coast and (b) coast, shoreface and continental shelf, Pakiri Bay	9
1.3 Geology and bathymetry of the Pakiri-Mangawhai coast and shore normal dune, shoreface and inner shelf sections	10
1.4 Areal extent of the Pakiri dune field, and drainage pattern of the Poutawa and Pakiri stream catchments	11
1.5 (a) Location of wave rider buoy measurements, frequency of (b) wave directions, (c) significant wave heights, (d) wave periods and (e) percentage occurrence of height-period combinations	15
1.6 (a) Southwest Pacific synoptic meteorological situation, 10-28 September 1985, showing blocking pattern, (b) wind speed, daily wind run and direction, and (c) wave surge	17
1.7 Percentage of the total time that waves having significant heights greater than given values persisted for given times, or longer, Hicks Bay, East Cape	19
1.8 Sums of the monthly means of wave surge, 1968-1987, Leigh Marine Laboratory	20
2.1 Interrelationships of environmental factors and their control of coast sedimentary facies	30
2.2 Interpretations of present-day shelf profiles and sediment covers	32
2.3 Potential directions of sediment transport in response to onshore, offshore and alongshore coastal and shelf currents	35

2.4	Representative shoreface and continental shelf profile showing normal arrangement of inner nearshore, outer nearshore, inner shelf and mid shelf sediment types, New South Wales shelf	43
3.1	Location of samples obtained during initial survey of Pakiri Bay sediments	46
3.2	Location of Pakiri Bay beach and transect samples	48
3.3	Variation in (a) mean grain size and sorting, (b) size grades and (c) percent mud across (d) Walkway profile	51
3.4	Representative grain size frequency distributions, Williams transect (samples Z 1-59)	53
3.5	Variation in (a) mean grain size, (b) sediment grades and (c) percent mud across (d) Okakari, Matheson and Brown transects	54
3.6	Variation in (a) mean grain size, (b) size grades and (c) percent mud across (d) Williams, Couldrey, Walkway and Gravel transects	55
3.7	Variation in (a) mean grain size, (b) sediment grades and (c) percent mud across (d) Williams transect	57
3.8	Scatterplots of mean grain size against standard deviation (phi units), for shoreface, inner shelf and mid shelf sediments	59
3.9	Scatterplot of mean grain size against standard deviation (phi units), Okakari transect	60
3.10	Scatterplots of mean grain size versus standard deviation, Williams transect, for (a) multiple samples (depth increments) and (b) means of station means and standard deviations	61
3.11	Photographs of sediment samples obtained from Walkway transect, illustrating the nature of the transition across the textural boundaries that delineate the shoreface, inner shelf and middle continental shelf	62
3.12	Photographs of sediment samples obtained from across the inner continental shelf, Walkway transect	64

3.13	Interpretation of (a) morphologic components and (b) sediment types across a representative coastal and offshore transect	65
3.14	Variation in the percent weight of sediment present in 0.0, 0.5, 1.0, 1.5, 2.0 2.5 and 3.0 phi fractions, Williams transect	67
3.15	Isolines of mean grain size, Pakiri Bay	69
3.16	Isolines of standard deviation, Pakiri Bay	70
3.17	Isolines of fines concentration, Pakiri Bay	71
3.18	Variation in (a) mean grain size, (b) size grades and (c) percent mud across (d) Okakari transect	72
3.19	Variation in the proportion of carbonate material in the sediments across Walkway, Gravel, Couldrey, Brown, Williams and Matheson transects	74
3.20	Mean carbonate concentrations across Williams transect, derived from multiple sampling at each station	75
3.21	Isolines of carbonate concentration, Pakiri Bay	77
3.22	Photographs of bed sediments across Goat Island Bay transect, showing the predominance of carbonate sediment in samples from the inner shelf adjacent to Cape Rodney to Okakari Point rocky coast	78
3.23	Variation in mean grain size for carbonate-digested and untreated samples and percent carbonate material across Walkway transect	79
3.24	Variation in mean grain size for carbonate-digested and non-digested sediments, and percent carbonate material across Okakari transect	80
3.25	Variation in the proportion of heavy minerals in the 1, 2 and 3 phi fractions of samples obtained across Walkway and Gravel (2 phi) transects	83
3.26	Sediment types of the Pakiri Bay sediment body and adjoining middle continental shelf	86
4.1	Location of initial benthos surveys (Te Arai, Couldrey, Goat Island and Cape Rodney transects) and subsequent Pakiri Bay transect surveys (Williams, Walkway and Matheson)	95

- 4.2 (a) Summary of distribution and abundance of the most commonly captured macrobenthos, (b) variation in sediment size grades and (c) sample locations and variation in percent mud, across Williams transect, June 1986 and March 1987 99
- 4.3 (a) Summary of distribution and abundance of the most commonly captured macrobenthos, (b) variation in sediment size grades and (c) sample locations and variation in percent mud, across Matheson transect, 9 March 1987 100
- 4.4 (a) Summary of distribution and abundance of the most commonly captured macrobenthos, (b) variation in sediment size grade and (c) sample locations and variation in percent mud, across Walkway transect, June 1986 and March 1987, and May 1989 101
- 4.5 (a) Interpretation of the relative abundance and distribution of the most commonly captured macrobenthos, showing the distribution of recognized associations, of species and (b) morphological and sedimentological variations across a representative shore normal profile 103
- 4.6 (a) Variation in the percentage of the total shell weight at each station contributed by the most commonly captured species and (b) estimates of the total (live) shell weight at each station across (c), Williams transect 106
- 4.7 Variation in (a) estimated (live) shell weight and, (b) carbonate content of the sediments, across (c) Williams transect (12.03.87) 110
- 4.8 (a) Offshore variation in (live) shell weight (March 1987, average of three transects) and (b) percent carbonate concentration in sediments 111
- 5.1 Area of seabed covered by (a) side-scan and sub-bottom sonar transect surveys (15 March 1987) H.M.S. Tui, and (b) sub-bottom transect surveys (April 1986) 124

5.2	Comparison of 1986 shore normal profiles, Te Arai Point to Cape Rodney, showing seabed slope angles at 500 m intervals	127
5.3	Superimposition of 1987 Pakiri Bay shoreface and continental shelf profiles	128
5.4	Reproduction of the inner continental shelf segment of a shore normal echosound profile, Walkway profile, showing sequence of contributory convexities	129
5.5	Segments of the Pakiri Bay transect profiles showing the transition zone between the shoreface and the inner continental shelf, and the location of minor convexities	131
5.6	Segments of the Pakiri Bay transect profiles, showing the transition zone between the inner and middle continental shelf, and location and geometry of the hummocks	132
5.7	Interpretation of side-scan sonar record, showing the transition from mid shelf to inner continental shelf sediment types (station 1728-1734)	134
5.8	Interpretation of side-scan sonar record of the area of contact between the inner shelf and mid shelf sediment types, showing the presence of large-scale bedforms (hummocks)	136
5.9	Interpretation of side-scan sonar record showing large scale bedforms (mounds) on the middle continental shelf	139
5.10	Photograph of Pakiri Bay in moderate wave conditions illustrating the continuity of the alongshore trough and bar system	145
5.11	Excursion distance analysis of a time series of beach surveys (1978-1988), Brown transect	146
5.12	Comparison of 1978 and 1988 beach surveys, Pakiri and Mangawhai Bay transects	147
5.13	Comparison of 1964 RNZN fair chart and 1987 echosound surveys, Pakiri Bay transects	149

5.14	Superimposed plots of (a) 1978 and (b) 1987 shoreface profiles, showing presence of convex bulge 250 to 750 m offshore on 1978 profiles, and characteristic concave geometry of the shoreface (1987 profiles)	150
5.15	Excursion distance analysis of a 10 year time series of foreshore, inshore and shoreface echosound surveys, Brown transect, Pakiri Bay	152
5.16	Comparison of 1978 (Auckland Regional Water Board) and 1987 inshore and shoreface echosound surveys, Brown transect	153
5.17	(a) Comparison of five echosound profiles, Walkway transect (1964-1989), and (b) superimposition of 1986-1989 profiles	154
5.18	Interpretations of sub-bottom sonar records (08.04.86), Pakiri Bay transects	157
5.19	Reproduction of a segment of ORE sub-bottom record, Walkway transect (08.04.86), showing the presence of a strong reflector beneath the juncture of the inner shelf and mid shelf	158
5.20	Sub-bottom sonar record, Couldrey transect, showing the presence of a strong reflector below the seaward margin of the alongshore bar	159
6.1	(a) Morphodynamically important parameters of waves, wave motion and wave-formed ripples, and (b) schematic representation of the chief morphological features of transverse bedforms	167
6.2	Velocity thresholds for grain movement and sheet flow of quartz sand in water	169
6.3	(a) Plot of ratio of ripple spacing to grain size against ratio of orbital diameter to grain size and (b) classification of ripples	170
6.4	Location of transect photo stations and side-scan sonar survey, Pakiri Bay.	176
6.5	Remotely triggered underwater photographic system	177

6.6	Normal (a) and wide-angle (b) lens images of the middle continental shelf seabed (type N configuration), Brown transect and Williams transect, respectively	179
6.7	Side-scan sonar record of rippled bands of relatively coarse sediment on the middle shelf	181
6.8	Wide-angle lens view of rippled bed (configuration Ri), inner shelf, Williams transect	181
6.9	Location and orientation of ripples ($\lambda > 0.50$ m) observed during photographic survey	183
6.10	Sections of side-scan sonar record showing (a) large ripples and megaripples and (b) alongshore pattern of rippled (coarse) and unrippled (fine) sediments	184
6.11	Alongshore side-scan sonar record (a) and seabed profile (b) showing pattern of alongshore convexities and associated fine and coarse sediments	185
6.12	Wide angle view of lattice-type (Lat) bed lower inner shelf bed configuration, Gravel transect	187
6.13	Example of minor irregular topography (Mit), shoreface bed configuration, Williams transect	187
6.14	Interpretation of photographic and side-scan bedform data, showing alongshore continuity of the major bed configurations identified	189
6.15	Combinations of wave height and water depth that will generate sheetflow of 0.250 mm quartz sand ($U_m = 100$ cm s ⁻¹) under waves of different period	198
7.1	(a) Location of intended (site 1) and unintended (site 2) current meter deployments, Pakiri Bay, and (b) equivalent location of deployments on Brown profile	204
7.2	Aanderaa current meter deployment (site 1) - speed frequency distribution and the percentage of time each class is exceeded	206
7.3	Time series of the (a) onshore-offshore velocity components and (b) alongshore velocity component of the Aanderaa current meter record, (c) simultaneous water level recording and (d) wave surge	207

7.4	Current directions and speeds, site 1 and site 2, Pakiri Bay	208
7.5	Summary of marine observations, Aanderaa site 1, Pakiri Bay, showing time series of the (a) alongshore velocity component from low-passed and sub-tidal data, (b) onshore-offshore velocity components and (c) speed values for the low-passed data with directional stick plot	209
7.6	Variation in maximum orbital velocity and grain size thresholds across a typical offshore profile, Pakiri Bay, under (a) modal and (b) storm waves	213
7.7	Maximum grain size capable of being disturbed by 1.5 to 5.0 m waves across a representative offshore profile, Pakiri Bay	214
7.8	Model of sediment transport across the shoreface and continental shelf under (a) calm and (b) storm wave conditions	220

ACKNOWLEDGEMENTS

I am grateful for the help and assistance of a number of people and organizations who have contributed to the completion of this thesis.

The research has been funded by the National Water and Soil Conservation Authority and subsequently supervised by the Department of Scientific and Industrial Research.

I thank Professor Roger McLean for initiating this project and for his counsel in the preparation of the thesis. I am grateful to my supervisor, Dr Kevin Parnell, for his continued interest in my work, and his guidance towards its completion.

Dr Bill Ballantine, of the Leigh Marine Laboratory, has been a source of ongoing encouragement and enthusiasm. I appreciate very much his contribution to my understanding of the marine environment. I appreciate also my discussions with Dr Peter Hoskings of the Department of Geography, and Professor Sandy Harris of the Leigh Marine Laboratory, University of Auckland.

I am grateful also to the Scientist in Charge (for much of my stay at the Leigh Laboratory) Dr Bob Creese, for extending to me the use of the facilities of the Laboratory.

I am indebted to Mr Jo Evans and Mr Marty Kampman, Senior Technical Officers of the Leigh Marine Laboratory, for their expert technical assistance, as well as for their patience and companionship. I am thankful also for the effort expended in the field on my behalf by Mr Nick Osborne, Technician, Department of Geography, University of Auckland.

The Defence Scientific establishment of the Royal New Zealand Navy kindly cooperated in undertaking a side-scan sonar survey in Pakiri Bay. I am grateful for the assistance of Mr Ian Rumble and Mr

George Crooke in particular.

The assistance of the staff of the New Zealand Forest Service (Mangawhai State Forest) in gaining access to the coastal datums is gratefully acknowledged. In this respect I am also thankful to the landowners of the Pakiri coast whose cooperation was much appreciated, and in particular Mr Keith Collier, Mr John Matheson, Mr and Mrs Greenwood and Mr Bud Russel.

The Auckland Regional Water Board provided beach and offshore survey data. The patient assistance of Mr Ian Smith, Chief Surveyor, Auckland Regional Council, is gratefully acknowledged.

Professor Alec Kibblewhite provided an ORE sub-bottom profiler and sea level recorder for the purpose of this investigation. Thanks also to Mr Percy Pearce, Senior Technical Officer, Department of Physics, University of Auckland, for his assistance with the interpretation of the records.

Ms Sarah Manning has been of incalculable value in the production stages of this thesis. My sincere thanks. Thanks also to Ms Brigitte O'Rourke for help with editing. Finally, thanks to my family, colleagues and remaining friends for their interminable patience and support.